This document was too large to scan as a single document. It has been divided into smaller sections.

Section 1 of 2

Document Information			
Document #	**RPP-12194**	**Revision**	**0**
Title	ACCELERATED TANK CLOSURE DEMONSTRATION ALTERNATIVES GENERATION & ANALYSIS REPORT		
Date	**9/12/2002**		
Originator	**RIESS MJ**	**Originator Co.**	**CHG**
Recipient		**Recipient Co.**	
References	**EDT-634310**		
Keywords	**AGA,RETRIEVED,CLOSURE RISK ASSESSMENT,REGULATORY**		
Projects	**TWRS,TFARM**		
Other Information			

S

SEP 12 2002 (22) Sta 15

ENGINEERING DATA TRANSMITTAL

1. EDT 634310

2. To: (Receiving Organization) Closure Projects	3. From: (Originating Organization) Single Shell Tank Projects	4. Related EDT No.: 634310
5. Proj./Prog./Dept./Div.: Accelerated Tank Closure Dem Proj	6. Design Authority/Design Agent/Cog. Engr.: N/A N/A/R.E. Day	7. Purchase Order No.: N/A
8. Originator Remarks: For Approval and Release		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
		12. Major Assm. Dwg. No.: N/A
11. Receiver Remarks:	11A. Design Baseline Document? ☐ Yes ☒ No	13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	RPP-12194		0	Accelerated Tank Closure	NA	1	1	1
				Demonstration ~~Project~~				
				Alternatives Generation and				
				Analysis Report				

16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)	1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
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		Design Agent				1	1	E.A. Fredenburg	Fredenburg	10 Sep 02	H9-03
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		QA									
		Safety			H9-03						
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18.	19.	20.	21. DOE APPROVAL (if required)
R.E. Day 10Sept02	M. Jarayssi 9/10/02	M.J. Riess 10Sept02	Ctrl No.
Signature of EDT Originator / Date	Authorized Representative for Receiving Organization / Date	Design Authority/ Cognizant Manager / Date	☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

BD-7400-172-2 (10/97)

BD-7400-172-1

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Accelerated Tank Closure Demonstration Alternatives Generation and Analysis Report

M.J. Riess
CH2MHILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: 634310 UC:
Cost Center: 7P700 Charge Code: 116707/B000
B&R Code: Total Pages: 411

Key Words: Closure; Demonstration; TWRS; Project; AGA; Retrieved; Closure Risk Assessment; Regulatory

Abstract: The purpose of this Alternatives Generation and Analysis report is to evaluate the regulatory and technical alternatives to downselect retrieval and closure technologies to support engineering design associated with the five tanks selected for the Accelerated Tank Closure Demonstration (ATCD) project. The initial demonstrations are for the purpose of developing closure processes and demonstrating initial Single-Shell Tank waste retrieval and closure actions.

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SEP 12 2002
DATE:
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ID: 22

Chris Willingham 9/12/02
Release Approval Date Release Stamp

Approved For Public Release

RPP-12194
Rev. 0

ACCELERATED TANK CLOSURE DEMONSTRATION ALTERNATIVES GENERATION AND ANALYSIS

September 2002

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EXECUTIVE SUMMARY

The purposes of this Alternatives Generation and Analysis (AGA) report are to evaluate the regulatory and technical alternatives for characterization, retrieval, and closure of the five tanks selected for the Accelerated Tank Closure Demonstration (ATCD) project, to assess the relationship between costs and benefits associated with waste retrieval to various possible end states, and to define the methodologies and approaches to be used for risk assessment. This report builds on information summarized in the *ATCD Data Assessment Report* (DAR) (Callison 2002), and supports finalization of preliminary engineering activities for waste retrieval and tank closure.

The ATCD approach is being implemented in a step-wise fashion to develop the technical basis for retrieval and closure of five single-shell tanks (SSTs) while working through the regulatory process and managing programmatic risk (Lee 2002).

Five tanks, all located within the C Tank Farm, were selected for demonstration of closure (the 241-C-106 tank and four 200 series tanks [241-C-201 through 241-C-204]). A complete description and background of C Tank Farm and the five selected tanks is found in the DAR. A brief summary of the tank capacities and current state as compared to the *Hanford Federal Facility Agreement and Consent Order* (HFFACO) retrieval goal is provided below:

Summary of Tank Capacity and Current State

Tank	Capacity L (gal)	Current Estimated Volume, L (gal)			Residual Volume Retrieval Goal[a] L (gal)
		Liquids	*Solids*	*Total*	
241-C-106	2,010,000 (530,000)	115,000 (30,000)	23,000 (6,000)	138,000 (36,000)	10,219 (2,700)
241-C-201	208,000 (55,000)	None	4,000 (1,000)	4,000 (1,000)	852 (225)
241-C-202	208,000 (55,000)	None	4,000 (1,000)	4,000 (1,000)	852 (225)
241-C-203	208,000 (55,000)	None	10,000 (3,000)	10,000 (3,000)	852 (225)
241-C-204	208,000 (55,000)	None	10,000 (3,000)	10,000 (3,000)	852 (225)

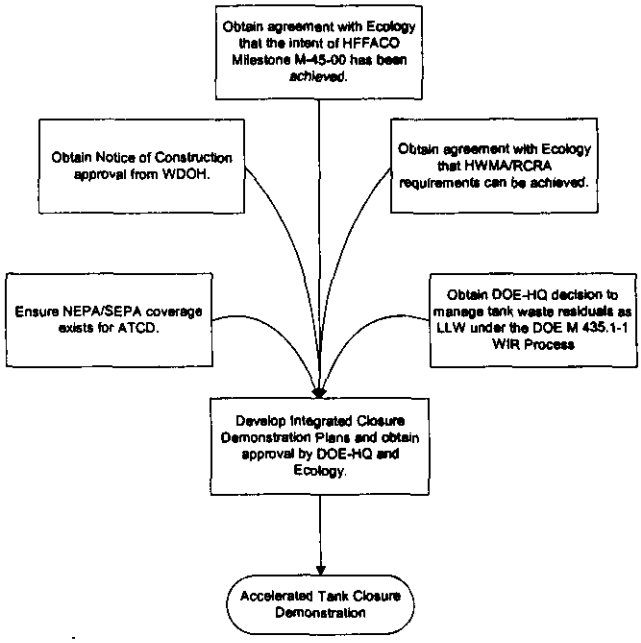
[a] Based on HFFACO milestone M-45.

REGULATORY ALTERNATIVES

The regulatory strategy for the ATCD project identifies an approach for obtaining the necessary approvals from the U.S. Department of Energy (DOE), Washington State Department of Ecology (Ecology), Washington State Department of Health (WDOH), and the Environmental Protection Agency for the proposed actions. The strategy focuses on addressing decisions associated with the key regulatory requirements controlling tank waste retrieval and closure technology demonstrations.

The recommended strategy for compliance with the regulatory requirements is summarized by the following elements:

- National Environmental Policy Act (NEPA) compliance with an Environmental Assessment and State Environmental Policy Act (SEPA) checklist.
- Tiered *Hazardous Waste Management Act*(HWMA)/*Resource Conservation and Recovery Act* (RCRA) Closure Plans for RCRA Permit modifications and DOE Order 435.1 requirements.
- Reclassifying residual tank waste as waste incidental to reprocessing (WIR) in accordance with DOE Order 435.1.
- Long- and short-term risk is evaluated through a detailed site-specific risk assessment based on conditions and knowledge of the C Tank Farm integrated with a site-wide composite analysis for a performance assessment.



Traditional in-tank characterization requires adjustments to support the ATCD accelerated schedule. Sampling techniques and a non-traditional characterization strategy are being evaluated in the data quality objectives. The strategy includes accelerating the analytical processing of the post-retrieval samples to support regulatory approval. It is assumed that residual wastes will have the same or very similar composition as pre-retrieval wastes.

COST-BENEFIT ANALYSIS

Selection of retrieval technologies and overall waste retrieval strategy must eventually consider factors other than retrieval technology capability. This need to consider other factors, including cost, is addressed in HFFACO Milestone M-45, Appendix H to the HFFACO, DOE Orders, and the 1996 Memorandum of Understanding agreed to by DOE and Ecology.

While we may lack the necessary understanding of the key elements impacting tank closure decisions to invoke a cost/benefit argument at this time, it is informative to conduct a preliminary evaluation of the risk reduction benefits of waste retrieval versus cost. The following principal conclusions may be drawn from this study:

- Significant risk reduction has already occurred from retrieval of 241-C-106 waste by past-practice sluicing

- Additional risk reduction by (a) pumping liquids only, (b) removing liquids and sludge to the HFFACO milestone, and (c) removing liquids and sludge to beyond the HFFACO milestone will cost significantly more, per unit of risk reduction, than the risk reduction that has already occurred.
- The cost per unit of risk reduction for progressively cleaner end states in 241-C-106 increases with increasing cost, i.e., in economic terms there is a diminishing marginal rate of return (measured by risk reduction) for increased retrieval costs.

It is important to note that this work effort and method for comparing the net benefit of a given waste retrieval action will continue to evolve as we gain maturity in the tools used to support tank closure decisions.

RETRIEVAL ALTERNATIVES

Previous analyses have been conducted evaluating retrieval technologies for removal of sludge waste from SSTs. This AGA uses the results of those studies to determine the appropriate technologies for retrieval of the sludge from tank 241-C-106 and the 241-C-200 tanks.

The selected alternative for retrieval of the remaining waste in 241-C-106 includes the following key elements:

1. Remove the necessary in-tank equipment to support the installation of retrieval system(s).
2. Proceed with the pumping of liquid waste volumes from the tank. This effort is intended to remove the majority of the liquid residues and acknowledges the fact that the majority of the key risk drivers (i.e., mobile radionuclide inventory) exist within the liquid waste component. Evaluate use of the existing pipe-in-pipe waste transfer system provided under project W-320 vs. interfacing with the overground transfer line used for 241-C-103 interim stabilization.
3. Using the existing infrastructure and the pumping systems deployed, design and place a modified sluicing system within the tank with the goal of retrieving the majority of the residual solid wastes within the tank.
4. Evaluate the success of the modified sluicing system. If this retrieval system does not meet the HFFACO goal (less than 360 cubic feet of residuals), then proceed with additional retrieval or, if approved by Ecology, appropriate closure activities pursuant to HFFACO Appendix H.
5. Maintain a parallel development and engineering activity for the Mobile Retrieval System as selected in the alternative analysis (Attachment 3). This system would be deployed in order to assure the acceleration of tank closure actions in the event modified sluicing is delayed, or waste retrieval does not achieve the HFFACO retrieval goal and an exception is not obtained.

Deployment of this multi-tiered approach will allow progress, while assuring that the tank closure schedules are not adversely affected by a single technology failure or a regulatory obstacle. CH2M HILL Hanford Group, Inc. has selected this approach as a means to ensure

that the success of each retrieval technology identified above can be directly linked to an associated reduction in risk. This approach will provide a means to evaluate the effectiveness of retrieval technology capabilities for application to future SST retrieval and illustrate a continued commitment to progress for the accelerated cleanup of the Hanford site.

A modified sluicing system has the potential to achieve compliance with the HFFACO retrieval requirements contained in milestone M-45-00. It is recommended for first line deployment since it fits within an allowable cost profile, can be implemented within the tight scheduling demands for the ATCD project, will assist in the removal of the balance of the liquid and solid wastes, and will achieve removal of key mobile contaminants (including the expected removal of soluble components from the remaining sludge).

It should be noted that the alternative analysis (Attachment 3) was primarily focused on a technical evaluation of retrieval systems. Subsequent strategic planning sessions with ORP modified this recommended approach in an effort to meet the needs for rapid progress in the field, accelerated removal of liquids and sludges and the expectation that the concentration of key contaminants and the volume of the existing waste piles (solids) within the tank would be dramatically reduced in the first two steps of a multi-tiered approach. If additional retrieval is required to comply with the HFFACO, the MRS will be deployed. This provides an opportunity to demonstrate the MRS efficacy in a less demanding environment prior to deployment in future tank retrievals.

This multi-tiered demonstration is proposed in an effort to meet the 360 cubic feet HFFACO retrieval goal. Pending the results of this planned demonstration, and subsequent regulatory approval, it is understood that Ecology may require the deployment of the MRS to complete the removal of additional waste residues. However, the efficiencies gained from early deployment of modified technologies, any Authorization Basis modifications, updated environmental permits, tank preparation activities and deployment of trained operational staff would be made available to accelerate the momentum of the retrieval and closure activities for 241-C-106. It is important to note that, per the approach described above, a multi-tiered path for technology development efforts will be pursued to maintain operational flexibility for waste retrieval operations.

CLOSURE ALTERNATIVES

The focus of ATCD project is to prepare the tank for closure. Closure period for ancillary equipment, surrounding soil and final surface cap design are not evaluated in the AGA.

The DAR (Callison 2002) identified several tank fill alternatives from previous engineering studies and DOE complex experience. Those alternatives were considered in this AGA. Also included in the DAR is a discussion on the use of chemical getters. The development of getters is progressing, and the selection of the particular type to be used will be driven by constituents of concern. It is assumed that some type of getter additive will be used as a component of tank fill for residual waste stabilization. The specific selection and method of application will be determined based on studies planned in fiscal year (FY) 2003. In the mid 1990's, two principal studies were conducted that evaluated structural tank fill alternatives for closure (Skelley, 1996 and SNL, 1998a,b). Alternatives evaluated assumed complete

filling of the tank. The alternatives proposed in Skelley 1996 were essentially homogeneous systems consisting of a single material type. The tank fill design proposed in SNL 1998a and 1998b assigned different functions to layered components of differing material types.

Fill alternatives being evaluated for the ATCD project adopt a multi-function approach, assigning different functions to an initial waste stabilization layer, and to the remaining tank void space to be filled (i.e., structural fill zone). An objective for the waste stabilization layer, but not for structural fill, is retrievability pending final decisions on tank farm closure and the amount of waste that must be removed from tanks to support closure. Waste stabilization can include both physical and chemical stabilization with the objective of reducing the mobility of the residual contaminants in the presence of infiltrating water.

Grout fill and granular fill alternatives were evaluated for the waste stabilization layer. Grout was identified as the preferred alternative for both tank 241-C-106 and the 200-series tanks. However, it was noted that events may necessitate revisiting this decision. For example, the issue of reversibility may take on increased importance pending results of the NEPA process, and the current lawsuit challenging DOE's authority to reclassify high-level waste under DOE Order 435.1. Also, planned development of getter materials in FY 2003 may reveal significant differences in performance in a granular fill versus a grout fill. Finally, the choice of retrieval technology could shift the balance in favor of granular fill with getters, if the retrieval equipment allowed mixing of fill material with waste.

Grout, gravel, concrete, hybrid (gravel, followed by grout injection), and a multi-layer fill were evaluated for the tank structural fill. For this application, grout installed in lifts was selected as the preferred tank fill alternative.

RISK ASSESSMENT STRATEGY

Numerous procedural and regulatory requirements drive the need to assess long-term and short-term risks for waste retrieval and tank closure. The risk assessment strategy for the ATCD project builds on a significant body of past work including the *C Tank Farm Retrieval Performance Evaluation* (RPE) (DOE-RL 1999), *A/AX and C Tank Farm Subsurface Characterization Report* (Draft), *Phase I RCRA Facility Investigation/Corrective Measures Study Work Plan for SST Waste Management Areas* (DOE-RL 2000), and the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) *200 Area RI/FS Master Plan*. Risk assessment for the ATCD project will be strongly integrated with the data gathering efforts of the Vadose Zone Characterization program, Immobilized Low Activity Waste program, RCRA Groundwater Monitoring Well Drilling program, improvements in the SST Farm Best Basis Inventory (BBI 2001), and the 200 Area CERCLA Remediation program.

The recommended long-term risk assessment approach includes the following elements:

- Define performance objectives
- Define the conceptual exposure model
- Define the site physical conceptual model

- Identify and catalog the input values for fate and transport simulations
- Identify relevant closure management alternatives and decisions
- Implement the risk assessment simulations

The recommended short-term risk assessment approach involves developing worker exposure scenarios for tank closure, assessing risk for those scenarios, and either mitigating risk through engineering design or operational controls, or avoiding risk by requesting exemption from regulatory criteria (e.g., HFFACO Appendix H).

The recommended ecological assessment approach is to become integrated with the Central Plateau Ecological Assessment currently underway between Ecology and DOE.

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3. ALTERNATIVE ANALYSIS REPORT FOR WASTE RETRIEVAL SYSTEM PRELIMINARY ENGINEERING TANKS C-106, C-201, C-202, C-203, AND C-204.

4. ALTERNATIVE ANALYSIS REPORT FOR ACCELERATED TANK CLOSURE DEMONSTRATION PROJECT TANKS C-106, C-201, C-202, C-203, AND C-204.

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ABBREVIATIONS AND ACRONYMS

AB	Authorization Basis
AGA	Alternatives Generation and Analysis
ALARA	as low as reasonably achievable
ATCD	Accelerated Tank Closure Demonstration
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
CFR	*Code of Federal Regulations*
CHG	CH2M HILL Hanford Group, Inc.
COC	contaminant of concern
DAR	data assessment report
DOE	U.S. Department of Energy
DST	double-shell tank
DQO	data quality objective
Ecology	Washington State Department of Ecology
ESH&Q	Environmental, Safety, Health, and Quality
FY	fiscal year
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HTI	Hanford Tanks Initiative
HWMA	*Hazardous Waste Management Act*
ILCR	incremental lifetime cancer risk
LDUA	Light Duty Utility Arm
MARS	Mobilization and Retrieval System
MDL	minimum detection level
MOU	Memorandum of Understanding
MRS	Mobile Retrieval System
NEPA	*National Environmental Policy Act*
ORP	Office of River Protection
OSHA	Occupational Safety and Health Administration
PNNL	Pacific Northwest National Laboratory
PPS	Past Practice Sluicing
PQL	practical quantitation limit
QAPjP	Quality Assurance Project Plan
RCRA	*Resource Conservation and Recovery Act*
RPE	Retrieval Performance Evaluation
S&A	Sampling and Analysis
SEPA	*State Environmental Policy Act of 1983*
SNL	Sandia National Laboratory
SST	single-shell tank
WAC	Washington Administrative Code
WIR	waste incidental to reprocessing
WMA	Waste Management Area

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1.0 INTRODUCTION

The mission of the U.S. Department of Energy (DOE) Office of River Protection (ORP) River Protection Project is to retrieve and treat Hanford Site tank waste and close the tank farms to protect the Columbia River.

The Single-Shell Tank (SST) Project mission is to retrieve waste from SSTs and prepare the SST farms for closure in a safe, regulatory compliant and economical manner.

In 1996, a Memorandum of Understanding (MOU) (MOU 1996) between DOE and Washington State Department of Ecology (Ecology) recognized that uncertainties existed with implementing the Hanford Federal Facility Agreement and Consent Order (HFFACO) (Ecology et al. 1989) milestones relative to:

- Performance limits of retrieval waste volumes and inventories
- Characterization of residual waste volumes and inventories
- Process for establishing tank-by-tank retrieval leak loss limits
- Relationship of end state requirements (i.e., closure performance measures) with retrieval and leak loss requirements.

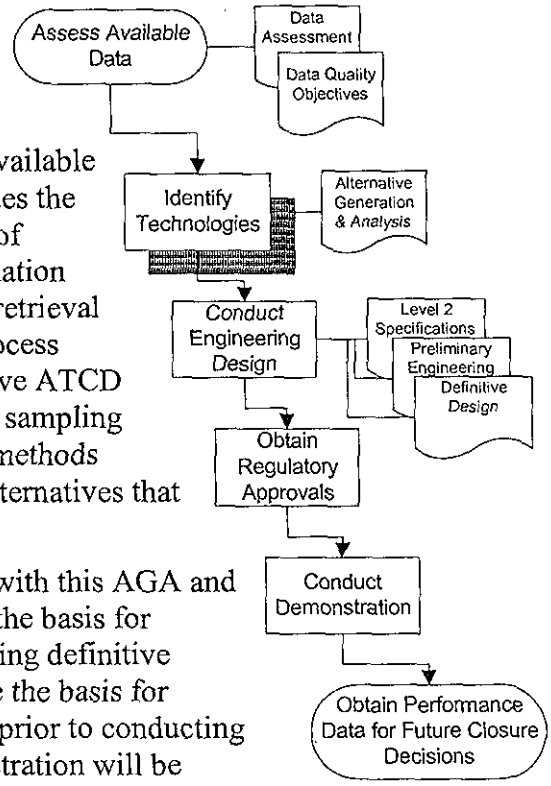
While some progress has been made, for the most part these uncertainities still remain, and significant resources will be required to retrieve waste and close SST farms in a manner that:

- Protects human health and the environment,
- Complies with applicable regulations,
- Realistically accommodates technical challenges,
- Cost effectively uses tax dollars.

In 2002, ORP established the Accelerated Tank Closure Demonstration (ATCD) project to break through barriers that have heretofore prevented meaningful progress in establishing end state criteria for tank farm closure, and closing tanks.

The purposes of this Alternatives Generation and Analysis (AGA) report are to evaluate the regulatory and technical alternatives for characterization, retrieval and closure of the five tanks selected for the ATCD project, to assess the relationship between costs and benefits associated with waste retrieval to various possible end states, and to define the methodologies to be used for risk assessment. This report builds on information summarized in the *ATCD Data Assessment Report* (DAR) (Callison 2002) and supports finalization of ongoing preliminary engineering activities for waste retrieval and tank closure.

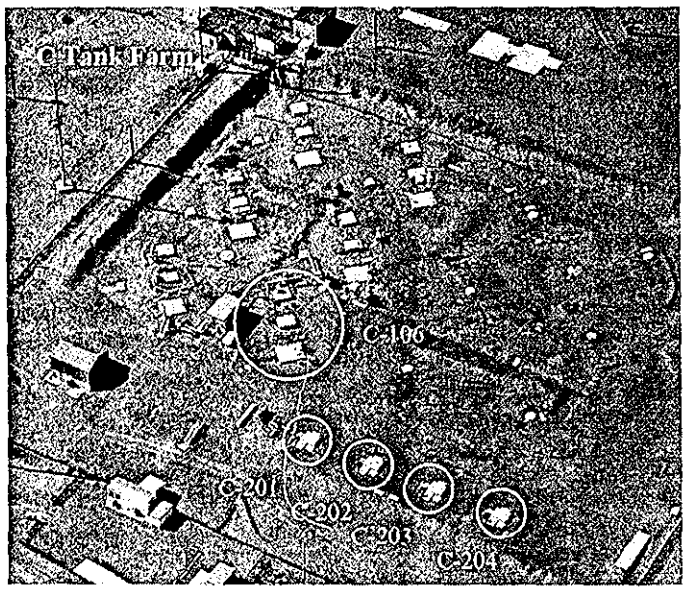
1.1 ATCD PROCESS & TANK INFORMATION



The ATCD approach is being implemented in a step-wise fashion to develop the technical basis for retrieval and closure of five SSTs while working through the regulatory process and managing programmatic risk (Lee 2002). The critical first step is an assessment of available data, as reported in the DAR (Callison 2002) that provides the foundation for the AGA. The DAR summarized results of previous engineering studies and other published information related to waste retrieval and closure at Hanford, waste retrieval and closure experience and plans at other DOE sites, process history and waste characterization data relevant to the five ATCD tanks, and information on techniques and equipment for sampling waste in tanks. Retrieval and closure technologies and methods identified in the DAR were considered in formulating alternatives that were then evaluated in this AGA.

Preliminary engineering is being conducted concurrent with this AGA and will be finalized based on these results. That will form the basis for refinement of cost and schedule baselines, and for focusing definitive design. These engineering design activities will provide the basis for obtaining the appropriate regulatory approvals required prior to conducting this demonstration. Performance data from the demonstration will be captured and evaluated in support of future closure decisions.

Five tanks, all located within the C Tank Farm, were selected for demonstration of retrieval and closure (the 241-C-106 tank and four 200 series tanks [241-C-201 through 241-C-204]). The C Tank Farm tanks were built between 1941 and 1944 in the 200 East Area in support of the planned C Plant chemical processing facility. The farm consists of twelve 100 series tanks and four 200 series tanks, all of which were constructed of reinforced concrete with welded carbon steel liners. A description and background of the five selected tanks is found in the DAR report. Following is a brief summary followed by a capacity and current state volume summary provided in Table 1-1:



- **Tank 241-C-106** is a 22.9 m (75 ft) diameter tank with a total volume of 2,010,000 L (530,000 gal). The tank was put into service in 1947 and declared inactive in 1979. The tank is classified as a sound tank with

no historical indication of leakage due to loss of integrity. Three sluicing campaigns were conducted in the 1998/1999 timeframe to resolve the high heat safety issue. Approximately 97% of the sludge in the tank was removed during this activity (Carothers et al 1999). It is currently estimated that 23,000 L (6,000 gal) of solids (sludge) and 115,000 L (30,000 gal) of liquid (supernatant) remain in the tank (Callison 2002). (Note: Recent reviews from in tank videos and preliminary engineering calculations indicate approximately 18,500 gallons of fluid and 9,000 gallons of sludge remain in the tank.)

- **Tanks 241-C-201 through –204** are four 6.1 m (20 ft) diameter tanks each with a volume of 208,000 L (55,000 gal). These tanks were put into service in 1947 and were removed from service in the late 1970's. These tanks are four of sixty-seven SSTs currently listed as assumed leakers. It is currently estimated that the 241-C-201 and 241-C-202 tanks each contain approximately 4,000 L (1,000 gal) of solids and the 241-C-203 and 241-C-204 tanks each contain approximately 10,000 L (3,000 gal) of solids (Callison 2002).

Table 1-1. Summary of Tank Capacity and Current State.

Tank	Capacity L (gal)	Current Estimated Volume, L (gal)			Maximum Residual Volume Retrieval Goal[a] L (gal)
		Liquids	Solids	Total	
241-C-106	2,010,000 (530,000)	115,000 (30,000)	23,000 (6,000)	138,000 (36,000)	10,219 (2,700)
241-C-201	208,000 (55,000)	None	4,000 (1,000)	4,000 (1,000)	852 (225)
241-C-202	208,000 (55,000)	None	4,000 (1,000)	4,000 (1,000)	852 (225)
241-C-203	208,000 (55,000)	None	10,000 (3,000)	10,000 (3,000)	852 (225)
241-C-204	208,000 (55,000)	None	10,000 (3,000)	10,000 (3,000)	852 (225)

[a] Based on HFFACO Milestone M-45-00.

1.2 REQUIREMENTS, CONSTRAINTS, AND ASSUMPTIONS

The principal requirements, constraints, and assumptions related to this alternative generation and analysis are described below.

- As this is a closure demonstration, the primary components addressed include the retrieval of tank contents and the evaluation of tank fill alternatives. As such, ancillary equipment (pipes, risers, etc), surrounding soil, vadose zone, groundwater, and future capping are not within the scope of the evaluation. It is assumed that final remediation of groundwater and soil surrounding the C Tank Farm will be addressed as part of the larger 200 Area groundwater remediation strategy and that ancillary equipment and future capping will be addressed as part of the larger C Tank Farm closure.
- Alternatives must be supportive of future C Tank Farm closure activities. Tank closure will not hamper access to adjacent tanks.

- Closure will be completed following the criteria established for landfill closure of the tank(s). Closure requirements will be established with the *Resource Conservation and Recovery Act of 1976* (RCRA) Closure Plans and the DOE Order 435.1 requirements.
- Ecology approval for this demonstration is required and will be obtained via submittal and approval of a closure plan. Ecology will accelerate the review cycle and approval process for all plans and permit applications.
- DOE approval for this demonstration is required and will be obtained via (1) a Waste Incidental to Reprocessing determination that the residual waste will be managed as mixed low level waste and (2) a closure plan in accordance with DOE Order 435.1. DOE will accelerate the review cycle and approval process for all activities.
- Retrieval of waste will use currently available technologies, as appropriate, including past-practice sluicing or low-liquid volume retrieval systems currently under development for tanks C-104, and S-102. Deployment of leak detection mitigation and monitoring technology would consist of use of currently available technologies and/or monitoring approaches appropriate to the retrieval technology used on a tank-by-tank basis.
- Data quality objectives (DQO) will be developed to support the ATCD project. It is assumed that archived tank samples can be located and characterized to partially satisfy data needs. The DQO process may identify additional waste characterization needs.
- Pre-retrieval characterization will be sufficient to support both retrieval and closure and existing characterization data is adequate to initiate the retrieval design selection
- Equipment left over in the tank will not be counted in the 360 cubic feet requirement.
- DOE and regulators will be involved in the project continually. This includes development of DQOs, determining when the Appendix H (Ecology et al 1989) process will be complete, and resolving how risk assessment will be done (e.g., future land use).

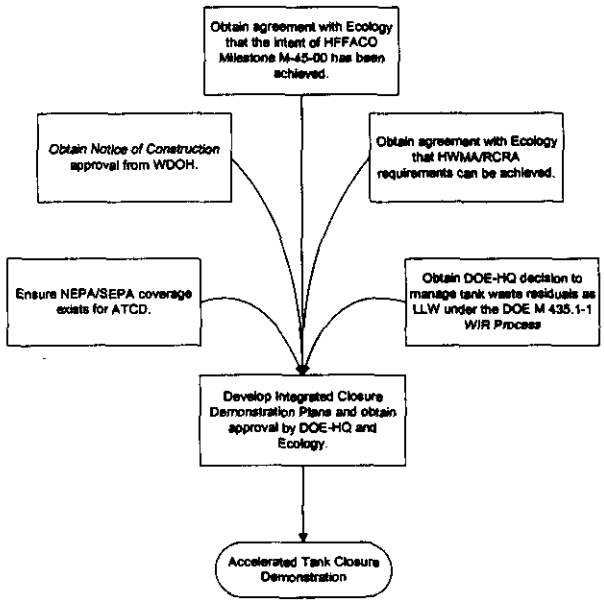
Schedule commitments for completing tank waste retrieval and closure technology demonstration activities are included in Table 1-2. These commitments are identified in Performance Based Incentive ORP-28 (Contract Number DE-AC27-99RL14047).

Table 1-2. Summary of Major ATCD Commitments.

Activity	Commitment
Complete retrieval of additional waste from first ATCD tank.	1/31/2004
Complete closure of first ATCD tank.	3/30/2004
Complete closure of additional four ATCD tanks.	12/31/2004

2.0 REGULATORY ALTERNATIVES

The regulatory strategy (Attachment 1) for the Hanford SST ATCD project identifies an approach for obtaining the necessary approvals from the DOE, Ecology, Washington State Department of Health (WDOH), and the Environmental Protection Agency for the proposed actions. As shown on the right, the strategy outlines decisions associated with the key regulatory requirements controlling tank waste retrieval and closure technology demonstrations.



Although there are a number of other regulations, requirements, and DOE Orders that may apply to retrieval and closure, each of the regulations or agreements listed above have associated compliance options that must be considered for planning and performance of the ATCD project. Other applicable laws, regulations, and requirements are summarized in Attachment 1.

2.1 RECOMMENDED REGULATORY APPROACH

The recommended approach for compliance with the regulatory requirements is summarized by the following elements:

- Demonstrating *National Environmental Policy Act of 1969* (NEPA) compliance with an Environmental Assessment and "State Environmental Policy Act of 1983" (SEPA) compliance with a SEPA Checklist as supported by the Environmental Assessment.
- Developing "Hazardous Waste Management Act"/RCRA Closure Plans in a tiered approach that provides the basis for RCRA Permit modifications and Ecology approval.
- Retrieving tank waste in accordance with HFFACO Milestones and Appendices.
- Reclassifying high level residual tank waste as waste incidental to reprocessing (WIR) and utilizing alternative risk-based requirements, for low-level radioactive waste, to demonstrate compliance with the performance objectives of 10 CFR 61 Subpart C and the applicable contaminant concentration limits of 10 CFR 61 Subpart D.
- Preparation of Closure Demonstration Plans that address *Radioactive Waste Management Manual* (DOE M 435.1-1) Tier 1 and Tier 2 Closure Plan requirements, and obtaining U.S Department of Energy Headquarters concurrence for a streamlined DOE review and approval process.

- Using the existing approved composite analysis (PNNL 1998) and successor documents for cumulative groundwater contamination impacts through the 1,000 year time period evaluated.
- Closure plan negotiations will include discussion focused on those results tied to data quality objective negotiations (including planned sampling and characterization activities) and include strategies linked to negotiated permit conditions and compliance schedules such as land disposal restriction determinations, closure (end-state) conditions, and fulfilling data needs to reduce uncertainty.
- Long- and short-term risk is evaluated through a detailed site-specific risk assessment based on conditions and knowledge of the C Tank Farm integrated with a site-wide composite analysis for a performance assessment.

Many additional State and Federal permitting and evaluation criteria (regulatory requirements) exist succinctly and generate indirect options within the ATCD strategy to reach an ultimate closure status for the SSTs and waste management areas (WMAs). These criteria are outlined in Attachment 1. The resolution and negotiation of any applicable requirements will be adopted in the governing regulatory documents that apply to this project.

2.2 GENERAL CHARACTERIZATION APPROACH

The ATCD project recognizes the importance of characterization to support closure decisions and as such will continue to seek the timely implementation of new tools and methods that may advance closure-planning decisions. Section 8.0 "Characterization Approaches and Technologies" of the DAR (Callison 2002) outlined general characterization approaches to support tank closure actions.

The traditional in-tank characterization strategy is to sample as part of the closure activities, analyze the samples, and then submit the required information to the regulators. However, the accelerated schedule for this project requires a 3-month window that does not support a traditional approach. It is assumed that the samples from the 241-C-106 tank are high activity samples requiring analysis at the 222-S Laboratory (or another suitable "on-site" laboratory facility). 222-S Format V RCRA compliance data has a turnaround time from delivery to the lab to publishing the data of 180 calendar days plus 30 day for validation. The sampling and characterization process may not be capable of being collected post-retrieval and analyzed in Format V in time to meet the required project completion dates. Therefore a non-traditional characterization strategy is being evaluated.

2.2.1 Characterization Strategy

The characterization strategy for 241-C-106 may require two sampling events to collect sufficient data to support the closure demonstration project and support the closure of the WMA.

The first sampling event can be conducted prior to retrieval. The pre-retrieval sampling will collect multiple, statistically defensible samples to characterize the constituents in the waste. Analysis at 222-S (or another suitable on-site laboratory facility) would be reported as Format V with the 180-day data turnaround for the data package plus additional 30-calendar days for validation of 5% of the data (210 calendar days total).

The second sampling event will be conducted after retrieval (it may also include sampling during waste retrieval operations). The post-retrieval sampling will collect multiple, statistically defensible samples to characterize the constituents in the residual waste. The analysis would be reported in 2 concurrent stages:

- **Stage 1**: Analysis would be reported as Format II (Process Control) on a 45-calendar day (or Format III Safety Screen 90-calendar day) data turnaround to confirm that the pre-retrieval data is consistent with the post retrieval data. Both the Format V pre-retrieval validated data and the Format III post-retrieval data may be used to support closure decisions. Note: Stages 1 and 2 run concurrently and if another suitable on-site laboratory facility equivalent data packages would be prepared.
- **Stage 2**: In support of the WMA closure, 222-S (or another suitable on-site laboratory facility) data analysis would continue and would be reported under Format V 210-calendar day validated data. Pacific Northwest National Laboratory (PNNL) physical property analysis is also expected to be conducted at this time. Note: Stages 1 and 2 run concurrently if another suitable on-site laboratory facility equivalent data packages would be prepared.

The normal requirement is "5% of the data" must be validated. For this effort, validation is expected to be limited to one sample in the data package.

The following assumptions support the proposed characterization strategy:

- Closure plan and Quality Assurance Project Plan (QAPjP) are either acceptable to Ecology or ORP/CHG proceeds with sampling 'at risk.'
- The pre-retrieval waste and post-retrieval waste have the same or very similar compositions. (Note: If the retrieval option requires addition of constituents that are part of the closure Contaminant of Concern (COC) list a material balance may be required as part of the comparison.)
- Ecology accepts the assumption that pre-retrieval waste and post retrieval waste have the same or very similar compositions.
- 222-S or another suitable on-site laboratory facility will meet the turnaround times and QAPjP requirements as noted.

2.2.2 STRATEGY IMPLEMENTATION

The following sections discuss how the strategy is being implemented within the time constraints.

2.2.2.1 Data Quality Objectives Process

A DQO process is underway with the regulators to develop COCs, closure demonstration standards, analytical methods and related DQOs (method detection limits [MDLs], practical quantitation limits [PQLs], precision, accuracy, etc.), and sample design, sample collection methods, and volume measurement methodology needed by the closure plan. The information needs of any post-retrieval risk assessments are included as part of the DQO. A document will be prepared to document the DQO effort, either as a standalone document or as an appendix to the Closure Plan.

2.2.2.2 Closure Plan

The Closure Plan will have a sampling and analysis section in Chapter 6, "Closure Activities" and a supporting QAPjP in the appendix. The sampling and analysis section will document the COCs, closure demonstration standards, analytical methods and related DQOs (MDLs, PQLs, precision, accuracy, etc.), and allowable sample designs and sample collection methods. Much of this information will be developed by the DQO. The information needs of any post-retrieval risk assessments are included in the closure plan.

It is intended that the sample collection methods will not be fully described within the Closure Plan. Instead, a menu of generic sample collection methods that can meet the DQOs will be listed, with the down-selection to occur at a later time.

2.2.2.3 Sampling Technologies

Initial screening of sampling technologies can be focused to effectively and quickly locate workable technologies that could be described in the closure plan text and could be in place to support closure decisions (DOE 435.1 Tier 1 and RCRA Closure Plans). Technologies examined during the initial screening effort include:

- Fingertrap: Proven to be able to collect tank waste samples with all the required documentation being in place. The fingertrap is lowered, via a rope, down to the waste. Access is available only at open riser positions. A complete subset of statistical samples cannot be collected, as access is limited to open riser positions. The fingertrap has been kept during the initial screening as a baseline sampling method. Also, it may be used for sample collection in conjunction with the sample arm or mobile retrieval system (MRS).
- Core Samplers: Proven to be able to collect tank waste samples with all the required documentation being in place. The Authorization Basis (AB) limits the distance the core sampling can penetrate to in reference to the tank bottom. Past experience with core sampling hardpan sludge waste has shown limited success. A complete subset of statistical samples cannot be collected, as access is limited to open riser positions.

- Auger Samplers: Proven to be able to collect tank waste samples with all the required documentation being in place. Auger samplers are available, but auger assemblies would need to be fabricated. A complete subset of statistical samples cannot be collected, as access is limited to open riser positions.
- Light-Duty Utility Arm (LDUA): Existing equipment. However, it is 1) not referenced in the AB, 2) needs repairs, 3) there is limited locations in which to perform repairs, and 4) it may not have enough power to collect a sample of hard tank waste. Use of this method requires modification to the AB, procedure development, and operator training prior to deployment.
- Sample Arm: This is equipment that has been deployed in previous tank sampling but would have to be redesigned and built to meet Tank 241-C-106 specific requirements. Lowered via a riser, it drops a hinged arm down onto the waste and collects a sample. The arm could not reach 100% of the tank but it could collect samples within a specific distance of the riser being used. Use of this equipment may require modification to the AB, procedure development, and operator training prior to deployment.
- Mobile Retrieval System (MRS): Existing equipment under consideration for retrieval. The MRS could be used to 'bulldoze' waste from a sample location over to an accessible riser for sampling via the fingertrap. There are then concerns about cross-contamination and sample representativeness after being dozed across the bottom of the tank. Alternatives that should be investigated include the possibility of mounting a front-end loader type bucket in place of the dozer-type blade or the attachment of a sampling device to the MRS. Further investigation on use of the MRS for sampling is on hold pending better definition of the systems to be used during waste retrieval operations. Use of this equipment may require modification to the AB, procedure development, and operator training prior to deployment.
- Robotic Sampler: Robotic sampler using off-the-shelf components (tracks, lights, cameras). PNNL had built and deployed a similar unit as a drain line inspection robot used in the Canyon Disposal Initiative to video tape the U Plant central drain line. The Robotic Sampler is expected to meet all sampling criteria. Design would use the existing sample cup from LDUA. Cost to develop and purchase 3 robots is less than the cost to core sample. This sample cup is useable with existing sample shipping equipment (pigs) and is in the Safety Analysis Report for Packaging. PNNL may be able to deploy the system as a demonstration for sampling 241-C-106. Therefore, no CHG procedures or training would be needed. Use directly by CHG could then be done for future tanks. Use of this equipment may require modification to the AB, procedure development, and operator training prior to deployment.

The Robotic Sampler is currently the favored approach because it has been successfully deployed on other Hanford projects and it is cost-effective. PNNL is currently working on a detailed cost estimate to support future planning. If deployed as a technology demonstration by PNNL, preparation of CHG procedures and training of CHG operators would not be necessary. It is expected that the closure plan will present multiple sampling methods that can meet the DQOs and the fingertrap, sample arm, and MRS are recommended for further consideration.

2.2.2.4 Analytical Strategies

The CHG contract with 222-S Laboratory recognizes the following timetable:

Table 2-1. 222-S Laboratory Sample Timetable.

Format	*Description*	*Timetable*
Format I	Early Notify	1 calendar day
Format II	Process Control	45 calendar day
Format III	Safety Screen	90 calendar day
Format IV	Waste Management	180 calendar day (180 calendar days at 222-S plus 30 days for independent validation)
Format V	RCRA Compliance	210 days
Format VI	Special	Depends

It is expected that 222-S or other on-site laboratories will be used for the radiological and chemical analysis of the residual tank wastes. If other on-site laboratories are utilized, or if negotiations with the 222-S labs are successful, this restraint could be minimized.

2.2.2.5 Number of Samples

The current number of samples to support RCRA closure decisions will be determined by the DQO process that is currently underway with involvement of regulators.

3.0 RETRIEVAL ALTERNATIVES

This section describes the approach used to select and evaluate retrieval technologies and identifies the alternative selected for the ATCD project.

3.1 HISTORY AND PREVIOUS EVALUATIONS

Previous analyses have been conducted evaluating retrieval technologies for removal of sludge waste from SSTs. Results of those analyses provide input to the selection of waste retrieval technologies to be demonstrated, pursuant to HFFACO M-45 series milestones, for tanks C-104 and S-102, and to the identification of retrieval technologies in the DAR (Callison 2002). This AGA has used the results of those studies to determine the appropriate technologies for retrieval of the sludge from tank 241-C-106 and the C-200 tanks. This study builds on the results of those previous engineering evaluations, AGAs, conceptual designs, preliminary designs, and testing and development efforts. Those studies and their conclusions are summarized below.

- The Hanford Tanks Initiative (HTI) Engineering Development – The HTI project evaluated, through competitive evaluation of vendor data and proposals, a wide variety of retrieval systems including arm based systems and vehicle based systems to retrieve the heel in tank 241-C-106 following sluicing. A down selection was performed on viable technologies and two vehicle-based retrieval systems were taken through conceptual design.
- C-104 AGA (Bogen et al. 1999)– This AGA evaluated alternate sludge retrieval technologies to retrieve waste from tank C-104. Tank C-104 is similar to tank 241-C-106, and contains sludge waste believed to be similar to the waste in 241-C-106. Technologies evaluated include past practice sluicing, a vehicle-based retrieval system, borehole mining, remote arm-based retrieval, and dry mechanical mining. The technologies were developed and evaluated against decision criteria that included implementability, cost, schedule, risk, maturity, leak potential, and performance characteristics. One objective of the study was to evaluate the alternate systems against the reference technology for SST retrieval of past practice sluicing. The C-104 AGA recommended retrieving the waste with an in-tank vehicle with a pump and attached umbilical system used to provide fluid to mobilize the waste and to transfer waste slurry from the tank. Several of the technologies identified in the C-104 AGA are used as candidate technologies for this AGA.
- C-104 Preliminary Engineering Report (Crass 2000) – The C-104 preliminary engineering further refined the system concept for retrieving waste sludge from tank C-104. The engineering identified operational issues such as retrieving around in tank debris and use of an umbilical system to transfer waste out of the tank that could lead to less than optimal retrieval performance. Operational limits of the crawler based retrieval system were established and areas for improvement were also identified.

- C-104 Conceptual Design (Carpenter 2001) – Based on the issues identified in the C-104 Preliminary Engineering Report, the retrieval approach was modified to eliminate the umbilical system, remove the transfer pump from the in-tank vehicle, and add the use of a movable mast supplied with a pump to transfer waste out of the tank. The system uses very small amounts of water during retrieval as opposed to earlier retrieval concepts, greatly reducing the potential for large liquid releases during retrieval. This system (i.e., MRS) is carried forward as a candidate technology for retrieving the tanks within the scope of this AGA. The MRS is planned to undergo cold testing at the Cold Test Facility during FY 2003. Upon successful completion of testing, the system could be deployed in 241-C-106.
- S-102 Preliminary Engineering Report (Doeler 2001) and Conceptual Design (Sturges 2002) - Tank S-102 contains both saltcake and sludge waste. A fluidic retrieval system will be used to dissolve the salts and mobilize the insoluble sludge waste in the tank. The fluidic system employs a series of charge vessels and discharge nozzles in the waste to mix and mobilize the waste. The fluidic retrieval system is included in this analysis as a candidate retrieval technology.

In addition to the C-104 and S-102 retrieval demonstration projects, a saltcake dissolution technology is under development for waste retrieval from tank S-112. However, this technology would not be applicable for sludge retrieval from the five ATCD tanks.

3.2 COST-BENEFIT ANALYSIS

This section summarizes results of an evaluation of the relationship between costs to retrieve waste from the ATCD tanks to various possible end states, and the associated impacts to human health and safety risk.

3.2.1 Basis for Cost Benefit Analysis

Selection of retrieval technologies and overall waste retrieval strategy must eventually consider factors other than retrieval technology capability. This need to consider other factors, including cost, is addressed in HFFACO Milestone M-45, Appendix H to the HFFACO, the 1996 MOU agreed to by the DOE and Ecology, and DOE Order 435.1.

HFFACO Milestone M-45-00: HFFACO Milestone M-45-00 requires closure of all SST farms by September 30, 2024, following waste retrieval to an acceptable level. Acceptable levels for cleanup of contaminated soil and ancillary equipment have not been defined, but an initial volumetric retrieval goal has been established for waste removal from SSTs. Regulatory authorization for final tank farm closure "will consider cost, technical practicability, and potential exposure to radiation."

Appendix H to the HFFACO: Appendix H to the HFFACO describes the process for establishing and modifying the initial volumetric waste retrieval goal as waste retrieval progresses. This process includes provisions for DOE to request exemptions to the waste retrieval goal, on a tank by tank basis, in the event the goal is not met. Information identified to be submitted as part of such exemption request includes "estimated schedules and costs for development and deployment" of retrieval technology.

1996 Memorandum of Understanding (MOU): Building on the requirements of HFFACO Milestone M-45 relating to the volumetric waste retrieval goal, the 1996 MOU that was developed as a framework for the Hanford Tanks Initiative Project contains the following statement:

> "Comparing the Interim Retrieval Goal to agreed upon performance measures that include risk reduction, cost, compliance with WAC 173-303, and other parameters will provide a firm basis for the retrieval program to move forward on tank waste retrieval technology demonstrations and deployment."

DOE Order 435.1: Under DOE Order 435.1, closure of high-level waste storage tanks requires designation of waste residues as WIR and reclassification of such waste as either low-level waste or transuranic waste. In either case, one of the criteria for obtaining such reclassification is to demonstrate that the waste has been or will be processed "to remove key radionuclides to the maximum extent that is technically and economically practical."

3.2.2 Scope of Cost Benefit Analysis

While we may lack the necessary understanding of the key elements impacting tank closure decisions to invoke a cost/benefit argument under either the HFFACO Appendix H waiver process or the DOE Order 435.1 WIR process, it is informative to conduct a preliminary evaluation of the risk reduction benefits of waste retrieval versus cost. This was conducted for the five tanks scheduled for retrieval and closure under the ATCD project. Attachment 2 provides results of that study.

The cost versus risk study considered long-term risks through the groundwater pathway at the tank farm fence line for both a residential farmer scenario, and an industrial worker scenario. Scenario risks were calculated in terms of incremental lifetime cancer risk (ILCR) and compared to the acceptance standard 10^{-5} ILCR. Contaminant concentrations in groundwater were based on scaling results from the AX Tank Farm Retrieval Performance Evaluation (DOE-RL 1999).

Intruder risks were evaluated for an acute dose to a postulated well driller from direct external exposure to the exhumed contaminants, as well as a chronic dose to humans who consume vegetables grown on land over which the exhumed waste has been spread. Scenario risks were calculated in terms of mrem for acute dose, and mrem/yr for chronic dose. Results are compared to the standards in DOE Order 435.1 (500 mrem for acute dose, and 100 mrem/yr for chronic dose.)

Short-term risks to workers involved in waste retrieval field activities were also evaluated. These estimates considered occupational injuries, illnesses, and fatalities, radiological risk from accidents, and radiological latent cancer fatalities from routine exposure to radiation.

There are substantial uncertainties associated with the risk calculations in this study, as acknowledged in Attachment 2. However the purpose of this cost vs. risk study was to compare retrieval scenarios on a common basis, not to provide definitive answers on estimated risk associated with retrieval and closure. There is also substantial uncertainty associated with retrieval costs reported in this study. For that reason, where actual data does not exist, costs were represented as ranges.

The objective of this study was not to evaluate cost vs. risk for specific retrieval technologies, but rather for a set of defined end states, for each of the five ATCD tanks. One of those end states included the current state, i.e., for no additional waste retrieval actions. This was necessary to quantify the risk reduction benefit for waste retrieval. For all five ATCD tanks, two additional end states were considered—retrieval to the current HFFACO volumetric retrieval goal (360 cubic feet for 100-Series tanks, 30 cubic feet for 200-Series tanks), and retrieval beyond the HFFACO goal. It was necessary to specify an assumed residual volume for the latter case, in order to perform the required risk calculations. Retrieval to 10% of the HFFACO retrieval goal was selected (36 cubic feet for 241-C-106, and 3 cubic feet for the 200-Series tanks in C Tank Farm) consistent with a corresponding case evaluated in the AX Farm RPE. Two additional end states were analyzed for 241-C-106. Because 241-C-106 was previously retrieved by past-practice sluicing under Project W-320, and costs for that retrieval project are known, it was useful to consider that additional data point. Also, since a large volume of pumpable liquid remained in 241-C-106 following completion of past-practice sluicing, a plausible retrieval action would be to simply pump the remaining liquid from the tank, which was the second additional end state considered for 241-C-106.

3.2.3 Results and Conclusions

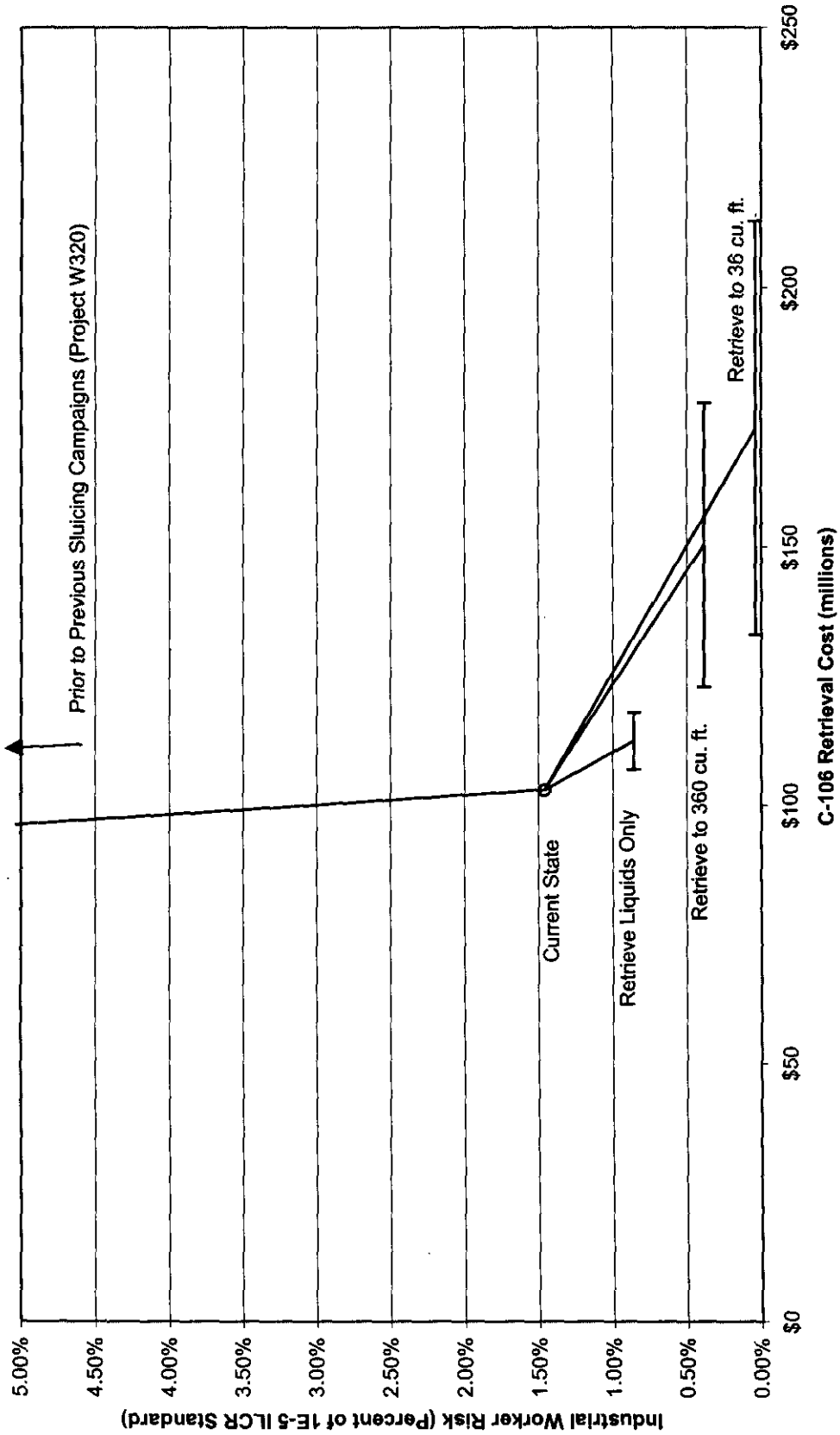
Results for all cases analyzed are provided in Attachment 2. Due to uncertainties in estimating risk, and given the purpose of this study, absolute values reported for any given case are less meaningful than the comparison of relative risk by assumed end state. This allows comparison of relative risk reduction (or, in the case of short term worker risk, relative risk increase) by estimated cost to achieve that end state. Not surprisingly, short-term worker risk is generally proportional to cost of field activities to install and operate retrieval equipment. The more interesting relationship is that between relative long-term and intruder risk reduction vs. retrieval cost. This relationship is best reflected in the risk reduction vs. retrieval cost evaluation for 241-C-106, since this includes two additional end states that were not relevant to the other four ATCD tanks. Both long-term groundwater risk scenarios, and both intruder risk scenarios show the same general relationship. For simplicity, the relationship for only one scenario, long-term groundwater risk to the industrial worker, is shown below in Figures 1 and 2. Data for the other risk scenarios and ATCD tanks are provided in Attachment 2.

The following principal conclusions may be drawn from these figures:

- Significant risk reduction has already occurred from retrieval of 241-C-106 waste by past-practice sluicing
- Additional risk reduction by (a) pumping liquids only, (b) removing liquids and sludge to the HFFACO milestone, and (c) removing liquids and sludge to beyond the HFFACO milestone will cost significantly more, per unit of risk reduction, than the risk reduction that has already occurred.
- The cost per unit of risk reduction for progressively cleaner end states in 241-C-106 increases with increasing cost, i.e., in economic terms there is a diminishing marginal rate of return (measured by risk reduction) for increased retrieval costs.

It is important to note that this work effort and method for comparing the net benefit of a given waste retrieval action will continue to evolve as we gain maturity in the tools used to support tank closure decisions.

Figure 3-1. Tank C-106 Long-Term Risk Versus Cost



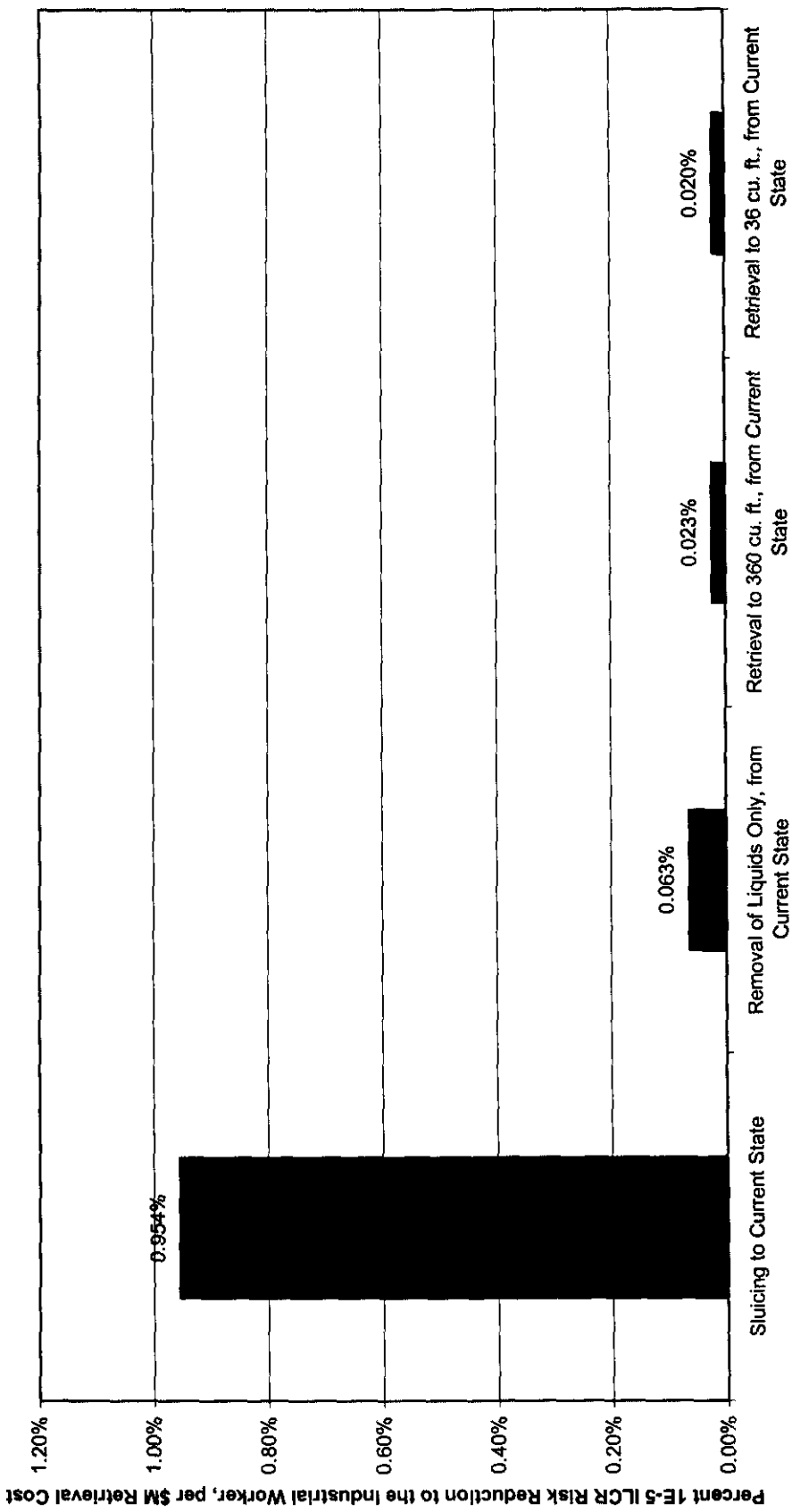


Figure 3-2. Percent 1E-5 ILCR Risk Reduction per $M Retrieval Cost for C-106 (Based on Midpoints of Estimated Retrieval Cost Ranges)

3.3 RETRIEVAL TECHNOLOGY EVALUATION

This section describes how the retrieval technologies were selected and evaluated for the ATCD project.

3.3.1 Retrieval Requirements

Candidate technologies for retrieval of the five ATCD tanks were identified considering the technologies discussed earlier in this section, as well as technologies evaluated for use and used at other DOE sites. Because these technologies have been addressed in detail in these and other technology assessments, this AGA relies on much of the data and results from these past analyses in the technology evaluation. A range of technologies is evaluated in this AGA. The range of technologies includes those techniques that have been used at Hanford and at other sites, as well as technologies that are in development that may be ready for deployment to support the retrieval and closure schedule.

Waste retrieval technologies that could potentially achieve the current HFFACO volumetric waste retrieval goal for this ATCD were subjected to an alternatives analysis. The complete study is included in Attachment 3. Below is a summary of the study and the identification of the preferred retrieval technology. Retrieval activities associated with the ATCD project were subject to the following constraints and requirements:

The requirements identified below were extracted from the HFFACO, tank farms operations documents, DOE Orders, and contract documents. Requirements are criteria that all retrieval system options must be able to meet in order to be considered viable options. Only options capable of addressing all the requirements below were evaluated against the decision criteria listed in the next section.

1. The retrieval option shall meet the schedule commitments addressed in Table 1-2.

2. Retrieval systems shall use only the existing riser access points.

3. Retrieval shall remove as much tank waste as technically possible, with tank waste residual not to exceed 360 cu ft in each of the 100 series tanks, 30 cu ft in each of the C-200 series tanks, or the limit of waste retrieval technology capability, whichever is less.

4. Leak detection is required.

5. The maximum live and dead loads allowed on the soil above the center of the tank dome should not exceed the values listed below. The load must be evenly distributed over at least a 10-ft radius over the tank and 20-ft outboard of tank:

    - C-200 series tanks- 50-ton or current limits in AB, and

- C-100 series tanks- 100-ton or current limits in AB. (Project W-320 used 50-ton of available limit.)

6. Retrieval equipment shall be designed to operate in the tank environment without failure for a complete tank retrieval cycle, including preventative maintenance.

7. Individual design doses to personnel shall not exceed 1,000 mrem on an annual basis.

8. The retrieval equipment shall not damage or breach the tank liner or dome.

9. In the event of a failure, the retrieval equipment must either be designed for removal from the tank for replacement or in-tank repair and return to service.

10. The retrieval system must be designed to be decontaminated and/or containerized to facilitate relocation to another tank, support system maintenance, or support disposal.

11. The retrieval system must be able to meet all applicable ESH&Q requirements (Clean Air Act, Clean Water Act, As Low As Reasonably Achievable [ALARA], Occupational Safety and Health Administration [OSHA] etc.) and tank farm contractor procedures and requirements.

12. Any rinse water needed for equipment decontamination and flush water must be removed from the tank or included in the allowed residual waste total.

13. Retrieval system must include ability to transfer mobilized waste to a receiver tank (e.g., double-shell tank [DST]).

3.3.2 Identification of Tank 241-C-106 Retrieval Technologies

Tank 241-C-106 contains both liquid and solid (sludge and heel) waste and is assumed to be structurally competent (i.e., non-leaking). The tank is approximately 75 ft in diameter. The following retrieval technologies were evaluated for tank 241-C-106:

- Mobile Retrieval System (MRS): MRS system consists of a centrally deployed articulating mast capable of deploying a vacuum head up to 15 ft radially out from the center of the tank. In conjunction with the mast, a tracked in-tank vehicle capable of mobilizing solid waste (i.e., simple push blade, scarifier, or sluicing nozzle) is deployed to mobilize solid waste to within reach of the vacuum pick-up head. The MRS system has been identified as the preferred retrieval technology for tank C-104.
- Past-Practice Sluicing (PPS): Past-Practice Sluicing technology specifically refers to sluicing as employed during project W-320 in which high-heat generating waste was removed from tank 241-C-106 (1998/1999).
- Modified Sluicing: This is a variant of PPS, with the sluicing system configuration modified to improve overall performance. Modifications could include relocating the slurry pump to the central riser (i.e., locate the intake in the center of the dished bottom),

add additional sluicing nozzles to improve access to remaining waste, and may consider chemically altering sluicing fluid to enhance dissolution of waste.

- Fluidic Mixing(AEA/ Fluidics): This system is based on alternating pumping and jetting of supernatant liquid to dislodge and mobilize the solid waste. Liquid supernatant is collected in a charge vessel and then discharged under pressure through wash nozzles to slurry and mobilize the solid waste. When significant waste has been mobilized and is in suspension, the slurry volume is pumped out of the tank.
- Crawler with Central Pump: This option is similar to the MRS technology described above with the exception that the articulating mast is replaced and a standard fixed pump is located in the center of the tank.
- Mobilization and Retrieval System (MARS): This system consists of a submersible pump with collocated valving system allowing it to mobilize waste through water jetting action, and/or pump waste out of the tank as a simple slurry pump.

3.3.3 Identification of Tanks 241-C-201 through 241-C-204 Retrieval Technologies

The four C-200 series tanks contain primarily dry granular sludge waste and are classified as assumed leakers. The tanks are approximately 20 ft in diameter. Minimizing the introduction of liquids to the 200 series tanks was determined to be critical to avoid further leakage to the soil column. The specific technologies evaluated are described below:

- Articulating Mast: An articulating mast would be used to remove the waste in dry form from the 200-series tanks. The mast will have the ability to reach the sides of the tanks and therefore an in-tank vehicle is not necessary. Mast and vacuum head would be sized to be deployed in the central 12-inch diameter riser.
- Articulating Mast with confined scarifier: Articulating mast with a scarifier attachment for the head would be used to enhance waste mobilization. The scarifier employs high pressure, low volume, rotating water jets to dislodge waste. Waste is then removed using a vacuum system or a close-coupled hydraulic pump.
- Light-Duty Utility Arm (LDUA) with scarifier: The LDUA uses a robotic arm designed to enter tanks with complicated in-tank obstructions and/or deploy tools in unusual positions, such as wall cleaning/inspection tools.
- Mast-mounted Arm w/ultrasonic: A mast similar to that used in the MRS system would be outfitted with an ultrasonic waste dislodging tool. Once dislodged, the waste would be removed using a vacuum or close-coupled pump.
- Crawler with motivator: A crawler system would be deployed through the 42 inch manway (requires excavation) and be outfitted with waste mobilization tools (i.e., scarifier, confined sluicer, simple push blade, etc.) to remove the waste.

3.3.4 Retrieval Technology Selection Criteria

Based on the requirements identified above and the retrieval goal of 360 cubic feet or less residual waste in tank 241-C-106 and not greater than 30 cubic feet of residual waste in the 200-Series tanks (HFFACO M-45-00), selection criteria were developed to evaluate the retrieval technologies. The selection criteria are performance characteristics used to distinguish between the identified options. Once the criteria were defined, they were weighted on a scale of 1 to 4, with 4 being the most favorable, according to relative importance. The selection criteria and weighting factors used to evaluate the retrieval technologies are presented in Table 3-1 below. :

Table 3-1. Retrieval Technology Selection Criteria.

Attribute	100 Series Tanks		200 Series Tanks	
	Weighting	Normalized Weighting	Weighting	Normalized Weighting
Cost	2	0.09	2	0.08
Schedule	3	0.14	3	0.13
Meet HFFACO requirement of 360 cu ft (30 cu ft)	4	0.18	4	0.17
DST Space Needs	2	0.09	2	0.08
Reliability, Maintainability, and Availability	2	0.09	2	0.08
Technology Maturity	2	0.09	2	0.08
ESH&Q and ALARA	2	0.09	2	0.08
Ease of Use of Application	2	0.09	2	0.08
Maximize Application to Future Retrieval	1	0.05	1	0.04
Minimize Introduction of Liquids into Tanks	2	0.09	4	0.18
Total	**22**		**24**	

Each of the retrieval technologies was evaluated against the selection criteria and given a raw score between 0 and 100. The weighting factors were normalized based on a percentage of the total points for each set of technologies (i.e., 241-C-106 and 200 series retrieval technologies). A discussion of the results and selection of the preferred alternative for tank 241-C-106 and the 200-Series tanks is presented in the following sections.

3.3.5 C-106 Retrieval Technology Evaluation

The weighted scoring results for retrieval technologies evaluated for tank 241-C-106 are provided in Attachment 3. The MRS was clearly identified as the preferred retrieval technology for tank 241-C-106 based on the weighted scoring system developed for this evaluation:

- Scored well against all decision criteria.
- Expected to have the capability to retrieve wide range of waste characteristics (i.e. physical waste types).
- Expected to be able to meet the HFFACO retrieval goal.
- Expected to meet schedule commitments.
- Use of dry retrieval mechanism (i.e., vacuum) eliminates need for the addition of liquids to tank.

The MRS received high scores, relative to the other alternatives, in expected performance, ESH&Q, reliability and maintainability, ease of use, application to future tanks, and minimizing water addition. The second ranked technology, the in-tank vehicle with pump, was the only other alternative ranked with a high probability of meeting the HFFACO waste removal goal of less than 360 cubic feet.

The MRS technology has previously been selected for planned retrieval activities in tank C-104. This technology is slated for demonstration at the Cold Testing Facility in FY 2003.

3.3.6 200-Series Retrieval Technology Evaluation

The weighted scoring results for retrieval technologies evaluated for the 200-Series tanks are provided in Attachment 3. The top three technologies are the articulating mast (no attachments), the articulating mast with a scarifier end attachment, and the LDUA with scarifier. These were closely ranked. The two alternatives utilizing the articulating mast are preferred for the ACTD project as they offer the additional advantage of utilizing the same retrieval equipment selected for tank 241-C-106. The main uncertainty concerning waste retrieval from the 200- series tanks is the nature of the remaining dry waste. Visual inspection of the tanks suggests the waste is dry and granular and may be retrievable simply with dry vacuuming utilizing the articulating mast alone. If the waste is more coherent, then the scarifier end effector may be required to mobilize the waste.

3.4 241-C-106 RECOMMENDED ALTERNATIVE

The selected alternative for retrieval of the remaining waste in 241-C-106 includes the following key elements:

1. Removal of the necessary in-tank equipment to support the installation of retrieval system(s).
2. Proceed with the pumping of liquid waste volumes from the tank. This effort is intended to remove the majority of the liquid residues and acknowledges the fact that the majority of the key risk drivers (i.e., mobile radionuclide inventory) exist within the liquid waste component. Evaluate use of the existing pipe-in-pipe waste transfer system provided under project W-320 vs. interfacing with the overground transfer line used for 241-C-103 interim stabilization.

3. Using the existing infrastructure and the pumping systems deployed, design and place a modified sluicing system within the tank with the goal of retrieving the majority of the residual solid wastes within the tank.
4. Evaluate the success of the modified sluicing system. If this retrieval system does not meet the HFFACO goal (less than 360 cubic feet of residuals), then proceed with additional retrieval or, if approved by Ecology, appropriate closure activities pursuant to HFFACO Appendix H.
5. Maintain a parallel development and engineering activity for the MRS as selected in the alternative analysis (Attachment 3). The MRS would be deployed in order to assure the acceleration of tank closure actions in the event modified sluicing is delayed, or waste retrieval does not achieve the HFFACO retrieval goal and an exception is not obtained.

Deployment of this multi-tiered approach will allow progress, while assuring that the tank closure schedules are not adversely affected by a single technology failure or a regulatory obstacle. CHG has selected this approach as a means to ensure that the success of each retrieval technology identified above can be directly linked to an associated reduction in risk. This approach will provide a means to evaluate the effectiveness of retrieval technology capabilities for application to future SST retrieval and illustrate a continued commitment to progress for the accelerated cleanup of the Hanford Site.

A modified sluicing system has the potential to achieve compliance with the HFFACO retrieval requirements contained in milestone M-45-00. It is recommended for first line deployment since it fits within an allowable cost profile, can be implemented within the tight scheduling demands for the ATCD project, will assist in the removal of the balance of the liquid and solid wastes, and will achieve removal of key mobile contaminants (including the expected removal of soluble components from the remaining sludge).

It should be noted that the alternative analysis (Attachment 3) was primarily focused on a technical evaluation of retrieval systems. Subsequent strategic planning sessions with ORP modified this recommended approach in an effort to meet the needs for rapid progress in the field, accelerated removal of liquids and sludges and the expectation that the concentration of key contaminants and the volume of the existing waste piles (solids) within the tank would be dramatically reduced in the first two steps of a multi-tiered approach. If additional retrieval is required to comply with the HFFACO, the MRS will be deployed. This provides an opportunity to demonstrate the MRS efficacy in a less demanding environment prior to deployment in future tank retrievals.

A lessons learned report, *Waste Retrieval Sluicing System (WRSS) and Project W-320, Tank 241-C-106 Sluicing, Lessons Learned* was issued to document experience from sluicing Tank 241-C-106 that occurred from November 18, 1998 through October 27, 1999 (Bailey 2000). Using the Integrated Safety Management System methodology, the report documented the following five significant items:

1. Oversight reviews provided only incremental value added for the substantial level of resources expended to support them,
2. Volatile Organic Carbon release response planning requires improvement,

3. Use of continuous sluicing operations would substantially reduce the cost of sluicing operations,
4. Increasing the operational flexibility allowed by AB and environmental permits is essential to efficient operations, and
5. Pump / Winch modifications should be made to avoid pump priming and discharge hose kinking problems.

Approximately 75% of the sludge removed from Tank 241-C-106 occurred in the first 10 batches. In the last 10 batches, sludge recovery progressively decreased, approaching zero recovery in the final batch. This occurred for the following reasons:

- Sizes of sludge pieces (up to 3") in sludge piles exceeded mesh size (0.25") on the submersible slurry pump screen,
- The sludge pile and debris under the submersible slurry pump prevented further lowering of the Pump,
- The sludge pile and debris under the submersible slurry pump could not be moved by the sluicing jet from the opposite side of the tank, and
- A severed thermocouple pipe and flexible hose/float interfered with lowering of submersible slurry pump.

This multi-tiered demonstration is proposed in an effort to meet the 360 cubic feet HFFACO retrieval goal. Pending the results of this planned demonstration, and subsequent regulatory approval, it is understood that Ecology may require the deployment of the MRS to complete the removal of additional waste residues. However, the efficiencies gained from early deployment of modified technologies, any AB modifications, updated environmental permits, tank preparation activities and deployment of trained operational staff would be made available to accelerate the momentum of the retrieval and closure activities for 241-C-106. It is important to note that, per the approach described above, a multi-tiered path for technology development efforts will be pursued to maintain operational flexibility for waste retrieval operations.

3.5 200 SERIES RECOMMENDED ALTERNATIVE

The articulating mast, with the option of utilizing a low liquid volume scarifier end effector, is the selected preferred retrieval alternative for the 200-series tanks.

4.0 CLOSURE ALTERNATIVES

This section describes the approach used to select and evaluate closure technologies and identifies the alternative selected for the ATCD project. The focus of the ATCD project is to prepare the tanks for closure. Ancillary equipment, surrounding soil, and final surface cap design are not included within the scope of this project.

4.1 HISTORY AND PREVIOUS EVALUATIONS

The DAR (Callison 2002) identified several tank fill alternatives from previous engineering studies and DOE complex experience. Those alternatives were considered in this AGA. Also included in the DAR is a discussion on the use of chemical getters. The development of getters is progressing, and the selection of the particular type to be used is largely driven by constituents of interest. It is assumed that some type of getter additive will be used for residual waste stabilization. The specific selection and method of application will be determined based on studies planned in FY 2003. In the mid 1990's, two principal studies were conducted that evaluated structural tank fill alternatives for closure (*Engineering Study of Tank Fill Alternatives for Closure of Single-Shell Tanks* [Skelley, 1996] and *Stabilization of In-Tank Residual Wastes and External-Tank Soil Contamination for the Tank Focus Area, Hanford Tank Iniative: Applications to the AX Tank Farm* [SNL, 1998a,b]). Alternatives evaluated assumed complete filling of the tank. The alternatives proposed in Skelley 1996 were essentially homogeneous systems consisting of a single material type. The tank fill design proposed in SNL 1998a,b, assigned different functions to layered components of differing material types. The distinguishing feature is the incorporation of a flowable sealing layer (e.g., bentonite or asphalt).

4.2 CLOSURE TECHNOLOGY EVALUATION

Fill alternatives being evaluated for the ATCD project adopt a multi-function approach, assigning different functions to an initial waste stabilization layer, and to the remaining tank void space to be filled (i.e., structural fill zone). Waste stabilization can include both physical and chemical stabilization with the objective of reducing the mobility of the residual contaminants in the presence of infiltrating water. Final closure of tanks will involve placing a fill material to stabilize residual waste and provide long-term structural stability. Stabilizing the tank structure will ultimately be necessary to ensure that the tanks do not collapse or fail structurally in a manner that would degrade performance of a tank farm surface barrier. Tank fill closure technologies evaluated for this ATCD were subjected to an analysis of alternatives. This study is included as Attachment 4.

Current regulatory issues have led to the conclusion that reversibility (i.e., retrievability of tank fill material) is an important factor when selecting tank fill materials. Thus, reversibility favors a multi-function approach where the initial waste stabilization layer would need to be retrievable, and the subsequent structural fill layer would then be placed only after final approval is granted for a final closure action. For purposes of the closure demonstration, a

phased approach to the tank fill closure activity has therefore been adopted. Initial tank closure will consist of placing a minimum thickness of tank fill material (estimated at 1 to 3 ft) to fulfill the desired waste stabilization function. This portion of the tank fill may include the addition of chemical sequestering agents and/or sorbent material to immobilize and/or retard contaminant migration. The remaining tank void space will be structurally stabilized at a later date prior to the installation of the final surface barrier.

4.2.1 Tank Fill Alternative Requirements

The following functional requirements were identified for selection of the tank fill design(s) and material.

1. **Minimize Contaminant Mobility**. Material shall be placed in contact with the residual waste, which minimizes risk of contaminant migration. Methods employed may include liquid absorption, waste encapsulation, cementitious bonding and/or chemical altration and stabilization.
2. **Structural Compatibility**. Waste stabilization materials must exhibit structural properties to be compatible with subsequent tank structural fill component.
3. **Reversibility**. Waste stabilization materials must be retrievable to comply with current NEPA requirements. Structural component of tank fill (i.e., above the waste stabilization layer) will not be installed until the reversibility issue has been resolved.
4. **Long-Term Structural Stability**. Completed tank fill design (waste stabilization layer + structural fill component) shall provide structural stability of the tank void space and prevent surface subsidence for minimum of 1,000 years. Prevention of future surface subsidence is critical to maintain the integrity of the designed surface barrier.
5. **Technical Maturity**. Selected tank fill design should use readily available and proven materials, equipment, and technologies. Consideration of previous applications in other DOE tank closure programs and regulatory experience will be evaluated.
6. **ESH&Q Compliance.** The tank fill material delivery system must be able to meet all applicable ESH&Q requirements (Clean Air Act, Clean Water Act, ALARA, OSHA, etc.) and tank farm contractor procedures and requirements.
7. **Worker Exposure.** Individual design doses to personnel shall not exceed 1,000 mrem on an annual basis.

4.2.2 Identification of Tank Fill Alternatives

As discussed above, tank closure activities will be conducted in a phased approach. Following planned waste retrieval actions, tank closure activities will be initiated with the placement of a waste stabilization layer designed to limit the mobility of residual waste constituents remaining near the bottom of the tank. The design requirements for this layer will incorporate the need to evaluate the retrievability of any action (i.e., reversibility). Following final regulatory approval, the remaining tank void space will be filled with a structural fill component to complete the closure of the tank. Tank fill material design

alternatives are discussed and evaluated separately for the two fill components. It is important to note that although fill design is discussed as two separate components, from a tank closure perspective, the long-term performance will be determined by its composite characteristics.

4.2.2.1 Waste Stabilization Layer

Following retrieval efforts and regulatory approvals, the waste stabilization layer for the selected tank will be placed within the bottom of the tank. The purpose of the waste stabilization layer is to assist in the reduction of the mobility of residual waste constituents by either physically isolating the residual waste from the environment and/or chemically treating the waste to reduce its solubility. Residual waste can be physically stabilized in one of three ways:

- **Microencapsulation**: Residual waste can be mixed with fill material to achieve dispersion of waste within the fill matrix (as much as technically possible) –or-
- **Macroencapsulation**: Residual waste is displaced by the fill material and "sandwiched" between a lower level containing getters and an upper layer. –or-
- **Isolation**: Residual solid waste not displaced by the fill material will remain adhered to the steel liner, and the fill material will function to minimize water infiltration through the waste and maintain a chemical environment that minimizes contaminant solubility.

Physical encapsulation of the waste reduces its mobility by isolating it from the environment and infiltration of water. Final hydraulic conductivity of the fill matrix, chemical characteristics of the fill, and degree of mixing are important factors controlling the benefit realized from encapsulation of the waste. Encapsulation with a flowable material reduces the surface area of the solid residual waste, decreasing the potential leaching rate of the soluble components.

Chemical stabilization of the residual waste focuses on using reactive materials (i.e., chemical "getters" or sequestering agents) to chemically alter potentially mobile constituents of concern to less leachable forms. Selection of a chemical treatment technology is dependent upon the constituents of concern. The primary constituents of concern expected in the selected demonstration tanks, in terms of long-term risk to groundwater, include Carbon-14, I-129, Tc-99, Se-79, Uranium, nitrate, nitrite, and possibly cyanide. A summary of current chemical stabilization techniques, is presented in the DAR (Callison 2002). Final selection of a specific chemical getter component into the waste stabilization layer will be made at a later date pending the results of residual waste characterization and on-going development studies.

Residual waste remaining in tank 241-C-106 is expected to consist of 360 cubic feet or less (HFFACO retrieval goal) of sludge, hard heel material and a small volume of free liquid. Residual waste in the 200-Series tanks is expected to consist of dry sludge and/or hard heel material totaling less than 30 cubic feet (HFFACO retrieval goal). Three alternatives were identified for the waste stabilization layer. They are described below.

Alternative # 1: High Density/Low Density Grout Encapsulation

An initial self-leveling, flowable, high-density grout will be placed in the bottom of each tank following retrieval. Chemical sequestering agents (getters) will likely be incorporated into the grout formulation to aid in immobilizing the residual waste constituents. Ideally, the high-density grout is expected to displace and "float" the residual waste (liquids and solids) off the tank floor. A second lift of low-density grout would then be placed to fully encapsulate the waste (macro-encapsulation). To the extent that displacement of waste by grout resulted in mixing, i.e., bringing contaminants in intimate contact with getters, some degree of micro-encapsulation may also occur. The standard chemical properties of grout (without getters) exhibit an ability to chemically immobilize both uranium and Carbon-14 through normal hydration and complexing reactions (Callison 2002). The mobility of the waste would be expected to be significantly reduced.

Alternative #2: Single Grout Layer

If the solid waste in the tanks is strongly adhered to the steel liner, then it is unlikely it will be displaced by the initial layer of grout. If this is determined to be the case, based on information gathered during retrieval activities, then low strength (< 200 psi compressive strength), grout will be placed in lifts on top of the waste residue. Chemical getters will likely be added to take advantage of the mixing that may occur with any remaining liquid waste. Incorporation of the liquid waste is significant as it is expected to contain the highest concentration of the mobile constituents. Residual solid waste will remain adhered to the steel liner of the tank and will be blanketed with the initial grout layer. Although the solid waste will not be fully encapsulated, the overlying grout is expected to minimize contact with infiltration water (isolation) and maintain a high pH environment conducive to minimizing contaminant solubility.

Alternative #3: Granular Layer

A granular layer can be placed in the tank bottom following retrieval. The granular material may consist of sand, gravel, dry bentonite, absorbent zeolite material, apatite, or apatite blended with another granular material. The purpose of the aggregate material will be to wick and contain the liquid fraction of the residual waste (in tank 241-C-106). Zeolites incorporate the added benefit of providing selective ion-exchange (i.e., immobilization) for certain constituents (e.g., Sr-90, Cs-137, etc). Use of dry bentonite (or similar swelling clay material) would create a low permeability capping layer physically incorporating the liquid waste fraction and effectively sealing the solid waste fraction from future infiltration waters. Development of apatite as a getter for key contaminants is planned for FY 2003. Coarser aggregate material may be added to increase the structural performance of the bentonite layer. Additional study will be required to identify optimal performance design using granular materials. An advantage of a granular type fill material over a coherent solid such as grout is it is anticipated the granular material would be easier to retrieve if necessary (i.e., more reversible). If the MRS is used for retrieval of 241-C-106 waste, the in-tank vehicle could be used to promote mixing of a granular material containing getters with the residual unretrievable waste (micro-encapsulation).

4.2.2.2 Structural Fill Layer

After the waste stabilization layer has been placed, regulatory approval will once again be required before initiating complete tank closure with structural fill materials. The two key performance factors associated with this component are the physical stability of the tank void space and minimizing infiltration water from reaching the waste. Identified structural tank fill alternatives, as outlined in the DAR, are described below:

- **Gravel**: Remaining tank void space will be filled with crushed aggregate to top of dome.
- **Grout**: Remaining tank void space will be filled with grout installed in layers.
- **Concrete**: Remaining tank void space will be filled with concrete installed in layers.
- **Hybrid**: Remaining tank void space will be filled with hybrid fill material (e.g., rounded aggregate plus grout).
- **Multi-layered Fill**: Remaining tank void space will be filled with grout and will incorporate the asphalt/aggregate sealing layer as described in SNL 1998b.

Alternative #1: Gravel

Filling the tank void space with gravel has been evaluated as a relatively simple means to provide structural stability. Crushed aggregate, possibly generated on site, would be placed in the tank via a rotating "rock slinger" apparatus installed in a central riser. Distribution of the gravel evenly throughout the tank is controlled by the discharge angle and rotation speed of the rock slinger. Prototype testing of a commercially available swiveloader was conducted at Hanford between 1983 and 1985 (Skelley 1996). The apparatus was designed handle a maximum particle size of ¾ in and to fit in a 42 in diameter central riser.

The following are initial advantages and disadvantages identified for the use of gravel as a tank fill material.

- Gravel is a relatively inexpensive inert material, potentially readily available on site.
- Structural Stability Performance requires that the gravel be placed in the tank evenly and at its maximum pack density to prevent the creation of void spaces and possible future settling. Proper placement of the gravel would be hampered given the presence of in-tank hardware (e.g., existing riser extensions and hanging equipment) and discarded equipment on the tank floor. To prevent "shadowing" effects of vertical in tank hardware (i.e., deflection of gravel material creating void space behind the equipment) it is likely that the larger pieces would have to be removed.
- Achieving optimal density may require additional compaction, a very difficult activity to perform inside the tank. Verification of design density may also represent a significant challenge.
- Implementation. Rock-Slinger apparatus described in Skelley 1996 requires a centrally located riser and was designed to fit within a 42-inch diameter riser. Some 100-series tanks may require the installation of appropriately sized and located risers to accept the

rock slinger, adding significant cost and worker exposure to using gravel fill. For the tank fill alternatives analysis (Attachment 4), it was assumed that a commercial rock slinger would be capable of adequately distributing gravel within the ATCD tanks.

- Use of gravel would not be anticipated to provide significant levels for hydraulic isolation of the waste. Resulting pore space and volumes would be expected to allow any infiltration water to pass through the fill and contact the residual waste.

Alternative #2: Hybrid

The hybrid tank fill alternative involves first filling the tanks with coarse, uncrushed (i.e., rounded) aggregate and then filling the remaining interstitial void space with grout injected through a series of vertical slotted grout injection pipes. The addition of grout resolves the in tank hardware problem of creating void spaces with the gravel fill alternative while providing additional hydraulic and waste stabilization performance of the fill. However, the implementation requirements are more difficult for the hybrid alternative.

The following are initial advantages and disadvantages identified for the use of the hybrid tank fill material.

- Current rock slinger design developed for the gravel material will likely not handle the larger rounded aggregate required for this alternative. A different apparatus would have to be designed to handle the material. Given the larger aggregate size, it is anticipated the modified rock slinger may require installation of a centrally located 42-inch diameter riser, or access through multiple existing risers.
- The grout component increases hydraulic performance of the hybrid design versus simple gravel.
- Use of free-flowing grout eliminates the potential for leaving void spaces with a dry aggregate (i.e., gravel). In-tank hardware would not need to be removed as recommended for the gravel fill material.
- Using aggregate to provide 55-60% of the fill material significantly reduces materials costs, although placement of the aggregate will be more difficult.

Alternative #3: Concrete

As a coherent fill material, concrete primarily differs from grout in terms of the size of aggregate component. Concrete incorporates gravel-sized aggregate (generally increasing strength) while grout can utilize a variety of sand size components. Given the desired tank fill properties of flowabililty and self-leveling, concrete would not be expected to perform as well as grout. Given the similarity in cost, grout is preferred to concrete as a fill material except where extreme high strength is required (i.e., for intruder resistance).

- The following are initial advantages and disadvantages identified for the use of concrete as a tank fill material. Concrete differs from grout primarily due to using gravel aggregate instead of fine aggregate. Given the larger aggregate size, flowability and segregation issues may be more problematic with concrete versus grout. Flowability issues would be present both in the transfer of the material to the tank (e.g., clogging in pipes and or

hoses) and in the distribution within the tank. Concrete may require the addition of more flow enhancing additives (e.g., super-plasticizers, rheological modifiers, etc) to get the similar performance of grout. Grout is preferred over concrete for these reasons.

- The cost difference between grout and concrete is slight.
- Concrete may be more difficult to retrieve than grout.

Alternative #4: Grout

Use of grout as a waste stabilization material and as a structural fill component has previously been employed at the Savannah River Site (tanks 17 and 20). Grout exhibits many desirable attributes for use as a tank fill closure material.

The following are initial advantages and disadvantages identified for the use of grout as a tank fill material.

- Grout exhibits the desirable properties of being flowable, self-leveling, and coherent. Grout formulations have been designed to produce zero-bleed water (reducing possible contaminant mobilization) and neutral volume change upon hydration (no shrinking or swelling).
- Grout is a proven tank fill technology that has been implemented at other DOE sites for tank closure purposes (Savannah River, Oak Ridge, and Idaho National Engineering and Environmental Laboratory).
- Grout readily incorporates the addition of sequestering agents.
- The flowability of grout allows for physical encapsulation of the residual waste. Although mixing is not anticipated to be perfect, it is intended that the grout will be introduced on layers allowing for the possibility for the first lift to displace some of the residual waste (e.g., "float" the waste), which will then be encapsulated with the second, lift.
- Grout forms a relatively low permeable solid fill. Hydraulic conductivity would be expected to be greater than three orders of magnitude less than the soil outside the tank (SNL 1998a,b).
- Use of grout as tank fill material is readily implementable given existing technologies and tank configurations. Grout will be simply tremied into the tank using existing risers. There is the potential to use a pressurized delivery system (i.e., single low pressure injection technique) to increase the amount of physical mixing with the residual waste.

Alternative #5: Multi-layered Grout with Sealing Layer

Sandia National Laboratory designed a tank fill alternative as part of the HTI with application to the AX Tank Farm (SNL 1998a). The 100-series tanks in the C tank farm are nearly identical to the AX Tank Farm and as such the design should be equally applicable.

The first design incorporates a desiccation of the residual waste by the addition of dry Portland cement (or lime or soda ash) to prevent the mobilization of constituents in soluble

form. Following desiccation, a layer of crushed aggregate would be placed to create pore to contain the residual sludge that may be displaced upwards during the placement of subsequent grout material. If the residual sludge volumes are slight, the aggregate would not be required (saving considerable cost and time). Next, the grout would be placed in multiple 16-inch lifts. Approximately 8 ft from the top of the tank, a 60 cm thick bentonite clay seal would be emplaced. The purpose of this bentonite layer is to arrest crack development. Cracks completely transgressing the tank fill will allow significantly more infiltration water to pass through the tank. The remaining portion of the tank is then filled with grout to the top of the dome.

This composite design was modified by a subsequent report (SNL 1998b). The initial action is the addition of dry chemical getters and desiccants to the residual waste to form a dry, grout/sludge layer. Alternatively, the residual waste may be mixed directly with an initial layer of grout ("float" or displace the waste for better encapsulation within the grout). Following the initial grout layer, a layer of crushed limestone aggregate (1 inch minus) is placed to relieve potential fluid and deformation pressures of the initial grout/waste layer and to develop a capillary break in the tank fill structure. Limestone is chosen to be compatible with the highly alkaline tank environment. Emplacement of this aggregate layer will face the same difficulties as identified above for the gravel fill alternative (i.e., even distribution, riser modifications). Above the aggregate layer, grout will be installed in 16-inch lifts nearly 22 ft thick. Next, a 2 ft thick soft cement asphalt layer will be placed on top of the grout surface. The viscosity of the asphalt will be such that it will flow under pressure. On top of the asphalt, a second layer of limestone aggregate will be installed. Its purpose is to allow the asphalt to flow into the void spaces in response to the overburden pressures as the remaining tank volume is filled. The aggregate is expected to completely penetrate the asphalt and transfer the overburden weight to the grout below. The result will be a rigid sealing layer that will flow under pressure to seal against the tank walls and fill any cracks that develop in the grout. Above the aggregate/asphalt sealing layer, the remaining tank volume will be filled with grout. If desired, this final grout layer may be replaced with high strength grout or concrete to function as an intruder barrier.

The purpose of this multi-layered fill design is maximizing long-term hydraulic performance of the tank fill material. It is considerably more complex than simply installing a grout monolith. The main advantage over grout is the asphalt sealing layer that will prevent the formation of through-going cracks in the grout. The long-term performance of the asphalt is unknown and would require further study.

4.2.3 Selection Criteria

Table 4-1 summarizes the selection criteria were used to evaluate and select the preferred tank fill closure alternative.

Table 4-1. Selection Criteria.

Criterion	Description	Weighting Factor
Cost	Rough order of magnitude costs including project capital, operating and maintenance, and demobilization costs.	5
Schedule	Waste retrieval activities must support ATCD schedule	6
ESH&Q / ALARA	Qualitative assessment of overall worker safety, risk of spills to the environment, risk of damage to the tank, leak detection, waste transfer safety, and impact to the facility AB.	7
Reversibility	Tank fill action and materials must be reasonably retrievable given current regulatory uncertainty concerning closure requirements	5
Limit Release of Contaminants	Ability of tank fill material/design to limit potential migration of liquid and/or solid waste (i.e., leaching) constituents	10
Long-Term Structural Stability	Ability of tank fill to support tank structure and prevent surface subsidence. Minimum 1000 yr time period.	8
Operations (Ease of Use)	Encompasses ease of operation, ease of deployment and demobilization, compatibility with existing systems and equipment, and minimizing infrastructure modifications.	5
Maximize Future Application	Applicability of tank fill design to other SSTs	2
Performance Evaluation	Addresses complexity of quality assurance testing to verify correct construction of tank fill design.	3

Waste stabilization fill and structural fill alternatives were evaluated separately for both tank 241-C-106 and the 200-series tanks. The "long-term" structural stability criterion was not used to evaluate the waste stabilization alternatives for either tank 241-C-106 or the 200-series tanks as it is assumed this layer will contribute very little to the overall structural stability of the tank void space. Likewise, the limit release of contaminants criterion was not used to evaluate the structural fill alternatives, as this is not a primary function of the structural fill component. However, control and minimization of infiltrating water was included in the evaluation of structural fill alternatives, which indirectly supports the prevention of releasing the contaminants. Scoring and evaluation of the tank fill alternatives is discussed below, along with the identification of the preferred alternative for both tank 241-C-106 and the 200-series tanks.

4.3 RECOMMENDED WASTE STABILIZATION ALTERNATIVE

The following three waste stabilization alternatives were evaluated for tank 241-C-106 and the 200-series tanks:

- **Grout #1**: High-density grout would be used to float residual waste, which would then be capped with a second low-density grout to fully encapsulate the waste.
- **Grout #2**: Single grout layer would be installed to cover the residual waste adhered to the bottom of the tank. Remaining liquid waste fraction would be incorporated into the grout matrix.
- **Granular Layer**: As-yet-to-be-determined granular fill material would be installed to stabilize the residual waste. Candidate materials include bentonite powder/granules, zeolites, granular getters, sand, and/or gravel.

The scoring of each alternative against the selection criteria for tank 241-C-106 and the 200-series tanks is provided in Attachment 4. Cost was not used as a discriminating factor for the waste stabilization evaluation, primarily due to the uncertainty associated with the cost of potential getter components, and the difficulty in allocating some costs (e.g., construction mobilization and equipment) between waste stabilization and structural fill. Also it was assumed that material and placement costs would be essentially the same for each of the alternatives.

The single layer of grout (Grout #2) alternative was clearly identified as the preferred alternative for both tank 241-C-106 and the 200-series tanks on the basis of the scoring and weighting system developed. This alternative scored well against the following criteria:

- **Limit Release of Contaminants**: Installation of the grout through the central riser is expected to incorporate residual liquid waste and encapsulate a portion of the residual solid waste. In addition to the physical encapsulation of the waste, the low permeability and high pH nature of the grout will contribute to reducing the mobility of the residual waste.
- **ESH&Q**: Grout is expected to meet all applicable ESH&Q requirements (pending resolution of the reversibility issue).
- **Schedule Risk**: Relatively simple emplacement method and previous deployment add confidence that it can be deployed within the identified schedule.
- **Operations**: Grout would be simply tremied into the tank through the central riser. Self-leveling nature of the grout will ensure proper emplacement.
- **Performance verification**: Grout characteristics are easily verified through observation and simple batch testing of prepared material external to the tank.

High-density/low-density grout encapsulation (Grout #1) alternative scored poorly against schedule risk, operations, and performance verification criteria. To maximize the potential for displacing all of the residual waste, the high-density grout may have to be injected from multiple risers, increasing the complexity and duration of the operation. Additionally,

verifying complete encapsulation of the residual waste would be extremely difficult, likely requiring in-tank core sampling of the grout layers.

The granular layer scored less than the simple grout layer against all criteria with the exception of reversibility. At this time, there have been few studies technically evaluating the use of granular type waste stabilization fill materials. Additional development and performance uncertainty are major issues with granular fills. If, however, additional studies support the use of a granular waste stabilization fill from a performance standpoint (e.g., use of a granular getter material) then the selection of the grout material may be re-evaluated. The major advantage of the granular fill material is its apparent retrievability (i.e., reversibility) to satisfy regulatory requirements (i.e., NEPA).

In addition to the three waste stabilization layer alternatives evaluated in the tank fill alternatives study, a 'no fill' alternative may be selected during the course of the project depending upon the following factors:

- **Reversibility** (i.e., NEPA requirements): Proposed grout waste stabilization layer may be determined unacceptable from a regulatory standpoint on the issue of reversibility.
- **High-level Waste Re-classification** (DOE Order 435.1 requirements): Waste stabilization layer may be postponed pending resolution of a lawsuit challenging the legality of DOE Order 435.1 and DOE's authority to reclassify high level waste.
- **Enhanced Mixing Opportunity**: Installation of the waste stabilization layer may be postponed if an opportunity exists to use the MRS in-tank vehicle to assist in the mixing of developed getter component with residual waste, and if getter material development in FY 2003 concludes that performance is significantly better in a granular material form than as a grout additive.

If the 'no fill' alternative is chosen, the small volume of liquids expected to remain post-retrieval will be controlled either by adding a desiccant to absorb the liquid, getters to immobilize dissolved contaminants, and/or evaporation. Institutional controls will be maintained to prevent infiltration of surface water.

4.4 RECOMMENDED STRUCTURAL FILL ALTERNATIVE

The following structural tank fill alternatives were evaluated against the selection criteria:

- Gravel
- Concrete
- Hybrid (rounded aggregate/grout)
- Grout
- Multi-layered Grout with Seal

The scoring of each alternative against the selection criteria for tank 241-C-106 and the 200-series tanks is provided in Attachment 4.

The physical difference in size between the tank types has little effect on the performance, installation, or schedule risk associated with the identified alternatives. The structural fill alternatives were not evaluated against the reversibility criterion as the structural fill component will not be installed until the reversibility issue is resolved (i.e., NEPA, DOE Order 435.1).

The grout and concrete structural fill alternatives were scored considerably higher than the other fill materials. It is not surprising these two received similar scores, as they are very similar materials. Grout is assumed to have a slight advantage over concrete, as it is less susceptible to segregation and flowability problems associated with concrete.

The hybrid alternative is unnecessarily complex without a clear performance advantage over grout. The simple gravel alternative is not expected to perform as well in terms of preventing infiltration from entering the tank. Also it was believed it would be difficult to place the gravel at a density required to prevent future subsidence. The multi-layered grout with sealing layer, while ranked the highest for long-term structural stability and prevention of infiltration, would be extremely difficult to install.

Filling the remaining tank void space with grout installed in lifts is the preferred tank fill alternative. Although grout is selected as the preferred structural fill material at the present time, additional studies and engineering evaluations may support modification of the tank fill design.

5.0 ACCELERATED TANK CLOSURE PROJECT RISK ASSESSMENT STRATEGY

The ATCD requires that long-term and short-term risks be evaluated. The long-term risks associated with this project are identified as human health risk related to long-term contamination of groundwater and subsequent consumption of groundwater. Estimates of risks must be quantified and compared to performance standards. The risk assessment to support the project will be conducted in a manner consistent with the approach to risk assessment described in the *Phase I RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas* (RFI/CMS) (DOE-RL 2000), the *Guidance for Clean Closure of Dangerous Waste Facilities* (Ecology 2001), and in DOE Order 435.1.

Numerous procedural and regulatory requirements drive the need to assess risks related to tank closure, therefore, a comprehensive strategy for approaching the risk assessment activities is essential. This document describes the requirements for risk assessment and the approach to performing the risk assessment to meet specific requirements in an efficient and comprehensive manner. It is essential that a consistent approach to risk assessment be implemented to ensure comparability between the various risk assessment requirements for this project and consistency with preceding risk assessment activities.

5.1 PURPOSE AND BACKGROUND

The purpose of this section is to present the strategy to develop the capability to conduct a credible risk assessment that provides an estimate of the risk and performance of engineering actions to support the retrieval and closure of selected single shell tanks. Specific capabilities include evaluation of:

1. Existing conditions,
2. Retrieval of wastes,
3. Partial retrieval of wastes
4. Engineered and chemical mitigation methods, and
5. Emplacement of selected fill material.

This strategy builds on a significant body of past work in this area including the AX Tank Farm Retrieval Performance Evaluation (RPE) (DOE-RL 1999), *A/AX and C Tank Farm Subsurface Characterization Report* (in Draft), RFI/CMS (DOE-RL 2000) and the *200 Areas Remedial Investigation/Feasibility Implementation Plan* (DOE-RL 1998). The initial scoping level RPE will serve as a basis and be refined incorporating the results of new field and engineering studies in a structured manner to reduce the levels of uncertainty in the predictions of performance as the project moves from single tank retrieval, interim retrieval, individual tank closure and eventually tank farm closure. These iterative assessments will be strongly integrated with data gathering efforts of the:

- Vadose Zone Characterization Program,
- Immobilized Low Activity Waste Program,
- RCRA groundwater monitoring well drilling program,
- Improvements in the SST Farm Best Basis Inventory (BBI 2001), and
- 200 Area CERCLA Remediation Program.

Significant work is ongoing under the 200 Area Integration project that directly supports the refinement of predictions of contaminant transport through the vadose zone and release of contaminants from tanks that will provide credibility and reduce the uncertainty inherent in predictions of future risk.

Risk will be examined on a range of scales beginning at the single tank level up to the area wide level. Area wide risk assessments will be conducted in conjunction with the System Assessment Capability to provide consistency across the site and between programs and make efficient use of ongoing activities funded by the DOE.

Multiple performance criteria will be evaluated at locations from the edge of the tank farm to the Columbia River for informational and regulatory purposes to provide comparability with past studies. As work progresses it would be expected that the number and locations would be refined in a manner that assures protection of human health and environment. Risk projections will support evaluation of multiple regulations, DOE Orders and other pertinent guidance. Both short term and long term risks will be evaluated.

5.2 RISK ASSESSMENT SCOPE AND OBJECTIVES

The scope and objectives of risk assessment activities to support the accelerated tank closure demonstration project are described in the following subsections.

5.2.1 Risk Assessment Scope

The scope of the project risk assessment is to provide quantitative estimates of short- and long-term risks related to closure activities and final conditions of the following single-shell waste tanks in Hanford's C Tank Farm:

- Tank 241-C-106
- Tank 241-C-201
- Tank 241-C-202
- Tank 241-C-203
- Tank 241-C-204

In order to more fully understand the risk contribution of the five tanks selected for accelerated closure activities, the long-term risk estimates will be placed in the perspective of potential risk contributions from all sources within the C Tank Farm and the immediate area.

The following regulatory and procedural requirements identify the need to perform risk assessment activities for the project and support scope definition:

- The HFFACO
- Dangerous Waste Treatment, Storage, and Disposal Facility Closure Requirements (WAC 173-303), (WAC 173-340) and supporting guidance (Ecology 2001)
- DOE Order 435.1
- 40 CFR 141
- Consensus advice #132: Exposure Scenarios Task Force on the 200 Area (DOE 2002)

If additional requirements are identified during the closure process, they will be evaluated and incorporated as appropriate.

5.2.2 Risk Assessment Objectives

The general objectives of the project risk assessment are as follows:

- Identify short-term risks and accident scenarios related to tank closure activities that may produce unacceptable risks to site workers or the public. These scenarios will be used to ensure that adequate controls are implemented to mitigate the risks.
- Provide quantitative estimates of long-term human health risk associated with the activities related to tank closure and final conditions of the tank systems.
- Provide sufficient quality and quantity of long-term human health risk estimates in a format that supports the decisions required by both the RCRA Closure Plan and the DOE Closure Plan specified under DOE Order 435.1.

5.3 RECOMMENDED LONG-TERM RISK ASSESSMENT APPROACH

The nature of long-term risk assessment for the project is based on estimation of the potential for tank wastes to migrate through the vadose zone, resulting in contamination of underlying groundwater. Subsequent exposure to, or consumption of, this contaminated groundwater by hypothetical future receptors may result in exposure to radioactive, toxic, and/or carcinogenic contaminants with resultant human health risks.

The long-term risk related to transport of contaminants to groundwater exposure points will be evaluated using the general approach described in the following subsections.

Additional long-term risks may be posed by the potential for future site intruders to penetrate the closed tank farm and be subsequently exposed to residual contamination in the tank(s) and subsurface soil.

5.3.1 Define Performance Objectives

Central to the development of a long-term risk analysis is the formulation of the performance objectives that project activities will be evaluated against. The disposing of wastes in the environment can be regulated by RCRA, CERCLA, *Model Toxic Control Act*, Clean Water Act, and high-level and low-level nuclear waste statutes. A comprehensive review of the pertinent regulations will be completed to develop a suite of performance objectives to guide the evaluation of the effectiveness of retrieval and remediation activities.

5.3.2 Define the Conceptual Exposure Model.

The conceptual exposure model for Hanford tank farms is described in previously-mentioned RFI/CMS work plan (DOE-RL 2000). Based on the referenced exposure model, a site-specific exposure model for the site will be prepared and documented in an interim report. This exposure model will identify the specific primary and secondary sources that will be considered (including contaminants of concern and their inventory and concentrations), the contaminant release and transport mechanisms, contaminated media, and exposure routes. Sources to be considered for this effort will include, at a minimum, the following:

- Past leaks
- Leaks during waste retrieval
- Residual waste in single shell tanks
- Residual waste in ancillary equipment

The conceptual exposure model will also include definition of the following aspects of the risk assessment, consistent with the RFI/CMS work plan:

- Identification of anticipated future land use scenarios including discussion of how the risk assessment scenarios fit into the "core and buffer " zones identified in recent correspondence between the Tri-Parties and Hanford Advisory Board.
- Definition of receptor scenarios that will be evaluated for this risk assessment
- Identification of contaminants of concern for which contribution to long-term risk will be calculated.
- Identification of the criteria that will be used to assess the estimated long-term risks (e.g., carcinogenic and non-carcinogenic risk and radiological dose criteria, numerical regulatory standards [e.g., maximum contaminant level])
- Selection of receptor locations for long-term groundwater exposure assessment, to include, at a minimum, 1) the downgradient boundary of C Tank Farm waste

management area, 2) the downgradient boundary of the 200 Areas exclusive zone, 3) the downgradient boundary of the 200 Areas buffer zone, and 3) the downgradient Columbia River shoreline.

- Specification of the time frame for the risk assessment and supporting fate and transport simulations. A 1,000-year time period is specified in the RFI/CMS workplan. The rationale for using a time domain longer that 1,000 years must be developed and appropriate uncertainties related to distant future projections defined.

5.3.3 Define the Site Physical Conceptual Model

A physical conceptual model of the site is being prepared that describes the physical (e.g., hydrologic, stratigraphic, and placement) characteristics of the site. The physical conceptual model will describe the physical interrelationships between the sources and the physical setting of the site. This model will become the basis for the fate and transport simulations. The model will be based on existing knowledge of site-specific conditions to the extent possible. The physical conceptual model will also identify boundary conditions to be used in transport simulations. The physical conceptual model will be constructed in a manner that supports extrapolation of fate and transport simulation results to all tanks within the C Tank Farm. The physical conceptual model will be documented in an interim report. The following elements will be defined in the physical conceptual model, at a minimum:

- Site-specific vadose and aquifer stratigraphy extending from ground surface to the selected exposure points
- Location of the known contaminant sources within the physical model
- Contaminant release scenarios that realistically describe the manner in which the individual constituents in the selected source materials (i.e., tank residuals, past leaks, ancillary equipment residuals, and retrieval leaks) are assumed to enter the transport system (e.g., solubility limits, duration of release, etc.)
- The location and magnitude of zones of near-field and far-field effects on constituent transport.
- A mechanism to reflect potentially variable effectiveness of final covers over the tank(s) at controlling infiltration through the site
- A mechanism to reflect the variability in hydraulic characteristics of alternative tank fill materials.

5.3.4 Identify and Catalog the Input Values for Fate and Transport Simulations

An interim report will be prepared that identifies the values (or realistic range of values) for the site hydrologic properties (e.g., soil density, porosity, hydraulic conductivity, infiltration rates) and values (or realistic range of values) for the physical and chemical properties of the radioactive and non-radioactive constituents (e.g., solubility, half-life, distribution coefficient). These values will be derived from a rigorous literature search and discussions with local subject experts to derive values from previous work under similar conditions and,

where possible, and from empirical measurements of site-specific materials. Current plans include funding for laboratory measurements of the solubility of waste constituents from samples of sludge material. In the event that the current state of knowledge regarding input values yields a substantial range of values for specific parameters, a strategy for quantifying the uncertainty in long-term risk related to the uncertain parameters will be prepared.

5.3.5 Identify Relevant Closure Management Alternatives and Decisions

Tank closure management alternatives will be identified for analysis of their effects on long-term risk. These alternatives will be selected for specific sensitivity analyses to quantify their impacts on risk. The closure management alternatives to be considered for sensitivity analysis include, but are not necessarily limited to, the following:

- Retrieval efficacy/residual waste volume
- Tank fill effects on infiltration and attenuation of waste constituents
- Final cover efficacy at reducing infiltration of precipitation through the site.

These alternatives and variables will be specified and included in the interim report described above for the additional fate and transport input values.

5.3.6 Implement the Risk Assessment Simulations

The long-term risk assessment simulations will be conducted in a sequential manner using a combination of deterministic and stochastic simulation techniques, as appropriate. This sequential approach will provide a sound basis for the following determinations:

- Demonstration of risks related to bounding conditions
- Identification of variables to which risk estimates are highly sensitive
- Quantification of risk uncertainty related to the sensitive variables, with particular focus on sensitive closure management variables
- Quantification of risk estimate uncertainty due to cumulative effects of non-sensitive variables.

Graphical and tabulated risk estimate results will be presented as required by the specific closure documents (i.e., RCRA facility closure plan or DOE Order 435.1 closure plan). The objective of risk estimate result presentation is as follows:

- Clearly indicate the resultant risk(s) and the criterion to which it is compared
- Clearly indicate the input variable set that generated the resultant risks
- Clearly indicate the efficacy and appropriateness of selected closure alternatives

5.4 RECOMMENDED SHORT TERM RISK ASSESSMENT APPROACH

Short-term risks are considered to be those risks posed by exposure of site workers and members of the public to contaminants during implementation of site closure activities (e.g., retrieval, tank filling, etc.) and by the effects of accident scenarios. More specific information regarding these approaches is presented in the following subsections.

Worker exposure scenarios will be developed for tank closure activities. These scenarios will be designed to accurately represent the type of worker exposures that are expected based on selected tank closure alternatives. These alternatives are expected to include waste retrieval activities (e.g., pumping, vacuuming, or sluicing among others) with subsequent transfer of waste to double-shell tanks. Various options for tank filling following waste retrieval will also be evaluated. Tank filling will also present potential exposures to workers.

Because the short-term risks will be encountered in the near future while the site is under physical and administrative control of the DOE, it can be reasonably anticipated that the tank closure activities will be conducted in a manner that maintains exposure to tank wastes ALARA through the use of engineered controls and protective equipment. It is assumed that after final closure of the tanks, short-term risk will be fully mitigated and will not be considered further. This is consistent with the regulatory definition of closure of a "treatment, storage, and disposal" facility (i.e., no further active site management required). During closure activities, the impracticability of engineered controls to maintain ALARA conditions may preclude some retrieval actions and the residual volume of waste in some, or all, tanks may be, therefore, defined by short-term risk conditions.

5.5 RECOMMENDED ECOLOGICAL ASSESSMENT APPROACH

Support of closure will require completion of an Ecological Assessment of the Tank Farm Areas. It is proposes that this assessment will be conducted in conjunction with the wider Ecological Assessment currently underway between Ecology and DOE covering the Central Plateau.

5.6 RISK ASSESSMENT COMMUNICATION

Shared understanding of the elements of the risk assessment and the inputs to the simulations are essential to successful preparation of the tank closure supporting documentation. Information sharing will be implemented between the DOE, implementing contractors and subcontractors, regulators and stakeholders through a series of presentations and workshops. The essential elements of the interim documents mentioned in the preceding approach descriptions will be presented for discussion and consensus during these workshops. The following topical presentations/workshops are currently anticipated based on development of the associated interim reports:

- Accelerated Tank Closure Risk Assessment Approach (presentation of the approach described in this document)

- Identify Performance Objectives
- Conceptual Exposure Model
- Site Physical Conceptual Model
- Fate and Transport Data Development
- Calculational Results and Comparison of Performance Objectives

The final risk assessment results will be presented in either final revisions of the closure plans or supplemental reports in support of the RCRA permit, as deemed appropriate.

6.0 REFERENCES

10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," *Code of Federal Regulations*, as amended.

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations,* as amended.

Bailey, J.W., 2000, *Waste Retrieval Sluicing System (WRSS) and Project W-320, Tank 241-C-106 Sluicing, Lessons Learned,* RPP-5687, CH2M HILL Hanford Group, Inc., Richland, Washington.

BBI, 2001, *Best Basis Inventory*, access page located at: http://twins.pnl.gov:8001/twins.htm, as of May 2001.

Bogen, G. J., G. C. DeWeese, T. H. May, and W. W. Pickett, 1999, *Alternatives Generation and Analysis C-104 Single-Shell Tanks Waste Feed Delivery,* TWR-4454, Numatec Hanford Corporation, Richland, Washington.

Callison, S. W., 2002, "Accelerated Tank Closure Demonstration Data Assessment," RPP-10950, Revision 0, August 2002, CH2M HILL Hanford Group, Inc., Richland, Washington.

Carothers, K. G., L. A. Stauffer, and J. W. Bailey, 1999, *Waste Retrieval Sluicing System Campaign Number 3 Volume Transfer Calculation,* HNF-5267, Rev. 2, Lockheed Martin Hanford, Corp., Richland, Washington

Carpenter, K. E., 2001, *241-C-104 Waste Retrieval System Conceptual Design Report (Project W-523)*, RPP-8312, CH2M HILL Hanford Group, Inc., Richland, Washington.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, Public Law 96-150, 94 Stat. 2767, Title 26, 42 USC 9601 et seq.

Crass, D. W., 2000, *Preliminary Engineering Report for the 241-C-104 Retrieval System,* RPP-6843, Numatec Hanford Corporation, Richland, Washington.

DOE, 2002, *Consensus Advice #132: Exposure Scenarios Task Force on the 200-Area,* U.S. Department of Energy, Washington State Department of Ecology, and U. S. Environmental Protection Agency, Olympia, Washington.

DOE Manual 435.1-1, *Radioactive Waste Management Manual*, as amended, U.S. Department of Energy, Washington, D.C.

DOE Order 435.1, *Radioactive Waste Management*, as amended, U.S. Department of Energy, Washington, D.C.

DOE-RL, 1998, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program,* DOE/RL 98-28, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1999, *Retrieval Performance Evaluation Methodology for the AX Tank Farm,* DOE/RL 98-72, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 2000, *Phase I RCRA Facility Investigation/Corrective Measures Study Work Plan for Single-Shell Tank Waste Management Areas*, DOE/RL-99-36, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Doeler, J. N., 2001, *Preliminary Engineering Report for the 241-S-102 Waste Retrieval System,* RPP-8381, CH2M HILL Hanford Group, Inc., Richland, Washington.

Ecology, 2001, *Guidance for Clean Closure of Dangerous Waste Facilities,* Publication #94-111, Washington State Department of Ecology, Hazardous Waste and Toxics Reduction Program, Olympia, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

"Hazardous Waste Management Act," RCW 70.105, *Revised Code of Washington*, as amended.

Lee, T. A., 2002, "Approach for the Accelerated Tank Closure Demonstration Project," RPP-11085, Revision 0, July 2002, CH2M HILL Hanford Group, Inc., Richland, Washington

MOU, 1996, *Memorandum of Understanding: Required Percent of Waste Retrieval*, U.S. Department of Energy and Washington State Department of Ecology, Richland, Washington.

National Environmental Policy Act of 1969, 42 USC 4321, et seq.

PNNL, 1998, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site,* PNNL-11800, Pacific Northwest National Laboratory, Richland, Washington.

Resource Conservation and Recovery Act of 1976, 42 USC 6901, et seq.

Skelly, W. A., 1996, *Engineering Study of Tank Fill Alternatives for Closure of Single-Shell Tanks,* WHC-SD-WM-ES-399, Westinghouse Hanford, Company, Richland, Washington.

SNL, 1998a, *Stabilization of In-Tank Residual Wastes and External-Tank Soil Contamination for the Hanford Tank Closure Program: Applications to the AX Tank Farm*, SAND98-1460, Sandia National Laboratories, Albuquerque, New Mexico.

SNL, 1998b, *Stabilization of In-Tank Residual Wastes and External-Tank Soil Contamination for the Hanford Tank Closure Program: Applications to the AX Tank Farm*, SAND98-2445, Sandia National Laboratories, Albuquerque, New Mexico.

"State Environmental Policy Act of 1983 (SEPA)," RCW 43.21c, *Revised Code of Washington*, as amended.

Sturges, M. E., 2002, *Tank 241-S-102 Waste Retrieval System Final Conceptual Design*, RPP-10292, CH2M HILL Hanford, Inc., Richland, Washington.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

WAC 173-340, "Model Toxics Control Act Cleanup Regulation," *Washington Administrative Code*, as amended.

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ATTACHMENT 1

ACCELERATED SINGLE-SHELL TANK RETRIEVAL AND CLOSURE DEMONSTRATION PROJECT - REGULATORY STRATEGY

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Attachment 1

EXECUTIVE SUMMARY

The regulatory strategy for the Hanford Accelerated Tank Retrieval and Closure Demonstration Project identifies an approach for obtaining the necessary approvals from the Department of Energy, the Washington State Department of Ecology, the Washington State Department of Health and the Environmental Protection Agency for the proposed interim actions.

This document focuses on addressing decisions associated with the *National Environmental Policy Act of 1969* and the *Washington State Environmental Policy Act*, the requirements of DOE Order 435.1 (*Radioactive Waste Management)* related to the Accelerated Retrieval and Closure Demonstration, including Waste Incidental to Reprocessing Determinations, *Hanford Federal Facility Agreement and Consent Order*, relating to retrieval and closure, and *Resource Conservation and Recovery Act of 1976,* and the "Hazardous Waste Management Act", implemented by Washington Administrative Code 173-303, relating to closure.

Although there are a number of other regulations, requirements, and U.S. Department of Energy Orders that may apply to closure, each of the regulations or agreements listed above has associated compliance options that must be considered for planning and performance of the Accelerated Tank Closure Demonstration Project. Other applicable laws, regulations, and requirements are summarized in an appendix to this document.
The strategy includes the following elements:

- Demonstrating National Environmental Policy Act of 1969 compliance with an Environmental Assessment and compliance with the Washington State Environmental Policy Act with a SEPA Checklist

- Developing "Hazardous Waste Management Act"/Resource Conservation and Recovery Act of 1976 closure plans in a tiered approach that provides the basis for Resource Conservation and Recovery Act of 1976 Permit modifications and Ecology approval

- Retrieving tank waste in accordance with "Hanford Federal Facility Agreement and Consent Order" Milestones and Appendices

- Reclassifying residual tank waste as Waste Incidental to Reprocessing and utilizing alternative requirements to 10 CFR 61.55 Class C waste limits, for low-level radioactive waste, to demonstrate compliance with the performance objectives of 10 CFR 61 Subpart C

- Preparation of Closure Demonstration Plans that address DOE M 435.1-1 Tier 1 and Tier 2 Closure Plan requirements, and obtaining the U.S. Department of Energy Headquarters concurrence for a streamlined review and approval process

- Using multiple types of analyses, including analyses of long and short-term risks for a performance assessment

- Using the existing approved Composite Analysis for cumulative groundwater contamination impacts.

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Attachment 1

LIST OF TERMS

AEA	*Atomic Energy Act of 1954*
ATCD	Accelerated Tank Closure Demonstration
BBI	Best Basis Inventory
C3T	Cleanup, Constraints, and Challenges Team
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CY	calendar year
DOE	U.S. Department of Energy
EA	Environmental Assessment
EIS	Environmental Impact Statement
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facility Compliance Act
HFFACO	Hanford Federal Facility Agreement and Consent Order
HWMA	Hazardous Waste Management Act
ILCR	incremental lifetime cancer risk
K_d	distribution coefficient
LDR	land disposal restrictions
LLW	low-level waste
MCL	maximum contaminant level
MTCA	Model Toxics Control Act
NAAQS	National Ambient Air Quality Standards
NEPA	*National Environmental Policy Act of 1969*
NRC	U.S. Nuclear Regulatory Commission
NWPA	*Nuclear Waste Policy Act of 1982*
ORP	Office of River Protection
PNNL	Pacific Northwest National Laboratory
RCRA	*Resource Conservation and Recovery Act of 1976*
SEPA	State Environmental Policy Act
SRS	Savannah River Site
SST	single-shell tank
TRU	transuranic
TSD	treatment, storage, and disposal
TWRS	Tank Waste Remediation System
WAC	Washington Administrative Code
WIR	waste incidental to reprocessing
WMA	waste management area

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Office of River Protection (ORP), the Richland Operations Office (RL), the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA) have agreed to accelerate Hanford Site closure. As part of accelerated closure, DOE Headquarters has requested that ORP close five single-shell tanks (SSTs) by the end of CY 2004 via the SST Accelerated Tank Closure Demonstration (ATCD) Project. Five tanks in the C tank farm have been selected as demonstration tanks for this project. To support the ATCD project, the proposed regulatory strategy satisfies the intent of legal and regulatory requirements. DOE, regulatory, and public acceptance of the ATCD will require demonstrating compliance with the *National Environmental Policy Act of 1969* (NEPA), Radioactive Waste Management (DOE O 435.1), Washington State Environmental Policy Act (SEPA), *Resource Conservation and Recovery Act of 1976* (RCRA), Hazardous Waste Management Act (HWMA), the Hanford Federal Facility Agreement and Consent Order (HFFACO), and other applicable requirements.

The regulations that apply to the SSTs are designed to protect the public and the environment. Separate regulations cover hazardous and radioactive waste components, air, groundwater, and drinking water. These regulations use different objectives, performance measures, time frames, and points of compliance.

Tank closure requirements for DOE facilities are defined in their respective Federal Facility Agreements under the Federal Facility Compliance Act (HFFACO for the Hanford Site) and applicable DOE Orders. These agreements define the statutory authority that the regulatory agencies and DOE have determined will be used to close tanks. The DOE has completed closures at the Savannah River Site and the Oak Ridge Reservation under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA). Savannah River Site is using the Clean Water Act through CERCLA for their cleanup goals. Hanford and Idaho National Engineering and Environmental Laboratory will be closed under their states' HWMAs, for compliance with the RCRA.

The HWMA and its implementing regulations, WAC 173-303 (Dangerous Waste Regulations), implement RCRA in Washington State. The EPA has delegated most of the RCRA program to the State of Washington, which gives Ecology the authority to regulate dangerous and mixed waste. The HFFACO provides the framework for applying the State's requirements for dangerous waste treatment, storage, and disposal (TSD) units at the Hanford Site. Washington State dangerous waste regulations specify requirements for design, permitting, operations, closure, and post-closure of dangerous and mixed waste management sites, including the tank farms. HWMA/RCRA Closure Demonstration Plans will provide the basis for modifications to the Hanford Site-Wide RCRA permit.

In November 1994 the EPA approved the Washington State Air Operating Permit Regulation, promulgated as "Operating Permit Regulation" (WAC 173-401). The state program, administered by the Washington State Department of Health, includes regulation of federal facilities. DOE has received a site wide Air Operating Permit for the Hanford Site. Based on the

retrieval or closure action to be implemented, state-issued Notice of Construction permits required to support modifications to the facility or construction of new stationary sources that would impact air quality will be prepared as needed. Specific requirements in Notice of Construction permits may require modification of the Site-Wide Air Operating Permit.

The Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS) Record of Decision (ROD) (62 FR 8693) concluded that insufficient information exists to make a decision on the approach for final closure of SST farms. Data-gathering activities, including closure demonstrations, will support future NEPA analysis and allow decision makers to select a closure path. For the ATCD, it is assumed that an Environmental Assessment (EA) will determine if there are significant environmental impacts from the proposed actions.

The ATCD must also comply with DOE 435.1, which requires the generation of Tier 1 and Tier 2 closure plans, and a waste incidental to reprocessing (WIR) Determination. Recent experience at the Savannah River Site indicates that preparation, review, and approvals for a DOE 435.1 Tier 1 closure plan could take several years. In order to meet the CY 2004 goal, it will be necessary to expedite the approval process.

Because of the nature of the ATCD, variations may be allowed by DOE Headquarters with respect to preparation of the Tier 1 closure plan and supporting documentation (e.g., preliminary performance assessment). The expectation of DOE Headquarters regarding this accelerated closure demonstration has not been determined as of this writing.

1.1 REGULATORY STRATEGY SUMMARY

A wide range of regulations, statutes, orders and requirements may be applicable to closure activities. The four regulations and agreements discussed below have associated compliance options that should be considered for planning and performance of the ATCD. The regulatory strategy for compliance with each is summarized below. Additional laws, regulations and requirements are described in Appendix A.

1.1.1 National Environmental Policy Act

An EA will be prepared to determine if the project has a significant environmental impact. The ATCD Project schedule would be significantly impacted if a Supplemental EIS or Closure EIS were required prior to proceeding with ATCD design. In addition, a Washington *State Environmental Policy Act* (SEPA) Checklist will be prepared identifying potential impacts of the proposed closure activity.

Data obtained from the ATCD project will support development of the final closure EIS. The demonstration activities undertaken will be planned to minimize adverse impact to the environment. Demonstration activities will not limit the choice of final SST farm closure alternatives.

1.1.2 U.S. Department of Energy Order 435.1

Three potential closure paths are identified in DOE M 435.1-1 Section II.U: 1) DOE-approved facility/site closure plan, 2) closure under CERCLA, or 3) deactivation and decommissioning. The deactivation and decommissioning option was not selected because it is planned that some amount of residual waste may remain in the selected SSTs upon completion of ATCD activities. The closure under CERCLA option was not selected because RCRA is the closure path described in the HFFACO. The selected approach is a DOE-approved closure demonstration plan.

1.1.2.1 Accelerated Retrieval and Closure Demonstration Plan. The purpose of the ATCD Plan is to define and bound the parameters of the closure demonstration approach to ensure long-term protection of public health and the environment.

The ATCD Plan, because the ATCD is a demonstration project that will not result in final closure actions, is a variation of Tier 1 and Tier 2 closure plans, as described in DOE M 435.1-1. Areas where these variations occur are as follows.

- Closure activities associated with ancillary equipment and contaminated soils will be addressed during tank farm closure.
- Any stabilization materials added to the selected tanks will be retrievable.
- Cost-Risk Assessment (JEG-02-017), and additional technical assessments based on updated waste inventory data or other technical information will provide a performance assessment of adequate rigor for the ATCD. Appendix B was developed to delineate where performance assessment criteria, as listed in the DOE Deactivated High-Level Waste Facility Manual, is addressed or explains variations from the criteria. A performance assessment will be completed to support final tank and tank farm closure. This performance assessment will comply with DOE G 435.1 IV.P for LLW disposal, assuming WIR determinations support disposal of residual waste as LLW.
- As this is an ATCD and complete closure will not be achieved, the approval pathway for this closure demonstration is different than for a full Tier 1 closure plan. Many of the approval decisions are expected to reside within the DOE ORP with concurrence from DOE Headquarters, as required.
- Normally, Tier 2 closure plans are written that detail closure activities for specific components. For this closure demonstration, the detailed closure activities for selected tanks will be appended to the closure demonstration plan.

1.1.2.2 Waste Incidental to Reprocessing (WIR) Determination. The WIR methodology in DOE M 435.1-1, Section II.B is used to determine whether waste resulting from reprocessing spent nuclear fuel is considered incidental to reprocessing. The resulting WIR Determination is expected to classify the selected SSTs as incidental waste and, as such, may be managed under DOE regulatory authority as low-level waste (LLW) if the following activities are taken:

- DOE exercises its authority to develop alternative requirements to 10 CFR 61.55 (Class C LLW limits), required for Tanks C-106, C-201, C-202 and C-203.
- Waste is retrieved from Tanks C-201 and C-106 to the HFFACO M-45 requirements to meet performance objectives of 10 CFR 61 Subpart C.
- Retrieve waste from Tank C-204 to meet HFFACO M-45 requirements only, as tank contents meet LLW classification limits and 10 CFR 61, Subpart C, Performance Objectives, without retrieval.

1.1.3 Hanford Federal Facility Agreement and Consent Order

It is anticipated that some or all SSTs selected for the ATCD will be retrieved to greater than 99 percent to meet the intent of the HFFACO M-45-02-03 Milestones, as revised (August 2002). If retrieval does not meet the HFFACO retrieval requirements, the HFFACO Appendix H process would be invoked.

1.1.4 Resource Conservation and Recovery Act and Hazardous Waste Management Act

The top, middle and third tier RCRA/HWMA closure plan approach, as described in the revised HFFACO M-45-02-03 Milestone, will be used for the ATCD. The closure plans will include discussions focused on results tied to Data Quality Objective negotiations including planning, sampling, and characterization activities and include objectives linked to negotiated permit conditions, compliance schedules, land disposal restriction (LDR) compliance strategies, closure end-state conditions, and fulfilling data needs to reduce uncertainty.

1.2 ASSUMPTIONS

- The ATCD focuses on tank contents only and does not address ancillary equipment.
- Closure demonstration actions will be reversible. If stabilization materials are added to the selected tanks, it will be retrievable.
- Long-term and short-term risk assessment assessments, developed as part of the Cost-Risk Analysis, and other analyses will demonstrate the ATCD is protective of public health and the environment.
- The existing DOE approved 1998 Composite Analysis will be used to assess incremental risk in lieu of initiating a new analysis specific to the ATCD project.

2.0 REGULATORY REQUIREMENTS

Federal and state laws are applicable to the SSTs selected for the ATCD project. The approval authorities associated with implementing accelerated SST closure actions are Ecology, DOE and the EPA, as appropriate. Additionally, Washington Department of Health has approval authority for radiological air operating permit requirements. The SSTs are regulated as hazardous waste storage units by Ecology under WAC 173-303; the SSTs must be closed in accordance with applicable parts of this regulation.

For the purposes of this report, closure is defined as Interim, not Final Closure. Final Closure will occur when the entire tank farm is closed as a Waste Management Area. Radioactive waste must also be managed in accordance with the AEA. These regulatory authorities pose different requirements. The following regulations and requirements (not all-inclusive) are relevant to the management of waste in SSTs, the ATCD, and final closure of the tank farms:

Federal regulations and requirements:

- RCRA
- *Federal Facility Compliance Act*
- HFFACO
- NEPA
- AEA
- *Nuclear Waste Policy Act*
- 10 CFR 61
- 40 CFR 191
- 10 CFR 835
- DOE O 435.1
- DOE Order 5400.5
- Clean Air Act
- *Safe Drinking Water Act*
- *Clean Water Act.*

State regulations and requirements:

- HWMA
- *The Model Toxics Control Act Cleanup Regulation* (MTCA)
- *Water Pollution Control Act*
- *Washington Clean Air Act*
- SEPA.

The following sections will address the requirements of NEPA, DOE O 435.1, HFFACO, and HWMA. Each of these regulations or agreements has associated compliance options that were considered for planning and performance of ATCD.

2.1 NATIONAL ENVIRONMENTAL POLICY ACT/STATE ENVIRONMENTAL POLICY ACT

The NEPA requires consideration of environmental impacts, alternatives and commitment of resources for any major federal action significantly affecting the quality of the environment.

In the TWRS EIS ROD, DOE committed to collect data necessary to support an environmental impact statement on closure of the tank farms. An environmental assessment has been drafted to evaluate whether the project has a significant environmental impact. The ATCD actions would be interim closure actions pending final tank farm closure. If a Supplemental EIS to the TWRS EIS or a Closure EIS were required prior to proceeding with ATCD design, there would be a significant delay in the ATCD Project.

The "Washington State Environmental Policy Act" (SEPA) requires a determination of significance of environmental impacts before project approval is granted. A SEPA Checklist will be prepared identifying potential impacts of the proposed closure activity. Ecology will make a determination if the closure demonstration activity produces any significant impacts. If Ecology determines that the impacts of the proposed action are significant, Ecology may require the preparation of an environmental impact statement or that mitigation measures be incorporated into the project. If the determination by Ecology is that the impacts are not significant, no further SEPA review is required and a determination of non-significance can be issued. Ecology may adopt NEPA documentation in lieu of independent SEPA documentation.

The data obtained from the ATCD Project will support the final tank farm closure EIS. The demonstration activities undertaken will be planned so that there should be no adverse impact to the environment nor will the demonstration activities limit the choice of reasonable final SST farm closure alternatives.

2.2 RADIOACTIVE WASTE MANAGEMENT (DOE O 435.1)

The primary DOE regulation on management of radioactive waste is DOE Order 435.1. With its associated manual (DOE M 435.1-1) and guide (DOE G 435.1-1 through 4), DOE O 435.1 establishes requirements and guidance for managing DOE high-level waste (HLW), transuranic (TRU) waste, LLW, and the radioactive component of mixed waste.

This section addresses the waste classification requirements for WIR and closure plans for closing HLW facilities.

Three closure paths are identified in DOE M 435.1-1 and (DOE G 435.1-1 for deactivated HLW facilities. The paths include 1) deactivation and decommissioning, 2) CERCLA closure, and 3) a DOE-approved facility/site closure plan.

Since the tanks will not be released for unrestricted use and closure under HWMA/RCRA, (CERCLA is the closure path described in the HFFACO), current planning is to pursue a DOE and Ecology approved facility/site closure plan under HWMA/RCRA for the ATCD.

Crucial to DOE approval of the ATCD is the WIR Determination DOE M-435.1-1, Section II.B). The WIR methodology in DOE M 435.1-1 can be used to determine whether HLW resulting from reprocessing spent nuclear fuel is considered incidental to reprocessing. If waste contained in SSTs is determined to be incidental waste, it is not HLW and is managed under DOE regulatory authority in accordance with the requirements for TRU waste or LLW, as appropriate. Either a citation or evaluation process is used to determine whether the waste is managed as LLW or TRU waste. Waste determined to be incidental to reprocessing by citation includes spent nuclear fuel reprocessing plant wastes such as contaminated job wastes including items such as clothing, laboratory residues, tools, and equipment. The SST tank wastes do not meet this description and must be determined by the WIR evaluation process.

According to DOE M 435.1-1 determination that a waste is incidental to reprocessing by the evaluation process must be documented. Such waste may include spent nuclear fuel reprocessing plant waste that will be managed as LLW, and meet the following:

- Has been processed, or will be processed, to remove key radionuclides to the maximum extent technically and economically practical; and
- Will be managed to meet safety requirements comparable to the performance objectives set out in 10 CFR 61, Subpart C, Performance Objectives; and
- Is managed pursuant to DOE's Authority under the AEA per Chapter IV of DOE M 435.1-1 and will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C LLW as set out in 10 CFR 61.55, or will meet alternative requirements for waste classification and characterization as DOE may authorize.

The waste may be managed as TRU waste if it meets the following:

- Has been processed, or will be processed, to remove key radionuclides to the maximum extent technically and economically practical; and
- Will be incorporated in a solid physical form and meet alternative requirements for waste classification and characteristics as DOE may authorize; and
- Is managed pursuant to DOE's authority under the AEA in accordance with Chapter III of DOE M 435.1-1.

Closure in accordance with a DOE-approved closure plan that defines the approach that will be taken to ensure long-term protection of the public and the environment from the closure of those facilities that contain residual waste is described in DOE M 435.1-1 Section U (3). The plan is to be completed and approved before the initiation of physical closure activities (Tier 1 closure plan), and updated periodically to reflect current analysis and status of individual facility closure actions (Tier 2 closure plan). The plan must include, as a minimum, the following elements:

- Identification of the closure standards and performance objectives to be applied for LLW against which the effect of the disposal action will be assessed
- A strategy for allocating waste disposal facility performance objectives from the closure standards identified in the closure plan among the facilities or units to be closed at the site
- An assessment of the project and performance of each unit to be closed relative to the performance objectives allocated to each unit under the closure plan
- An assessment of the projected composite performance of all units to be closed at the site relative to the performance objectives and closure standards identified in the closure plan
- Any other relevant closure controls including a monitoring plan, institutional controls, and land use limitations to be maintained in the closure activity.

A composite analysis entitled *Composite Analyses for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* (PNNL-11800) was completed in 1998 and has been approved by DOE. The composite analysis will be used to support the ATCD and updated periodically as more data become available.

The multi-phase closure plan process is considered appropriate and necessary because much of the site-specific and detailed facility and waste characterization data needed to conduct performance analyses of the closure action may not be available at the time the closure action is being defined and resources are being solicited. The Tier 1 closure plan is intended to define and bound the parameters of a closure action and has to be approved by DOE Headquarters Environmental Management before physical closure activities begin. The Tier 2 closure plan is approved at the DOE Field Office level and provides the detailed information related to a specific unit or facility closure action that is bounded by the analyses contained in the Tier 1 closure plan. Tier 2 closure plan documentation should demonstrate that the performance objectives and other commitments identified in the Tier 1 closure plan could be met and maintained. *Deactivated High-Level Waste Closure Manual* (DOE, 2000) specifically addresses the DOE Headquarters Environmental Management review and approval of the Tier 1 closure plan and defines a process with a HLW steering committee-led review.

Because of the ATCD goal to complete tank closure demonstrations in CY 2004, there is a need to streamline the ATCD closure plan contents and review process. A modified ATCD closure plan will address the requirements of a Tier 1 Plan and addenda will be added for each specific tank closed during the ATCD Project. Although the ATCD closure plan is modeled after Tier 1 and Tier 2 closure plans, it is not intended that all requirements for formal Tier 1 and Tier 2 closure plans will be met for the ATCD. Areas where formal requirements will not be met are as follows:

- The closure demonstration focuses on tank contents only and does not address ancillary equipment and any contaminated soils surrounding the selected tanks.

- Closure demonstration actions will be reversible to not prejudice final decisions of the tank farm closure EIS. Materials (e.g., grout) added to the selected tanks must be retrievable.

- Long-term and short-term risk assessments will be developed for a performance assessment to demonstrate this closure demonstration is protective of public health and the environment.

- As this is an ATCD and permanent closure will not be achieved, the approval pathway for this closure demonstration is different than for a full Tier 1 closure plan. Many of the approval decisions are expected to reside within the DOE Office of River Protection with concurrence from DOE Headquarters as required.

- Normally, Tier 2 closure plans are written that detail closure activities for specific components. For this closure demonstration, the detailed closure activities for selected tanks will be appended to the closure demonstration plan.

2.3 HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER

The HFFACO, signed by DOE, Ecology, and the EPA in 1989, is an agreement to clean up radioactive and hazardous waste at the Hanford Site. The HFFACO establishes an action plan for cleanup that addresses priority actions, methods for resolving problems, and milestones. The HFFACO sets milestones to achieve coordinated cleanup of the Hanford Site and provides for the enforcement of these milestones to keep the program on schedule. In January 1994 the HFFACO was amended to incorporate the revised TWRS program technical strategy, which includes waste retrieval, remediation of SST and double-shell tank waste, and closure of the tank farms under RCRA. Waste retrieval under Milestone M-45-00 states that "closure will follow retrieval of as much tank waste as technically possible, with tank waste residues not to exceed 360 cubic feet (cu.ft.) in each of the 100 series tanks, 30 cu.ft. in each of the 200 series tanks, or the limit of waste retrieval technology capability, whichever is less."

HFFACO Milestone M-45-00 further states, " if DOE believes waste retrieval to the specified levels is not achievable for a tank, DOE will submit a detailed explanation to EPA and Ecology explaining why these levels cannot be achieved and specifying the quantities of waste that DOE proposes to leave in the tank (Ecology et al. 1989). Such requests from DOE will be approved or disapproved by EPA and Ecology on a tank-by-tank basis." It may be necessary for DOE to submit such a request to Ecology for tanks included in the ATCD. Appendix H of the HFFACO details the process for requesting a waiver to M-45-00. Appendix H also requires DOE to establish an interface with the U.S. Nuclear Regulatory Commission (NRC) to reach formal agreement on the retrieval goals or allowable waste residuals

The HFFACO requires that all TSD units located within the boundary of each SST farm be closed pursuant to WAC 173-303-610, including contaminated soil and ancillary equipment that were previously identified for cleanup under RCRA corrective action process authority. This reclassification of RCRA past-practice units as ancillary equipment to the TSD unit is an attempt to ensure the application of a consistent closure approach. The final closure of all TSD

units within the boundary of a given SST farm must be addressed in the final closure plan along with the SSTs for the tank farm. The HFFACO and SST RCRA Part A Permit have been amended to include a list of ancillary equipment impacted by this decision. Contaminated soils and groundwater will be addressed before preparing any permit applications for final closure for the SST TSD units as landfill(s).

2.4 HAZARDOUS WASTE MANAGEMENT ACT

The HWMA and its implementing regulations, WAC 173-303, implement RCRA in Washington State. The EPA has delegated most of the RCRA program to the State of Washington, which gives Ecology the authority to regulate dangerous and mixed waste. Washington State dangerous waste regulations specify requirements for design, permitting, operations, closure, and post-closure of dangerous and mixed waste management sites, including the tank farms.

The SSTs historically received hazardous, dangerous and mixed waste, but are now out of service (i.e., no additional waste can be added other than is required for the purposes of waste retrieval). Over the years, much of the liquid stored in the SSTs has been evaporated or pumped to double-shell tanks.

The Hanford Site has been assigned a single identification number for use in State Dangerous Waste Program/RCRA permitting activity. Accordingly, the Hanford Site is considered to be a single RCRA facility although there are numerous unrelated units spread over large geographic areas on the Site. The RCRA Permit, *Dangerous Waste Portion of the RCRA Permit for the Treatment, Storage, and Disposal of Dangerous Waste Hanford Site-Wide Permit (RCRA Permit)* (Ecology 2000), was issued and has been effective since September 28, 1994.

Under the HFFACO, SSTs are regulated as RCRA hazardous waste storage tank systems (i.e., they are RCRA TSD units). The SSTs are subject to the operating standards of RCRA Section 3004 and permit requirements of RCRA Section 3005, implemented by Ecology through WAC 173-303. The TSD units that were in operation on the effective date of the governing regulations were allowed to continue operation without a final status permit by fulfilling certain notification and submittal requirements.

The Part A permit application under RCRA is used by the regulatory agency to grant interim status for facilities that have complied with notification and submittal requirements in accordance with regulatory timeframes. Existing TSD unit owners/operators that have been granted interim status may temporarily continue hazardous waste management activities without a final status permit. Part A permit applications do not require public comment, and interim status is automatically granted on meeting the requirements pursuant to WAC 173-303-805. The owner/operator is required to submit a Part B post-closure permit application should the facilities change processes (e.g., change from storage to disposal). DOE submitted a Part A permit application for SSTs to Ecology on March 1, 1988, and was granted RCRA interim status.

The Part B permit application under RCRA is used by the regulatory agency to issue final status permits for TSD units. The Part B permit application is used to establish permit conditions related to operation and closure (including post-closure care where applicable). A closure plan

must be submitted with the Part B permit application. The plan must describe procedures that will be used by the owner/operator to remove dangerous waste and associated contaminated soil and equipment from TSD units at the facility. If the owner/operator is unable to remove all waste (and associated soils and equipment), post-closure care will be required. ORP does not intend to seek final operating status for SSTs; the tanks will undergo closure in lieu of final status permitting. A Part B permit will be required to close the SSTs (Ecology et al. 1989). An approved closure plan is required regardless of the closure path for the SST farms.

The following three paths exist for closure and post-closure planning under the RCRA permit for TSD of dangerous waste at the Hanford Site:

- Clean closure
- Modified closure
- Landfill closure.

It is assumed that post-closure care will be required because there will be residual waste in the SSTs, residual soil contamination, or both. Therefore, a post-closure plan will be required for submittal into the RCRA Permit. Final corrective action for contaminated environmental media, as currently being performed, will be an element of the closure and post-closure plans. Specific final corrective action activities have not yet been identified and will depend on the amount of residual tank waste and environmental media contamination levels, if any.

As stated in Section 2.3, the HFFACO requires that TSD units closed within the SST system be closed pursuant to WAC 173-303-610. WAC 173-303-610(1)(c) states, "for the purposes of the closure and post-closure requirements, any portion of a facility which closes is subject to the applicable closure and post-closure standards even if the rest of the facility does not close and continues to operate." Although the ATCD will only include closure of portions of the SST units (i.e., tanks-only and without closure of its associated ancillary equipment, contaminated soil or groundwater), closure to WAC 173-303-610 standards must be assured. Compliance with these standards includes the requirement to submit a closure plan with the Hanford Site-Wide RCRA Permit (WAC 173-303-610[3][a]).

ATCD tank-specific closure plans will be prepared and submitted to Ecology for inclusion in the Hanford Site-Wide RCRA Permit. This requirement will be met utilizing a tiered approach, as described in the HFFACO M-45-02-03 revision (August 2002).

2.4.1 Top Tier (Framework Document)

The top tier will be an overarching closure plan for the entire SST system. This framework document will describe general historical information common to all tanks within the tank farms and will provide the basis to which implementing tank(s)-specific closure plans will be added to the Hanford Site-Wide RCRA Permit. The framework document will also include the following:

- Key Definitions - This section will provide a description of items such as individual tank closure, tank farm closure, interim status, final status, partial and final closure for the

purposes of forming the basis for how components of the SST system will be added to the Hanford Site-Wide RCRA Permit.

- Process for integrating components of the SST System into the SST closure plan, including ancillary equipment, contaminated soils and groundwater and ultimately the development of the SST Post-closure Plan.

- Process for completion of waste residual retrieval as a pre-closure activity and completion of the retrieval endpoint through the closure plan approval process (i.e., the permit modification process) and the HFFACO Appendix H process, if required.

- Evaluation and Justification of Closure Performance Standards Including Risk Assessment Information - This section will define general information regarding the approach to the assessment of risk. The closure activity must minimize the need for further maintenance of the facility by controlling or eliminating to the extent necessary to protect human health and the environment and escape of waste to the ground, surface/groundwater or atmosphere. The action must also return the land to the appearance and use of surrounding areas given the future activity of the facility. This evaluation will be conducted using agreed upon exposure scenarios and potential land use alternatives.

- Schedule of Specific closure plan Submittals - This section provides the integration of established HFFACO due dates for submittal of specific closure plan documents in which the closure activity schedules will be included.

- Post-Closure Monitoring and Maintenance Plan - This section of the document will describe the intentions regarding groundwater monitoring and other interim measures such as maintenance and environmental monitoring through final post closure for the entire SST system.

- Other Closure Requirements - A discussion of the integration of DOE Order 435.1, NEPA, and SEPA requirements into ATCD closure actions will be included. Some or all of the sections that will ultimately make up the SST framework closure plan will more appropriately be added later rather than during initial ATCD closure plan submittals (e.g., after all tanks are closed, after contaminated soil corrective actions have been performed).

2.4.2 Middle Tier (Waste Management Area Closure)

The middle tier will contain the closure and post closure discussion for each of the seven SST Waste Management Areas (241-A/AX, 241-B/BX/BY, 241-C, 241-S/SX, 241-T, 241-TX/TY, and 241-U WMAs). The WMA is considered to be a contiguous portion of the SST System that, upon final closure actions, will result in a partial closure for the SST System. At this point, post-closure permit conditions for all of the components within the WMA can be defined. The timing for incorporation of information into the second tier will remain flexible. As with the Upper Tier (Framework) closure plan, some or all of the sections that will ultimately make up the WMA closure plan will more appropriately be added later rather than during initial ATCD closure plan

submittals (e.g., after all tanks are closed, after contaminated soil corrective actions have been performed).

- WMA Description - This section will include a description of the WMA location, past and current uses, geologic setting, and tanks and ancillary equipment.

- Risk Evaluation - This section will provide a general discussion on the approach to evaluating the risks associated with contamination (radiological and dangerous waste-related) within the WMA. The evaluation will include risks from the tank waste, ancillary equipment, surface soils, vadose zone, and groundwater.

- WMA Groundwater Monitoring - This section will provide a description of the current groundwater monitoring program.

- Post-Closure - This section will describe those potential future surveillance and maintenance efforts that will be conducted to assure risk exposure requirements are sustained.

2.4.3 Third Tier (Individual Tank Closure)

The third tier document would include the submittal of specific individual SST component closure plan(s), e.g., the accelerated tank closure demonstration under the ATCD Project. The specific plan(s) will include:

- Risk Evaluation - This section will provide a general discussion on the approach to evaluating the risks associated with individual SST components. The evaluation will include risks from the tank waste residuals that would remain after closure actions are implemented. Where data are available, the results of the risk evaluation will be included in the closure plan. Where data are not yet available, the actions for obtaining risk results will be defined and permit conditions will be written by Ecology that will require approval of this information prior to initiation of closure activities.

- Current Inventory of Wastes - This description will include an estimate of the maximum inventory of dangerous/mixed wastes that have been in the selected tanks during their active life.

- Compliance with Closure Performance Standards - The closure activity must minimize the need for further maintenance of the facility by controlling or eliminating to the extent necessary to protect human health and the environment the escape of waste to the ground, surface/groundwater or atmosphere. Compliance will include determination of acceptable risk. The action must also return the land to the appearance and use of surrounding areas given the future activity of the facility.

- Closure Activities - A detailed description of the methods for sampling and analysis of residuals, tank stabilization, isolation of the tank, waste management for wastes generated during closure activities, and personnel training will be included in this section. In

addition, criteria for determining the extent to which the action has satisfied the closure performance standard will be included.

- Schedules for Implementation of the Plan(s) - The schedule will document the time required to close each facility and time required for intervening activities as part of a partial closure activity.

- Interim Post-Closure Monitoring and Maintenance Plan - This portion of the document will describe the interim post-closure maintenance and monitoring which will provided to ensure the stability of the facility until final closure is accomplished.

- LDRs - The applicability of the LDRs to residual waste remaining in the tanks will be assessed. At the time of finalization of this report, a path forward for LDR had not been defined by ORP and Ecology. Should LDRs be determined to apply to the residual waste left in the tank, the requirements of WAC 173-303-140 and 40 CFR 268 must be complied with. It is probable that the residuals left in the tank will be above LDR treatment standards contained in 40 CFR 268 Subpart D. It is also probable that closure actions envisioned for the tank at this time may not comply with these concentration-based standards. Therefore, under these circumstances, a treatability variance would need to be submitted to Ecology for approval of an alternative standard to meet LDR requirements. This variance will likely be based on the closure actions that will be agreed to by Ecology in the modification to the RCRA permit. In other words, implementation of the closure actions for the ATCD tank will result in both the best available treatment technology for the waste (which can be demonstrated to be significantly different from the waste that EPA used to base the 40 CFR 268 Subpart D treatment standards on), and will result in protection of human health and the environment, a parallel requirement of both WAC 173-303-610 and the HFFACO.

- As with final risk decision-making, it is anticipated that a treatability variance could not be approved by Ecology until sometime after permit modification, but before ATCD closure actions commence. Thus, separate Ecology approval of a treatability variance would be required. This section of the third tier closure plan will likely define the path forward for determining LDR compliance, and as with the risk assessment, a permit condition would be written by Ecology requiring a compliance determination prior to implementation of closure actions.

- SEPA Checklist - A SEPA checklist will be included in the closure plan submittal for approval.

The implementation of the component closure plan(s) is intended to demonstrate the selected closure technology and provide performance data necessary to evaluate final closure actions.

2.5 REQUIRED PERMITS AND PLANS

To obtain closure for a tank(s), permits and plans are required under the various regulations that relate to additional waste retrieval from a tank. This section discusses the permits and plans required prior to and during retrieval and closure activities.

For retrieval of additional waste and closure of a tank, permits and/or plans required include the following:

- National Emissions Standards For Hazardous Air Pollutants permit (WAC-173-480 and 40 CFR 61)
- Non-radioactive air emissions Notice of Construction permit (WAC-173-401)
- Radioactive air emissions Notice of Construction permit (WAC 246-247)
- Preparation of a leak detection, monitoring, and mitigation plan approved by Ecology for potential retrieval leakage to the environment based on the retrieval technology prepared to be deployed (HFFACO)
- Ecology approval of ATCD closure plan and inclusion in the Hanford Site-Wide RCRA Permit. (HFFACO and WAC-173-303.610).

2.6 REQUIRED DOE ACELERATED TANK CLOSURE DEMONSTRATION PROJECT APPROVALS

- Approval by DOE-ORP and DOE Richland Operations Office of adequate NEPA documentation.
- Approval by DOE Field Manager of WIR Determination in concurrence with the DOE Office of Environmental Management (EM).
- For the ATCD Project a modified DOE Order 435.1 Tier 1 closure plan will be submitted, which includes closure activities for individual SSTs (Tier 2 plans). Approval by DOE Headquarters may not be required in this case. Approval by the DOE ORP Manager with concurrence from DOE Headquarters may be sufficient, but this is yet to be determined.
- Authorization to Proceed (HQ or delegated to ORP).

3.0 REGULATORY STRATEGY AND LOGIC DIAGRAM

The strategy for tank farm closure in the *Single-Shell Tank System Closure Work Plan* (DOE/ORP-2001-18, Rev. 0) involves waste retrieval, removal and disposal of above and below grade ancillary equipment, stabilization of the residual waste, soil remediation and construction of an infiltration barrier. For the ATCD Project, only some of these steps will be performed. The balance of the steps will be performed as required during tank farm closure.

The ATCD regulatory strategy focuses on defining the requirements for the closure demonstration of five selected tanks as a landfill under RCRA as implemented by HWMA (WAC 173-303-610(2)(a)). The strategy also addresses the requirements of DOE O 435.1, HFFACO and NEPA processes.

This section describes the overall regulatory strategy for the ATCD and provides a logic diagram and a narrative description that walks through the applicable regulatory requirements. The major step of the regulatory logic diagram are described separately and numbered for reference. For ease of reference, the processes are color-coded.

The regulatory logic diagram for the ATCD is shown in Figure 1. This logic diagram starts with preparation of the appropriate NEPA documentation and proceeds through the processes and decisions associated with the WIR LLW Criteria, the WIR TRU Criteria (as necessary), the HFFACO, SEPA, and HWMA requirements before developing detailed ATCD closure plans and requesting a RCRA Permit modification to proceed with the demonstration of partial closure activities. Many of the activities shown can be done in parallel. The regulatory logic begins simultaneously in Boxes 1 and 2.

Box 1 represents the NEPA compliance process. In the TWRS EIS ROD, DOE committed to collect data necessary to support an EIS that will support decisions on closure of the tank farms. An EA has been drafted to evaluate whether the proposed activities of the ATCD are bounded under the existing TWRS EIS or, if the proposed activity will have any significant environmental impact. The data obtained from the ATCD Project will support the final closure EIS. The ATCD will be planned so that there should be no significant adverse impact. The ATCD actions would be partial closure actions pending final tank farm closure. The EA is required before starting final design of the first closure demonstration. If a Supplemental EIS to the TWRS EIS or Closure EIS is required prior to proceeding with ATCD design, there would be a significant delay in the ATCD Project.

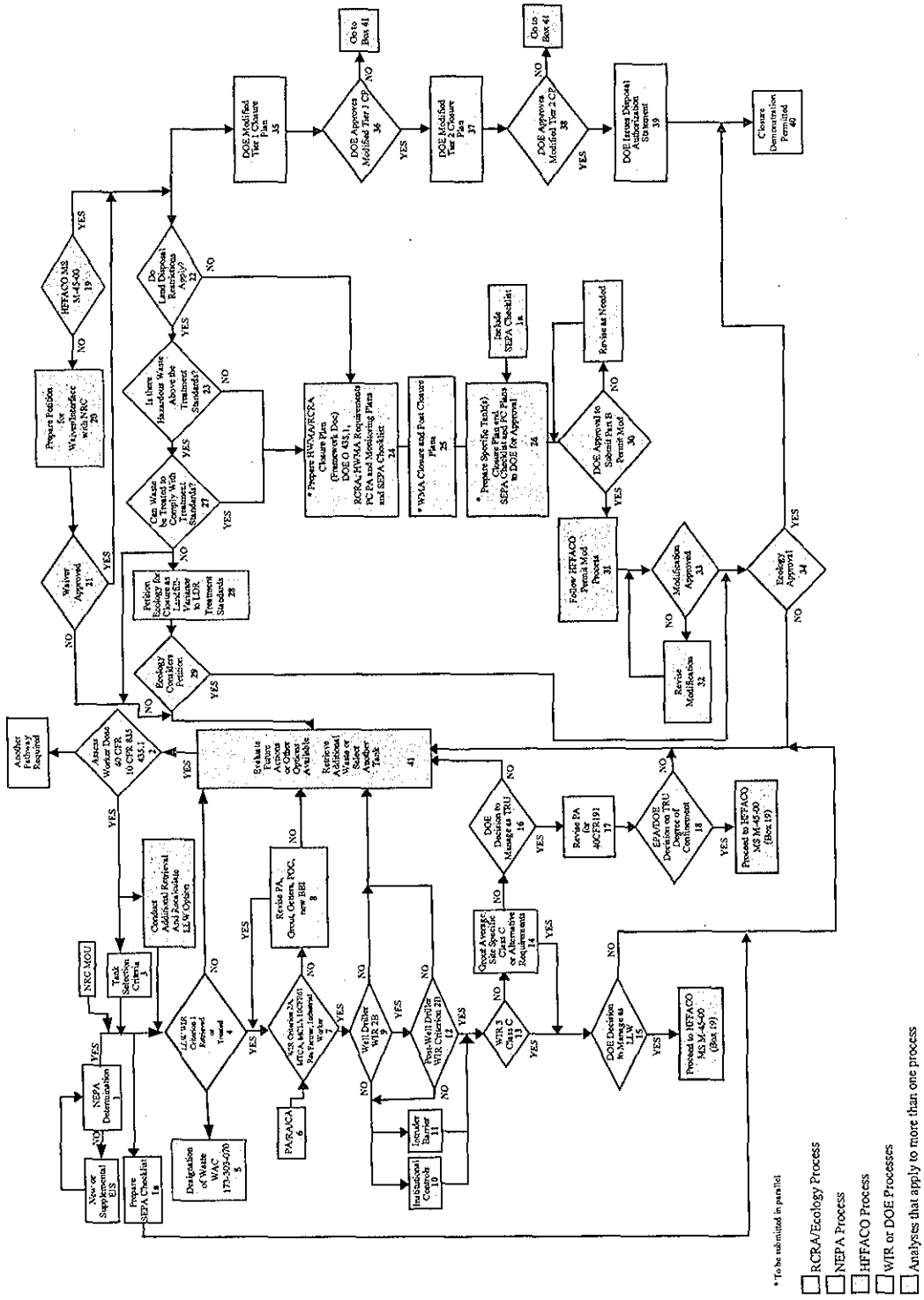
A SEPA checklist, Box 1a, will be prepared and presented to DOE and Ecology at the time the ATCD closure plans are submitted identifying potential impacts of the proposed closure activity.

The next step in the process requires a decision as to which tanks are going to undergo regulatory evaluation for partial closure. Several types of analyses feed into this decision. Such factors as degree of risk reduction, level of information about the tank and its surrounding environment, and past retrieval history may all influence a decision on which tanks undergo evaluation for closure. For the Closure Demonstration, the five selected tanks have undergone some past-practice retrieval. The ATCD has utilized characterization data in the Best Basis Inventory (BBI)

and previous Retrieval Performance Evaluations and developed an overall relative risk ranking of SSTs based on inventory information to support the decision of the initial five tanks.

Box 2 A number of assessments are performed. The assessments include calculations of worker doses due to accidents and normal operations. Should retrieval be required, considerations such as retrieval or closure effects to on-site and off-site receptors will be evaluated. If any surface disturbances occur, air quality standards must be evaluated.

Figure 1. Regulatory Strategy Logic Diagram



Box 3 represents the application of the Tank Selection Criteria as developed by the Cleanup, Constraints, and Challenges Team (C3T). After considering the results obtained in Box 2, these Criteria may then be applied to determine exactly which tanks may enter into the DOE O 435.1 process for WIR evaluations. Technical rankings based on inventory or other selection criteria may also be utilized at this point to address which tanks may enter the WIR evaluation process

In order to conduct a closure demonstration, the DOE must reclassify the waste from HLW to WIR. To do this, the WIR process requires DOE to manage the waste as either LLW or TRU waste. The WIR evaluation process lists three criteria that must be met in order to manage waste as LLW rather than as HLW. It also has another three criteria to be met in order to manage waste as TRU. The logic diagram illustrates a process whereby the DOE will first screen candidate tanks for the ability to meet the LLW criteria. At each main step in the process feedback loops exist to consider additional retrieval or other options.

Box 4 represents a preliminary evaluation of DOE O 435.1 WIR Criterion 1. To satisfy WIR Criterion 1, key radionuclides must be defined. Key radionuclides are defined as those radionuclides that are important contributions to risk or to the short-term and long-term performance of the tank, i.e., that are important to satisfying the performance objectives of 10 CFR Part 61, Subpart C. The main radionuclides contributing to dose for the five selected ATCD tanks are shown in Table 2.

Evaluation of removal of additional key radionuclides from the current inventory of waste from the candidate ATCD tanks on a tank specific basis will be presented in the ATCD closure plan. The analytical tools utilized will be summarized and referenced. Passage into the next step assumes that key radionuclides have been removed to the extent technically and economically feasible.

Box 5 is the point in the process that DOE must determine the classification of the waste that will remain in the tanks after tank waste retrieval is completed. Once the tanks are selected, DOE must disclose the Retrieval and Waste Classification Data.

Table 1. Main Radionuclides Contributing to Dose for Five Candidate Accelerated Retrieval and Closure Demonstration Tanks

Radionuclide			
3H	90Y	238Pu	241Pu
14C	99Tc	239/240Pu	242Cm
60Co	129I	238U	242Pu
90Sr	137Cs	241Am	243Am

Box 6 represents the point in the process where the performance and risk assessments, composite analyses or other calculations are undertaken to assess the WIR Criterion 2. These analyses are also utilized to assess technical performance objectives from other regulations or acts mentioned in Sections 2 through 5, such as HWMA or RCRA. Worker protection during operations is also considered in Box 6. These analyses will consider doses due to accidents and normal closure actions as opposed to retrieval actions done previously in Box 2.

For the ATCD, several technical analyses are used for a performance assessment. A composite analysis, completed by PNNL in 1998, will be utilized to fulfill DOE O 425.1 requirements.

Box 7 represents the WIR Criterion 2 evaluation step that is to examine the 10 CFR 61 Subpart C Performance Objectives. These objectives have four parts:

- Protection of the General Population
- Protection of Workers During Operations
- Protection of an Inadvertent Intruder
- Site Stability.

For the ATCD, the requirements are evaluated separately and are shown in two parts in the logic diagram, each containing different analyses and scenarios that are evaluated at the tank farm boundary or at the tank. The first part of the analysis is accomplished in the Performance Assessment/Risk Assessment Box shown as Box 6. This analysis will examine the protection of the general population requirement, and utilizes Residential Farmer and Industrial Worker Scenarios. These are future site user scenarios developed by the DOE and evaluated at the tank farm boundary. The conceptual model for the analyses assumes that the tank waste will eventually dissolve and move from the tanks, downward through the vadose zone and then laterally through the saturated zone to the tank farm boundary. As mentioned earlier, the analyses can also assess other requirements, such as groundwater and drinking water protection standards. These groundwater protection standards are the most stringent as they are calculated to 10,000 years. Also, the analyses can determine compliance with maximum contaminant levels (MCLs) as required by MTCA and RCRA. If the requirements shown in Box 7 are met, then the next part of the analysis can be performed.

Box 8 is an additional analysis step that may be considered if compliance with WIR Criterion 2, Protection of the General Population, standards are not met. Additional analyses will be needed to assess if chemical getters, sequestering agents or retardants can slow or otherwise lower the concentrations such that the requirements may be met. If so, then additives are assumed in the subsequent analyses. Other measures may be considered such as different points of compliance, (e.g., the 200 Area Boundary or Buffer Zone) and the analyses re-run. If compliance can be met with these changes, then the next part of the Subpart C requirements may be considered, if not, additional retrieval or other options may be considered.

The Inadvertent Intruder analysis required in 10 CFR 61 Subpart C contains two scenarios designed by DOE and includes the Inadvertent Well Driller and the Post-Well Driller scenarios.

Box 9 illustrates the location in the process where the Well Driller Scenario is conducted. The well driller scenario is conducted at 100 years post closure. The driller inadvertently drills a well directly into the tank. The driller is exposed to waste brought up by the drill bit and receives a one time acute dose. If this scenario is not protective of health by failing to meet the 500 mrem acute dose requirement, then other options will be evaluated.

Box 10 allows for the use of extended institutional controls for greater than the present regulated time interval of 100 years. If these controls are deemed adequate, then the Post-Well Driller scenario is no longer required because the well would not have been drilled. (Extended institutional controls have been considered at Savannah River and other DOE facilities.)

Box 11 examines the use of physical controls in the form of intruder barriers. If institutional controls are extended, or an intruder barrier is utilized to prevent the well driller from accessing waste until 300 – 500 years post-closure, then any post-driller analyses which fail due to the concentrations of strontium and cesium would then pass this test, as the strontium and cesium would have decayed by 10 half-lives. Alternatively, DOE may choose to reevaluate other options, including additional retrieval.

Box 12 is the location in the process where the Post-Well Driller scenario is evaluated. The Post-Well Driller scenario assumes an individual lives at the site contaminated by the Well Driller. The resident consumes food grown and irrigated, but does not drink the water from the contaminated well. The same options apply to this analysis as for the well driller. Institutional or physical controls may be considered as well as additional retrieval to prevent these doses from occurring.

Box 13 represents the third WIR Criterion which assesses applicable concentration limits for Class C low-level waste in 10 CFR 61.55 It is expected that most of the ATCD tanks will not meet the limits that are described by the two tables in 10 CFR 61.55. If the tank meets the Class C requirements it may move on to Box 15.

Box 14 represents various options for those tanks not meeting the limits set forth in 10 CFR 61.55. These options consist of such actions as grout averaging, Site-Specific Class C limits or alternative requirements. It is envisioned that, for most of the demonstration tanks, alternative requirements, such as those utilized by the NRC at West Valley, may be needed to allow the waste to be managed as LLW. If any of these options are acceptable, then the WIR evaluation is complete and DOE can formally approve the WIR Determination Report for the residuals. If these above mentioned options are not acceptable, then two other choices can be made at this point. DOE may choose to manage the waste as TRU, as shown in Box 16, or they may choose to attempt further retrieval or examine other disposal options.

Box 15 represents the DOE approval of the WIR Determination Report for the residuals. If DOE chooses not to approve the Determination Report, the logic diagram provides a means of selecting additional retrieval or choosing another tank.

Box 16 represents a DOE decision to manage the waste as TRU. If this choice is made, three options exist, 1) exhume waste, treat and send to the Waste Isolation Pilot Plant, 2) meet the

performance objectives of 40 CFR 191 and 3) develop alternative standards with the concurrence of EPA. Performance assessments are required to assess compliance with 40 CFR 191.

Box 17 represents the analyses of WIR TRU Criterion 2. Criterion 2 states the following:

> *"Will be incorporated in a solid physical form and meet alternative requirements of waste classification and characteristics, as DOE may authorize;"*

While this Criterion doesn't specifically state that the performance objectives of 40 CFR 191 must be met, the DOE O 435.1 Implementation Guide Chapter 2 states the following:

> *"The DOE Headquarters Deputy Assistant Secretary for Waste Management will establish a process similar to that used for low-level waste disposal facilities for reviewing and approving performance assessments. Additional details on the criteria for reviewing and approving 40 CFR 191 performance assessments are included in the guidance to Section III.P. Performance assessment is defined and the requirements that must be included in a performance assessment for a transuranic waste disposal facility are discussed in 40 CFR 191. This section of the guidance and the transuranic waste chapter only contain reference to the 40 CFR 191 standards, with no additional minimum requirements for disposal."*

It is therefore assumed that DOE must comply with the performance objectives of 40 CFR 191. While 40 CFR 191 prohibits near surface disposal of TRU, it does not specify any depth requirements. The requirements of 40 CFR 191 are technically different, though radiologically identical to those of 10 CFR 61.55. If the radiological performance objectives can be met in Box 17, DOE may chose to approach EPA for a joint decision on whether the greater isolation requirements are needed for the particular tank waste.

Box 18 shows the place in the process where DOE and EPA make the joint decision on whether the greater isolation requirements of 40 CFR 191 are needed. If the DOE and EPA determine that the residual waste may be disposed in place, then the process moves to the next step, if not, the DOE must conduct additional analyses or additional retrieval may be considered.

Box 19 is the step in the process where the requirements of the HFFACO Milestone M-45-00 are formally examined. This milestone requires that residual waste volumes be less than 360 cubic feet for the 100 series of tanks or 30 cubic feet for the 200 series, or the limit of waste retrieval technology capability, whichever is less. If the residuals meet these volume goals, then the DOE process can proceed to Box 35, prepare Tier 1 closure plan (For the ATCD project, this is a modified Tier 1 closure plan.) The RCRA/Ecology process however, still requires evaluation of the LDRs (Box 22). If the residual volumes exceed the HFFACO goals, then the Appendix H process is initiated.

Box 20 represents the Appendix H requirement that an assessment is made as to the applicability of petitioning for regulatory waiver. This requires an interface with NRC and a formal agreement on the retrieval and closure actions for single-shell tanks with respect to the allowable waste residuals in the tank and prepare input to the retrieval goal evaluation to accommodate agreements on allowable residuals. If DOE believes waste retrieval to the specified levels is not

plausible for a tank, DOE will submit a detailed explanation to EPA and Ecology explaining why these levels cannot be achieved and specifying the quantities of waste that DOE proposes to leave in the tank (Ecology et al. 1989). Such requests from DOE will be approved or disapproved by EPA and Ecology on a tank-by-tank basis.

Box 21 represents approval of the waiver on the quantity of residuals allowed to remain in place. The process can move to the next step, which considers the LDR of RCRA mixed waste. If not, additional retrieval or other options must be considered.

Box 22 is the place in the process where the LDRs are addressed. These requirements could be addressed in parallel to the WIR analyses, since they are inventory-related versus performance-related requirements. If contaminant concentrations do not exceed LDR standards the HWMA/RCRA closure plan (Framework – First Tier document) may be prepared (Box 24). If the LDRs do apply, then the process moves to Box 23, Hazardous Waste classification.

Box 23 is the place in the process where Hazardous Wastes are identified and compared to their allowable concentration limits (Treatment Standards). If there are Hazardous Wastes above the concentration limits, then the process proceeds to Box 27. If there are no Hazardous Wastes above the Treatment Standards, then the HWMA/RCRA closure plans can be prepared.

Box 24 is the location in the process where the HWMA/RCRA closure plan (Framework) documentation is prepared.

Box 25 represents the HWMA/RCRA Second Tier documentation, which will contain information on each WMA.

Box 26 represents the preparation of tank-specific Closure plans, i.e., the Third Tier documentation. At this point in the process the SEPA Checklist will become part of the documentation. The document will be submitted to DOE for review and comment.

Box 27 is the place where analyses are conducted to ascertain if the dangerous waste can be treated to comply with the Treatment Standards. If there is the ability to treat the waste, possibly by grouting to the Treatment Standards, then the HWMA/RCRA closure plan documentation can proceed. If not, DOE has the choice to retrieve additional residuals, evaluate other disposal options, or request a treatability variance as defined in 40 CFR 268.44.

Box 28 represents a petition to Ecology for a treatability variance if required under LDR.

Box 29 is a decision box regarding the treatability variance under LDR. Should Ecology deny the petition then DOE will evaluate other disposal options, retrieve additional waste or select another tank. Approval of the petition allows the HWMA/RCRA Third Tier closure documentation to proceed to Box 34.

Box 30 represents DOE approval of the HWMA/RCRA closure plans for submittal to Ecology. If DOE does not approve the plans, the documents will be revised as needed.

Box 31 starts the HFFACO Permit modification process for a Part B permit modification to the Hanford Site-Wide RCRA Permit. This process includes Ecology review and comment, issuance of the document for public review, and comment resolution.

Box 32 shows the Notice of Deficiency review cycle, if needed.

Box 33 shows that upon completion and resolution of public comment, Ecology will approve the permit modification.

Box 34 is the point at which Ecology will modify the existing Site-Wide Permit.

Box 35 shows that once HFFACO retrieval goals are satisfied, the DOE O 435.1 modified Tier 1 closure plan may be prepared.

Box 36 represents the DOE approval of the modified Tier 1 closure plan.

Box 37 represents the development of the modified Tier 2 closure plan. It should be noted that for the ATCD project, the modified Tier 1 and Tier 2 Closure plans would be combined into one submittal.

Box 38 represents the DOE approval of the modified Tier 2 Closure plan.

Box 39 represents the point where DOE issues a Disposal Authorization Statement.

Box 40 is the point where partial closure is permitted. This can occur after the DOE approvals have been obtained, the Disposal Authorization Statement issued and Ecology approvals are received.

Box 41 is the step in the process where, failing any of the previous criteria or requirements, additional retrieval, other disposal options or other tanks may be considered.

4.0 TANK-SPECIFIC REGULATORY STRATEGIES

Five tanks have been selected for the ATCD Project. A preliminary analysis was conducted for each of the five tanks to assess the pathway through the DOE O 435.1 WIR methodology. After a WIR determination is made, the planned closure actions for each tank will be developed within the framework of the HFFACO, HWMA, and RCRA requirements.

The analyses utilized to make these determinations are preliminary, but are considered representative given the uncertainties in the inventory, distribution coefficients, infiltration rates, and solubilities. However, if further sampling or testing shows that the assumptions used in the analyses are no longer valid, these analyses will be reevaluated per the *Cost-Risk Analysis in Support of Accelerated Tank Closure Demonstration* (JEG 2002).

Preliminary analyses were performed for tanks C-106, C-201, C-202, C-203 and C-204. For all tanks except C-106 the strategies refer back to Figure 1.

4.1 TANK C-106 REGULATORY STRATEGY AND LOGIC DIAGRAM

The strategy for the closure demonstration for tank C-106 is illustrated in the C-106 Logic Diagram shown as Figure 2.

A summary of the preliminary results obtained by applying the WIR Criteria (Boxes 4-13) to C-106, in its current state follows:

Groundwater Protection Standards - Residential Farmer (incremental lifetime cancer risk)[ILCR] 10^{-5})	Passes
Groundwater Protection Standards – Industrial Worker (ILCR 10^{-5})	Passes
Inadvertent Intruder – Well Driller (500 mrem) acute dose	Passes
Inadvertent Intruder – Post-Well Driller (100 mrem annual dose) (Fails primarily due to ^{90}Sr - 374 mrem annual dose at 100 years)	Fails
10 CFR 61.55 Class C, Tables 1 and 2	Fails

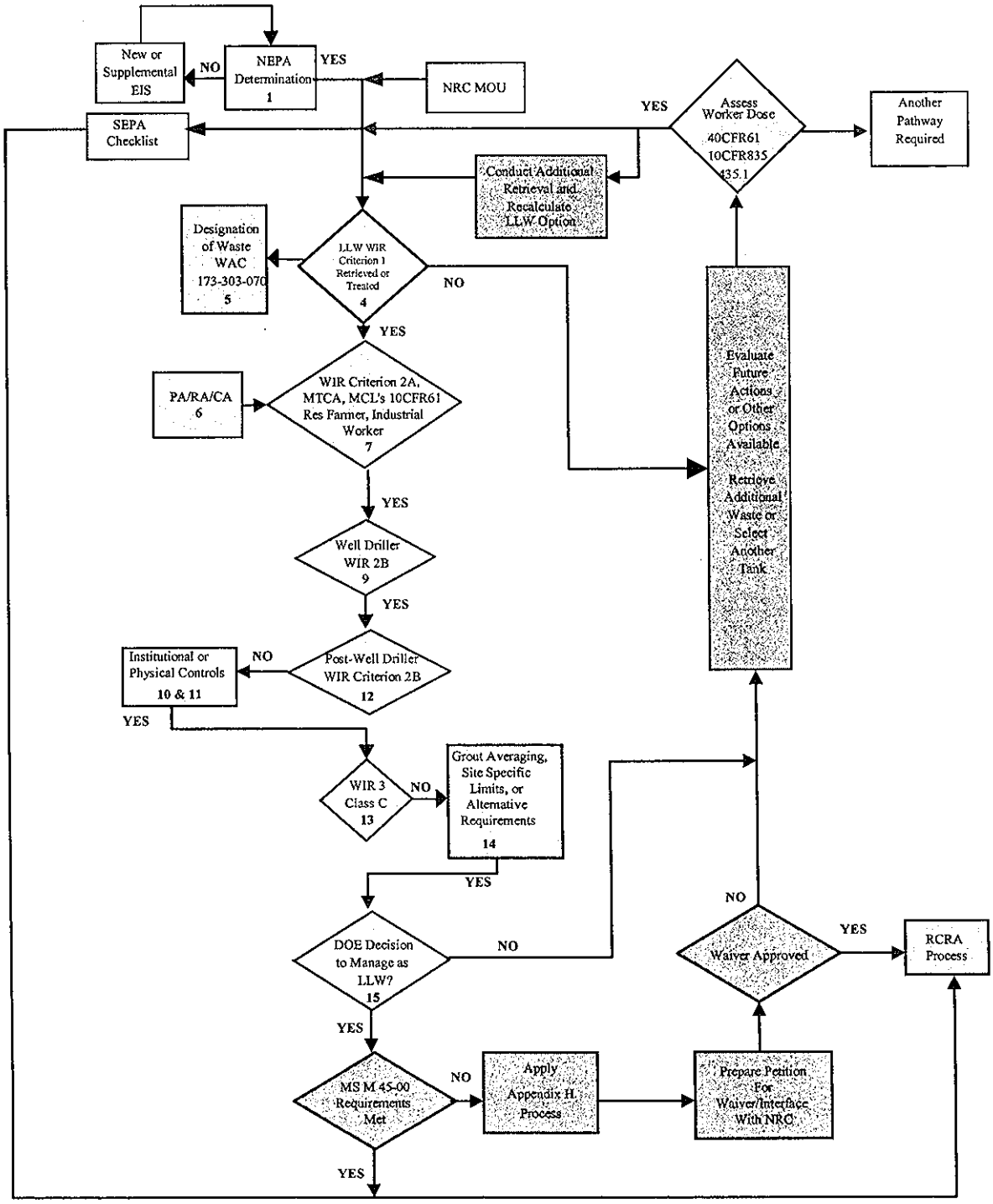
The strategy for closing tank C-106 begins in Box 1. It is assumed that the NEPA documentation requirements will be satisfied through an EA and preparation of a new or supplemental EIS to the TWRS EIS will not be required. A SEPA checklist will be prepared (Box 1a).

WIR CRITERION 1

After Box 1, NEPA documentation is satisfied and Box 2, assessment of worker doses and cost/risk analyses are completed, the next step is evaluation against WIR Criterion 1, removal of key radionuclides. Tank C-106 does not pass WIR Criterion 1 (Box 4). Its waste has been retrieved previously, but preliminary analyses indicate that the remaining liquid could be retrieved at a reasonable cost. Tank C-106 has an existing inventory that is distributed between

residual solids and liquid. The latest BBI indicates that some 6,000 gallons of sludge would remain after retrieving the liquids.

Figure 2. C-106 Regulatory Strategy Approach Logic Diagram



When the liquid waste is retrieved, the remaining waste will be reassessed for compliance with WIR Criteria 1. For this exercise, it is assumed that tank C-106 passes WIR Criterion 1 after retrieval of liquids and may proceed to the evaluation of WIR Criterion 2.

WIR CRITERION 2

WIR Criteria 2 contains four Performance Objectives:

- Protection of the General Population
- Protection of Workers During Operations
- Protection of Inadvertent Intruders
- Stability of the Site.

Since tank C-106 passes the Residential Farmer and the Industrial Worker scenarios in its non-retrieved state, it is assumed that it also passes these scenarios in its retrieved state (Boxes 6 and 7). Therefore, Performance Objective 1 is met.

Performance Objective 2, Protection of Workers was assessed in Box 2. Tank C-106 will incur worker exposures during the retrieval of liquids. Minimal worker exposures will occur during closure demonstration operations such as grouting for stabilization purposes, though these exposures are small and within the performance objective requirement of 5 rem/yr.

Performance Objective 3, the Inadvertent Intruder Well Driller Scenario, is assessed in Box 9. Tank C-106 passes the Well Driller Scenario in the non-retrieved state, and it is assumed that it also will with the liquid inventory retrieved. Box 12 evaluates the Post-Well Driller scenario. This scenario has not been specifically assessed in the retrieved state, however, given the large inventory of Cesium-137 and Strontium-90 in the solids, it is expected that tank C-106 will still fail this scenario after liquid retrieval. Because the Post–Well Driller Scenario fails primarily due to strontium and cesium concentrations, institutional controls for 300- 500 years are recommended to ensure that the Post-Well Driller Scenario does not occur (Box 10). Alternatively, DOE may choose to design an intruder barrier to last 300 to 500 years to prevent exposures for this scenario. (Box 11 of Figure 1.)

Performance Objective 4, Site Stability is met through the use of stabilizing grout, or grout encapsulation, if required during final closure.

WIR CRITERION 3

WIR Criterion 3 Class C limits of 10 CFR 61.55 (Box 13) are not met for tank C-106, even with the retrieval of liquids. Grout averaging may be used in this tank to meet the Class C limits after retrieval of liquids based on preliminary calculations, but it would require between 11 and 19 feet of grout to do so. This would be far more than the previous NRC position for the Savannah River Site, which allows only a factor of 10 dilution. Alternatively, this tank could undergo retrieval of solids to the HFFACO Milestone M-45-00 level, but it would still require between 5 and 8.5 feet of grout to reach the Class C limits. It is therefore recommended that, because it meets Performance Objectives 1 and 2, and the DOE has the ability to use either institutional

controls or design an effective intruder barrier to protect against the post-well driller, that this tank is a candidate to be closed under the alternative requirements directive of WIR Criterion 3. This is shown in Box 14.

Alternative requirements for waste classification are permitted in DOE O 435.1. It is proposed that DOE adopt a performance-based approach to the development of alternate requirements for the ATCD. If, after evaluation of the specific characteristics of the waste, disposal site, and method of disposal, DOE finds reasonable assurance of compliance with the performance objectives of Subpart C, the residual waste need not meet the LLW classification as defined in 10 CFR 61.55 Tables 1 and 2.

If DOE chooses this route for closure of tank C-106, the above analyses supporting this closure demonstration must be documented in the WIR Determination Report. It is anticipated that the DOE will ask the NRC to review and comment on the WIR Determination Report, before it is approved by the DOE ORP Field Manager (Box 15).

Once the WIR Determination Report has been approved, HFFACO Milestone M-45-00 must be addressed. Interface with NRC is required by HFFACO Appendix H if the HFFACO retrieval goal is not met. A formal agreement must be reached regarding retrieval goals and conversely, the amount of residuals that can be left in the tanks. It is also expected that the analyses conducted in the WIR Determination Report will provide justification for leaving residuals in place, even if they do not strictly meet the volumetric requirements of the milestone. If DOE believes waste retrieval to the specified levels is not plausible, DOE will submit a detailed explanation to EPA and Ecology in accordance with the HFFACO Appendix H, explaining why these levels cannot be achieved and specifying the volume of waste proposed to be left in place, and its chemical and radiological characteristics and expected impacts to human health and the environment. Such requests from DOE will be approved or disapproved by EPA and Ecology on a tank-by-tank basis.

HWMA and RCRA requirements for this tank are defined in Section 2.4

4.2 REGULATORY STRATEGY FOR TANK C-201

A summary of the results of applying the WIR Criteria to tank C-201 follows:

Groundwater Protection Standards – Residential Farmer (ILCR 10^{-5})	Passes
Groundwater Protection Standards – Industrial Worker (ILCR 10^{-5})	Passes
Inadvertent Intruder – Well Driller (500 mrem) acute dose	Passes
Inadvertent Intruder – Post-Well Driller (100 mrem annual dose)	Fails
10 CFR 61.55 Class C, Tables 1 and 2	Fails

<u>WIR CRITERION 1</u>

Following from Figure 1, after the NEPA documentation is complete (Box 1), assessment of worker doses, and cost/risk analyses must be done (Box 2). C-201 has undergone past practice retrieval. Therefore, it may pass Criterion 1 depending on the results of the retrieval cost and risk analyses. For the purpose of this analysis, it is assumed that Criterion 1 is satisfied (Box 4), and the analysis may proceed to the evaluation of WIR Criterion 2.

WIR CRITERION 2

Tank C-201 passes the WIR Criterion 2 Performance Objectives 1 and 2 as shown in Boxes 2 through 8. Tank C-201 also meets the Well Driller part of Performance Objective 3 (Box 9), but not the Post-Well Driller Scenario (Box 12). For this tank, it is recommended that additional retrieval be undertaken because the doses to the Post-Well Driller are largely due to isotopes of plutonium. (While still dominated by strontium-90, there are large contributions from long-lived radionuclides such as plutonium-239, plutonium-240, plutonium-241, and americium-241.) Institutional controls for 300 – 500 years or intruder barriers are not effective under these conditions. After this tank waste is retrieved to the HFFACO goal, it will pass through all the Boxes again to this point, and must be reevaluated against the post-well driller intruder. If retrieval to the HFFACO M-45-00 limits is protective, C-201 may pass on to WIR 3. If not, additional retrieval may be considered. Site Stability requirements will be met by utilizing grout. It may then pass to Box 13 to evaluate WIR Criterion 3.

WIR CRITERION 3

WIR Criterion 3 Class C concentrations will still not be met even with retrieval to the HFFACO goal (Box 13). Grout averaging may be attempted, but is not likely to be acceptable, based on the high ratio (e.g., greater than a factor of ten) of grout to waste. Additional retrieval could be attempted to below the HFFACO goal, but large amounts of grout would still be required to grout average, if retrieval to this level is feasible. It is therefore recommended to retrieve to the extent possible and then close the tank as LLW under the alternate requirements directive of Criterion 3.

If DOE chooses this route for closure of C-201, a WIR Determination Report must be developed. Additionally HFFACO, HWMA, and RCRA compliance must be evaluated.

4.3 REGULATORY STRATEGY FOR TANK C-202

A summary of the results of applying the WIR Criteria to C-202 follows:

Groundwater Protection Standards – Resident Farmer (ILCR 10^{-5})	Passes
Groundwater Protection Standards – Industrial Worker (ILCR 10^{-5})	Passes
Inadvertent Intruder – Well Driller (500 mrem) Acute dose	Passes
Inadvertent Intruder – Post-Well Driller (100 mrem annual dose)	Passes
10 CFR 61.55 Class C, Tables 1 and 2	Fails

WIR CRITERION 1

Following from Figure 1, after the NEPA documentation is complete (Box 1), assessment of worker doses, and cost/risk analyses must be done (Box 2). C-202 has undergone past practice retrieval. Therefore, it may pass Criterion 1 depending on the results of the retrieval cost and risk analyses. For the purpose of this analysis, it is assumed that Criterion 1 is satisfied (Box 4), and the analysis may proceed to the evaluation of WIR Criterion 2.

WIR CRITERION 2

Tank C-202 passes all of the WIR Criterion 2 Performance Objectives 1 and 2 as shown in Boxes 2, 6, 7 and 8. Tank C-202 meets the Well Driller and Post-Well Driller parts of Performance Objective 3 (Boxes 9 and 12). Site stability requirements will be met by utilizing grout at the time of tank farm closure. Tank C-202 may then pass to Box 13 for evaluation of WIR Criterion 3.

WIR CRITERION 3

Tank C-202 does not meet the Class C Criteria and grout averaging will not reach the Class C Criteria mainly due to a long-lived TRU component. This tank is a good candidate for closure under alternate requirements. This is the recommended pathway and is shown in Box 14.

If DOE chooses this route for closure of tank C-202, a WIR Determination Report must be developed. Additionally HFFACO, HWMA, and RCRA compliance must be evaluated.

4.4 REGULATORY STRATEGY FOR TANK C-203

A summary of the results of applying the WIR Criteria to C-203 follows:

Groundwater Protection Standards – Residential Farmer	Passes
Groundwater Protection Standards – Industrial Worker	Passes
Inadvertent Intruder – Well Driller (500 mrem) Acute dose	Passes
Inadvertent Intruder – Post-Well Driller (100 mrem annual dose)	Passes
10 CFR 61.55 Class C, Tables 1 and 2	Fails

WIR CRITERION 1

Following from Figure 1, after the NEPA documentation is complete (Box 1), assessment of worker doses, and cost/risk analyses must be done (Box 2). C-202 has undergone past practice retrieval. Therefore, it may pass Criterion 1 depending on the results of the retrieval cost and risk analyses. For the purpose of this analysis, it is assumed that Criterion 1 is satisfied (Box 4), and the analysis may proceed to the evaluation of WIR Criterion 2.

WIR CRITERION 2

Tank C-203 passes all of the WIR Criterion 2 Performance Objectives as shown in Boxes 2, 6, 7, and 8. Tank C-203 also meets the Well Driller and Post-Well Driller parts of Performance Objective 3 (Boxes 9 and 12). Site Stability requirements will be met by utilizing grout at the time of tank farm closure. It may then pass to Box 13 to evaluate WIR Criterion 3.

WIR CRITERION 3

Tank C-203 does not meet the Class C Criteria and grout averaging may be used to meet the Class C Criteria. Grout averaging may be attempted, but is not likely to be acceptable without additional retrieval, based on the high ratio (e.g., greater than a factor of ten) of grout to waste. This tank would also be a candidate for retrieval to the HFFACO goal. Grout averaging would be more feasible after retrieval and is estimated to meet the 10 CFR 61.55Class C tables. Since tank C-203 meets all of the performance objectives in its non-retrieved state, it is recommended to close this tank without additional retrieval under the alternate requirements of WIR Criterion 3 (Box 14 of Figure 1).

If DOE chooses this route for closure of C-203, a WIR Determination Report must be developed. Additionally HFFACO, HWMA, and RCRA compliance must be evaluated.

4.5 REGULATORY STRATEGY FOR TANK C-204

A summary of the results of applying the WIR Criteria to C-204 in its non-retrieved state follows:

Groundwater Protection Standards Residential Farmer (ILCR 10^{-5})	Passes
Groundwater Protection Standards – Industrial Worker (ILCR 10^{-5})	Passes
Inadvertent Intruder – Well Driller (500 mrem) Acute dose	Passes
Inadvertent Intruder – Post-Well Driller (100 mrem annual dose)	Passes
10 CFR 61.55 Class C, Tables 1 and 2	Passes

WIR CRITERION 1

Following from Figure 1, after the NEPA documentation is complete (Box 1), assessment of worker doses, and cost/risk analyses must be done (Box 2). C-202 has undergone past practice retrieval. Therefore, it may pass Criterion 1 depending on the results of the retrieval cost and risk analyses. For the purpose of this analysis, it is assumed that Criterion 1 is satisfied (Box 4), and the analysis may proceed to the evaluation of WIR Criterion 2.

WIR CRITERION 2

Tank C-204 passes all of the WIR Criterion 2 Performance Objectives as shown in Boxes 2, 6, 7, 8, 9 and 12. Site Stability requirements will be met by utilizing grout at the time of tank farm closure. It may then pass to Box 13 to evaluate WIR Criterion 3.

WIR CRITERION 3

C-204 also meets WIR Criterion 3, Class C requirements of 10 CFR 61.55 (Box 13). It is therefore recommended to close this tank in its existing state as it meets all the WIR criteria and performance objectives for LLW.

If DOE chooses this route for closure of C-204, a WIR Determination Report must be developed. Additionally HFFACO, HWMA, and RCRA compliance must be evaluated.

4.6 PRELIMINARY WIR EVALUATION SUMMARY

Preliminary evaluations have been completed, comparing the WIR Criteria to selected tanks to determine if the ATCD tank residuals can be managed as LLW. The results are summarized in Table 3.

Table 2. Selected Single Shell Tank Waste Incidental to Reprocessing Preliminary Evaluation Summary

WIR Criteria	C-106	C-201	C-202	C-203	C-204
Removal of key radionuclides	Passes*	Passes*	Passes*	Passes*	Passes*
Groundwater Protection Standards - Residential Farmer (ILCR 10^{-5})	Passes	Passes	Passes	Passes	Passes
Groundwater Protection Standards – Industrial Worker (ILCR 10^{-5})	Passes	Passes	Passes	Passes	Passes
Inadvertent Intruder – Well Driller (500 mrem) acute dose	Passes	Passes	Passes	Passes	Passes
Inadvertent Intruder – Post-Well Driller (100 mrem annual dose)	Fails	Fails	Passes	Passes	Passes
10 CFR 61.55 Class C Tables 1 and 2	Fails	Fails	Fails	Fails	Passes

* All tanks are assumed to pass WIR criterion 1 pending results of retrieval cost and risk analyses.

The results of the preliminary WIR determinations indicate that all five tanks may be managed and disposed as LLW, based on the following:

- Tank C-204 in its current state meets all the performance objectives and waste classification requirements of 10 CFR 61.
- Tanks C-202 and C-203 pass all of the performance objectives of 10 CFR 61, but do not meet the strict requirements for LLW classification described in 10 CFR 61.55 (Class C Tables). They still may be disposed as LLW by exercising the DOE authority to develop alternative requirements to 10 CFR 61.55.
- Tanks C-201 and C-106 are retrieval candidates because, while they meet most of the Performance Objectives, they both fail the Inadvertent Intruder analysis scenario of the Post-Well Driller. Neither of these tanks meets the LLW Classification of 10 CFR 61.55.

While both may need further retrieval, the exact management pathways to closure and disposal of residuals are different due to the different character of the residual inventories as discussed below.

Tank C-106 - DOE has committed to retrieve the liquids from Tank C-106, which is required to meet the 10 CFR 61 requirement that residual waste be in a solid form. Preliminary analysis results indicate that approximately 6,000 gallons of sludge remaining after the liquids are pumped will still not meet the waste LLW classification requirements. Even with additional solids removal to the HFFACO volumetric goal, grout averaging is not likely to be an acceptable means of meeting the classification requirement. In addition, the Post-Well Driller Inadvertent Intruder scenario dose is still likely to be exceeded with retrieval of the liquids and with additional solids retrieval to the HFFACO goal. The Post-Well Driller intruder dose is due primarily to strontium and cesium, which have relatively short half-lives; therefore, institutional or physical controls could be utilized to prevent inadvertent intruder exposures. The waste classification requirements may be met utilizing alternative requirements under DOE authority.

Tank C-201 Tank C-201 must undergo retrieval as doses to the Inadvertent Intruder Post-Well Driller scenario are dominated by long-lived radionuclides, mainly isotopes of plutonium. These doses can only be prevented by retrieval. An intruder barrier is not a viable option for the time period necessary for intruder protection with risk dominated by long-lived radionuclides. Even with retrieval to the HFFACO goal, the waste will not meet the waste classification requirements of 10 CFR 61.55, though it would meet all other performance objectives in its retrieved state. After retrieval of C-201 to the HFFACO goal, it could also be closed as LLW by utilizing alternative requirements.

5.0 RESOLUTION OF ISSUES

A number of issues require resolution prior to completing the tank closure demonstration plans. The *Single-Shell Tank System Closure Work Plan* (DOE/ORP-2001-18, Rev. 0) contains a list of issues identified to date and the resolution status of each. Other issues relevant to the completion of the ATCD Project are uncertainty in tank inventory distribution coefficients, applicability of LDR, and points of compliance. These are addressed below.

5.1 UNCERTAINTY IN TANK INVENTORY

Tank inventory estimates for the regulatory compliance analyses are from the current BBI. For several of the tanks selected in the ATCD Project, the upper and lower bounding estimates for some contaminants of concern are very large, i.e. approximately eight orders of magnitude. Because of this range, efforts are ongoing to reduce the uncertainty in the BBI. Additional confirmatory sampling may be necessary in order to develop confidence in risk and dose estimates.

5.2 UNCERTAINTY IN DISTRIBUTION COEFFICIENTS

Uncertainty exists in the results of stochastic groundwater contamination calculations in progress on the ATCD tanks due to the manner in which the distribution coefficients are assigned. The results of these calculations are used for estimating long-term risk. Analyses are underway to better define the range of distribution coefficient for isotopes of concern. This may require additional laboratory testing to reduce the uncertainty.

5.3 UNCERTAINTY REGARDING APPLICABILITY OF LAND DISPOSAL RESTRICTIONS

Regulatory uncertainties are associated with the applicability of LDR regulations to Hanford Site residual tank waste and contaminated soils. The LDR regulations apply to generators and transporters of hazardous and dangerous waste and to treatment, storage, and/or disposal facilities. The LDR regulations could be argued to not be applicable to the SSTs in that in situ stabilization of residuals would not trigger placement of waste. In other words, land disposal of restricted wastes would not occur. If the wastes or contaminated media are subject to the LDR regulations, compliance with treatment standards will be required, or alternately, approval of a treatability variance may be required.

5.4 POINTS OF COMPLIANCE

Several points of compliance are listed in the regulatory requirements and they differ. For example, Ecology has indicated that the only point of compliance recognized in the WAC regulations is the tank farm boundary with the regulatory avenue of pursuing further points of compliance should technical impracticability be identified for meeting action levels at the tank farm boundary. In the DOE orders, the point of compliance is the point of maximum concentration, no closer than 100 meters from the boundary of the unit. Other requirements specify compliance at the Columbia River. Discussions are on-going regarding how the 200 Area

and Central Plateau will be managed or controlled in the future. If institutional controls prohibit entry to an area for a sufficiently long period of time, the potential exists to affect the results of the current calculations due to natural attenuation of contaminants down gradient and radioactive decay of some contaminants of concern. (These effects would act to lower concentrations downgradient of the tank farm boundary.)

The analyses completed to date have been calculated at the tank farm boundary. For the five tanks selected for the ATCD Project, compliance with general population protection standards is achieved for reasonable cases evaluated. However, this may not be the case for future tanks selected for closure. Prompt resolution of land use issues on the Central Plateau and the corresponding points of compliance will help to give a more realistic picture of future risk.

6.0 CONCLUSIONS

The regulatory strategy for the ATCD Project identifies an approach for obtaining required approvals to proceed with the ATCD and complete closure demonstration actions within the prescribed schedule. To accomplish these actions in the 2004 timeframe, modifications to the DOE 435.1 Tier 1 closure plan requirements and modification to regulatory approval processes are necessary.

Preliminary evaluations against the WIR criteria indicate that it may be possible to close the five demonstration tanks as LLW utilizing DOE authority and approval for development of alternative requirements to Class C waste limits of 10 CFR 61.55. The alternative requirements to Class C are proposed for those tanks that can demonstrate compliance with the performance objectives of Subpart C.

7.0 REFERENCES

10 CFR 60, "Disposal of Radioactive Waste in Geological Repositories," *Code of Federal Regulations*, as amended.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations,* as amended.

10 CFR 1021, "National Environmental Policy Act Implementing Procedures," *Code of Federal Regulations*, as amended.

40 CFR 61, "National Emission Standards for Hazardous Air Pollutants," *Code of Federal Regulations*, as amended.

40 CFR 70, "State Operating Permit Programs," *Code of Federal Regulations*, as amended.

40 CFR 100-149, "Subchapter D – Water Programs," *Code of Federal Regulations*, as amended.

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*, as amended.

40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, as amended.

40 CFR 260-280, "Solid Wastes. Subchapter I – Solid Wastes (Hazardous Waste Management Systems)," *Code of Federal Regulations*, as amended.

40 CFR 268, "Land Disposal Restrictions," *Code of Federal Regulations*, as amended.

55 FR 22520, 1990, "Land Disposal Restrictions for Third-third Scheduled Wastes," *Federal Register*, U.S. Environmental Protection Agency, Washington, D.C.

62 FR 8693, 1997, "Record of Decision for the Tank Waste Remediation System, Hanford Site, Richland, Washington," *Federal Register*, February 26.

Atomic Energy Act of 1954, 42 USC 2011 et seq., as amended.

Clean Air Act, Public Law 88-206, 42 USC 7401 et seq., as amended.

Clean Water Act, Public Law 95-217, 91 Stat. 1566 and Public Law 96-148, December 1977.

Comprehensive Environmental Response, Compensation, and Liability Act, Public Law 96-150, 94 Stat. 2767, Title 26, December 1980.

DOE G 435.1, 1997, *Implementation Guide for use with DOE Manual 435.1-1*, U.S. Department of Energy, Washington, D.C.

DOE M 435.1-1, 1997, *Radioactive Waste Management Manual*, U.S. Department of Energy, Washington, D.C.

DOE O 435.1, 1997, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE Order 5400.5, 1993, *Radiation Protection of the Public and Environment*, U.S. Department of Energy, Washington, D.C.

DOE/EIS-0189, 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, U.S. Department of Energy and Washington State Department of Ecology, Washington, D.C.

DOE/ORP-2001-18, 2001, *Single-Shell Tank System Closure Work Plan*, Rev. 0, U.S. Department of Energy, Office of River Protection, Richland, Washington.

Ecology, 2000, *Dangerous Waste Portion of the RCRA Permit for the Treatment, Storage, and Disposal of Dangerous Waste Hanford Site-Wide Permit*, Rev. 6, Washington State Department of Ecology, Olympia, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Energy Reorganization Act of 1974, 42 USC 5842, as amended.

Federal Facility Compliance Act of 1992, Public Law 102-386, 42 USC 6921 et seq.

62 FR 8693m 1997, "Record of Decision for the Tank Waste Remediation System, Hanford Site, Richland, WA" *Federal Register, February 26, 1997*

Hazard and Solid Waste Amendments of 1984, Public Law 98-616, 42 USC 6991 et seq.

"Hazardous Waste Management Act," RCW 70.105, *Revised Code of Washington*, as amended.

Jacobs, 2002, *Cost-Risk Analysis in Support of Accelerated Tank Closure Demonstration*, JEG-02-017, Jacobs Engineering Group, Inc., Richland, Washington

National Environmental Policy Act of 1969, 42 USC 4321 et seq.

Nuclear Waste Policy Act of 1982, 42 USC 10101 et seq.

PNNL-11800, 1998, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington.

Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2795, Title 42.

Rosenthal, 1997, *Approaches to Closure of High-Level Mixed Waste Tanks Considering the Hazardous Waste Component of the Waste*, Colorado Center for Environmental Management, Denver, Colorado.

Safe Drinking Water Act, Public Law 93-523, December 16, 1974, 88 Stat. 1660, Title 21.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

WAC 173-340, "The Model Toxics Control Act Cleanup Regulation," *Washington Administrative Code*, as amended.

WAC 173-401, "Operating Permit Regulation," *Washington Administrative Code*, as amended.

WAC 246-247, "Radiation Protection-Air Emissions, *Washington Administrative Code*, as amended.

"Washington Clean Air Act of 1967," Chapter 70.94, *Revised Code of Washington*, as amended.

"Washington Model Toxics Control Act," Chapter 70.105D, *Revised Code of Washington*, as amended.

"Washington State Environmental Policy Act (SEPA)," Chapter 43.21C, *Revised Code of Washington*, as amended.

"Water Pollution Control Act," Chapter 90.48, *Revised Code of Washington*, as amended.

WHC-SD-WM-34-313, 1996, *Supporting Document for the Historical Tank Content Estimate for C Tank Farm*, Revision 1, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

APPLICABLE REGULATORY REQUIREMENTS

Attachment 1

CONTENTS

A.1.0 FEDERAL FACILITY COMPLIANCE ACT A-1

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A.7.0 REFERENCES A-6

This appendix contains additional descriptions of the applicable regulations listed, but not described in Section 2.

A.1.0 FEDERAL FACILITY COMPLIANCE ACT

The *Federal Facility Compliance Act* (FFCA) waives sovereign immunity for RCRA violations at federal facilities. However, provisions in the act postpone compliance with RCRA mixed waste storage regulations at DOE sites. DOE is instead required to prepare site treatment plans for developing required treatment capacity for mixed waste stored or generated at each facility unless a state-enforceable agreement for RCRA compliance is put into effect. The FFCA provides that DOE will not be subject to fines and penalties for violating prohibitions on land disposal of mixed waste as long as it is in compliance with an approved site treatment plan and meets all other applicable regulations. The HFFACO constitutes a state-enforceable agreement that meets the FFCA.

A.2.0 ATOMIC ENERGY ACT

The AEA establishes the authority of the federal government to regulate the production and use of source, byproduct, and special nuclear material. This responsibility was originally under the sole purview of the Atomic Energy Commission. In 1970, the responsibility for establishing generally applicable environmental standards for the protection of the environment from radioactive materials was transferred to the EPA. EPA also assumed the previous responsibility of the Federal Radiation Council (established in 1959) to provide guidance to the President on radiation matters affecting health. Responsibility for implementation and licensing remained with the Atomic Energy Commission and its successor agencies (Energy Research and Development Administration, DOE, and NRC).

Regulations applicable to SSTs under the AEA are issued by both EPA and DOE. The NRC has regulatory responsibility for commercial facilities. The NRC has licensing authority under the *Energy Reorganization Act* for disposal facilities for all HLW, including that produced by DOE facilities. Because the current strategy includes determining that tank residuals would be WIR, not HLW, licensing by the NRC is not required.

The AEA has been implemented through various acts or regulations. The most important to a closure demonstration strategy are:

- Nuclear Waste Policy Act
- Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR 191)
- Occupational Radiation Protection, Final Rule (10 CFR 1021)
- Radiation Protection of the Public and Environment (DOE Order 5400.5)

- DOE O 435.1.

The following sections discuss each of these regulations:

A.2.1 NUCLEAR WASTE POLICY ACT

Congress passed the *Nuclear Waste Policy Act of 1982*(NWPA) in response to the continued nationwide accumulation of spent nuclear fuel, HLW, and a growing public awareness and concern for public health and safety. The NWPA establishes a national policy for disposal of HLW and spent nuclear fuel in a geologic repository and directs DOE to characterize Yucca Mountain in Nevada for suitability as the site of the first United States HLW repository. The NWPA authorizes disposal of HLW and spent nuclear fuel in the first repository subject to a limit on repository capacity and the payment of appropriate fees. The NWPA specifically instructs the NRC to limit the first geologic repository to 70,000 metric tons (77,000 tons) of heavy metal or a quantity of solidified HLW resulting from the reprocessing of such a quantity of spent nuclear fuel until such time as a second geologic repository is in operation. For planning purposes, DOE assumes that some or all of the Hanford Site spent nuclear fuel and immobilized HLW that satisfies the repository acceptance criteria could be placed in potential geologic repositories developed under the NWPA. NRC regulations governing the licensing of a geologic repository are contained in "Disposal of Radioactive Waste in Geological Repositories" (10 CFR 60).

A.2.2 40 CFR 191

The NWPA also directs EPA to promulgate waste standards pursuant to the AEA. EPA responded on September 19, 1985, by issuing 40 CFR 191. Over a period of years 40 CFR 191 was vacated and remanded by the courts in response to petitions for review. Certain sections of 40 CFR 191 were reinstated, and on December 20, 1993, EPA promulgated the current final rule including a revised Section 191.15, "Individual Protection Requirements," and a new Subpart C, "Environmental Standards for Ground-Water Protection."

The final 40 CFR 191 rule consists of three subparts. Subpart A established dose limits for members of the public including doses resulting from management and storage of spent nuclear fuel and HLW or TRU waste at any disposal facility operated by DOE that is not regulated by NRC or by agreement states. Subpart B establishes containment requirements, assurance requirements, and individual protection requirements for disposal systems for spent nuclear fuel, HLW, and TRU waste. This part specifies a 10,000-year design objective, discusses requirements for institutional controls, monitoring performance of the disposal system, designation by records, markers, and passive controls, avoidance of resource areas, and finally retrievability of wastes. Subpart C establishes groundwater protection standards for disposal systems for spent nuclear fuel, HLW, and TRU waste. The groundwater limit is the current MCL from "National Primary Drinking Water Regulations" (40 CFR 141).

The rule was developed primarily for mined geologic repositories. However, 40 CFR 191 does not apply to any facility regulated by the NRC or agreement states, but does apply to any disposal facility operated by DOE involving HLW or TRU waste.

The Hanford SST closure strategy includes determining that the residual tank waste is not HLW, but WIR, allowing it to be managed and disposed of as either low-level waste (LLW) or transuranic (TRU) waste. It is possible that residual waste in some tanks will still be TRU waste. If the residual wastes are determined to be TRU waste, then the decision could be made to proceed with disposal in place. The rule requires a performance assessment to demonstrate compliance with stated limits in 40 CFR 191.

A.2.3 10 CFR 835

Worker radiation protection is regulated by 10 CFR 835. This rule establishes the primary limit of 5 rem/yr, with a number of modifications for special cases. The rule also covers a variety of topics, such as monitoring, entry control, posting records, facility designs, emergency exposures, and release of materials and equipment. An appendix on derived air concentrations is included in 10 CFR 835.

A.2.4 DOE ORDER 5400.5

Public radiation protection is regulated by DOE Order 5400.5. This establishes the general public dose limit for all pathways of 100 mrem/yr effective dose equivalent (EDE) and an air pathway limit of 10 mrem/yr. Additional detailed requirements are provided for specific situations, sources, and liquid discharges.

A.3.0 CLEAN AIR ACT

The *Clean Air Act* is intended to protect and enhance the quality of the nation's air resources and promote public health and welfare and the productive capacity of its population. Section 118 of the *Clean Air Act* requires that each federal agency, with jurisdiction over any property or facility that might result in the discharge of air pollutants, comply with all federal, state, interstate, and local requirements regarding the control and abatement of air pollution.

The *Clean Air Act* requires the EPA to establish National Ambient Air Quality Standards to protect public health, with an adequate margin of safety, from any known or anticipated adverse health effects of a regulated pollutant (40 CFR 50). Ambient air refers to air outside buildings that the general public has access. NATIONAL AMBIENT AIR QUALITY STANDARDS exist for six criteria pollutants (i.e., oxides of nitrogen, sulfur oxides, carbon monoxide, particulate matter less than 10 microns in size, ozone, and lead) and numerous other requirements regulate the emissions of 189 other hazardous air pollutants. Separate regulations limit radionuclide emissions (40 CFR 61). Washington State has largely adopted the current federal standards. However, the state has established more stringent standards for sulfur dioxide and ozone and maintains state ambient air quality standards for total suspended particulate and gaseous fluorides.

The *Clean Air Act Amendments*, which amended the *Clean Air Act*, require that the EPA develop a national Air Operating Permit Program, including provisions to approve similar state programs to permit, in addition to these six criteria pollutants all major stationary sources of regulated pollutants. EPA responded to this directive by promulgating "State Operating Permit Programs" (40 CFR 70). In November 1994 the EPA approved the Washington State Air Operating Permit Regulation, promulgated as "Operating Permit Regulation" (WAC 173-401). The state program, administered by the Washington State Department of Health, includes regulation of federal facilities. DOE has received a site wide Air Operating Permit for the Hanford Site. Based on the retrieval or closure action to be implemented, state-issued Notice of Construction permits required to support modifications to the facility or construction of new stationary sources that would impact air quality will be prepared as needed. Specific requirements in Notice of Construction permits may require modification of the Site-Wide Air Operating Permit. The basic limit is 10 mrem/yr effective dose equivalent to a member of the public through the air pathway only.

A.4.0 SAFE DRINKING WATER ACT

The primary objective of the *Safe Drinking Water Act* is to protect the quality of the public water supplies and all sources of drinking water. The implementing regulations, which are administered by the EPA unless delegated to the states, establish standards applicable to public water systems. Public water systems are defined as water systems that serve at least 15 service connections used by year-round residents, or regularly serve at least 25 year-round residents. These regulations establish MCLs (including those for radionuclides) in public water systems. The *Safe Drinking Water Act* requirements were implemented by the EPA in "Water Programs" (40 CFR 141 through 149).

Concentration limits for radionuclides in drinking water are contained in 40 CFR 141. The standards are expressed as MCLs, which include specific concentrations for radium-226/228 (i.e., 5 picocuries per liter combined); gross alpha (i.e., excluding radon and uranium – 15 picocuries per liter); uranium 30 micrograms/liter; and beta particle and photon emitter concentrations corresponding to 4 mrem/yr to whole body or any organ. The organ dose system will be used to determine compliance. These standards are applicable to community water systems (both ground and surface water) designated by the state as utilizing waters. Contaminant releases to groundwater from past tank leaks and potential leakage during retrieval actions and from tank waste residuals will need to comply with drinking water standards as part of either a CERCLA remedial action or a RCRA corrective action. Ultimately, compliance with these provisions must be assured in order to close the SST System as a treatment, storage, and disposal (TSD) unit under the HWMA. Should compliance with MCLs not be technically feasible, approval of alternate concentration limits may be required.

A.5.0 CLEAN WATER ACT

The *Clean Water Act*, which amended the *Federal Water Pollution Control Act*, was enacted to restore and maintain the chemical, physical, and biological integrity of the nation's water. The *Clean Water Act* regulates the discharge of pollutants to navigable waters of the United

States. Section 313 of the *Clean Water Act* requires all branches of the federal government, engaged in any activity that might result in a discharge or runoff of pollutants to surface waters, to comply with federal, state, interstate, and local requirements.

The *Clean Water Act* establishes guidelines and limitations for effluents from point-source discharges and authorizes the EPA to implement the National Pollutant Discharge Elimination System Permitting Program. The National Pollutant Discharge Elimination System Permitting Program is administered by the Water Management Division of the EPA pursuant to regulations in 40 CFR 100-140. EPA retains regulatory authority over the National Pollutant Discharge Elimination System Program for federal facilities in Washington State (e.g., Hanford Site).

A.6.0 RESOURCE CONSERVATION AND RECOVERY ACT

The RCRA, as amended, establishes requirements for generators and transporters of hazardous waste and also establishes a specific permit program for TSD facilities of hazardous waste. RCRA, for purposes of this report, covers RCRA and all amendments including the *Hazardous and Solid Waste Amendments*, the *Federal Facility Compliance Act*, and the *Land Disposal Program Flexibility Act*. RCRA creates cradle-to-grave regulations for the generation, identification, transportation, and TSD of hazardous waste. RCRA imposes requirements on all organizations, including DOE, which perform regulated activities. The EPA is the agency responsible for implementing RCRA; regulations are found in "Solid Wastes. Subchapter I – Solid Wastes (Hazardous Waste Management Systems)" (40 CFR 260 through 280).

Congress allows states to seek authorization from the EPA to administer and enforce a hazardous waste program pursuant to RCRA. The EPA is responsible for implementing the undelegated portions of the hazardous waste management program and may enforce both delegated and undelegated portions of the program. Most, but not all, of the EPA hazardous waste program in Washington State has been delegated to Ecology. Hazardous waste management is regulated by Ecology through WAC 173-303.

Neither EPA nor Ecology has authority to regulate the radioactive portion of the mixed waste or the authority to regulate HLW under RCRA. Regulation of the radioactive portion of the tank waste occurs under the AEA. As described in the HFFACO, DOE, Ecology, and EPA determined that the Hanford Site tank farms, including the tank waste, tanks and ancillary equipment, and surrounding soils, would be regulated under the provisions of RCRA. The HFFACO also states that releases to the groundwater beneath the tank farms from past and/or future contaminant releases are regulated by RCRA.

RCRA regulations require a permit for TSD facilities. For facilities that were already in existence in 1984 Congress provided a grace period for TSD facilities to either obtain a permit or to close; the permit for this is referred to as interim status. In the *Hazardous and Solid Waste Amendments*, Congress required that new, replaced, or expanded landfills or surface impoundments meet minimum technological requirements, including double liners, a leachate collection system, and groundwater monitoring. Congress also required that new (built after the *Hazardous and Solid Waste Amendments*) landfills, surface impoundments, waste piles, underground tanks, and land treatment units have leak detection systems. These minimum

technological requirements are detailed in EPA regulations applicable to permitted TSD facilities.

In 1984 Congress prohibited the land disposal of untreated hazardous waste and mandated that EPA establish a schedule for establishing treatment standards for various categories of hazardous waste (often referred to as the land ban). Storage of such hazardous waste also was prohibited "unless such storage is solely for the purpose of the accumulation of such quantities of hazardous waste as are necessary to facilitate proper recovery, treatment or disposal" (referred to as the storage prohibition). Congress provided some relief from the land disposal restrictions (LDRs) by allowing persons to demonstrate "to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" (referred to as a no migration petition) (40 CFR 268). Congress defined the term land disposal as "to include, but not be limited to, any placement of such hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (Rosenthal 1997).

In the *Hazardous and Solid Waste Amendments* Congress requires corrective action for releases of hazardous waste and hazardous constituents from any solid waste management unit at a TSD facility subject to a RCRA permit, regardless of when the waste was placed in the unit (Rosenthal 1997). Additionally, corrective action is required for releases that have migrated beyond the boundary of a TSD facility. Finally, if the facility is under interim status, EPA is authorized to issue administrative orders or seek judicial orders that require corrective action to protect human health and the environment.

A.7.0 REFERENCES

10 CFR 60, "Disposal of Radioactive Waste in Geological Repositories," *Code of Federal Regulations*, as amended.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations,* as amended.

10 CFR 1021, "National Environmental Policy Act Implementing Procedures," *Code of Federal Regulations*, as amended.

40 CFR 70, "State Operating Permit Programs," *Code of Federal Regulations*, as amended.

40 CFR 100-149, "Subchapter D – Water Programs," *Code of Federal Regulations*, as amended.

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*, as amended.

40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Code of Federal Regulations*, as amended.

40 CFR 260-280, "Solid Wastes. Subchapter I – Solid Wastes (Hazardous Waste Management Systems)," *Code of Federal Regulations*, as amended.

40 CFR 268, "Land Disposal Restrictions," *Code of Federal Regulations*, as amended.

Atomic Energy Act of 1954, 42 USC 2011 et seq., as amended.

Clean Air Act, Public Law 88-206, 42 USC 7401 et seq., as amended.

Clean Water Act, Public Law 95-217, 91 Stat. 1566 and Public Law 96-148, December 1977.

Comprehensive Environmental Response, Compensation, and Liability Act, Public Law 96-150, 94 Stat. 2767, Title 26, December 1980.

DOE G 435.1, 1997, *Implementation Guide for use with DOE Manual 435.1-1*, U.S. Department of Energy, Washington, D.C.

DOE M 435.1-1, 1997, *Radioactive Waste Management Manual*, U.S. Department of Energy, Washington, D.C.

DOE O 435.1, 1997, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE Order 5400.5, 1993, *Radiation Protection of the Public and Environment*, U.S. Department of Energy, Washington, D.C.

Ecology, 2000, *Dangerous Waste Portion of the RCRA Permit for the Treatment, Storage, and Disposal of Dangerous Waste Hanford Site-Wide Permit*, Rev. 6, Washington State Department of Ecology, Olympia, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Energy Reorganization Act of 1974, 42 USC 5842, as amended.

Federal Facility Compliance Act of 1992, Public Law 102-386, 42 USC 6921 et seq.

Hazard and Solid Waste Amendments of 1984, Public Law 98-616, 42 USC 6991 et seq.

"Hazardous Waste Management Act," RCW 70.105, *Revised Code of Washington*, as amended.

Nuclear Waste Policy Act of 1982, 42 USC 10101 et seq.

Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2795, Title 42.

Safe Drinking Water Act, Public Law 93-523, December 16, 1974, 88 Stat. 1660, Title 21.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

WAC 173-340, "The Model Toxics Control Act Cleanup Regulation," *Washington Administrative Code*, as amended.

WAC 173-401, "Operating Permit Regulation," *Washington Administrative Code*, as amended.

WAC 246-247, "Radiation Protection-Air Emissions, *Washington Administrative Code*, as amended.

"Washington Clean Air Act of 1967," Chapter 70.94, *Revised Code of Washington*, as amended.

"Washington Model Toxics Control Act," Chapter 70.105D, *Revised Code of Washington*, as amended.

"Water Pollution Control Act," Chapter 90.48, *Revised Code of Washington*, as amended.

APPENDIX B

COMPARISON OF CLOSURE DEMONSTRATION ANALYSES TO PRELIMINARY PERFORMANCE ASSESSMENT CRITERIA

Table B.1. Comparison of Closure Demo Analyses to Preliminary Performance Assessment Criteria (3 pages)

Criterion	Discussion
Criterion 6.1 The Performance Assessment presents information on the closure design features that address water infiltration, disposal unit cover integrity, structural stability, and the inadvertent intruder barrier sufficient to support the analysis presented in the Performance Assessment.	Closure design features, such as cover integrity, intruder barriers, etc. are outside the scope of the closure demonstration but will be addressed in a future, formal Tier 1 closure plan for closure of an entire tank farm.
Criterion 6.2 The Performance Assessment identifies procedures and facility related documentation (e.g., Safety Analysis Report, Operational Readiness Review, Waste Acceptance Criteria) that may impact site engineering, facility design, or facility operations. The Performance Assessment also describes the impacts of these procedures and documents based on the results of the analyses.	Safety analysis requirements will be met by adopting current Authorization Basis (AB) requirements for tank farms. Checklists and compliance matrix tables are being developed to support retrieval and closure activities. Waste acceptance criteria will consider double-shell tank compatibility reviews and the negotiation of Data Quality Objectives to support in-tank sampling of residuals and future closure decisions.
Criterion 6.3 The Performance Assessment identifies the point of assessment for each performance measure, and briefly discusses the basis for its selection. The point of assessment is where compliance with the performance measures is evaluated.	Section 4.2 of the Cost-Risk Assessment identifies the point of assessment as the C-Tank Farm boundary. **NOTE: As additional data and maturity is developed within performance assessments, other site-specific (e.g., 200-area) criteria will be adopted into this criterion and subsequent enhancements to Tier 1 closure plans.**
Criterion 6.4 The Performance Assessment describes the projected radionuclide inventory in the residual waste present in the closure facility or site that could significantly contribute to dose for the all pathways analysis, the air pathway analysis, the groundwater analysis, and the intruder analysis. Technical justification is provided for those radionuclides present but not considered in detail in the analyses.	Radionuclide inventory is listed in section 2.3.1 of the Accelerated SST Retrieval and closure plan. A discussion of sourced term inventories is provided in Section 4.1 of the Cost-Risk Analysis. Technical justification for long-term and intruder risk in the AGA, Section 5.0 (Risk Assessment Strategy). Cost-Risk Analysis and the TWRS EIS. Short-term risk radionuclides were selected based on the GENII computer program (PNL-6584)
Criterion 6.5 The Performance Assessment identifies the mathematical models used in the analysis, the basis for their selection, and their linkage.	Sections in the Cost-Risk Analysis were calculations are performed have accompanied explanations for the formulas used. (Sections 4.2.2, 4.2.4, A.6.2, A.8.0, B.3.0, C.2.1.1, C.2.1.2, C.2.2.2, C.2.3.2)
Criterion 6.6 The Performance Assessment provides a general description of the important exposure pathways and scenarios in the evaluation of the potential doses to a hypothetical, individual member of the public and inadvertent intruder, consistent with site-specific environmental conditions and local and regional practices. These exposure pathways and scenarios are justified as conservative representations of the long-term	The exposure pathways are described in Section 4 of the Cost-Risk Analysis. Conservatism is built into each analysis and is discussed in the appendix associated with each risk category. See the note listed in Criterion 6.3.

Table B.1. Comparison of Closure Demo Analyses to Preliminary Performance Assessment Criteria (3 pages)

Criterion	Discussion
performance of each closed facility or site.	
Criterion 6.7 The preliminary calculated results presented in the Performance Assessment adequately bound the available site monitoring data and supporting field investigations as a benchmark of model adequacy.	Section 6.0 of the Cost-Risk Analysis summarizes the results, which are based on available site data.
Criterion 6.8 The Performance Assessment includes a comparison to the performance measures used, and includes any necessary limitations on individual facility design, inventories, or closure operations that are required to meet the performance measures.	The Cost-Risk Analysis discusses, for each area (long-term, intruder and short-term risk), a comparison to the applicable performance limitations.
Criterion 6.9 The conceptual model for the source term, groundwater flow, and radionuclide transport includes parameters for unsaturated and saturated flow, total and effective porosity, hydraulic conductivity, water retention, relative permeability relationships, volumetric water content, retardation, and diffusion that are based on data, related investigations, or documented references relevant to each facility. This may be done collectively within the Performance Composite Analyses if these characteristics can be justified to be similar throughout.	Section 4.2.2 of the Cost-Risk Analysis addresses Criterion 6.9.
Criterion 6.10 The dose analysis considers the exposure pathways and transfer factors and calculates the maximum dose using acceptable methodologies and parameters.	Section 4.2.2 of the Cost-Risk Analysis addresses Criterion 6.10.
Criterion 6.11 The inadvertent intruder analysis considers the natural and man-made processes that impact the possible exposure to an intruder and calculates the dose using acceptable methodologies and parameters.	Section 4.3 of the Cost-Risk Analysis addresses Criterion 6.11.
Criterion 6.12 The results of the analyses for transport of radionuclides and the inadvertent intrusion into the closure facility or site, and the sensitivity and uncertainty of the calculated results are comprehensive representations of the existing knowledge of the site and the closure facility or site design and operations.	Risks relating to sources outside the tanks selected for the closure demonstration (e.g., other tank farms, other sources) will be evaluated in the Tier 1 tank farm closure plan's performance assessment.

Table B.1. Comparison of Closure Demo Analyses to Preliminary Performance Assessment Criteria (3 pages)

Criterion	Discussion
Criterion 6.13 The Performance Assessment presents valid conclusions that demonstrate the all-pathways analysis, air pathway analysis, groundwater resource protection analysis, and inadvertent intruder analysis meet the performance objectives or measures of DOE M 435.1-1.	Section 6.0 of the Cost-Risk Analysis addresses Criterion 6.13.
Criterion 6.14 The Performance Assessment conclusions incorporate the findings of the calculated results for the all pathways analysis, air pathway analysis, groundwater resource protection analysis, inadvertent intruder analysis, and sensitivity and uncertainty analysis. The results are interpreted and integrated to formulate conclusions, which are supported by the results and the uncertainties in the results.	Technical justification for long-term and intruder risk in the AGA, Section 5.0 (Risk Assessment Strategy)
Criterion 6.15 The conclusions of the Performance Assessment are applied to the proposed closure action design. The resulting design constraints and limitations on closure operations can be reasonably accomplished at the closure facility or site.	The AGA and engineering design need to be completed before this criterion is fully addressed.
Criterion 6.16 The Performance Assessment conclusions are within the budget allocated to the closed facility or site for performance relative to each pathway. Rationale is provided to justify the adequacy of individual facilities that do not agree with budgeted performance objectives.	The budget (risk) allocation is calculated for each case; however, since the closure demonstration is not intended to achieve final closure, risk allocation will be determined for final tank/tank farm closure and addressed in the Tier 1 tank farm closure plan's performance assessment. Risk budget will be addressed for the demo tanks in relation to the tank farm.
Criterion 6.17 The results of the Performance Composite Analysis options analysis are reflected, as appropriate, in the Performance Assessment of the individual facility or site(s).	The results of the composite analysis are reflected in the Cost-Risk Analysis (retrieval case) as discussed in the CA.
Criterion 6.18 The analysis, results, and conclusions of the Performance Assessment provide both a reasonable representation of the closure facility's or site's long-term performance and a reasonable expectation that the closure facility or site will remain in compliance with DOE M 435.1-1.	The analyses to support the ATCD plan will provide sufficient assurance that long-term risk will be acceptable for the demonstration tanks. Criterion 6.18 will be addressed in more detail in the tank farm Tier 1 closure plan's performance assessment.

Note: With few exceptions, the Cost-Risk Analysis addresses the requirements for a preliminary performance assessment. The areas of departure are summarized below:

1. Criteria 6.1 (Closure Design Features), and 6.12 (Evaluate Sources from Outside the Tanks), will be addressed during closure of the tank farm in the full Tier 1 closure plan.

2. Criteria 6.2 discusses documents (e.g., SAR, ORR, etc.) that have not been fully developed for the closure demonstration.
3. Criteria 6.15 (Closure Action Design) cannot be evaluated until the AGA and engineering design are completed.

ATTACHMENT 2

COST-RISK ANALYSIS IN SUPPORT OF ACCELERATED TANK CLOSURE DEMONSTRATION PROJECT

Attachment 2

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Attachment 2

COST–RISK ANALYSIS IN SUPPORT OF ACCELERATED TANK CLOSURE DEMONSTRATION

September 10, 2002

Prepared for
CH2M HILL Hanford Group, Inc.
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Attachment 2

EXECUTIVE SUMMARY

This cost-risk analysis has been prepared to support an Alternatives Generation and Analysis for waste retrieval and closure activities associated with tanks planned for closure demonstration activities under the Accelerated Tank Closure Demonstration Project.

This report analyzes the costs and risks associated with retrieving waste from closure demonstration tanks C-106, C-201, C-202, C-203, and C-204. Three different retrieval cases are evaluated, encompassing a range of assumed residual waste end states. The three cases are:

- Current state (no additional waste retrieval)
- Waste retrieval to the goals of the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989)
- Waste retrieval to 10% of the HFFACO.

In addition, the following two cases are analyzed for tank C-106:

- Risks associated with the inventory of contaminants estimated to exist in tank C-106 prior to sluicing under Project W-320
- Liquid removal only.

Risks are analyzed in three categories: 1) long-term human health risk posed by groundwater use, 2) human health risks from inadvertent intrusion (drilling) directly into a tank, and 3) short-term human health risks due to the construction and operation of retrieval systems.

Cost estimates are taken from best available data based on preliminary project planning. Activity-based cost estimates are currently in progress. Until these are completed, the cost estimates will be pre-conceptual in nature.

Costs and risks are compared for the five demonstration tanks to determine the extent of long-term risk mitigation achieved per dollar spent on waste retrieval. In addition, risks are

compared with regulatory standards to determine levels of retrieval required to meet the standards.

The major findings of this report are as follows:

- Of the five demonstration tanks, waste retrieval from tank C-106 is more cost-effective than waste retrieval from the 200-series tanks.
- None of the five demonstration tanks requires waste retrieval to meet the standards for long-term human health risk from groundwater use.
- Contribution to groundwater contamination from the five demonstration tanks is minor compared to the entire C Farm.
- Waste retrieval will be required from tanks C-106 and C-201 to meet standards for the inadvertent intruder.
- Short-term risks are generally not a controlling factor except in the case of the worst-case, low-probability accident. Engineering measures can compensate for this risk.
- Tanks in the C farm are very unequal in their contribution to total risk.
- Waste retrieval to the HFFACO goal from the C tank farm would meet the standard for long-term human health risks from groundwater use.
- In the current state, only about 1% of total C tank farm long-term risk would come from the five closure demonstration tanks; about 99% would come from the 11 remain C 100-series tanks.
- Addition of the estimated past leak risks to the residual waste risks calculated in this analysis would not result in any additional exceedance of risk standards for the C tank farm as a whole.

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Attachment 2

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Attachment 2

LIST OF TERMS

ATCD	Accelerated Tank Closure Demonstration Project
BBI	Best-Basis Inventory
CoC	contaminant of concern
DST	double-shell tank
EDTA	ethylenediaminetetraacetic acid
GP	general public
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
ILCR	incremental lifetime cancer risk
IW	involved worker
LCF	latent cancer fatality
LD	lethal dose
LWC	lost workday case
MEI	maximum exposed individual
MRS	mobile retrieval system
NIW	noninvolved worker
RCRA	*Resource Conservation and Recovery Act*
RPE	retrieval performance evaluation
TWINS	tank waste information network system
TRC	total reportable cases
ULD	unit liter dose
URF	unit risk factor

Attachment 2

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1.0 INTRODUCTION

This cost-risk analysis has been prepared to determine the costs, short-term human health risks, long-term human health risks, and intruder risks associated with retrieving waste from a set of closure demonstration tanks. Retrieval cases encompassing a range of assumed residual waste end states are evaluated. By knowing the costs and risks associated with each retrieval case, decision makers can better determine the appropriate waste retrieval actions for the closure demonstration program.

This cost-risk analysis focuses in detail on five candidate closure demonstration tanks in the C tank farm in the 200 East Area: tanks C-106, C-201, C-202, C-203, and C-204. Tank C-106 is one of twelve 530,000-gal (2,000,000-L) capacity 100-series single-shell tanks located in the C tank farm. Tanks C-201, C-202, C-203, and C-204 are 55,000-gal (210,000-L) 200-series single-shell tanks. To address the issue of risk allocation and assess the performance of these five tanks in the context of the C tank farm as a whole, this analysis also includes an evaluation of the long-term risk performance of the balance of the C tank farm 100-series tanks.

It is estimated that tank C-106 currently contains about 23,000 L (6,000 gal) of sludge and 114,000 L (30,000 gal) of supernatant (BBI 2002). An in-tank video taken in August 2002 shows more sludge visible than was the case in July 2000 when a previous video was taken. Consequently, a current estimate of visible sludge volume would be higher than the 23,000 L (6,000 gal) currently reported. The estimate would be even higher if the portion below the liquid layer, currently not visible, could be estimated. However, these observations have not been quantified and are not factored into the tank inventory estimates in this analysis.

The 200-series tanks contain only sludge. It is estimated that tanks C-201 and C-202 each contain about 4,000 L (1,000 gal) of sludge and that tanks C-203 and C-204 each contain about 11,000 L (3,000 gal) of sludge (BBI 2002).

Costs and risks for all five of the ATCD tanks are examined for three retrieval cases:

- Current state (all waste now in the tanks stays in the tanks)
- Retrieval to the goals of the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989)
- Retrieval to 10% of the goal specified in the HFFACO.

Two additional cases are evaluated for tank C-106:

- Risks associated with the inventory of contaminants estimated to exist in tank C-106 prior to sluicing under Project W-320
- Liquid removal only

Retrieval to HFFACO goals means retrieval to the upper residual waste volume goal allowable under HFFACO Milestone M-45-00, which states, in part:

> "Closure will follow retrieval of as much tank waste as technically possible, with tank waste residues not to exceed 360 cubic feet in each of the 100-series tanks, 30 cubic feet in each of the 200-series tanks, or the limit of waste retrieval technology capability, which ever is less."

Both short-term and long-term human health risks are calculated. Short-term risks are associated with waste retrieval operations and are evaluated for routine (non-accident) radiation exposure as well as radiological and non-radiological accidents. Long-term risks are associated with use of the Hanford Site in the post-closure period and are evaluated for two potential future exposure pathways: contaminated groundwater use and inadvertent human intrusion.

Costs are estimated from the best available data and are based on preliminary project planning. Because the configuration of the retrieval system for the demonstration tanks is currently under development, and an activity-based cost estimate has not been performed to date, the cost estimates provided are rough order-of-magnitude estimates.

Costs and short-term human health risks are evaluated for waste retrieval operations only and do not include tank stabilization, capping, and remediation of soil contaminants and tank ancillary equipment. These activities are omitted because they are assumed to be approximately the same for all scenarios. Long-term human health risks are evaluated as the peak risks projected to occur over a 10,000-year post-closure period, assuming landfill closure with a modified *Resource Conservation and Recovery Act of 1976* (RCRA) Subtitle C closure barrier.

2.0 CONCLUSIONS SUMMARY

This section presents an overview of conclusions based on the preliminary cost and risk assessments in this report.

Long-term risk analysis indicates that, without retrieval of waste from at least some of the tanks, the C tank farm will exceed the State risk standard of 1.0×10^{-5} incremental lifetime cancer risk (ILCR) by a wide margin (over 40 times the standard). Retrieving waste from all the C farm tanks to the HFFACO goals will just meet the standard.

The tanks are very unequal in their contribution to the total risk. Of the five tanks currently selected for closure demonstration, tank C-106 is the dominant tank in terms of risk contribution. In fact, the C-200 tanks are small contributors; and therefore resources would be better spent retrieving waste from tank C-106 to higher levels of cleanliness. For example, retrieving tank C-106 waste from the HFFACO residual waste volume goal of 360 ft^3 (10,200L) to 10% of the HFFACO residual waste volume goal (36 ft^3 [1,020L]) gains seven times the benefit of retrieving waste from all four C-200 tanks to the HFFACO goal.

Tank C-106 cannot meet the post-drilling resident inadvertent human intruder performance objective unless its waste is retrieved to below the HFFACO residual waste volume goal of 360 ft^3 (10,200L). Tank C-201 will only meet the post-drilling resident performance objectives if additional waste retrieval is performed.

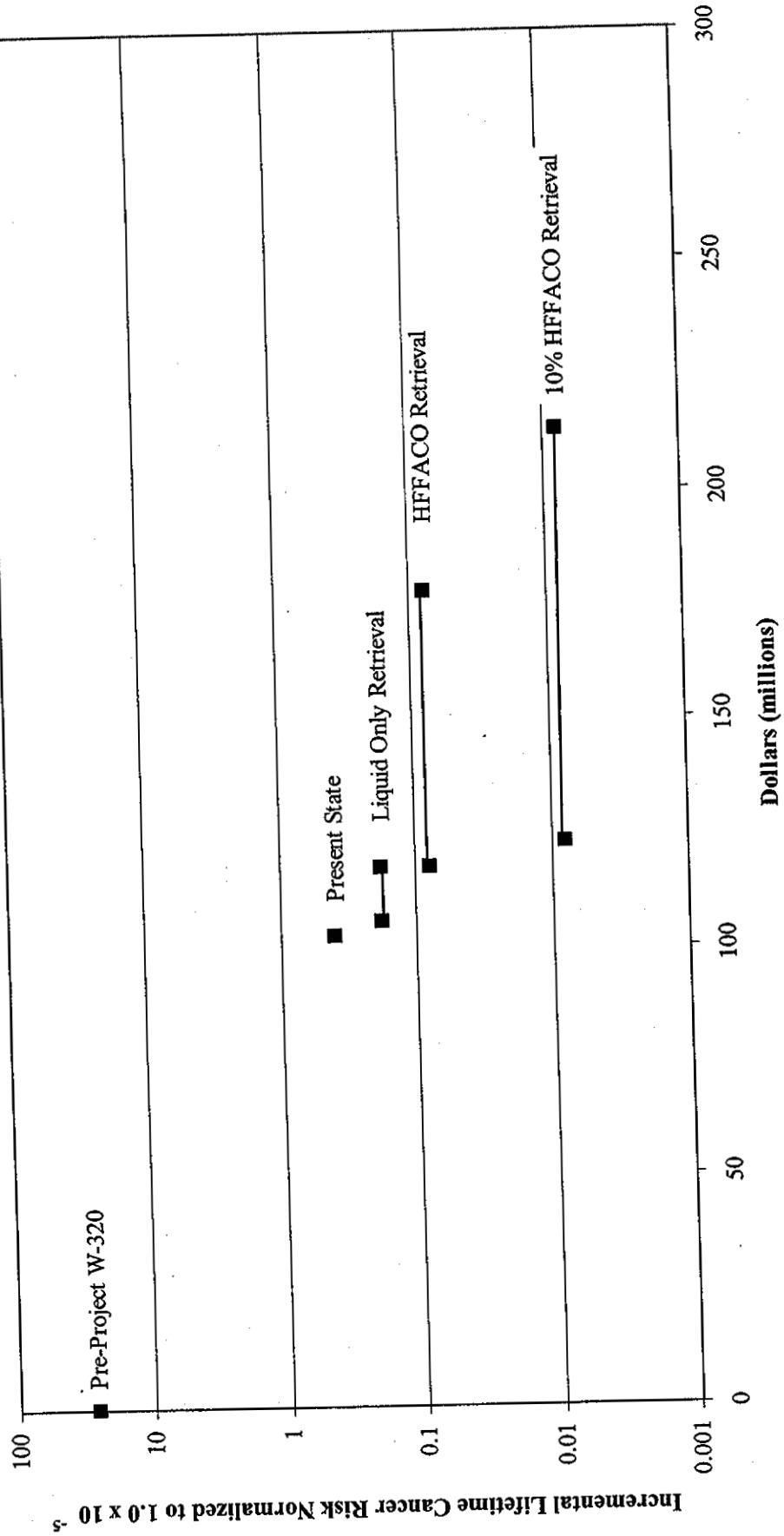
Short-term risk analysis demonstrates that radiological accidents resulting in a release of tank inventory to the atmosphere need to be prevented or mitigated to keep exposures at an acceptable level. Exposure to radiological constituents from routine releases can be managed at well below acceptable levels using current engineering designs for tank ventilation during retrieval operations.

Cost estimates, although approximate and not based on detailed engineering cost estimating, suggest that it could cost \$20 to \$75 million to retrieve waste from tank C-106 to the HFFACO goal of 360 ft^3 (10,200L), and \$30 to \$110 million to retrieve to 36 ft^3 (1,020L), which is 10% of the HFFACO goal. Retrieving liquids only from tank C-106 could cost \$4 million to \$15 million. Retrieval of waste from all C-200 tanks could cost \$50 million to \$80 million to achieve the HFFACO goal of 30 ft^3 (850L) and \$75 million to \$120 million to retrieve to 3 ft^3 (85 L), which is 10% of the HFFACO goal.

Figures 2.1 and 2.2 show the risks (long-term and intruder) and the range of costs (represented by horizontal lines) associated with each of the cases analyzed for tank C-106. The long-term risks are based on a residential farmer scenario (the bounding case) and are normalized to 1.0×10^{-5} ILCR. The intruder risks are based on a post-drilling resident scenario (the bounding case) and are normalized to a chronic dose of 100 mrem/yr.

There are substantial uncertainties associated with long-term risk calculations presented in this analysis. These uncertainties, which are discussed in more detail later in the report, result from incomplete knowledge of contaminant inventories, site characteristics, and exposure parameters.

Figure 2.1. Tank C-106 Long-Term Risk Versus Cost



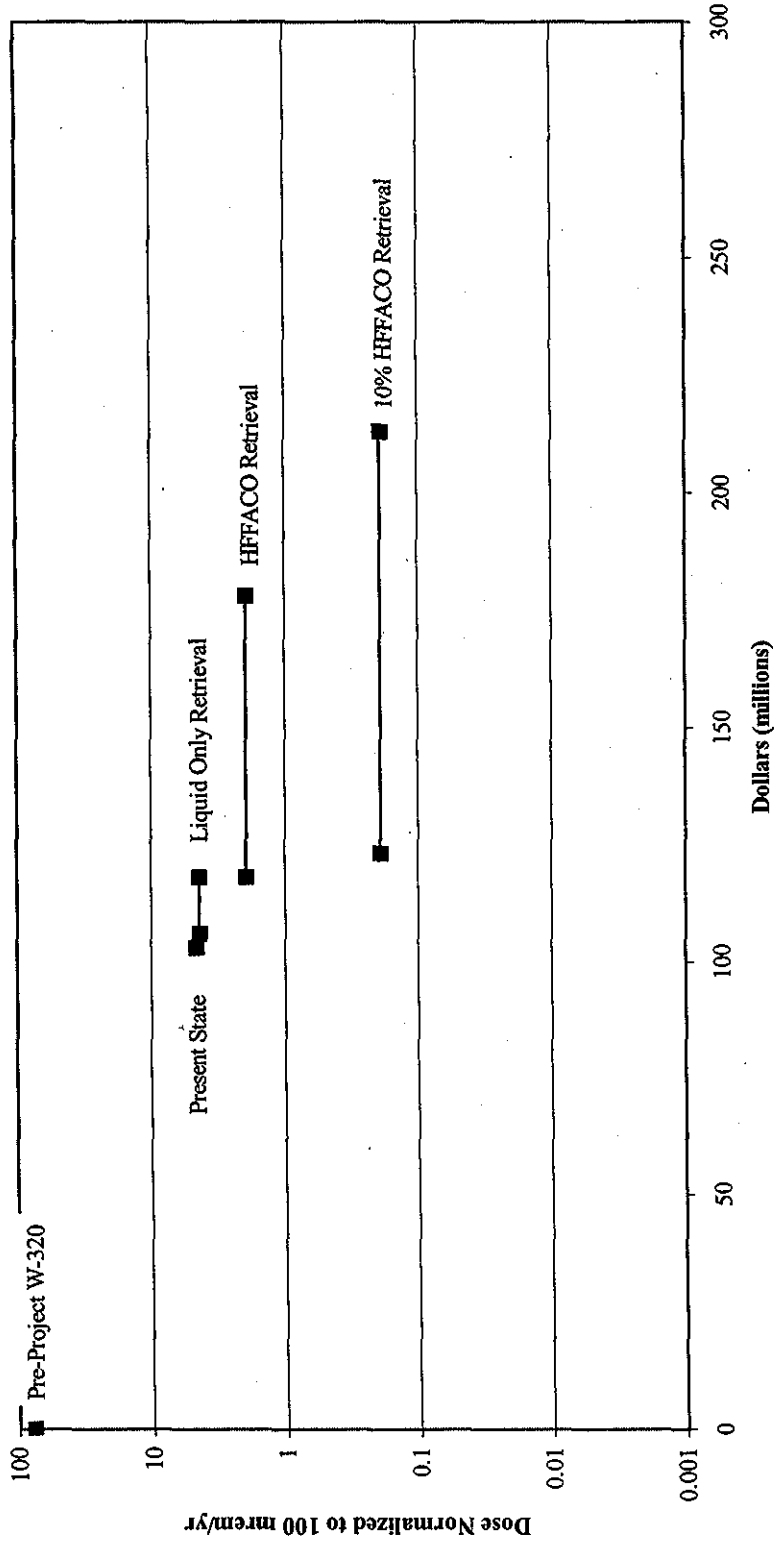


Figure 2.2. Tank C-106 Intruder Risk (Chronic Dose) Versus Cost

Attachment 2

3.0 DESCRIPTION OF WASTE RETRIEVAL CASES

Three waste retrieval cases are considered for all five of the closure demonstration tanks and two additional cases are considered for tank C-106. Descriptions of the cases are provided below.

3.1 CURRENT STATE

This case assumes that all waste currently in the closure demonstration tanks remains in these tanks.

3.2 RETRIEVAL TO THE GOALS OF THE HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER (HFFACO RETRIEVAL)

In this analysis, "HFFACO Retrieval" means retrieval to residual waste volumes of 360 ft^3 (10,200 L [2,700 gal]) in each of the 100-series tanks and 30 ft^3 (850 L [220 gal]) in each of the 200-series tanks.

3.3 RETRIEVAL TO 10% OF THE GOALS SPECIFIED IN THE HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER (10% HFFACO RETRIEVAL)

This case assumes retrieval to residual waste volumes of 36 ft^3 (1,020 L [270 gal]) in each of the 100-series tanks and 3 ft^3 (85 L [22 gal]) in each of the 200-series tanks.

3.4 ADDITIONAL CASES FOR TANK C-106

Waste was retrieved from tank C-106 during 1998-1999 by past-practice sluicing, under Project W-320. This retrieval effort was for the purpose of resolving the high-heat safety issue for that tank, not for closing the tank. However, retrieval continued beyond the level required simply to resolve the high-heat safety issue and was ended only when it became apparent that little to no additional sludge could be removed using the installed equipment. Thus, the cost and risk reduction benefit associated with retrieval of waste under Project W-320 provides relevant and valuable data in a cost-risk analysis for retrieval. This benefit is addressed in this report by estimating the risk that would result for a no retrieval case from tank C-106, i.e., prior to Project W-320. The risk reduction benefit due to the initial stage of waste retrieval is then the difference between the risk consequence for no retrieval and the risk estimated under the tank's current state.

One additional case evaluated for tank C-106 is removal of only the estimated 114,000 L (30,000 gal) of remaining liquid. This case is of interest because it is possible that most of the inventory of soluble contaminants of concern, and therefore most of the potential contribution to risk through the groundwater pathway, would be contained in the liquid phase.

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4.0 METHODOLOGY

This section describes the methods applied to evaluate risks and costs for each of the retrieval cases evaluated. It also summarizes how source term inventories were estimated; describes the methods employed in a long-term human health risk analysis; describes the methods employed in an analysis of intruder risks; describes methods employed in analysis of short-term health risk impacts if additional waste is retrieved from the tanks; and describes methods used to estimate costs for each of the waste retrieval cases.

4.1 SOURCE TERM INVENTORIES

This section provides the methodology used to develop the source terms contributing to the impacts analysis for the five closure demonstration tanks and the remaining C farm tanks. Identification and quantification of source terms are necessary to evaluate 1) short-term impacts to on-site workers and general public health, 2) long-term impacts to human health and the environment resulting from releases before, during, and after tank waste retrieval, and 3) impacts from inadvertent human intrusion into the residual tank waste. Inventory estimates are developed for each of four source term components:

- Current waste in tanks
- Residual waste in tanks after removal to the HFFACO goals
- Residual waste in tanks after removal to 10% of the HFFACO goals
- Past tank leaks.

In addition, source terms were developed for the two special cases for tank C-106. Source terms are not developed for retrieval leakage because it is assumed that dry or low-liquid retrieval methods will be used, consistent with current project planning assumptions.

A summary of the methods used to develop each of the source terms is provided in the following subsections.

4.1.1 Current Waste Inventory Estimates

Current waste inventories are taken from the best-basis inventory (BBI) for each tank (BBI 2002). The BBI uses tank waste samples, engineering evaluation, calculation, or tank composition models, depending on the best available information. The BBI methodology and its strengths and weaknesses have been described in detail in several earlier documents (e.g., *Data to Support Tank C-106 Waste Retrieval Determination* [RPP-6696]). While there are a number of reasons to believe that the BBI is only a general approximation of the content of each tank, it is the best currently available information.

Current BBI values are used in the long-term human health risk and intruder risk analyses to represent the assumed residual waste source term in each tank under the current state case. The current state contaminant of concern (CoC) inventories used for the long-term human health risk and intruder risk analyses are provided in the calculation details in Appendices A and B, respectively. Current BBI values are also used as the basis for source term development for the

short-term human health risk analysis for each tank. The CoC inventory concentrations used for the short-term human health risk analysis are provided in the calculation details in Appendix C.

4.1.2 Residual Waste Inventory Estimates

For this cost-risk analysis, the residual waste source term is evaluated as the primary driver for long-term human health risk and inadvertent intruder risk. This section summarizes the methodology used for estimating the residual waste inventories for these two analyses. These estimates are assumed to represent the residual waste remaining in the tanks after all waste retrieval and closure actions are completed. Calculation details for the long-term human health risk and intruder risk analyses, including residual waste source term inventory estimates for all the evaluation cases, are provided in Appendix A and B, respectively.

As discussed above, the residual waste inventory for each tank under the current state case is assumed to be equal to the current total waste inventory reported in the BBI (BBI 2002). For the HFFACO retrieval case, residual waste inventories for tank C-106 and the remaining C 100-series tanks are calculated based on an assumed residual waste volume equal to the HFFACO goal of 360 ft^3 (10,200 L [2,700 gal]); for the C 200-series tanks, residual waste inventories are calculated based on an assumed residual waste volume equal to the HFFACO goal of 30 ft^3 (850 L [220 gal]). For the 10% HFFACO retrieval case, residual waste inventories are calculated based on assumed residual waste volumes of 36 ft^3 (1,020 L [270 gal]) and 3 ft^3 (85 L [22 gal]) for the 100- and 200-series tanks, respectively.

For tanks C-106 and C-103, the BBI gives separate inventory estimates for supernatant and sludge waste fractions. For the C 200-series tanks and the remaining C 100-series tanks, the BBI gives only sludge inventory estimates, as there is no supernatant fraction in these tanks. For this analysis it is assumed that the post-retrieval residual waste remaining in all tanks has the composition of the current BBI sludge fraction. This assumption is consistent with current project planning assumptions for the use of a dry or low liquid volume technology. It is assumed that with this type of retrieval technology all significant quantities of supernatant present in a tank will be removed during the initial waste retrieval stages, prior to commencing with the removal of significant quantities of sludge.

Inventory estimates following retrieval are calculated by multiplying the current BBI sludge inventories by the ratio of the assumed residual waste volume to the current BBI sludge volume for each tank. For example, for tank C-106, the current BBI sludge volume is 6,000 gal (23,000 L [800 ft^3]). To obtain the HFFACO retrieval case inventories, the current tank C-106 BBI sludge inventories are multiplied by the ratio 360/800 (0.45). To obtain the 10% HFFACO retrieval case inventory, the current tank C-106 BBI sludge inventories are multiplied by 0.045. A similar procedure is followed for the remaining C 100-series tanks.

For the 200-series tanks the methodology used is analogous to the method used for the 100-series tanks. In the case of tanks C-201 and C-202, which contain 1,000 gal (3,800 L [133 ft^3]) of sludge each, the volume ratio for the HFFACO retrieval case is 30/133 (0.23) and for the 10% HFFACO retrieval case is 0.023. For tanks C-203 and C-204, which contain 3,000 gal (11,000 L [400 ft^3]) of sludge each, the volume ratio is 30/400 (0.075) for the HFFACO retrieval case and 0.0075 for the 10% HFFACO retrieval case.

The post-closure residual waste CoC inventory values for the tank C-106 pre-Project W-320 case are assumed to equal the values reported in *Tank Characterization Report for Single-Shell Tank 241-C-106* (WHC-SD-WM-ER-615), released September 30, 1998, which was the most recent revision of the tank C-106 BBI issued prior to the Project W-320 sluicing retrieval. The tank C-106 post-closure residual waste CoC inventory values for the liquid-only retrieval case are assumed to equal the BBI values (BBI 2002) reported for the 23,000 L (6,000 gal) of tank solids.

When calculating the residual waste inventories, it is assumed that a dry or very low liquid technology, such as the mobile retrieval system (MRS), would be employed. In such a case, there would be relatively little, if any, retrieval fluid used, so the assumption has been made that it is unnecessary to adjust the remaining inventory to account for the relative solubilities of the sludge components.

4.1.3 Waste Retrieval Leakage Loss Inventory Estimates

The four C-200 tanks as well as three of the C 100-series tanks are classified as assumed leakers (*Waste Tank Summary Report for Month Ending January 31, 2002,* HNF-EP-0182). During fluid-based waste retrieval it is possible that some additional waste could leak from these tanks, or even from the tanks (such as tank C-106) currently classified as sound. However, the MRS is designed as a low-liquid retrieval method, and for purposes of this analysis it is assumed that there is no leakage loss from any tank during retrieval. This assumption is conservative in the sense that it tends to underestimate the risk from tank retrieval and therefore creates a bias in favor of retrieval.

4.1.4 Past Leak Inventory Estimates

The long-term risk evaluation places primary emphasis on the residual waste source term. However, in evaluating long-term risk at the tank farm level to address the issue of risk allocation, the risk contribution from the past leak source term is also considered. The risk budget available for the residual waste source term must account for the portion of the risk threshold (e.g., 1.0×10^{-5}) made unavailable because of the past leak source term. Estimates of C tank farm past leak inventories and associated long-term risks are provided in a previous document, *Retrieval Performance Evaluation for Single-Shell Tank C-104* (HNF-7643). For this cost-risk analysis, the past leak risks reported in HNF-7643 are incorporated without modification or additional analysis.

Current records indicate that seven tanks in the C tank farm (C-101, C-110, C-111, and the four C 200-series tanks) are classified as assumed leakers (HNF-EP-0182). The HNF-7643 analysis used best estimate inventories taken from recent work conducted to develop inventory estimates for past leaks in support of the Systems Assessment Capability (*Hanford Soil Inventory and Uncertainty Model*, LA-UR-00-4050). The methodology was based on available process information regarding the type of waste that was stored in the tank or that was transferred at the time the leaks were believed to have occurred. The tank waste releases were estimated based on location, timing, and leak volume information. The leak compositions were defined using Hanford defined waste model waste streams (*Hanford Defined Wastes: Chemical and Radionuclide Compositions,* LA-UR-96-3860) and the supernatant mixing model subroutine as a

function of time (LA-UR-00-4050). Details of the past leak inventory calculations are provided in HNF-7643.

4.2 LONG-TERM HUMAN HEALTH RISK

The intent of the long-term human health risk analysis is to estimate the potential health effects to a hypothetical future site user from exposure to tank waste contaminants remaining onsite following the completion of waste retrieval and tank farm closure actions. The analysis identifies peak groundwater pathway risks at the C tank farm boundary under residential farmer and industrial worker exposure scenarios over a 10,000-year assessment period. A summary of the methodology for this assessment is provided in this section; a detailed discussion is provided in Appendix A.

The approach for this risk assessment is consistent with the overall approach established in *Retrieval Performance Evaluation Methodology for the AX Tank Farm* (DOE/RL-98-72). The risks presented are incremental risks for contamination sources inside the C tank farm. The analysis focuses on the five candidate closure demonstration tanks. To address the issue of risk allocation and assess the risk performance of these five tanks in the context of the C tank farm as whole, this analysis also includes an evaluation of long-term risk for the balance of the C farm tanks.

Groundwater is considered the principal pathway (excluding inadvertent intrusion) for post-remediation human exposure to tank waste at compliance points at and beyond the tank farm boundary. The exposure pathways used in this assessment are therefore based on withdrawal and use of groundwater via wells. Only the human health effects from the use of the groundwater are considered; the well drilling activity itself is an assumed but not explicitly evaluated component of the exposure scenarios.

The groundwater concentrations used in this analysis are estimated by extrapolating from the results of the fate and transport analysis performed at the nearby AX tank farm for DOE/RL-98-72. Those results are scaled, based on the inventory differences between the AX and C tank farm source terms, to estimate the groundwater concentration CoCs at the C tank farm boundary. The scaling approach is based on the proximity of the C tank farm to the AX tank farm and on similarities in their vadose zone properties, conceptual site model, and source term release mechanisms. This approach has been applied in two previous C tank farm analyses, starting with a tank C-106 post-retrieval residual waste assessment (RPP-6696), and continuing with a tank C-104 retrieval performance evaluation (HNF-7643). The uncertainties introduced by the use of a scaling approach are discussed in Appendix A.

4.2.1 Source Term

This assessment considers the residual waste source term to be the primary driver for long-term human health risks. This approach is consistent with current project planning assumptions on the use of a generally dry retrieval technology, such as the MRS. With the MRS, no to very little additional fluids would be added to a tank during waste retrieval. For this reason, a retrieval leak source term is not evaluated. A past leak source term is not explicitly evaluated; however, in

evaluating risk at the tank farm level to address risk allocation, the past leak source term is considered by incorporation from the C tank farm past leak analysis in HNF-7643.

The CoCs for this evaluation are consistent with those used in HNF-7643. Those CoCs are as follows:

- **Radionuclides**: carbon-14, selenium-79, technetium-99, iodine-129, and uranium isotopes -233, -234, -235, -236, and -238
- **Chemicals**: nitrite, nitrate, chromium, and total uranium.

This CoC subset was selected for inclusion in HNF-7643 based on a screening analysis in DOE/RL-98-72 that indicated these constituents would be highly mobile in the vadose zone and groundwater and would contribute approximately 95% of the total groundwater pathway long-term human health risk. Case-specific residual waste source term inventory estimates are developed for each CoC in each tank as discussed in Section 4.1. The long-term risk CoC inventories are provided in Appendix A (Tables A.6 and A.7).

4.2.2 Transport

Groundwater is the transport pathway of interest for this evaluation, which is consistent with the approach used in numerous previous analyses (e.g., DOE/RL-98-72, DOE/EIS-0189, HNF-7643, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* [PNNL-11800], *Groundwater/Vadose Zone Integration Project System Assessment Capability* [BHI-01365], *Field Investigation Report for Waste Management Area S-SX* [RPP-7884], *Single-Shell Tank C-104 Full Scale Sludge/Hard Heel, Confined Sluicing and Robotic Technologies, Waste Retrieval Demonstration Functions and Requirements* [RPP-7807], *Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements* [RPP-7825], *241-S-102 Initial Waste Retrieval Project Functions and Requirements* [RPP-10901]). Because the groundwater pathway is currently not used at the Hanford Site (i.e., not used as a drinking water source), exposure to contaminants in groundwater would occur to a future site user only after an assumed loss of institutional controls.

Long-term human health risks are calculated based on maximum groundwater CoC concentrations scaled from the results of the vadose zone and groundwater contaminant transport analysis completed for DOE/RL-98-72. The scaling factors used are constituent-specific factors calculated from the input and output data from the DOE/RL-98-72 analysis. These factors are expressed as the peak groundwater CoC concentration at the receptor per unit inventory released at the source (Ci/mL per Ci for radionuclides, g/mL per g for chemicals) and are calculated using the following expression.

$$K^{i}_{S(x,y,t)} = \frac{C^{i}_{S(x,y,t)}}{I^{i}_{S(AX)}} \qquad (1)$$

Where:

$K^{i}_{S(x,y,t)}$ = scaling factor for contaminant i released from source term S at calculation point x,y,t

$C^{i}_{S(x,y,t)}$	=	groundwater concentration of contaminant *i* from source term *S* (DOE/RL-98-72 model output) at calculation point *x,y,t*
$I^{i}_{S(AX)}$	=	initial source inventory of contaminant i released from source term *S* (DOE/RL-98-72 model input)
x,y	=	horizontal location coordinates
t	=	time.

The DOE/RL-98-72 groundwater concentrations used to derive the scaling factors are taken at the AX tank farm boundary at the time of peak human health risk over the 10,000-year analysis period. Risks calculated with these scaling factors are therefore assumed to provide peak risks at the C tank farm boundary. The scaling factors used for the analysis are provided in Appendix A (Table A.1). Receptor groundwater concentrations are calculated as the product of the contaminant-specific scaling factors and the C tank farm source inventories.

4.2.3 Exposure

The exposure scenarios used for this evaluation are taken from the *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (DOE/EIS-0189) analysis and include the residential farmer and industrial worker scenarios. Both scenarios were adapted for use in DOE/EIS-0189 from scenarios described in *Hanford Site Risk Assessment Methodology* (DOE/RL-91-45). Both scenarios involve multi-pathway groundwater exposures based on hypothetical future land uses and activities.

It is important to note that both scenarios require an assumption that groundwater wells are drilled at the downgradient C tank farm boundary and used as a water supply for the receptors.

4.2.3.1 Residential Farmer Scenario. The residential farmer scenario represents exposures associated with the use of the land for residential and agricultural purposes. This scenario is a slight modification to the residential scenario described in DOE/RL-91-45; it includes all of the exposure pathways for the residential scenario plus most of the food ingestion pathways described in the DOE/RL-91-45 agriculture scenario.

4.2.3.2 Industrial Worker Scenario. The industrial worker scenario represents exposures to workers in a commercial or industrial setting. The receptors are adult employees assumed to work at a location for 20 years. The scenario is intended to represent nonremediation workers who do not wear job-specific personal protective equipment.

4.2.4 Risk

Long-term human health risk is calculated for this evaluation using a unit risk factor (URF) approach consistent with the approach used for the DOE/EIS-0189 and DOE/RL-98-72 analyses. A URF is the risk associated with exposure to one concentration unit (e.g., risk per Ci/mL for radionuclides in groundwater) of a given contaminant in a given exposure medium for a given human exposure scenario. Risk is calculated in the URF approach as the product of the URF and the contaminant concentration at the receptor for the exposure medium of interest.

The URF values used for this analysis are contaminant- and scenario-specific groundwater URFs taken from Appendix D of DOE/EIS-0189. The URFs for the industrial worker and residential

farmer scenarios are given in Appendix A (Table A.2). The basic expression for risk using a URF approach is:

$$R_{S(x,y,t)} = \sum C^{i}_{S(x,y,t)} \cdot URF^{i}_{R} \qquad (2)$$

Where:

$R_{S(x,y,t)}$	=	risk from source term S at point of compliance x,y,t
$C^{i}_{S(x,y,t)}$	=	groundwater concentration at point of compliance x,y,t for contaminant i released from source term S
URF^{i}_{R}	=	groundwater URF for contaminant i and receptor scenario R
x,y	=	horizontal location coordinates
t	=	time.

The summation in Equation 2 represents the addition of the contributions from all CoCs in a given source term. The addition of contributions from each source term gives the total or composite risk for a given tank. Only the residual waste source term is calculated for this analysis, although the past leak contribution is considered by incorporation from a previous analysis. The addition of total risks from all tanks gives the total risk for the tank farm.

The human health impact measures given by the URFs are ILCR for radionuclides and carcinogenic chemicals, and hazard index (sum of individual hazard quotients) for non-carcinogenic chemicals. An ILCR is an estimate of the increased probability of an individual developing cancer over an assumed 70-year lifetime from exposure to radionuclide and carcinogenic chemicals. Washington State generally sets the upper limit of the ILCR at 1.0×10^{-5} ("The Model Toxics Control Act Cleanup Regulation," WAC 173-340). The Federal Standard for ILCR is 1.0×10^{-4} ("National Oil and Hazardous Substances Pollution Contingency Plan," 55 FR 8666, "National Oil and Hazardous Substances Pollution Contingency Plan," 40 CFR 300). The ILCRs differ from the latent cancer fatalities (LCFs) calculated in the short-term risk analysis in that ILCRs are total cancers (nonfatal and fatal) where LCFs are fatal cancers. A hazard quotient is the ratio of chemical intake to a reference dose below which no adverse health effects would be expected. For a hazard quotient greater than 1.0, adverse health effects would be expected. For a hazard quotient less than 1.0, no adverse health effects would be expected.

Calculation detail for long-term human health risk is provided in Appendix A (Tables A.6 and A.7).

4.2.5 Uncertainty in Long-Term Risk Analysis

Long-term risk calculations are presented in this report as a deterministic estimate of long-term risk. However, there is known uncertainty associated with contaminant inventories and source terms, vadose zone properties, saturated zone properties, contaminant mobility, and exposure parameters. Prior analysis of long-term risk uncertainty in DOE/RL-98-72 indicated that the uncertainty range in the early time periods is approximately three and one-half orders of

magnitude and increases to approximately seven orders of magnitude at later time periods. A subset of parameters was identified with uncertainties that had the greatest influence on long-term human health risk. These parameters were related to source term inventories and receptor exposure. The analysis in this report was scaled from the analysis provided in DOE/RL-98-72; hence it carries with it the uncertainties documented in that report as well as those associated with using a scaling approach to calculate contaminant concentrations in groundwater.

4.3 INADVERTENT HUMAN INTRUDER

The intent of the inadvertent human intrusion analysis is to estimate the potential health effects to a hypothetical future site user from direct intrusion into tank waste contaminants remaining onsite following waste retrieval and tank farm closure actions. The methodology used for assessing intruder impacts is consistent with the approach used in DOE/RL-98-72. Because an inadvertent intruder can only penetrate one tank at a time, the intruder analysis separately addresses each of the tanks (C-106, C-201, C-202, C-203 and C-204). Intruder impacts are examined based on scenarios and goals established in DOE regulations (*Radioactive Waste Management* [DOE O 435.1]; *Issuance of Low-Level Waste Performance Assessment Guidance* [Frei 1996]). A summary of the intruder analysis is presented in this section; additional detail is provided in Appendix B.

The scenarios used in this analysis are consistent with those used in DOE/RL-98-72 and are based on the intrusion model in *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Burial Grounds* (WHC-EP-0645). The scenarios used are the well driller scenario (which results in an acute dose) and the post-drilling resident scenario (which results in a chronic dose). These scenarios were selected based on their applicability to the deep contamination sources (i.e., tank residual waste) involved in this analysis.

Contaminant transport is not considered for this analysis. Contaminants are assumed to be exhumed during well drilling and spread over the surface of certain land areas. The intruders receive radiation exposures because of their proximity to and use of these contaminated surface areas.

The source term is calculated as the total activity in curies of each constituent exhumed and made available at the surface. The well is assumed to be drilled through the residual waste in the tanks and into the underlying soil column down to the aquifer. The source term is calculated based on the residual waste in each tank. The source term (Ci_{exh}) from each tank is calculated using the following equation:

$$Ci_{exh} = Ci_{tnk} \cdot \left[r_{well} \div r_{tnk}\right]^2 \qquad (3)$$

Where:

Ci_{tnk} = total activity of each radionuclide of concern
r_{well} = radius of the well or 0.15 m (0.5 ft)
r_{tnk} = radius of 100-series tanks, 11.4 m (37.5 ft), radius of 200-series tanks, 3.05 m (10 ft).

The source term activity (Ci_{exh}) is then multiplied by a unit dose factor for each receptor (well driller and post-drilling resident) to produce the receptor dose. Unit dose factors are calculated for a unit activity (Ci) for each constituent based on the exposure conditions defined for each receptor. Unit dose factors for each radionuclide of concern in the exhumed waste for the well driller and post-drilling resident scenarios are given in Appendix B (Table B.1). The dose calculations are performed at 100 years from tank closure, corresponding to the time of assumed loss of institutional control. The well driller dose is derived from 40 hours of external exposure to the exhumed contaminants. The post-drilling resident dose is based on the following assumptions:

- Lives on a 2,500-m^2 (27,000-ft^2) parcel of land over which the exhumed waste has been spread
- Grows a variety of vegetables on the land
- Obtains 25% of total vegetables consumed from this garden.

Calculation detail for the intruder analysis is provided in Appendix B (Tables B.3 through B.19)

4.4 SHORT-TERM HUMAN HEALTH RISK

The intent of the short-term human health risk analysis is to estimate the potential health impacts from both accident and normal (non-accident) conditions resulting from various tank waste retrieval scenarios for tanks C-106, C-201, C-202, C203, and C-204. The analysis identifies the spectrum of potential accidents associated with construction and operation activities.
The hazards associated with these activities include potential occupational hazards resulting in physical trauma and radiological exposure resulting in LCFs. Initiating events that could result in hazardous health effects may include natural phenomena, human error, component failure, and spontaneous reactions. Health risks during normal conditions include anticipated exposure to radiation fields and radiological releases to the atmosphere during normal retrieval activities. The methodology used for these analyses is summarized in this section and discussed in detail in Appendix C.

4.4.1 Occupational Injuries, Illnesses, and Fatalities

The number of injuries, illnesses, and fatalities resulting from retrieval and closure activities are calculated based on the most currently available incidence rates that would be applicable to the retrieval activities (*Injury/Illness Rates at Hanford* [Millet 2000]). The number of injuries, illnesses, and fatalities from construction or operations is calculated by multiplying the total person-years required to support the activity by the incidence rates.

4.4.2 Radiological Risk From Accidents

The radiological risk is expressed as the number of LCFs resulting from accidents in which people are exposed to radiation fields or radiological constituents released to the atmosphere. The probability of the accident occurring also is evaluated. The methodology used to identify and quantify the radiological risk from accidents is performed using an eight-step process. Each of the eight steps is discussed in detail in Appendix C.

4.4.3 Radiological Latent Cancer Fatalities Risk from Routine Exposure

The involved worker exposure is a combination of exposure from inhalation and direct radiation. Involved worker dose rates are estimated based on time, distance, and shielding considerations associated with the various tasks. Noninvolved workers and general public exposure are estimated by determining the expected routine radiological releases during retrieval and closure. Exposure to the noninvolved worker is assumed to be from inhalation and external radiation from the plume continuously throughout the year and from deposition of radionuclides on the ground. The exposure pathways for the general public are assumed to be inhalation, external exposure from submersion in a plume, and ingestion of contaminated farm products. The GENII computer code (*GENII – The Hanford Environmental Radiation Dosimetry Software System*, PNL-6584) is used to calculate the dose based on X/Qs generated by the GXQ computer code. The LCF risk is then calculated using the calculation methods detailed in Appendix C.

4.5 COSTS

Cost estimates are based on the best available preliminary engineering cost estimates for the retrieval evaluation cases and include all design, construction, and operations related to tank waste retrieval, using an MRS. Cost details are contained in Appendix D.

The configuration of the retrieval system for these tanks is currently under development. An activity-based cost estimate has not been performed to date. Due to uncertainties, cost estimates for retrieval are presented as ranges that are based on rough order-of-magnitude estimates.

Costs for subsequent tank fill, disposition of ancillary equipment, placement of surface barriers, licensing, and performance monitoring are not included because these costs are assumed to be approximately the same for all retrieval cases. Several other key activities have been omitted because of lack of cost estimates and uncertainty regarding the extent to which they may be required: transfer systems and receiving tank modifications, equipment removal from risers, and equipment disposal.

Subsequent waste treatment, storage, transportation and disposal will add cost to the retrieval cases. These costs are not considered, since the costs would be the incremental costs of adding a very small fraction to the waste already being treated, stored, transported, and disposed.

5.0 ANALYSIS

This section contains the results of the analysis performed using the evaluation methods described in Section 4.0.

5.1 LONG-TERM HUMAN HEALTH RISK RESULTS

Tables 5.1 and 5.2 summarize the analysis results for the residential farmer and industrial worker exposure scenarios, respectively, for the three evaluation cases that involve all five ATCD tanks. Both tables show the estimated peak ILCR and hazard index for the five candidate closure demonstration tanks, both individually and in combination, under each of the three evaluation cases considered. The tables also summarize the analysis results for the balance of the C farm tanks and the C tank farm as a whole. Table 5.3 summarizes the analysis results for the two additional evaluation cases for tank C-106. The calculation detail provided in Appendix A (Tables A.6 and A.7) indicates that, for the five candidate closure demonstration tanks and the C tank farm as a whole, the ILCR would be driven primarily by technetium-99 and selenium-79 and the hazard index would be driven by nitrate, nitrite, and chromium. The State and Federal performance standards for ILCR are 1.0×10^{-5} and 1.0×10^{-4}, respectively. The performance standard for the hazard index (both State and Federal) is 1.0.

Table 5.1. Summary of Peak Residential Farmer Long-Term Human Health Risks at C Tank Farm Fenceline From Residual Waste Source Term (2 Sheets)

Tank or Tank Combination	Impact Measure	Current State	HFFACO Retrieval	10% HFFACO Retrieval
C-106	ILCR	3.90E-06	8.36E-07	8.69E-08
	HI	5.12E-02	3.28E-03	3.24E-04
C-201	ILCR	2.20E-08	4.65E-09	4.67E-10
	HI	1.12E-02	2.32E-03	2.31E-04
C-202	ILCR	2.30E-08	4.85E-09	4.87E-10
	HI	3.52E-02	7.29E-03	7.28E-04
C-203	ILCR	4.28E-08	3.72E-09	3.74E-10
	HI	4.52E-02	3.71E-03	3.70E-04
C-204	ILCR	2.75E-08	2.39E-09	2.40E-10
	HI	2.91E-02	2.39E-03	2.39E-04
C-200 Tanks Total	ILCR	1.15E-07	1.56E-08	1.57E-09
	HI	1.21E-01	1.57E-02	1.57E-03
C-106 Plus C-200 Tanks	ILCR	4.01E-06	8.52E-07	8.84E-08
	HI	1.72E-01	1.90E-02	1.89E-03

Attachment 2

Table 5.1. Summary of Peak Residential Farmer Long-Term Human Health Risks at C Tank Farm Fenceline From Residual Waste Source Term (2 Sheets)

Tank or Tank Combination	Impact Measure	Current State	HFFACO Retrieval	10% HFFACO Retrieval
Balance of C-100 Tanks	ILCR	4.23E-04	1.06E-05	1.11E-06
	HI	1.79E+01	4.97E-01	4.90E-02
C Tank Farm Total	ILCR	4.27E-04	1.15E-05	1.20E-06
	HI	1.81E+01	5.16E-01	5.09E-02

ILCR = incremental lifetime cancer risk
HI = hazard index

Table 5.2. Summary of Peak Industrial Worker Long-Term Human Health Risks at C Tank Farm Fenceline From Residual Waste Source Term

Tank or Tank Combination	Impact Measure	Current State	HFFACO Retrieval	10% HFFACO Retrieval
C-106	ILCR	1.46E-07	3.84E-08	3.96E-09
	HI	8.52E-04	4.60E-04	4.54E-05
C-201	ILCR	7.14E-10	1.51E-10	1.51E-11
	HI	5.00E-05	1.04E-05	1.04E-06
C-202	ILCR	7.45E-10	1.57E-10	1.58E-11
	HI	7.14E-05	1.48E-05	1.48E-06
C-203	ILCR	1.39E-09	1.20E-10	1.21E-11
	HI	1.19E-04	9.79E-06	9.78E-07
C-204	ILCR	8.94E-10	7.74E-11	7.76E-12
	HI	7.70E-05	6.32E-06	6.31E-07
C-200 Tanks Total	ILCR	3.74E-09	5.05E-10	5.07E-11
	HI	3.18E-04	4.13E-05	4.12E-06
C-106 Plus C-200 Tanks	ILCR	1.50E-07	3.90E-08	4.01E-09
	HI	1.17E-03	5.01E-04	4.95E-05
Balance of C-100 Tanks	ILCR	1.53E-05	3.31E-07	3.45E-08
	HI	8.70E-02	2.07E-03	2.04E-04
C Tank Farm Total	ILCR	1.54E-05	3.70E-07	3.85E-08
	HI	8.82E-02	2.57E-03	2.54E-04

ILCR = incremental lifetime cancer risk
HI = hazard index

Table 5.3. Summary of Tank C-106 Additional Case Peak Long-Term Human Health Risks at C Tank Farm Fenceline From Residual Waste Source Term

Tank	Impact Measure	Pre-Project W-320		Liquid-Only Retrieval	
		Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
C-106	ILCR	2.71E-04	9.97E-06	1.84E-06	8.58E-08
	HI	7.34E-01	6.83E-03	6.28E-03	7.54E-04

ILCR = incremental lifetime cancer risk
HI = hazard index

5.1.1 Results for Tank C-106

If tank C-106 had been closed with the pre-Project W-320 sluicing retrieval waste inventory in place, the ILCR would have peaked at an estimated value of 2.71×10^{-4} for the residential farmer and 9.97×10^{-6} for the industrial worker. The hazard index prior to Project W-320 would have peaked at an estimated value of 7.34×10^{-1} for the residential farmer and 6.83×10^{-3} for the industrial worker.

Closing tank C-106 in its current state would cause the ILCR from residual waste to peak at an estimated value of 3.90×10^{-6} for residential farmer and 1.46×10^{-7} for the industrial worker. The hazard index under a current state case would peak at an estimated value of 5.12×10^{-2} for residential farmer and 8.52×10^{-4} for the industrial worker.

If tank C-106 were closed after retrieving the liquids only, the peak ILCR would be lowered slightly to an estimated value of 1.84×10^{-6} for the residential farmer and 8.58×10^{-8} for the industrial worker. The hazard index under a liquids-only retrieval case would be lowered to an estimated peak value of 6.28×10^{-3} for the residential farmer and 7.54×10^{-4} for the industrial worker.

Closing tank C-106 after retrieving waste to the HFFACO residual waste volume goal would lower the estimated peak ILCR to 8.36×10^{-7} for the residential farmer and 3.84×10^{-8} for the industrial worker. The hazard index under a HFFACO retrieval case would drop to an estimated peak of 3.28×10^{-3} for the residential farmer and 4.60×10^{-4} for the industrial worker.

Closing tank C-106 after retrieving waste to 10% of the HFFACO residual waste volume goal would lower the estimated peak impacts by approximately one order of magnitude compared to the peaks under a HFFACO retrieval case.

5.1.2 Results for C 200-Series Tanks

If the C 200-series tanks were closed without retrieving waste, the four tanks in combination would result in an estimated peak ILCR on the order of 10^{-7} for the residential farmer and 10^{-9} for the industrial worker. The hazard index for the four tanks in combination would peak at an

estimated value on the order of 10^{-2} for the residential farmer and 10^{-4} for the industrial worker. Risk values for tank C-203 would be highest among the four tanks by a slight margin.

Closing the four C 200-series tanks after retrieving waste to the HFFACO residual waste volume goal would lower each tank's estimated peak ILCR to the 10^{-9} range for the residential farmer and the 10^{-10} range for the industrial worker. Each tank's estimated peak hazard index under a HFFACO retrieval case would drop to the 10^{-3} range for the residential farmer and the 10^{-5} range for the industrial worker.

Closing the four C 200-series tanks after retrieving waste to 10% of the HFFACO residual waste volume goal would lower each tank's estimated peak impacts by approximately one order of magnitude compared to the peaks under a HFFACO retrieval case.

5.1.3 Results for C Tank Farm

Closing all 16 C farm tanks without retrieving waste would cause the total C farm ILCR to peak at an estimated value of 4.27×10^{-4} for the residential farmer and 1.54×10^{-5} for the industrial worker. The total C farm hazard index under a current state case would peak at an estimated value of 1.81×10^{1} for the residential farmer and the 8.82×10^{-2} for the industrial worker.

Closing all 16 C farm tanks after retrieving waste to the HFFACO residual waste volume goal would lower the total C farm estimated peak ILCR to 1.15×10^{-5} for the residential farmer and 3.7×10^{-7} for the industrial worker. The total C farm estimated peak hazard index under a HFFACO retrieval case would drop to 5.16×10^{-1} for the residential farmer and 2.56×10^{-3} for the industrial worker.

Closing all 16 C farm tanks after retrieving waste to 10% of the HFFACO residual waste volume goal would lower the total C farm estimated peak ILCR to 1.20×10^{-6} for the residential farmer and 3.85×10^{-8} for the industrial worker. The total C farm estimated peak hazard index under a 10% HFFACO retrieval case would drop to 5.09×10^{-2} for the residential farmer and 2.54×10^{-4} for the industrial worker.

5.1.4 Risk Allocation

The analysis results indicate that the residual waste in tank C-106 would not be expected to exceed the State of Washington standards for either ILCR (1.0×10^{-5}) or hazard index (1.0) even if no additional waste were retrieved prior to closure. The residual waste in the C 200-series tanks, whether considered on an individual tank basis or in combination, also would not be expected to cause an exceedance of State standards even without additional waste retrieval prior to closure.

If the State ILCR standard of 1.0×10^{-5} is assumed as the overall tank farm closure risk budget and a residential farmer scenario is used, tank C-106 would subtract about 40% (3.90×10^{-6}) of the budget if closed without waste retrieval. Unretrieved, the C 200-series tanks together would subtract about 1% (1.15×10^{-7}) of the budget. Closed after liquid-only retrieval, tank C-106 would subtract about 18% (1.84×10^{-6}) of the budget. Retrieved to the HFFACO limits, tank C-106 would subtract about 8% (8.36×10^{-7}) of the budget and the C 200-series tanks would

subtract about 0.2% (1.56×10^{-8}) of the budget. Retrieved to 10% of the HFFACO limits, tank C-106 would subtract about 1% (8.69×10^{-8}) of the budget and the C 200-series tanks would subtract an insignificant amount of the budget.

On the tank farm level, if no waste were retrieved from any of the C farm tanks prior to closure, the waste left in place would be expected to cause risk in excess of not only the State ILCR standard (1.0×10^{-5}) but also the Federal ILCR standard (1.0×10^{-4}), assuming use of a residential farmer scenario. Exceeding the hazard index standard (1.0) would also be expected at the tank farm level under a current state case. Only about 1% of the total C farm long-term human health impacts would come from the five closure demonstration tanks; about 99% would come from the 11 remaining C 100-series tanks. Of these 11 tanks, the largest contributors would be tanks C-104, C-105, and C-107. Retrieving waste from all C farm tanks to the HFFACO goals prior to closure would be expected to lower human health impacts by about a factor of 40 compared to the current state impacts, but the residual waste would still be expected to cause a slight exceedance of the State ILCR standard. The total C farm residential farmer ILCR would fall below the State standard if all C farm tanks were retrieved to 10% of the HFFACO goals.

The estimated risks from C farm past leaks would not be expected to significantly change the results of this analysis at the tank farm level. Based on the analysis presented in HNF-7643, the C farm past leaks would contribute an additional estimated ILCR of 6.8×10^{-7} (about 7% of a 10^{-5} budget) for the residential farmer and 2.0×10^{-8} (about 0.2% of a 10^{-5} budget) for the industrial worker at the time of peak residual waste impacts. The additional estimated hazard index contribution from past leaks would be 5.7×10^{-3} for the residential farmer and 5.2×10^{-5} for the industrial worker. Addition of these past leak risks to the residual waste risks calculated in this analysis would not result in any additional exceedance of risk standards for the C tank farm as whole.

5.2 INADVERTENT HUMAN INTRUDER RISK RESULTS

The doses calculated at 100 years post-closure for the well driller and post-drilling resident intrusion scenarios for each of the five cases analyzed are presented in Tables 5.4 through 5.8. DOE regulations limit exposures to an inadvertent human intruder to no greater than 100 mrem/yr for chronic exposure (post-drilling resident) and 500 mrem for an acute or single event (well driller) at a point in time 100 years after closure (DOE O 435.1).

Table 5.4 summarizes the results of the inadvertent intruder calculation for the current state case. All five of the tanks pass the DOE regulated acute exposure limit. Tanks C-106 and C-201 exceed the chronic exposure limit. The tank C-106 chronic dose is primarily driven by the short-lived isotope strontium-90. The long-lived isotope plutonium-239 primarily drives the tank C-201 chronic dose.

Table 5.5 summarizes the results of the inadvertent intruder calculations for the HFFACO retrieval case. All five of the tanks pass the DOE regulated acute exposure limit. Tank C-106 continues to exceed the chronic exposure limit. The tank C-106 dose is primarily driven by the short-lived isotope strontium-90.

Table 5.6 summarizes the results of the inadvertent intruder calculations for the 10% HFFACO retrieval case. For both the well driller and post-drilling resident inadvertent intruder scenarios none of the tanks exceed the limits of exposure.

Table 5.4. Well Driller and Post-Drilling Resident Dose, Current State

Tank	Well Driller (mrem/incident)	Post-Drilling Resident (mrem/yr)
C-106	4.84E+01	4.58E+02
C-201	7.09E+01	1.52E+02
C-202	3.78E+01	8.57E+01
C-203	2.08E+01	6.03E+01
C-204	2.05E+00	1.60E+01

Table 5.5. Well Driller and Post-Drilling Resident Dose, HFFACO Retrieval

Tank	Well Driller (mrem/Incident)	Post-Driller Resident (mrem/yr)
C-106	1.85E+01	1.93E+02
C-201	1.48E+01	3.17E+01
C-202	7.87E+00	1.78E+01
C-203	1.74E+00	5.02E+00
C-204	1.71E-01	1.33E+00

Table 5.6. Well Driller and Post-Drilling Resident Dose, 10% of HFFACO Retrieval

Tank	Well Driller (mrem/Incident)	Post-Drilling Resident (mrem/yr)
C-106	1.85E+00	1.93E+01
C-201	1.48E+00	3.17E+00
C-202	7.87E-01	1.78E+00
C-203	1.74E-01	5.02E-01
C-204	1.71E-02	1.33E-01

Tables 5.7 and 5.8 summarize the results for two additional evaluation cases for tank C-106 only. These two cases evaluate the risks associated with the inventory of contaminants estimated to exist in tank C-106 prior to sluicing under Project W-320 and after liquid retrieval only.

Table 5.7 indicates that prior to the Project W-320 sluicing campaign, tank C-106 exceeded both the chronic and acute exposure limits for the inadvertent intruder. The short-lived (28-year) strontium-90 isotope primarily drives the chronic exposure for tank C-106. The acute exposure for tank C-106 pre-Project W-320 is driven by cesium-137, which also considered a short-lived (30-year) isotope.

Table 5.8 indicates that for liquids only retrieval, tank C-106 exceeds the chronic exposure limit. The chronic dose for tank C-106 is driven primarily by the short-lived strontium-90 isotope.

Table 5.7. Well Driller and Post-Drilling Resident Dose, Tank C-106 Prior to Project W-320

Tank	Well Driller (mrem/incident)	Post-Drilling Resident (mrem/yr)
C-106	5.70E+02	7.72E+03

Table 5.8. Well Driller and Post-Drilling Resident Dose, Tank C-106 Liquid Retrieval Only

Tank	Well Driller (mrem/incident)	Post-Drilling Resident (mrem/yr)
C-106	4.15E+01	4.35E+02

5.3 SHORT-TERM HUMAN HEALTH RISK RESULTS

The purpose of the short-term human health risk analyses is to estimate the potential health risk from both routine (non-accident) and accident conditions resulting from additional retrieval of waste from tanks C-106, C-201, C-202, C-203, and C-204. Routine conditions include anticipated exposure to radiation fields and radiological releases to the atmosphere during normal construction and operation conditions. Accidents are unplanned events or a sequence of events that result in undesirable consequences. The accident analysis evaluates potential accidents associated with construction and operation activities involved with tank waste retrieval. The methodology used for these analyses is summarized in Section 4 and discussed in detail in Appendix C.

The current state case was dismissed from further short-term risk evaluation since there would be no retrieval exposure (routine or accident) and no occupational accidents from retrieval activities.

5.3.1 Occupational Accident Risk Results

The potential exists for accidents (i.e., cuts, falls, etc.) resulting from construction and operation activities associated with additional tank retrieval.

Occupational injuries, illnesses, and fatalities resulting from potential accidents are calculated based on assumed labor requirements for waste retrieval from each candidate tank and current incidence rates for occupational accidents. Calculation detail is provided in Appendix C.

Table 5.9 presents the number of incidences resulting from potential occupational accidents under the cases analyzed.

Table 5.9. Worker Risk From Occupational Accidents

Case	Incidence	Tank				
		C-106	C-201	C-202	C –203	C-204
Project W-320 Retrieval	TRC	2.2E+01	NA	NA	NA	NA
	LWC	9.2E+00	NA	NA	NA	NA
	Fatalities	1.6E-02	NA	NA	NA	NA
Liquid-only Retrieval	TRC	3.2E+00	NA	NA	NA	NA
	LWC	1.3E+00	NA	NA	NA	NA
	Fatalities	2.3E-03	NA	NA	NA	NA
HFFACO Retrieval	TRC	1.6E+01	1.7E+01	1.7E+01	1.7E+01	1.7E+01
	LWC	6.7E+00	7.2E+00	7.2E+00	7.2E+00	7.2E+00
	Fatalities	1.1E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
10% HFFACO Retrieval	TRC	2.4E+01	2.6E+01	2.6E+01	2.6E+01	2.6E+01
	LWC	9.9E+00	1.1E+01	1.1E+01	1.1E+01	1.1E+01
	Fatalities	1.7E-02	1.8E-02	1.8E-02	1.8E-02	1.8E-02

Notes:

Project W-320 Retrieval = Retrieval to current waste volume

Liquid-only Retrieval = Retrieval of liquids only

HFFACO Retrieval = Retrieval of tank waste to HFFACO goals of 360 ft^3 (10,200 L [2,700 gal]) for tank C-106 and 30 ft^3 (850 L [220 gal]) for tanks C-201, C-202, C-203, and C-204

10% HFFACO Retrieval = Retrieval of tank waste to a level of 36 ft^3 (1,020 L [270 gal]) for tank C-106 and 3 ft^3 (85 L [22 gal]) for tanks C-201, C-202, C-203, and C-204.

TRC = Total recordable cases
LWC = Lost workday cases

5.3.2 Radiological Accident Risk Results

Radiological accidents are unplanned events or a sequence of events that result in undesirable consequences. The potential exists for radiological accidents resulting from the tank waste

retrieval operations. Radiological accidents could result in the unmitigated release of radiological constituents to the atmosphere, exposing the involved worker, noninvolved worker and general public (these receptors are defined in Section 5.3.3) resulting in a LCF risk. The probability of the accident occurring is taken into consideration. When the consequences of the accident or LCF risk is evaluated with the probability of the accident occurring, the product of the two is referred to as the point-estimate LCF risk.

A spectrum of potential accidents associated with additional retrieval of waste from tanks C-106, C-201, C-202, C-203, and C-204 was reviewed in the *Safety Assessment for Tank 241-C-106 Waste Retrieval Project W-320* (WHC-SD-WM-SAD-024). The "spray leak from a transfer line" accident with a high severity level (major onsite and offsite impacts on people) and an unlikely probability was selected for evaluation in this analysis because it was determined to be the bounding accident. As evaluated in WHC-SD-WM-SAD-024, a spray leak is assumed to occur at a jumper connection within a jumper pit. The jumper pit is equipped with a removable cover block to provide the necessary confinement of radioactive releases to the environment should a leak occur and is required to be in place before commencing transfer. It was assumed that the operators failed to place the cover block prior to commencing transfer and that the orientation of spray leaks directed the spray out of the jumper pit area.

The calculated LCF risk to the various receptors from the postulated spray leak accident is summarized in Table 5.10.

Table 5.10. LCF Risk From Spray Leak Accident

Receptor	C-106[d]	C-106	C-201	C-202	C-203	C-204
IW MEI	LD[e]	LD[a]	LD[a]	LD[a]	LD[a]	LD[b]
IW Pop	LD[e]	LD[a]	LD[a]	LD[a]	LD[a]	LD[b]
NIW MEI	1.9E-04	LD[c]	LD[c]	LD[c]	6.4E-02	2.1E-03
NIW Pop	4.3E-03	4.0E+00	1.3E+01	7.0E+00	1.5E+00	5.0E-02
GP MEI	2.7E-07	1.3E-04	4.2E-04	2.2E-04	4.7E-05	3.1E-06
GP Pop	9.9E-04	4.5E-01	1.5E+00	8.1E-01	1.7E-01	1.1E-02

Notes:

[a] LD = lethal dose to involved worker within 10 minute exposure
[b] LD = lethal dose to involved worker within 20 minute exposure
[c] LD = lethal dose to involved worker MEI at 100 m (328 ft) from 8-hour exposure
[d] C-106 = LCF risk from spray leak accident during liquid-only retrieval
[e] LD = lethal dose to involved worker within 4 hour exposure

IW MEI = involved worker maximum exposed individual
IW Pop = involved worker population
NIW MEI = noninvolved worker maximum exposed individual
NIW Pop = noninvolved worker population
GP MEI = general public maximum exposed individual
GP Pop = general pubic population

The point estimate risks, calculated by multiplying the receptor LCF risk by the probability of the accident occurring are summarized in Table 5.11.

Table 5.11. Point Estimate Risk From Spray Leak Accident

Case	Receptor	C-106	C-201	C-202	C-203	C-204
Project W-320 Retrieval	IW MEI	7.4E-03	NA	NA	NA	NA
	IW Pop	7.4E-03	NA	NA	NA	NA
	NIW MEI	4.2E-04	NA	NA	NA	NA
	NIW Pop	2.9E-02	NA	NA	NA	NA
	GP MEI	9.2E-07	NA	NA	NA	NA
	GP Pop	3.4E-03	NA	NA	NA	NA
Liquid-Only Retrieval	IW MEI	4.2E-04	NA	NA	NA	NA
	IW Pop	4.2E-04	NA	NA	NA	NA
	NIW MEI	7.8E-08	NA	NA	NA	NA
	NIW Pop	1.8E-06	NA	NA	NA	NA
	GP MEI	1.2E-10	NA	NA	NA	NA
	GP Pop	4.2E-07	NA	NA	NA	NA
HFFACO Retrieval	IW MEI	6.2E-04	6.2E-04	6.2E-04	6.2E-04	6.2E-04
	IW Pop	6.2E-04	6.2E-04	6.2E-04	6.2E-04	6.2E-04
	NIW MEI	6.2E-04	6.2E-04	6.2E-04	3.9E-05	1.3E-06
	NIW Pop	2.4E-03	8.2E-03	4.3E-03	9.2E-04	3.1E-05
	GP MEI	7.7E-08	2.6E-07	1.4E-07	2.9E-08	1.9E-09
	GP Pop	2.8E-04	9.3E-04	5.0E-04	1.1E-04	7.0E-06
10% HFFACO Retrieval	IW MEI	3.5E-03	3.5E-03	3.5E-03	3.5E-03	3.5E-03
	IW Pop	3.5E-03	3.5E-03	3.5E-03	3.5E-03	3.5E-03
	NIW MEI	3.5E-03	3.5E-03	3.5E-03	2.3E-04	7.5E-06
	NIW Pop	1.4E-02	4.7E-02	2.5E-02	5.3E-03	1.8E-04
	GP MEI	4.4E-07	1.5E-06	7.9E-07	1.7E-07	1.1E-08
	GP Pop	1.6E-03	5.4E-03	2.9E-03	6.0E-04	4.0E-05

Table 5.11. Point Estimate Risk From Spray Leak Accident

Case	Receptor	C-106	C-201	C-202	C-203	C-204

Notes:

Project W-320 Retrieval = Retrieval of tank waste to current volume

Liquid-only Retrieval = Retrieval of liquids only

HFFACO Retrieval = Retrieval of tank waste to HFFACO goals of 360 ft^3 (10,200 L [2,700 gal]) for tank C-106 and 30 ft^3 (850 L [220 gal]) for tanks C-201, C-202, C-203, and C-204

10% HFFACO Retrieval = Retrieval of tank waste to a level of 36 ft^3 (1,020 L [270 gal]) for tank C-106 and 3 ft^3 (85 L [22 gal]) for tanks C-201, C-202, C-203, and C-204.

IW = involved worker
NIW = noninvolved worker
GP = general public

5.3.3 Routine Radiological Exposure Risk Results

Retrieval activities require radiation workers to work in radiation zones during the construction and installation of retrieval equipment and during the retrieval operation. Due to the nature of the work in a radiation zone, the workers will be exposed to and receive an occupational radiological dose from ionizing radiation. Atmospheric emissions will also result from retrieval activities. Although the emissions are first filtered through HEPA filters, the abated emissions released to the atmosphere and carried downwind will be inhaled by onsite workers and the offsite population, resulting in an exposure and subsequent dose. The offsite population will receive an additional dose from ingesting radiological contaminants attached to food substances such as fruits, vegetables, meat, and milk. Every effort is made to reduce the exposures to the radiation workers and the air emissions, but the exposures are still anticipated and are considered routine. The risk from these exposures is measured in terms of LCFs.

This analysis considers the risk from routine radiological exposures to three receptor groups of people and a maximum exposed individual (MEI) person from each group.

1. Involved workers – radiation workers in radiation zones directly involved in the construction and retrieval operation activities.

2. Noninvolved workers – Hanford Site workers distributed within the Hanford Site boundary but no closer than 100 m (328 feet) from the source of missions.

3. General public – offsite population distributed from the Hanford Site to a distance of 80 km (50 miles).

The calculated radionuclides released in the abated air emissions (Appendix C) are used as input to the GENII computer code (PNL 6584) to calculate the dose. The atmospheric dispersion coefficients for exposures used in the GENII code are calculated using the GXQ computer code.

The doses generated from the GENII computer code for the various receptors under the cases analyzed are presented in Appendix C.

The LCF risk to the various receptor populations and MEIs are calculated using the calculated dose values for the various tanks and retrieval cases and applying the appropriate dose-to-risk conversion factors. Results of the calculation are presented in Table 5.12.

Table 5.12. LCF Risk From Routine Radiological Exposure

Case	Receptor	Latent Cancer Fatality Risk				
		Tk C-106	Tk C-201	Tk C-202	Tk C-203	Tk C-204
Project W-320 Retrieval	IW MEI	2.0E-04	NA	NA	NA	NA
	IW Pop	3.3E-02	NA	NA	NA	NA
	NIW MEI	1.4E-10	NA	NA	NA	NA
	NIW Pop	6.8E-09	NA	NA	NA	NA
	GP MEI	1.8E-11	NA	NA	NA	NA
	GP Pop	3.6E-07	NA	NA	NA	NA
Liquid-Only Retrieval	IW MEI	2.0E-04	NA	NA	NA	NA
	IW Pop	1.9E-03	NA	NA	NA	NA
	NIW MEI	3.7E-12	NA	NA	NA	NA
	NIW Pop	1.6E-10	NA	NA	NA	NA
	GP MEI	9.5E-12	NA	NA	NA	NA
	GP Pop	1.9E-07	NA	NA	NA	NA
HFFACO Retrieval	IW MEI	2.0E-04	2.0E-04	2.0E-04	2.0E-04	2.0E-04
	IW Pop	3.4E-03	3.4E-03	3.4E-03	3.4E-03	3.4E-03
	NIW MEI	1.6E-11	4.8E-15	4.8E-15	2.0E-14	1.2E-14
	NIW Pop	7.2E-10	2.1E-13	2.2E-13	9.2E-13	5.6E-13
	GP MEI	1.8E-11	3.0E-14	3.0E-14	6.0E-14	3.7E-14
	GP Pop	3.6E-07	6.0E-10	6.0E-10	1.2E-09	7.5E-10
10% HFFACO Retrieval	IW MEI	2.0E-04	2.0E-04	2.0E-04	2.0E-04	2.0E-04
	IW Pop	1.9E-02	1.9E-02	1.9E-02	1.9E-02	1.9E-02
	NIW MEI	9.6E-11	4.8E-14	4.8E-14	2.0E-13	1.2E-13
	NIW Pop	4.4E-09	2.1E-12	2.2E-12	9.2E-12	5.6E-12
	GP MEI	1.8E-11	3.0E-14	3.0E-14	6.0E-14	3.7E-14
	GP Pop	3.6E-07	6.0E-10	6.0E-10	1.2E-09	7.5E-10

Table 5.12. LCF Risk From Routine Radiological Exposure

Case	Receptor	Latent Cancer Fatality Risk				
		Tk C-106	Tk C-201	Tk C-202	Tk C-203	Tk C-204

Notes:

Project W-320 Retrieval = Retrieval of tank waste to the current volume

Liquid-Only Retrieval = Retrieval of liquids only

HFFACO Retrieval = Retrieval of tank waste to HFFACO goals of 360 ft^3 (10,200 L [2,700 gal]) for tank C-106 and 30 ft^3 (850 L [220 gal]) for tanks C-201, C-202, C-203, and C-204

10% HFFACO Retrieval = Retrieval of tank waste to a level of 36 ft^3 (1,020 L [270 gal]) for tank C-106 and 3 ft^3 (1,020 L [270 gal]) for tanks C-201, C-202, C-203, and C-204.

IW MEI = involved worker maximum exposed individual
IW Pop = involved worker population
NIW MEI = noninvolved worker maximum exposed individual
NIW Pop = noninvolved worker population
GP MEI = general public maximum exposed individual
GP Pop = general public population

5.4 RETRIEVAL COST ESTIMATES

Appendix D provides the basis for the cost estimate ranges reported in this section. Table 5.13 summarizes the estimated range of costs for waste retrieval cases evaluated that are applicable to all five ATCD tanks.

Table 5.13. Estimated Range of Costs for Evaluated Waste Retrieval Cases

Tanks	Retrieval to HFFACO Goal	Retrieval to 10% of the HFFACO Goal
C-106	$20 million to $75 million	$30 million to $110 million
200-Series (all 4 tanks)	$50 million to $80 million	$75 million to $120 million

Costs for the two special cases for tank C-106 described earlier are provided below:

- The initial phase of tank C-106 retrieval, under Project W-320, is estimated to have cost $103 million (*RPP-6696*, Appendix B, Section B.2.3)
- Costs for liquid removal only are estimated to range from $4 million to $15 million.

The costs for the current state option were assumed to be zero, relative to the other waste retrieval options. However for tank C-106, these costs would be added to the costs already incurred under Project W-320 for a fair and accurate estimate of retrieval costs for tank C-106.

For the 200-series tanks, the costs given above are based on retrieval of waste from all four tanks together; the per-tank costs are somewhat higher if less than four tanks are retrieved, due to shared equipment.

These costs do not include costs of storage of the retrieved waste. A range of storage costs is documented in Appendix D, and under most assumptions the storage costs are small (less than $100,000). There could be cases where storage costs are much higher, especially in the case that additional storage tanks must be built to accommodate retrieval waste. It is unlikely that additional storage tanks will be required for a limited closure demonstration. However, as additional tanks are added to the list for retrieval and closure, or if the closure demonstration is changed to add tanks containing higher waste volumes, it is possible that storage capacity would become an important issue.

Costs include only these elements of cost directly related to retrieval of waste. Not included are costs for tank fill, disposition of ancillary equipment, placement of an interim surface barrier, licensing and performance monitoring. These costs are not shown because they are assumed to be approximately equal for all cases, both retrieval and current state.

For similar reasons, costs also do not include savings from not treating, storing, transporting, and disposing of the relatively small volumes of waste from the five closure demonstration tanks. These would be incremental costs (that is, the overall sizing of the facilities would not be changed). However, if significant changes are made in facility sizing (for example, by deciding to forego retrieval of large volumes of waste), then these costs could be significant.

The configuration of the retrieval system for the closure demonstration tanks is under development at this time. An activity-based cost estimate has not been performed to date. For that reason, the cost estimate ranges provided in this analysis are based on rough order-of-magnitude estimates.

An effort was made to compare these cost estimates with actual costs incurred at other DOE sites, but it was concluded that there are such wide differences in waste and tank characteristics, regulatory requirements, site conditions, and other factors affecting cost that such comparisons are of minimal value. A brief description of costs at other sites is contained in Appendix D.

6.0 CONCLUSIONS

Based on the analysis presented in Section 5, and subject to the uncertainties in cost estimates and uncertainties in the long-term risk analysis, the following preliminary conclusions may be drawn regarding long-term risks, inadvertent human intrusion risks, short-term risks, costs, and cost-risk comparisons for the three cases examined. However, the purpose of this study was not to provide a definitive analysis of risks associated with retrieval and closure actions for the five ATCD tanks, but rather to provide a common basis for comparing relative costs and risk reduction benefits of retrieval alternatives. Risk analysis for purposes of evaluating compliance with regulatory standards will be provided later in support of closure plans addressing WAC 173-303-610 and DOE O 435.1 requirements.

6.1 LONG-TERM HUMAN HEALTH RISK CONCLUSIONS

Based on the results of the long-term human health risk analysis presented in Section 5.1, the following conclusions can be drawn:

- In no case was a hazard index of 1.0 exceeded for the five candidate tanks. Hazard index is not a limiting performance objective for decisions regarding waste removal from tanks.

- Long-term human health risks are greater for the residential farmer scenario than for the industrial worker scenario, so retrieval decisions based on the residential farmer scenario favor greater retrieval levels than decisions based on the industrial worker scenario.

- The risk from the waste in tank C-106 in a current state case is about 40% of the Washington State standard of 1.0×10^{-5} ILCR. Removing the liquids reduces this risk by a factor of about 2, to 18% of the standard. Removing the waste to the HFFACO goal reduces this risk by a factor of 5, to 8% of the standard. Removal to 10% of HFFACO further reduces the risk to 0.8% of the standard.

- The risk from the waste in all the C-200 tanks in the current state case is about one percent of the standard. Retrieval to the HFFACO goal reduces this to 0.2% of the standard.

- Tank C-106 represents about 1% of the total risk from the C Tank Farm in the current state case scenario and 7% of the total C Tank Farm risk in the HFFACO and 10% of HFFACO retrieval cases.

- The total risk from the C Tank Farm in the current state case is 44 times the standard. In the HFFACO retrieval case, it drops to approximately equal to the standard; and in the 10% HFFACO retrieval case, it drops to about 10% of the standard.

- In the current state, only about 1% of the total C Farm long-term human health impacts would come from the five closure demonstration tanks; about 99% would come from the 11 remaining C 100-series tanks.

- Table 6.1 summarizes the peak residential farmer long-term human health risks at the C Tank Farm fenceline from residual waste source terms for each tank in the C Tank Farm in the current state case. The data were taken from Table A.6 in Appendix A. The comparison shows a wide difference in risks among these tanks, ranging from a low of 2.20E-08 ILCR for tank C-201 to 8.88E-05 ILCR for tank C-105. Three tanks (C-105, C-104, C-107) contribute over half the total C Farm risk in a current state case. The results in Table 6.1 are shown graphically in Figure 6.1.

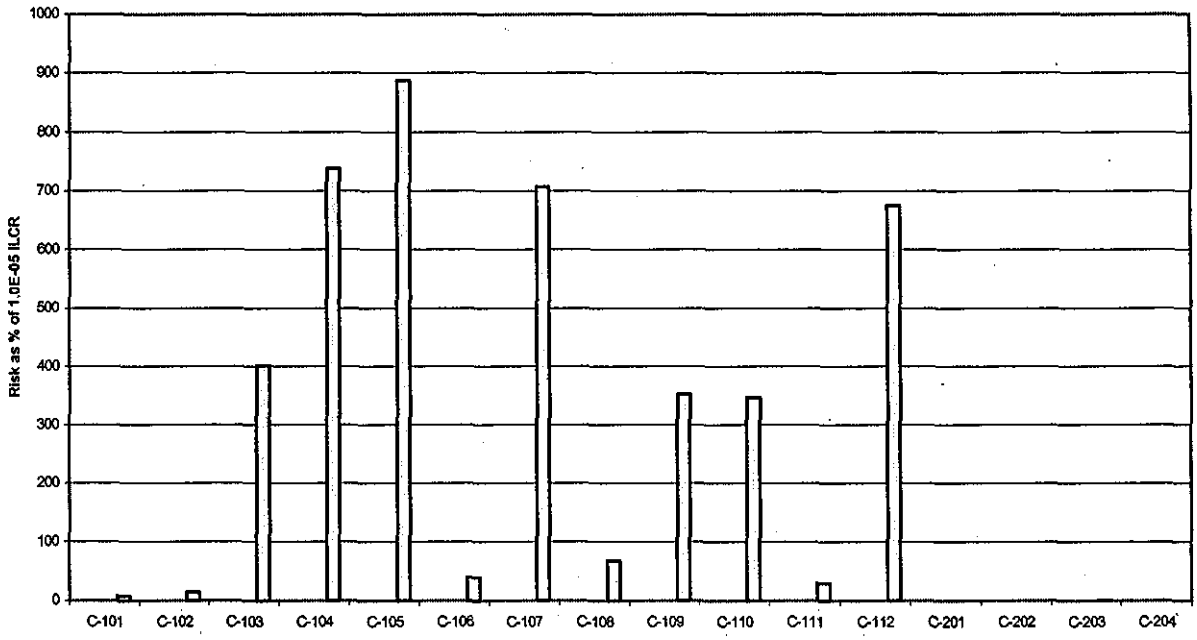
- During the Project W-320 waste retrieval campaign, long-term risk was reduced from 2700% of the 1.0 x 10^{-5} ILCR standard to 40% of the standard.

- Addition of the estimated past leak risks to the residual waste risks calculated in this analysis would not result in any additional exceedance of risk standards for the C tank farm as a whole.

Table 6.1. Peak Residential Farmer Long-Term Health Risks at the C Tank Farm Fenceline from Residual Waste Source Terms: Current State Case

Tank	Total ILCR	ILCR as % of Standard (1.0E-05) (Current State)
C-101	7.72E-07	7.72
C-102	1.45E-06	14.5
C-103	4.02E-05	402
C-104	7.39E-05	739
C-105	8.88E-05	888
C-106	3.90E-06	39
C-107	7.07E-05	707
C-108	6.75E-06	67.5
C-109	3.52E-05	352
C-110	3.47E-05	347
C-111	2.96E-06	29.6
C-112	6.75E-05	675
C-201	2.20E-08	0.22
C-202	2.30E-08	0.23
C-203	4.28E-08	0.43
C-204	2.75E-08	0.28

Figure 6.1. Comparative Risks for C-Farm Tanks (Current State)



6.2 INADVERTENT HUMAN INTRUDER RISK CONCLUSIONS

DOE regulations require that exposure to the inadvertent human intruder not exceed 500 mrem for an acute or single event (well driller) and 100 mrem in a year from chronic exposure (post-drilling resident) (DOE O 435.1). A comparison (Section 5 above) of the well driller and post-driller resident doses to the DOE regulations for the various cases results in the following conclusions.

- None of the well driller cases analyzed from each of the tanks exceeds the 500-mrem acute dose limit set in DOE O 435.1. For the current state case, tank C-201 has the greatest acute dose impact (70.9 mrem) to the well driller.

- Only tanks C-106 and C-201 in the current state case exceed the 100 mrem/yr chronic dose limit. C-201 is below the 100 mrem/yr limit for both the HFFACO and 10% of HFFACO retrieval cases. This is shown in Figure 6.2.

- Tank C-106 continues to exceed the 100 mrem/yr chronic dose limit in the HFFACO retrieval case but is below the 100 mrem/yr limit for the 10% HFFACO retrieval case. This is shown in Figure 6.2.

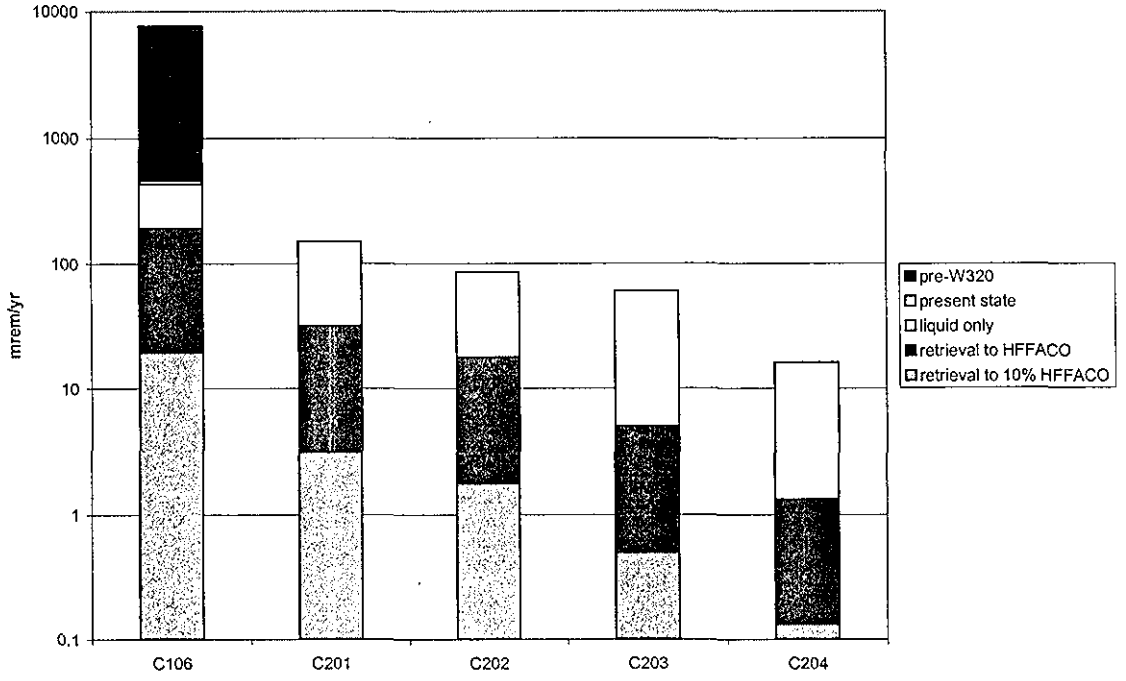
The following conclusions were drawn from the analysis of the two additional tank C-106 cases.

- Tank C-106 pre-Project W-320 sluicing inventory exceeded both the chronic and acute exposure limits set for the inadvertent intruder. The short-lived strontium-90 isotope primarily drives the chronic exposure for tank C-106. The acute exposure for tank C-106 prior to Project W-320 is driven by cesium-137, which is also a short-lived isotope.

- Following retrieval of liquids only from tank C-106, the tank contents would still exceed the chronic exposure limit. The chronic dose for tank C-106 is primarily driven by strontium-90.

Figure 6.2 shows intruder risk reduction graphically.

Figure 6.2. Intruder Chronic Doses



6.3 SHORT-TERM HUMAN HEALTH RISK CONCLUSIONS

Based on the short-term human health risk analysis, the estimated potential health impacts from both accident and normal (non-accident) conditions resulting from various tank waste retrieval scenarios for tanks C-106, C-201, C-202, C-203, and C-204 are as follows.

- In all cases, there would be at least one lost workday.
- In no case was the administrative control level of 0.5 rem/yr for an occupationally-exposed worker exceeded under routine conditions.
- In no case were the standards for routine exposure of the public of 0.1 rem/yr exceeded.

- In all cases the acute exposure limit of 5.0 rem to an onsite MEI noninvolved worker (located at 100 m [330 ft] from the point of release) from a radiological accident with an unlikely probability of occurrence (> 10^{-4} to 10^{-2}) would be exceeded. Tanks C-106, C-201, and C-202 would result in a lethal dose to the MEI noninvolved worker located at 100 m (330 ft) from the point of release. However, the assumptions used in calculating this probability were extremely conservative.

- Short-term radiation risk to the public for both retrieval cases, expressed as LCFs, is very small, on the order of 1.0×10^{-11} LCF.

6.4 COST CONCLUSIONS

Cost estimates, although approximate and not based on detailed engineering cost estimating, suggest that it will cost an additional $20 million to $75 million to retrieve tank C-106 waste to HFFACO residual waste volume goals and $30 million to $110 million (in addition to the $103 million already spent under Project W-320) to achieve 10% of the HFFACO goals. Waste retrieval for the C-200 tanks will cost $50 million to $80 million to achieve the HFFACO goals for all four tanks and $75 million to $120 million to achieve 10% of the HFFACO goals for all four tanks.

6.5 COST-RISK CONCLUSIONS

Tables 6.2 and 6.3 summarize long-term risks for the five closure demonstration tanks for the five cases examined. Risk reductions are expressed as both ILCR and as a percentage of the State standard of 1.0×10^{-5} ILCR. Table 6.4 shows the risk reduction achieved in going from current state to HFFACO retrieval goals, and from current state to 10% of the HFFACO retrieval goals. This table also shows the costs associated with each step of risk reduction. Costs and risks are compared by calculating the costs to achieve a risk reduction of one percent of the State standard of 1.0×10^{-5} ILCR. Similar data are shown in Table 6.5 for the two special cases for tank C-106.

It may be seen from these tables that the most cost-effective retrieval for tank C-106 (in terms of long-term risk reduction) occurred during the Project W-320 sluicing campaign, when long-term risk was reduced from 2700% of the 1.0×10^{-5} ILCR standard to 40% of the standard at a cost of $103 million, or $0.04 million per percent risk reduction. The next most cost-effective retrieval action would be liquids-only retrieval, which will cost somewhere in the range of $0.19 to $0.72 million per percent risk reduction. The next most effective retrieval action would be retrieval to the HFFACO goal, which will cost somewhere in the range of $0.65 to $2.45 million per percent risk reduction. Finally, retrieval of tank C-106 to 10% of the HFFACO goal would be accomplished for a range of $0.79 to $2.89 million per percent risk reduction. These results are summarized as follows:

Project W-320 sluicing	$0.04 million per % risk reduction
Liquids only retrieval	$0.19 to $0.72 million per % risk reduction
Retrieval to HFFACO goal	$0.65 to $2.45 million per % risk reduction
Retrieval to 10% HFFACO	$0.79 to $2.89 million per % risk reduction

This last number is the total cost to retrieve waste from the current state to 10% of the HFFACO goal; the incremental cost to go from the HFFACO goal to 10% of the HFFACO goal would be considerably higher, on the order of $0.70 to $5.0 million per percent risk reduction.

Similar results may be calculated for the intruder scenario and produce similar results in terms of ranking the retrieval options, with one exception: relatively little reduction in the intruder risk is gained from retrieving the liquids only from tank C-106, due to the fact that the isotopes driving the intruder risk reside primarily in the sludge fraction.

Cost-risk comparisons for tank C-106 are shown graphically on Figures 6.3 and 6.4 (also shown in Section 2 as Figures 2.1 and 2.2).

For the 200-series tanks, using the same methods described above, it will cost somewhere in the range of $50 to $80 million per percent risk reduction to retrieve waste to the HFFACO goal and $66 to $105 million per percent to retrieve waste from the current state to 10% of the HFFACO goal.

Table 6.2. Summary of Peak Residential Farmer Long-Term Human Health Risk at the Tank Farm Fenceline, Expressed as ILCR and as a Percent of the Standard (1.0E-05 ILCR)

Tank	Current State		HFFACO		10% HFFACO	
	Risk (ILCR)	% of 1.0E-05 ILCR	Risk (ILCR)	% of 1.0E-05 ILCR	Risk (ILCR)	% of 1.0E-05 ILCR
C-106	3.90E-06	39	8.36E-07	8.36	8.69E-08	0.869
4 C-200 Tanks	1.15E-07	1.15	1.56E-08	0.156	1.57E-09	0.0157

Table 6.3. Summary of Peak Residential Farmer Long Term Human Health Risk at the Tank Farm Fenceline, Expressed as ILCR and as a Percent of the Standard (1.0E-05 ILCR) for the Two Special Cases for Tank C-106

	Pre-Sluicing Under Project W-320		Removal of Liquids Only	
	Risk (ILCR)	% of 1.0E-05 ILCR	Risk (ILCR)	% of 1.0E-05 ILCR
C-106	2.71E-04	2710	1.84E-06	18.4

Table 6.4. Risk, Costs, and Costs per Percentage Reduction

Tank	From Current State, to HFFACO			From Current State, to 10% HFFACO		
	Risk Reduction (% of Standard)	Cost ($ Million)	$/% [a]	Risk Reduction (%)	Cost ($ Million)	$/% [a]
C-106	30.6	20 – 75	.65 – 2.45	38.1	30 – 110	.79 – 2.89
4 C-200 Tanks	1.0	50 – 80	50 – 80	1.14	75 – 120	66 – 105

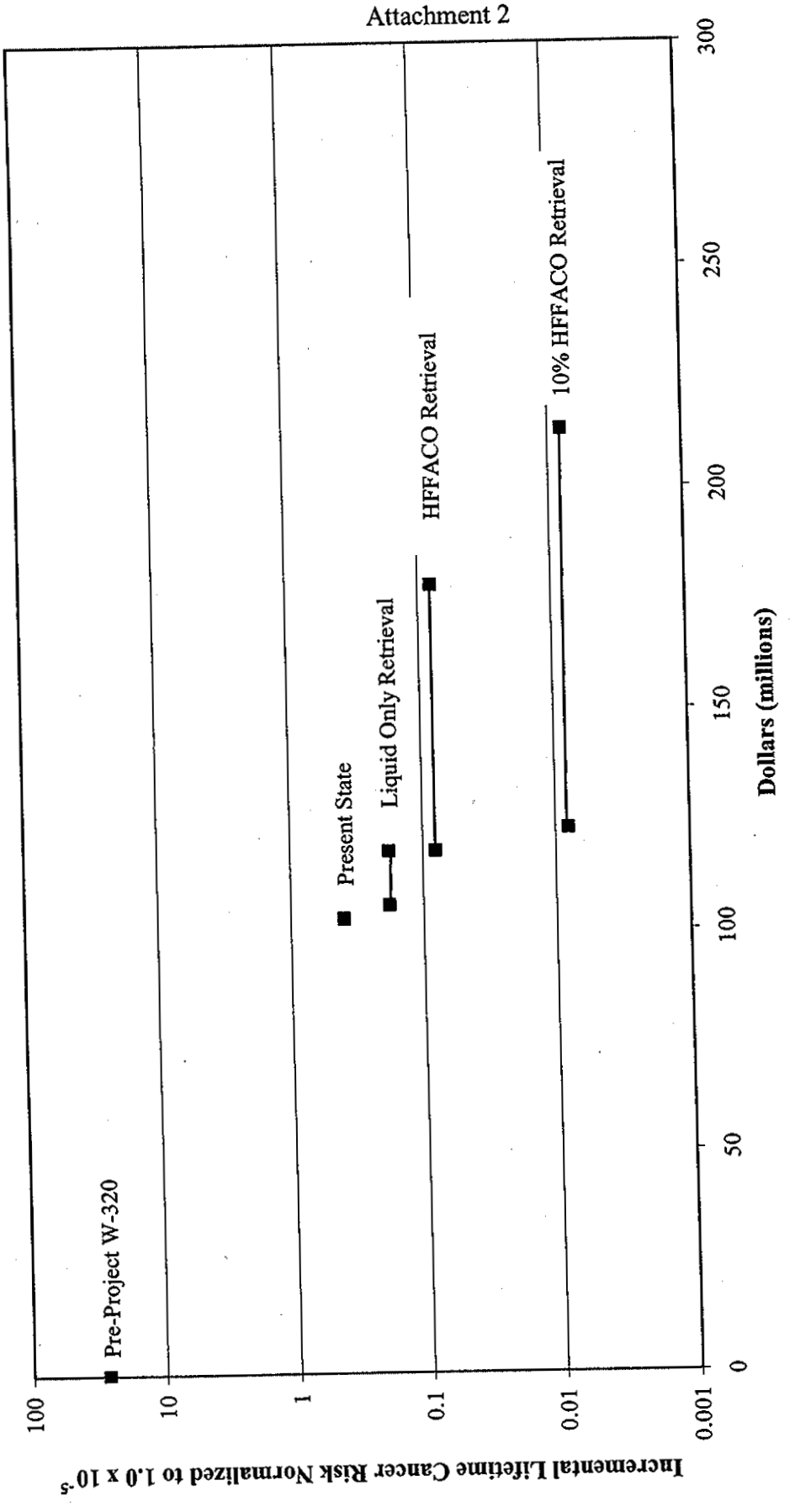
[a] Cost (in millions) to reduce risk by one percent of the 1.0E-05 ILCR standard.

Table 6.5. Risk, Costs, and Cost-per-Percentage-Reduction for the Two Special Cases, Tank C-106

Pre-Project W-320 to Current State			Current State to Liquid CHG Retrieval		
Risk Reduction (% of Standard)	Cost ($ Million)	$/% [a]	Risk Reduction (%)	Cost ($ Million)	$/%[a]
2671	103	0.04	20.6	4 – 15	0.19 – 0.72

[a] Cost (in millions) to reduce risk by one percent of the 1.0E-05 ILCR standard.

Figure 6.3. Tank C-106 Long-Term Risk Versus Cost



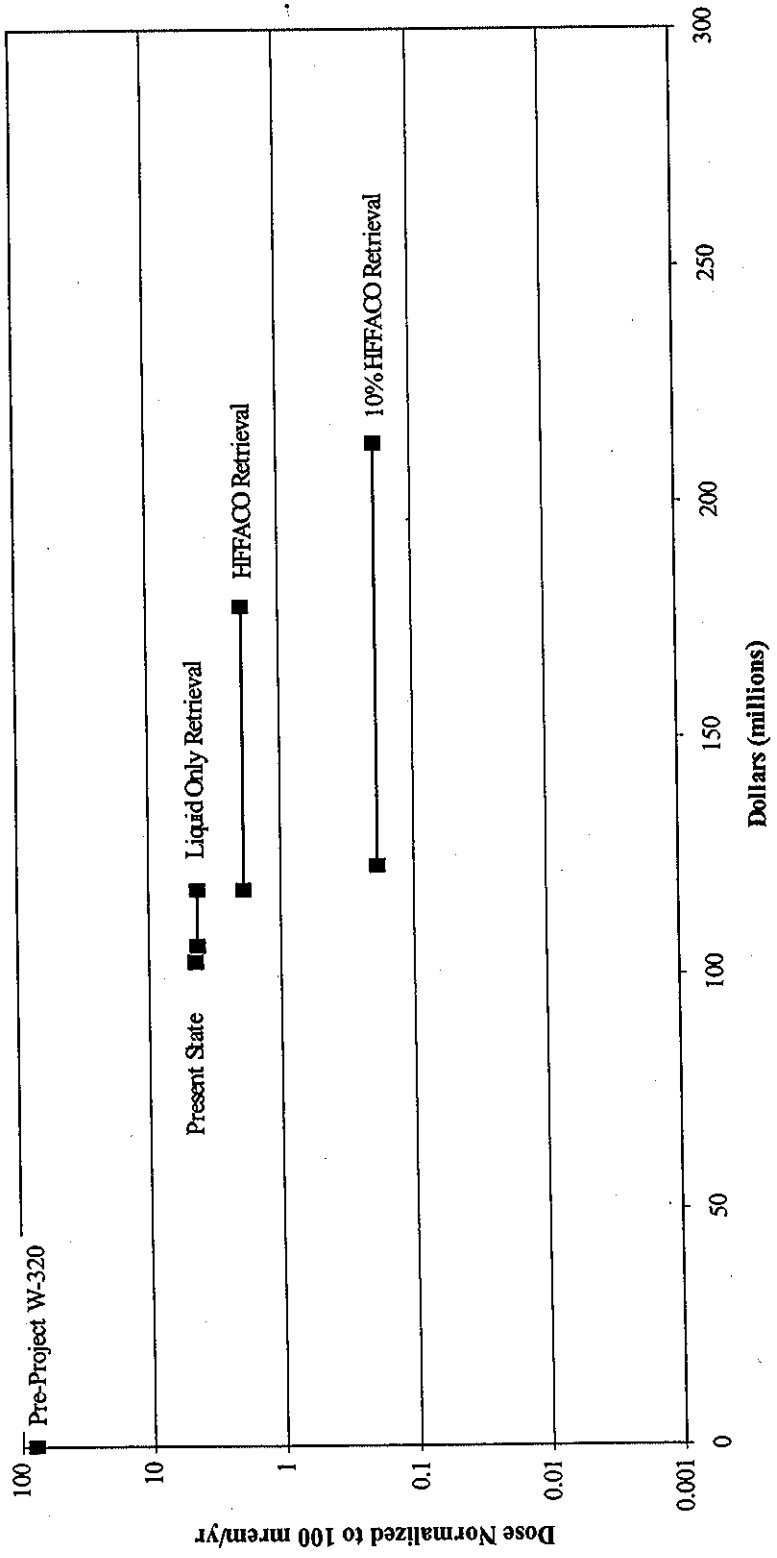


Figure 6.4. Tank C-106 Intruder Risk (Chronic Dose) Versus Cost

Attachment 2

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7.0 REFERENCES

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*, as amended.

55 FR 8666, 1990, "National Oil and Hazardous Substances Pollution Contingency Plan," *Federal Register*, March 8.

BBI, 2002, *Tank Waste Information Network System (TWINS)*, April 15, 2002, [Best Basis Inventory, Best Basis/TCR Tank Inventory], http://twins.pnl.gov/data/datamenu.htm#.

BHI-01365, 2000, *Groundwater/Vadose Zone Integration Project System Assessment Capability*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

DOE/EIS-0189, 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, U.S. Department of Energy and Washington State Department of Ecology, Washington, D.C.

DOE O 435.1, 1997, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE/RL-91-45, 1995, *Hanford Site Risk Assessment Methodology*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-98-72, 1999, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Frei, M.W., 1996, *Issuance of Low-Level Waste Performance Assessment Guidance* (Memorandum on Distribution Issuing the Interim Format and Content Guide and Standard Review Plan for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments), U.S. Department of Energy, Washington, D.C.

HNF-EP-0182, 2002, *Waste Tank Summary Report for Month Ending January 31, 2002*, Rev. 166, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-7643, 2001, *Retrieval Performance Evaluation for Single-Shell Tank C-104*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

LA-UR-96-3860, 1997, *Hanford Defined Wastes: Chemical and Radionuclide Compositions*, Rev. 4, Los Alamos National Laboratory, Los Alamos, New Mexico.

LA-UR-00-4050, 2000, *Hanford Soil Inventory and Uncertainty Model*, Rev. 1, Los Alamos National Laboratory, Los Alamos, New Mexico.

Millet, B., 2000, *Injury/Illness Rates at Hanford* (electronic mail to M.R. Harker, Jacobs Engineering Group, Inc., August 18), U.S. Department of Energy, Idaho Falls Operations Office, Idaho Falls, Idaho.

PNL-6584, 1988, *GENII – The Hanford Environmental Radiation Dosimetry Software System*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-11800, 1998, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington.

Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2795, 42 USC 901 et seq.

RPP-6696, 2000, *Data to Support Tank C-106 Waste Retrieval Determination*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7807, 2001, *Single-Shell Tank C-104 Full Scale Sludge/HardHeel, Confined Sluicing and Robotic Technologies, Waste Retrieval Demonstration Functions and Requirements*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7825, 2001, *Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7884, 2002, *Field Investigation Report for Waste Management Area S-SX*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-10901, 2002, *241-S-102 Initial Waste Retrieval Project Functions and Requirements*, Draft, CH2M HILL Hanford Group, Inc., Richland, Washington.

WAC 173-340, "The Model Toxics Control Act Cleanup Regulation," *Washington Administrative Code*, as amended.

WHC-SD-WM-ER-615, 1998, *Tank Characterization Report for Single-Shell Tank 241-C-106*, Rev. 0B, Westinghouse Hanford Company, Richland, Washington.

WHC-EP-0645, 1995, *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Burial Grounds*, Westinghouse Hanford Company, Richland, Washington.

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Document Information			
Document #	**RPP-12194**	**Revision**	**0**
Title	ACCELERATED TANK CLOSURE DEMONSTRATION ALTERNATIVES GENERATION & ANALYSIS REPORT		
Date	**9/12/2002**		
Originator	**RIESS MJ**	**Originator Co.**	**CHG**
Recipient		**Recipient Co.**	
References	**EDT-634310**		
Keywords	**AGA,RETRIEVED,CLOSURE RISK ASSESSMENT,REGULATORY**		
Projects	**TWRS,TFARM**		
Other Information			

APPENDIX A

LONG-TERM HUMAN HEALTH RISK

Attachment 2

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A.1.0 INTRODUCTION

This appendix describes the evaluation of long-term human health risks for a cost-risk analysis to support the U.S. Department of Energy Office of River Protection accelerated tank closure demonstration program. Because long-term human health risks are linked to and are directly proportional to groundwater impacts, this evaluation also includes an evaluation of groundwater impacts. The intent of the analysis is to estimate the potential health effects to a hypothetical future site user from exposure to tank waste contaminants remaining onsite following the completion of waste retrieval and tank farm closure actions. The analysis identifies peak groundwater pathway risks at the C tank farm boundary under residential farmer and industrial worker exposure scenarios over a 10,000-year assessment period.

The approach for this risk assessment is consistent with the retrieval performance evaluation (RPE) approach established in *Retrieval Performance Evaluation Methodology for the AX Tank Farm* (DOE/RL-98-72) and subsequently applied in *Retrieval Performance Evaluation for Single-Shell Tank C-104* (HNF-7643). The risks presented are incremental risks for contamination sources inside the C tank farm. The analysis does not include an evaluation of cumulative risks to account for potential contamination sources from nearby waste sites outside the C tank farm. This analysis departs somewhat from the RPE approach taken in DOE/RL-98-72 and HNF-7643 in that it evaluates residual tank waste as the primary source term for long-term risk. Past leak and retrieval leak source terms are not explicitly evaluated. This approach reflects current plans to employ a dry or nearly dry retrieval technology for the closure demonstration project.

Five candidate closure demonstration tanks in the C tank farm in the 200 East Area are the focus of this analysis. This group of tanks consists of tanks C-106, C-201, C-202, C-203, and C-204. To address the issue of risk allocation and assess the risk performance of these five tanks in the context of the C tank farm as a whole, this analysis also includes an evaluation of long-term risk for the balance of the C farm tanks.

Groundwater is considered the principal pathway (excluding inadvertent intrusion) for post-remediation human exposure to tank waste at compliance points at and beyond the tank farm boundary. The exposure pathways used in this assessment are therefore based on withdrawal and use of groundwater via wells. Only the human health effects from the use of the groundwater are considered; the well drilling activity itself is assumed but not explicitly evaluated as a component of the exposure scenarios.

The groundwater concentrations used in this analysis are estimated by extrapolating from the results of the fate and transport analysis performed at the nearby AX tank farm for DOE/RL-98-72. Those results are scaled, based on the inventory differences between the AX and C tank farm source terms, to estimate the groundwater concentration of contaminants of concern (CoCs) at the C tank farm boundary. The scaling approach is based on the proximity of the C tank farm to the AX tank farm and on similarities in their vadose zone properties, conceptual site model, and source term release mechanisms. This approach has been applied in two previous C tank farm analyses starting with a tank C-106 post-retrieval residual waste assessment (*Data to Support Tank C-106 Waste Retrieval Determination* [RPP-6696]) and

continuing with a tank C-104 retrieval performance evaluation (HNF-7643). The HNF-7643 was issued first as a stand-alone document and then subsequently incorporated into *Single-Shell Tank C-104 Full Scale Sludge/Hard Heel, Confined Sluicing and Robotics Technologies Waste Retrieval Demonstration Functions and Requirements* (RPP-7807) to fulfill requirements of Milestone M-45-03-T04 of the *Hanford Federal Facility and Consent Order* (HFFACO; Ecology et al. 1989). The technical rationale for the scaling approach is summarized in this appendix and described in detail in RPP-6696 and HNF-7643.

A.2.0 CONCEPTUAL MODEL

The basic conceptual model of the C tank farm used for this assessment is consistent with that presented in HNF-7643 and represents the following.

- The C tank farm including all tanks and soils within the tank farm boundary and from the surface to the groundwater.
- Releases to the environment from residual waste potentially remaining in the tank farm following completion of waste retrieval and assumed closure actions.
- Long-term degradation of the tanks and assumed tank closure system.
- Migration of mobile contaminants from the tank farm through the vadose zone and groundwater.
- Human exposure under residential farmer and industrial scenarios and resulting human health impacts from contaminants that have migrated to the tank farm boundary.

A.3.0 USE OF EVALUATION CASES

Three evaluation cases covering a range of assumed residual waste volumes in the C farm tanks are evaluated.

- Current state (tanks closed with current waste inventories in place)
- Retrieval to the goals of the HFFACO
- Retrieval to 10% of the goals of the HFFACO.

Two additional evaluation cases are included for tank C-106:

- Risks associated with the inventory of contaminants estimated to exist in tank C-106 prior to sluicing under Project W-320
- Liquid removal only.

Retrieval to the HFFACO goals is evaluated using a residual waste volume equal to the volume goal identified in HFFACO Milestone M-45-00, or 360 ft^3 (10,200 L [2,700 gal]) in the 100-Series tanks and 30 ft^3 (850 L [220 gal]) in the 200-Series tanks. Retrieval to 10% of the HFFACO goals is evaluated using 10% of the HFFACO Milestone M-45-00 residual waste

volume goals, or 36 ft^3 (1,020 L [270 gal]) and 3 ft^3 (85 L [22 gal]) in the 100- and 200-Series tanks, respectively.

A single baseline closure scenario, consistent with the landfill closure scenario evaluated in the DOE/RL-98-72 analysis, is assumed for each case. This closure scenario involves the addition of stabilizing tank fill (gravel) and placement of a modified *Resource Conservation and Recovery Act of 1976* (RCRA) Subtitle C closure barrier. No risk mitigation agents (either in-tank or ex-tank) are assumed to be used. The principal variable among the three cases is the volume of waste retrieved (evaluated as residual waste volume).

The overall evaluation approach is to calculate peak long-term risks for each tank under each of the waste retrieval cases. The results for the five candidate tanks are discussed individually and as a group. The results for the balance of the C farm tanks also are presented and the candidate tank contributions are discussed in the context of the C tank farm as a whole.

A.4.0 CONTAMINANTS OF CONCERN

The best-basis inventory (BBI 2002) currently reports approximately 46 radionuclides and 25 chemicals in the C farm tanks. Not all of these contaminants are of interest for long-term human health risk. Many have a strong tendency to sorb to subsurface sediment and would decay to insignificant levels before reaching the receptor or would move so slowly they would not reach the receptor within the time period of interest. CoC selection for this analysis is therefore based on selecting just the subset of contaminants that have been shown through previous analysis to dominate long-term human health risks.

The CoCs for this evaluation are consistent with those used in HNF-7643. Those CoCs are as follows.

- **Radionuclides**: carbon-14, selenium-79, technetium-99, iodine-129, and uranium isotopes -233, -234, -235, -236, and -238.

- **Chemicals**: nitrite, nitrate, chromium, and total uranium.

This CoCs subset was selected for inclusion in HNF-7643 based on a screening analysis in DOE/RL-98-72 that indicated these constituents would be highly mobile in the vadose zone and groundwater and would contribute approximately 95% of the total groundwater pathway long-term human health risk. Inventory estimates could not be developed for cyanide and ethylenediaminetetraacetic acid (EDTA) because cyanide and EDTA are not routinely analyzed for and are not part of the BBI standard list of constituents (BBI 2002). The EDTA is present in the estimated past leak inventory for several C farm tanks; however, no scaling factor could be developed for EDTA in the past leak source term because EDTA was not present in the past leak inventory for AX tank farm. Additionally, chromium has been identified as a CoC in the RCRA facility investigation/corrective measures study process and is included as a CoC in this analysis. The chemical CoCs for this evaluation therefore consist of nitrite, nitrate, chromium, and total uranium (evaluated as a chemical toxicant).

A.5.0 SOURCE TERM

The methodology used for this assessment considers the residual waste source term to be the primary driver for long-term human health risks. This approach is consistent with current project planning assumptions on the use of a generally dry retrieval technology, such as the mobile retrieval system (MRS). With the MRS, very little, if any, additional fluid would be added to a tank during waste retrieval. For this reason a retrieval leak source term is not evaluated. A past leak source term is not explicitly evaluated; however, in evaluating risk at the tank farm level to address risk allocation the past leak source term is considered by incorporation from a previous analysis. Inventory estimates are developed for each CoC in each of four source term components.

- Current waste in tanks
- Residual waste in tanks after removal to HFFACO goals
- Residual waste in tanks after removal to 10% of HFFACO goals
- Past tank leaks.

Inventory estimates are also developed fro each CoC in the source term components for the two additional tank C-106 evaluation cases:

- Waste in tank C-106 prior to the Project W-320 sluicing retrieval
- Residual waste in tank C-106 after removal of liquids only.

A summary of the method used to develop each of the source terms is provided in the following subsections.

A.6.0 CURRENT WASTE INVENTORY ESTIMATES

Estimates of each tank's current CoC inventory are taken directly from an April 2002 query of the tank waste information network system (TWINS) online database (BBI 2002). Current BBI values obtained from this query are used to represent each tank's residual waste source term under the no-retrieval case. These estimates are assumed to represent the residual waste remaining in the tanks after all closure actions are completed. Current BBI values are also used as the starting point for developing residual waste source terms under the HFFACO and 10% HFFACO retrieval cases and the tank C-106 liquids-only retrieval case. Current BBI values are shown in the calculation detail presented in Section A.9.0.

A.7.0 RESIDUAL WASTE INVENTORY ESTIMATES

As discussed in the previous section, residual waste CoC inventories for the no-retrieval case are assumed to be equal to each tank's current waste inventory (BBI 2002). For the HFFACO retrieval case, CoC inventory estimates for the residual waste in tank C-106 and the remaining C 100-Series tanks are calculated based on an assumed residual waste volume equal to 10,200 L (2,700 gal [360 ft^3]). For the C 200-Series tanks, residual waste CoC inventories for the HFFACO retrieval case are calculated based on an assumed residual waste volume equal to 850 L (220 gal [30 ft^3]). For the 10% HFFACO retrieval case, residual waste inventories are

calculated based on assumed residual waste volumes of 1,020 L (270 gal [36 ft^3]) and 85 L (22 gal [3 ft^3]) for the 100- and 200-Series tanks, respectively.

For tanks C-106 and C-103, the BBI gives separate inventory estimates for supernatant and sludge waste fractions. For the C 200-Series tanks and the remaining C 100-Series tanks, the BBI gives only sludge inventory estimates, as there is no supernatant fraction in these tanks. For this analysis it is assumed that the post-retrieval residual waste remaining in all tanks has the CoC composition of the current BBI sludge fraction. This assumption is consistent with the current project planning assumptions on the use of the MRS. It is assumed that with this type of retrieval technology all significant quantities of supernatant present in a tank will be removed during the initial waste retrieval stages, prior to commencing with the removal of significant quantities of sludge. In calculating the residual waste inventories for the HFFACO and 10% HFFACO retrieval cases, it is assumed that little if any retrieval fluid is added; therefore, no adjustment is made to account for solubility variations in the sludge components.

Residual waste CoC inventory estimates are calculated in the HFFACO and 10% HFFACO retrieval cases by multiplying the current BBI sludge inventories by the ratio of the assumed residual waste volume to the current BBI sludge volume for each tank. For example, for tank C-106, the current BBI sludge volume estimated is 23,000 L (6,000 gal [800 ft^3]). To obtain the HFFACO retrieval case inventories, the current tank C-016 BBI sludge inventories are multiplied by the ratio 360/800 (0.45). To obtain the 10% HFFACO retrieval case inventories, the current tank C-106 BBI sludge inventories are multiplied by 0.045. A similar procedure is followed for the other C 100-Series tanks.

For the C 200-Series tanks the methodology is analogous to the method used for the 100-Series tanks. For tanks C-201 and C-202, which contain approximately 3,800 L (1,000 gal [130 ft^3]) of sludge each, the volume ratio for the HFFACO retrieval case is 30/130 (0.23) and for the 10% HFFACO retrieval case is 0.023. For tanks C-203 and C-204, which contain approximately 11,000 L (3,000 gal [400 ft^3]) of sludge each, the volume ratio is 30/400 (0.075) for the HFFACO retrieval case and 0.0075 for the 10% HFFACO retrieval case.

Under Project W-320, approximately 97% (187,000 gal out of 192,000 gal) of the waste in tank C-106 was sluiced to tank AY-102 over the period November 1998 to October 1999 using a fixed-position sluicing system. The pre-Project W-320 evaluation case represents a hypothetical case of closing tank C-106 prior to the Project W-320 sluicing retrieval. This case is a non-viable historical case provided as a baseline for comparison purposes only. The post-closure residual waste CoC inventory values for this case are assumed to equal the values reported in *Tank Characterization Report for Single-Shell Tank 241-C-106* (WHC-SD-WM-ER-615), released September 30, 1998, which was the most recent revision of the tank C-106 BBI issued prior to the Project W-320 sluicing retrieval.

The tank C-106 liquid-only retrieval case represents a hypothetical case of closing tank C-106 after retrieving all of the supernatant but none of the solids. Tank C-106 is currently (April 2002 BBI) reported to contain approximately 23,000 L (6,000 gal) of solids (designated as Sludge/AR Solid) and 114,000 L (30,000 gal) of liquids (designated as Supernatant/AR Liquid). The

post-closure residual waste CoC inventory values for this case are assumed to equal the BBI values reported for the 23,000 L (6,000 gal) of tank solids.

CoC inventory estimates for all evaluation cases are shown in the calculation detail presented in Section A.9.0.

A.8.0 RETRIEVAL LEAKAGE INVENTORY ESTIMATES

The four C 200-Series tanks as well as three of the C 100-Series tanks are classified as assumed leakers (*Waste Tank Summary Report for Month Ending January 31, 2002* [HNF-EP-0182]). During fluid-based waste retrieval, it is possible that some additional waste could leak from these tanks, or even from the tanks (such as tank C-106) currently classified as sound. However, for purposes of this analysis, it is assumed that retrieval is performed with a low-liquid retrieval method such as the MRS and there is therefore no leakage loss from any tank during retrieval.

A.8.1 PAST LEAK INVENTORY ESTIMATES

The analysis places primary emphasis on the residual waste source term. However, in evaluating long-term risk at the tank farm level to address the issue of risk allocation, the risk contribution from the past leak source term is also considered. The risk budget available for the residual waste source term must account for the portion of the risk threshold (e.g., 1.0×10^{-5}) made unavailable because of the past leak source term. Estimates of C tank farm past leak inventories and associated long-term risks are provided in HNF-7643. For this assessment, the HNF-7643 past leak risks are incorporated without modification or additional analysis.

Current records indicate that seven tanks in the C tank farm (C-101, C-110, C-111, and the four C 200-Series tanks) are classified as assumed leakers (HNF-EP-0182). The HNF-7643 analysis used best estimate inventories taken from recent work conducted to develop inventory estimates for past leaks in support of the Systems Assessment Capability (*Hanford Soil Inventory and Uncertainty Model* [LA-UR-00-4050]). The methodology was based on available process information regarding the type of waste that was stored in the tank or that was transferred at the time the leaks were believed to have occurred. The tank waste releases were estimated based on location, timing, and leak volume information. The leak compositions were defined using Hanford defined waste model waste streams (*Hanford Defined Wastes: Chemical and Radionuclide Compositions* [LA-UR-96-3860]) and the supernatant mixing model subroutine as a function of time (LA-UR-00-4050). Details of the past leak inventory calculations are provided in HNF-7643.

A.9.0 TRANSPORT

The long-term human health risk assessments performed for DOE/RL-98-72 and *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* (DOE/EIS-0189) have assumed that the long-term risk arising from tank remediation and closure is solely associated with the groundwater transport pathway (i.e., risk from withdrawal and use of groundwater contaminated by tank waste). In addition, the groundwater transport pathway assumption has been adopted for risk assessments supporting Hanford Site composite analyses (*Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau*

of the Hanford Site [PNNL-11800], *Groundwater/Vadose Zone Integration Project System Assessment Capability* [BHI-01365]), RCRA past leak investigations at the S-SX waste management area (*Field Investigation Report for Waste Management Area S-SX* [RPP-7884]), and RPEs for retrieval demonstration functions and requirements for tank C-104 (RPP-7807), tank S-112 (*Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements* [RPP-7825]), and tank S-102 (*241-S-102 Initial Waste Retrieval Project Functions and Requirements* [RPP-10901]). The methodology for this evaluation also adopts the groundwater pathway assumption.

Groundwater is the medium of interest because tank waste contaminants remaining onsite following closure are anticipated to be isolated in the subsurface below the plant-rooting zone and will not be accessible (except for inadvertent intrusion) through the air or soil transport pathways. DOE/EIS-0189 and DOE/RL-98-72 analyses determined that the most credible pathway for post-remediation human contact with tank waste would be for the waste to dissolve in infiltrating precipitation and be transported through the vadose zone to groundwater, where it would be withdrawn from a well and used by a receptor. Because the groundwater pathway is currently not used at the Hanford Site, exposure would occur only to a future site user after the loss of institutional controls.

For the DOE/RL-98-72 and DOE/EIS-0189 analyses, concentration predictions were generated with the use of sophisticated vadose zone and groundwater numerical models. Use of sophisticated models may be required for several reasons. For the DOE/RL-98-72 and DOE/EIS-0189 analyses, the uncertainty in the impact analysis needed to be understood and minimized. This will likely be the case for tank farm final closure decisions; but, to support the initial decisions for a closure demonstration project, it is anticipated that a higher level of uncertainty can be tolerated. Acceptance of greater uncertainty may be justified at this stage because the estimated impacts from this assessment can be revisited using characterization data collected as the project moves forward. A rigorous contaminant transport assessment will be required to support the final closure process after retrieval decisions are implemented for the remaining C farm tanks. For these reasons, the approach for this evaluation involves scaling groundwater concentrations from the results of the modeling-based groundwater analysis completed for DOE/RL-98-72.

The C and AX tank farm locations are separated by less than half a kilometer and the hydrostratigraphic framework underlying the two tank farms is very similar. A detailed comparison of the subsurface conditions between the AX and C tank farms that potentially affect scaling impact assessment results is provided in RPP-6696. Vadose zone contaminant transport modeling conducted for DOE/EIS-0189 indicated no significant differences in time to contaminant first arrival at the water table and time to contaminant peak concentration for the two tank farms. Scaling factors derived from the AX tank farm modeling results are therefore assumed to provide a reasonable basis for developing C tank farm groundwater concentration estimates.

A.9.1 AX TANK FARM CONTAMINANT TRANSPORT MODELING

The groundwater impact assessment approach used in the AX tank farm RPE (DOE/RL-98-72) was based in part on two calculations. First the contaminant flux downward through the vadose zone associated with releases from the tanks was calculated. Then, this contaminant flux was input into one finite volume element of a sitewide groundwater flow and transport model to calculate the movement and concentration of the contaminants in the groundwater from the vicinity of the tanks to the Columbia River. The sitewide model was constructed with a finite volume grid spacing of 250 m by 250 m (820 ft by 820 ft). The AX tank farm consists of four tanks with a layout of approximately 90 m by 90 m (300 ft by 300 ft). The contaminant flux through the vadose zone was then input into the finite volume element that was directly beneath the AX tank farm. The larger C tank farm consists of 12 large tanks and 4 small tanks with a layout of approximately 120 m by 150 m (400 ft by 500 ft). Because the C tank farm impacts are scaled from the AX tank farm results, the flux from this tank farm is also effectively input onto a 250 m by 250 m (820 ft by 820 ft) volume element in the sitewide groundwater model.

As described in Section 3.5 of DOE/RL-98-72, the approach to assessing the groundwater impacts for releases from the AX tank farm began with developing vadose zone and saturated zone conceptual models and associated assumptions based on best available data and analysis. The next step, using these conceptual models as a basis, was to determine uncertainty and the most sensitive parameters for the complete pathway beginning with the source and ending with the calculated risk. This step focused efforts on near-term data collection and numeric model development. Based on the best available data, information learned from model application in the SX tank farm and screening-level analysis numeric models for the AX tank farm, vadose zone and groundwater models were developed. After this step, the migration of contaminants through the vadose zone and groundwater was calculated for various strategies and options. This approach was intended to be iterative such that analysis would be updated when additional data become available, and these in turn would be used to focus the subsequent data collection efforts on the most important data.

Individual calculations (i.e., numerical model simulations) were performed for the following AX tank farm contaminant source terms:

- Contamination already released to the vadose zone from past tank leaks and spills
- Future waste retrieval leakage releases
- Tank and ancillary equipment waste residual releases.

The calculated contaminant flux through the vadose zone from each of these sources was used as input to a sitewide two-dimensional groundwater flow model that calculated the contaminant concentrations in the unconfined aquifer at selected time periods over a 10,000-year period. The fact that the groundwater impacts from each of the three AX tank farm source terms were calculated separately enables the evaluation of the AX tank farm results for the specific contaminant inventory scenarios associated with the C tank farm.

The PORFLOW numerical model (PORFLOW: A Multifluid Multiphase Model for Simulating Flow, Heat Transfer, and Mass Transport in Fractured Porous Media, User's Manual –

Version 2.41 [NUREG/CR-5991]) was used to implement the calculation of flow and transport in the vadose zone and saturated zone (i.e., the unconfined aquifer or groundwater). The PORFLOW model numerically solves a variable set of equations for general transport, multi-phase pressure, and one or more chemical species. The governing equations are supplemented by constitutive equations, phase-change relations, equations of state, and initial and boundary conditions. Numerical implementation of the vadose zone flow and transport portion of the problem was based on the vadose zone conceptual model specifically developed for conditions known or assumed for the AX tank farm.

The saturated zone (groundwater) conceptual model is a working model describing the horizontal flow and transport of contaminants from the point where they reach the unconfined aquifer immediately below the AX tank farm to where they reach a receptor or are discharged to the Columbia River. The conceptual groundwater model used for the AX tank farm impact assessment was modified from a composite analysis of the Hanford Site central plateau (PNNL-11800). The PNNL-11800 study uses a three-dimensional transient flow and transient transport model for groundwater flow and transport (*Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report* [PNL-10886]; *Tritium Monitoring in Groundwater and Evaluation of Model Predictions for the Hanford Site 200 Area Effluent Treatment Facility* [PNNL-11665]; *Three-Dimensional Analysis of Future Groundwater Flow Conditions and Contaminant Plume Transport in the Hanford Site Unconfined Aquifer System: FY 1996 and 1997 Status Report* [PNNL-11801]). In general, the hydraulic and transport parameters adopted for the AX tank farm groundwater model can be traced back to the site groundwater model used in PNNL-11800, although implementation is significantly different. The numerous strategies that required analyses coupled with a long-term period of interest (10,000 years) necessitated an approach that was computationally efficient yet provided the appropriate level of detail. Numerical implementation and testing of both the AX tank farm vadose zone and groundwater model are provided in Appendix B of DOE/RL-98-72.

A.9.2 USE OF SCALING APPROACH TO ESTIMATE C TANK FARM GROUNDWATER CONCENTRATIONS

The first step in the scaling methodology is to develop scaling factors based on the DOE/RL-98-72 transport modeling results. The scaling factors are constituent-specific factors calculated from the input and output data from the DOE/RL-98-72 analysis. These factors are expressed as the peak groundwater CoC concentration at the receptor per unit inventory released at the source (Ci/mL per Ci for radionuclides, g/mL per g for chemicals) and are calculated using the following expression.

$$K^{i}_{S(x,y,t)} = \frac{C^{i}_{S(x,y,t)}}{I^{i}_{S(AX)}} \qquad \text{(A-1)}$$

Where:

$K^{i}_{S(x,y,t)}$ = scaling factor for contaminant i released from source term S at calculation point x,y,t

$C^{i}_{S(x,y,t)}$	=	groundwater concentration of contaminant *i* from source term *S* (DOE/RL-98-72 model output) at calculation point *x,y,t*
$I^{i}_{S(AX)}$	=	initial source inventory of contaminant i released from source term *S* (DOE/RL-98-72 model input)
x,y	=	horizontal location coordinates
t	=	time.

The DOE/RL-98-72 groundwater concentrations used to calculate the scaling factors are taken at the model volume element beneath the AX tank farm at the time of peak human health risk from residual waste over the 10,000-year analysis period. Risks calculated with these scaling factors are therefore assumed to provide peak 10,000-year risks for an equivalent volume element beneath the C tank farm. For purposes of this analysis, these risks can be considered equivalent to the risks that would occur at the tank farm boundary. Peak risks are projected to occur in the DOE/RL-98-72 analysts at 2,600 years from the present.

Groundwater impact and long-term risk results are presented in DOE/RL-98-72 using profiles (e.g., risk versus time curves) and contour maps (i.e., isopleth plots showing the location and distribution of risk levels at selected times). Profile and contour map presentation methods are useful for illustrating impact trends in time and space. From a regulatory perspective, however, post-closure performance is generally evaluated based on a peak value at a point of compliance. Because profiles and contour maps are computationally intensive to prepare and provide more information than is anticipated to be necessary, the methodology for this evaluation involves generating peak values only.

The DOE/RL-98-72 modeling results are broken out separately for past leak, retrieval leak, and residual waste source terms. This approach allows development of source-term-specific scaling factors. Because this evaluation focuses on residual waste, the scaling factors used are calculated from the DOE/RL-98-72 residual waste source term data. In the DOE/RL-98-72 analysis, separate inventory estimates are developed for AX tank farm residual waste and ancillary equipment. For modeling purposes, the ancillary equipment inventory was as simulated as additional residual tank waste. The residual waste inventories used in the scaling factor calculations are therefore the sum of the inventories reported in DOE/RL-98-72 for the AX tank farm residual waste and ancillary equipment. The DOE/RL-98-72 analysis evaluates three residual waste release cases involving residual waste volumes of 1,020; 10,200; and 102,000 L (270; 2,700; and 27,000 gal) per tank. A set of contaminant-specific scaling factors is generated from each DOE/RL-98-72 release case for use in this evaluation. The scaling factors are shown in Table A.1.

Table A.1. Residual Waste Source Term Scaling Factors

CoC	Ancillary Equipment Inventory[a] (Ci or g)	36 ft³ (270 gal)			360 ft³ (2,700 gal)			3,600 ft³ (27,000 gal)		
		Initial Source Inventory[a] (Ci or g)	Max Groundwater Concentration at 2,600 yr[b] (Ci/mL or g/mL)	Scaling Factor (Ci/mL per Ci or g/mL per g)	Initial Source Inventory[a] (Ci or g)	Max Groundwater Concentration at 2,600 yr[b] (Ci/mL or g/mL)	Scaling Factor (Ci/mL per Ci or g/mL per g)	Initial Source Inventory[a] (Ci or g)	Max Groundwater Concentration at 2,600 yr[b] (Ci/mL or g/mL)	Scaling Factor (Ci/mL per Ci or g/mL per g)
I-129	4.69E-04	1.02E-03	1.65E-20	1.61E-17	6.02E-03	9.69E-20	1.61E-17	6.85E-02	3.36E-19	4.91E-18
C-14	3.51E-02	7.65E-02	8.93E-19	1.17E-17	4.49E-01	4.11E-18	9.15E-18	4.83E+00	2.28E-17	4.73E-18
U-233	9.80E-04	9.80E-04	2.47E-25	2.52E-22	9.80E-04	2.47E-25	2.52E-22	5.13E-01	1.19E-20	2.32E-20
U-234	2.03E-03	2.32E-03	1.14E-20	4.92E-18	4.90E-03	2.55E-20	5.21E-18	1.10E-01	1.16E-19	1.05E-18
U-235	8.21E-05	9.38E-05	4.74E-22	5.05E-18	1.99E-04	1.07E-21	5.38E-18	4.42E-03	4.90E-21	1.11E-18
U-236	9.01E-05	1.02E-04	4.90E-22	4.80E-18	2.10E-04	8.83E-22	4.20E-18	3.61E-03	3.37E-21	9.33E-19
U-238	1.81E-03	2.07E-03	1.04E-20	5.02E-18	4.42E-03	2.42E-20	5.48E-18	1.41E-01	1.17E-19	8.31E-19
Se-79	9.40E-02	2.04E-01	1.08E-15	5.29E-15	1.15E+00	6.01E-15	5.21E-15	2.76E+00	1.58E-14	5.72E-15
Tc-99	2.42E-01	5.28E-01	3.01E-15	5.70E-15	3.10E+00	1.69E-14	5.45E-15	4.09E+01	1.71E-13	4.18E-15
Cr(VI)[c]	NR	NR	NR	5.38E-12	NR	NR	5.46E-12	NR	NR	3.97E-12
NO2+NO3	2.85E+02	7.99E+02	4.30E-09	5.38E-12	4.72E+03	2.58E-08	5.46E-12	6.77E+04	2.69E-07	3.97E-12
U(Total)[d]	NR	NR	NR	5.02E-18	NR	NR	5.48E-18	NR	NR	8.31E-19

[a] Source = DOE/RL-98-72, Table A.3.1. Initial source inventory values are the sum of tank residual and ancillary equipment inventories.
[b] Source = DOE/RL-98-72 model output data files (AX RPE Residuals.xls).
[c] Chromium (VI) is not a CoC for the DOE/RL-98-72 analysis. The NO2+NO3 scaling factor is used as a surrogate for the Chromium (VI) scaling factor.
[d] Uranium (total) is not a CoC for the DOE/RL-98-72 analysis. The U-238 scaling factor is used as a surrogate for the Uranium (total) scaling factor.

NR = not reported in DOE/-RL-98-72
CoC = contaminant of concern

C tank farm groundwater concentrations are obtained by multiplying the CoC inventories in each C farm tank under each of the evaluation cases by the corresponding scaling factors. The scaling factor is interpolated from the DOE/RL-98-72 volume case (1,020; 10,200; and 102,000 L [270; 2,700; and 27,000 gal]) nearest to each tank's assumed residual waste volume. For residual waste volumes greater than 102,000 L (27,000 gal), it is assumed that the scaling factor remains constant at the value for the 10,200 L (27,000 gal) case (i.e., the relationship between Ci released at the source and resulting peak groundwater concentration is assumed to level off rather than climb indefinitely).

Scaling groundwater concentrations from the DOE/RL-98-72 analysis to the C tank farm introduces greater uncertainty into the risk assessment. The AX tank farm consists of 4 tanks while the C tank farm consists of 12 large tanks and 4 small tanks. The two-dimensional contaminant transport model developed for the AX tank farm vadose zone consisted of two half tanks. The residual waste inventory was aggregated into these two half tanks. Because of the areal differences, scaling the AX tank farm analysis results to the C tank farm could underestimate contaminant concentrations in the groundwater. Additionally, because of the size of the C tank farm, one would not expect a receptor located at any point along the tank farm boundary to be in a position to intercept contaminant plumes from all tanks at the same time.

A.10.0 EXPOSURE

Exposure scenarios describe the route and method by which the CoCs in the source term would come in contact with and/or enter the human body. The exposure scenarios used for this evaluation are taken from the DOE/EIS-0189 analysis and include the residential farmer and industrial worker scenarios. Both scenarios were adapted for use in DOE/EIS-0189 from scenarios described in *Hanford Site Risk Assessment Methodology* (DOE/RL-91-45). Both scenarios involve groundwater pathway exposures based on hypothetical future land uses and activities. These scenarios are the same two scenarios evaluated in the RPE risk evaluations for the retrieval demonstration functions and requirements for tank C-104 (RPP-7807), tank S-112 (RPP-7825), and tank S-102 (RPP-10901).

It is important to note that both exposure scenarios require an assumption that groundwater wells are drilled at the downgradient C tank farm boundary and used as a water supply for the receptors.

A.10.1 RESIDENTIAL FARMER SCENARIO

The residential farmer scenario represents exposures associated with the use of the land for residential and agricultural purposes. This scenario is a slight modification to the residential scenario described in DOE/RL-91-45; it includes all the exposure pathways for the residential scenario plus most of the food ingestion pathways described in the DOE/RL-91-45 agriculture scenario. The residential farmer scenario includes using groundwater for drinking water (ingestion rate of 2L/day [0.5 gal/day]) and other domestic uses as well as for irrigation to produce and consume animals, vegetables, and fruit products. The exposures are assumed to be continuous. A composite adult is used as the receptor for some of the exposure pathways. The composite adult is evaluated using child parameters for 6 years and adult parameters for

24 years, with total exposure duration of 30 years. Body weights of 16 kg (35 lb) for a child and 70 kg (150 lb) for an adult and a lifetime of 70 years are assumed.

A.10.2 INDUSTRIAL WORKER SCENARIO

The industrial worker scenario represents exposures to workers in a commercial or industrial setting. The receptors are adult employees assumed to work at a location for 20 years. A body weight of 70 kg (150 lb) and a lifetime of 70 years are assumed. The scenario involves mainly indoor activities, although outdoor activities (e.g., soil contact) also are included.
The groundwater exposure pathways for this scenario include drinking water ingestion (1 L/day [0.2 gal/day]), dermal absorption during showering, shower-water ingestion, and inhalation. These exposures would not be continuous because the worker would go home at the end of each workday (i.e., after 8 hours). The scenario is intended to represent nonremediation workers who do not wear job-specific personal protective equipment.

A.11.0 RISK

Long-term human health risk is calculated using a unit risk factor (URF) approach consistent with the approach used for the DOE/EIS-0189 and DOE/RL-98-72 analyses. A URF is the risk associated with exposure to one concentration unit (e.g., risk per Ci/mL for radionuclides in groundwater) of a given contaminant in a given exposure medium for a given human exposure scenario.

The URF values used in DOE/RL-98-72 and DOE/EIS-0189 are based on the summation of all relevant exposure pathways (i.e., ingestion, inhalation, dermal contact, and direct radiation exposure) for a given exposure scenario and are calculated based on the summary intake factors concept presented in DOE/RL-91-45. A detailed discussion of the calculation of unit risk factors is presented in Appendix D of DOE/EIS-0189. This assessment uses the same URFs and calculation approach as used for DOE/RL-98-72 and DOE/EIS-0189. The only significant difference in approach is that groundwater concentrations for this assessment are generated using scaling factors instead of model simulations.

Risk is calculated in the URF approach as the product of the URF and the contaminant concentration at the receptor for the exposure medium of interest. As previously discussed, the exposure medium of interest is groundwater and the contaminant concentration values used are scaled from the results of the DOE/RL-98-72 analysis. The URF values are contaminant- and scenario-specific groundwater URFs taken from Appendix D of DOE/EIS-0189. The URFs for the industrial worker and residential farmer scenarios are listed in Table A.2.

Table A.2. Groundwater Pathway Unit Risk Factors

Constituent	Units	Industrial Worker[a]	Residential Farmer[b]
C-14	ILCR per Ci/mL	5.23E+06	6.06E+08
I-129	ILCR per Ci/mL	9.33E+08	1.29E+10
Se-79	ILCR per Ci/mL	3.22E+07	2.87E+08
Tc-99	ILCR per Ci/mL	7.11E+06	2.61E+08
U-233	ILCR per Ci/mL	3.03E+08	1.38E+09
U-234	ILCR per Ci/mL	3.00E+08	1.34E+09
U-235	ILCR per Ci/mL	2.98E+08	1.37E+09
U-236	ILCR per Ci/mL	2.85E+08	1.27E+09
U-238	ILCR per Ci/mL	2.84E+08	1.28E+09
NO2	HQ per g/mL	9.92E+03	3.73E+04
NO3	HQ per g/mL	6.20E+03	7.59E+06
Cr	HQ per g/mL	3.31E+06	1.14E+07
U (Total)	HQ per g/mL	3.52E+06	1.41E+07

[a] Source = DOE/EIS-0189, Appendix D, Tables D.2.1.21 and D.2.1.23.
[b] Source = DOE/EIS-0189, Appendix D, Tables D.2.1.18 and D.2.1.20.
HQ = hazard quotient.
ILCR = incremental lifetime cancer risk.

The basic expression for risk using a URF approach is:

$$R_{S(x,y,t)} = \sum C^{i}_{S(x,y,t)} \cdot URF^{i}_{R} \qquad \text{(A-2)}$$

Where:

$R_{S(x,y,t)}$ = risk from source term S at point of compliance x,y,t

$C^{i}_{S(x,y,t)}$ = groundwater concentration at point of compliance x,y,t for contaminant i released from source term S

URF^{i}_{R} = groundwater URF for contaminant i and receptor scenario R

x,y = horizontal location coordinates

t = time.

The summation in Equation A-2 represents the addition of contributions from all CoCs in a given source term. The addition of contributions from each source term gives the total or composite risk for a given tank. Only the residual waste source term is calculated for this analysis, although the past leak contribution is considered by incorporation from a previous analysis. The addition of total risks from all tanks gives the total risk for the tank farm.

The human health impact measures given by the URFs constitute the ILCR for radionuclides and carcinogenic chemicals, and hazard index (sum of individual hazard quotients) for non-carcinogenic chemicals. The ILCRs differ from the LCFs calculated in the short-term risk analysis in that ILCRs are total cancers (nonfatal and fatal) where LCFs are fatal cancers.

An ILCR is an estimate of the increased probability of an individual developing cancer over an assumed 70-year lifetime from exposure to radionuclides or nonradioactive carcinogenic chemicals. An ILCR is considered incremental in that it represents the increase in risk beyond that related to natural background conditions. The CoCs for this assessment do not include any nonradioactive carcinogenic chemicals; therefore, the ILCR calculations are based on the sum of the risk contributions from the radionuclide CoCs only. Although hexavalent chromium is classified as carcinogenic by inhalation, carcinogenic impacts from hexavalent chromium would apply only for airborne releases from a facility, or for suspension of surface contamination. Because groundwater is the only exposure medium considered in this assessment, neither of these exposure routes applies and hexavalent chromium is treated as an ingestion toxicant.

There is no universal standard for the level of risk that is considered acceptable. Generally acceptable exposure levels, suggested by Federal ("National Oil and Hazardous Substances Pollution Contingency Plan" [55 FR 8666] and "National Oil and Hazardous Substances Pollution Contingency Plan" [40 CFR 300]) and State ("The Model Toxics Control Act Cleanup Regulation" [WAC 173-340]) standards for known or suspected carcinogens, are those that represent an ILCR in the range of 1.0×10^{-4} and 1.0×10^{-6}, which indicates a probability of 1 in 10,000 to 1 in 1,000,000, respectively. Washington State generally sets the upper limit of risk at 1.0×10^{-5} (1 in 100,000 probability). An ILCR of 1.0 means that an individual's lifetime probability of developing cancer approaches 100%.

Toxic effects from exposure to non-carcinogenic chemicals are evaluated in terms of a hazard index, which is the ratio of chemical intake to a reference dose below which no adverse health effects would be expected. The hazard index calculations are based on the sum of the toxic effects contributions from the non-carcinogenic chemical CoCs. For a hazard index greater than 1.0, adverse health effects would be expected. For a hazard index less than 1.0, no adverse health effects would be expected. A health effect could be fatal or it could be a minor temporary effect on the human body, depending on the specific chemical and the amount of exposure involved.

A.12.0 RESULTS

Tables A.3 and A.4 summarize the analysis results for the residential farmer and industrial worker exposure scenarios, respectively, for the three evaluation cases that involve all five candidate closure demonstration tanks. Both tables show the estimated peak ILCR and hazard index for the five candidate closure demonstration tanks, both individually and in combination, under each of the three evaluation cases considered. The tables also summarize the analysis results for the balance of the C farm tanks and the C tank farm as a whole. Table A.5 summarizes the analysis results for the two additional tank C-106 evaluation cases. The calculation detail for the summary results shown in Tables A.3 through A.5 is shown in Tables A.6 and A.7. The calculation detail indicates that, for the five candidate closure

demonstration tanks and the C tank farm as a whole, the ILCR is driven primarily by technetium-99 and selenium-79 and the hazard index is driven by nitrate, nitrite, and chromium.

Table A.3. Summary of Peak Residential Farmer Long-Term Human Health Risks at C Tank Farm Fenceline From Residual Waste Source Term

Tank or Tank Combination	Impact Measure	No Retrieval	HFFACO Retrieval	10% HFFACO Retrieval
C-106	ILCR	3.90E-06	8.36E-07	8.69E-08
	HI	5.12E-02	3.28E-03	3.24E-04
C-201	ILCR	2.20E-08	4.65E-09	4.67E-10
	HI	1.12E-02	2.32E-03	2.31E-04
C-202	ILCR	2.30E-08	4.85E-09	4.87E-10
	HI	3.52E-02	7.29E-03	7.28E-04
C-203	ILCR	4.28E-08	3.72E-09	3.74E-10
	HI	4.52E-02	3.71E-03	3.70E-04
C-204	ILCR	2.75E-08	2.39E-09	2.40E-10
	HI	2.91E-02	2.39E-03	2.39E-04
C-200 Tanks Total	ILCR	1.15E-07	1.56E-08	1.57E-09
	HI	1.21E-01	1.57E-02	1.57E-03
C-106 Plus C-200 Tanks	ILCR	4.01E-06	8.52E-07	8.84E-08
	HI	1.72E-01	1.90E-02	1.89E-03
Balance of C-100 Tanks	ILCR	4.23E-04	1.06E-05	1.11E-06
	HI	1.79E+01	4.97E-01	4.90E-02
C Tank Farm Total	ILCR	4.27E-04	1.15E-05	1.20E-06
	HI	1.81E+01	5.16E-01	5.09E-02

ILCR = incremental lifetime cancer risk
HI = hazard index

Table A.4. Summary of Peak Industrial Worker Long-Term Human Health Risks at C Tank Farm Fenceline From Residual Waste Source Term

Tank or Tank Combination	Impact Measure	No Retrieval	HFFACO Retrieval	10% HFFACO Retrieval
C-106	ILCR	1.46E-07	3.84E-08	3.96E-09
	HI	8.52E-04	4.60E-04	4.54E-05
C-201	ILCR	7.14E-10	1.51E-10	1.51E-11
	HI	5.00E-05	1.04E-05	1.04E-06
C-202	ILCR	7.45E-10	1.57E-10	1.58E-11
	HI	7.14E-05	1.48E-05	1.48E-06
C-203	ILCR	1.39E-09	1.20E-10	1.21E-11
	HI	1.19E-04	9.79E-06	9.78E-07
C-204	ILCR	8.94E-10	7.74E-11	7.76E-12
	HI	7.70E-05	6.32E-06	6.31E-07
C-200 Tanks Total	ILCR	3.74E-09	5.05E-10	5.07E-11
	HI	3.18E-04	4.13E-05	4.12E-06
C-106 Plus C-200 Tanks	ILCR	1.50E-07	3.90E-08	4.01E-09
	HI	1.17E-03	5.01E-04	4.95E-05
Balance of C-100 Tanks	ILCR	1.53E-05	3.31E-07	3.45E-08
	HI	8.70E-02	2.07E-03	2.04E-04
C Tank Farm Total	ILCR	1.54E-05	3.70E-07	3.85E-08
	HI	8.82E-02	2.57E-03	2.54E-04

ILCR = incremental lifetime cancer risk
HI = hazard index

Table A.5. Summary of Tank C-106 Additional Case Peak Long-Term Human Health Risks at C Tank Farm Fenceline From Residual Waste Source Term

Tank	Impact Measure	Pre-Project W-320		Liquid-Only Retrieval	
		Residential Farmer	Industrial Worker	Residential Farmer	Industrial Worker
C-106	ILCR	2.71E-04	9.97E-06	1.84E-06	8.58E-08
	HI	7.34E-01	6.83E-03	6.28E-03	7.54E-04

ILCR = incremental lifetime cancer risk
HI = hazard index

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-101	I-129	1.34E-03	4.10E-05	4.10E-06	6.58E-21	6.60E-22	6.61E-23	6.14E-12	6.16E-13	6.16E-14	8.48E-11	8.52E-12	8.52E-13
	C-14	1.00E-01	3.08E-03	3.08E-04	4.73E-19	2.81E-20	3.59E-21	2.47E-12	1.47E-13	1.88E-14	2.86E-10	1.71E-11	2.18E-12
	U-233	4.62E-06	1.42E-07	1.42E-08	1.07E-25	3.58E-29	3.58E-30	3.25E-17	1.08E-20	1.08E-21	1.48E-16	4.94E-20	4.94E-21
	U-234	3.14E+00	9.64E-02	9.64E-03	3.31E-18	5.02E-19	4.74E-20	9.93E-10	1.51E-10	1.42E-11	4.44E-09	6.72E-10	6.35E-11
	U-235	1.36E-01	4.18E-03	4.18E-04	1.51E-19	2.25E-20	2.11E-21	4.49E-11	6.70E-12	6.30E-13	2.06E-10	3.08E-11	2.90E-12
	U-236	4.48E-02	1.37E-03	1.37E-04	4.18E-20	5.77E-21	6.59E-22	1.19E-11	1.64E-12	1.88E-13	5.31E-11	7.33E-12	8.37E-13
	U-238	3.21E+00	9.85E-02	9.85E-03	2.67E-18	5.40E-19	4.95E-20	7.57E-10	1.53E-10	1.40E-11	3.41E-09	6.91E-10	6.33E-11
	Se-79	2.11E-03	6.49E-05	6.49E-06	1.21E-17	3.38E-19	3.44E-20	3.88E-10	1.09E-11	1.11E-12	3.46E-09	9.70E-11	9.87E-12
	Tc-99	6.97E-01	2.14E-02	2.14E-03	2.91E-15	1.17E-16	1.22E-17	2.07E-08	8.29E-10	8.67E-11	7.60E-07	3.04E-08	3.18E-09
	Total (ILCR)							2.29E-08	1.15E-09	1.17E-10	7.72E-07	3.20E-08	3.33E-09
	Cr(VI)	2.99E+02	9.17E+00	9.17E-01	1.19E-09	5.01E-11	4.94E-12	3.93E-03	1.66E-04	1.63E-05	1.35E-02	5.71E-04	5.63E-05
	NO2+NO3	7.06E+04	2.17E+03	2.17E+02	2.80E-07	1.18E-08	1.17E-09	1.74E-03	7.33E-05	7.23E-06	2.13E+00	8.98E-02	8.85E-03
	U(Total)	9.61E+03	2.95E+02	2.95E+01	7.99E-15	1.62E-15	1.48E-16	2.81E-08	5.69E-09	5.21E-10	4.10E-08	1.64E-09	1.72E-10
	Total (HI)							5.67E-03	2.39E-04	2.36E-05	2.14E+00	9.03E-02	8.91E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-102	I-129	2.74E-03	2.35E-05	2.35E-06	1.34E-20	3.78E-22	3.79E-23	1.25E-11	3.53E-13	3.53E-14	1.73E-10	4.88E-12	4.88E-13
	C-14	2.83E-01	2.42E-03	2.42E-04	1.34E-18	2.21E-20	2.82E-21	6.99E-12	1.16E-13	1.48E-14	8.10E-10	1.34E-11	1.71E-12
	U-233	9.58E-01	8.19E-03	8.19E-04	2.22E-20	2.07E-24	2.07E-25	6.73E-12	6.26E-16	6.26E-17	3.07E-11	2.85E-15	2.85E-16
	U-234	2.72E+00	2.33E-02	2.33E-03	2.87E-18	1.21E-19	1.15E-20	8.60E-10	3.64E-11	3.44E-12	3.84E-09	1.62E-10	1.53E-11
	U-235	1.17E-01	1.00E-03	1.00E-04	1.30E-19	5.39E-21	5.07E-22	3.86E-11	1.61E-12	1.51E-13	1.78E-10	7.39E-12	6.94E-13
	U-236	4.45E-02	3.81E-04	3.81E-05	4.15E-20	1.60E-21	1.83E-22	1.18E-11	4.56E-13	5.21E-14	5.28E-11	2.03E-12	2.32E-13
	U-238	2.72E+00	2.32E-02	2.32E-03	2.26E-18	1.27E-19	1.17E-20	6.42E-10	3.62E-11	3.31E-12	2.89E-09	1.63E-10	1.49E-11
	Se-79	4.70E-03	4.01E-05	4.01E-06	2.69E-17	2.09E-19	2.12E-20	8.65E-10	6.72E-12	6.83E-13	7.71E-09	5.99E-11	6.09E-12
	Tc-99	1.32E+00	1.13E-02	1.13E-03	5.51E-15	6.16E-17	6.44E-18	3.92E-08	4.38E-10	4.58E-11	1.44E-06	1.61E-08	1.68E-09
	Total (ILCR)							4.16E-08	5.20E-10	5.34E-11	1.45E-06	1.65E-08	1.72E-09
	Cr(VI)	7.35E+02	6.28E+00	6.28E-01	2.92E-09	3.43E-11	3.38E-12	9.66E-03	1.13E-04	1.12E-05	3.33E-02	3.91E-04	3.85E-05
	NO2+NO3	9.01E+04	7.70E+02	7.70E+01	3.58E-07	4.20E-09	4.14E-10	2.22E-03	2.61E-05	2.57E-06	2.72E+00	3.19E-02	3.15E-03
	U(Total)	8.15E+03	6.96E+01	6.96E+00	6.77E-15	3.82E-16	3.50E-17	2.38E-08	1.34E-09	1.23E-10	7.77E-08	8.68E-10	9.08E-11
	Total (HI)							1.19E-02	1.40E-04	1.38E-05	2.75E+00	3.23E-02	3.18E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-103	I-129	6.62E-02	1.13E-03	1.13E-04	3.25E-19	1.82E-20	1.82E-21	3.03E-10	1.70E-11	1.70E-12	4.19E-09	2.35E-10	2.35E-11
	C-14	4.89E+00	8.29E-02	8.29E-03	2.31E-17	7.58E-19	9.67E-20	1.21E-10	3.97E-12	5.06E-13	1.40E-08	4.60E-10	5.86E-11
	U-233	2.20E-01	1.50E-03	1.50E-04	5.10E-21	3.79E-25	3.79E-26	1.55E-12	1.15E-16	1.15E-17	7.04E-12	5.23E-16	5.23E-17
	U-234	1.95E+00	3.27E-02	3.27E-03	2.06E-18	1.70E-19	1.61E-20	6.17E-10	5.10E-11	4.82E-12	2.75E-09	2.28E-10	2.15E-11
	U-235	8.32E-02	1.40E-03	1.40E-04	9.22E-20	7.51E-21	7.06E-22	2.75E-11	2.24E-12	2.10E-13	1.26E-10	1.03E-11	9.67E-13
	U-236	3.48E-02	5.81E-04	5.81E-05	3.25E-20	2.44E-21	2.79E-22	9.26E-12	6.96E-13	7.94E-14	4.13E-11	3.10E-12	3.54E-13
	U-238	1.99E+00	3.35E-02	3.35E-03	1.65E-18	1.84E-19	1.68E-20	4.70E-10	5.22E-11	4.78E-12	2.12E-09	2.35E-10	2.15E-11
	Se-79	1.76E+00	3.73E-02	3.73E-03	1.01E-14	1.94E-16	1.98E-17	3.24E-07	6.26E-09	6.36E-10	2.89E-06	5.58E-08	5.67E-09
	Tc-99	3.42E+01	5.84E-01	5.84E-02	1.43E-13	3.19E-15	3.33E-16	1.02E-06	2.27E-08	2.37E-09	3.73E-05	8.32E-07	8.70E-08
	Total (ILCR)							1.34E-06	2.90E-08	3.02E-09	4.02E-05	8.89E-07	9.28E-08
	Cr(VI)	6.90E+02	1.47E+01	1.47E+00	2.74E-09	8.04E-11	7.93E-12	9.07E-03	2.66E-04	2.62E-05	3.12E-02	9.17E-04	9.04E-05
	NO2+NO3	1.77E+04	2.68E+02	2.68E+01	7.02E-08	1.47E-09	1.44E-10	4.35E-04	9.08E-06	8.96E-07	5.33E-01	1.11E-02	1.10E-03
	U(Total)	5.96E+03	1.00E+02	1.00E+01	4.95E-15	5.50E-16	5.04E-17	1.74E-08	1.94E-09	1.77E-10	2.01E-06	4.49E-08	4.70E-09
	Total (HI)							9.51E-03	2.75E-04	2.71E-05	5.64E-01	1.20E-02	1.19E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-104	I-129	7.54E-01	7.86E-03	7.86E-04	3.70E-18	1.27E-19	1.27E-20	3.45E-09	1.18E-10	1.18E-11	4.77E-08	1.63E-09	1.63E-10
	C-14	1.85E+00	1.93E-02	1.93E-03	8.74E-18	1.77E-19	2.26E-20	4.57E-11	9.26E-13	1.18E-13	5.30E-09	1.07E-10	1.37E-11
	U-233	4.13E+02	4.31E+00	4.31E-01	9.58E-18	1.09E-21	1.09E-22	2.90E-09	3.29E-13	3.29E-14	1.32E-08	1.50E-12	1.50E-13
	U-234	2.08E+01	2.17E-01	2.17E-02	2.19E-17	1.13E-18	1.07E-19	6.58E-09	3.38E-10	3.20E-11	2.94E-08	1.51E-09	1.43E-10
	U-235	6.03E-01	6.29E-03	6.29E-04	6.68E-19	3.38E-20	3.18E-21	1.99E-10	1.01E-11	9.47E-13	9.15E-10	4.63E-11	4.35E-12
	U-236	6.84E-01	7.13E-03	7.13E-04	6.39E-19	3.00E-20	3.42E-21	1.82E-10	8.55E-12	9.76E-13	8.11E-10	3.81E-11	4.35E-12
	U-238	1.17E+01	1.22E-01	1.22E-02	9.72E-18	6.70E-19	6.14E-20	2.76E-09	1.90E-10	1.74E-11	1.24E-08	8.57E-10	7.85E-11
	Se-79	6.41E+00	6.68E-02	6.68E-03	3.66E-14	3.48E-16	3.54E-17	1.18E-06	1.12E-08	1.14E-09	1.05E-05	9.98E-08	1.01E-08
	Tc-99	5.80E+01	6.04E-01	6.04E-02	2.42E-13	3.29E-15	3.44E-16	1.72E-06	2.34E-08	2.45E-09	6.32E-05	8.59E-07	8.98E-08
	Total (ILCR)							2.92E-06	3.53E-08	3.65E-09	7.39E-05	9.63E-07	1.00E-07
	Cr(VI)	1.46E+03	1.52E+01	1.52E+00	5.80E-09	8.31E-11	8.20E-12	1.92E-02	2.75E-04	2.71E-05	6.61E-02	9.48E-04	9.35E-05
	NO2+NO3	5.61E+04	5.85E+02	5.85E+01	2.23E-07	3.20E-09	3.15E-10	1.38E-03	1.98E-05	1.95E-06	1.69E+00	2.43E-02	2.39E-03
	U(Total)	3.53E+04	3.68E+02	3.68E+01	2.93E-14	2.02E-15	1.85E-16	1.03E-07	7.11E-09	6.51E-10	3.42E-06	4.64E-08	4.85E-09
	Total (HI)							2.06E-02	2.95E-04	2.91E-05	1.76E+00	2.52E-02	2.49E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-105	I-129	9.30E-02	1.90E-03	1.90E-04	4.56E-19	3.06E-20	3.06E-21	4.26E-10	2.86E-11	2.86E-12	5.89E-09	3.95E-10	3.95E-11
	C-14	5.07E-01	1.04E-02	1.04E-03	2.40E-18	9.48E-20	1.21E-20	1.25E-11	4.96E-13	6.32E-14	1.45E-09	5.74E-11	7.33E-12
	U-233	5.65E-06	1.16E-07	1.16E-08	1.31E-25	2.92E-29	2.92E-30	3.97E-17	8.84E-21	8.84E-22	1.81E-16	4.02E-20	4.02E-21
	U-234	3.21E+00	6.56E-02	6.56E-03	3.38E-18	3.42E-19	3.23E-20	1.02E-09	1.03E-10	9.69E-12	4.53E-09	4.58E-10	4.33E-11
	U-235	1.37E-01	2.79E-03	2.79E-04	1.52E-19	1.50E-20	1.41E-21	4.52E-11	4.48E-12	4.21E-13	2.08E-10	2.06E-11	1.93E-12
	U-236	5.56E-02	1.14E-03	1.14E-04	5.19E-20	4.77E-21	5.45E-22	1.48E-11	1.36E-12	1.55E-13	6.59E-11	6.06E-12	6.92E-13
	U-238	3.29E+00	6.72E-02	6.72E-03	2.73E-18	3.69E-19	3.38E-20	7.76E-10	1.05E-10	9.59E-12	3.50E-09	4.72E-10	4.32E-11
	Se-79	2.64E-03	5.39E-05	5.39E-06	1.51E-17	2.81E-19	2.85E-20	4.86E-10	9.04E-12	9.19E-13	4.33E-09	8.05E-11	8.19E-12
	Tc-99	8.14E+01	1.66E+00	1.66E-01	3.40E-13	9.07E-15	9.48E-16	2.42E-06	6.45E-08	6.74E-09	8.87E-05	2.37E-06	2.47E-07
	Total (ILCR)							2.42E-06	6.47E-08	6.76E-09	8.88E-05	2.37E-06	2.48E-07
	Cr(VI)	4.13E+02	8.45E+00	8.45E-01	1.64E-09	4.61E-11	4.55E-12	5.43E-03	1.53E-04	1.51E-05	1.87E-02	5.26E-04	5.19E-05
	NO2+NO3	1.66E+04	3.39E+02	3.39E+01	6.58E-08	1.85E-09	1.82E-10	4.08E-04	1.15E-05	1.13E-06	4.99E-01	1.40E-02	1.38E-03
	U(Total)	9.84E+03	2.01E+02	2.01E+01	8.18E-15	1.10E-15	1.01E-16	2.88E-08	3.88E-09	3.56E-10	4.79E-06	1.28E-07	1.34E-08
	Total (HI)							5.84E-03	1.64E-04	1.62E-05	5.18E-01	1.46E-02	1.44E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-106	I-129	1.70E-02	3.68E-03	3.68E-04	8.34E-20	5.93E-20	5.93E-21	7.78E-11	5.53E-11	5.53E-12	1.08E-09	7.64E-10	7.65E-11
	C-14	5.73E-02	3.68E-03	3.68E-04	2.71E-19	3.37E-20	4.29E-21	1.42E-12	1.76E-13	2.25E-14	1.64E-10	2.04E-11	2.60E-12
	U-233	2.18E-03	3.03E-04	3.03E-05	5.06E-23	7.64E-26	7.64E-27	1.53E-14	2.31E-17	2.31E-18	6.98E-14	1.05E-16	1.05E-17
	U-234	4.31E-02	5.95E-03	5.95E-04	4.54E-20	3.10E-20	2.93E-21	1.36E-11	9.30E-12	8.79E-13	6.09E-11	4.15E-11	3.93E-12
	U-235	1.84E-03	2.55E-04	2.55E-05	2.04E-21	1.37E-21	1.29E-22	6.08E-13	4.08E-13	3.83E-14	2.79E-12	1.88E-12	1.76E-13
	U-236	7.66E-04	1.06E-04	1.06E-05	7.15E-22	4.46E-22	5.10E-23	2.04E-13	1.27E-13	1.45E-14	9.08E-13	5.67E-13	6.47E-14
	U-238	4.40E-02	6.09E-03	6.09E-04	3.66E-20	3.34E-20	3.06E-21	1.04E-11	9.48E-12	8.68E-13	4.68E-11	4.27E-11	3.91E-12
	Se-79	2.88E-01	1.23E-01	1.23E-02	1.65E-15	6.41E-16	6.52E-17	5.30E-08	2.06E-08	2.10E-09	4.72E-07	1.84E-07	1.87E-08
	Tc-99	3.14E+00	4.58E-01	4.58E-02	1.31E-14	2.50E-15	2.61E-16	9.32E-08	1.77E-08	1.85E-09	3.42E-06	6.51E-07	6.81E-08
	Total (ILCR)							1.46E-07	3.84E-08	3.96E-09	3.90E-06	8.36E-07	8.69E-08
	Cr(VI)	6.18E+01	2.54E+01	2.54E+00	2.45E-10	1.39E-10	1.37E-11	8.12E-04	4.59E-04	4.52E-05	2.80E-03	1.58E-03	1.56E-04
	NO2+NO3	1.61E+03	4.11E+01	4.11E+00	6.38E-09	2.25E-10	2.22E-11	3.96E-05	1.39E-06	1.37E-07	4.84E-02	1.71E-03	1.68E-04
	U(Total)	1.32E+02	1.83E+01	1.83E+00	1.10E-16	1.00E-16	9.17E-18	3.86E-10	3.52E-10	3.23E-11	1.85E-07	3.52E-08	3.68E-09
	Total (HI)							8.52E-04	4.60E-04	4.54E-05	5.12E-02	3.28E-03	3.24E-04

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-107	I-129	4.83E-02	5.25E-04	5.25E-05	2.37E-19	8.45E-21	8.46E-22	2.21E-10	7.89E-12	7.89E-13	3.06E-09	1.09E-10	1.09E-11
	C-14	3.80E+00	4.13E-02	4.13E-03	1.80E-17	3.78E-19	4.83E-20	9.39E-11	1.98E-12	2.52E-13	1.09E-08	2.29E-10	2.92E-11
	U-233	2.26E-02	2.46E-04	2.46E-05	5.24E-22	6.20E-26	6.20E-27	1.59E-13	1.88E-17	1.88E-18	7.23E-13	8.56E-17	8.56E-18
	U-234	5.63E-01	6.12E-03	6.12E-04	5.94E-19	3.19E-20	3.01E-21	1.78E-10	9.56E-12	9.04E-13	7.95E-10	4.27E-11	4.04E-12
	U-235	1.37E-01	1.48E-03	1.48E-04	1.52E-19	7.98E-21	7.50E-22	4.52E-11	2.38E-12	2.23E-13	2.08E-10	1.09E-11	1.03E-12
	U-236	8.92E-02	9.70E-04	9.70E-05	8.33E-20	4.08E-21	4.65E-22	2.37E-11	1.16E-12	1.33E-13	1.06E-10	5.18E-12	5.91E-13
	U-238	3.10E+00	3.37E-02	3.37E-03	2.58E-18	1.85E-19	1.69E-20	7.32E-10	5.25E-11	4.81E-12	3.30E-09	2.37E-10	2.17E-11
	Se-79	1.79E+01	1.95E-01	1.95E-02	1.02E-13	1.01E-15	1.03E-16	3.29E-06	3.26E-08	3.32E-09	2.94E-05	2.91E-07	2.96E-08
	Tc-99	3.79E+01	4.12E-01	4.12E-02	1.58E-13	2.25E-15	2.35E-16	1.13E-06	1.60E-08	1.67E-09	4.13E-05	5.87E-07	6.14E-08
	Total (ILCR)							4.42E-06	4.87E-08	5.00E-09	7.07E-05	8.78E-07	9.10E-08
	Cr(VI)	9.30E+02	1.01E+01	1.01E+00	3.69E-09	5.52E-11	5.45E-12	1.22E-02	1.83E-04	1.80E-05	4.21E-02	6.30E-04	6.21E-05
	NO2+NO3	8.31E+04	9.04E+02	9.04E+01	3.30E-07	4.94E-09	4.87E-10	2.05E-03	3.06E-05	3.02E-06	2.51E+00	3.75E-02	3.69E-03
	U(Total)	9.29E+03	1.01E+02	1.01E+01	7.72E-15	5.54E-16	5.07E-17	2.72E-08	1.95E-09	1.79E-10	2.23E-06	3.17E-08	3.31E-09
	Total (HI)							1.43E-02	2.13E-04	2.10E-05	2.55E+00	3.81E-02	3.76E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-108	I-129	1.32E-03	5.38E-05	5.38E-06	6.48E-21	8.67E-22	8.67E-23	6.04E-12	8.09E-13	8.09E-14	8.36E-11	1.12E-11	1.12E-12
	C-14	1.31E-01	5.36E-03	5.36E-04	6.19E-19	4.91E-20	6.26E-21	3.24E-12	2.57E-13	3.27E-14	3.75E-10	2.97E-11	3.79E-12
	U-233	3.58E-08	1.46E-09	1.46E-10	8.30E-28	3.69E-31	3.69E-32	2.52E-19	1.12E-22	1.12E-23	1.15E-18	5.09E-22	5.09E-23
	U-234	5.03E-02	2.05E-03	2.05E-04	5.30E-20	1.07E-20	1.01E-21	1.59E-11	3.21E-12	3.03E-13	7.11E-11	1.43E-11	1.35E-12
	U-235	2.26E-03	9.25E-05	9.25E-06	2.50E-21	4.97E-22	4.67E-23	7.46E-13	1.48E-13	1.39E-14	3.43E-12	6.82E-13	6.40E-14
	U-236	3.22E-04	1.32E-05	1.32E-06	3.01E-22	5.53E-23	6.32E-24	8.57E-14	1.58E-14	1.80E-15	3.82E-13	7.02E-14	8.02E-15
	U-238	5.09E-02	2.08E-03	2.08E-04	4.23E-20	1.14E-20	1.05E-21	1.20E-11	3.24E-12	2.97E-13	5.41E-11	1.46E-11	1.34E-12
	Se-79	2.12E-03	8.68E-05	8.68E-06	1.21E-17	4.52E-19	4.59E-20	3.90E-10	1.45E-11	1.48E-12	3.48E-09	1.30E-10	1.32E-11
	Tc-99	6.19E+00	2.53E-01	2.53E-02	2.59E-14	1.38E-15	1.44E-16	1.84E-07	9.81E-09	1.03E-09	6.75E-06	3.60E-07	3.76E-08
	Total (ILCR)							1.84E-07	9.83E-09	1.03E-09	6.75E-06	3.60E-07	3.77E-08
	Cr(VI)	2.32E+02	9.49E+00	9.49E-01	9.21E-10	5.18E-11	5.11E-12	3.05E-03	1.72E-04	1.69E-05	1.05E-02	5.91E-04	5.83E-05
	NO2+NO3	2.44E+04	1.00E+03	1.00E+02	9.71E-08	5.46E-09	5.38E-10	6.02E-04	3.39E-05	3.34E-06	7.37E-01	4.14E-02	4.09E-03
	U(Total)	1.53E+02	6.24E+00	6.24E-01	1.27E-16	3.42E-17	3.13E-18	4.47E-10	1.20E-10	1.10E-11	3.65E-07	1.95E-08	2.03E-09
	Total (HI)							3.65E-03	2.05E-04	2.03E-05	7.47E-01	4.20E-02	4.14E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-109	I-129	2.00E-03	8.48E-05	8.48E-06	9.81E-21	1.37E-21	1.37E-22	9.16E-12	1.27E-12	1.27E-13	1.27E-10	1.76E-11	1.76E-12
	C-14	1.63E-02	6.93E-04	6.93E-05	7.70E-20	6.34E-21	8.09E-22	4.03E-13	3.32E-14	4.23E-15	4.67E-11	3.84E-12	4.90E-13
	U-233	2.52E-06	1.07E-07	1.07E-08	5.85E-26	2.71E-29	2.71E-30	1.77E-17	8.21E-21	8.21E-22	8.07E-17	3.74E-20	3.74E-21
	U-234	1.44E+00	6.15E-02	6.15E-03	1.52E-18	3.20E-19	3.03E-20	4.55E-10	9.60E-11	9.08E-12	2.03E-09	4.29E-10	4.05E-11
	U-235	5.75E-02	2.45E-03	2.45E-04	6.37E-20	1.32E-20	1.24E-21	1.90E-11	3.92E-12	3.68E-13	8.73E-11	1.80E-11	1.69E-12
	U-236	2.09E-02	8.89E-04	8.89E-05	1.95E-20	3.74E-21	4.27E-22	5.56E-12	1.07E-12	1.22E-13	2.48E-11	4.75E-12	5.42E-13
	U-238	1.36E+00	5.78E-02	5.78E-03	1.13E-18	3.17E-19	2.90E-20	3.21E-10	8.99E-11	8.24E-12	1.45E-09	4.05E-10	3.71E-11
	Se-79	5.34E-03	2.28E-04	2.28E-05	3.05E-17	1.18E-18	1.20E-19	9.83E-10	3.81E-11	3.88E-12	8.76E-09	3.40E-10	3.46E-11
	Tc-99	3.23E+01	1.37E+00	1.37E-01	1.35E-13	7.50E-15	7.84E-16	9.59E-07	5.33E-08	5.57E-09	3.52E-05	1.96E-06	2.05E-07
	Total (ILCR)							9.61E-07	5.35E-08	5.59E-09	3.52E-05	1.96E-06	2.05E-07
	Cr(VI)	1.18E+02	5.04E+00	5.04E-01	4.69E-10	2.75E-11	2.71E-12	1.55E-03	9.10E-05	8.98E-06	5.34E-03	3.14E-04	3.09E-05
	NO2+NO3	3.02E+04	1.29E+03	1.29E+02	1.20E-07	7.03E-09	6.93E-10	7.44E-04	4.36E-05	4.30E-06	9.10E-01	5.34E-02	5.26E-03
	U(Total)	4.06E+03	1.73E+02	1.73E+01	3.37E-15	9.47E-16	8.67E-17	1.19E-08	3.33E-09	3.05E-10	1.90E-06	1.06E-07	1.11E-08
	Total (HI)							2.29E-03	1.35E-04	1.33E-05	9.16E-01	5.37E-02	5.29E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-110	I-129	1.10E-03	1.68E-05	1.68E-06	5.40E-21	2.70E-22	2.70E-23	5.04E-12	2.52E-13	2.52E-14	6.96E-11	3.49E-12	3.49E-13
	C-14	3.33E-01	5.06E-03	5.06E-04	1.57E-18	4.63E-20	5.91E-21	8.23E-12	2.42E-13	3.09E-14	9.54E-10	2.81E-11	3.58E-12
	U-233	4.62E-07	7.05E-09	7.05E-10	1.07E-26	1.78E-30	1.78E-31	3.25E-18	5.39E-22	5.39E-23	1.48E-17	2.45E-21	2.45E-22
	U-234	6.51E-01	9.91E-03	9.91E-04	6.86E-19	5.16E-20	4.88E-21	2.06E-10	1.55E-11	1.46E-12	9.20E-10	6.92E-11	6.54E-12
	U-235	2.93E-02	4.47E-04	4.47E-05	3.25E-20	2.40E-21	2.26E-22	9.68E-12	7.16E-13	6.73E-14	4.45E-11	3.29E-12	3.09E-13
	U-236	4.16E-03	6.33E-05	6.33E-06	3.88E-21	2.66E-22	3.04E-23	1.11E-12	7.58E-14	8.66E-15	4.93E-12	3.38E-13	3.86E-14
	U-238	6.59E-01	1.01E-02	1.01E-03	5.48E-19	5.51E-20	5.05E-21	1.56E-10	1.57E-11	1.43E-12	7.01E-10	7.05E-11	6.46E-12
	Se-79	2.02E-03	2.70E-05	2.70E-06	1.15E-17	1.41E-19	1.43E-20	3.72E-10	4.53E-12	4.60E-13	3.31E-09	4.03E-11	4.10E-12
	Tc-99	3.18E+01	4.85E-01	4.85E-02	1.33E-13	2.64E-15	2.77E-16	9.44E-07	1.88E-08	1.97E-09	3.47E-05	6.90E-07	7.22E-08
	Total (ILCR)							9.45E-07	1.88E-08	1.97E-09	3.47E-05	6.91E-07	7.22E-08
	Cr(VI)	4.20E+02	6.39E+00	6.39E-01	1.67E-09	3.49E-11	3.44E-12	5.52E-03	1.16E-04	1.14E-05	1.90E-02	3.98E-04	3.92E-05
	NO2+NO3	1.05E+05	1.59E+03	1.59E+02	4.15E-07	8.68E-09	8.56E-10	2.57E-03	5.38E-05	5.31E-06	3.15E+00	6.59E-02	6.50E-03
	U(Total)	1.97E+03	3.00E+01	3.00E+00	1.64E-15	1.65E-16	1.51E-17	5.76E-09	5.80E-10	5.31E-11	1.87E-06	3.73E-08	3.90E-09
	Total (HI)							8.10E-03	1.69E-04	1.67E-05	3.17E+00	6.63E-02	6.54E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-111	I-129	2.01E-03	9.49E-05	9.49E-06	9.86E-21	1.53E-21	1.53E-22	9.20E-12	1.43E-12	1.43E-13	1.27E-10	1.97E-11	1.97E-12
	C-14	1.62E-01	7.65E-03	7.65E-04	7.65E-19	7.00E-20	8.93E-21	4.00E-12	3.66E-13	4.67E-14	4.64E-10	4.24E-11	5.41E-12
	U-233	1.84E-06	8.67E-08	8.67E-09	4.27E-26	2.19E-29	2.19E-30	1.29E-17	6.63E-21	6.63E-22	5.89E-17	3.02E-20	3.02E-21
	U-234	1.40E+00	6.58E-02	6.58E-03	1.48E-18	3.42E-19	3.24E-20	4.43E-10	1.03E-10	9.71E-12	1.98E-09	4.59E-10	4.34E-11
	U-235	6.10E-02	2.87E-03	2.87E-04	6.76E-20	1.55E-20	1.45E-21	2.01E-11	4.60E-12	4.33E-13	9.26E-11	2.12E-11	1.99E-12
	U-236	1.85E-02	8.70E-04	8.70E-05	1.73E-20	3.66E-21	4.18E-22	4.92E-12	1.04E-12	1.19E-13	2.19E-11	4.64E-12	5.30E-13
	U-238	1.42E+00	6.69E-02	6.69E-03	1.18E-18	3.67E-19	3.36E-20	3.35E-10	1.04E-10	9.54E-12	1.51E-09	4.69E-10	4.30E-11
	Se-79	6.10E-03	2.87E-04	2.87E-05	3.49E-17	1.49E-18	1.52E-19	1.12E-09	4.81E-11	4.89E-12	1.00E-08	4.29E-10	4.36E-11
	Tc-99	2.70E+00	1.27E-01	1.27E-02	1.13E-14	6.93E-16	7.25E-17	8.02E-08	4.93E-09	5.15E-10	2.94E-06	1.81E-07	1.89E-08
	Total (ILCR)							8.21E-08	5.19E-09	5.40E-10	2.96E-06	1.82E-07	1.91E-08
	Cr(VI)	8.52E+01	4.01E+00	4.01E-01	3.38E-10	2.19E-11	2.16E-12	1.12E-03	7.24E-05	7.14E-06	3.86E-03	2.49E-04	2.46E-05
	NO2+NO3	2.68E+04	1.26E+03	1.26E+02	1.06E-07	6.88E-09	6.78E-10	6.60E-04	4.27E-05	4.21E-06	8.08E-01	5.22E-02	5.15E-03
	U(Total)	4.25E+03	2.00E+02	2.00E+01	3.53E-15	1.10E-15	1.01E-16	1.24E-08	3.86E-09	3.54E-10	1.59E-07	9.77E-09	1.02E-09
	Total (HI)							1.78E-03	1.15E-04	1.13E-05	8.11E-01	5.25E-02	5.17E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-112	I-129	4.26E-03	1.11E-04	1.11E-05	2.09E-20	1.78E-21	1.78E-22	1.95E-11	1.66E-12	1.67E-13	2.70E-10	2.30E-11	2.30E-12
	C-14	3.61E+00	9.39E-02	9.39E-03	1.71E-17	8.60E-19	1.10E-19	8.92E-11	4.50E-12	5.73E-13	1.03E-08	5.21E-10	6.64E-11
	U-233	5.99E-01	1.56E-02	1.56E-03	1.39E-20	3.93E-24	3.93E-25	4.21E-12	1.19E-15	1.19E-16	1.92E-11	5.42E-15	5.42E-16
	U-234	7.98E+00	2.08E-01	2.08E-02	8.41E-18	1.08E-18	1.02E-19	2.52E-09	3.24E-10	3.06E-11	1.13E-08	1.45E-09	1.37E-10
	U-235	3.50E-01	9.09E-03	9.09E-04	3.88E-19	4.89E-20	4.59E-21	1.16E-10	1.46E-11	1.37E-12	5.31E-10	6.70E-11	6.29E-12
	U-236	9.88E-02	2.57E-03	2.57E-04	9.22E-20	1.08E-20	1.23E-21	2.63E-11	3.08E-12	3.51E-13	1.17E-10	1.37E-11	1.57E-12
	U-238	8.06E+00	2.10E-01	2.10E-02	6.70E-18	1.15E-18	1.05E-19	1.90E-09	3.26E-10	2.99E-11	8.57E-09	1.47E-09	1.35E-10
	Se-79	5.56E-01	1.45E-02	1.45E-03	3.18E-15	7.53E-17	7.66E-18	1.02E-07	2.42E-09	2.47E-10	9.12E-07	2.16E-08	2.20E-09
	Tc-99	6.11E+01	1.59E+00	1.59E-01	2.55E-13	8.66E-15	9.06E-16	1.81E-06	6.16E-08	6.44E-09	6.66E-05	2.26E-06	2.36E-07
	Total (ILCR)							1.92E-06	6.47E-08	6.75E-09	6.75E-05	2.29E-06	2.39E-07
	Cr(VI)	1.39E+02	3.61E+00	3.61E-01	5.52E-10	1.97E-11	1.95E-12	1.83E-03	6.53E-05	6.44E-06	6.29E-03	2.25E-04	2.22E-05
	NO2+NO3	6.50E+04	1.69E+03	1.69E+02	2.58E-07	9.22E-09	9.09E-10	1.60E-03	5.71E-05	5.63E-06	1.96E+00	7.00E-02	6.90E-03
	U(Total)	2.41E+04	6.27E+02	6.27E+01	2.00E-14	3.44E-15	3.15E-16	7.05E-08	1.21E-08	1.11E-09	3.60E-06	1.22E-07	1.28E-08
	Total (HI)							3.43E-03	1.22E-04	1.21E-05	1.97E+00	7.02E-02	6.92E-03

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-201	I-129	2.74E-05	5.70E-06	5.70E-07	4.41E-22	9.19E-23	9.19E-24	4.12E-13	8.58E-14	8.58E-15	5.69E-12	1.19E-12	1.19E-13
	C-14	2.01E-03	4.18E-04	4.18E-05	2.18E-20	4.91E-21	4.99E-22	1.14E-13	2.57E-14	2.61E-15	1.32E-11	2.97E-12	3.03E-13
	U-233	2.66E-10	5.54E-11	5.54E-12	6.71E-32	1.40E-32	1.40E-33	2.03E-23	4.23E-24	4.23E-25	9.26E-23	1.93E-23	1.93E-24
	U-234	3.75E-04	7.81E-05	7.81E-06	1.88E-21	3.84E-22	3.82E-23	5.64E-13	1.15E-13	1.15E-14	2.52E-12	5.14E-13	5.12E-14
	U-235	1.69E-05	3.52E-06	3.52E-07	8.72E-23	1.78E-23	1.77E-24	2.60E-14	5.29E-15	5.26E-16	1.19E-13	2.43E-14	2.42E-15
	U-236	2.39E-06	4.98E-07	4.98E-08	1.10E-23	2.39E-24	2.42E-25	3.14E-15	6.82E-16	6.89E-17	1.40E-14	3.04E-15	3.07E-16
	U-238	3.80E-04	7.91E-05	7.91E-06	1.96E-21	3.97E-22	3.94E-23	5.58E-13	1.13E-13	1.12E-14	2.52E-12	5.08E-13	5.04E-14
	Se-79	8.79E-04	1.83E-04	1.83E-05	4.63E-18	9.69E-19	9.70E-20	1.49E-10	3.12E-11	3.12E-12	1.33E-09	2.78E-10	2.79E-11
	Tc-99	1.41E-02	2.94E-03	2.94E-04	7.92E-17	1.67E-17	1.68E-18	5.63E-10	1.19E-10	1.20E-11	2.07E-08	4.37E-09	4.39E-10
	Total (ILCR)							7.14E-10	1.51E-10	1.51E-11	2.20E-08	4.65E-09	4.67E-10
	Cr(VI)	2.29E+00	4.77E-01	4.77E-02	1.24E-11	2.57E-12	2.56E-13	4.10E-05	8.49E-06	8.48E-07	1.41E-04	2.93E-05	2.92E-06
	NO2+NO3	2.69E+02	5.60E+01	5.60E+00	1.45E-09	3.01E-10	3.01E-11	9.02E-06	1.87E-06	1.87E-07	1.10E-02	2.29E-03	2.28E-04
	U(Total)	1.14E+00	2.37E-01	2.37E-02	5.89E-18	1.19E-18	1.18E-19	2.07E-11	4.19E-12	4.16E-13	1.12E-09	2.36E-10	2.37E-11
	Total (HI)							5.00E-05	1.04E-05	1.04E-06	1.12E-02	2.32E-03	2.31E-04

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-202	I-129	2.85E-05	5.93E-06	5.93E-07	4.59E-22	9.56E-23	9.56E-24	4.28E-13	8.92E-14	8.92E-15	5.92E-12	1.23E-12	1.23E-13
	C-14	2.09E-03	4.35E-04	4.35E-05	2.27E-20	5.10E-21	5.19E-22	1.19E-13	2.67E-14	2.71E-15	1.38E-11	3.09E-12	3.15E-13
	U-233	7.31E-10	1.52E-10	1.52E-11	1.84E-31	3.84E-32	3.84E-33	5.59E-23	1.16E-23	1.16E-24	2.55E-22	5.30E-23	5.30E-24
	U-234	3.99E-04	8.31E-05	8.31E-06	2.00E-21	4.08E-22	4.06E-23	6.00E-13	1.22E-13	1.22E-14	2.68E-12	5.47E-13	5.44E-14
	U-235	1.68E-05	3.50E-06	3.50E-07	8.67E-23	1.76E-23	1.76E-24	2.58E-14	5.26E-15	5.23E-16	1.19E-13	2.42E-14	2.41E-15
	U-236	9.28E-06	1.93E-06	1.93E-07	4.27E-23	9.30E-24	9.39E-25	1.22E-14	2.65E-15	2.68E-16	5.43E-14	1.18E-14	1.19E-15
	U-238	3.96E-04	8.24E-05	8.24E-06	2.05E-21	4.13E-22	4.10E-23	5.82E-13	1.17E-13	1.16E-14	2.62E-12	5.29E-13	5.25E-14
	Se-79	9.16E-04	1.91E-04	1.91E-05	4.82E-18	1.01E-18	1.01E-19	1.55E-10	3.25E-11	3.26E-12	1.38E-09	2.90E-10	2.90E-11
	Tc-99	1.47E-02	3.06E-03	3.06E-04	8.26E-17	1.75E-17	1.75E-18	5.87E-10	1.24E-10	1.25E-11	2.16E-08	4.56E-09	4.57E-10
	Total (ILCR)							7.45E-10	1.57E-10	1.58E-11	2.30E-08	4.85E-09	4.87E-10
	Cr(VI)	2.39E+00	4.98E-01	4.98E-02	1.29E-11	2.68E-12	2.68E-13	4.28E-05	8.87E-06	8.86E-07	1.47E-04	3.05E-05	3.05E-06
	NO2+NO3	8.53E+02	1.78E+02	1.78E+01	4.61E-09	9.56E-10	9.55E-11	2.86E-05	5.93E-06	5.92E-07	3.50E-02	7.26E-03	7.25E-04
	U(Total)	1.19E+00	2.48E-01	2.48E-02	6.15E-18	1.24E-18	1.23E-19	2.17E-11	4.37E-12	4.34E-13	1.16E-09	2.46E-10	2.47E-11
	Total (HI)							7.14E-05	1.48E-05	1.48E-06	3.52E-02	7.29E-03	7.28E-04

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-203	I-129	5.46E-05	4.55E-06	4.55E-07	8.79E-22	7.33E-23	7.33E-24	8.21E-13	6.84E-14	6.84E-15	1.13E-11	9.45E-13	9.45E-14
	C-14	4.00E-03	3.33E-04	3.33E-05	3.68E-20	3.91E-21	3.97E-22	1.93E-13	2.04E-14	2.08E-15	2.23E-11	2.37E-12	2.41E-13
	U-233	5.30E-10	4.41E-11	4.41E-12	1.34E-31	1.11E-32	1.11E-33	4.05E-23	3.37E-24	3.37E-25	1.85E-22	1.54E-23	1.54E-24
	U-234	7.47E-04	6.22E-05	6.22E-06	3.88E-21	3.06E-22	3.04E-23	1.17E-12	9.17E-14	9.13E-15	5.20E-12	4.10E-13	4.08E-14
	U-235	3.36E-05	2.80E-06	2.80E-07	1.80E-22	1.41E-23	1.40E-24	5.38E-14	4.21E-15	4.19E-16	2.47E-13	1.93E-14	1.92E-15
	U-236	4.77E-06	3.97E-07	3.97E-08	2.01E-23	1.91E-24	1.93E-25	5.73E-15	5.45E-16	5.50E-17	2.55E-14	2.43E-15	2.45E-16
	U-238	7.56E-04	6.30E-05	6.30E-06	4.14E-21	3.16E-22	3.13E-23	1.17E-12	8.96E-14	8.89E-15	5.29E-12	4.04E-13	4.01E-14
	Se-79	1.75E-03	1.46E-04	1.46E-05	9.11E-18	7.72E-19	7.73E-20	2.93E-10	2.48E-11	2.49E-12	2.62E-09	2.21E-10	2.22E-11
	Tc-99	2.82E-02	2.35E-03	2.35E-04	1.54E-16	1.34E-17	1.34E-18	1.09E-09	9.53E-11	9.56E-12	4.02E-08	3.50E-09	3.51E-10
	Total (ILCR)							1.39E-09	1.20E-10	1.21E-11	4.28E-08	3.72E-09	3.74E-10
	Cr(VI)	4.57E+00	3.81E-01	3.81E-02	2.49E-11	2.05E-12	2.05E-13	8.26E-05	6.78E-06	6.77E-07	2.84E-04	2.34E-05	2.33E-06
	NO2+NO3	1.08E+03	9.02E+01	9.02E+00	5.91E-09	4.85E-10	4.85E-11	3.67E-05	3.01E-06	3.01E-07	4.49E-02	3.68E-03	3.68E-04
	U(Total)	2.26E+00	1.88E-01	1.88E-02	1.24E-17	9.43E-19	9.36E-20	4.35E-11	3.32E-12	3.30E-13	2.17E-09	1.89E-10	1.90E-11
	Total (HI)							1.19E-04	9.79E-06	9.78E-07	4.52E-02	3.71E-03	3.70E-04

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C-204	I-129	3.52E-05	2.93E-06	2.93E-07	5.67E-22	4.72E-23	4.72E-24	5.29E-13	4.41E-14	4.41E-15	7.31E-12	6.09E-13	6.09E-14
	C-14	2.58E-03	2.15E-04	2.15E-05	2.38E-20	2.52E-21	2.56E-22	1.24E-13	1.32E-14	1.34E-15	1.44E-11	1.53E-12	1.55E-13
	U-233	3.42E-10	2.85E-11	2.85E-12	8.63E-32	7.19E-33	7.19E-34	2.61E-23	2.18E-24	2.18E-25	1.19E-22	9.92E-24	9.92E-25
	U-234	4.82E-04	4.01E-05	4.01E-06	2.51E-21	1.97E-22	1.96E-23	7.52E-13	5.92E-14	5.89E-15	3.36E-12	2.64E-13	2.63E-14
	U-235	2.17E-05	1.81E-06	1.81E-07	1.17E-22	9.12E-24	9.07E-25	3.47E-14	2.72E-15	2.70E-16	1.60E-13	1.25E-14	1.24E-15
	U-236	3.08E-06	2.56E-07	2.56E-08	1.30E-23	1.23E-24	1.25E-25	3.70E-15	3.52E-16	3.55E-17	1.65E-14	1.57E-15	1.58E-16
	U-238	4.89E-04	4.07E-05	4.07E-06	2.68E-21	2.04E-22	2.03E-23	7.60E-13	5.80E-14	5.75E-15	3.42E-12	2.61E-13	2.59E-14
	Se-79	1.13E-03	9.41E-05	9.41E-06	5.88E-18	4.98E-19	4.99E-20	1.89E-10	1.60E-11	1.61E-12	1.69E-09	1.43E-10	1.43E-11
	Tc-99	1.81E-02	1.51E-03	1.51E-04	9.88E-17	8.60E-18	8.63E-19	7.03E-10	6.11E-11	6.14E-12	2.58E-08	2.24E-09	2.25E-10
	Total (ILCR)							8.94E-10	7.74E-11	7.76E-12	2.75E-08	2.39E-09	2.40E-10
	Cr(VI)	2.95E+00	2.46E-01	2.46E-02	1.61E-11	1.32E-12	1.32E-13	5.33E-05	4.38E-06	4.37E-07	1.84E-04	1.51E-05	1.51E-06
	NO2+NO3	6.99E+02	5.82E+01	5.82E+00	3.82E-09	3.13E-10	3.13E-11	2.37E-05	1.94E-06	1.94E-07	2.90E-02	2.38E-03	2.38E-04
	U(Total)	1.46E+00	1.22E-01	1.22E-02	7.99E-18	6.09E-19	6.05E-20	2.81E-11	2.14E-12	2.13E-13	1.39E-09	1.21E-10	1.22E-11
	Total (HI)							7.70E-05	6.32E-06	6.31E-07	2.91E-02	2.39E-03	2.39E-04

Table A.6. C Tank Farm Long-Term Human Health Risk Calculation Detail for No Retrieval, HFFACO Retrieval, and 10% HFFACO Retrieval Evaluation Cases (17 Sheets)

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)			Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)			Peak Industrial Worker Risk at Fence Line			Peak Residential Farmer Risk at Fence Line		
		No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval	No Retrieval	HFFACO Compliant Retrieval	10% HFFACO Retrieval
C Tank Farm Total (ILCR)								1.54E-05	3.70E-07	3.85E-08	4.27E-04	1.15E-05	1.20E-06
C Tank Farm Total (HI)								8.82E-02	2.57E-03	2.54E-04	1.81E+01	5.16E-01	5.09E-02

Table A.7. Tank C-106 Long-Term Human Health Risk Calculation Detail for Pre-Project W-320 and Liquid-Only Retrieval Cases

Tank	Contaminant of Concern	Residual Waste Inventory (Ci or g)		Peak Groundwater Concentration at Fence Line (Ci/mL or g/mL)		Peak Industrial Worker Risk at Fence Line		Peak Residential Farmer Risk at Fence Line	
		Pre-Project W-320[a]	Liquid-Only Retrieval	Pre-Project W-320	Liquid-Only Retrieval	Pre-Project W-320	Liquid-Only Retrieval	Pre-Project W-320	Liquid-Only Retrieval
C-106	I-129	1.00E-02	8.28E-03	4.91E-20	4.06E-20	4.58E-11	3.79E-11	6.33E-10	5.24E-10
	C-14	2.30E-01	8.28E-03	1.09E-18	7.08E-20	5.68E-12	3.70E-13	6.59E-10	4.29E-11
	U-233	2.32E-02	6.81E-04	5.38E-22	2.29E-24	1.63E-13	6.95E-16	7.43E-13	3.17E-15
	U-234	4.58E-01	1.34E-02	4.83E-19	6.22E-20	1.45E-10	1.87E-11	6.47E-10	8.34E-11
	U-235	1.95E-02	5.73E-04	2.16E-20	2.75E-21	6.44E-12	8.19E-13	2.96E-11	3.77E-12
	U-236	8.14E-03	2.39E-04	7.60E-21	8.98E-22	2.17E-12	2.56E-13	9.65E-12	1.14E-12
	U-238	4.68E-01	1.37E-02	3.89E-19	6.65E-20	1.10E-10	1.89E-11	4.98E-10	8.51E-11
	Se-79	1.85E+01	2.77E-01	1.06E-13	1.46E-15	3.41E-06	4.70E-08	3.04E-05	4.19E-07
	Tc-99	2.21E+02	1.03E+00	9.23E-13	5.44E-15	6.56E-06	3.87E-08	2.41E-04	1.42E-06
	Total (ILCR)					9.97E-06	8.58E-08	2.71E-04	1.84E-06
	Cr(VI)	4.75E+02	5.71E+01	1.89E-09	2.27E-10	6.24E-03	7.51E-04	2.15E-02	2.59E-03
	NO2+NO3	2.36E+04	9.26E+01	9.38E-08	4.87E-10	5.82E-04	3.02E-06	7.12E-01	3.70E-03
	U(Total)	1.40E+03	4.11E+01	1.16E-15	1.99E-16	4.09E-09	7.02E-10	1.64E-08	2.81E-09
	Total (HI)					6.83E-03	7.54E-04	7.34E-01	6.28E-03

[a] Source = Tank Characterization Report for Single-Shell Tank 241-C-106 (WHC-SD-WM-ER-615, Revision 0B, September 30, 1998) as reported in Letter Report #1: Inventory Estimates to Support Tank C-106 Residual Waste Assessment (RPP-6629, Tables 1 and 2).

ILCR = incremental lifetime cancer risk
HI = hazard index

A.12.1 RESULTS FOR TANK C-106

If tank C-106 had been closed prior to Project W-320 sluicing retrieval waste inventory in place, the ILCR would have peaked at an estimated value of 2.71×10^{-4} for the residential farmer and 9.97×10^{-6} for the industrial worker. The hazard index prior to Project W-320 closure scenario would have peaked at an estimated value of 7.34×10^{-1} for the residential farmer and 6.83×10^{-3} for the industrial worker.

Closing tank C-106 in its current condition would cause the ILCR from residual waste to peak at an estimated value of 3.90×10^{-6} for residential farmer and 1.46×10^{-7} for the industrial worker. The hazard index under a current status case would peak at an estimated value of 5.12×10^{-2} for residential farmer and 8.52×10^{-4} for the industrial worker.

If tank C-106 were closed after retrieving the liquids only, the peak ILCR would be lowered slightly to an estimated value of 1.84×10^{-6} for the residential farmer and 8.58×10^{-8} for the industrial worker. The hazard index under a liquids-only retrieval case would be lowered to an estimated peak value of 6.28×10^{-3} for the residential farmer and 7.54×10^{-4} for the industrial worker.

Closing tank C-106 after retrieving waste to the HFFACO residual waste volume limit would lower the estimated peak ILCR to 8.36×10^{-7} for the residential farmer and 3.84×10^{-8} for the industrial worker. The hazard index under a HFFACO retrieval case would drop to an estimated peak of 3.28×10^{-3} for the residential farmer and 4.60×10^{-4} for the industrial worker.

Closing tank C-106 after retrieving waste to 10% of the HFFACO residual waste volume goal would lower the estimated peak impacts by approximately one order of magnitude compared to the peaks under a HFFACO retrieval case.

A.12.2 RESULTS FOR C 200-SERIES TANKS

Closing the four C 200-Series tanks without retrieving waste would cause the ILCR for each tank to peak at an estimated value in the 10^{-8} range for the residential farmer and the 10^{-9} range for the industrial worker. Each tank's hazard index under a no retrieval case would peak at an estimated value in the 10^{-2} range for the residential farmer and the 10^{-4} range for the industrial worker. Risk values for tank C-203 would be highest among the four tanks by a slight margin.

If the C 200-Series tanks were closed without retrieving waste, the four tanks in combination would result in an estimated peak ILCR on the order of 10^{-7} for the residential farmer and 10^{-9} for the industrial worker. The hazard index for the four tanks in combination would peak at an estimated value on the order of 10^{-2} for the residential farmer and 10^{-4} for the industrial worker.

Closing the four C 200-Series tanks after retrieving waste to the HFFACO residual waste volume goal would lower each tank's estimated peak ILCR to the 10^{-9} range for the residential farmer and the 10^{-10} range for the industrial worker. Each tank's estimated peak hazard index under a HFFACO retrieval case would drop to the 10^{-3} range for the residential farmer and the 10^{-5} range for the industrial worker.

Closing the four C 200-Series tanks after retrieving waste to 10% of the HFFACO residual waste volume goal would lower each tank's estimated peak impacts by approximately one order of magnitude compared to the peaks under a HFFACO retrieval case.

A.12.3 RESULTS FOR C TANK FARM

Closing all 16 C farm tanks without retrieving waste would cause the total C farm ILCR to peak at an estimated value of 4.27×10^{-4} for the residential farmer and 1.54×10^{-5} for the industrial worker. The total C farm hazard index under a current status case would peak at an estimated value of 1.81×10^{1} for the residential farmer and the 8.82×10^{-2} for the industrial worker.

Closing all 16 C farm tanks after retrieving waste to the HFFACO residual waste volume goal would lower the total C farm estimated peak ILCR to 1.15×10^{-5} for the residential farmer and 3.7×10^{-7} for the industrial worker. The total C farm estimated peak hazard index under a HFFACO retrieval case would drop to 5.16×10^{-1} for the residential farmer and 2.56×10^{-3} for the industrial worker.

Closing all 16 C farm tanks after retrieving waste to 10% of the HFFACO residual waste volume goal would lower the total C farm estimated peak ILCR to 1.20×10^{-6} for the residential farmer and 3.85×10^{-8} for the industrial worker. The total C farm estimated peak hazard index under a 10% HFFACO retrieval case would drop to 5.09×10^{-2} for the residential farmer and 2.54×10^{-4} for the industrial worker.

A.12.4 RISK ALLOCATION

The analysis results indicate that the residual waste in tank C-106 would not be expected to cause an exceedance of State standards for either ILCR (1.0×10^{-5}) or hazard index (1.0) even if no waste were retrieved prior to closure. The residual waste in the C 200-Series tanks, whether considered on an individual tank basis or in combination, also would not be expected to cause an exceedance of State standards even without waste retrieval prior to closure.

If the State ILCR standard of 1.0×10^{-5} is assumed as the overall tank farm closure risk budget and a residential farmer scenario is used, tank C-106 would subtract about 40% (3.90×10^{-6}) of the budget if closed without waste retrieval. Unretrieved, the C 200-Series tanks together would subtract about 1% (1.15×10^{-7}) of the budget. Closed after liquid-only retrieval, tank C-106 would subtract about 18% (1.84×10^{-6}) of the budget. Retrieved to the HFFACO goals, tank C-106 would subtract about 8% (8.36×10^{-7}) of the budget and the C 200-Series tanks would subtract about 0.2% (1.56×10^{-8}) of the budget. Retrieved to 10% of the HFFACO goals, tank C-106 would subtract about 1% (8.69×10^{-8}) of the budget and the C 200-Series tanks would subtract an insignificant amount of the budget.

On the tank farm level, if no waste were retrieved from any of the C farm tanks prior to closure, the waste left in place would be expected to cause an exceedance of not only the State ILCR standard (1.0×10^{-5}) but also the Federal ILCR standard (1.0×10^{-4}), assuming use of a residential farmer scenario. Exceedance of the hazard index standard (1.0) would also be expected at the tank farm level under a no retrieval case. Only about 1% of the total C farm human health impacts would come from the five closure demonstration tanks; about 99% would

come from the 11 remaining C 100-Series tanks. Of these 11 tanks, the largest contributors would be tanks C-104, C-105, and C-107. Retrieving waste from all C farm tanks to the HFFACO goals prior to closure would be expected to lower human health impacts by about a factor of 40 compared to the no retrieval impacts, but the residual waste would still be expected to cause a slight exceedance of the State ILCR standard. The total C farm residential farmer ILCR would fall below the State standard if all C farm tanks were retrieved to 10% of the HFFACO goals.

The estimated risks from C farm past leaks would not be expected to significantly change the results of this analysis at the tank farm level. Based on the analysis presented in HNF-7643, the C farm past leaks would contribute an additional estimated ILCR of 6.8×10^{-7} for the residential farmer and 2.0×10^{-8} for the industrial worker at the time of peak residual waste impacts. The additional estimated hazard index contribution from past leaks would be 5.7×10^{-3} for the residential farmer and 5.2×10^{-5} for the industrial worker. Addition of these past leak risks to the residual waste risks calculated in this analysis would not result in any additional exceedance of risk standards for the C tank farm as whole.

A.13.0 REFERENCES

40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Code of Federal Regulations, as amended.

55 FR 8666, 1990, "National Oil and Hazardous Substances Pollution Contingency Plan," Federal Register, U.S. Environmental Protection Agency, Washington, D.C.

BBI, 2002, Tank Waste Information Network System (TWINS), April 15, 2002, [Best Basis Inventory, Best Basis/TCR Tank Inventory], http://twins.pnl.gov/data/datamenu.htm#.

BHI-01365, 2000, *Groundwater/Vadose Zone Integration Project System Assessment Capability*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

DOE/EIS-0189, 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, U.S. Department of Energy and Washington State Department of Ecology, Washington, D.C.

DOE/RL-91-45, 1995, *Hanford Site Risk Assessment Methodology*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL-98-72, 1999, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

HNF-EP-0182, 2002, *Waste Tank Summary Report for Month Ending January 31, 2002*, Rev. 166, CH2M HILL Hanford Group, Inc., Richland, Washington.

HNF-7643, 2001, *Retrieval Performance Evaluation for Single-Shell Tank C-104*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

LA-UR-00-4050, 2000, *Hanford Soil Inventory and Uncertainty Model*, Rev. 1, Los Alamos National Laboratory, Los Alamos, New Mexico.

LA-UR-96-3860, 1997, *Hanford Defined Wastes: Chemical and Radionuclide Compositions*, Rev. 4, Los Alamos National Laboratory, Los Alamos, New Mexico.

NUREG/CR-5991, 1993, *PORFLOW: A Multifluid Multiphase Model for Simulating Flow, Heat Transfer, and Mass Transport in Fractured Porous Media, User's Manual – Version 2.41*, U.S. Nuclear Regulatory Commission, Washington, D.C.

PNL-10886, 1995, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-11665, 1997, *Tritium Monitoring in Groundwater and Evaluation of Model Predictions for the Hanford Site 200 Area Effluent Treatment Facility*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11800, 1998, Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11801, 1997, *Three-Dimensional Analysis of Future Groundwater Flow Conditions and Contaminant Plume Transport in the Hanford Site Unconfined Aquifer System: FY 1996 and 1997 Status Report*, Pacific Northwest National Laboratory, Richland, Washington.

Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2795, 42 USC 901 et seq.

RPP-6696, 2000, *Data to Support Tank C-106 Waste Retrieval Determination*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7807, 2001, *Single-Shell Tank C-104 Full Scale Sludge/HardHeel, Confined Sluicing and Robotic Technologies, Waste Retrieval Demonstration Functions and Requirements*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7884, 2002, *Field Investigation Report for Waste Management Area S-SX*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7825, 2001, *Single-Shell Tank S-112 Full Scale Saltcake Waste Retrieval Technology Demonstration Functions and Requirements*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-10901, 2002, *241-S-102 Initial Waste Retrieval Project Functions and Requirements*, Draft, CH2M HILL Hanford Group, Inc., Richland, Washington.

Attachment 2

WAC 173-340, "The Model Toxics Control Act Cleanup Regulation," *Washington Administrative Code*, as amended.

WHC-SD-WM-ER-615, 1998, *Tank Characterization Report for Single-Shell Tank 241-C-106*, Rev. 0B, Westinghouse Hanford Company, Richland, Washington.

APPENDIX B

INADVERTENT INTRUDER ANALYSES

Attachment 2

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B.1.0 INTRODUCTION

The intent of the inadvertent human intrusion analysis is to estimate the potential health effects to a hypothetical future site user from direct intrusion into tank waste contaminants remaining onsite following waste retrieval and tank farm closure actions. The inadvertent human intruder is assumed to drill through the contamination within the tank farm. The methodology used for assessing intruder impacts is consistent with the approach used in *Retrieval Performance Evaluation Methodology for the AX Tank Farm* (DOE/RL-98-72). Because an inadvertent intruder can only penetrate one tank at a time, the intruder analysis separately addresses each of the tanks (C-106, C-201, C-202, C-203 and C-204). Intruder impacts are examined based on scenarios and requirements established in DOE Order 435.1, *Radioactive Waste Management* (Frei 1996).

The DOE demonstrates protection of the inadvertent human intruder through site-specific performance assessments using a 100-mrem/yr chronic dose standard and a 500-mrem acute dose standard. The scenarios used in this analysis are consistent with those used in DOE/RL-98-72 and are based on the intrusion model in *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Burial Grounds* (WHC-EP-0645). The scenarios are the well driller scenario and the post-drilling resident scenario. These scenarios were selected based on their applicability to the deep contamination sources (i.e., tank residual waste) involved in this analysis. The CoCs to the inadvertent human intruder include isotopes of cesium, strontium, tin and transuranic waste that would remain in the tanks.

Contaminant transport is not considered for this analysis. Contaminants are assumed to be exhumed during well drilling and spread over the surface of certain land areas. The intruders receive radiation exposures because of their proximity to and use of the contaminated surface areas. The analysis considers radionuclide contaminants only. These radionuclides were selected because their half-lives are greater than five years and they have been shown in past performance assessments to dominate intruder doses (*Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement* [DOE/EIS-0189]).

B.2.0 DOSE FACTORS

Table B.1. shows half-lives and unit dose factors for each radionuclide of concern in the exhumed waste under the exposure conditions for the well driller and post-drilling resident scenarios. The dose factors are calculated using *GENII – The Hanford Environmental Radiation Dosimetry Software System* (PNL-6584) and are the same as those used in DOE/EIS-0189.

Table B.1. Intruder Scenario Unit Dose Factors

Isotope	Half Life (yr)	Dose Factor[a] (mrem/Ci exhumed)	
		Post-Drilling Resident	Driller
Sn-126	1.00E+05	6.93E+03	2.13E+03
Cs-137	3.02E+01	2.03E+02	6.13E+01
Pu-238	8.77E+01	2.82E+02	8.29E+01
U-238	4.49E+09	2.15E+02	5.49E+01
Pu-239	2.41E+04	6.96E+02	2.04E+02
Pu-240	6.57E+03	6.91E+02	2.00E+02
Am-241	4.32E+02	1.87E+02	6.45E+02
Pu-241	1.44E+01	2.21E+01	6.42E+00
Sr-90	2.86E+01	8.42E+01	6.93E-01

[a] Source = TWRS EIS (DOE/EIS-0189) Table D.7.3.1.

The well driller dose results from 40 hours of external exposure to the exhumed contaminants. The following is assumed of the post-drilling resident:

- Lives on a 2,500-m^2 (27,000-ft^2) parcel of land over which the exhumed waste has been spread
- Grows a variety of vegetables on the land
- Obtains 25% of total vegetables consumed from this garden.

The post-drilling resident ingests small amounts of contaminated soil each day, 100 mg/day (0.004 oz/day) and the total ingestion is 37 g/yr (1.3 oz/yr). The annual inhalation and external exposures are based on the post-drilling resident spending 1,800 hours in his garden and 4,380 hours in his house. The remaining 2,580 hours are spent elsewhere away from the intruder site.

B.3.0 EXHUMED WASTE FRACTION

The methodology for calculating the intruder exhumed waste fraction is the same as that used in DOE/EIS-0189 and is summarized in Table B.2. The source term is calculated as the total activity in curies of each constituent exhumed and made available at the surface. The well is assumed to be drilled through the residual waste in the tanks and into the underlying soil column down to the aquifer. The source term is calculated based on the residual waste in each tank. The source term (Ci_{exh}) from each tank is calculated based on the following relationships:

Given:

$$Ciexh = Citank * (Vexh/Vtank)$$

And Since:

$$Vtank = 3.14 * R^2tank * htank$$
$$Vexh = 3.14 * R^2exh * hexh$$
$$hexh = htank$$

Then:

$$Ciexh = Citank * [(3.14 * R^2exh * hexh)/(3.14 * R^2tank * htank)]$$

Therefore:

$$Ciexh = Citank * (Rexh/Rtank)^2 \qquad \text{(Eq. 1)}$$

Where:

Ciexh, Citank	=	exhumed curies, tank curies
Vexh, Vtank	=	exhumed volume, tank volume
Rexh, Rtank	=	exhumed radius, tank radius (see table below)
hexh, htank	=	exhumed waste height, tank waste height

Table B.2. Exhumed Waste Fraction For 100 and 200 Series Tanks

Tank Series	Tank Diameter (ft)	Well Diameter (ft)[a]	Tank Radius (ft)	Well Radius (ft)	Exhumed Waste Fraction[b]
100	7.50E+01	1.00E+00	3.75E+01	5.00E-01	1.78E-04
200	2.00E+01	1.00E+00	1.00E+01	5.00E-01	2.50E-03

[a] Consistent with drilling scenario used in TWRS EIS (see DOE/EIS-0189, Section D.7.0).
[b] From Eq. 1 above, calculated as $(R_{exh}/R_{tank})^2$.

B.4.0 DOSE CALCULATION

In order to represent the 100 years of institutional control the exhumed inventory is calculated using Equation 1 and a 100-year decay term. Unit dose factors calculated for a unit activity for each constituent based on the exposure conditions defined for each receptor are used. The source activity (Ci) is then multiplied by the unit dose factor for each receptor to produce the receptor dose.

B.5.0 EVALUATION CASES

Each tank is evaluated based on three cases: current status, retrieval to *Hanford Federal Facility Agreement* and Consent Order (HFFACO; Ecology et al. 1989) residual waste volume goals, and retrieval to 10% of the HFFACO goals. All tanks' starting inventories are based on BBI data as of April 2002. The HFFACO retrieval case assumes that 360 ft^3 (2,700 gal) of residual waste remains in tank C-106 and 30 ft^3 (225 gal) of residual waste remains in each of the 200-series tanks. The 10% HFFACO retrieval case reduces these inventories by a factor of ten.

For the cases involving retrieval, it is assumed that an MRS-type retreival system is used in an essentially dry mode, producing tank residuals with compositions equal to the current tank solids. Tank inventories are calculated by multiplying the BBI solids inventories by the ratio of either 2,700 gal (360 ft^3) or 220 gal (30ft^3) to the current tank solids volume.

In addition to the three cases discussed above, two additional evaluation cases for tank C-106 only were analyzed. These two additional cases evaluate the risks associated with the inventory of contaminants estimated to exist in tank C-106 prior to sluicing under project W-320 and liquid retrieval only.

B.6.0 CALCULATION DETAIL

The doses calculated for the well driller and post-drilling resident for each of the three cases analyzed are presented in Tables B.3. through B.17. Tables B.18. and B.19. represent two additional evaluation cases for tank C-106 only. These two additional cases will evaluate the risks associated with the inventory of contaminants estimated to exist in tank C-106 prior to sluicing under project W-320 and liquid retrieval only. For each tank under each case, the tables provide the tank inventory, exhumed inventory (decayed 100 years), calculated doses for the driller and post-drilling resident, and the results of a comparison (pass/fail) of the doses to the DOE dose standards for the two scenarios.

Tables B.3. through B.7. summarize the results of the inadvertent intruder calculation for the current state case for the well driller and the post-drilling resident. All five of the tanks pass the DOE-regulated acute exposure limit for exposure to the driller. Tanks C-106 and C-201 exceed the DOE chronic exposure limit for the post-drilling resident. Tank C-106 chronic dose is primarily driven by the short-lived isotope strontium-90, which institutional controls or an intruder barrier could mitigate. Tank C-201 is primarily driven by plutonium-239.

Table B.8. through Table B.12. summarize the results of the inadvertent intruder calculations for the case of retrieval to the HFFACO goals for the well driller and the post-drilling resident. All

five of the tanks analyzed pass the DOE acute exposure limit for exposure to the well driller. However, tank C-106 exceeds the post-drilling resident chronic exposure limit. Tank C-106 exposure is primarily driven by the short-lived isotope strontium-90, which institutional controls or an intruder barrier could mitigate.

Tables B.13. through Table B.17. summarize the results of the inadvertent intruder calculations for the case of retrieval to 10% of HFFACO goals. For both the well driller and post-drilling resident inadvertent intruder scenarios none of the tanks exceed the limits of exposure.

Table B.3. Inadvertent Intruder Calculation Detail for a Current State Case for Tank C-106

Tank Number =	241-C-106		Fails	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	2.14E+00	3.80E-04	2.63E+00	8.10E-01
Cs-137	1.75E+04	3.13E-01	6.36E+01	1.92E+01
Pu-238	3.50E+00	2.82E-04	7.96E-02	2.34E-02
U-238	4.40E-02	7.82E-06	1.68E-03	4.29E-04
Pu-239	7.56E+01	1.34E-02	9.33E+00	2.73E+00
Pu-240	1.54E+01	2.71E-03	1.87E+00	5.42E-01
Am-241	2.25E+02	3.41E-02	6.37E+00	2.20E+01
Pu-241	1.85E+02	2.67E-04	5.90E-03	1.71E-03
Sr-90	2.82E+05	4.44E+00	3.74E+02	3.08E+00
Total			4.58E+02	4.84E+01
Standard			1.00E+02	5.00E+02

Table B.4. Inadvertent Intruder Calculation Detail for a Current State Case for Tank C-201 (2 Sheets)

Tank Number =	241-C-201		Fails	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	5.61E-03	1.40E-05	9.71E-02	2.99E-02
Cs-137	7.87E+01	1.98E-02	4.02E+00	1.22E+00
Pu-238	1.45E+00	1.64E-03	4.64E-01	1.36E-01
U-238	3.80E-04	9.50E-07	2.04E-04	5.22E-05

Table B.4. Inadvertent Intruder Calculation Detail for a Current State Case for Tank C-201 (2 Sheets)

Tank Number =	241-C-201		Fails	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Pu-239	6.48E+01	1.62E-01	1.12E+02	3.30E+01
Pu-240	1.07E+01	2.65E-02	1.83E+01	5.29E+00
Am-241	2.27E+01	4.83E-02	9.04E+00	3.12E+01
Pu-241	7.92E+01	1.61E-03	3.55E-02	1.03E-02
Sr-90	4.13E+02	9.15E-02	7.70E+00	6.34E-02
Total			1.52E+02	7.09E+01
Standard			1.00E+02	5.00E+02

Table B.5. Inadvertent Intruder Calculation Detail for a Current State Case for Tank C-202

Tank Number =	241-C-202		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	5.85E-03	1.46E-05	1.01E-01	3.11E-02
Cs-137	8.22E+01	2.07E-02	4.20E+00	1.27E+00
Pu-238	7.62E-01	8.64E-04	2.44E-01	7.16E-02
U-238	3.96E-04	9.90E-07	2.13E-04	5.44E-05
Pu-239	3.39E+01	8.45E-02	5.88E+01	1.72E+01
Pu-240	5.57E+00	1.38E-02	9.52E+00	2.76E+00
Am-241	1.19E+01	2.53E-02	4.74E+00	1.63E+01
Pu-241	4.14E+01	8.40E-04	1.86E-02	5.39E-03
Sr-90	4.31E+02	9.55E-02	8.04E+00	6.62E-02
Total			8.57E+01	3.78E+01
Standard			1.00E+02	5.00E+02

Attachment 2

Table B.6. Inadvertent Intruder Calculation Detail for a Current State Case for Tank C-203

Tank Number =	241-C-203		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	1.12E-02	2.80E-05	1.94E-01	5.96E-02
Cs-137	1.57E+02	3.95E-02	8.03E+00	2.42E+00
Pu-238	3.81E-01	4.32E-04	1.22E-01	3.58E-02
U-238	7.56E-04	1.89E-06	4.06E-04	1.04E-04
Pu-239	1.70E+01	4.24E-02	2.95E+01	8.65E+00
Pu-240	2.79E+00	6.90E-03	4.77E+00	1.38E+00
Am-241	5.95E+00	1.27E-02	2.37E+00	8.17E+00
Pu-241	2.07E+01	4.20E-04	9.29E-03	2.70E-03
Sr-90	8.23E+02	1.82E-01	1.53E+01	1.26E-01
Total			6.03E+01	2.08E+01
Standard			1.00E+02	5.00E+02

Table B.7. Inadvertent Intruder Calculation Detail for a Current State Case for Tank C-204

Tank Number =	241-C-204		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	7.21E-03	1.80E-05	1.25E-01	3.84E-02
Cs-137	1.01E+02	2.54E-02	5.16E+00	1.56E+00
Pu-238	7.76E-03	8.80E-06	2.48E-03	7.30E-04
U-238	4.89E-04	1.22E-06	2.63E-04	6.71E-05
Pu-239	3.47E-01	8.65E-04	6.02E-01	1.76E-01
Pu-240	5.69E-02	1.41E-04	9.73E-02	2.82E-02
Am-241	1.21E-01	2.58E-04	4.82E-02	1.66E-01
Pu-241	4.23E-01	8.59E-06	1.90E-04	5.51E-05
Sr-90	5.32E+02	1.18E-01	9.92E+00	8.17E-02
Total			1.60E+01	2.05E+00
Standard			1.00E+02	5.00E+02

Table B.8. Inadvertent Intruder Calculation Detail for a HFFACO Retrieval Case for Tank C-106

Tank Number =	241-C-106		Fails	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	8.04E-01	1.43E-04	9.90E-01	3.04E-01
Cs-137	5.07E+03	9.07E-02	1.84E+01	5.56E+00
Pu-238	1.55E+00	1.25E-04	3.52E-02	1.03E-02
U-238	6.09E-03	1.08E-06	2.33E-04	5.94E-05
Pu-239	3.34E+01	5.92E-03	4.12E+00	1.21E+00
Pu-240	6.84E+00	1.20E-03	8.32E-01	2.41E-01
Am-241	1.00E+02	1.51E-02	2.83E+00	9.76E+00
Pu-241	8.18E+01	1.18E-04	2.61E-03	7.58E-04
Sr-90	1.25E+05	1.97E+00	1.66E+02	1.37E+00
Total			1.93E+02	1.85E+01
Standard			1.00E+02	5.00E+02

Table B.9. Inadvertent Intruder Calculation Detail for a HFFACO Retrieval Case for Tank C-201

Tank Number =	241-C-201		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	1.17E-03	2.92E-06	2.02E-02	6.21E-03
Cs-137	1.64E+01	4.13E-03	8.38E-01	2.53E-01
Pu-238	3.02E-01	3.42E-04	9.65E-02	2.84E-02
U-238	7.91E-05	1.98E-07	4.25E-05	1.09E-05
Pu-239	1.35E+01	3.36E-02	2.34E+01	6.86E+00
Pu-240	2.23E+00	5.51E-03	3.81E+00	1.10E+00
Am-241	4.73E+00	1.01E-02	1.88E+00	6.49E+00
Pu-241	1.65E+01	3.35E-04	7.40E-03	2.15E-03
Sr-90	8.60E+01	1.90E-02	1.60E+00	1.32E-02
Total			3.17E+01	1.48E+01
Standard			1.00E+02	5.00E+02

Table B.10. Inadvertent Intruder Calculation Detail for a HFFACO Retrieval Case for Tank C-202

Tank Number =	241-C-202		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	1.22E-03	3.04E-06	2.11E-02	6.48E-03
Cs-137	1.71E+01	4.31E-03	8.75E-01	2.64E-01
Pu-238	1.59E-01	1.80E-04	5.07E-02	1.49E-02
U-238	8.24E-05	2.06E-07	4.43E-05	1.13E-05
Pu-239	7.06E+00	1.76E-02	1.22E+01	3.59E+00
Pu-240	1.16E+00	2.87E-03	1.98E+00	5.74E-01
Am-241	2.48E+00	5.28E-03	9.86E-01	3.40E+00
Pu-241	8.62E+00	1.75E-04	3.87E-03	1.12E-03
Sr-90	8.97E+01	1.99E-02	1.67E+00	1.38E-02
Total			1.78E+01	7.87E+00
Standard			1.00E+02	5.00E+02

Table B.11. Inadvertent Intruder Calculation Detail for a HFFACO Retrieval Case for Tank C-203

Tank Number =	241-C-203		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	9.33E-04	2.33E-06	1.61E-02	4.96E-03
Cs-137	1.31E+01	3.29E-03	6.68E-01	2.02E-01
Pu-238	3.17E-02	3.60E-05	1.01E-02	2.98E-03
U-238	6.30E-05	1.57E-07	3.38E-05	8.64E-06
Pu-239	1.42E+00	3.53E-03	2.46E+00	7.20E-01
Pu-240	2.32E-01	5.75E-04	3.97E-01	1.15E-01
Am-241	4.95E-01	1.06E-03	1.97E-01	6.80E-01
Pu-241	1.72E+00	3.50E-05	7.73E-04	2.25E-04
Sr-90	6.85E+01	1.52E-02	1.28E+00	1.05E-02
Total			5.02E+00	1.74E+00

Standard		1.00E+02	5.00E+02

Table B.12. Inadvertent Intruder Calculation Detail for a HFFACO Retrieval Case for Tank C-204

Tank Number =	241-C-204		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	6.00E-04	1.50E-06	1.04E-02	3.19E-03
Cs-137	8.41E+00	2.12E-03	4.30E-01	1.30E-01
Pu-238	6.46E-04	7.33E-07	2.07E-04	6.08E-05
U-238	4.07E-05	1.02E-07	2.19E-05	5.59E-06
Pu-239	2.89E-02	7.20E-05	5.01E-02	1.47E-02
Pu-240	4.74E-03	1.17E-05	8.10E-03	2.34E-03
Am-241	1.01E-02	2.15E-05	4.01E-03	1.38E-02
Pu-241	3.52E-02	7.15E-07	1.58E-05	4.59E-06
Sr-90	4.43E+01	9.81E-03	8.26E-01	6.80E-03
Total			1.33E+00	1.71E-01
Standard			1.00E+02	5.00E+02

Table B.13. Inadvertent Intruder Calculation Detail for a 10 percent HFFACO Retrieval Case for Tank C-106

Tank Number =	241-C-106		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	8.04E-02	1.43E-05	9.90E-02	3.04E-02
Cs-137	5.07E+02	9.07E-03	1.84E+00	5.56E-01
Pu-238	1.55E-01	1.25E-05	3.52E-03	1.03E-03
U-238	6.09E-04	1.08E-07	2.33E-05	5.94E-06
Pu-239	3.34E+00	5.92E-04	4.12E-01	1.21E-01
Pu-240	6.84E-01	1.20E-04	8.32E-02	2.41E-02
Am-241	1.00E+01	1.51E-03	2.83E-01	9.76E-01
Pu-241	8.18E+00	1.18E-05	2.61E-04	7.58E-05
Sr-90	1.25E+04	1.97E-01	1.66E+01	1.37E-01
Total			1.93E+01	1.85E+00
Standard			1.00E+02	5.00E+02

Table B.14. Inadvertent Intruder Calculation Detail for a 10 percent HFFACO Retrieval Case for Tank C-201

Tank Number =	241-C-201		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	1.17E-04	2.92E-07	2.02E-03	6.21E-04
Cs-137	1.64E+00	4.13E-04	8.38E-02	2.53E-02
Pu-238	3.02E-02	3.42E-05	9.65E-03	2.84E-03
U-238	7.91E-06	1.98E-08	4.25E-06	1.09E-06
Pu-239	1.35E+00	3.36E-03	2.34E+00	6.86E-01
Pu-240	2.23E-01	5.51E-04	3.81E-01	1.10E-01
Am-241	4.73E-01	1.01E-03	1.88E-01	6.49E-01
Pu-241	1.65E+00	3.35E-05	7.40E-04	2.15E-04
Sr-90	8.60E+00	1.90E-03	1.60E-01	1.32E-03
Total			3.17E+00	1.48E+00
Standard			1.00E+02	5.00E+02

Table B.15. Inadvertent Intruder Calculation Detail for a 10 percent HFFACO Retrieval Case for Tank C-202

Tank Number =	241-C-202		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	1.22E-04	3.04E-07	2.11E-03	6.48E-04
Cs-137	1.71E+00	4.31E-04	8.75E-02	2.64E-02
Pu-238	1.59E-02	1.80E-05	5.07E-03	1.49E-03
U-238	8.24E-06	2.06E-08	4.43E-06	1.13E-06
Pu-239	7.06E-01	1.76E-03	1.22E+00	3.59E-01
Pu-240	1.16E-01	2.87E-04	1.98E-01	5.74E-02
Am-241	2.48E-01	5.28E-04	9.86E-02	3.40E-01
Pu-241	8.62E-01	1.75E-05	3.87E-04	1.12E-04
Sr-90	8.97E+00	1.99E-03	1.67E-01	1.38E-03
Total			1.78E+00	7.87E-01
Standard			1.00E+02	5.00E+02

Table B.16. Inadvertent Intruder Calculation Detail for a 10 percent HFFACO Retrieval Case for Tank C-203

Tank Number =	241-C-203		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	9.33E-05	2.33E-07	1.61E-03	4.96E-04
Cs-137	1.31E+00	3.29E-04	6.68E-02	2.02E-02
Pu-238	3.17E-03	3.60E-06	1.01E-03	2.98E-04
U-238	6.30E-06	1.57E-08	3.38E-06	8.64E-07
Pu-239	1.42E-01	3.53E-04	2.46E-01	7.20E-02
Pu-240	2.32E-02	5.75E-05	3.97E-02	1.15E-02
Am-241	4.95E-02	1.06E-04	1.97E-02	6.80E-02
Pu-241	1.72E-01	3.50E-06	7.73E-05	2.25E-05
Sr-90	6.85E+00	1.52E-03	1.28E-01	1.05E-03
Total			5.02E-01	1.74E-01
Standard			1.00E+02	5.00E+02

Table B.17. Inadvertent Intruder Calculation Detail for a 10 percent HFFACO Retrieval Case for Tank C-204

Tank Number =	241-C-204		Passes	Passes
Radionuclide	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	6.00E-05	1.50E-07	1.04E-03	3.19E-04
Cs-137	8.41E-01	2.12E-04	4.30E-02	1.30E-02
Pu-238	6.46E-05	7.33E-08	2.07E-05	6.08E-06
U-238	4.07E-06	1.02E-08	2.19E-06	5.59E-07
Pu-239	2.89E-03	7.20E-06	5.01E-03	1.47E-03
Pu-240	4.74E-04	1.17E-06	8.10E-04	2.34E-04
Am-241	1.01E-03	2.15E-06	4.01E-04	1.38E-03
Pu-241	3.52E-03	7.15E-08	1.58E-06	4.59E-07
Sr-90	4.43E+00	9.81E-04	8.26E-02	6.80E-04
Total			1.33E-01	1.71E-02

Standard		1.00E+02	5.00E+02

Tables B.18. and B.19. represent two additional evaluation cases for tank C-106 only. These two additional cases will evaluate the risks associated with the inventory of contaminants estimated to exist in tank C-106 prior to sluicing under Project W-320 and liquid retrieval only.

Table B.18. summarizes the results of the inadvertent intruder calculation for the status of tank C-106 prior to Project W-320 sluicing campaign. Tank C-106 exceeded both the chronic and acute exposure limits set for the inadvertent intruder. The short-lived (23 years) strontium-90 isotope primarily drives the chronic exposure for tank C-106. The acute exposure for tank C-106 Pre-Project W-320 is driven by cesium-137, which also considered a short-lived isotope (30 years).

Table B.19. summarizes the results of the inadvertent intruder calculation for the retrieval of liquids only from tank C-106. Tank C-106 exceeds the chronic exposure limit. The chronic exposure for tank C-106 is driven primarily by the short-lived strontium-90 isotope, which could be mitigated by institutional controls or an intruder barrier.

Table B.18. Inadvertent Intruder Calculation Detail for Tank C-106 Pre-Project W-320

Tank Number =	**241-C-106**		**Fails**	**Fails**
Radionuclide	**Tank Inventory[a] (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	3.02E+01	5.37E-03	3.72E+01	1.14E+01
Cs-137	2.67E+05	4.78E+00	9.71E+02	2.93E+02
Pu-238	1.16E+02	9.36E-03	2.64E+00	7.76E-01
U-238	4.68E-01	8.32E-05	1.79E-02	4.57E-03
Pu-239	2.37E+03	4.20E-01	2.92E+02	8.57E+01
Pu-240	4.85E+02	8.53E-02	5.90E+01	1.71E+01
Am-241	1.12E+03	1.70E-01	3.17E+01	1.09E+02
Pu-241	8.17E+03	1.18E-02	2.61E-01	7.57E-02
Sr-90	4.77E+06	7.51E+01	6.33E+03	5.21E+01
Total			7.72E+03	5.70E+02
Standard			1.00E+02	5.00E+02

[a] Source = Tank Characterization Report for Single-Shell Tank 241-C-106 (WHC-SD-WM-ER-615, Revision 0B, September 30, 1998) as reported in Letter Report #1: Inventory Estimates to Support Tank C-106 Residual Waste Assessment (RPP-6629, Table 2).

Table B.19. Inadvertent Intruder Calculation Detail for Tank C-106 Liquid Only Retrieval

Tank Number =	241-C-106			Fails	Passes
Radionuclide	**Inventory in C-106 Supernatant/ AR (Liquid)**	**Tank Inventory (Ci)**	**Exhumed Inventory (Ci) (Decayed 100 yr)**	**Post-Drilling Resident Dose (mrem/yr)**	**Driller Dose (mrem)**
Sn-126	3.30E-01	1.81E+00	3.22E-04	2.23E+00	6.85E-01
Cs-137	6.16E+03	1.13E+04	2.03E-01	4.12E+01	1.24E+01
Pu-238	2.12E-02	3.48E+00	2.81E-04	7.91E-02	2.33E-02
U-238	3.03E-02	1.37E-02	2.44E-06	5.24E-04	1.34E-04
Pu-239	4.57E-01	7.51E+01	1.33E-02	9.27E+00	2.72E+00
Pu-240	9.33E-02	1.53E+01	2.69E-03	1.86E+00	5.39E-01
Am-241	5.36E-02	2.25E+02	3.41E-02	6.37E+00	2.20E+01
Pu-241	1.12E+00	1.84E+02	2.65E-04	5.87E-03	1.70E-03
Sr-90	3.43E+02	2.82E+05	4.44E+00	3.74E+02	3.07E+00
Total				4.35E+02	4.15E+01
Standard				1.00E+02	5.00E+02

B.7.0 CONCLUSIONS

DOE regulations require that exposure to the inadvertent human intruder not exceed 500 mrem for an acute or single event (well driller) and 100 mrem in a year from chronic exposure (post-drilling resident) (DOE O 435.1). A comparison of the well driller and post-driller resident doses to the DOE regulations for the various cases results in the following conclusions.

- None of the well driller cases analyzed from each of the tanks exceeds the 500-mrem acute dose limit set in DOE O 435.1. For the no-retrieval case, tank C-202 has the greatest acute dose impact (70.9 mrem) to the well driller.

- Only tank C-106 and tank C-201 in the no-retrieval case exceed the 100-mrem/yr chronic dose limit. Tank C-201 is below the 100 mrem/yr limit for both the HFFACO and 10% HFFACO retrieval cases.

- Tank C-106 continues to exceed the 100-mrem/yr chronic dose limit under the HFFACO retrieval case but is below the 100-mrem/yr limit for the 10% HFFACO retrieval case.

The following conclusions were drawn from the analysis of the additional two cases.

- Tank C-106 prior to Project W-320 sluicing exceeded both the chronic and acute exposure limits set for the inadvertent intruder. The short-lived strontium-90 isotope

primarily drives the chronic exposure for tank C-106. The acute exposure for tank C-106 prior to Project W-320 is driven by cesium-137, which also is considered a short-lived isotope.

- Following retrieval of liquids only from tank C-106, the tank exceeds the chronic exposure limit. The chronic dose for tank C-106 is primarily driven by the strontium-90 isotope, which is considered short-lived.

B.8.0 REFERENCES

BBI, 2002, *Tank Waste Information Network System (TWINS)*, April 15, 2002, [Best Basis Inventory, Best Basis/TCR Tank Inventory], http://twins.pnl.gov/data/datamenu.htm#.

DOE/EIS-0189, 1996, *Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement*, U.S. Department of Energy and Washington State Department of Ecology, Washington, D.C.

DOE O 435.1, 1997, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

DOE/RL-98-72, 1999, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Frei, M.W., 1996, *Issuance of Low-Level Waste Performance Assessment Guidance* (Memorandum on Distribution Issuing the Interim Format and Content Guide and Standard Review Plan for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments), U.S. Department of Energy, Washington, D.C.

PNL-6584, 1988, *GENII – The Hanford Environmental Radiation Dosimetry Software System*, Pacific Northwest Laboratory, Richland, Washington.

WHC-EP-0645, 1995, Performance Assessment for the Disposal of Low-Level Waste in the 200 West Burial Grounds, Westinghouse Hanford Company, Richland, Washington.

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APPENDIX C

SHORT-TERM HUMAN HEALTH RISK FROM ROUTINE AND ACCIDENT RELEASES

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Attachment 2

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C.1.0 INTRODUCTION

The intent of the short-term human health risk analysis is to estimate the potential health impacts from both accident and normal (non-accident) conditions resulting from various tank waste retrieval scenarios for tanks C-106, C-201, C-202, C203, and C-204. The analysis identifies the spectrum of potential accidents associated with construction and operation activities.

The hazards associated with these activities include 1) potential occupational hazards resulting in physical trauma and 2) radiological exposure resulting in LCFs. Initiating events that could result in hazardous health effects may include natural phenomena, human error, component failure, and spontaneous reactions. Health risks during normal conditions include anticipated exposure to radiation fields and radiological releases to the atmosphere during normal retrieval activities.

C.1.1 OCCUPATIONAL INJURIES, ILLNESSES, AND FATALITIES

The number of injuries, illnesses, and fatalities resulting from retrieval and closure activities is calculated based on the most currently available incidence rates that would be applicable to the retrieval activities ("Injury/Illness Rates at Hanford," Millet 2000). The number of injuries, illnesses, and fatalities from construction or operations is calculated by multiplying the total person-years required to support the activity by the incidence rates.

C.1.2 RADIOLOGICAL RISK FROM ACCIDENTS

The radiological risk is expressed as the number of LCFs resulting from accidents in which people are exposed to radiation fields or radiological constituents released to the atmosphere. The probability of the accident occurring also is evaluated. The methodology used to identify and quantify the radiological risk from accidents is performed using the following steps.

Step 1. Accident Identification. Potential hazards associated with retrieval activities are identified from existing preliminary hazards analyses and other safety documents. The hazards will be reported in a tabular format showing, for each accident, the barriers within the facility that prevent or mitigate the consequences of the accident, a rough estimate of the magnitude of consequences of the accident assuming that the listed preventive barriers fail, and the estimated likelihood of the accident occurring.

Step 2. Accident Strategy Selection. The accident with the highest risk is screened for further analysis to determine, as accurately as possible, the consequences and probability of occurrence. The risk of a given accident is the product of the consequences of the accident and the estimated likelihood of the event occurring. Screening for the highest risk accidents follows the same methodology as outlined in the *Preparation Guide For U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports* (DOE-STD-3009-94, Section 3.3.2.3.5).

Step 3. Accident Sequence Quantification. The frequency of occurrence of the selected accidents is taken from referenced documents where available. Where accident frequencies are not available, they are estimated.

Step 4. Source-Term Development. The source term is the respirable fraction of inventory from which the receptor dose is calculated. The source term is developed based on the inventory that could potentially be released to the environment from an accident. The major reduction factors that control the source term are considered in the evaluation. The reduction factors include damage ratios, airborne release fractions, airborne release rates, leak path factors, and respirable fractions. Use of the reduction factors will be dependent on the nature of the accident (i.e., energy of accident at impact, waste form, and effectiveness of mitigating barriers). Exposure resulting from direct exposure to radiation under accident conditions is also evaluated. Direct exposure is the direct gamma radiation dose rate to a receptor.

Step 5. Atmospheric Dispersion Coefficients (X/Q). The X/Q values are generated using the GXQ computer code in the GXQ Program Users Guide (WHC-SD-GN-SWD-3002) following the methodology outlined in the *Atmospheric Dispersion Models for Potential Accident Consequence Assessment at Nuclear Power Plants* as referenced in the NRC Regulatory Guide 1.145 (NRC 1982). The meteorological data used by GXQ are in the form of joint frequency tables. The joint frequency data are taken from data collected at the Hanford Site meteorology tower in the 200 Area. The X/Q values are used in equations to calculate the radiological dose experienced by the noninvolved worker and general public receptors as a result of inhaling radioactive materials (ingestion will also be included for the general public receptor dose).

Step 6. Receptor Determination. Potential health effects from radiological exposures are estimated for three subsets of populations and MEIs in those populations. The dose to a receptor depends on the location of the receptor relative to the point of release of the radioactive material. The involved workers are those involved in the proposed action and are in the workplace performing work at the facility. They are assumed to be in the center of a 10-m (33.0-ft) radius hemisphere where the airborne released material has spread instantaneously and uniformly and would expose a crew of 10 people. The noninvolved workers would be on the Hanford Site but not involved in the action. They are assumed to extend from 100 m (330 ft) out to the Hanford Site boundary. The general public is assumed to be located at the site boundary to a distance of 80 km (50 mi) from the point of release. The Hanford Site boundary used in the analysis is the adjusted site boundary that excludes areas designated as the Hanford Reach National Monument. These areas include the North Slope, the Hanford Reach of the Columbia River, and the Fitzner Eberhardt Arid Lands Ecology Reserve. The site boundaries are as follows:

- North: Columbia River - 0.4 km (0.25 mi) south of the south river bank
- East: Columbia River - 0.4 km (0.25 mi) west of the west riverbank
- South: A line running west from the Columbia River, just north of the Washington Public Power Supply System leased area, through the Wye Barricade to Highway 240
- West: Highway 240 and Highway 24.

Step 7. Radiological Dose Assessment. The inventory involved in each accident is evaluated to determine the activity concentrations. The activity concentrations are converted to unit liter

dose (ULD) factors. The GENII computer code (*GENII – The Hanford Environmental Radiation Dosimetry Software System* [PNL-6584]) is used to generate a single ULD factor for each composite source term for a 70-year dose commitment period. The receptor doses are given in terms of committed effective dose equivalents. The ULD factors are used along with the appropriate atmospheric dispersion coefficient and the source term to determine the radiological dose to the noninvolved worker and general public receptors.

Step 8. LCF Risk Development. The likelihood that a dose of radiation would result in a fatal cancer at some future time is calculated by multiplying the receptor dose by a dose-to-risk conversion factor. Conversion factors are predictions of health effects from radiation exposure. The dose-to-risk conversion factors used for estimating LCFs from low doses of radiological exposure and from high doses are consistent with those taken from *Recommendations of the International Commissions on Radiological Protection* (ICRP 1991).

C.1.3 RADIOLOGICAL LATENT CANCER FATALITIES RISK FROM ROUTINE EXPOSURE

The involved worker exposure is a combination of exposure from inhalation and direct radiation. Involved worker dose rates are estimated based on time, distance, and shielding considerations associated with the various tasks. Noninvolved workers and general public exposure are estimated by determining the expected routine radiological releases during retrieval and closure. Exposure to the noninvolved worker is assumed to be from inhalation and external radiation from the plume continuously throughout the year and from deposition of radionuclides on the ground. The exposure pathways for the general public are assumed to be inhalation, external exposure from submersion in a plume, and ingestion of contaminated farm products.
The receptors are in the same location and the same population size as defined in Section C.1.2 for radiological accidents. The GENII computer code is used to calculate the dose based on X/Qs generated by GXQ. The LCF risk is then calculated by multiplying the receptor dose by a dose-to-risk conversion factor from ICRP 1991 defined in Section C.1.2 for radiological accidents.

C.2.0 METHODOLOGY, CALCULATION DETAIL, AND RESULTS

This section provides the methodology, calculation detail, and results for the short-term human health risk analysis. The no retrieval case was dismissed from the evaluation since there would be no retrieval exposure (routine or accident) and no occupational accidents from retrieval activities. The analysis focuses on four evaluation cases involving:

- Retrieval to the current waste volume (Project W-320)
- Retrieval of liquids only (Liquid-Only Retrieval)
- Retrieval to the residual waste volume goals in the HFFACO (*Hanford Federal Facility Agreement and Consent Order* [Ecology et at. 1989])
- Retrieval to 10% of the HFFACO residual waste volume goals.

C.2.1 OCCUPATIONAL ACCIDENT RISK RESULTS

The potential exists for accidents (i.e., cuts, falls, etc.) to occur resulting from construction and operation activities associated with additional tank retrieval.

C.2.1.1 Assumptions

Occupational injuries, illnesses, and fatalities resulting from potential accidents are calculated based on the following assumptions:

- Tank C-106 labor requirements for waste retrieval (*Calculations to Support the Cost-Risk Analysis* [Jacobs 2002])
  - Project W-320 retrieval = 1,147,641 hours
  - Liquid-only retrieval = 167,132 hours
  - Retrieve to HFFACO goal = 835,661 hours
  - Retrieve to 10% of HFFACO goal = 1,225,585 hours
- Tanks C-201, C-202, C-203, and C-204 labor requirements for waste retrieval collectively (Jacobs 2002)
  - Retrieve to HFFACO goal = 898,986 hours
  - Retrieve to 10% of HFFACO goal = 1,351,266 hours
- Hanford specific incidence rates for occupational accidents ("*Injury/Illness Rates at Hanford*" [Millet 2000])
  - Total recordable cases (TRCs) = 1.93E-05 TRCs/hour
  - Lost workday cases (LWCs) = 8.04E-06 LWCs/hour
  - Fatalities = 1.35E-08 fatalities/hour.

C.2.1.2 Risk Calculation and Results for Occupational Accidents

The number of incidences (I) resulting from potential occupational accidents is calculated using Equation C-1 and presented in Table C.1.

$$I = L \times ir \qquad \text{(C-1)}$$

Where:

L = labor requirement (hours)
ir = incidence rates (I/hour)

Table C.1. Worker Risk From Occupational Accidents

Case	Incidence	Tank				
		C-106	C-201	C-202	C -203	C-204
Project W-320 Retrieval	TRC	2.2E+01	NA	NA	NA	NA
	LWC	9.2E+00	NA	NA	NA	NA
	Fatalities	1.6E-02	NA	NA	NA	NA
Liquid-only Retrieval	TRC	3.2E+00	NA	NA	NA	NA
	LWC	1.3E+00	NA	NA	NA	NA
	Fatalities	2.3E-03	NA	NA	NA	NA
HFFACO	TRC	1.6E+01	1.7E+01	1.7E+01	1.7E+01	1.7E+01
Retrieval	LWC	6.7E+00	7.2E+00	7.2E+00	7.2E+00	7.2E+00
	Fatalities	1.1E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
10% HFFACO	TRC	2.4E+01	2.6E+01	2.6E+01	2.6E+01	2.6E+01
Retrieval	LWC	9.9E+00	1.1E+01	1.1E+01	1.1E+01	1.1E+01
	Fatalities	1.7E-02	1.8E-02	1.8E-02	1.8E-02	1.8E-02

Notes:

Project W-320 Retrieval = Retrieval to current waste volume

Liquid-only Retrieval = Retrieval of liquids only

HFFACO Retrieval = Retrieval of tank waste to HFFACO goals of 360 ft^3 (10,200 L [2,700 gal]) for tank C-106 and 30 ft^3 (850 L [220 gal]) for tanks C-201, C-202, C-203, and C-204

10% HFFACO Retrieval = Retrieval of tank waste to a level of 36 ft^3 (1,020 L [270 gal]) for tank C-106 and 3 ft^3 (85 L [22 gal]) for tanks C-201, C-202, C-203, and C-204.

TRC = total recordable cases
LWC = lost workday cases

C.2.2 RADIOLOGICAL ACCIDENT RISK

Radiological accidents are unplanned events or a sequence of events that result in undesirable consequences. The potential exists for radiological accidents to result from the tank waste

retrieval operations. Radiological accidents could result in the unmitigated release of radiological constituents to the atmosphere, exposing the involved worker, noninvolved worker and general public (these receptors are defined in Section 5.3.1) resulting in an LCF risk. The probability of the accident occurring is also taken into consideration. When the consequences of the accident or LCF risk is evaluated with the probability of the accident occurring, the product of the two is referred to as the point-estimate LCF risk.

A spectrum of potential accidents associated with additional retrieval of waste from tanks C-106, C-201, C-202, C-203, and C-204 was reviewed in the *Safety Assessment for Tank 241-C-106 Waste Retrieval Project W-320* (WHC-SD-WM-SAD-024). Several of the more bounding accidents identified in the safety assessment are summarized in Table C.2. The WHC-SD-WM-SAD-024 safety assessment was used to provide the technical basis for a change to the authorization basis to allow the Project W-320 retrieval of high-heat waste from tank C-106 to tank AY-102 to proceed. An additional review in *Preliminary Hazard Identification and Evaluation for the Tank 241-C-106 Waste Heel Retrieval Demonstration* (10245-CD-006) identified several more potential accidents that were not identified in WHC-SD-WM-SAD-024. These accidents are also summarized in Table C.2. The purpose of the 10245-CD-006 evaluation was to identify hazards associated with the deployment of the waste retrieval equipment proposed for the tank C-106 heel retrieval demonstration as part of the Hanford Tank Initiative Project. The "spray leak from a transfer line" accident with a high severity level (major onsite and offsite impacts on people) and an unlikely probability (1.0E-02 to 1.0E-04) was selected for evaluation in this analysis because it was determined to be the bounding accident.

As evaluated in WHC-SD-WM-SAD-024, a spray leak was assumed to occur at a jumper connection within a jumper pit and go undetected for 8 hours. Double-sided leaks could develop as a result of events such as earthquakes, improperly sized connection gaskets, and loose connection installation. A maximum expected pipe pressure of 350 lb/in.^{2} gauge was used to determine liquid aerosolization rates. The jumper pit is equipped with a removable cover block to provide the necessary confinement of radioactive releases to the environment should a leak occur and are required to be in place before commencing transfer. It was assumed that the operators failed to place the cover block prior to commencing transfer and that the orientation of spray leaks directed the spray out of the jumper pit area. Accumulating liquid was assumed to drain through the jumper pit drain before the liquid level reached the alarm detection level.

Table C.2. Preliminary Hazard Analysis

Accident	Consequences	Mitigative/Preventive Barriers		Severity Level	Probability
		Administrative	Engineered		
Opening a riser[a]	Increases exposure to worker from direct radiation and release of radiological contaminants	Surveillance by radiation protection technician Radiological workers will wear personal protective gear while removing risers	Radiation detectors	Low	Likely
Flammable gas deflagration[b]	Energy from deflagration could compromise the tank dome or ventilation system resulting in release of radiological contaminants and exposure to the workers Potential trauma to workers from deflagration	Flammable gas control	Tank ventilation system	High	Extremely unlikely
Spray leak from transfer line[a]	Spray leak from transfer line resulting in release of radiological contaminants and exposure to the workers	Operator surveillance	Cover block over jumper pit Leak detection Radiation detectors	High	Unlikely
Ventilation failure[a]	Ventilation failure resulting in unfiltered release of radiological contaminants and exposure to the workers	Evacuation procedures	Differential pressure alarms	High	Extremely unlikely
Natural phenomena[a]	Seismic event compromises waste tank or transfer lines resulting in release of radiological contaminants and exposure to the workers	Evacuation procedures	Seismic switch on transfer pump	Medium	Extremely unlikely

[a] Accident taken from WHC-SD-WM-SAD-024.
[b] Accident taken from 10245-CD-006.

C.2.2.1 Assumptions

During the spray leak accident a volume of waste with a concentration of radionuclides would be released to the atmosphere, dispersed in the atmosphere as it travels downwind from the point of release, inhaled by the various receptors, and resulting in a LCF risk. In calculating the LCF risk the following assumptions were made.

- The volume of respirable waste released in the accident are as calculated in (WHC-SD-WM-SAD-024).
- The concentrations of radionuclides are calculated based on best-basis inventory (BBI 2002) and are presented in Table C.3.
- For the noninvolved workers and general public exposure scenarios, the atmospheric dispersion coefficients were calculated using the GXQ computer code (WHC-SD-GN-SWD-30002).
- For the involved workers it was assumed the respirable waste released in the accident would spread instantaneously, and uniformly over a hemisphere 10 m in radius. (Potential Accidents with Radiological and Toxicological Source Terms for Hanford Tank Waste Remediation System Environmental Impact Statement [WHC-SD-WM-ANAL-041]).
- The breathing rates for the various receptors are referenced in the 1975 Report of the Task Group on Reference Man (ICRP 1975).
- The inhalation dose conversion factors for a 70-year dose commitment for each radionuclide is referenced in GENII (PNL-6584).
- The dose-to-risk conversion factors for converting receptor doses to LCFs are referenced in the Preamble to Standard for Protection Against Radiation (NRC 1991) and the 1990 Recommendation of the International Commission on Radiological Protection (ICRP 1991) and apply as follows:
  - Involved worker and non-involved worker = 4.0×10^{-4} LCF/rem for low doses under 20 rem, 8.0×10^{-4} LCF/rem for high doses over 20 rem
  - General public = 5×10^{-4} LCF/rem for low doses under 20 rem, 10^{-3} LCF/rem for high doses over 20 rem.

Table C.3. Radiological Constituent Concentrations in Tanks

Analyte	Concentrations in Ci/L					
	C-106[a]	C-106	C-201	C-202	C-203	C-204
129I	7.7E-08	1.3E-07	6.8E-09	7.1E-09	5.5E-09	3.5E-09
137Cs	5.4E-02	1.3E-01	2.0E-02	2.1E-02	1.6E-02	1.0E-02
14C	4.3E-07	4.2E-07	5.0E-07	5.2E-07	4.0E-07	2.6E-07
238U	2.7E-07	3.2E-07	9.5E-08	9.9E-08	7.6E-08	4.9E-08
238Pu	1.9E-07	2.5E-05	3.6E-04	1.9E-04	3.8E-05	7.8E-07
239Pu	4.0E-06	5.5E-04	1.6E-02	8.5E-03	1.7E-03	3.5E-05
240Pu	8.2E-07	1.1E-04	2.7E-03	1.4E-03	2.8E-04	5.7E-06
241Pu	9.9E-06	1.3E-03	2.0E-02	1.0E-02	2.1E-03	4.2E-05
241Am	4.7E-07	1.6E-03	5.7E-03	3.0E-03	6.0E-04	1.2E-05
60Co	1.0E-05	1.0E-05	2.1E-07	2.2E-07	1.7E-07	1.1E-07
90Sr	3.0E-03	2.0E+00	1.0E-01	1.1E-01	8.2E-02	5.3E-02
90Y	3.0E-03	2.0E+00	1.0E-01	1.1E-01	8.2E-02	5.3E-02
99Tc	1.9E-05	2.3E-05	3.5E-06	3.7E-06	2.8E-06	1.8E-06

Notes:

[a] C-106 = concentrations for liquid phase.

Calculations are based on total Ci for each constituent and total waste volume documented in (BBI 2002).

The probability of the accident was calculated by multiplying the annual frequency of the accident by the time required to perform the activity. The annual frequency of a spray leak accident is referenced in (WHC-SD-WM-ANAL-041). The time required to retrieve the waste for Project W-320 was based on the *Review of Waste Retrieval Sluicing System Operations and Data for Tanks 241-C-106 and 241-AY-102* (PNNL-13319). The time required to retrieve the Liquid-only and the waste to the HFFACO limit for each tank was based on the *Preliminary Engineering Report for the 241-C-104 Retrieval System* (RPP-6843, Rev. 0, calculation #4412.038.NCAL.002, page C-52). It was further assumed that it would take 10 times longer to remove the additional waste to achieve 10% of the HFFACO limit.

C.2.2.2 Risk Calculations for Radiological Accidents

It is estimated that the involved workers would receive a lethal dose within 10 minutes from tanks C-106, C-201, C-202, and C-203 and within 20 minutes from tank C-204. The involved workers would receive a lethal dose within 4 hours from tank C-106 during liquid-only retrieval. The dose to the involved workers resulting from a postulated spray leak accident is calculated using Equation C-2:

$$D = ST\ (L) \times BR(m^3/s) \times t(s) \times (2/3 \times \pi r^3)^{-1} \times ULD\ (rem/L) \qquad \text{(C-2)}$$

Where:

ST	=	liters of respirable tank waste released, 14 L (3.7 gal)
BR	=	typical acute breathing rate, 7.2E-04 m^3/s
t	=	duration of worker exposure, 10 minutes for tanks C-106 and C-201 and 203, or
	=	duration of worker exposure , 20 minutes for tank C-204, or
	=	duration of worker exposure, 4 hours for tank C-106 liquid-only retrieval
r	=	assumed radius for distribution of source activity, 10 m (33 ft.)
ULD	=	committed effective dose equivalent per unit liter inhaled (Table C.4)
Cf	=	dose-to-risk conversion factor, $8x10^{-4}$ LCF/rem

The LCF risk to the noninvolved workers and general public resulting from a postulated spray leak accident is calculated using Equation C-3:

$$LCF = ST\ (L) \times BR(m^3/s) \times \chi/Q\ (s/m^3) \times ULD\ (rem/L) \times cf\ (LCF/rem) \qquad \text{(C-3)}$$

Where:

ST	=	liters of respirable tank waste released, 14 L (3.7 gal)
BR	=	typical acute breathing rate, 3.3E-04 m^3/s
χ/Q	=	atmospheric dispersion coefficient,
		1.13E-02 s/m^3, noninvolved worker MEI
		2.65E-01 s/m^3, noninvolved worker population
		1.34E-05 s/m^3, general public MEI
		4.86E-02 s/m^3, general public population
ULD	=	committed effective dose equivalent per unit liter inhaled (Table C.4)
Cf	=	dose-to-risk conversion factor,
		8.0E-04 LCF/rem for the noninvolved worker receptors
		5.0E-04 LCF/rem for the general public receptors

Applying Equation C-2 for the involved worker and Equation C-3 for the noninvolved worker and general public the LCF risk to the various receptors are calculated and summarized in Table C.5.

Attachment 2

Table C.4. Unit Liter Dose

Radionuclide	Unit Liter Dose (rem/L)					
	C-106[a]	C-106	C-201	C-202	C-203	C-204
^{14}C	8.9E-04	8.6E-04	1.0E-03	1.1E-03	8.3E-04	5.3E-04
^{60}Co	2.1E+00	2.0E+00	4.2E-02	4.4E-02	3.4E-02	2.2E-02
^{90}Sr	4.1E+03	2.8E+06	1.4E+05	1.5E+05	1.1E+05	7.2E+04
^{90}Y	2.8E+01	1.8E+04	9.0E+02	9.4E+02	7.2E+02	4.6E+02
^{99}Tc	1.7E-01	2.1E-01	3.2E-02	3.3E-02	2.5E-02	1.6E-02
^{129}I	1.2E-02	1.9E-02	1.0E-03	1.1E-03	8.2E-04	5.3E-04
^{137}Cs	1.6E+03	3.8E+03	5.9E+02	6.2E+02	4.7E+02	3.0E+02
^{238}Pu	8.5E+01	1.2E+04	1.7E+05	8.7E+04	1.7E+04	3.5E+02
^{239}Pu	2.1E+03	2.9E+05	8.6E+06	4.5E+06	9.0E+05	1.8E+04
^{240}Pu	4.4E+02	5.9E+04	1.4E+06	7.4E+05	1.5E+05	3.0E+03
^{238}U	1.2E+02	1.5E+02	4.3E+01	4.5E+01	3.4E+01	2.2E+01
^{241}Am	2.5E+02	8.7E+05	3.0E+06	1.6E+06	3.2E+05	6.5E+03
^{241}Pu	1.1E+02	1.5E+04	2.2E+05	1.2E+05	2.3E+04	4.7E+02
Total	8.9E+03	4.0E+06	1.4E+07	7.2E+06	1.5E+08	1.0E+05

Notes:

[a] C-106 = unit liter dose for tank C-106 liquids.

Unit liter dose values are given in terms of committed effective dose equivalent per unit liter of waste inhaled at the receptor location.

Table C.5. LCF Risk From Spray Leak Accident

Receptor	C-106[d]	C-106	C-201	C-202	C-203	C-204
IW MEI	LD[e]	LD[a]	LD[a]	LD[a]	LD[a]	LD[b]
IW Pop	LD[e]	LD[a]	LD[a]	LD[a]	LD[a]	LD[b]
NIW MEI	1.9E-04	LD[c]	LD[c]	LD[c]	6.4E-02	2.1E-03
NIW Pop	4.3E-03	4.0E+00	1.3E+01	7.0E+00	1.5E+00	5.0E-02
GP MEI	2.7E-07	1.3E-04	4.2E-04	2.2E-04	4.7E-05	3.1E-06
GP Pop	9.9E-04	4.5E-01	1.5E+00	8.1E-01	1.7E-01	1.1E-02

Notes:

[a] LD = lethal dose to involved worker within 10 minute exposure.
[b] LD = lethal dose to involved worker within 20 minute exposure.
[c] LD = lethal dose to involved worker MEI at 100 meters (328 ft) from 8 hr exposure.
[d] C-106 = LCF risk from spray leak accident during Liquid-only retrieval.
[e] LD = lethal dose to involved worker within 4 hour exposure.
IW MEI = involved worker maximum exposed individual
IW Pop = involved worker population
NIW MEI = noninvolved worker maximum exposed individual
NIW Pop = noninvolved worker population
GP MEI = general public maximum exposed individual
GP Pop = general pubic population

The frequency for a spray leak in a jumper pit with the cover block off is estimated to range from 1.1×10^{-2} per year to 8.0×10^{-3} per year (WHC-SD-WM-ANAL-041). The upper bound frequency was used in the probability calculations for Project W-320 and liquid-only retrieval due to the low viscosity of the waste being removed from the tank. The lower bound frequency was used for HFFACO and 10% of HFFACO retrieval because of the high viscosity of the waste. The time required to retrieve the waste during Project W-320 was 35 weeks (PNNL-13319, 2000). The time required to retrieve the liquid-only is estimated to be approximately two weeks (RPP-6843). The time required to retrieve the waste to the HFFACO level is estimated to be approximately four weeks for each tank (RPP-6843). The time required to retrieve the waste to 10% of HFFACO goals is estimated to be approximately 23 weeks for each tank (RPP-6843). Therefore, the probability of the accident is calculated as follows:

- Project W-320 = (1.1E-02/yr) x (35 weeks) x (1yr/52 weeks) = 6.2E-04
- Liquid-only retrieval = (1.1E-02/yr) x (2 weeks) x (1yr/52 weeks) = 4.2E-04
- HFFACO = (8.0E-03/yr) × (4 weeks) × (1 yr/52 weeks) = 6.2E-04
- 10% HFFACO = (8.0E-03/yr) × (23 weeks) × (1 yr/52 weeks) = 4.2E-03.

The point estimate risks are calculated by multiplying the receptor LCF risk by the probability of the accident occurring. The results are summarized in Table C.6.

Table C.6. Point Estimate Risk From Spray Leak Accident

Case	Receptor	C-106	C-201	C-202	C-203	C-204
Project W-320 Retrieval	IW MEI	7.4E-03	NA	NA	NA	NA
	IW Pop	7.4E-03	NA	NA	NA	NA
	NIW MEI	4.2E-04	NA	NA	NA	NA
	NIW Pop	2.9E-02	NA	NA	NA	NA
	GP MEI	9.2E-07	NA	NA	NA	NA
	GP Pop	3.4E-03	NA	NA	NA	NA
Liquid-Only Retrieval	IW MEI	4.2E-04	NA	NA	NA	NA
	IW Pop	4.2E-04	NA	NA	NA	NA
	NIW MEI	7.8E-08	NA	NA	NA	NA
	NIW Pop	1.8E-06	NA	NA	NA	NA
	GP MEI	1.2E-10	NA	NA	NA	NA
	GP Pop	4.2E-07	NA	NA	NA	NA
HFFACO Retrieval	IW MEI	6.2E-04	6.2E-04	6.2E-04	6.2E-04	6.2E-04
	IW Pop	6.2E-04	6.2E-04	6.2E-04	6.2E-04	6.2E-04
	NIW MEI	6.2E-04	6.2E-04	6.2E-04	3.9E-05	1.3E-06
	NIW Pop	2.4E-03	8.2E-03	4.3E-03	9.2E-04	3.1E-05
	GP MEI	7.7E-08	2.6E-07	1.4E-07	2.9E-08	1.9E-09
	GP Pop	2.8E-04	9.3E-04	5.0E-04	1.1E-04	7.0E-06
10% HFFACO Retrieval	IW MEI	3.5E-03	3.5E-03	3.5E-03	3.5E-03	3.5E-03
	IW Pop	3.5E-03	3.5E-03	3.5E-03	3.5E-03	3.5E-03
	NIW MEI	3.5E-03	3.5E-03	3.5E-03	2.3E-04	7.5E-06
	NIW Pop	1.4E-02	4.7E-02	2.5E-02	5.3E-03	1.8E-04
	GP MEI	4.4E-07	1.5E-06	7.9E-07	1.7E-07	1.1E-08
	GP Pop	1.6E-03	5.4E-03	2.9E-03	6.0E-04	4.0E-05

Notes:

Project W-320 Retrieval = Retrieval of tank waste to current volume

Liquid-only Retrieval = Retrieval of liquids only

HFFACO Retrieval = Retrieval of tank waste to HFFACO goals of 360 ft^3 (10,200 L [2,700 gal]) for tank C-106 and 30 ft^3 (850 L [220 gal]) for Tanks C-201, C-202, C-203, and C-204

10% HFFACO Retrieval = Retrieval of tank waste to a level of 36 ft^3 (1,020 L [270 gal]) for tank C-106 and 3 ft^3 (85 L [22 gal]) for tanks C-201, C-202, C-203, and C-204.

IW = involved worker
NIW = noninvolved worker
GP = general public

C.2.3 ROUTINE RADIOLOGICAL EXPOSURE RISK

Retrieval activities require radiation workers to work in radiation zones during the construction and installation of retrieval equipment and during the retrieval operation. Due to the nature of the work in a radiation zone, the workers will be exposed to and receive a radiological dose from ionizing radiation. Atmospheric emissions will also result from retrieval activities. Although the emissions are first filtered through HEPA filters, the abated emissions released to the atmosphere and carried downwind will be inhaled by onsite workers and the offsite population, resulting in an exposure and subsequent dose. The offsite population will receive an additional dose from ingesting radiological contaminants attached to food substances such as fruits, vegetables, meat, and milk. Every effort is made to reduce the exposures to the radiation workers and the air emissions, but the exposures are still anticipated and are considered routine. The risk from these exposures is measured in terms of LCFs and is analyzed in this appendix.

This analysis considers the risk from routine radiological exposures to three receptor groups of people and a MEI from each group.

1. Involved workers – radiation workers in radiation zones directly involved in the construction and retrieval operation activities.

2. Noninvolved workers – Hanford Site workers distributed within the Hanford Site boundary but no closer than 100 m (328 ft) from the source of missions.

3. General public – offsite population distributed from the Hanford Site to a distance of 80 km (50 mi).

C.2.3.1 Assumptions

The LCF risk is calculated by multiplying the dose (in units of person-rem for the population and rem for the MEI) by an appropriate dose-to-risk conversion factor (in units of LCF/person-rem for the population and LCF/rem for the MEI).

C.2.3.1.1 Involved Worker Dose. The involved worker population dose resulting from construction and operations is based on worker exposures to support retrieval of tank C-104 in the C-104 PER (RPP-6843, Rev. 0, calculation #4412.038.NCAL.002, page C-52). It is further assumed that it would take 10 times longer to remove the additional waste to achieve 10% HFFACO Retrieval than to achieve HFFACO retrieval goal. The involved worker MEI dose is based on a current site administrative control level of 0.5 rem/year (*Hanford Site Radiological Control Manual* [HSRCM-1 1994]).

C.2.3.1.2 Noninvolved Worker and General Public Dose. Exposure to the noninvolved workers and general public are from abated air emissions of radionuclides. Abated air emissions for each radionuclide from each tank is scaled from the abated air emissions estimated in the *Radioactive Air Emissions Notice of Construction Project W-320, Tank 241-C-106 Sluicing* (DOE/RL-95-45) and *Calculations to Support the Cost-Risk Analysis* (Jacobs 2002). The radionuclides released in the abated air emissions are then used as input to the GENII computer code (PNL-6584). The GENII system has been designed for calculating radiation doses for acute

and chronic releases. It evaluates inhalation and ingestion pathways and targeted populations identified by distance and direction for individuals and populations. Atmospheric dispersion coefficients used in the GENII code are calculated using the GXQ computer code (WHC-SD-GN-SWD-30002).

C.2.3.1.3 Conversion Factors. Two different conversion factors are used, one for involved workers and noninvolved workers and another for the general public. The accepted conversion factor for the worker is 4.0×10^{-4} LCFs per person-rem (per rem for the MEI) effective dose equivalent (400 cancer deaths per million person-rem). The accepted conversion factor for the public is 5.0×10^{-4} LCFs per person-rem (per rem for the MEI) effective dose equivalent (500 cancer deaths per million person-rem) (NRC 1991, ICRP 1991). The value for the public is higher because the public includes children (children are more sensitive to radiation exposure).

C.2.3.2 Latent Cancer Fatality Risk Calculation for Routine Radiological Exposure

The LCF risk from routine radiological exposures to the various receptor populations and MEIs is calculated using Equation C-4:

$$LCF = D \times cf \qquad \text{(C-4)}$$

Where:

D = Dose to the receptor (person-rem [population] or rem [MEI])
cf = Dose-to-risk conversion factor (LCF/person-rem [population] or LCF/rem [MEI])

The dose to the involved worker population for the various tank cases is based on (RPP-6843). The dose from Project W-320 retrieval, liquid-only retrieval, HFFACO retrieval, and 10% HFFACO retrieval is estimated as follows:

- Project W-320 Retrieval – The dose is equal to the sum of the doses from the following activities (RPP-6843) and is typical for only tank C-106.

  1.72 person-rem; construction
  + 81.98 person-rem; bulk retrieval(8 person/shift)(14 mrem/day)(244 days)(3 shifts)
  = 83.70 person-rem; total dose

- Liquid-Only Retrieval – The dose is equal to the sum of the doses from the following activities (RPP-6843) and is typical for only tank C-106.

  1.72 person-rem; construction
  + 3.02 person-rem; bulk retrieval (6 person/shift)(14 mrem/day)(12 days)(3 shifts)
  = 4.74 person-rem; total dose

- HFFACO Retrieval – The dose is equal to the sum of the doses from the following activities (RPP-6843) and is typical for all the tanks evaluated in this analysis.

  1.72 person-rem; construction
  + 3.02 person-rem; bulk retrieval (6 person/shift)(14 mrem/day)(12 days)(3 shifts)
  + 3.78 person-rem; heel retrieval (6 person/shift)(14 mrem/day)(15 days)(3 shifts)
  = 8.53 person-rem; total dose

- 10% HFFACO Retrieval – The dose is equal to the sum of the doses from the following activities (RPP-6843) and is typical for all tanks evaluated in this analysis.

  1.72 person-rem; construction
  + 3.02 person-rem; bulk retrieval (6 person/shift)(14 mrem/day)(12 days)(3 shifts)
  + 3.78 person-rem; heel retrieval (6 person/shift)(14 mrem/day)(15 days)(3 shifts)
  = 37.8 person-rem, additional heel retrieval (10 times heel removal to 360 ft^3 (10,200 L [2,700 gal]) 46.3 person-rem; total dose

The dose to the non-involved workers and general public are based on air emissions that are scaled from the abated air emissions (DOE/RL-95-45, Jacobs 2002) and presented in Table C.7.

Table C.7. Abated Air Emissions from Retrieval Activities

Radionuclide	Abated Air Emissions in Ci/yr					
	C-106[a]	C-106	C-201	C-202	C-203	C-204
C-14	3.4E-17	3.9E-17	1.4E-18	1.4E-18	2.8E-18	1.8E-18
Co-60	2.7E-15	3.3E-15	2.0E-18	2.1E-18	4.0E-18	2.6E-18
Sr-90	1.3E-13	1.1E-10	1.6E-13	1.6E-13	3.1E-13	2.0E-13
Y-90	1.3E-13	1.1E-10	1.6E-13	1.6E-13	3.1E-13	2.0E-13
Tc-99	1.4E-15	2.1E-15	9.5E-18	9.9E-18	1.9E-17	1.2E-17
I-129	1.7E-05	3.3E-05	5.3E-08	5.5E-08	1.1E-07	6.8E-08
Cs-137	5.2E-12	1.5E-11	6.6E-14	6.9E-14	1.3E-13	8.5E-14
Ba-137m	6.5E-12	1.9E-11	8.4E-14	8.7E-14	1.7E-13	1.1E-13
Pu-239	7.8E-16	1.3E-13	1.1E-13	5.8E-14	2.9E-14	6.0E-16
Pu-240	1.6E-16	2.6E-14	1.8E-14	9.5E-15	4.8E-15	9.8E-17
Am-241	4.6E-17	1.9E-13	1.9E-14	1.0E-14	5.1E-15	1.0E-16

Notes:
[a] C-106 = abated air emissions from liquid-only retrieval.
Tank inventory was based on (BBI 2002).

The radionuclides released in the abated air emissions are then used as input to the GENII computer code (PNL-6584) to calculate the dose. The atmospheric dispersion coefficients for

exposures used in the GENII code that are calculated using the GXQ computer code are summarized as follows:

- Noninvolved worker MEI = 4.0E-04 s/m^3
- Noninvolved worker population = 1.8E-02 s/m^3
- General public MEI = 1.0E-07 s/m^3
- General public population = 2.9E-03 s/m^3.

The doses generated from the GENII computer code for the various receptors under the Project W-320, liquid-only, HFFACO, and 10% HFFACO retrieval cases are presented in Table C.8.

Table C.8. Dose From Routine Radiological Exposure (2 Sheets)

Case	Receptor	Dose (person-rem for population or rem for MEI)				
		C-106	C-201	C-202	C-203	C-204
Project W-320 Retrieval	NIW MEI	3.6E-07	NA	NA	NA	NA
	NIW Pop	1.7E-05	NA	NA	NA	NA
	GP MEI	3.6E-08	NA	NA	NA	NA
	GP Pop	7.2E-04	NA	NA	NA	NA
Liquid-Only Retrieval	NIW MEI	9.2E-09	NA	NA	NA	NA
	NIW Pop	4.1E-07	NA	NA	NA	NA
	GP MEI	1.9E-08	NA	NA	NA	NA
	GP Pop	3.7E-04	NA	NA	NA	NA
HFFACO Retrieval	NIW MEI	3.9E-08	1.2E-11	1.2E-11	5.0E-11	3.0E-11
	NIW Pop	1.8E-06	5.3E-10	5.6E-10	2.3E-09	1.4E-09
	GP MEI	3.6E-08	5.9E-11	6.0E-11	1.2E-10	7.4E-11
	GP Pop	7.2E-04	1.2E-06	1.2E-06	2.4E-06	1.5E-06

Table C.8. Dose From Routine Radiological Exposure (2 Sheets)

Case	Receptor	Dose (person-rem for population or rem for MEI)				
		C-106	C-201	C-202	C-203	C-204
10% HFFACO Retrieval	NIW MEI	2.4E-07	1.2E-10	1.2E-10	5.0E-10	3.0E-10
	NIW Pop	1.1E-05	5.3E-09	5.6E-09	2.3E-08	1.4E-08
	GP MEI	3.6E-08	5.9E-11	6.0E-11	1.2E-10	7.4E-11
	GP Pop	7.2E-04	1.2E-06	1.2E-06	2.4E-06	1.5E-06

Notes:

Project W-320 Retrieval = Retrieval of tank waste to current volume

Liquid-Only Retrieval = Retrieval of only liquids

HFFACO Retrieval = Retrieval of tank waste to HFFACO goals of 360 ft^3 (10,200 L [2,700 gal]) for tank C-106 and 30 ft^3 (850 L [220 gal]) for tanks C-201, C-202, C-203, and C-204

10% HFFACO Retrieval = Retrieval of tank waste to a level of 36 ft^3 (1,020 L [270 gal]) for tank C-106 and 3 ft^3 (1,020 L [270 gal]) for tanks C-201, C-202, C-203, and C-204.

NIW MEI = noninvolved worker maximum exposed individual
NIW Pop = noninvolved worker population
GP MEI = general public maximum exposed individual
GP Pop = general public population

Applying Equation C-4 with the appropriate dose values estimated for the various tanks and cases and using the appropriate dose-to-risk conversion factors, the LCF risk to the various receptor populations and MEIs are calculated and presented in Table C.9.

Table C.9. LCF Risk From Routine Radiological Exposure (2 Sheets)

Case	Receptor	Latent Cancer Fatality Risk				
		Tk C-106	Tk C-201	Tk C-202	Tk C-203	Tk C-204
Project W-320 Retrieval	IW MEI	2.0E-04	NA	NA	NA	NA
	IW Pop	3.3E-02	NA	NA	NA	NA
	NIW MEI	1.4E-10	NA	NA	NA	NA
	NIW Pop	6.8E-09	NA	NA	NA	NA
	GP MEI	1.8E-11	NA	NA	NA	NA
	GP Pop	3.6E-07	NA	NA	NA	NA
Liquid-Only Retrieval	IW MEI	2.0E-04	NA	NA	NA	NA
	IW Pop	1.9E-03	NA	NA	NA	NA
	NIW MEI	3.7E-12	NA	NA	NA	NA
	NIW Pop	1.6E-10	NA	NA	NA	NA
	GP MEI	9.5E-12	NA	NA	NA	NA
	GP Pop	1.9E-07	NA	NA	NA	NA

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Table C.9. LCF Risk From Routine Radiological Exposure (2 Sheets)

Case	Receptor	Latent Cancer Fatality Risk				
		Tk C-106	Tk C-201	Tk C-202	Tk C-203	Tk C-204
HFFACO Retrieval	IW MEI	2.0E-04	2.0E-04	2.0E-04	2.0E-04	2.0E-04
	IW Pop	3.4E-03	3.4E-03	3.4E-03	3.4E-03	3.4E-03
	NIW MEI	1.6E-11	4.8E-15	4.8E-15	2.0E-14	1.2E-14
	NIW Pop	7.2E-10	2.1E-13	2.2E-13	9.2E-13	5.6E-13
	GP MEI	1.8E-11	3.0E-14	3.0E-14	6.0E-14	3.7E-14
	GP Pop	3.6E-07	6.0E-10	6.0E-10	1.2E-09	7.5E-10
10% HFFACO Retrieval	IW MEI	2.0E-04	2.0E-04	2.0E-04	2.0E-04	2.0E-04
	IW Pop	1.9E-02	1.9E-02	1.9E-02	1.9E-02	1.9E-02
	NIW MEI	9.6E-11	4.8E-14	4.8E-14	2.0E-13	1.2E-13
	NIW Pop	4.4E-09	2.1E-12	2.2E-12	9.2E-12	5.6E-12
	GP MEI	1.8E-11	3.0E-14	3.0E-14	6.0E-14	3.7E-14
	GP Pop	3.6E-07	6.0E-10	6.0E-10	1.2E-09	7.5E-10

Notes:

Project W-320 Retrieval = Retrieval of tank waste to the current volume

Liquid-Only Retrieval = Retrieval of liquids only

HFFACO Retrieval = Retrieval of tank waste to HFFACO goals of 360 ft^3 (10,200 L [2,700 gal]) for tank C-106 and 30 ft^3 (850 L [220 gal]) for tanks C-201, C-202, C-203, and C-204

10% HFFACO Retrieval = Retrieval of tank waste to a level of 36 ft^3 (1,020 L [270 gal]) for tank C-106 and 3 ft^3 (1,020 L [270 gal]) for tanks C-201, C-202, C-203, and C-204.

IW MEI = involved worker maximum exposed individual
IW Pop = involved worker population
NIW MEI = noninvolved worker maximum exposed individual
NIW Pop = noninvolved worker population
GP MEI = general public maximum exposed individual
GP Pop = general public population

C.3.0 CONCLUSIONS

Based on the short-term human health risk analysis in this appendix, the estimated potential health impacts from both accident and normal (non-accident) conditions resulting from various tank waste retrieval scenarios for tanks C-106, C-201, C-202, C203, and C-204 are as follows:

- In no case is the administrative control level of 0.5 rem/yr for a worker exceeded under routine conditions.
- In no case are the standards for routine exposure of the public of 0.1 rem/yr exceeded.
- In all cases the acute exposure limit of 5.0 rem to an onsite worker (located at 100 meters (330 ft) from the point of release) from a radiological accident with an unlikely probability of occurrence ($>10^{-4}$ to 10^{-2}) would be exceeded. However, the assumptions used in calculating this probability are extremely conservative.
- In no case would there be a fatality from occupational accidents.
- In all cases, there would be at least one lost workday case.
- Short-term radiation risk to the public for both retrieval cases, expressed as LCFs, is very small, and the order of 1.0×10^{-11} LCF.
- The short-term risk from the closure demonstration of tanks C-106 and the C-200 tanks are small and not a factor in decision-making.

C.4.0 REFERENCES

10245-CD-06, 1998, *Preliminary Hazard Identification and Evaluation for the Tank 241-C-106 Waste Heel Retrieval Demonstration*, Rev A, Los Alamos Technical Associates, Richland, Washington.

BBI, 2002, *Tank Waste Information Network System (TWINS)*, April 15, 2002, [Best Basis Inventory, Best Basis/TCR Tank Inventory], http://twins.pnl.gov/data/datamenu.htm#.

DOE/RL-95-45, 1995, *Radioactive Air Emissions Notice of Construction Project W-320, Tank 241-C-106 Sluicing*, United States Department of Energy, Richland, Washington.

DOE-STD-3009-94, 1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports,* U.S. Department of Energy, Washington, D.C.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

HSRCM-1, 1994, *Hanford Site Radiological Control Manual*, Westinghouse Hanford Company, Richland, Washington.

ICRP, 1975, *1975 Report of the Task Group on Reference Man*, Report No. 23, International Commission on Radiological Protection.

ICRP, 1991, *1990 Recommendation of the International Commission on Radiological Protection*, ICRP Publication 60, International Commission on Radiological Protection, Pergamon Press, New York, New York.

Jacobs, 2002, *Calculations to Support the Cost-Risk Analysis*, Jacobs Engineering Group, Richland, Washington.

Millet, B., 2000, "Injury/Illness Rates at Hanford" (electronic mail to M.R. Harker, Jacobs Engineering Group, Inc., August 18), U.S. Department of Energy, Idaho Falls Operations Office, Idaho Falls, Idaho.

NRC 1982, Nuclear Regulatory Commission. Regulatory Guide 1.145.

NRC 1991, Nuclear Regulatory Commission. Preamble to Standard for Protection Against Radiation. 56 Federal Register 23363.

PNL-6584, 1988, *GENII – The Hanford Environmental Radiation Dosimetry Software System*, Pacific Northwest Laboratory, Richland, Washington.

PNNL-13319, 2000, *Review of Waste Retrieval Sluicing System Operations and Data for Tanks 241-C-106 and 241-AY-102,* Pacific Northwest Laboratory, Richland, Washington.

RPP-6843, 2000, *Preliminary Engineering Report for the 241-C-104 Retrieval System*, Rev. 0, (calculation #4412.038.NCAL.002, page C-52), CH2M HILL Hanford Group, Inc., Richland, Washington.

WHC-SD-GN-SWD-30002, 1993, GXQ Program Users Guide, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-ANAL-041, 1995, Potential Accidents with Radiological and Toxicological Source Terms for Hanford Tank Waste Remediation System Environmental Impact Statement, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-SAD-024, 1995, Safety Assessment for Tank 241-C-106 Waste Retrieval Project W-320, Rev 0, Westinghouse Hanford Company, Richland, Washington.

APPENDIX D

COST DETAILS

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D.1.0 RETRIEVAL TO THE HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER GOALS

> **Caveat:** The configuration of the retrieval system for these tanks is unknown. An activity-based cost estimate has not been performed to date. At best, the numbers provided are rough order-of-magnitude estimates.

Tables D.1. and D.2. are taken from a CHG document titled "Closure Demo Project Planning" dated April 7, 2002 and incorporated into (Jacobs, 2002). In August 2002, alternative technologies for retrieving the residual waste from tank C-106 and the 200-Series tanks in C Farm were evaluated as input to an Alternatives Generation and Analysis for the Accelerated Tank Closure Demonstration Project (ATCD). Rough cost estimates generated for that evaluation are also germane to this cost-risk analysis. The preliminary engineering report for retrieving waste from the five ATCD tanks, which is in process, will provide the best estimate of retrieval costs for these tanks. However, that estimate is not available as of the time of this report. The following discussion describes the basis for the very preliminary April 2002 cost estimate.

Tables D.1. and D.2. show those costs relating to retrieval of waste to HFFACO goals (*Hanford Federal Facility Agreement and Consent Order,* Ecology et at. 1989) using an MRS. Tables D.3. and D.4. show only those elements of cost that are directly related to retrieval of waste to HFFACO goals (360 ft^3 for tank C-106 and 30 ft^3 for each C-200 Series tank).

Not included in Tables D.3. and D.4. are costs for tank fill, disposition of ancillary equipment, placement of an interim surface barrier, licensing, and performance monitoring, which are assumed to be approximately equal for all cases, both retrieval cases and non-retrieval cases.

Several key activities have been omitted because of lack of cost estimates and the pre-conceptual state of design. These activities, which may or may not be required, include transfer system modifications, modifications to receiving tanks, equipment removal from risers, and disposal of equipment. For this reason, a 35% contingency factor has been used

Also not included are cost estimates for waste treatment, storage, transportation, and disposal. The reason these costs are omitted is that facilities for waste treatment, storage, transportation, and disposal are sized to accommodate retrieval of almost all the tank waste, so, by omitting the relatively small volume of waste in tank C-106 and the 200 Series tanks, the cost savings would be incremental for this small volume. However, these costs may be significant and should be developed for inclusion in future cost optimization analysis.

In the case of the C –200 Series tanks, many costs are common to all four tanks. In Table D.2., costs are categorized as being common to all tanks or required for individual tanks.

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Table D.1. Conversion of Closure Demo Project Planning Estimates to Cost-Risk Analysis: Tank C-106 (Dollars) (2 Sheets)

Cost Element Tank C-106 Retrieval & Closure	Total Cost	Disposition
C-106 Retrieval		
Ecology/ORP agreement on strategy	$-	
Develop specs for mobile retrieval system	$30,000	
Prepare order for MRS	$10,000	
Fabricate and ship MRS	$3,500,000	
Receive MRS	$-	
Test MRS	$250,000	
Prepare SOW for tank farm mod. Design	$5,000	
Procure A/E for tank farm mods.	$10,000	
Award contract for tank farm mods design	$-	
Tank farm mod design	$1,000,000	
Procure materials for tank farm mods.	$700,000	
Conduct USQ screening & determination	$30,000	
Prepare work packages	$200,000	
Tank prep & equipment installation	$3,500,000	
Conduct readiness assessment	$200,000	
Retrieve C-106 waste	$2,000,000	
Conduct topographic mapping	$50,000	
Total C-106 Retrieval	**$11,485,000**	
C-106 Post-Retrieval Characterization		
Design/procure post-retrieval sampling EQT	$200,000	
Prepare C-106 post-retrieval DQO & SAP	$50,000	
Obtain C-106 post-retrieval sample	$50,000	
Analyze C-106 post retrieval sample	$200,000	
Total C-106 Post-Retrieval Characterization	**$500,000**	
Tank fill		Not included, per text
Ancillary equipment		Not included, per text
Interim surface barrier		Not included, per text
Licensing		Not included, per text
Performance monitoring		Not included, per text

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Table D.1. Conversion of Closure Demo Project Planning Estimates to Cost-Risk Analysis: Tank C-106 (Dollars) (2 Sheets)

Cost Element Tank C-106 Retrieval & Closure	Total Cost	Disposition
Management and Integration		
Establish C-106 admin isolation	$50,000	
C-106 project mgmt, admin, integration	$1,200,000	
CV-106 project support	$600,000	
C-106 project closeout	$100,000	
Total C-106 Management and Integration	**$1,950,000**	
Total C-106 Waste Retrieval to HFFACO Goals	**$13,935,000**	

Source: Closure demonstration project planning data sheets prepared April 7, 2002 by CHG.

Caveat: The configuration of the retrieval system for these tanks is unknown. An activity-based cost estimate has not been performed to date. At best, the numbers provided are rough order-of-magnitude estimates.

Table D.2. Conversion of Closure Demo Project Planning Estimates to Cost-Risk Analysis: Tank C-200 Series (Dollars) (2 Sheets)

Cost Element C-201,202,203,204 Retrieval & Closure	Total Cost	Disposition	Cost for One Tank	Cost for Four Tanks
C-203, 204 Retrieval				
Ecology/ORP agreement on approach	$-			
Prepare SOW for tank farm mod. design	$10,000	Same cost, one tank or all	$10,000	$10,000
Procure A/E for tank farm mods.	$10,000	Same cost, one tank or all	$10,000	$10,000
Award contract for tank farm mods. design	$-			
Tank farm mod. design	$750,000	For two tanks; $375,000 per tank	$375,000	$1,500,000
Prepare spec for retrieval equip	$30,000	Same cost, one tank or all	$30,000	$30,000
Buy retrieval equipment	$500,000	For two tanks; $250,000 per tank	$250,000	$1,000,000
Test retrieval equipment	$-			
Procure materials for tank farm mods.	$750,000	For two tanks; $375,000 per tank	$375,000	$1,500,000
Conduct USQ screening & determination	$50,000	Same cost, one tank or all	$50,000	$50,000
Prepare work packages	$100,000	For one tank	$100,000	$400,000
Tank prep & equip. Installation	$5,000,000	For two tanks; $2,500,000 per tank	$2,500,000	$10,000,000
Conduct readiness assessment	$200,000	Same cost, one tank or all	$200,000	$200,000
Retrieve C-203 waste	$500,000	For one tank	$500,000	$2,000,000
Conduct C-203 topographic mapping	$50,000	For one tank	$50,000	$200,000
Demob & remob	$50,000	For two tanks; $25,000 per tank	$25,000	$100,000
Total Retrieval	**$8,000,000**		**$4,475,000**	**$17,000,000**

Table D.2. Conversion of Closure Demo Project Planning Estimates to Cost-Risk Analysis: Tank C-200 Series (Dollars) (2 Sheets)

Cost Element C-201,202,203,204 Retrieval & Closure	Total Cost	Disposition	Cost for One Tank	Cost for Four Tanks
C-200s Post-Retrieval Characterization				
Prepare C-200s post-retrieval SAP	$50,000	Same cost, one tank or all	$50,000	$50,000
Obtain C-203 post-retrieval sample	$50,000	For one tank	$50,000	$200,000
Analyze C-201,202,203,204 samples	$400,000	For four tanks; $100,000 per tank	$100,000	$400,000
Total C-200s Post-Retrieval Characterization	**$500,000**		**$200,000**	**$650,000**
Tank fill		Not included, per text		
Ancillary equipment		Not included, per text		
Interim surface barrier		Not included, per text		
Licensing		Not included, per text		
Performance monitoring		Not included, per text		
C-201,202,203,204 Management & Integration				
establish C-200s administrative isolation	$50,000	Same cost, one tank or all	$50,000	$50,000
C-200s project mgmt, admin, integration	$1,600,000	Same cost, one tank or all	$1,600,000	$1,600,000
C-200s project support	$800,000	Same cost, one tank or all	$800,000	$800,000
C-200s project closeout	$100,000	Same cost, one tank or all	$100,000	$100,000
Total Management & Integration	**$2,550,000**		**$2,550,000**	**$2,550,000**
Total C-200 Waste Retrieval to HFFACO Goals			**$7,225,000**	**$20,200,000**

Source: Closure demo project planning data sheets prepared April 7, 2002 by CHG.

Caveat: The configuration of the retrieval system for these tanks is unknown. An activity-based cost estimate has not been performed to date. At best, the numbers provided are rough order-of-magnitude estimates.

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Table D.3. Cost Calculations, Tank C-106 Waste Retrieval to HFFACO Goals (Dollars)

Cost Element	Cost
C-106 Retrieval	
Develop MRS specs	$30,000
Prepare order for MRS	$10,000
Fabricate/ship MRS	$3,500,000
Test MRS	$250,000
Prepare SOW for tank farm mod. Design	$5,000
Procure A/E for tank farm mods	$10,000
Tank farm mod design	$1,000,000
Procure materials for tank farm mods	$700,000
Conduct USQ screening & determination	$30,000
Prepare work packages	$200,000
Tank prep and equipment installation	$3,500,000
Conduct readiness assessment	$200,000
Retrieve C-106 waste	$2,000,000
Conduct topographic mapping	$50,000
Total C-106 Retrieval	**$11,485,000**
C-106 Post-Retrieval Characterization	
Design/procure post-retrieval sampling EQT	$200,000
Prepare C-106 post-retrieval DQO & SAP	$50,000
Obtain C-106 post-retrieval sample	$50,000
Analyze C-106 post-retrieval sample	$200,000
Total C-106 Post-Retrieval Characterization	**$500,000**
C-106 Management and Integration	
Establish C-106 admin isolation	$50,000
C-106 project mgmt, admin, integration	$1,200,000
C-106 project support	$600,000
C-106 project closeout	$100,000
Total C-106 Management and Integration	**$1,950,000**
Total C-106 Waste Retrieval	**$13,935,000**
Contingency (35%)	**$4,877,250**
Total C-106 Waste Retrieval	**$18,812,250**

Source: Closure demo project planning data sheets prepared April 7, 2002 by CHG.

Caveat: The configuration of the retrieval system for these tanks is unknown. An activity-based cost estimate has not been performed to date. At best the numbers provided are rough order-of-magnitude estimates.

Table D.4. Cost Calculations, Tank C-200 Waste Retrieval to HFFACO Goals (Dollars)

Cost Element	Cost
C-200 Retrieval: Common to All Tanks	
Prepare SOW for tank farm mod. Design	$10,000
Procure A/E for tank farm mods	$10,000
Prepare spec for retrieval equipment	$30,000
Conduct USQ screening & determination	$50,000
Conduct readiness assessment	$200,000
Prepare C-200s post-retrieval SAP	$50,000
Management and integration	$2,550,000
Total C-200 Common Costs	**$2,900,000**
Contingency (35%)	**$1,015,000**
Total C-200 Common Costs	**$3,915,000**
C-200 Individual Tank Costs	
Tank farm mod design	$375,000
Buy retrieval equipment	$250,000
Procure materials for tank farm mods	$375,000
Prepare work packages	$100,000
Tank prep and equip. Installation	$2,500,000
Retrieve waste	$500,000
Conduct topographic mapping	$50,000
Demob and remob	$25,000
Obtain post-retrieval sample	$50,000
Analyze sample	$100,000
Total C-200 Individual Tank Costs	**$4,325,000**
Contingency (35%)	**$1,513,750**
Total C-200 Individual Tank Costs	**$5,838,750**

Source: Closure demo project planning data sheets prepared April 7, 2002 by CHG.

Caveat: The configuration of the retrieval system for these tanks is unknown. An activity-based cost estimate has not been performed to date. At best the numbers provided are rough order-of-magnitude estimates.

In August 2002, several alternative technologies for retrieving residual waste from tank C-106 and the 200-Series tanks in C farm were evaluated. For tank C-106, estimated life-cycle costs for the alternatives (excluding past practice slurring, which failed to achieve the HFFACO retrieval goal under Project W-320) evaluated ranged from ~$14 million to ~$50 million, plus an additional 40% to 50% for costs common to each alternative that were not estimated. For the 200-Series tanks in C farm, estimated life-cycle costs for the alternatives evaluated ranged from ~$8 million per tank to ~$13 million per tank, plus an additional 40% to 50% for costs common to each alternative that were not estimated. Until the preliminary engineering report for retrieving waste from the five ATCD tanks is completed, estimates for retrieving waste from tank C-106 and the four 200-Series tanks to the HFFACO retrieval goal are best represented by the range of values produced as part of the August 2002 retrieval technology evaluation. The cost estimate for tank C-106 provided in Table D.3 below the low end of that range. The cost estimate for the 200-Series tanks also falls below the low end of that range. For this study, the appropriate cost estimate for retrieving waste from tank C-106 and the four 200-Series tanks in C farm is then given by the following:

- Tank C-106 waste retrieval (to 360 ft^3): $20 million to $75 million
- 200-Series tanks waste retrieval (to 30 ft^3/tank): $50 million to $80 million.

D.2.0 RETRIEVAL TO 10% OF HANFORD FEDERAL FACILITY AGREEMENT AND CONSENT ORDER GOALS

If retrieval to beyond the HFFACO goal could be accomplished by simply incorporating and operating an acid dissolution system, it has been estimated that the incremental costs could be as little as $1 to $2 million for tank C-106, and an additional $1 to $2 million for the four 200-Series tanks. This estimate does not take into consideration additional costs that would be associated with resolving worker health and safety issues, or potential safety authorization basis issues. Additional costs for storage of waste volumes generated by acid dissolution are addressed in Section D.4.0. Operational impacts associated with additional demands on double-shell tank (DST) storage space have not been considered.

Therefore, retrieval to 10% of HFFACO goals (equivalent to a film covering the tank floor and lower walls less than 0.1 in. thick) will likely require new technology beyond simply adding acid cleaning to the existing technology or extending the operating duration of the MRS or mast systems. It is believed that the MRS or mast systems can be designed to achieve retrieval to the HFFACO goals, but reaching beyond the HFFACO goal would require deployment of a new system capable of 1) directional retrieval of waste from walls and 2) retrieval of waste around and off in-tank hardware with yet untried and undemonstrated capability.

As a result, assuming more sophisticated equipment is deployed following retrieval to the HFFACO goal, a new system would be required, and this system would require higher capital cost and extended (multi-year) operation. The campaign to retrieve to 10% of the HFFACO requirement is estimated to cost 50% more than the estimated life-cycle cost range, or ~$30 million to ~$110 million for tank C-106, and ~$75 million to ~$120 million for the four 200-Series tanks in C farm. It is assumed that such systems would include the capability to wash the in-tank surfaces with an acidic solution using multi-directional, low-volume spray systems that have a high degree of mechanical flexibility and agility to reach all the in-tank surfaces.

D.3.0 RETRIEVAL OF LIQUID ONLY FROM TANK C-106

If the objective for tank C-106 were to remove only the existing 114,000 L (30,000 gal) of liquid, which would be expected to contain most of the soluble contaminants of concern for groundwater risk, this task could be accomplished with a much simpler and less costly approach than described for retrieval to HFFACO goals. Although cost of equipment procurement and installation for a liquid-only retrieval system would be much lower than what is currently reflected for more extensive retrieval options, without further study it is not clear that tank preparation costs, retrieval system operating cost, and costs for modifying/installing waste transfer systems would be significantly lower than corresponding costs for retrieval systems that are also designed to remove sludge. For purposes of this cost-risk analysis, it is assumed that costs for liquid removal only would be 20% of the range of estimated life-cycle costs reported for retrieval to the HFFACO goal:

- Tank C-106 liquid removal only: $4 million to $15 million.

D.4.0 COSTS FOR PROJECT W-320

Waste was retrieved from tank C-106 during 1998 to 1999 by past-practice sluicing, under Project W-320. This retrieval effort was for the purpose of resolving the high-heat safety issue for that tank; it was not for the purpose of closing the tank. However, retrieval continued beyond the level required simply to resolve the high-heat safety issue and was ended only when it became apparent that little-to-no additional sludge could be removed using the installed equipment. Thus, the cost and risk reduction benefit associated with retrieval of waste under Project W-320 provides relevant and valuable data in a cost-risk analysis for retrieval. The initial phase of tank C-106 retrieval, under Project W-320, is estimated to have cost $103 million (*Data to Support Tank C-106 Waste Retrieval Determination*, RPP-6696).

D.5.0 COSTS FOR STORAGE OF ADDITIONAL LIQUIDS

The costs calculated above do not include additional costs for storage of the liquid volumes generated during the acid dissolution process. The Extensive Retrieval Alternative document estimates that 784,000 L (207,000 gal) of liquid waste would be generated from acid cleaning of the five tanks to 10% of HFFACO levels; this estimate does not include any additions for pH adjustments.

There is additional storage capacity available in the DSTs, but this capacity is carefully regulated, managed and allocated to future programs. Adding heretofore unanticipated waste to the DSTs requires performing technical evaluations, permit modifications, and modifying operating documents. Cost estimates to perform these activities for the 784,000 L (207,000 gal) of liquid waste generated from acid cleaning of the five closure demonstration tanks range from $0.22/gal (decrease dedicated operational space) to $7.23/gal (use restricted tank capacity) (*Tank Space Options Report* [RPP-7702]). Another alternative is to build new DSTs. The pro-rata cost of new DSTs is $62.50/gal.

For this cost-risk analysis it is assumed that the low-cost option is selected.

Additional DST construction would not be required for the 784,000 L (207,000 gal) of liquid generated during the acid dissolution process. However, if policy is amended to require all tanks to achieve 10% of the HFFACO goals, then additional DSTs may be required. Additional waste treatment would also be required to manage this additional liquid, although the additional solids from this process would be small.

The cost of storing the additional liquid generated from the 10% of HFFACO case is:

	Low-end (existing storage space)	**High-end (build new DSTs)**
• Tank C-106 (161,000 gal)	• $35,000	• $10.1M
• C-200 Tanks (46,300 gal)	• $10,000	• $2.9M

Which cost to use within this very wide range depends on the objective posed as a question If the question is: "What will it cost to perform a closure demonstration on these five tanks to HFFACO goals?" then the answer will include the low-end estimate, which contributes only a small fraction to the total cost. If the question is "What will it cost to retrieve all tanks to 10% of the HFFACO goals?" then the answer may be the high-end estimate, and in this case the cost for liquid storage is a dominant cost factor.

D.6.0 SUMMARY OF COSTS

Applying the assumptions detailed above, Table D.5 presents the costs used in performing this cost-risk analysis:

Table D.5. Costs Used in the Cost-Risk Analysis

Tank	HFFACO	10% of HFFACO	Liquid Storage[a]
C-106	$20M to $75M	$30M to $110M	$ 0 to $10M
C-200 Series Total (for 4 tanks)	$50M to $80M	$75 million to $120M	$ 0 to $3M

[a] The low end of the range applies to the demo project; the high end applies if all or most tanks are retrieved to 10% of HFFACO goals.

D.7.0 EXPERIENCE AT OTHER DOE SITES

Experience at West Valley, Oak Ridge and the Savannah River Site has shown that effective tank cleaning is a protracted process. Cost comparisons between Hanford and other DOE sites are not directly applicable due to wide differences in waste and tank characteristics, regulatory requirements, site conditions, and other factors affecting cost. However, experience from other sites does offer valuable benchmarks relative to determining where cost thresholds are expected for Hanford retrievals. Comparing 1) the duration and effectiveness of waste retrieval from tanks at these other sites with 2) the Hanford Site Single-Shell Tank Retrieval Projects projected costs provides the most reliable estimate of costs of retrieval at Hanford. Based on data obtained from several DOE sites (Raudenbush 2002), the operating duration of the more successful

tank-cleaning activities was several years for retrieving waste beyond 99% of the original waste volume. This extensive operating duration alone can translate into costs similar to the Hanford SST retrieval project estimates. Acceleration will increase the capital investment required. Actual retrieval experience at Hanford will strengthen these estimates.

D.8.0 EXPERIENCE AT WEST VALLEY

West Valley has completed cleaning two 23-m-dia (75-ft-dia), 2.8 million-L (750,000 gal) tanks, one containing about 4m (12 ft) of PUREX sludge, the other about a foot of cesium-loaded zeolite ion-exchange media, and one 6-m-dia 2(0-ft-dia), (15,000 gal) tank containing processing residue. The tanks have been cleaned to greater than 99% removal (99.9%, based on curies). Actual cost figures are not readily available, but retrieval was a significant portion of the site's $1.4 billion annual budget. The budget also covered building and running a small vitrification plant, a low-level waste grout facility, and attendant interim storage facilities. Waste was removed using five and six 150-hp long-shaft mixers in each large tank, along with sluicing. The tanks do not leak. Eighty-four percent of the radioactivity was removed in two years. It then took five more years to remove the remaining activity. The first three and a half years were primarily spent running the original equipment with a diminishing production (waste retrieval) rate. Over a year ago it was discovered that soluble species from the waste had plated out in a "bathtub ring" high on the walls, and sluicers were used to wash surfaces and support columns. It took a year to remove about half the ring activity. Performance criteria at West Valley were based on radioactivity and not volume (Jacobs 2002).

D.9.0 EXPERIENCE AT SAVANNAH RIVER

Savannah River spent about $5 million total to clean out two 4.5-million-L (1.2-million gal), 25-m-dia (80-ft-dia) tanks (Tank 17 and Tank 20). The $5 million was for design, construction, equipment procurement, and operations to pump liquid from Tank 20 and to remove the waste heel from Tank 17. The bulk waste removal campaigns were performed in the 1980s and removed most of the waste from each tank. By comparison, the final removal efforts only removed several thousand gallons of liquid from Tank 20, leaving approximately 400 m (100 gal) of sludge, and about 34,000 L (9,000 gal) of sludge/solids from Tank 17, leaving approximately 800 L (2,200 gal) of heavier sludge behind. Water spraying (sluicing) was used in Tank 17 heel removal to push the residual solids into a positive displacement pump suction.

Tank 19, also an 25-m-dia (80-ft-dia) tank, was retrieved in the 1980's by two 150-hp mixer pumps. The125,000 L (33,000 gal) of mixed salt, sludge and zeolite ion-exchange media were left (approximately 11 in. of solids). After three years of effort and about $14 million spent on relatively simple, inexpensive equipment and operations, half the solids had been removed, leaving 57,000 L (15,000 gal) behind (5 in. of solids). Additional equipment will be required if further retrieval is desired (Jacobs 2002).

D.10.0 EXPERIENCE AT OAK RIDGE

Final retrieval of the gunite and associated tanks (GAAT) included three 6-m-dia (20-ft-dia), 159,000 L (42,000 gal) tanks and six 15-m-dia (50-ft-dia), 640,000 L (170,000 gal) tanks. These tanks are constructed of "gunite," a type of concrete, and have no steel liners. Five of the six

15 m (50-ft) tanks were sluiced in the 1980's with a water/bentonite clay mixture. Ninety percent of the waste activity was taken out in forty percent of the solids during that campaign. No cost data are available for the original campaign. The GAAT clean up project ran from 1993 through 2000 and removed 1. 6 million L (420,000 gal) of supernate and sludge, at a cost of $85 million. Retrieval operations began in 1997 using a high-pressure scarifier combined with a jet pump eductor deployed by a robotic arm and/or a remote vehicle in the tanks. One system, moved from tank to tank, was used to clean seven of the nine tanks. Costs were significantly less to operate at ORNL than estimates at Hanford. A reference point is the addition of new 24-in.-dia access risers needed for use of the retrieval system. At Oak Ridge, the risers were installed for $10,000 each, which is less than two orders of magnitude beyond estimates for similar installations at Hanford. The project removed 98.1% of the residual waste and 95.4% of the residual curies (Jacobs 2002).

D.11.0 SUMMARY OF OTHER SITES' EXPERIENCE

The above discussion of experience at other sites is summarized in Table D.6.

Table D.6. Summary of Other Sites' Experience

Site	Number of Tanks	Cost	Technology	% of Tank Capacity Remaining	% of Original Curies Remaining	Notes
WV	3	>$200M	Long Shaft Mixers and sluicing	N/A	<1%	
SRS	3	$20M	Spray; Flygt Mixers	0.6	Unknown	Final heel removal only
OR	8	$ 70M	Rinse/spray	0.1	0.4	Final heel removal only

Note: WV = West Valley, OR = Oak Ridge, SRS = Savannah River Site

D.12.0 REFERENCES

Raudenbush, M.H., 2002, "Tank Waste Retrieval Operations at Other DOE Sites," (Communication Record: email message from P. Gibbons, CHG, September 4), Richland, Washington.

RPP-6696, 2000, *Data to Support Tank C-106 Waste Retrieval Determination*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-7702, 2001, *Tank Space Options Report*, Rev 0, CH2M Hill Hanford Group, Inc., Richland, Washington.

Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

Jacobs, 2002, *Calculations to Support the Cost-Risk Analysis*, Jacobs Engineering Group, Richland, Washington.

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ATTACHMENT 3

ALTERNATIVE ANALYSIS REPORT FOR WASTE RETRIEVAL SYSTEM PRELIMINARY ENGINEERING TANKS C-106, C-201, C-202, C-203, AND C-204

Attachment 3

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Attachment 3

ALTERNATIVE ANALYSIS REPORT FOR WASTE RETRIEVAL SYSTEM PRELIMINARY ENGINEERING TANKS C-106, C-201, C-202, C-203, AND C-204

prepared for

CH2M HILL Hanford Group, Inc.
Contract No. 15766
Report No. 020310401-002
Revision 0

August 2002

prepared by

ARES Corporation

Attachment 3

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Attachment 3

Acronyms

AB	Authorization Basis
ALARA	As Low As Reasonably Achievable
CHG	CH2M HILL Hanford Group, Inc.
DOE	U.S. Department of Energy
DST	Double Shell Tank
ESQ&H	Environmental, Safety, Quality & Health
LDUA	Light Duty Utility Arm
MARS	Mobilization and Retrieval System
MRS	Mobile Retrieval System
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety Health Administration
PPS	Past Practice Sluicing
RAM	Reliability, Availability and Maintainability
SST	Single-Shell Tank
TPA	Tri-Party Agreement

Attachment 3

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1.0 INTRODUCTION

A group of five single-shell tanks (SSTs) have been selected for early retrieval in support of the Accelerated Tank Closure Demonstration Project. The removal of the residuals from tank C-106 and the recovery of the waste remaining in tanks C-201, C-202, C-203, and C-204 comprise the scope to be accomplished. As a part of the Preliminary Engineering for the retrieval of these tanks, an equipment evaluation was conducted to identify the viable retrieval system options, weigh them against requirements and decision criteria, and recommend the strongest retrieval equipment configuration for advancement into the Preliminary Engineering phase.

2.0 EVALUATION PROCESS

The evaluation process followed a systematic methodology that led to the recommendation of a retrieval approach(es) for tank C-106 and the C-200 series tanks. The intent of this methodology was to judge candidate technologies as to their ability to meet requirements and then again for how well they are expected to perform against predefined decision criteria.

The evaluation process occurs in five phases:

- Information Gathering Phase - This phase looked at historical information to identify viable system concepts, requirements applicable to retrieval, and preferred characteristics for a retrieval system.

- Options, Requirements & Criteria, and Weighting Factors Selection Phase - This was an initial evaluation of the options performed to identify the viable retrieval concepts and select the applicable requirements and decision criteria. The relative importance of each criteria to the success of the task was established by applying weighting factors.

- Concept Development Phase - In this phase, additional information was developed to assist with the selection of the conceptual option(s). The information developed was centered around the decision criteria selected previously.

- Evaluation Process Phase - A team familiar with SST farm operations, retrieval process, Environmental, Safety, Quality & Health (ESQ&H) requirements, available technology, and closure strategies was assembled to review the requirements, decision criteria, weighting factors, and options. The team then evaluated each of the options against the requirements and decision criteria.

- Report Generation Phase - A final report was generated to document the results from the preceding phases.

The similarity of the tank conditions and the wastes characteristics in the C-200 series tanks meant that a single retrieval system approach should be able to retrieve the wastes in all four of the smaller tanks. Therefore, the selection process recommends an approach for tank C-106 and another approach for the C-200 series tanks.

3.0 REQUIREMENTS

The requirements identified below were extracted from the Tri-Party Agreement (TPA), tank farms operations documents, U.S. Department of Energy (DOE) Orders, and contract documents. Requirements are criteria that all retrieval system options must be able to meet in order to be considered viable options. Only options capable of addressing all the requirements below were evaluated against the decision criteria listed in the next section.

1. The retrieval option shall meet the schedule as follows:
   - Complete evaluation of retrieval alternatives & preliminary engineering, 9/30/02
   - Complete retrieval from tank C-106, and 1/31/04*
   - Complete retrieval of C-200 series tanks. 9/30/04*
     (retrieval completed approximately three months earlier than closure).
     * Physical retrieval complete. Does not include post-retrieval sampling, tank volume measurements, etc.

2. Retrieval systems shall use only the existing riser access points.

3. Retrieval shall remove as much tank waste as technically possible, with tank waste residual not to exceed 360 cu ft in each of the 100 series tanks, 30 cu ft in each of the C-200 series tanks, or the limit of waste retrieval technology capability, whichever is less.

4. Leak detection is required.

5. The maximum live and dead loads allowed on the soil above the center of the tank dome should not exceed the values listed below. The load must be evenly distributed over at least a 10-ft radius over the tank and 20-ft outboard of tank:
   - C-200 series tanks- 50-ton or current limits in authorization basis (AB), and
   - C-100 series tanks- 100-ton or current limits in AB.**
     ** Project W-320 used 50-ton of available limit.

6. Retrieval equipment shall be designed to operate in the tank environment without failure for a complete tank retrieval cycle, including preventative maintenance.

7. Individual design doses to personnel shall not exceed 1,000 mrem on an annual basis.

8. The retrieval equipment shall not damage or breach the tank liner or dome.

9. In the event of a failure, the retrieval equipment must either be designed for removal from the tank for replacement or in-tank repair and return to service.

10. The retrieval system must be designed to be decontaminated and/or containerized to facilitate relocation to another tank, support system maintenance, or support disposal.

11. The retrieval system must be able to meet all applicable ESQ&H requirements [Clean Air Act, Clean Water Act, As Low As Reasonable Achievable (ALARA), Occupational Safety Health Administration (OSHA) etc.] and tank farm contractor procedures and requirements.

12. Any rinse water needed for equipment decontamination and flush water must be removed from the tank or included in the allowed residual waste total.

13. Retrieval system must include ability to transfer mobilized waste to a receiver tank.

    Note: Requirements 4 & 10 did not have an effect on the option evaluation process. Needed as part of the overall retrieval process.

4.0 DECISION CRITERIA

Decision criteria are performance characteristics the evaluator considers important and are used to help distinguish one option from others as being better able to perform the function. Decision criteria are not absolutes as in the case of requirements. An option that does not score well on one or two decision criteria may still do well enough overall to be selected as the preferred approach.

Each option is weighed against each decision criteria and given a score from between 0 to 100 based upon how strongly (or weakly) that option performs against that criteria. For this evaluation, the scoring was performed in two stages. First, an option was ranked qualitatively high, medium, or low in its ability to meet the criteria. Then a numerical rating was assigned based upon the evaluator's judgment as to whether a concept was strong or weak in that range (low- 0 to 30, medium 31 to 60, high 61 to 100).

Decision Criteria:

1. Life Cycle Costs - Rough Order of Magnitude cost comparisons including project capital costs, operating and maintenance costs, and demobilization costs. Life-cycle costs shall include solid waste disposal costs.

2. Schedule - Implementation of the waste retrieval must support the TPA retrieval and closure milestone dates.

3. Probability of Meeting TPA Goals - Retrieval concepts that have a high probability of meeting the TPA cleanliness requirements, etc., are favored.

4. Double Shell Tank (DST) Space Needs - Total retrieved tank waste volume including tank waste, flushes, and added supernatant and/or raw water.

5. Reliability, Availability, and Maintainability (RAM) - Relative changes (qualitative assessment) in overall RAM performance considering changes such as estimates of overall system reliability, how easily the system can be repaired and maintained, complexity of the design in regards to availability and reliability, numbers or types of pumps and other needed equipment (number of valves and pipe connections), accessibility for decon and repair, and/or ease of replacement.

6. Technology Maturity - Technical maturity of the major components (this could range from a theoretical concept, through technology applied in a related industry, to a technology already used by Tank Farms under comparable conditions).

7. ESQ&H requirements, and ALARA - a qualitative comparison of topics such as: overall worker safety, dose rates to worker over the life cycle, risk of spills to the environment, releases to the air, risk of damage to tank wall, material at risk, secondary transfer line holdup volume prior to leak detection, recovery time, a potential of primary transfer line leakage, and minimizing impacts to the facility AB.

8. Relative Ease of Use of Application - This encompasses ease of operator use, ease of deployment and set up, compatibility with existing systems and equipment, and ability to retrieve a wide range of waste types. This includes minimizing infrastructure modification.

9. Maximize Application to Future Retrieval Actions - This criteria addresses the relative ability to use the retrieval system on other SST. This will enable the project to gain practical experience and recommend retrieval technologies for future retrievals.

10. Minimize Water/Supernatant Addition - Technologies that minimize liquid addition into the tank are critical for applications in leaking SSTs.

5.0 DECISION CRITERIA WEIGHTING

Each of the decision criteria identified above were weighted for importance. The weighting helps place more emphasis on those criteria that are higher on the "desired attribute" list. The weighting criteria followed the logic described below:

- If the criteria influenced the ability to meet a commitment beyond the control of the DOE, such as the ability to meet TPA agreements, the criteria was given a 4 weighting.

- If the criteria was associated with a commitment to DOE and was in the control of the DOE, the criteria was weighted as 3.

- Those criteria that may impact or influence the criteria weighted 3 or 4 and possibly prevent those goals from being met were weighted as 2.

- Finally, the criteria that are internal goals of the Hanford contractor were weighted as 1.

The weighting factors were then normalized (based on a percentage of the total points). The results of this effort are shown on Table 5-1.

Table 5-1. Criteria Weightings.

	100 Series Tanks		200 Series Tanks	
Attribute	Weighting	Normalized Weighting	Weighting	Normalized Weighting
Cost	2	0.09	2	0.08
Schedule	3	0.14	3	0.13
Meet TPA requirement of 360 cu ft (30 cu ft)	4	0.18	4	0.17
DST Space Needs	2	0.09	2	0.08
Reliability, Maintainability, and Availability	2	0.09	2	0.08
Technology Maturity	2	0.09	2	0.08
ESQ&H and ALARA	2	0.09	2	0.08
Ease of Use of Application	2	0.09	2	0.08
Maximize Application to Future Retrieval	1	0.05	1	0.04
Minimize Introduction of Liquids into Tanks	2	0.09	4	0.18
Total	**22**		**24**	

6.0 ASSUMPTIONS

The following assumptions were identified during the process of establishing the requirements and decision criteria. These assumptions were important to the evaluation team, because they establish a baseline where information may be lacking or uncertain in quality.

1. The allowed residual waste following retrieval does not include waste that may be trapped in hardware and equipment resident in the tanks. [CH2M HILL Hanford Group, Inc. (CHG) to verify].

2. In-tank hardware and equipment does not have to be removed as part of retrieval.

3. C-106 is not a leaking tank.

4. C-200 series tanks are potential leakers.

5. Limited characterization will be available and, therefore, a wide range of waste characteristics may be encountered and a variety of debris.

6. Assume that the existing equipment, structures, and systems are usable or usable with minor modification. (Needs to be verified prior to completion of design. This covers infrastructure and transfer line, not old retrieval equipment).

7. The receiver tank is AY-102 and will be used for the retrieval of all five C-Tanks. CHG will identify other DSTs which could receive the retrieved wastes. Tank AN-106 is another potential candidate (two months to install over grand transfer).

8. Ventilation may be required during future retrieval actions, because of off-gassing, over-pressurization, fume control, etc. At the present time, active ventilation is not required by the AB for flammable gas or containment.

9. Tank C-106 is not a retrieval demonstration tank. The goal is to the clean tank of waste and leave no more than 360 cu ft.

10. The retrieval technology will be selected based upon the current characterization data. This data is assumed to accurately reflect the waste characteristics in the tanks to be retrieved (worse-case characteristics will be assumed).

11. The walls of the C-200 series tanks contain <30 cu ft of waste and wall cleaning technology is not necessarily a required capability.

12. The Mobile Retrieval System (MRS) safety analysis work for tank C-104 can be extended to cover the retrieval of tank C-106.

13. The MRS equipment can be made available for the retrieval of C-106.

14. Chemical addition (acid) is expected to be a high-risk uncertainty for approval in a modification to the AB.

15. Twelve-inch risers are available in all the C-200 series tanks being considered for retrieval. An additional riser is also available for camera deployment.

16. The 42-in manway on the C-200 series tanks are considered a usable access to the tank.

7.0 RETRIEVAL CONCEPTS

A total of 11 retrieval system concepts were identified as potential options to be considered for use in C-106 and the C-200 series tanks. All 11 concepts were expected to be able to meet the requirements stated in Section 3.0. The concepts were grouped in two categories; those appropriate for retrieval of tank C-106 and those appropriate for retrieval of the small C tanks. The principle characteristics that distinguish the two groups are whether the technology was appropriate for leaking tanks and the ability of the technology to cover the area in a 75-ft diameter tank, in the case of tank C-106.

The identified concepts for each application are shown below.

Tank C-106
- Mobile Retrieval System (C-104)
- Past Practice Sluicing (PPS)
- Modified Sluicing
- Fluidic Mixing (AEA/Russian)
- Crawler with Pump
- Mobilization and Retrieval System (MARS)

C-200 Series Tanks
- Articulated Mast System (C-104)
- Mast with Confined Scarifier
- Light Duty Utility Arm w/scarifier
- Mast Mounted Arm with Ultrasonics
- Crawler Based System w/Motivator

Tank C-106 Options:

MRS - MRS is the baseline retrieval system for C-104, as shown in Figure D-1 in Appendix D. The system consists of a centrally deployed articulated mast that is capable of deploying a vacuum head up to 15-ft radially out from the center. The system is augmented by a tracked, crawler system that is capable of pushing waste towards the vacuum head and/or pumping the waste and shooting it towards the pick up head. The system has the capability to recover a wide variety of waste over the entire area of the tank without becoming encumbered by the in-tank debris or hardware.

PPS - PPS specifically refers to sluicing as employed by Project W-320 in "Tank 241-C-106 Waste Retrieval" tank C-106 to recover the high heat wastes. Figure D-2 in Appendix D shows the configuration of PPS with the exception that the slurry pump was mounted in a side riser.

Modified Sluicing - Modified sluicing is a variant of PPS and could relocate the slurry pump to the central riser, add additional sluice nozzles to improve access to waste, may consider the use of chemicals to enhance dissolution of the waste, etc.

Fluidic Mixing (AEA/Russian) (Fluidics) - This system is based upon fluidic pumping action by sucking up supernatant into a charge vessel and then quickly discharging back into the tank through wash nozzles. When sufficient waste has been mobilized, the batch is pumped out of the tank, as shown in Figure D-3 in Appendix D.

Crawler with Central Pump - This concept is similar to the MRS system with the exception that a fixed pump has been placed into the central riser in place of the articulated mast system. Crawler is shown in Figure D-4 in Appendix D.

MARS - MARS is a submersible pump with collocated valving system packed into a single unit that is placed into the tank. MARS is able to either mobilize the waste or pump waste out of the tank by varying the arrangement of the collocated valves.

Tank C-200 Series Options:

Articulated Mast - The articulated mast is the same mast system that forms part of the MRS. The articulated mast and vacuum head are sized to enter the tank through the central 12-in riser.

Mast w/Confined Scarifier - The mast is the same mast used by the MRS, however in this option, the pickup head is a scarifier. The scarifier employs high pressure, low volume, rotating water jets to break up waste, which is then removed using an air conveyance system or by close coupled hydraulic pump. The scarifier has been used at Oak Ridge National Laboratory (ORNL) to clean out eight of their underground waste tanks, as shown in Figure D-5 in Appendix D.

Light Duty Utility Arm (LDUA) w/Scarifier - The LDUA is a highly articulated robotic arm with the capability of being deployed into a tank through a 12-in riser, see Figure D-6 in Appendix D. The LDUA was designed to enter tanks that are complicated by in-tank obstructions and/or require the placement of tools in unusual positions, such as wall cleaning/inspection tool. The LDUA has been used in the tanks at ORNL and once in a Hanford tank. The scarifier is the same unit described above.

Mast Mounted Arm w/Ultrasonics - This system utilizes a mast similar to the unit used in the MRS to deploy a dislodging tool based upon ultrasonic waves to break up the waste. The waste would be removed from the tank using an air conveyance system or close coupled pump system.

Crawler w/Motivator - A crawler system is envisioned to be able to enter a C-200 series tank through the 42-in manway (manway requires excavation to provide access). The crawler would then be used to deploy tooling, such as a confined scarifier, to mobilize and remove the waste.

8.0 RETRIEVAL OPTIONS EVALUATIONS

In advance of conducting the options evaluation, a presentation on the W-320 Project using PPS was provided by John Bailey (the project engineer on Project W-320). The presentation was an overview of PPS in tank C-106 and a discussion about "lessons learned." The following were the key points taken from those discussions.

- Sluicing methods based upon the use of water and/or supernatant are unlikely to meet the 360 cu ft goals, since the remaining material in tank C-106 does not appear to be soluble and not easily broken up by sluice streams.

- The heel jet pump located in the central riser will be difficult to remove. The W-320 project was unsuccessful in removing this equipment. A removal jig has been made to pull heel jet pump, but has not been tried. It is probably still available.

- Mr. John Bailey believes that the residual in C-106 is broken up phosphate waste. There is probably no intact hard pan, but he is not sure that is the case. He was uncertain as to the physical characteristics of the residual waste, other than it appears to be insoluble in water and does not readily break up when subjected to sluicing (even for prolonged periods of time).

- Tank C-106 has considerable debris left in the bottom of the tank- sludge weight tapes, hoses, two remaining float bells with flexible lines, etc.

- When caustic has been used in the past, an improvement in the solids removal has been noted.

- The tank C-106 equipment is in poor shape and would require significant renovation to be reused, including replacement of seals on the booster pump and replacement of the submersible pump.
- Not much trapped waste is expected in the slurry pump or the heel jet pump.
- The pump pit exhibits high radiation dose rates - 20 rem/hr gamma (not much improvement following cleaning during Project W-320). The heel pit does not have much of a dose rate.
- A recent radiation survey shows C-106 has a 65 rad/hr dose rate (gamma) 2 ft above the waste. The dose rate was above 200 rads/hr (total) from all sources at the same location.
- The C-200 series tanks have a 42-in manway that does not have a riser to the ground level.
- Tank C-201 radiation dose rate is 58 rads/hr total radiation dose and 2.5 rads/hr from gamma alone.
- CHG estimates that tank C-106 contains 15,000-gal of solids and 30,000-gal of liquids and solids in the residual; however, CHG has little confidence in that estimate. (Hanlon 2002 estimates C-106 to contain 6,000-gal of solids and 31,000-gal total)
- Tank C-106 is a dish bottom tank and the differential height between the center and the outer edge is 12-in.
- It is estimated that there is one-foot of sludge under the retrieval pump.

Retrieval Evaluation:

The retrieval options evaluation was conducted on August 1, 2002, with a team knowledgeable and familiar with SST farm operations, the retrieval process, ESQ&H requirements, retrieval technology options, and closure issues and requirements. Appendix A identifies the attendees and their current area of expertise. Each retrieval option was evaluated against the decision criteria and scored as a high, medium, or low according to the definitions provided in Appendix B. The team members were then asked to determine a numerical score based upon whether the option was considered to be at the high end or the low end of the range selected. For example, if an option was determined to be a strong candidate in the medium category, it might be scored with 50 to 60 points (high end of medium).

The results of the evaluations are shown in Tables 8-1 and 8-2 below. The key points brought out during the evaluations along with a summary of the reasons for the score awarded follow the tables.

Table 8-1. Raw and Weighted Scores for Tank C-106 Retrieval Technologies.

	LC Cost (.09 Weight)	Schedule (.14 Weight)	TPA (.18 Weight)	DST Space (.09 Weight)	(Raw Score/Weighted Score)	Tech. Maturity(.09 Weight)	ESH&Q(.09 Weight)	Ease of Use (.09 Weight)	Future Applic. (.05 Weight)	Min H_2O Addition (.09 Weight)	Sub Total (Raw Score/Weighted Score)
MRS	61	61	90	65	70	60	75	55	85	80	702
	5.49	8.54	16.20	5.85	6.30	5.40	6.75	4.95	4.25	7.20	70.93
PPS	100	70	10	90	75	100	55	50	55	10	615
	9.00	9.80	1.80	8.10	6.75	9.00	4.95	4.50	2.75	0.90	57.55
Mod Sluicing	75	35	65	60	65	61	50	55	45	10	521
	6.75	4.90	11.70	5.40	5.85	5.49	4.50	4.95	2.25	0.90	52.69
Crawler/Pump	40	60	90	65	75	60	70	55	70	60	645
	3.60	8.40	16.20	5.85	6.75	5.40	6.30	4.95	3.50	5.40	66.35
Fluidics	10	10	20	50	85	70	60	45	45	45	440
	0.90	1.40	3.60	4.50	7.65	6.30	5.40	4.05	2.25	4.05	40.10
MARS	83	20	20	50	60	55	60	45	60	60	513
	7.47	2.80	3.60	4.50	5.40	4.95	5.40	4.05	3.00	5.40	46.57

Table 8-2. Raw and Weighted Scores for C-200 Tank Series Retrieval Technologies.

	Cost (.08 weight)	Schedule (.13 weight)	TPA (.17 weight)	DST Space (.08 weight)	RAM (.08 weight)	Tech. Maturity (.08 weight)	ESH&Q (.08 weight)	Ease of Use (.08 weight)	Future Applic. (.04 weight)	Min H_2O Addition (.18 weight)	Sub Total (Raw Score/Weighted Score)
Articulated Mast	100	75	50	NA	70	60	75	75	NA	90	595
	8.00	9.75	8.50	NA	5.60	4.80	6.00	6.00	NA	14.40	63.05
Mast with Confined Scarifier	80	60	80	NA	60	65	70	80	NA	80	575
	6.40	7.80	13.60	NA	4.80	5.20	5.60	6.40	NA	14.40	64.20
LDUA With Scarifier	80	45	80/90	NA	50	75	70	70	NA	80	550/560
	6.40	5.85	15.30	NA	4.00	6.00	5.60	5.60	NA	14.40	63.15
Mast Mounted Arm With Ultrasonics	50	30	65	NA	60	40	70	80	NA	90	485
	4.00	3.90	11.05	NA	4.80	3.20	5.60	6.40	NA	16.20	55.15
Crawler/ Motivator	10	30	70	NA	50	55	75	30	NA	90	410
	0.80	3.90	11.90	NA	4.00	4.40	6.00	2.40	NA	16.20	49.60

Evaluation Rationale:

- Cost rankings are relative with the lowest cost option rating 100 pts and the more expensive options scoring progressively lower. The life-cycle costs were developed in advance of the meeting and supplied as background information to the evaluation team. These cost projections are shown in Appendix C. The costs for modifications to the C-Farm utilities or tanks that were common to all the concepts were not included (which is estimated to be 40 percent of the cost basis). Transportation and receiver tank costs were also excluded. Only the costs that are considered discriminator costs; those that differ between concepts were presented.

- Schedule – In the case of tank C-106, none of the options were considered 100 percent certain to meet the scheduled retrieval completion dates and hence the highest score was 70 points. However, it could not be concluded that the schedule would not be met by any concepts, therefore even concepts considered to be poor in their ability to meet schedule were given some points.

  Factors that resulted in lower scores:
  - Long lead equipment that must be procured and is a significant concern in regards to meeting schedule,
  - Equipment and systems that require design further extends the concern about ability to meet schedule, and
  - Magnitude of authorization basis (AB) impacts.

  Factors that positively affected scores:
  - Equipment available on-site or easily obtainable,
  - Equipment that has been designed and built before, and
  - Systems that are covered by the AB or easily incorporated.

  Key points from discussion:
  * MRS and crawler scored well, because equipment has been ordered and delivery is immanent,
  * PPS also scored well, since the equipment needed is either on hand or easily obtained, and
  * The other systems scored lower due to long lead times and/or AB issues, such as the use of acid for modified sluicing.

  In the C-200 series tanks, the same concerns were discussed. In the case of the LDUA, even though it is an existing piece of equipment, extensive refurbishment and testing of a complicated system meant that confidence in its ability to meet schedule was medium at best.

- TPA - the consensus of the group was to score the technologies according to their ability to accomplish the goal of removing enough waste to satisfy the definition of a clean tank (<360 cu ft for C-100 series tanks and <30 cu ft for C-200 series tanks). In tank C-106, technologies that are able to physically break up the waste scored better than those that relied upon sluicing/pump/or dissolution alone. The MRS has the added feature of being able to pick and remove material in small, solid form. Past practice sluicing performed poorly on this criteria, because of pessimism about the ability of PPS to meet the goal of leaving no more than 360 cu ft of waste.

  In the case of the C-200 series tanks, the uncertainty associated with the physical characteristics of the waste resulted in technologies that could handle hard waste as well as soft waste scoring better than those that were limited to a particular waste characteristic. If requirements for a clean tank require removal of waste from the wall, then the LDUA in combination with a scarifier technology appears to be the only system capable of accomplishing the task (and, therefore, scores better then other technologies).

- DST Space - PPS scored well in this area, because it uses existing supernatant as the removal media and very little new water. The other technologies did not score as well, because they required the use of water for wash down or as the means for waste mobilization. In the case of the C-200 series tanks, DST space is not considered a factor, because of the small quantity of waste present and the fact most of the technologies being considered will require some water for wash down and water will have to be added to be able to transport and meet compatibility purposes with DST wastes.

- RAM – Tank C-106 – RAM was considered to be best with systems that were simpler in design, have fewer moving parts, and had parts requiring maintenance located outside the tank environment. In this case the fluidic systems were ranked the best, since they have no moving in tank parts and are of a durable design. The MARS system scored the worst. Even though the system contains few system components, the moving parts vulnerable to failure are located in tank.

  The C-200 series technologies were ranked very closely, because the complexity and the expected failure rate for the systems are all considered similar. The configuration of an acceptable crawler system is an uncertainty, since it was not known whether a system small enough to go down a 12-in riser would be effective in removing waste. A crawler that requires a 42-in manway access would require a significant support system for hose management, radiation & contamination control, etc. The RAM score given to the crawler was an estimate of what the RAM of a system of this type might be.

- Technical Maturity - In both the C-100 and C-200 series tanks, those systems that had been deployed into DOE waste tanks scored the best, followed next by those systems that have been used in similar industrial applications, and finally those systems being placed into a new application (not used for this purpose before) scored the worst.

- ESH&Q - In both the C-100 and C-200 series tanks the point spread between technologies was not great. The reason was that all technologies were deemed to be able to meet ESQ&H requirements and regulations stated earlier in the requirements section. None of the technologies appeared to excel in achieving compliance in any of these areas.

- Ease of Use - The point spread within the tank C-106 or within the C-200 series tanks was not great. However, between the large and the smaller tanks the spread was significant, because the large tank systems required multiple riser access and therefore caused significant deployment impacts. The smaller tanks are expected to use a central riser only. In the case of crawler for the small tanks, it was expected to require access through the manway, which is a major deployment impact.

- Future Applications – Tank C-106 technologies were deemed to be usable for a number of future tanks. Those technologies that were also usable in leaking tanks were given higher scores. The technologies for the small C tanks were considered of limited value to other tanks since their reach was very limited and not directly usable in the large tanks. There are few of the small size tanks.

- Minimum In-Tank Water Addition - The small tanks require technologies that favor no net water addition or could retrieve dry. The highest scoring technologies used no water and the systems with no resident water systems scored closely behind.

  For the tank C-106 case, PPS and modified sluicing technology require a large flow of liquid into the tank to be able to remove waste and therefore scored poorly. In the case of fluidic mixing and MARS, a resident pool of liquid is required for waste removal and scored a little better then PPS. MRS scored best, since very little water is needed retrieval and cleanup.

9.0 CONCLUSIONS

The evaluation of the tank C-106 candidate technologies resulted in the MRS being the recommended system approach.

MRS Strengths:
- Scored well against all decision criteria,
- Has the capability to tackle wide range of waste characteristics,
- Expected to be able to meet TPA goals,
- Expected to meet schedule goals, and
- Minimizes the need for in-tank liquid addition.

The other technologies scored significantly behind the MRS, with the crawler and central pump concept coming in second best (scored approximately 6 percent behind MRS weighted score). Since the crawler and central pump system is a derivative of the MRS, it was to be expected that the two would be close in score. PPS came in 19 percent (weighted score) behind the MRS, which may be a higher score than it deserves based on the uncertainty as to the ability of PPS to break up the remaining waste. Many of the

team questioned the ability of PPS to achieve the TPA goals. However given time, PPS might be able to eventually recover enough waste to reach the residual waste volumes required by the TPA and, hence, was not disqualified completely from the evaluation.

The evaluation of the C-200 series tanks resulted in the articulated mast system (63.05 points weighted score) and the mast with a confined scarifier system (64.20 points weighted score) being ranked as the top recommendations. It is not surprising that the two scored closely, since they are essentially the same with the exception of the mobilization tool. The scarifier head tended to edge out the vacuum head, because of the proven track record of the scarifier head. It has been used to cleanout eight underground tanks at ORNL. Both concepts should be considered for the retrieval of the C-200 series tanks. Though the characterization videos show the waste remaining in the tanks to be loose and dry, there is the possibility that a hardpan layer is present and a scarifier system would provide the additional capability needed to remove a hard pan. The infrastructure needed to support either system will be very similar if not the same.

An uncertainty was raised during the discussions regarding the need for the retrieval technology to be able to remove waste from the walls of the tank. In the videos, it appeared waste was present on the walls and may need to be removed in order to meet the 30 cu ft residual goal in the small tanks. If this capability is needed, the LDUA with scarifier is the only technology with the ability to clean the walls. Though this system approach scored as well as the two systems above, concerns with the extent of the refurbishment needed and the complexity of the system suggest this system should only be used if wall cleaning is required.

With the exceptions noted above, the resulting scores were distributed over a large band. The large spread in scores indicate that a sensitivity analysis of the results will not influence the outcome of the recommendations. Both the raw scores and the weighted scores support this conclusion.

Attachment 3

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Attachment 3

Appendix A
Meeting Attendees

Attachment 3

ATTENDANCE			
NAME	COMPANY	NUMBER	E-MAIL
ERIC SHEN	ARES	946-3300	eshen@arescorporation.com
JOHN BORES	CHG QA	376-8131	John_F_Bores@rl.gov
JIM THOMPSON	ORP	373-9757	
CHANTHE CREZE	NHC	373-0973	
STEVE O'TOOLE	CHG	376-4284	StevenM_Steve_O'Toole@RL.gov
JAMES A. TUCK	CHG	372-3236	
CHRIS BURKE	CHG	372-3305	Christopher_A_Burke@rl.gov
KEITH CARPENTER	CHG	372-2452	Keith_E_Carpenter@rl.gov
JOHN W. BAILEY	CHG	372-0045	John_W_Bailey@rl.gov
PAUL PATTERSON	ARES	946-3300	ppatterson@arescorporation.com
MIKE RINKER	BATTELLE	375-6623	Mike_rinker@pnl.gov
BOB FRITZ	ARES	946-3300	bfritz@arescorporation.com
ED FREDENBURG	CHG	372-0435	edfredenburg@charter.net
DAVID PARKMAN	CHG	373-3462	
DAVID SMET	CHG	372-3537	DAVID_B_SMET@rl.gov
JOHN WINTERS	CH2M	375-0683 ext. 212	jwinters@ch2m.com
MATT LANDON	CHG	373-1379	Matthew_R_Landon@rl.gov
GRANT McCALLUM	CBCG	947-0988	Grant_J_McCallum@rl.com
MIKE WHITE	ARES	946-8946	Mwhite@arescorporation.com
SCOTT PIERCE	ARES	946-3300	spierce@arescorporation.com

Attachment 3

Appendix B
Scoring Guidelines

B1.0 COST

Cost considerations are life-cycle costs that include construction, operations and maintenance, startup/readiness testing and acceptance, environmental, and safety basis costs associated with each alternative. The alternative with the lowest cost is scored as 100 points. All other alternatives are scored according to the guidelines below based on the percent difference from the lowest cost alternative.

	Points
Low	**0-30**

This alternative has estimated life-cycle costs that are 50 percent to 500 percent higher than the lowest cost competing alternative.

Medium	**31 – 60**

This alternative has life-cycle costs that are 25 percent to 50 percent higher than the lowest cost competing alternative.

High	**61 – 100**

This alternative has life-cycle costs that are 0 percent to 25 percent higher than the lowest cost competing alternatives.

B2.0 SCHEDULE

Schedule considerations include integrated, operating and construction, and accelerated shipping.

	Points
Low	**0-30**

Selection of this alternative does little or nothing to improve or maintain the ability to meet the project schedules.

Selection of this alternative provides a low probability (<50 percent) of meeting the project schedule.

Medium	**31 – 60**

Selection of this alternative enhances the ability to meet the project schedules.

Selection of this alternative provides a medium probability (50-75 percent) of meeting the project schedule.

High	**61 – 100**

Selection of this alternative results in significant improvement in the ability to meet the project schedules.

Sections of this alternative provides a high probability (>75 percent) of meeting the project schedule.

B3.0 MEET TPA REQUIREMENT OF 360 CU FT (30 CU FT)

	Points
Low	**0-30**

Selection of this alternative is unlikely (< 20 percent) to be able to meet this criteria.

Medium	**31 – 60**

Selection of this alternative has a moderate probability of meeting this criteria (20-70 percent).

High	**61 – 100**

Selection of this alternative has a high probability of meeting this criteria (>70 percent)

B4.0 DST SPACE NEEDS

	Points
Low	**0-30**

Selection of this alternative would provide a significant strain on available DST space.

Medium	**31 – 60**

Selection of this alternative has significant impact on available DST space, but won't place a strain on the system.

High	**61 – 100**

Selection of this alternative has little impact on available DST space.

B5.0 RELIABILITY, MAINTAINABILITY, AVAILABILITY

	Points
Low	**0-30**

This alternative is expected to require extensive maintenance prior to completion of a retrieval campaign.

Medium	**31 – 60**

This alternative is expected to require some maintenance activities prior to completion of a campaign, but can be accomplished with minimal exposure and lost time.

High	**61 – 100**

This alternative is expected to require no maintenance during the retrieval campaign.

Technology Maturity

	Points
Low	**0-30**

This technology is still being developed beyond the conceptual design phase.

Medium	**31 – 60**

This technology is very similar to practices used successfully in similar applications. The engineering is straightforward.

High	**61 – 100**

This technology has been used successfully before in this or a similar application.

B6.0 ESQ&H, AND ALARA

	Points
Low	**0 – 30**

This alternative reduces or eliminates the risk of minor to moderate injury to facility personnel.

Selection of this alternative has no implications with respect to ALARA, OSHA requirements, AB compliance, fire concerns, and personnel injury.

Medium **31 – 60**

Selection of this alternative enhances safety for facility personnel.

Selection of this alternative has a reduced potential for radiological or toxicological harm to facility workers, and alternative workers, but does not impact public risk.

Selection of this alternative improves, but does not optimize, conditions with respect to ALARA, OSHA requirements, AB compliance, fire concerns, and personnel injury.

High **61- 100**

Selection of this alternative enhances safety to help prevent an accident causing the death of one or more facility worker.

Selection of this alternative reduces or eliminates the potential for radiological or toxicological harm to the public.

Selection of this alternative optimizes conditions with respect to ALARA, OSHA requirements, AB compliance, fire concerns, and prevention of personnel injury.

B7.0 EASE OF USE OF APPLICATION

	Points
Low	**0-30**

This technology is difficult for operators to use.

The technology is difficult to deploy and setup on the tank.

The technology has a low compatibility with existing equipment

The technology has a limited ability to address varying waste characteristics.

This approach requires extensive infrastructure modifications.

Medium **31 – 60**

This technology is of medium difficulty for operators to use.

The technology is moderately difficult to deploy and setup on the tank.

The technology is somewhat compatible with existing equipment

The technology has some ability to address varying waste characteristics.

This approach requires moderate level of infrastructure modifications.

High **61 – 100**

This technology is easy for operators to use.

The technology is not difficult to deploy and setup on the tank.

The technology is very compatible with existing equipment

The technology has a significant ability to address varying waste characteristics.

This approach requires very little infrastructure modification.

B8.0 MAXIMIZE APPLICATION TO FUTURE RETRIEVAL

	Points
Low	**0-30**

This technology is unlikely (<20 percent probability) to be useful for future retrieval operations.

Medium **31 – 60**

This technology is moderately likely (20 percent - 70 percent probability) to be useful for future retrieval operations.

High **61 – 100**

This technology is highly likely (>70 percent probability) to be useful for future retrieval operations.

B9.0 MINIMIZE INTRODUCTION OF LIQUIDS INTO TANKS

	Points
Low	**0-30**

This technology introduces a large quantity of liquid in-tank during the retrieval process.

Medium **31 – 60**

This technology requires some quantity of liquid in tank during the retrieval process.

High **61 – 100**

This technology requires a small quantity of liquid or no liquid in tank during the retrieval process.

Attachment 3

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Attachment 3

Appendix C
Life-Cycle Cost Data

TANK C-106 - WATER MOUSE ALTERNATIVE - LIFE-CYCLE COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
Retrieval System		-	-	-	-	-	-	-		CONTR	-	-	-	-		-	-	-	-	-
Installation of Retrieval System																				
Retrieval system		-	-	-	-	-	-	-	0.00	CONTR	12.0	MO	2,150	25,800	(25,800)	42.00	-	-	-	-
CONTR		-	-	-	-	-	-	-												
FP		-	-	-	-	-	-	-												
BASE COST SUBTOTAL		-	-	-	-	-	-	-						25,800	(25,800)					
CONSUMABLES	4.0%	-	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	-	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	-	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	-	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	-	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		-																		
FP SUBCONTRACTOR MARKUP	10.0%	-	*S/C * 0.1 FP ONLY*																	
FP CONTRACTOR MARKUP	42.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0.42 FP ONLY*																	
FP CM	22.0%	-	*BASE COST SUBTOTAL * 0.22 FP ONLY*																	
CF CM	36.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0.36 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		-																		
ENGINEERING DESIGN	33.0%	-	*ESTIMATE SUBTOTAL * 0.33*																	
ENGINEERING CONST SUPPORT	17.0%	-	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	-	*ESTIMATE SUBTOTAL * 0.25*																	
CAPITAL SUBTOTAL		-																		
SHARED SERVICES & PHMC G&A	14.4%	-	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		-																		
WORK PACKAGE PREPARATION	17.0%	-	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS (No. of Months)	20	17,200,000	*$860K / MO * # OF MONTHS*																	
PROTOTYPE & TESTING	n/a	400,000	*PROTOTYPE & TESTING TOTAL*																	
A/B COSTS	6.0%	1,056,000	*(SITE ALLOC + OPC's) * 0.06*																	
OPC's SUBTOTAL		18,656,000																		
CONTINGENCY	45.0%	8,395,200	*OPC's SUBTOTAL * 0.45*																	
GRAND TOTAL		***27,051,200***																		

PROTOTYPE & TESTING - TESTING CLASSIFICATION (1=NONE, 2=SOME 3=SIGNIFICANT)			3
TEST DESCRIPTION	*QTY*	*COST*	*TOTAL*
INTEGRATED TEST	1	200,000	200,000
DEVELOPMENT TEST	2	50,000	100,000
PROTOTYPE TEST	1	100,000	100,000
TOTAL			400,000

FACTOR BASED ON PROTOTYPE TESTING	
NORMAL	FACTORED
20%	33%
10%	17%
15.0%	25%
10.0%	17%

A/B COSTS	3
CLASS	*%*
1=NONE	1.0%
2=SIMPLE	3.0%
3=SIGNIFICANT	6.0%

PROBABILITY OF SCHEDEDULE SUCCESS	3
CLASS	*%*
1=HIGH	25.0%
2=MEDIUM	35.0%
3=LOW	45.0%

Assumptions / Factors

1) Construction labor costs are based off of W-320 construction items associated with riser prep, shielding, and equipment installation. The Installation Complexity Factor is used to increase construction labor costs based on an assumed construction complexity equal to or greater than the construction complexity of W-320.

2) Additional costs and the associated "normal" markup % are shown for Engineering Design, Engineering Const Support, Project Management, and Work Package Preparation. These markup %'s are factored up depending on the Prototype and Testing Classification. If the classification is "None" it is not factored up, if it is "Some" it is factored up 33%, and if it is "Significant" it is factored up 66%.

3) Operations costs for Tank C-106 are based off of W-320 retrieval operation costs which is $860K per month. Operations costs for Tanks C-200 are based off of 2/3 of the W-320 retrieval operation costs which is $580K per month. The number of months for retrieval is based off of the pumping flow rate.

4) Prototype & Testing costs are based off of the assumed number of integrated tests, development tests, and prototype tests required.

5) The Authorization Basis (A/B) cost markup is 1% for non-perceived modification, 3% for moderate modifications, and 6% for significant modifications to the existing A/B. The markup is applied to all costs and is based of percentages derived from W-320.

6) Contingency is based off of an assumed degree of schedule success. 25% for a high degree, 35% for a medium degree, and 45% for a low degree of success.

Attachment 2

Appendix D
Figures

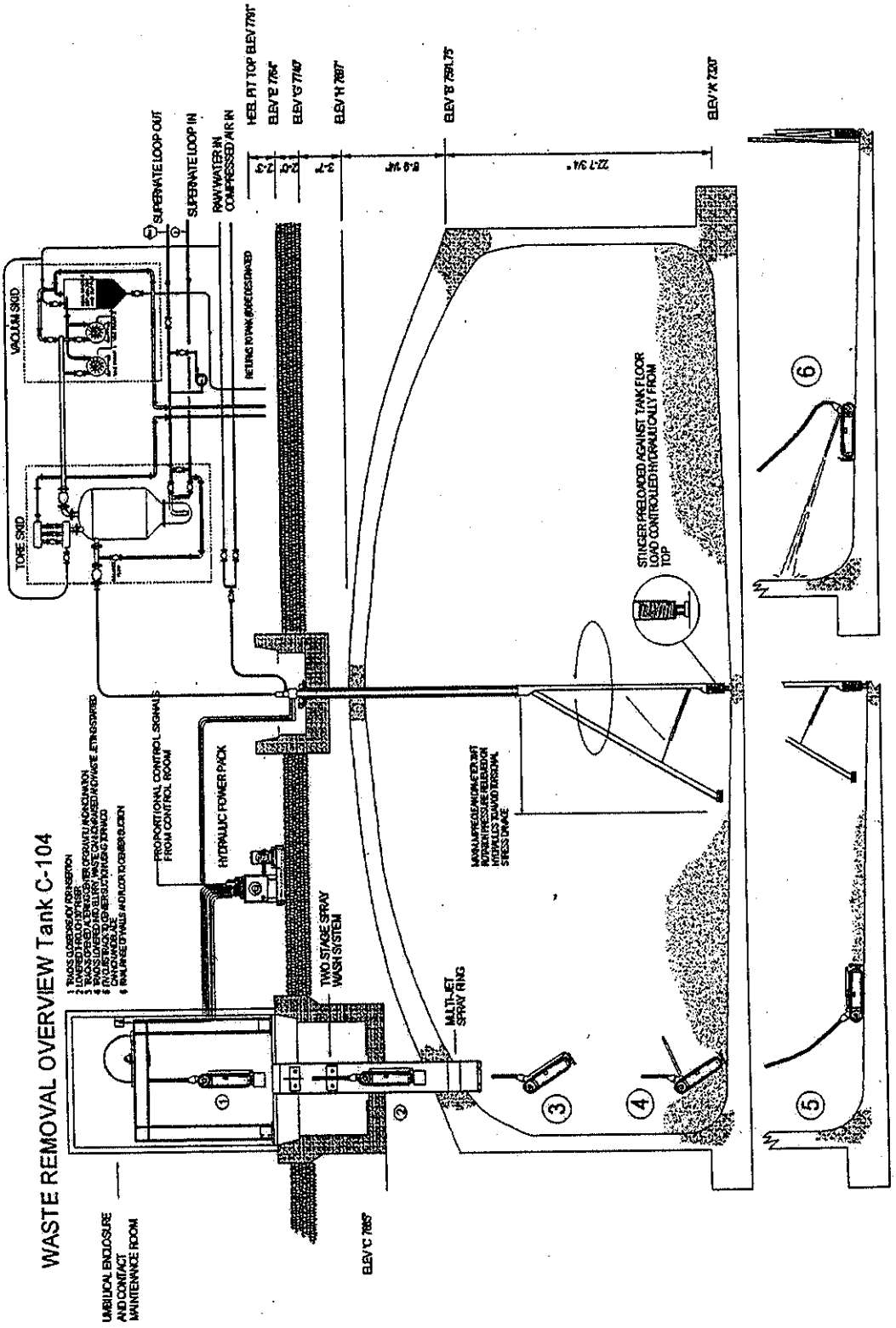


Figure D-1. Mobile Retrieval System.

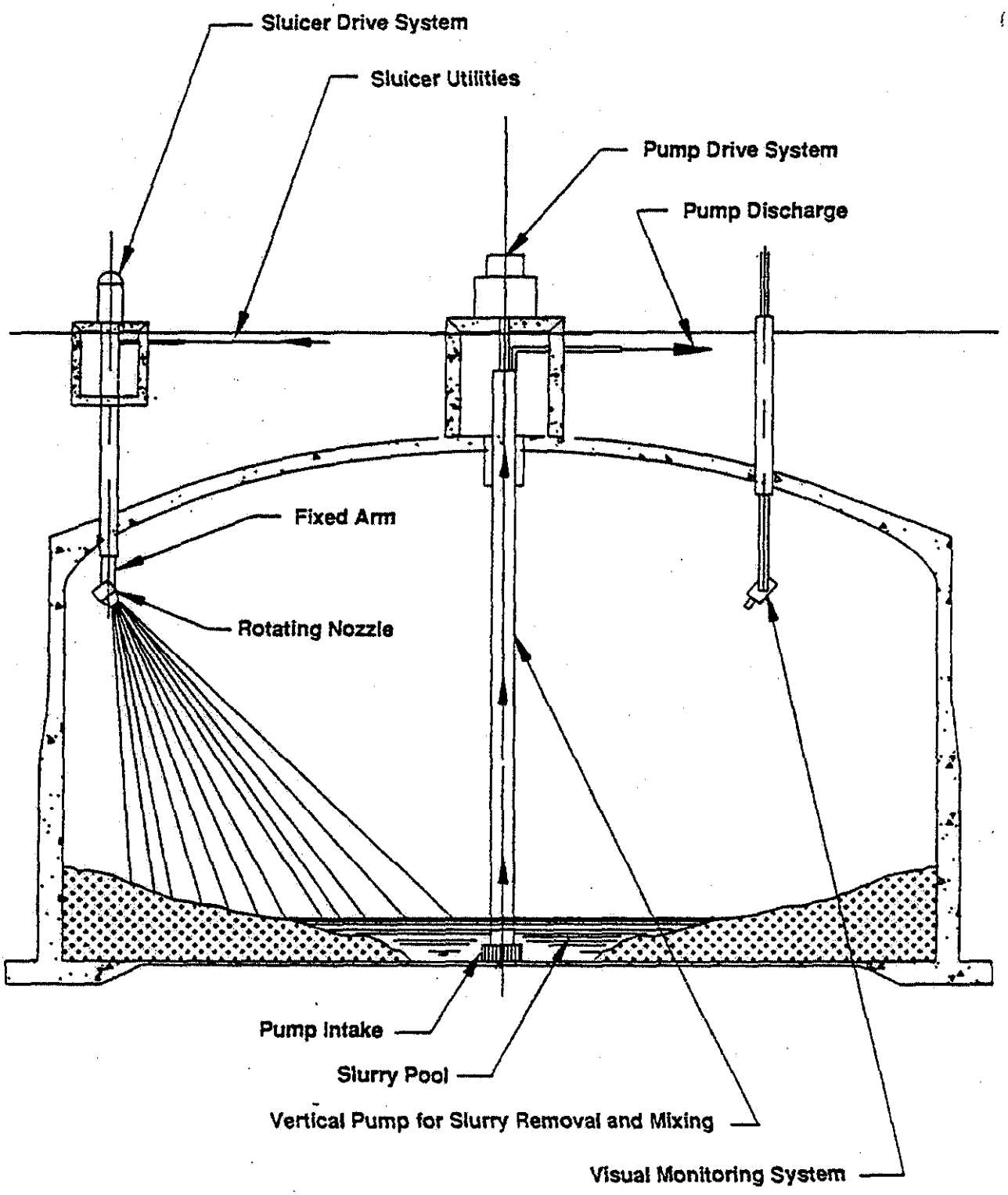


Figure D-2. Past Practice Sluice.

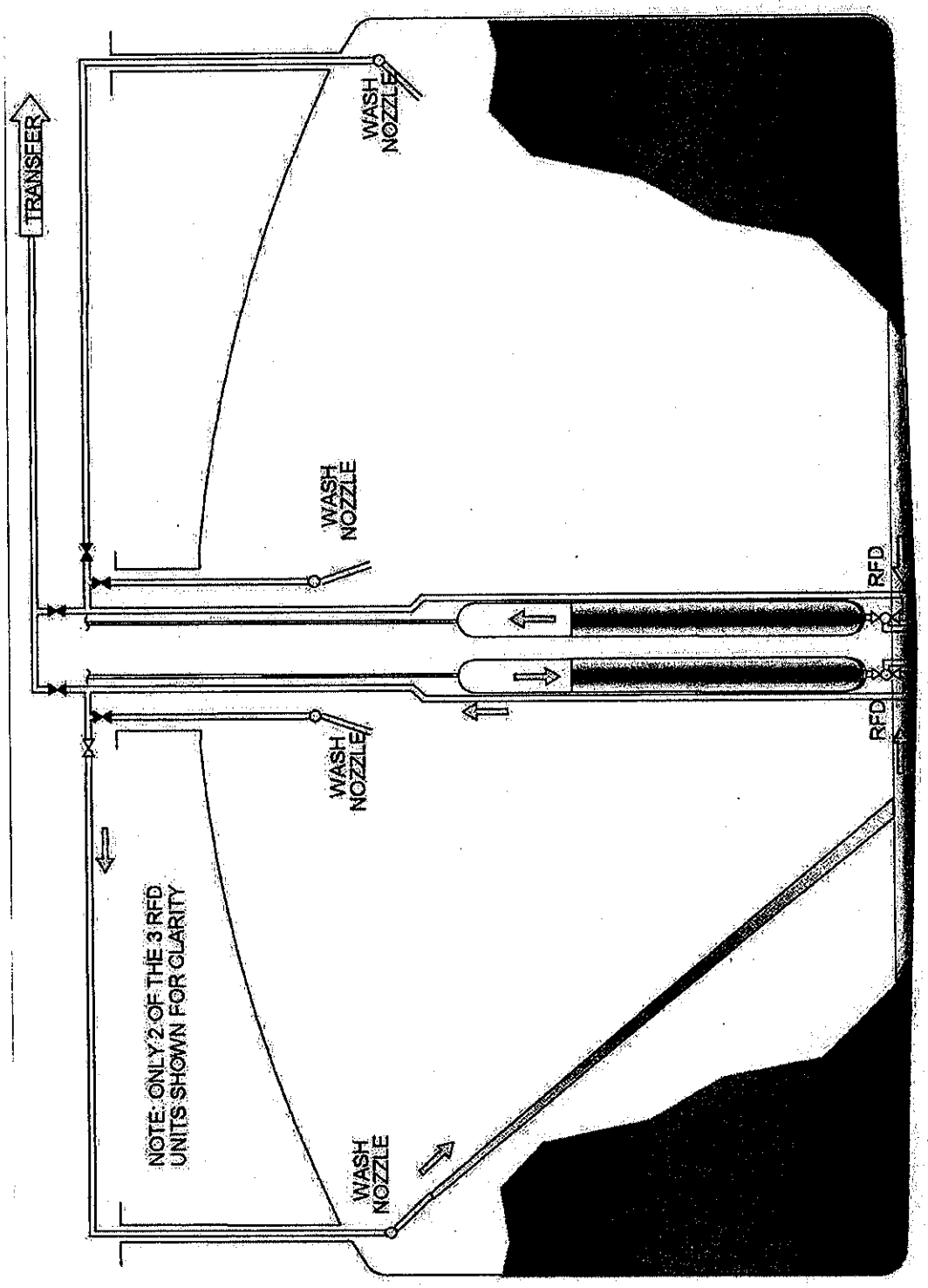


Figure D-3. Fluidic Mixing System.

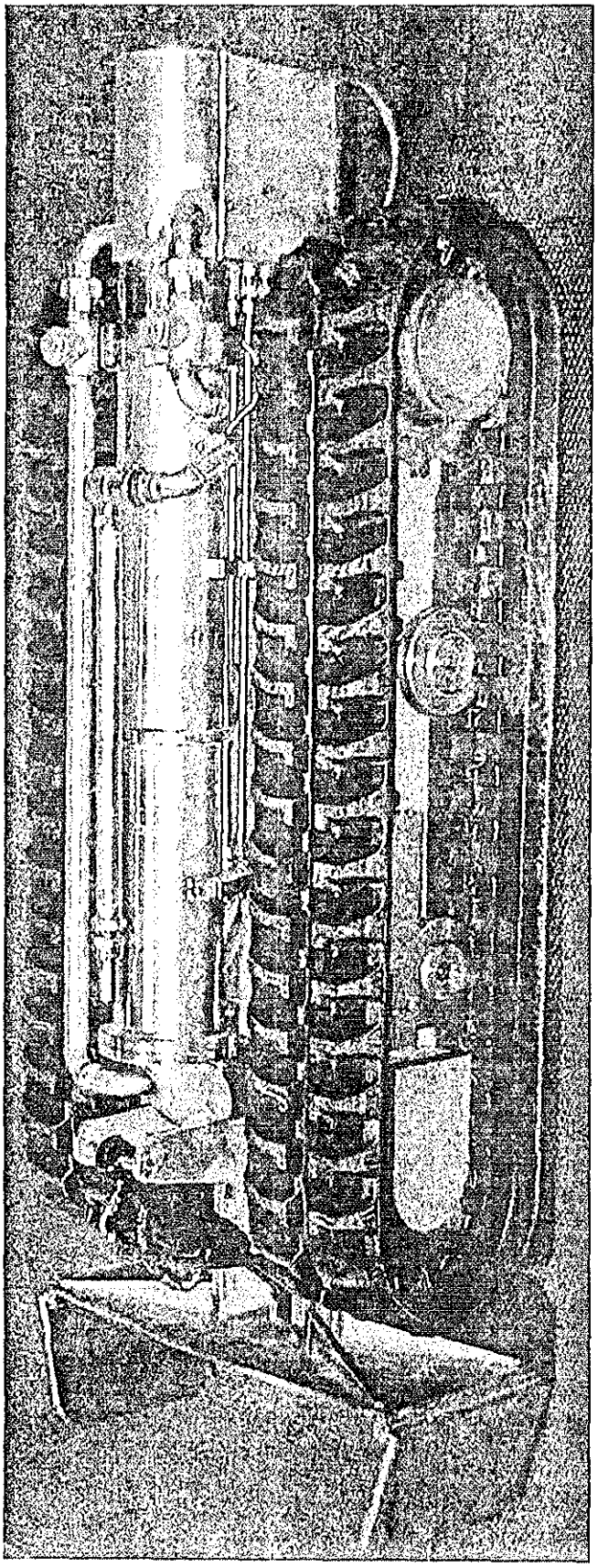
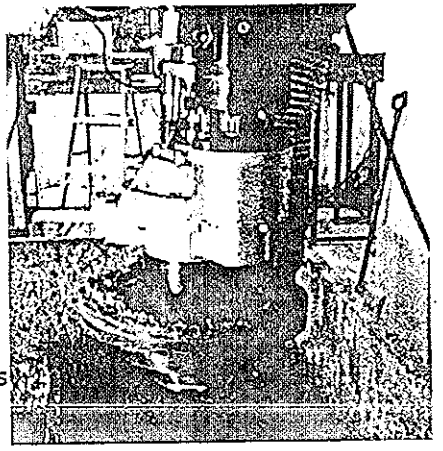


Figure D-4. Typical Crawler.

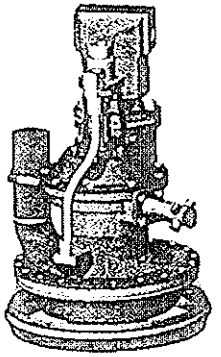
Confined Sluicing Technology



Battelle designed and developed unique waste removal systems to support the U.S. Department of Energy's nuclear waste clean-up projects. In field deployments at several different sites, the specialized sluicing and waste conveyance systems were successfully used to remove sludges and stubborn heels from waste storage tanks.

Design Features Include:

- rotating high-pressure waterjets to dislodge sludges and saltcakes
- specifically designed to operate safely in flammable gas environments
- fabrication with corrosion-resistant materials
- Weight is 83-pounds
- Height is 19.2-in, Diameter is 12.5-in,
- waterjets are rotated at up to 900rpm using a hydraulic motor that operates at pressures at up to 3000psi
- waterjet pressure is variable up to 10,000psi
- waste retrieval rate for sludge is nominally 10-15gpm



Leveraged Capability:

This technology appears to be well suited for applications in the petroleum industry where clean-out of petroleum storage tanks to support periodic inspection is a man-power intensive effort.

For More Information:
Mike Rinker
(509)375-6623

Battelle Northwest
P.O. Box 999
Richland, WA 99352

Battelle

U.S. Department of Energy
Pacific Northwest National Laboratory

Figure D-5. Confined Scarifier.

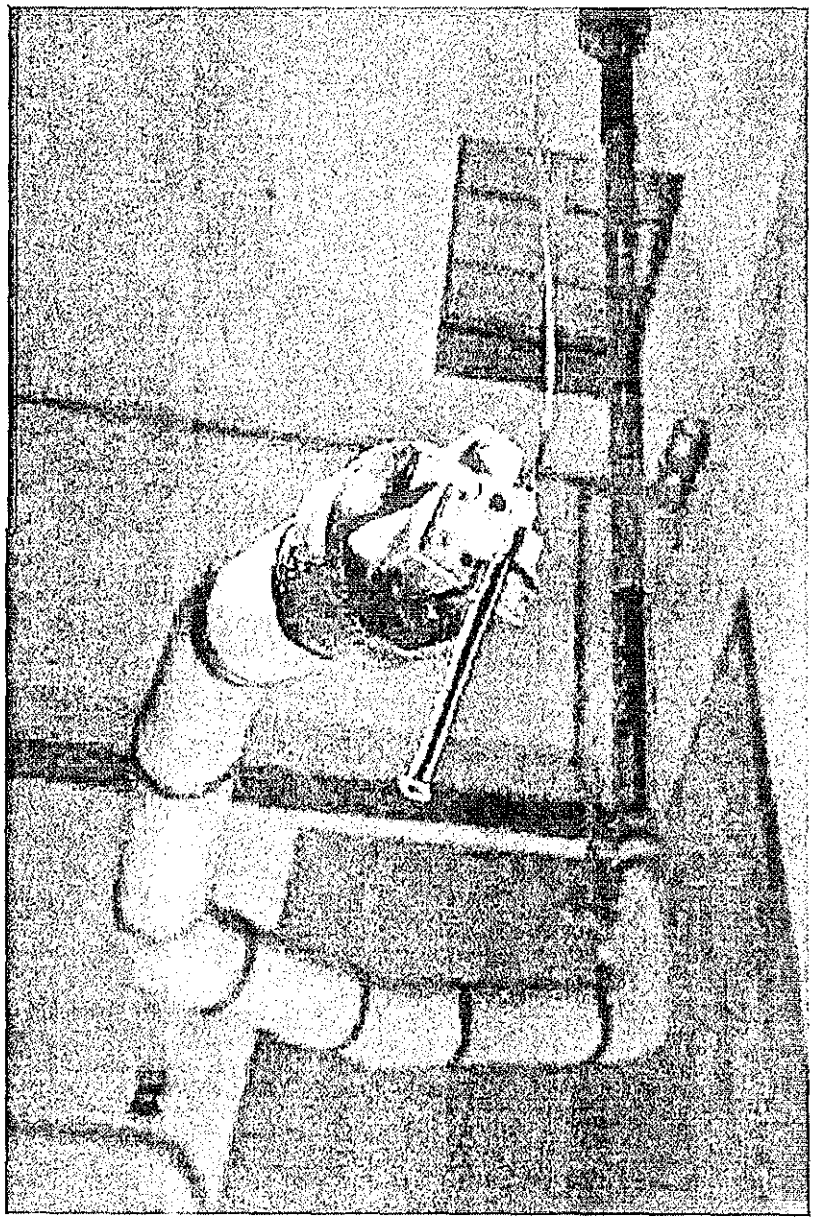


Figure D-6. Light Duty Utility Arm.

TANKS C-200 - AMS (ARTICULATED MAST SYSTEM) C-104 - LIFE-CYCLE COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
Retrieval System																				
Mast system		140,000	-	-	-	-	-	140,000		CONTR	1.0	EA	-	-		-	-	-	-	140,000
Vessel skid		600,000	-	-	-	-	-	600,000		CONTR	1.0	EA	-	-		-	-	-	-	600,000
Vacuum skid		85,000	-	-	-	-	-	85,000		CONTR	1.0	EA	-	-		-	-	-	-	85,000
Camera system		125,000	-	-	-	-	-	125,000		CONTR	0.5	EA	-	-		-	-	-	-	250,000
Installation of Retrieval System																				
Retrieval system		1,083,600	25,800	1,083,600	-	-	-	-	1.00	CONTR	12.0	MO	2,150	25,800	-	42.00	-	-	-	-
CONTR		*2,033,600*	*25,800*	*1,083,600*	-	-	-	*950,000*												
FP		-	-	-	-	-	-	-												
BASE COST SUBTOTAL		*2,033,600*	*25,800*	1,083,600	-	-	-	950,000						25,800	-					
CONSUMABLES	4.0%	43,344	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	32,508	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	54,180	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	43,344	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	3,598	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		176,974																		
FP SUBCONTRACTOR MARKUP	10.0%	-	*S/C * 0.1 FP ONLY*																	
FP CONTRACTOR MARKUP	42.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0.42 FP ONLY*																	
FP CM	22.0%	-	*BASE COST SUBTOTAL * 0.22 FP ONLY*																	
CF CM	36.0%	794,511	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0.36 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		794,511																		
ESTIMATE SUBTOTAL		3,005,085																		
ENGINEERING DESIGN	20.0%	601,017	*ESTIMATE SUBTOTAL * 0.2*																	
ENGINEERING CONST SUPPORT	10.0%	300,509	*ESTIMATE SUBTOTAL * 0.1*																	
PROJECT MANAGEMENT	15.0%	450,763	*ESTIMATE SUBTOTAL * 0.15*																	
CAPITAL SUBTOTAL		4,357,374																		
SHARED SERVICES & PHMC G&A	14.4%	432,732	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		4,790,106																		
WORK PACKAGE PREPARATION	10.0%	300,509	*ESTIMATE SUBTOTAL * 0.1*																	
OPERATIONS (No. of Months)	0.3	258,000	*$580K / MO * # OF MONTHS*																	
PROTOTYPE & TESTING	n/a	200,000	*PROTOTYPE & TESTING TOTAL*																	
A/B COSTS	3.0%	166,458	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		5,715,073																		
CONTINGENCY	35.0%	2,000,276	*OPC's SUBTOTAL * 0.35*																	
GRAND TOTAL		***7,715,349***																		

PROTOTYPE & TESTING - TESTING CLASSIFICATION (1=NONE, 2=SOME 3=SIGNIFICANT)			1
TEST DESCRIPTION	*QTY*	*COST*	*TOTAL*
INTEGRATED TEST	1	200,000	200,000
DEVELOPMENT TEST	0	50,000	-
PROTOTYPE TEST	0	100,000	-
TOTAL			200,000

FACTOR BASED ON PROTOTYPE TESTING	
NORMAL	FACTORED
20%	20%
10%	10%
15.0%	15%
10.0%	10%

A/B COSTS	2
CLASS	*%*
1=NONE	1.0%
2=SIMPLE	3.0%
3=SIGNIFICANT	6.0%

PROBABILITY OF SCHEDEDULE SUCCESS	2
CLASS	*%*
1=HIGH	25.0%
2=MEDIUM	35.0%
3=LOW	45.0%

Assumptions / Factors

1) Construction labor costs are based off of W-320 construction items associated with riser prep, shielding, and equipment installation. The Installation Complexity Factor is used to increase construction labor costs based on an assumed construction complexity equal to or greater than the construction complexity of W-320.

2) Additional costs and the associated "normal" markup % are shown for Engineering Design, Engineering Const Support, Project Management, and Work Package Preparation. These markup %'s are factored up depending on the Prototype and Testing Classification. If the classification is "None" it is not factored up, if it is "Some" it is factored up 33%, and if it is "Significant" it is factored up 66%.

3) Operations costs for Tank C-106 are based off of W-320 retrieval operation costs which is $860K per month. Operations costs for Tanks C-200 are based off of 2/3 of the W-320 retrieval operation costs which is $580K per month. The number of months for retrieval is based off of the pumping flow rate.

4) Prototype & Testing costs are based off of the assumed number of integrated tests, development tests, and prototype tests required.

5) The Authorization Basis (A/B) cost markup is 1% for non-perceived modification, 3% for moderate modifications, and 6% for significant modifications to the existing A/B. The markup is applied to all costs and is based of percentages derived from W-320.

6) Contingency is based off of an assumed degree of schedule success. 25% for a high degree, 35% for a medium degree, and 45% for a low degree of success.

TANKS C-200 - MAST WITH CONFINED SCARIFIER - LIFE-CYCLE COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
Retrieval System																				
Mast system		140,000	-	-	-	-	-	140,000		CONTR	1.0	EA	-	-		-	-	-	-	140,000
Vessel skid		600,000	-	-	-	-	-	600,000		CONTR	1.0	EA	-	-		-	-	-	-	600,000
Camera system		125,000	-	-	-	-	-	125,000		CONTR	0.5	EA	-	-		-	-	-	-	250,000
Scarifier head		200,000	-	-	-	-	-	200,000		CONTR	1.0	EA	-	-		-	-	-	-	200,000
Installation of Retrieval System																				
Retrieval system		1,083,600	25,800	1,083,600	-	-	-	-	1.00	CONTR	12.0	MO	2,150	25,800	-	42.00	-	-	-	-
CONTR		*2,148,600*	*25,800*	*1,083,600*	-	-	-	*1,065,000*												
FP		-	-	-	-	-	-	-												
BASE COST SUBTOTAL		*2,148,600*	*25,800*	1,083,600	-	-	-	1,065,000						25,800	-					
CONSUMABLES	4.0%	43,344	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	32,508	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	54,180	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	43,344	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	3,598	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		176,974																		
FP SUBCONTRACTOR MARKUP	10.0%	-	*S/C * 0.1 FP ONLY*																	
FP CONTRACTOR MARKUP	42.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0.42 FP ONLY*																	
FP CM	22.0%	-	*BASE COST SUBTOTAL * 0.22 FP ONLY*																	
CF CM	36.0%	835,911	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0.36 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		835,911																		
ESTIMATE SUBTOTAL		3,161,485																		
ENGINEERING DESIGN	27.0%	853,601	*ESTIMATE SUBTOTAL * 0.27*																	
ENGINEERING CONST SUPPORT	13.0%	410,993	*ESTIMATE SUBTOTAL * 0.13*																	
PROJECT MANAGEMENT	20.0%	632,297	*ESTIMATE SUBTOTAL * 0.2*																	
CAPITAL SUBTOTAL		5,058,376																		
SHARED SERVICES & PHMC G&A	14.4%	455,254	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		5,513,630																		
WORK PACKAGE PREPARATION	13.0%	410,993	*ESTIMATE SUBTOTAL * 0.13*																	
OPERATIONS (No. of Months)	0.3	258,000	*$580K / MO * # OF MONTHS*																	
PROTOTYPE & TESTING	n/a	250,000	*PROTOTYPE & TESTING TOTAL*																	
A/B COSTS	3.0%	192,979	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		6,625,602																		
CONTINGENCY	35.0%	2,318,961	*OPC's SUBTOTAL * 0.35*																	
GRAND TOTAL		*8,944,563*																		

PROTOTYPE & TESTING - TESTING CLASSIFICATION (1=NONE, 2=SOME 3=SIGNIFICANT)			2
TEST DESCRIPTION	*QTY*	*COST*	*TOTAL*
INTEGRATED TEST	1	200,000	200,000
DEVELOPMENT TEST	1	50,000	50,000
PROTOTYPE TEST	0	100,000	-
TOTAL			250,000

FACTOR BASED ON PROTOTYPE TESTING	
NORMAL	FACTORED
20%	27%
10%	13%
15.0%	20%
10.0%	13%

A/B COSTS	2
CLASS	*%*
1=NONE	1.0%
2=SIMPLE	3.0%
3=SIGNIFICANT	6.0%

PROBABILITY OF SCHEDEDULE SUCCESS	2
CLASS	*%*
1=HIGH	25.0%
2=MEDIUM	35.0%
3=LOW	45.0%

Assumptions / Factors

1) Construction labor costs are based off of W-320 construction items associated with riser prep, shielding, and equipment installation. The Installation Complexity Factor is used to increase construction labor costs based on an assumed construction complexity equal to or greater than the construction complexity of W-320.

2) Additional costs and the associated "normal" markup % are shown for Engineering Design, Engineering Const Support, Project Management, and Work Package Preparation. These markup %'s are factored up depending on the Prototype and Testing Classification. If the classification is "None" it is not factored up, if it is "Some" it is factored up 33%, and if it is "Significant" it is factored up 66%.

3) Operations costs for Tank C-106 are based off of W-320 retrieval operation costs which is $860K per month. Operations costs for Tanks C-200 are based off of 2/3 of the W-320 retrieval operation costs which is $580K per month. The number of months for retrieval is based off of the pumping flow rate.

4) Prototype & Testing costs are based off of the assumed number of integrated tests, development tests, and prototype tests required.

5) The Authorization Basis (A/B) cost markup is 1% for non-perceived modification, 3% for moderate modifications, and 6% for significant modifications to the existing A/B. The markup is applied to all costs and is based of percentages derived from W-320.

6) Contingency is based off of an assumed degree of schedule success. 25% for a high degree, 35% for a medium degree, and 45% for a low degree of success.

TANKS C-200 - LDUA (LIGHT DUTY UTILITY ARM) WITH SCRIFIER - LIFE-CYCLE COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
Retrieval System																				
Upgrade LDUA		400,000	-	-	-	-	-	400,000		CONTR	1.0	EA	-	-		-	-	-	-	400,000
Scarifier head		200,000	-	-	-	-	-	200,000		CONTR	1.0	EA	-	-		-	-	-	-	200,000
Vessel skid		600,000	-	-	-	-	-	600,000		CONTR	1.0	EA	-	-		-	-	-	-	600,000
Camera system		125,000	-	-	-	-	-	125,000		CONTR	0.5	EA	-	-		-	-	-	-	250,000
Installation of Retrieval System																				
Retrieval system		1,083,600	25,800	1,083,600	-	-	-	-	1.00	CONTR	12.0	MO	2,150	25,800	-	42.00	-	-	-	-
CONTR		*2,408,600*	*25,800*	*1,083,600*	-	-	-	*1,325,000*												
FP		-	-	-	-	-	-	-												
BASE COST SUBTOTAL		*2,408,600*	*25,800*	1,083,600	-	-	-	1,325,000						25,800	-					
CONSUMABLES	4.0%	43,344	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	32,508	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	54,180	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	43,344	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	3,598	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		176,974																		
FP SUBCONTRACTOR MARKUP	10.0%	-	*S/C * 0.1 FP ONLY*																	
FP CONTRACTOR MARKUP	42.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0.42 FP ONLY*																	
FP CM	22.0%	-	*BASE COST SUBTOTAL * 0.22 FP ONLY*																	
CF CM	36.0%	929,511	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0.36 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		929,511																		
ESTIMATE SUBTOTAL		3,515,085																		
ENGINEERING DESIGN	20.0%	703,017	*ESTIMATE SUBTOTAL * 0.2*																	
ENGINEERING CONST SUPPORT	10.0%	351,509	*ESTIMATE SUBTOTAL * 0.1*																	
PROJECT MANAGEMENT	15.0%	527,263	*ESTIMATE SUBTOTAL * 0.15*																	
CAPITAL SUBTOTAL		5,096,874																		
SHARED SERVICES & PHMC G&A	14.4%	506,172	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		5,603,046																		
WORK PACKAGE PREPARATION	10.0%	351,509	*ESTIMATE SUBTOTAL * 0.1*																	
OPERATIONS (No. of Months)	0.3	258,000	*$580K / MO * # OF MONTHS*																	
PROTOTYPE & TESTING	n/a	200,000	*PROTOTYPE & TESTING TOTAL*																	
A/B COSTS	3.0%	192,377	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		6,604,932																		
CONTINGENCY	35.0%	2,311,726	*OPC's SUBTOTAL * 0.35*																	
GRAND TOTAL		***8,916,658***																		

PROTOTYPE & TESTING - TESTING CLASSIFICATION (1=NONE, 2=SOME 3=SIGNIFICANT)			1
TEST DESCRIPTION	*QTY*	*COST*	*TOTAL*
INTEGRATED TEST	1	200,000	200,000
DEVELOPMENT TEST	0	50,000	-
PROTOTYPE TEST	0	100,000	-
TOTAL			200,000

FACTOR BASED ON PROTOTYPE TESTING	
NORMAL	FACTORED
20%	20%
10%	10%
15.0%	15%
10.0%	10%

A/B COSTS	2
CLASS	*%*
1=NONE	1.0%
2=SIMPLE	3.0%
3=SIGNIFICANT	6.0%

PROBABILITY OF SCHEDEDULE SUCCESS	2
CLASS	*%*
1=HIGH	25.0%
2=MEDIUM	35.0%
3=LOW	45.0%

Assumptions / Factors

1) Construction labor costs are based off of W-320 construction items associated with riser prep, shielding, and equipment installation. The Installation Complexity Factor is used to increase construction labor costs based on an assumed construction complexity equal to or greater than the construction complexity of W-320.

2) Additional costs and the associated "normal" markup % are shown for Engineering Design, Engineering Const Support, Project Management, and Work Package Preparation. These markup %'s are factored up depending on the Prototype and Testing Classification. If the classification is "None" it is not factored up, if it is "Some" it is factored up 33%, and if it is "Significant" it is factored up 66%.

3) Operations costs for Tank C-106 are based off of W-320 retrieval operation costs which is $860K per month. Operations costs for Tanks C-200 are based off of 2/3 of the W-320 retrieval operation costs which is $580K per month. The number of months for retrieval is based off of the pumping flow rate.

4) Prototype & Testing costs are based off of the assumed number of integrated tests, development tests, and prototype tests required.

5) The Authorization Basis (A/B) cost markup is 1% for non-perceived modification, 3% for moderate modifications, and 6% for significant modifications to the existing A/B. The markup is applied to all costs and is based of percentages derived from W-320.

6) Contingency is based off of an assumed degree of schedule success. 25% for a high degree, 35% for a medium degree, and 45% for a low degree of success.

TANKS C-200 - ARMS / MAST WITH ULTRASONIC DISLODGER - LIFE-CYCLE COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
Retrieval System																				
Ultrasonic dislodger tool		400,000	-	-	-	-	-	400,000		CONTR	1.0	EA	-	-		-	-	-	-	400,000
Pump skid		600,000	-	-	-	-	-	600,000		CONTR	1.0	EA	-	-		-	-	-	-	600,000
Arm		140,000	-	-	-	-	-	140,000		CONTR	1.0	EA	-	-		-	-	-	-	140,000
Installation of Retrieval System																				
Retrieval system		1,354,500	32,250	1,354,500	-	-	-	-	1.25	CONTR	12.0	MO	2,150	25,800	6,450	42.00	-	-	-	-
CONTR		*2,494,500*	*32,250*	*1,354,500*	-	-	-	*1,140,000*												
FP		-	-	-	-	-	-	-												
BASE COST SUBTOTAL		*2,494,500*	*32,250*	1,354,500	-	-	-	1,140,000						25,800	6,450					
CONSUMABLES	4.0%	54,180	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	40,635	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	67,725	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	54,180	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	4,497	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		221,217																		
FP SUBCONTRACTOR MARKUP	10.0%	-	*S/C * 0.1 FP ONLY*																	
FP CONTRACTOR MARKUP	42.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0.42 FP ONLY*																	
FP CM	22.0%	-	*BASE COST SUBTOTAL * 0.22 FP ONLY*																	
CF CM	36.0%	976,039	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0.36 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		976,039																		
ESTIMATE SUBTOTAL		3,691,756																		
ENGINEERING DESIGN	33.0%	1,218,279	*ESTIMATE SUBTOTAL * 0.33*																	
ENGINEERING CONST SUPPORT	17.0%	627,599	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	922,939	*ESTIMATE SUBTOTAL * 0.25*																	
CAPITAL SUBTOTAL		6,460,573																		
SHARED SERVICES & PHMC G&A	14.4%	531,613	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		6,992,186																		
WORK PACKAGE PREPARATION	17.0%	627,599	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS (No. of Months)	0.6	516,000	*$580K / MO * # OF MONTHS*																	
PROTOTYPE & TESTING	n/a	450,000	*PROTOTYPE & TESTING TOTAL*																	
A/B COSTS	6.0%	515,147	*(SITE ALLOC + OPC's) * 0.06*																	
OPC's SUBTOTAL		9,100,932																		
CONTINGENCY	45.0%	4,095,419	*OPC's SUBTOTAL * 0.45*																	
GRAND TOTAL		***13,196,351***																		

PROTOTYPE & TESTING - TESTING CLASSIFICATION (1=NONE, 2=SOME 3=SIGNIFICANT)			3
TEST DESCRIPTION	*QTY*	*COST*	*TOTAL*
INTEGRATED TEST	1	200,000	200,000
DEVELOPMENT TEST	3	50,000	150,000
PROTOTYPE TEST	1	100,000	100,000
TOTAL			450,000

FACTOR BASED ON PROTOTYPE TESTING	
NORMAL	FACTORED
20%	33%
10%	17%
15.0%	25%
10.0%	17%

A/B COSTS	3
CLASS	*%*
1=NONE	1.0%
2=SIMPLE	3.0%
3=SIGNIFICANT	6.0%

PROBABILITY OF SCHEDEDULE SUCCESS	3
CLASS	*%*
1=HIGH	25.0%
2=MEDIUM	35.0%
3=LOW	45.0%

Assumptions / Factors

1) Construction labor costs are based off of W-320 construction items associated with riser prep, shielding, and equipment installation. The Installation Complexity Factor is used to increase construction labor costs based on an assumed construction complexity equal to or greater than the construction complexity of W-320.

2) Additional costs and the associated "normal" markup % are shown for Engineering Design, Engineering Const Support, Project Management, and Work Package Preparation. These markup %'s are factored up depending on the Prototype and Testing Classification. If the classification is "None" it is not factored up, if it is "Some" it is factored up 33%, and if it is "Significant" it is factored up 66%.

3) Operations costs for Tank C-106 are based off of W-320 retrieval operation costs which is $860K per month. Operations costs for Tanks C-200 are based off of 2/3 of the W-320 retrieval operation costs which is $580K per month. The number of months for retrieval is based off of the pumping flow rate.

4) Prototype & Testing costs are based off of the assumed number of integrated tests, development tests, and prototype tests required.

5) The Authorization Basis (A/B) cost markup is 1% for non-perceived modification, 3% for moderate modifications, and 6% for significant modifications to the existing A/B. The markup is applied to all costs and is based of percentages derived from W-320.

6) Contingency is based off of an assumed degree of schedule success. 25% for a high degree, 35% for a medium degree, and 45% for a low degree of success.

Attachment 2

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ATTACHMENT 4

ALTERNATIVE ANALYSIS REPORT FOR ACCELERATED TANK CLOSURE DEMONSTRATION PROJECT TANKS C-106, C-201, C-202, C-203, AND C-204

Attachment 4

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Attachment 4

ALTERNATIVE ANALYSIS REPORT FOR ACCELERATED TANK CLOSURE DEMONSTRATION PROJECT TANKS C-106, C-201, C-202, C-203, AND C-204

prepared for

CH2M HILL Hanford Group, Inc.
Contract No. 16137
Report No. 020310501-001
Revision 0

September 2002

prepared by

ARES Corporation
1100 Jadwin, Suite 400
Richland, Washington 99352

Attachment 4

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Attachment 4

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Attachment 4

Acronyms

AB	Authorization Basis
ALARA	As Low As Reasonably Achievable
ATCD	Accelerated Tank Closure Demonstration
CHG	CH2M HILL Hanford Group, Inc.
DOE	U.S. Department of Energy
ESH&Q	Environmental, Safety, Health & Quality
LDR	Land Disposal Requirements
MRS	Mobile Retrieval System
ROM	Rough Order of Magnitude
SST	Single-Shell Tank

1.0 INTRODUCTION

The U.S. Department of Energy (DOE), Office of River Protection and River Protection Project have selected landfill closure as the baseline strategy to close 200 Area single-shell tanks (SSTs). This strategy is based upon the assumption that the waste residuals in the tanks, SST structure, and ancillary in-tank equipment can be disposed of in place and in accordance with applicable Federal and State regulations and agreements.

Landfill closure of tanks will involve injection of fill materials into tanks to stabilize residual waste and provide structural integrity. Waste stabilization can include both physical and chemical stabilization. Tank structural integrity will ultimately be necessary to ensure that the tanks do not collapse under their own weight or added weight of a final tank for a surface barrier.

A group of five SSTs has been selected for early retrieval and preferred closure in support of the Accelerated Tank Closure Demonstration (ATCD) project. The five tanks chosen for this demonstration are: C-106, C-201, C-202, C-203, and C-204.

2.0 EVALUATION PROCESS

The evaluation process followed a systematic methodology that led to the recommendation of a closure method for the five tanks. The intent of this methodology was to judge candidate closure methods as to their ability to meet requirements and for how well they are expected to perform against predefined decision criteria.

The evaluation process consisted of four phases:

- Information Gathering Phase - This phase looked at historical information to identify viable system concepts, requirements applicable to closure, and preferred characteristics for a closure system.

- Alternatives, Requirements & Criteria, and Weighting Factors Selection Phase - This phase consisted of an initial evaluation of the alternatives performed to identify the viable closure methods and applicable requirements and select appropriate decision criteria. The relative importance of each criterion to the success of the task was established by applying weighting factors.

- Evaluation Process Phase - A team familiar with SST farm operations, Environmental, Safety, Health & Quality (ESH&Q) requirements, available technology, and closure methods was assembled to review the general requirements, criteria, weighting factors, and alternatives. The team then evaluated each of the alternatives against the decision criteria.

- Report Generation Phase – A final report was generated to document the results from the preceding phases.

The information-gathering phase yielded alternatives that were two-phase in nature; both phases would be necessary to facilitate safe and compliant tank closure. Viable tank closure alternatives needed to include methods for waste stabilization (Phase 1) and for tank structural support (Phase 2), including filling of void spaces.

The similarity of the tank conditions for the C-200 series tanks meant that a single-closure method approach could be utilized for these tanks. Therefore, the philosophy for a selection process included one approach for tank C-106 and another approach for all C-200 series tanks. However, closure methods could be the same for each type of tank.

3.0 REQUIREMENTS

The requirement topics identified in Appendix A were extracted from ATCD project data and RPP-11094, *Tank Closure Structural System for the Accelerated Tank Closure Demonstration Level 2 Specification* (CHG 2002). The Level 2 Specification establishes the performance specification for tank closure definition and preliminary engineering. Only alternatives judged to be capable of addressing all of the following requirements were evaluated against the decision criteria listed in section 4.0. ESH&Q elements were included as evaluation criteria because safety and health risk factors may distinguish one option from another and because a particular option may exceed State and Federal regulations compared to another option. Appendix A contains a summary of each requirement element, the Level 2 Specification section where the requirement is documented, and general remarks for some specific requirements. Each alternative evaluated against the section 4.0 decision criteria was judged to be capable of meeting the minimum requirements of the Level 2 Specification.

During the evaluation phase of this analysis, Environmental Impact Statement, Land Disposal Requirements (LDR), and other Washington Department of Ecology or National Environmental Policy Act issues were not fully determined due to inherent uncertainty and the outcome of future EIS Record(s) of Decision. However, it was determined that no considered option had characteristics that would preclude state or federal regulatory compliance.

3.1 Constraints

The tank closure option shall meet the schedule as follows:

- Complete evaluation of closure alternatives & preliminary engineering 9/30/02
- Complete closure of tank C-106 3/31/04*
- Complete closure of C-200 series tanks 12/31/04*

4.0 DECISION CRITERIA

Decision criteria are performance characteristics an evaluator considers important and are used to help distinguish one option from those better suited to perform the function. Decision criteria are not absolutes, as in the case of requirements. An option that does not score well on one or two decision criteria may still do well enough overall to be selected as the preferred approach.

Decision Criteria

1. Limit Release of Contaminants – Criteria associated with stabilization materials designed to limit or restrict mobility of contaminants. The material was evaluated based it's ability to minimize risk of contaminant migration before placement of succeeding lifts of tank structural material. Acceptable methods include liquid absorption, waste encapsulation, cementitious bonding of waste and stabilization material, or chemical interaction with key contaminant drivers for risk through the groundwater pathway.

2. Long Term Structure and Infiltration Control – Criteria regarding a material's ability to provide structural integrity to the tank and in-tank equipment. This criterion also factors in infiltration control of moisture or other potential contaminants with respect to the structural layer material.

3. ESH&Q requirements and ALARA - Qualitative criteria of topics such as overall worker safety, dose rates to worker over the life cycle, risk of spills to the environment, releases to the air, risk of damage to tank wall, material at risk, recovery time, and minimizing impacts to the facility authorization basis (AB). Generally, all regulatory elements were included within this criteria.

4. Schedule Risk - Implementation of the tank closures must support the project closure milestone dates.

5. Operations - This encompasses ease of operator use, deployment, and set up, compatibility with existing systems and equipment, and the ability to stabilize a wide range of waste types. This includes minimizing infrastructure modification.

6. Life-Cycle Costs - Rough Order of Magnitude (ROM) cost comparisons including project capital costs, operating and maintenance costs, and demobilization costs.

7. Reversibility – This concerns the ability of a material to facilitate removal if decisions on final tank farm closure preclude placement of subsequent lifts of tank structural fill material. This criterion only applies to the waste stabilization layer material.

8. Maximize Application to Future Closure Actions - This criterion addresses the relative ease of performance verification to use the closure method on other SST. This will enable the project to gain practical experience and recommend closure methods for future closures.

9. Performance Verification – This criterion addresses the relative ability of a particular type of structural or stabilization material to perform closure functions as identified in the Level 2

Specification (CHG 2002). This will be associated with Quality Assurance aspects needed to verify and document successful tank stabilization and structural layer application.

5.0 DECISION CRITERIA WEIGHTING

Each of the decision criteria identified above were weighted for importance. The weighting helps place more emphasis on those criteria that are more significant with respect to desired attributes. The weighting criteria were generally developed using the logic described below. However, the weighting factors were finalized by experienced experts during the evaluation group meeting, based on consideration of how each criteria would impact the overall safe and successful completion of the ATCD project.

- If the criteria influenced the ability to meet a commitment beyond the control of the U.S. Department of Energy (DOE), such as the ability to meet state and federal schedule agreements, the criteria was rated at the upper end of the scale.

- If the criteria was associated with a commitment to DOE and was in the control of the DOE, the criteria was rated in the medium range of the scale.

- Those criteria that could impact or influence the criteria weighted higher and possibly prevent those goals from being met were rated at the low end of the scale. Criteria that were internal goals of the Hanford contractor were also rated at the low end of the scale.

The weighting factors were then normalized (based on a percentage of the total points). Criteria relating to cost and long-term structure and infiltration control were determined not to apply for the stabilization layer alternatives for both tank C-106 and the C-200 series tanks and were, therefore, given a zero when calculating total points. As identified in section 4.0, long-term structure and infiltration control were not factors associated with the stabilization layer. Cost was determined to be a non-discriminate factor concerning the different alternatives for the stabilization layer as the costs between alternatives was insignificant. Criteria relating to limiting release of contaminants and reversibility were determined not to apply for the structural layer alternatives for both types of tanks and were, therefore, given a zero when calculating total points. As identified in section 4.0, limiting release of contaminants was not a factor associated with the structural fill layer. Also reversibility was not considered a factor for any option considered for the structural fill layer.

The results of the decision criteria weighting effort are shown in Table 5-1 for the stabilization layer and Table 5-2 for the structural layer.

Table 5-1. Stabilization Layer Criteria Weightings.

	Tank C-106		C-200 Series Tanks	
Attribute	Weighting	Normalized Weighting	Weighting	Normalized Weighting
Limit Release of Contaminants	10	26	10	26

Long Term Structure and Infiltration Control	8	0	8	0
ESH&Q and ALARA	7	18	7	18
Schedule Risk	6	16	6	16
Operations	5	13	5	13
Life-Cycle Costs	5	0	5	0
Reversibility	5	13	5	13
Maximize Application to Future Closures	2	5	2	5
Performance Verification	3	8	3	8
Total	**51**	100	**51**	100

Table 5-2. Structural Layer Criteria Weightings.

	Tank C-106		**C-200 Series Tanks**	
Attribute	**Weighting**	**Normalized Weighting**	**Weighting**	**Normalized Weighting**
Limit Release of Contaminants	10	0	10	0
Long Term Structure and Infiltration Control	8	22	8	22
ESH&Q and ALARA	7	19	7	19
Schedule Risk	6	17	6	17
Operations	5	14	5	14
Life-Cycle Costs	5	14	5	14
Reversibility	5	0	5	0
Maximize Application to Future Closures	2	6	2	6
Performance Verification	3	8	3	8
Total	**51**	100	**51**	100

6.0 ASSUMPTIONS

The following assumptions were identified during the process of establishing the requirements and decision criteria. These assumptions were important to the evaluation team because they establish a baseline for determining where information may be lacking or uncertain in quality.

1. Limited characterization will be available and, therefore, a wide range of residual waste characteristics and a wide variety of debris may be encountered.

2. The existing systems, structures, and components are usable or usable with minor modification. (Needs to be verified prior to completion of design.).

3. Ventilation will be required during closure actions because of off-gassing, over-pressurization, fume or dust control, etc. At the present time, active ventilation is not required by the AB for flammable gas or containment.

4. Twelve-inch risers are available in all the C-200 series tanks being considered for closure. An additional riser is also available for camera deployment.

5. The 42-in. man-ways on the C-200 series tanks are not considered a usable access to the tank.

6. The stabilization layer will be a minimum depth of 12-in.

7. The stabilization layer is not intended to stabilize waste on the tank walls.

8. It was assumed in WHC-SD-WM-ES-399, *Engineering Study of Tank-Structural Alternatives for Closure of Single-Shell Tanks* (WHC 1996), that a 42-in. diameter riser would be needed for the gravel structural fill option. However, it was assumed for the purposes of this evaluation that a commercial grade rock-thrower could be employed to adequately distribute a gravel type material through the existing tank C-106 central riser, even if the diameter of the central riser is not 42-in.

9. The structural layer will not be installed until all reversibility issues concerning tank stabilization layers are resolved with regulators.

10. See the individual cost estimate sheets for each option in Appendix B for the associated cost assumptions.

11. New activities will be authorized via closure plans. Some activities may need to be conducted under existing AB via Unreviewed Safety Question process. With the exception of schedule, AB impacts will be equal for all alternatives.

7.0 COST ESTIMATE BASIS

The approach to the cost data developed for each alternative was to identify a set of activities unique to each deliverable (cost discriminators) and establish, through utilization of previous data and other methods, a cost for each option for only those unique activities. There were a number of activities that will be essentially the same for all alternatives (utilities, fence removal, riser surveys, etc.). No attempt was made to develop a cost for these "common elements," as it was determined that those elements did not affect the selection of a preferred option.

In addition, certain cost discriminators were identified as subjective (such as "AB modifications, design, etc.") and derived, based on the relative complexity of the option, from similar activities cost data.

For the schedule considerations, a preliminary qualitative assessment of the probability of meeting the schedule was made (high, medium, low). This schedule assessment was then factored into the contingency budget.

The estimates were not intended to be a total job cost estimate, but rather a ROM estimate of selected activities to be used in comparing relative costs of various alternatives. Details on the costs that were considered as "discriminators," along with a summary sheet for all alternatives, are provided. The following were key factors in assimilating the cost estimates and related data:

Discriminator Costs

- Equipment/Material Procurement/Installation - Determined from input of previous studies, CHG/Battelle/ARES Experience, vender data, and Project W-320, *Tank 241-C-106 Sluicing* Project, actual costs (tank farm activities).

- Design - Factored percentage of installation costs and adjusted per the complexity of the alternative.

- AB Modifications - Factored as a small percentage of construction, noting that it was unclear what type of AB modifications will be required, but believing that they would be very similar for all closure activities.

- Operations Support (based on closure activities duration) - Calculated as typical support crew costs multiplied by the activity duration.

- Project Management/Other Support Costs - Factored as a percentage of installation costs and adjusted per the complexity of the alternative.

- Contingency - Contingency was calculated from all discriminator costs and adjusted for schedule risks and complexity of each alternative.

The following costs were not calculated since they were considered similar for all alternatives:

- Utilities/instrumentation,
- Disposal of Equipment,
- Escalation, and
- Pit Cleanup.

8.0 CLOSURE CONCEPTS

A total of three waste stabilization layer concepts and five structural fill layer concepts were identified as potential alternatives to be considered for use in tank C-106 and the C-200 series tanks. One alternative from each type of layer will be chosen as a preferred alternative. All alternatives for stabilization were determined to be structurally compatible with any of the structural fill layers. All of the concepts were expected to be able to address the requirements stated in section 3.0.

The identified alternatives for the stabilization and structural fill concepts are shown below. See Appendix C for figures associated with each of the alternatives.

Waste Stabilization Layer Alternatives

1. Grout – Case #1 - Two layers of grout would be placed in the bottom of each tank following retrieval. Chemical sequestering agents (getters) would be incorporated, as necessary/desired,

into the grout formulation to aid in immobilizing the residual waste constituents. The grout is expected to interact with the waste in one of two ways. Ideally, the residual waste (liquids and solids) would be displaced off the bottom of the tank and floated on top of the initial grout layer (high-density grout would be used). The second lift of grout would then be placed to fully encapsulate the waste (using a lower density grout).

2. Grout – Case #2 - If the solid fraction of the residual waste is strongly adhered to the bottom of the tank, then the initial grout layer (high-density grout) may displace and encapsulate the liquid only fraction. Incorporation of the liquid waste was significant in that the liquid fraction would contain the highest concentration of the mobile constituents.

3. Granular Layer - A granular layer would be placed in the bottom of the tank following retrieval. The granular material may consist of sand, gravel, dry bentonite, and/or absorbent zeolite material. The purpose of the aggregate material would be to wick and contain the liquid fraction of the residual waste. Zeolites incorporate the added benefit of providing selective ion exchange (i.e., immobilization) for certain constituents (e.g., Sr-90, Cs-137, etc.). Use of dry bentonite (or similar swelling clay material) would create a low permeability capping layer physically incorporating the liquid waste fraction and effectively capping the solid fraction. Coarser aggregate material could be added to increase the structural performance of the bentonite layer.

Tank Structural Fill Alternatives

1. Gravel – The tank would be filled with crushed aggregate.

2. Concrete – The tank would be filled with concrete installed in lifts.

3. Hybrid (rounded aggregate injected with grout) – The tank would be filled with rounded aggregate and then injected with a highly flowable grout to structural the interstitial void spaces.

4. Grout – The tank would be filled with flowable, self-leveling grout installed in lifts. Chemical sequestering agents (e.g., hydroxy-apatite) could be added to provide additional waste stabilization properties.

5. Multi-Layered Grout With Seal (asphalt or clay) – The tank would be filled with grout installed in lifts. Near the top of the tank, a low permeability, high elastic sealing layer of asphalt or clay would be installed to arrest crack development and improve hydraulic performance. A similar multi-layer approach was evaluated in SAND98-2445, *Stabilization of In-Tank Residual Wastes and External-Tank Soil Contamination for the Hanford Tank Closure Program: Application to the AX Tank Farm* (Sandia 1998).

9.0 CLOSURE ALTERNATIVES EVALUATION

In advance of conducting the alternatives evaluation, the Level 2 Specification (CHG 2002) and other ATCD project documentation were reviewed. The key points listed below were taken from that review.

- The approach is to close the tanks farms to the *Washington State Hazardous Waste Management Act Dangerous Waste Regulations* (WAC 173-303) landfill standards and *Radioactive Waste Management* (DOE Order 435.1) low-level radioactive waste standards.

- As a result of the kick-off meeting held on August 20, 2002, all of the closure alternatives identified in section 8.0 were all judged to be capable of addressing the requirements referenced in Appendix A.

- The retrieval goal for the ATCD will be 360 cu ft or less residual waste in tank C-106 and 30 cu ft or less in the C-200 series tanks.

- After waste retrieval activities are complete, residual waste volumes and inventories will be quantified and assessed from a risk-based perspective. If the residual waste is determined to present minimal, acceptable long-term risk, and concurrence from regulatory agencies is given, then in-situ closure of the tanks will be initiated.

- Tank C-106 is a dish-bottom tank, and the differntial height between the center and the outer edge is 12-in.

Closure System Evaluation

The closure alternatives evaluation was conducted on August 27, 2002, with a team knowledgeable and familiar with SST farm operations, ESH&Q requirements, closure method alternatives, and closure issues and requirements. Appendix D identifies the attendees. Each closure alternative was evaluated against the decision criteria and scored as a high, medium, or low according to the scoring guidelines provided in Appendix E. The team members were then asked to determine a numerical score based upon whether the alternatives were considered to be at the high end or the low end of the range selected. For example, if an option was determined to be a strong candidate in the medium category, it might be scored with 50 to 60 points (high-end of medium). Several of the criteria were determined to either not apply to various alternatives or to be non-discriminate factors, as discussed in section 5.0.

The results of the evaluations are shown in Table 9-1. Following are the key points brought out during the evaluations, along with evaluation rationale:

Evaluation Rationale

- The closure alternatives evaluation was performed independent of possible benefits from retrieval technology.

- Limit Release of Contaminants – In both tank C-106 and the C-200 series tanks, the scoring values were the same. As discussed in section 5.0, this criterion only applied to the stabilization layer alternatives. The grout alternatives scored higher than the granular alternative due to uncertainty (lack of data) concerning the performance of different types of granular material (bentonite, zeolite, etc.) with respect to tank applications. Grout Case 1 scored slightly higher

than Grout Case 2 because it fully encapsulated both liquid and solid waste and was a proven tank stabilization method, implemented at other DOE Sites for tank closure activities.

- Long-Term Structure and Infiltration Control – In both tank C-106 and the C-200 series tanks, the scoring values were the same. As discussed in section 5.0, this criterion only applies to the structural fill layer alternatives. All of the alternatives, with the exception of gravel, received similar scoring due to common material characteristics. The alternative consisting of multi-layered grout with seal scored the highest because it provided the best infiltration control and long-term structural stability for a minimum of one thousand years.

- ESH&Q and ALARA - In both tank C-106 and the C-200 series tanks, the scoring values were the same. For the stabilization layer, Grout Case 2 scored the highest due to ALARA considerations and a fairly high potential for regulatory acceptance as an adequate "treatment" with respect to LDR [i.e., granular materials in any configuration have not been used in waste preparation for LDR. Conversely, grout materials in two-layer configurations (Grout Case 1) have been accepted]. Grout and concrete received the highest scores for the structural layer because they provide equal long-term structural stability, ALARA considerations, and long-term environmental compliance.

- Schedule – None of the alternatives were considered 100 percent certain to meet the scheduled retrieval completion dates and hence the highest score was 85 points. However, it could not be concluded that the schedule would not be met by any of the alternatives; therefore, even alternatives considered to be poor in their ability to meet schedule were given some points. Factors that resulted in lower scores included:
  - Equipment, systems, and materials that require design further extends the concern about ability to meet schedule, and
  - Magnitude of AB impacts (time required to process AB change or deviation).

Tank 241-C-106		Limit Release of Contaminants	Long Term Structure & Infiltration Control	ESH&Q ALARA	Schedule Risk	Operations	Life-Cycle Cost	Reversibility	Maximized Future Use	Performance Verification	Total Raw Score	Total Weighted Score
		WF = 10 (26%)	WF = 8 (0%)	WF = 7 (18%)	WF = 6 (16%)	WF = 5 (13%)	WF = 5 (0%)	WF = 5 (13%)	WF = 2 (5%)	WF = 3 (8%)		
Stabilization Layer	Grout Case #1	75 / 19.7	n/a	60 / 11.1	30 / 4.7	35 / 4.6	n/a	30 / 3.9	40 / 2.1	20 / 1.6	155	47.8
	Grout Case #2	70 / 18.4	n/a	70 / 12.9	85 / 13.4	70 / 9.2	n/a	30 / 3.9	50 / 2.6	80 / 6.3	315	66.8
	Granular Layer	60 / 15.8	n/a	40 / 7.4	60 / 9.5	50 / 6.6	n/a	60 / 7.9	40 / 2.1	60 / 4.7	270	53.9
		WF = 10 (0%)	WF = 8 (22%)	WF = 7 (19%)	WF = 6 (17%)	WF = 5 (14%)	WF = 5 (14%)	WF = 5 (0%)	WF = 2 (6%)	WF = 3 (8%)		
Structural Fill Layer	Gravel	n/a	30 / 6.7	40 / 7.8	50 / 8.3	30 / 4.2	75 / 10.4	n/a	40 / 2.2	50 / 4.2	245	43.8
	Concrete	n/a	50 / 11.1	70 / 13.6	65 / 10.8	60 / 8.3	100 / 13.9	n/a	50 / 2.8	70 / 5.8	345	66.4
	Hybrid (Grout/Aggregate)	n/a	50 / 11.1	50 / 9.7	35 / 5.8	25 / 3.5	70 / 9.7	n/a	40 / 2.2	50 / 4.2	220	46.3
	Grout	n/a	50 / 11.1	70 / 13.6	65 / 10.8	70 / 9.7	100 / 13.9	n/a	50 / 2.8	80 / 6.7	365	68.6
	Multi-Layered Grout with Seal	n/a	60 / 13.3	40 / 7.8	25 / 4.2	15 / 2.1	65 / 9.0	n/a	40 / 2.2	40 / 3.3	185	41.9

200 Series Tanks		Limit Release of Contaminants	Long Term Structure & Infiltration Control	ESH&Q ALARA	Schedule Risk	Operations	Life-Cycle Cost	Reversibility	Maximized Future Use	Performance Verification	Total Raw Score	Total Weighted Score
		WF = 10 (26%)	WF = 8 (0%)	WF = 7 (18%)	WF = 6 (16%)	WF = 5 (13%)	WF = 5 (0%)	WF = 5 (13%)	WF = 2 (5%)	WF = 3 (8%)		
Stabilization Layer	Grout Case #1	75 / 19.7	n/a	60 / 11.1	30 / 4.7	50 / 6.6	n/a	50 / 6.6	40 / 2.1	20 / 1.6	190	52.4
	Grout Case #2	70 / 18.4	n/a	70 / 12.9	85 / 13.4	70 / 9.2	n/a	50 / 6.6	50 / 2.6	80 / 6.3	335	69.5
	Granular Layer	60 / 15.8	n/a	40 / 7.4	55 / 8.7	60 / 7.9	n/a	60 / 7.9	50 / 2.6	60 / 4.7	285	55.0
		WF = 10 (0%)	WF = 8 (22%)	WF = 7 (19%)	WF = 6 (17%)	WF = 5 (14%)	WF = 5 (14%)	WF = 5 (0%)	WF = 2 (6%)	WF = 3 (8%)		
Structural Fill Layer	Gravel	n/a	30 / 6.7	40 / 7.8	50 / 8.3	30 / 4.2	80 / 11.1	n/a	40 / 2.2	50 / 4.2	250	44.4
	Concrete	n/a	50 / 11.1	70 / 13.6	65 / 10.8	60 / 8.3	100 / 13.9	n/a	50 / 2.8	70 / 5.8	345	66.4
	Hybrid (Grout/Aggregate)	n/a	50 / 11.1	50 / 9.7	35 / 5.8	25 / 3.5	85 / 11.8	n/a	40 / 2.2	50 / 4.2	235	48.3
	Grout	n/a	50 / 11.1	70 / 13.6	65 / 10.8	70 / 9.7	95 / 13.2	n/a	50 / 2.8	80 / 6.7	360	67.9
	Multi-Layered Grout with Seal	n/a	60 / 13.3	40 / 7.8	25 / 4.2	15 / 2.1	65 / 9.0	n/a	40 / 2.2	40 / 3.3	185	41.9

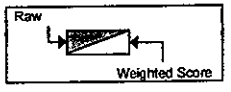

Table 9-1. Raw and Weighted Scores for ATCD Alternatives.

Factors that positively affected scores included:

- Equipment, systems and materials are available on-site or are easily obtainable,
- Equipment that has been designed and built before,
- Systems that are covered by the AB or easily incorporated, and
- Proven methods (i.e., grout had been used for waste stabilization at other DOE Sites).

- Operations – In both tank C-106 and the C-200 series tanks, the scoring values for the structural fill layer were the same. The scoring values were different for the stabilization layers due to the size differences between the tanks. Grout Case 2 scored the highest for the stabilization layer for both types of tanks as it would be the easiest alternative to install. Grout scored the highest for the structural fill layer for the same reason.

- Cost Rankings - Cost rankings are relative with the lowest cost alternative rating 100 points and the more expensive alternatives scoring progressively lower. The life-cycle costs were developed in advance of the meeting and supplied as background information to the evaluation team. These cost projections are shown in Appendix B.

- Reversibility – The scoring values were different due to size differences between the tanks and the amount of material needed for stabilization. As discussed in section 5.0, this criteria only applies to stabilization layer alternatives. The granular alternative received the highest score because granular material would be the easiest to remove (either not adhered to tank at all or adhered to tank at a very low strength).

- Maximized Future Use – In both tank C-106 and the C-200 series tanks, the scoring values were virtually the same. All of the alternatives were determined to be moderately likely to be useful for future tank closures, as is the scoring guidance in Appendix E. Grout Case 2 scored the highest for the C-106 tank and was tied with the granular layer for the C-200 series tanks for the stabilization layer. Grout and concrete scored the highest for the structural fill layer for both sizes of tanks.

- Performance Verification - In both tank C-106 and the C-200 series tanks, the scoring values were the same. Grout Case 2 received the highest score for the stabilization layer as it could be easily verified through standard procedures and techniques. Grout received the highest score for the structural fill layer because it could be easily verified through standard procedures and techniques, much the same as the stabilization layer.

10.0 CONCLUSIONS

The evaluation of closure methods for both tank C-106 and C-200 series tanks yielded the following results:

- For the stabilization fill layer, Grout Case 2 scored the highest, with the granular layer rating second highest.
- For the structural fill layer, grout scored the highest, with concrete being a close second.

The strengths of Grout Case 2 for the stabilization layer are listed below.

- It scored well against all decision criteria except reversibility.
- Although it is not a proven tank stabilization method, it is likely that the solid fraction of the residual waste is strongly adhered to the tank and that one initial grout layer would both fix the solid fraction and displace/encapsulate the residual liquid fraction.
- It is expected to meet schedule goals.

The other alternatives scored significantly below the Grout Case 2 option, with the granular layer coming in second with a score that was approximately 13 percent lower for tank C-106 and 15 percent lower for the C-200 series tanks.

The strengths of grout for the structural fill layer were:

- It scored well against all decision criteria,
- It is a proven tank fill technology that has been implemented at other DOE Sites for tank closure activities,
- It has low life-cycle costs relative to most of the other methods, and
- It is expected to meet schedule goals.

The concrete alternative was second to grout by only 2.2 percent for tank C-106 and 1.5 percent for the C-200 series tanks. It is not surprising that the two scored closely since they are essentially the same with the exception of the size of aggregate used in the mix. Both concepts could be considered for the closure of all five tanks. The infrastructure needed to support either system will be very similar if not the same.

With the exceptions noted above, the resulting scores were distributed over a large band. The large spread in scores indicates that a sensitivity analysis of the results will not influence the outcome of the recommendations. Both the raw scores and the weighted scores support this conclusion.

11.0 REFERENCES

CHG 2002, *Tank Closure Structural System for the Accelerated Tank Closure Demonstration Level 2 Specification*, RPP-11094, Revision 0, CH2M Hill Hanford Group, Inc., Richland, Washington.

DOE Order 435.1, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C.

Sandia 1998, *Stabilization of In-Tank Residual Wastes and External-Tank Soil Contamination for the Hanford Tank Closure Program: Application to the AX Tank Farm*, SAND98-2445, Sandia National Laboratories, Albuquerque, New Mexico.

WAC 173-303, *Washington State Hazardous Waste Management Act Dangerous Waste Regulation*, State of Washington, Olympia, Washington.

WHC 1996, *Engineering Study of Tank-Structural Alternatives for Closure of Single-Shell Tanks*, WHC-SD-WM-ES-399, Revision 0, Westinghouse Hanford Company, Richland, Washington.

Attachment 4

Appendix A

Tank Closure Requirements Traceability

Taken From RPP-11094, Tank Closure Fill System For The Accelerated Tank Closure Demonstration Level 2 Specification

Section	Function/Requirement Title	Source Document(s)	Remarks
3.0	REQUIREMENTS	N/A	Header
3.1	SYSTEM DEFINITION (HFFACO modification M-45-00-01A Section M-45-00; WA780008967, Section II.J)		Background Information
3.1.1	Performance Objectives and Limitations	N/A	Header
3.1.1.1	WAC 173-303-610 Performance Objectives (DOE/ORP-2001-18, Rev. 0 (draft), Section 3.3.1)		--
3.1.1.2	DOE-M-435.1-1 Performance Objectives (DOE/ORP-2001-18, Rev. 0 (draft), Section 6.5)		--
3.1.1.3	10 CFR 61 Performance Objectives	DOE/ORP-2001-18, Rev 0 (draft), section 3.4.4	--
3.1.1.4	10 CFR 830 Performance Objectives	HNF-IP-0842, Volume 4, Section 5.3, Rev. 13n	Section requested by Nuclear Safety and Licensing
3.1.1.2	Performance Limitations	40 CFR 1021.211; 40 CFR 1506.1	--
3.1.2	Waste Heel Stabilization Material	N/A	Header
3.1.2.1	Function	Engineering Direction	--
3.1.2.2	Structural Properties	Engineering Direction	--
3.1.2.3	Retrievability	Engineering Direction	--
3.1.3	Tank Fill Material	N/A	Header
3.1.3.1	Fill Material	Engineering Directive	General criteria from DOE/ORP-2001-18, Rev. 0 (draft), Section 6.7.1
3.1.3.2	Fill Characteristics	Engineering Directive	General criteria from DOE/ORP-2001-18, Rev. – (draft), Section 6.0 and WHC-SD-WM-CSD-003, Rev.0
3.1.3.3	Fill Stability	Engineering Directive	--
3.1.4	Tank Fill Process	Bullets 1-5, DOE/ORP-2001-18, Rev. 0 (draft), Section 6.0; bullet 7, WSRC-TR-2001-00359, Rev. 0 draft; all other bullets, Engineering Directive	--
3.1.5	Tank Air Filtration System	DOE/ORP-2001-18,	--

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Taken From RPP-11094, Tank Closure Fill System For The Accelerated Tank Closure Demonstration Level 2 Specification

Section	Function/Requirement Title	Source Document(s)	Remarks
		Rev. 0 (draft), Section 6.7.1	
3.1.6	Ancillary Equipment	Engineering Directive	--
3.1.7	Post-Closure Performance Evaluation	RPP-10525, Rev. 0, Section 8.6	--
3.1.8	Tank Farm Interfaces	N/A	Header
3.1.8.1	Functional Interfaces	N/A	General lead-in
3.1.8.1.a	SST Electrical Power System	RPP-8144, Rev. 1, Section 3.1.2.1	--
3.1.8.1.b	SST Raw Water	RPP-8144, Rev. 1, Section 3.1.2.1	--
3.1.8.1.c	SST Service Air System	RPP-8144, Rev. 1, Section 3.1.2.1	--
3.1.8.2	Physical Interfaces	H-2-73338, H-2-73346, H-2-73352, H-2-73353, H-2-73354, H-2-73355	--
3.1.9	Government Furnished Property Lists	N/A	--
3.1.10	Government Loaned Property Lists	N/A	--
3.2	CHARACTERISTICS	N/A	General lead-in
3.2.1	Performance Characteristics	N/A	Header
3.2.1.1	Control Tank Structure Temperature	OSD-T-151-00013, Section 13.2.1.E; HNF-4712, Rev. 0; HNF-SD-RE-TI-035, Rev. 1	These are tank design limits
3.2.1.2	Control Tank Level	Engineering Directive; OSD-T-T-151-00013, Section 13.2.1.B; HNF-4712, Rev. 0, HNF-4047	--
3.2.1.3	Control Vapor Space Pressure	OSD-T-T-151-00013, Section 13.2.1.F; HNF-4712, Rev. 0;	--
3.2.1.4	Control Gaseous Discharges	OSD-T-T-151-00013, Section 13.2.2	Refer to report sections 3.3.6.3.b, c and d for control limits
3.2.2	Physical Characteristics	N/A	Header

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Taken From RPP-11094, Tank Closure Fill System For The Accelerated Tank Closure Demonstration Level 2 Specification

Section	Function/Requirement Title	Source Document(s)	Remarks
3.2.2.1	Dome Loading Controls	HNF-4712, Rev. 0; HNF-IP-1266, Section 5.16, Rev. 4; OSD-T0151-00013, Section 13.2.1.C; SD-WM-SAR-067; SD-WM-TSR-006, Section AC-5.16	--
3.2.2.2	Axial Loads	N/A	Header
3.2.2.2a	Axial Loads, 4-inch Tank Risers	SD-W320-ANAL-003	Riser load limits based on Project W320
3.2.2.2b	Axial Loads, 12-inch and Larger Risers	SD-W320-ANAL-003	Riser load limits based on Project W320
3.2.2.2c	Axial Load on Tank Bottom	SD-W320-ANAL-003	Riser load limits based on Project W320
3.2.3	Reliability	N/A	Header
3.2.3.1	Component Selection	Good Engineering Practice	--
3.2.3.2	Overall Reliability/Availability	Project Directive	--
3.2.3.3	Operational Life	Project Directive	--
3.2.3.4	Design Life	N/A	Header
3.2.3.4.a	In-Tank/In-Pit Design Life	Initial design life based on RPP-8144 (C-104) Level 2 Specification	Design life to eliminate the need for maintenance (incorporating ALARA principles)
3.2.3.4.b	Above grade System/Components	Initial design life based on RPP-8144 (C-104_ Level Specification	Five year design life is based on an operational life to complete filling of the five selected tanks
3.2.3.5	Design Qualification	HNF-2919, Rev. 2	--
3.2.4	Environmental Conditions	N/A	Header
3.2.4.1	Natural Environments	N/A	Header
3.2.4.1.a	Natural Environments	HNF-IP-0842, Vol. 4, Section 3.14, Rev. 1a; HNF-SD-GN-ER-501, Rev. 1A	--
3.2.4.1.b	Natural Phenomena Hazards	HNF-IP-0842, Vol. 4, Section 3.14, Rev. 1a	--
3.2.4.2	Induced Environments	N/A	Header
3.2.4.2.a	Chemical	HNF-SD-WM-SP-012, Appendix B, Rev. 3	--
3.2.4.2.b	Radiation	Good Engineering	--

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Taken From RPP-11094, Tank Closure Fill System For The Accelerated Tank Closure Demonstration Level 2 Specification

Section	Function/Requirement Title	Source Document(s)	Remarks
		Practice	
3.2.4.3	Residual In-Tank Waste	N/A	Header
3.2.4.3.a	Residual Waste Quantities	M-45-00-01A, Milestone M-45-00	--
3.2.4.3.b	Residual Waste Inventory	Best-Basis Inventory	--
3.2.5	Transportability	Good Engineering Practice	--
3.2.6	Flexibility and Expansion	Good Engineering Practice	--
3.3	DESIGN AND CONSTRUCTION	N/A	Header
3.3.1	Materials and Design Practices		Header
3.3.1.1	Toxic Products and Formulations		Header
3.3.1.1.a	Lead	HNF-2919, Rev. 2; HNF-IP-0842, Volume 9, Section 4.24, Rev.0	Implements 29 CFR 1910.1025 (operations) and 29 CFR 1926.62 (construction)
3.3.1.1.b	Toxic Substance Control Act	HNF-2919, Rev. 2; HNF-IP-0842, Volume 6, Section 2.6, Rev. 0	Implements 40 CFR, Subchapter R
3.3.1.1.c	Ozone-Depleting Substances	HNF-2919, Rev. 2	--
3.3.1.2	Decontamination and Decommissioning	HNF-2919, Rev. 2; HNF-3912, Rev. 0	--
3.3.2	Electromagnetic Radiation	HNF-2919, Rev. 2; HNF-2962, Rev. 0	--
3.3.3	Nameplates, Product Markings, and Labels	HNF-2919, Rev. 2; HNF-IP-0842, Vol. 2, Section 6.1, Rev. 1	--
3.3.4	Workmanship	Good Engineering Practice	Establishes responsibility for workmanship call-outs on design media
3.3.5	Equipment Standardization	Good Engineering Practice	--
3.3.6	Safety	HNF-2919, Rev. 2; HNF-MP-003, Rev. 3	--
3.3.6.1	Personnel Safety	N/A	Header/Lead-in
3.3.6.1.a	Occupational Radiological Protection	HNF-2919, Rev. 2; 10 CFR 835	--
3.3.6.1.b	Occupational Safety and Health	HNF-2919, Rev. 2; HNF-3912,	--

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Taken From RPP-11094, Tank Closure Fill System For The Accelerated Tank Closure Demonstration Level 2 Specification

Section	Function/Requirement Title	Source Document(s)	Remarks
		Rev. 0	
3.3.6.2	Equipment Protection	N/A	Header/Lead-in
3.3.6.2.a	Materials and Design	HNF-2919, Rev. 2	--
3.3.6.2.b	Fire Protection	HNF-2919, Rev. 2; HNF-IP-0842, Vol. 9, Section 5.2, Rev. 0c	--
3.3.6.3	Environmental Safety	N/A	Header/Lead-in
3.3.6.3.a	Spill Prevention and Controls	HNF-2919, Rev. 2	--
3.3.6.3.b	Non-Radioactive Airborne Emissions	HNF-2919, Rev. 2; HNF-IP-0842, Volume 6, Section 1.8	--
3.3.6.3.c	Radioactive Airborne Emissions	HNF-2919, Rev. 2; HNF-IP-0842, Volume 6, Section 1.7	--
3.3.6.3.d	Radiation Protection of the Public and Environment	HNF-2919, Rev. 2	--
3.3.6.3.e	Monitoring of Liquid Effluent Discharges to the Environment	HNF-2919, Rev. 2	--
3.3.6.3.f	Flammable Gas Design Requirements	HNF-3912, Rev. 0; HNF-4047, Rev. 0	--
3.3.7	Human Performance/Human Engineering	Project Directive	Human Engineering in this context primarily deals with designing a system analyzed for, and protected from, operator error
3.3.8	Nuclear Safety	N/A	Header
3.3.8.1	Safety Basis Requirements	HNF-SD-WM-TSR-006; HNF-IP-1266	Based on input from Nuclear Safety and Licensing
3.3.8.2	Nuclear Safety Classification	HNF-2919, Rev. 2; HNF-IP-0842, Vol. 4, Sections 6.9 (Rev. 1a), 6.10 (Rev. 0), 6.11 (Rev. 0), and 6.12, Rev. 0b; HNF-SD-WM-SAR-067, Section 3, Rev. 3-B; RPP-DI-ENG-002, Rev. 0	Based on input from Nuclear Safety and Licensing. Quality assurance required reference to RPP-DI-ENG-002
3.4	DOCUMENTATION	N/A	Header
3.4.1	Engineering Documents	HNF-PRO-222, Rev. 2;	HNF-PRO-222 is a Category

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Taken From RPP-11094, Tank Closure Fill System For The Accelerated Tank Closure Demonstration Level 2 Specification

Section	Function/Requirement Title	Source Document(s)	Remarks
		HNF-IP-0842, Vol. 4, Section 3.5, Rev. 2a	3 procedure adopted by CHG
3.4.2	Master Equipment List	RPP-MP-606, Rev. 3c; HNF-IP-0842, Volume 5, Section 7.3	--
3.5	LOGISTICS	N/A	Header
3.5.1	Maintenance and Operation	N/A	Header
3.5.1.1	Work Activities	RPP-10525, Section 2.4.3, Rev. 0	--
3.5.1.2	Operation	Good Engineering Practice	--
3.5.2	Spares	Good Engineering Practice	Spare parts control requested by quality assurance
3.5.3	Solid Waste	HNF-2919, Rev. 0; HNF-IP-0842, Vol. 18, Section 2.0 procedures	Radioactive waste is not included in this category
3.6	PERSONNEL AND TRAINING	HNF-2919, Rev. 0; HNF-IP-0842, Vol. 3, Section 10	--
3.7	CHARACTERISTICS OF SUBELEMENTS	N/A	Descriptive section only
3.8	PRECEDENCE	HNF-3912, Rev. 0	--
3.9	SECURITY	HNF-5183, Rev. 1a	--
3.9.1	General System and Information Security	HNF-2919, Rev. 0;	--
3.9.2	Radiation Area Security	HNF-2919, Rev. 0;	--
3.10	COMPUTER RESOURCE RESERVE CAPACITY	N/A	Not applicable to the accelerated closure project

Attachment 4

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Attachment 4

Appendix B

Life-Cycle Cost Data

C-106 TANK - ALTERNATIVE 1 - "GRAVEL" TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 1 - GRAVEL																				
Structual Fill - "Gravel" Crushed or Pea Gravel"		90,000	-	-	-	90,000	-	-		CONTR	4,500.0	CYD	-	-		-	-	20.00	-	-
Stabilization fill - 3'		20,000	-	-	-	20,000	-	-		CONTR	500.0	CYD	-	-		-	-	40.00	-	-
Clearance of 36" Riser		450,000	-	300,000	-	-	-	150,000		CONTR	1.0	EA	-	-		-	-	-	-	-
Placement System/Movement of Pipe for Risers(FRONT END LOADER,METERING HOPPER,PIPING,ROCKSLINGER,CONVEYOR)		449,429	7,680	308,429	-	15,000	-	126,000		CONTR	1.0	EA	7,680.0	7,680		40.16	-	15,000.00	-	126,000
Demob / Disposal Placement System		14,096	240	11,786	-	-	-	2,310		CONTR	1.0	EA	240.0	240		49.11	-	-	-	2,310
Grout fill alternative add exhauster		300,000	-	-	-	-	-	300,000		CONTR	1.0	EA	-	-		-	-	-	-	300,000
CONTR		*1,323,525*	*7,920*	*620,215*	-	*125,000*	-	*578,310*												
BASE COST SUBTOTAL		*1,323,525*	*7,920*	620,215	-	125,000	-	578,310						7,920	-					
CONSUMABLES	4.0%	24,809	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	18,606	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	31,011	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	24,809	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	12,434	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		111,669																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		1,435,194																		
ENGINEERING DESIGN	15.0%	215,279	*ESTIMATE SUBTOTAL * 0.15*																	
ENGINEERING CONST SUPPORT	17.0%	243,983	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	358,799	*ESTIMATE SUBTOTAL * 0.25*																	
ESTIMATE SUBTOTAL		2,253,255																		
SITE ALLOCATIONS	14.4%	206,668	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		2,459,923																		
WORK PACKAGE PREPARATION	17.0%	243,983	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS SUPPORT DURING INSTALLATION (No. of Weeks)	32	320,000	*$10K / WK * # OF Weeks*																	
A/B COSTS	3.0%	90,717	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		3,114,623																		
CONTINGENCY	25.0%	778,656	*OPC's SUBTOTAL * 0.25*																	
GRAND TOTAL		*3,893,279*																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 200'.

3) Placement of material is assumed to be at 32 cubic yards per day.

4) The Authorization Basis (A/B) cost markup is 3% for all activities.

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that C-106 tank will have a 3' layer of stabilization installed in the bottom of the tank.

8) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included.

C-106 TANK - ALTERNATIVE 2 - "CONCRETE" TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 1 - CONCRETE																				
Structual Fill - "Concrete"		405,000	-	-	-	405,000	-	-		CONTR	4,500.0	CYD	-	-		-	-	90.00	-	-
Stabilization fill - 3'		20,000	-	-	-	20,000	-	-		CONTR	500.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement (Pipe,fabbed univeral joint pipe,Pumper Truck,)		211,739	4,032	178,739	-	15,000	-	18,000		CONTR	1.0	EA	4,032.0	4,032		44.33	-	15,000.00	-	18,000
Demob / Disposal Placement System		14,096	240	11,786	-	-	-	2,310		CONTR	1.0	EA	240.0	240		49.11	-	-	-	2,310
Grout fill alternative add exhauster		300,000	-	-	-	-	-	300,000		CONTR	1.0	EA	-	-		-	-	-	-	300,000
CONTR		*950,835*	*4,272*	*190,525*	-	*440,000*	-	*320,310*												
BASE COST SUBTOTAL		*950,835*	*4,272*	190,525	-	440,000	-	320,310						4,272	-					
CONSUMABLES	4.0%	7,621	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	5,716	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	9,526	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	7,621	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	37,153	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		67,637																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		1,018,472																		
ENGINEERING DESIGN	15.0%	152,771	*ESTIMATE SUBTOTAL * 0.15*																	
ENGINEERING CONST SUPPORT	17.0%	173,140	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	254,618	*ESTIMATE SUBTOTAL * 0.25*																	
ESTIMATE SUBTOTAL		1,599,001																		
SITE ALLOCATIONS	14.4%	146,660	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		1,745,661																		
WORK PACKAGE PREPARATION	17.0%	173,140	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS SUPPORT DURING INSTALLATION (No. of Weeks)	12	120,000	*$10K / WK * # OF Weeks*																	
OPERATIONS SUPPORT DURING CURING (No. of Weeks)	22	77,000	*$3.5K / WK * # OF Weeks*																	
A/B COSTS	3.0%	61,164	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		2,176,965																		
CONTINGENCY	35.0%	761,938	*OPC's SUBTOTAL * 0.35*																	
GRAND TOTAL		*2,938,903*																		

Assumptions / Factors

1) *Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material.* A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 200'.

3) Placement of material is assumed to be at 60 cubic yards per day.

4) The Authorization Basis (A/B) cost markup is 3% for all activities.

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that C-106 tank will have a 3' layer of stabilization installed in the bottom of the tank.

8) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

9) Assume 1/3 for Operations support for instrumentation and exhauster for cure time.

Note: Grout and concrete construction increased due to long schedule impacts.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included.

C-106 TANK - ALTERNATIVE 3 - "HYBRID" TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 1 - HYBRID																				
Structual Fill - "ROUND AGGREGATE"		70,000	-	-	-	70,000	-	-		CONTR	3,500.0	CYD	-	-		-	-	20.00	-	-
Structual Fill - "GROUT"		100,000	-	-	-	100,000	-	-		CONTR	1,000.0	CYD	-	-		-	-	100.00	-	-
Clearance of 36" Riser		450,000	-	300,000	-	-	-	150,000		CONTR	1.0	EA	-	-		-	-	-	-	-
Stabilization fill - 3'		20,000	-	-	-	20,000	-	-		CONTR	500.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement of Pipe for Risers(FRONT END LOADER,CONVEYOR,PUMP TRUCKMETERING HOPPER,PIPING,ROCKSLINGER)		401,164	6,528	262,164	-	15,000	-	124,000		CONTR	1.0	EA	6,528.0	6,528		40.16	-	15,000.00	-	124,000
Demob / Disposal Placement System		14,096	240	11,786	-	-	-	2,310		CONTR	1.0	EA	240.0	240		49.11	-	-	-	2,310
Grout fill alternative add exhauster		300,000	-	-	-	-	-	300,000		CONTR	1.0	EA	-	-		-	-	-	-	300,000
CONTR		*1,355,260*	*6,768*	*573,950*	-	*205,000*	-	*576,310*												
BASE COST SUBTOTAL		*1,355,260*	*6,768*	573,950	-	205,000	-	576,310						6,768	-					
CONSUMABLES	4.0%	22,958	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	17,219	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	28,698	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	22,958	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	18,921	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		110,754																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		1,466,014																		
ENGINEERING DESIGN	15.0%	219,902	*ESTIMATE SUBTOTAL * 0.15*																	
ENGINEERING CONST SUPPORT	17.0%	249,222	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	366,504	*ESTIMATE SUBTOTAL * 0.25*																	
ESTIMATE SUBTOTAL		2,301,642																		
SITE ALLOCATIONS	14.4%	211,106	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		2,512,748																		
WORK PACKAGE PREPARATION	17.0%	249,222	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS SUPPORT DURING INSTALLATION (No. of Weeks)	17	170,000	*$10K / WK * # OF WEEKS*																	
OPERATIONS SUPPORT DURING CURING (No. of Weeks)	5	17,500	*$3.5K / WK * # OF WEEKS*																	
A/B COSTS	3.0%	87,959	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		3,037,429																		
CONTINGENCY	30.0%	911,229	*OPC's SUBTOTAL * 0.3*																	
GRAND TOTAL		*3,948,658*																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 200'.

3) Placement of material is assumed to be at 60 cubic yards per day for rock and 32 cyd for grout.

4) The Authorization Basis (A/B) cost markup is 3% for all activities.

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that C-106 tank will have a 3' layer of stabilization installed in the bottom of the tank.

8) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

9) Assume 1/3 for Operations support for instrumentation and exhauster for cure time.

Note: Grout and concrete construction increased due to long schedule impacts.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included.

C-106 TANK - ALTERNATIVE 4 - "GROUT W/ CLAY SEALING LAYER TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 4 - GROUT W/ CLAY SEALING LAYER																				
Structual Fill - "GROUT"		366,000	-	-	-	366,000	-	-		CONTR	3,660.0	CYD	-	-		-	-	100.00	-	-
Structual Fill - "CLAY"		33,600	-	-	-	33,600	-	-		CONTR	840.0	CYD	-	-		-	-	40.00	-	-
Stabilization fill - 3'		20,000	-	-	-	20,000	-	-		CONTR	500.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement of Pipe for Risers(FRONT END LOADER,CONVEYOR,PUMP TRUCK,METERING HOPPER,PIPING,UNIVERSAL JOINT PIPE)		324,057	4,608	185,057	-	15,000	-	124,000		CONTR	1.0	EA	4,608.0	4,608		40.16	-	15,000.00	-	124,000
Demob / Disposal Placement System		14,096	240	11,786	-	-	-	2,310		CONTR	1.0	EA	240.0	240		49.11	-	-	-	2,310
Grout fill alternative add exhauster		600,000	-	-	-	-	-	600,000		CONTR	1.0	EA	-	-		-	-	-	-	600,000
CONTR		*1,357,753*	*4,848*	*196,843*	-	*434,600*	-	*726,310*												
BASE COST SUBTOTAL		*1,357,753*	*4,848*	196,843	-	434,600	-	726,310						4,848	-					
CONSUMABLES	4.0%	7,874	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	5,905	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	9,842	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	7,874	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	36,725	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		68,220																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		1,425,973																		
ENGINEERING DESIGN	15.0%	213,896	*ESTIMATE SUBTOTAL * 0.15*																	
ENGINEERING CONST SUPPORT	17.0%	242,415	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	356,493	*ESTIMATE SUBTOTAL * 0.25*																	
ESTIMATE SUBTOTAL		2,238,777																		
SITE ALLOCATIONS	14.4%	205,340	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		2,444,117																		
WORK PACKAGE PREPARATION	17.0%	242,415	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS SUPPORT DURING INSTALLATION (No. of Weeks)	14	140,000	*$10K / WK * # OF WEEKS*																	
OPERATIONS SUPPORT DURING CURING (No. of Weeks)	9	31,500	*$10K / WK * # OF WEEKS*																	
A/B COSTS	3.0%	84,796	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		2,942,828																		
CONTINGENCY	35.0%	1,029,990	*OPC's SUBTOTAL * 0.35*																	
GRAND TOTAL		***3,972,818***																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 200'.

3) Placement of material is assumed to be at 60 cubic yards per day.

4) The Authorization Basis (A/B) cost markup is 3% for all activities.

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that C-106 tank will have a 3' layer of stabilization installed in the bottom of the tank.

8) It is assumed that the last 5' of fill will be clay.

9) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

10) Assume 1/3 for Operations support for instrumentation and exhauster for cure time.

Note: Grout and concrete construction increased due to long schedule impacts.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included.

C-106 TANK - ALTERNATIVE 5 - "GROUT" TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 5 - GROUT																				
Structual Fill - "GROUT"		450,000	-	-	-	450,000	-	-		CONTR	4,500.0	CYD	-	-		-	-	100.00	-	-
Stabilization fill - 3'		20,000	-	-	-	20,000	-	-		CONTR	500.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement of Pipe for Risers(FRONT END LOADER,PUMP TRUCK,PIPING,UNIVERSAL JOINT PIPE)		194,925	4,032	161,925	-	15,000	-	18,000		CONTR	1.0	EA	4,032.0	4,032		40.16	-	15,000.00	-	18,000
Demob / Disposal Placement System		14,096	240	11,786	-	-	-	2,310		CONTR	1.0	EA	240.0	240		49.11	-	-	-	2,310
Grout fill alternative add exhauster		300,000	-	-	-	-	-	300,000		CONTR	1.0	EA	-	-		-	-	-	-	300,000
CONTR		*979,021*	*4,272*	*173,711*	-	*485,000*	-	*320,310*												
BASE COST SUBTOTAL		*979,021*	*4,272*	173,711	-	485,000	-	320,310						4,272	-					
CONSUMABLES	4.0%	6,948	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	5,211	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	8,686	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	6,948	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	40,832	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		68,625																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		1,047,646																		
ENGINEERING DESIGN	15.0%	157,147	*ESTIMATE SUBTOTAL * 0.15*																	
ENGINEERING CONST SUPPORT	17.0%	178,100	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	261,912	*ESTIMATE SUBTOTAL * 0.25*																	
ESTIMATE SUBTOTAL		1,644,805																		
SITE ALLOCATIONS	14.4%	150,861	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		1,795,666																		
WORK PACKAGE PREPARATION	17.0%	178,100	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS SUPPORT DURING INSTALLATION (No. of Weeks)	12	120,000	*$10K / WK * # OF WEEKS*																	
OPERATIONS SUPPORT DURING CURING (No. of Weeks)	11	38,500	*$3.5K / WK * # OF WEEKS*																	
A/B COSTS	3.0%	62,813	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		2,195,079																		
CONTINGENCY	35.0%	768,278	*OPC's SUBTOTAL * 0.35*																	
GRAND TOTAL		*2,963,357*																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 200'.

3) Placement of material is assumed to be at 60 cubic yards per day.

4) The Authorization Basis (A/B) cost markup is 3% for all activities.

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that C-106 tank will have a 3' layer of stabilization installed in the bottom of the tank.

8) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

9) Assume 1/3 for Operations support for instrumentation and exhauster for cure time.

Note: Grout and concrete construction increased due to long schedule impacts.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included.

C-200 SERIES TANKS - ALTERNATIVE 1 - "GRAVEL" TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 1 - GRAVEL																				
Structual Fill - "Gravel" Crushed or Pea Gravel"		5,600	-	-	-	5,600	-	-		CONTR	280.0	CYD	-	-		-	-	20.00	-	-
Stabilization fill - 12"		480	-	-	-	480	-	-		CONTR	12.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement of Pipe for Risers(FRONT END LOADER,CONVEYOR)		43,627	480	19,277	-	-	-	24,350		CONTR	1.0	EA	480.0	480		40.16	-	-	-	24,350
Placement System (METERING HOPPER/PIPE SYSTEM)		14,500	-	-	-	4,500	-	10,000		CONTR	1.0	EA	-	-		-	-	4,500.00	-	10,000
Demob / Disposal Placement System		4,699	80	3,929	-	-	-	770		CONTR	1.0	EA	80.0	80		49.11	-	-	-	770
	CONTR	68,906	560	23,206	-	10,580	-	35,120						560	-					
BASE COST SUBTOTAL		68,906																		
CONSUMABLES	4.0%	928		LABOR * 0.04 CONTR ONLY																
QUALITY INSPECTION	3.0%	696		LABOR * 0.03 CONTR ONLY																
CLEANUP	5.0%	1,160		LABOR * 0.05 CONTR ONLY																
PERSONNEL / MATL MOVEMENT	4.0%	928		LABOR * 0.04 CONTR ONLY																
WASH ST SALES TAX	8.3%	955		(MATL + EQUIP + CONSUMBLS) * 0.083																
		4,667																		
GENERAL RQMTS																				
FP SUBCONTRACTOR MARKUP	0.0%	-		S/C * 0 FP ONLY																
FP CONTRACTOR MARKUP	0.0%	-		(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY																
FP CM	0.0%	-		BASE COST SUBTOTAL * 0 FP ONLY																
CF CM	0.0%	-		(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY																
		-																		
CONTRACTOR MKUP & CM SUBTOTAL		73,573																		
ESTIMATE SUBTOTAL		19,865		ESTIMATE SUBTOTAL * 0.27																
ENGINEERING DESIGN	27.0%	9,564		ESTIMATE SUBTOTAL * 0.13																
ENGINEERING CONST SUPPORT	13.0%	14,715		ESTIMATE SUBTOTAL * 0.2																
PROJECT MANAGEMENT	20.0%																			
		117,717																		
ESTIMATE SUBTOTAL		10,595		ESTIMATE SUBTOTAL * 0.144																
SITE ALLOCATIONS	14.4%	128,312																		
SITE ALLOCATIONS SUBTOTAL		9,564		ESTIMATE SUBTOTAL * 0.13																
WORK PACKAGE PREPARATION	13.0%	20,000		$10K / WK * # OF WEEKS																
OPERATIONS (No. of Weeks)	2																			
A/B COSTS	3.0%	4,736		(SITE ALLOC + OPC's) * 0.03																
		162,612																		
OPC's SUBTOTAL		56,914		OPC's SUBTOTAL * 0.35																
CONTINGENCY	35.0%																			
GRAND TOTAL		219,526																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 60'.

3) Placement of material is assumed to be at 32 cubic yards per day. This should be an approx. 5' lift .

4) The Authorization Basis (A/B) cost markup is 3% for all activities

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that all C-200 tanks will have a 12" layer of stabilization installed in the bottom of each tank.

8) Assume Rockslinger will not be used in the C-200 tanks due to ALARA and the amount of time and cost to excavate down to use the 42" manhole size required to get it into the tank.

9) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included. The exhauster will be used from C-106 and therefore only a small amount of material cost for duct work to hook up with the exhauster would be added but since this is common to all tanks it will not be added to the estimate comparison.

C-200 SERIES TANKS - ALTERNATIVE 2 - "CONCRETE" TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 2 - CONCRETE																				
Structual Fill - "Concrete"		25,200	-	-	-	25,200	-	-		CONTR	280.0	CYD	-	-		-	-	90.00	-	-
Stabilization fill - 12"		480	-	-	-	480	-	-		CONTR	12.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement (Pipe,fabbed univeral joint pipe,Pumper Truck,)		33,139	240	10,639	-	4,500	-	18,000		CONTR	1.0	EA	240.0	240		44.33	-	4,500.00	-	18,000
Demob / Disposal Placement System		4,699	80	3,929	-	-	-	770		CONTR	1.0	EA	80.0	80		49.11	-	-	-	770
CONTR		*63,518*	*320*	*14,568*	-	*30,180*	-	*18,770*												
BASE COST SUBTOTAL		*63,518*	*320*	14,568	-	30,180	-	18,770						320	-					
CONSUMABLES	4.0%	583	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	437	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	728	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	583	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	2,553	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		4,884																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		68,402																		
ENGINEERING DESIGN	20.0%	13,680	*ESTIMATE SUBTOTAL * 0.2*																	
ENGINEERING CONST SUPPORT	10.0%	6,840	*ESTIMATE SUBTOTAL * 0.1*																	
PROJECT MANAGEMENT	15.0%	10,260	*ESTIMATE SUBTOTAL * 0.15*																	
ESTIMATE SUBTOTAL		99,182																		
SITE ALLOCATIONS	14.4%	9,850	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		109,032																		
WORK PACKAGE PREPARATION	10.0%	6,840	*ESTIMATE SUBTOTAL * 0.1*																	
OPERATIONS (No. of Weeks)	1	10,000	*$10K / WK * # OF WEEKS*																	
A/B COSTS	3.0%	3,776	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		129,648																		
CONTINGENCY	25.0%	32,412	*OPC's SUBTOTAL * 0.25*																	
GRAND TOTAL		*162,060*																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10' steel piping with fittings and assumed to be approx. 60'.

3) Placement of material is assumed to be at 60 cubic yards per day. This should be an approx. 5' lift .

4) The Authorization Basis (A/B) cost markup is 3% for all activities

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that all C-200 tanks will have a 12" layer of stabilization installed in the bottom of each tank.

8) Assume Rockslinger will not be used in the C-200 tanks due to ALARA and the amount of time and cost to excavate down to use the 42" manhole size required to get it into the tank.

9) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

10) The operations cost assumes all four C-200 series tanks worked simultaneously, thus allowing cure of C-201, while concrete is placed in C-202, C-203,etc..

11) Contingency adjusted based on the perceived schedule risk. (25% being moderate schedule risk).

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included. The exhauster will be used from C-106 and therefore only a small amount of material cost for duct work to hook up with the exhauster would be added but since this is common to all tanks it will not be added to the estimate comparison.

C-200 SERIES TANKS - ALTERNATIVE 3 - "HYBRID" TANK STRUCTURAL STABILITY ALTERNATIVE COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 3 - HYBRID																				
Structual Fill - "ROUND AGGREGATE"		4,760	-	-	-	4,760	-	-		CONTR	238.0	CYD	-	-		-	-	20.00	-	-
Structual Fill - "GROUT"		5,000	-	-	-	5,000	-	-		CONTR	50.0	CYD	-	-		-	-	100.00	-	-
Stabilization fill - 12"		480	-	-	-	480	-	-		CONTR	12.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement of Pipe for Risers(END LOADER,CONVEYOR,PUMP TK)		38,627	480	19,277	-	-	-	19,350		CONTR	1.0	EA	480.0	480		40.16	-	-	-	19,350
Placement System (METERING HOPPER/PIPE SYSTEM)		14,500	-	-	-	4,500	-	10,000		CONTR	1.0	EA	-	-		-	-	4,500.00	-	10,000
Demob / Disposal Placement System		4,699	80	3,929	-	-	-	770		CONTR	1.0	EA	80.0	80		49.11	-	-	-	770
CONTR		*68,066*	*560*	*23,206*	-	*14,740*	-	*30,120*												
BASE COST SUBTOTAL		*68,066*	*560*	23,206	-	14,740	-	30,120						560	-					

CONSUMABLES	4.0%	928	*LABOR * 0.04 CONTR ONLY*
QUALITY INSPECTION	3.0%	696	*LABOR * 0.03 CONTR ONLY*
CLEANUP	5.0%	1,160	*LABOR * 0.05 CONTR ONLY*
PERSONNEL / MATL MOVEMENT	4.0%	928	*LABOR * 0.04 CONTR ONLY*
WASH ST SALES TAX	8.3%	1,300	*(MATL + EQUIP + CONSUMBLS) * 0.083*
GENERAL RQMTS		5,012	
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*
CONTRACTOR MKUP & CM SUBTOTAL		-	
ESTIMATE SUBTOTAL		73,078	
ENGINEERING DESIGN	20.0%	14,616	*ESTIMATE SUBTOTAL * 0.2*
ENGINEERING CONST SUPPORT	10.0%	7,308	*ESTIMATE SUBTOTAL * 0.1*
PROJECT MANAGEMENT	15.0%	10,962	*ESTIMATE SUBTOTAL * 0.15*
ESTIMATE SUBTOTAL		105,964	
SITE ALLOCATIONS	14.4%	10,523	*ESTIMATE SUBTOTAL * 0.144*
SITE ALLOCATIONS SUBTOTAL		116,487	
WORK PACKAGE PREPARATION	10.0%	7,308	*ESTIMATE SUBTOTAL * 0.1*
OPERATIONS (No. of Weeks)	2	20,000	*$10K / WK * # OF WEEKS*
A/B COSTS	3.0%	4,314	*(SITE ALLOC + OPC's) * 0.03*
OPC's SUBTOTAL		148,109	
CONTINGENCY	30.0%	44,433	*OPC's SUBTOTAL * 0.3*
GRAND TOTAL		*192,542*	

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 60'.

3) Placement of material is assumed to be at 32 cubic yards per day. This should be an approx. 5' lift .

4) The Authorization Basis (A/B) cost markup is 3% for all activities

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that all C-200 tanks will have a 12" layer of stabilization installed in the bottom of each tank.

8) Assume Rockslinger will not be used in the C-200 tanks due to ALARA and the amount of time and cost to excavate down to use the 42" manhole size required to get it into the tank.

9) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included. The exhauster will be used from C-108 and therefore only a small amount of material cost for duct work to hook up with the exhauster would be added but since this is common to all tanks it will not be added to the estimate comparison.

C-200 SERIES TANKS - ALTERNATIVE 4 - "GROUT" TANK STRUCTUAL STABILITY COMPARSION ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 4 - GROUT																				
Structual Fill - "GROUT"		28,000	-	-	-	28,000	-	-		CONTR	280.0	CYD	-	-		-	-	100.00	-	-
Stabilization fill - 12"		480	-	-	-	480	-	-		CONTR	12.0	CYD	-	-		-	-	40.00	-	-
Placement System/Movement (Pipe,fabbed univeral joint pipe,Pumper Truck, Concrete)		33,139	240	10,639	-	4,500	-	18,000		CONTR	1.0	EA	240.0	240		44.33	-	4,500.00	-	18,000
Demob / Disposal Placement System		4,699	80	3,929	-	-	-	770		CONTR	1.0	EA	80.0	80		49.11	-	-	-	770
CONTR		*66,318*	*320*	*14,568*	-	*32,980*	-	*18,770*												
BASE COST SUBTOTAL		*66,318*	*320*	14,568	-	32,980	-	18,770						320	-					
CONSUMABLES	4.0%	583	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	437	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	728	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	583	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	2,786	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		5,117																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		71,435																		
ENGINEERING DESIGN	27.0%	19,287	*ESTIMATE SUBTOTAL * 0.27*																	
ENGINEERING CONST SUPPORT	13.0%	9,287	*ESTIMATE SUBTOTAL * 0.13*																	
PROJECT MANAGEMENT	20.0%	14,287	*ESTIMATE SUBTOTAL * 0.2*																	
ESTIMATE SUBTOTAL		114,296																		
SITE ALLOCATIONS	14.4%	10,287	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		124,583																		
WORK PACKAGE PREPARATION	13.0%	9,287	*ESTIMATE SUBTOTAL * 0.13*																	
OPERATIONS (No. of Weeks)	1	10,000	*$10K / WK * # OF WEEKS*																	
A/B COSTS	3.0%	4,316	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		148,186																		
CONTINGENCY	25.0%	37,047	*OPC's SUBTOTAL * 0.25*																	
GRAND TOTAL		***185,233***																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 60'.

3) Placement of material is assumed to be at 32 cubic yards per day. This should be an approx. 5' lift .

4) The Authorization Basis (A/B) cost markup is 3% for all activities

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that all C-200 tanks will have a 12" layer of stabilization installed in the bottom of each tank.

8) Assume Rockslinger will not be used in the C-200 tanks due to ALARA and the amount of time and cost to excavate down to use the 42" manhole size required to get it into the tank.

9) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included. The exhauster will be used from C-106 and therefore only a small amount of material cost for duct work to hook up with the exhauster would be added but since this is common to all tanks it will not be added to the estimate comparison.

C-200 SERIES TANKS - ALTERNATIVE 5 - "GROUT W/ SEALING LAYER" TANK STRUCTURAL STABILITY COMPARISON ESTIMATE

DESCRIPTION	MARKUP %	TOTAL COST	TOTAL HOURS	LABOR	EQP USAGE	MATL	S/C	EQUIP	INSTALLATION COMPLEXITY FACTOR	CONTRACT TYPE	QTY	UNIT	HRS/ UNIT	HRS	COMPLEXITY FACTOR HRS	LABOR COST/ HR	EQP USAGE COST/ HR	MATL COST/ UNIT	S/C COST/ UNIT	EQUIP COST/ UNIT
STABILITY ALTERNATIVE 5 - GROUT W/ CLAY SEALING LAYER																				
Structual Fill - "GROUT"		22,800	-	-	-	22,800	-	-		CONTR	228.0	CYD	-	-		-	-	100.00	-	-
Structual Fill - "CLAY"		3,000	-	-	-	3,000	-	-		CONTR	60.0	CYD	-	-		-	-	50.00	-	-
Stabilization fill - 12"		480	-	-	-	480	-	-		CONTR	12.0	CYD	-	-		-	-	40.00	-	-
Placement System (Pipe,Pumper Truck,Conveyor)		47,442	336	12,442	-	4,500	-	30,500		CONTR	1.0	EA	336.0	336		37.03	-	4,500.00	-	30,500
Demob / Disposal Placement System		4,699	80	3,929	-	-	-	770		CONTR	1.0	EA	80.0	80		49.11	-	-	-	770
CONTR		*78,421*	*416*	*16,371*	-	*30,780*	-	*31,270*												
BASE COST SUBTOTAL		*78,421*	*416*	16,371	-	30,780	-	31,270						416	-					
CONSUMABLES	4.0%	655	*LABOR * 0.04 CONTR ONLY*																	
QUALITY INSPECTION	3.0%	491	*LABOR * 0.03 CONTR ONLY*																	
CLEANUP	5.0%	819	*LABOR * 0.05 CONTR ONLY*																	
PERSONNEL / MATL MOVEMENT	4.0%	655	*LABOR * 0.04 CONTR ONLY*																	
WASH ST SALES TAX	8.3%	2,609	*(MATL + EQUIP + CONSUMBLS) * 0.083*																	
GENERAL RQMTS		5,229																		
FP SUBCONTRACTOR MARKUP	0.0%	-	*S/C * 0 FP ONLY*																	
FP CONTRACTOR MARKUP	0.0%	-	*(LABOR + EQP USAGE + MATL + EQUIP) * 0 FP ONLY*																	
FP CM	0.0%	-	*BASE COST SUBTOTAL * 0 FP ONLY*																	
CF CM	0.0%	-	*(BASE COST SUBTOTAL + SWP + CONSUMBLS + CLEANUP + MATL MVMT) * 0 CONTR ONLY*																	
CONTRACTOR MKUP & CM SUBTOTAL		-																		
ESTIMATE SUBTOTAL		83,650																		
ENGINEERING DESIGN	33.0%	27,605	*ESTIMATE SUBTOTAL * 0.33*																	
ENGINEERING CONST SUPPORT	17.0%	14,221	*ESTIMATE SUBTOTAL * 0.17*																	
PROJECT MANAGEMENT	25.0%	20,913	*ESTIMATE SUBTOTAL * 0.25*																	
ESTIMATE SUBTOTAL		146,389																		
SITE ALLOCATIONS	14.4%	12,046	*ESTIMATE SUBTOTAL * 0.144*																	
SITE ALLOCATIONS SUBTOTAL		158,435																		
WORK PACKAGE PREPARATION	17.0%	14,221	*ESTIMATE SUBTOTAL * 0.17*																	
OPERATIONS (No. of Weeks)	1.5	15,000	*$10K / WK * # OF WEEKS*																	
A/B COSTS	3.0%	5,630	*(SITE ALLOC + OPC's) * 0.03*																	
OPC's SUBTOTAL		193,286																		
CONTINGENCY	35.0%	67,650	*OPC's SUBTOTAL * 0.35*																	
GRAND TOTAL		*260,936*																		

Assumptions / Factors

1) Assume that the piping will need to be moved from riser to riser to get an even distribution of fill material. A designed universal type joint attached to the end of the pipe will help for placement of material. The labor hours for this activity will be included in the placement system hours using the same craft.

2) Placement of material will use 10" steel piping with fittings and assumed to be approx. 60'.

3) Placement of material is assumed to be at 60 cubic yards per day. This should be an approx. 5' lift .

4) The Authorization Basis (A/B) cost markup is 3% for all activities.

5) It is assumed that the placement piping will remain in the risers until demolition.

6) It is assumed that no active ventilation is required.

7) Assumed that all C-200 tanks will have a 12" layer of stabilization installed in the bottom of each tank.

8) It is assumed that the last 5' of fill will be clay.

9) Assume Rockslinger will not be used in the C-200 tanks due to ALARA and the amount of time and cost to excavate down to use the 42" manhole size required to get it into the tank.

10) Assume all work activities outside of current authorization basis will be the same cost for all tanks.

Note: This comparitive cost estimate only compares those work items which are unique to the specific activities. "Common costs" such as utilities, sampling, testing of fill material, etc. are not included. The exhauster will be used from C-106 and therefore only a small amount of material cost for duct work to hook up with the exhauster would be added but since this is common to all tanks it will not be added to the estimate comparison.

Attachment 4

Appendix C

Figures

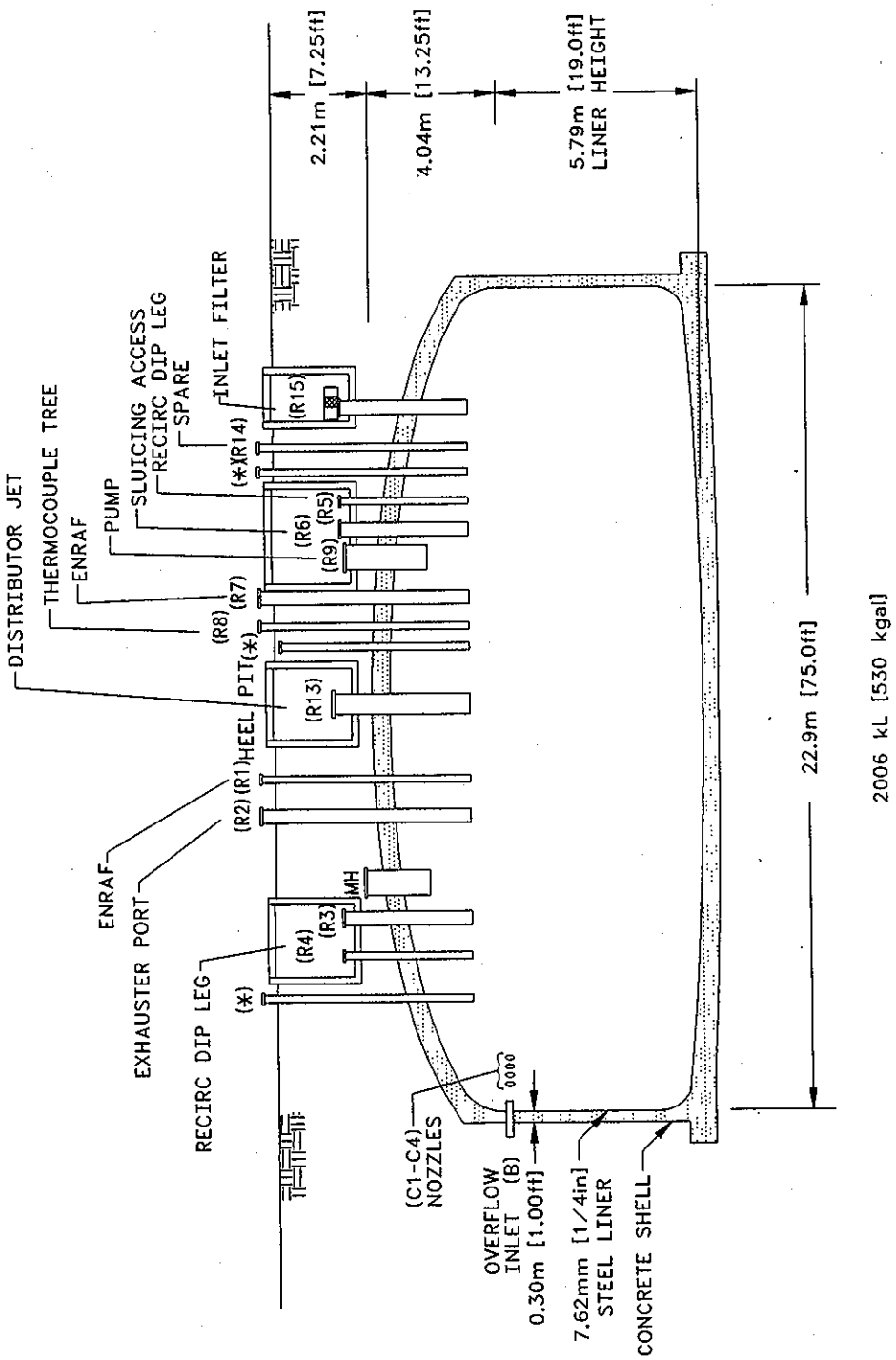

Figure C-1. Cross-Section View of Tank C-106.

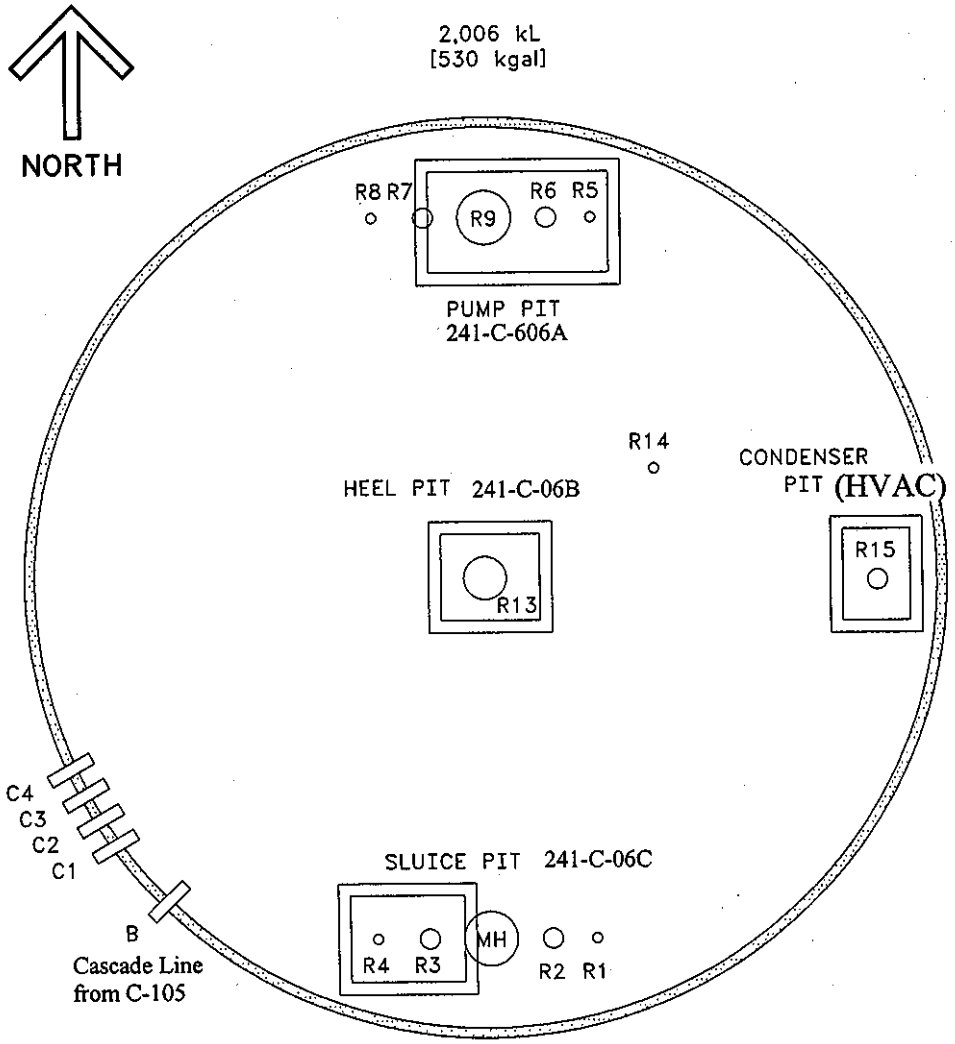

Figure C-2. Plan View of Tank C-106.

Attachment 4

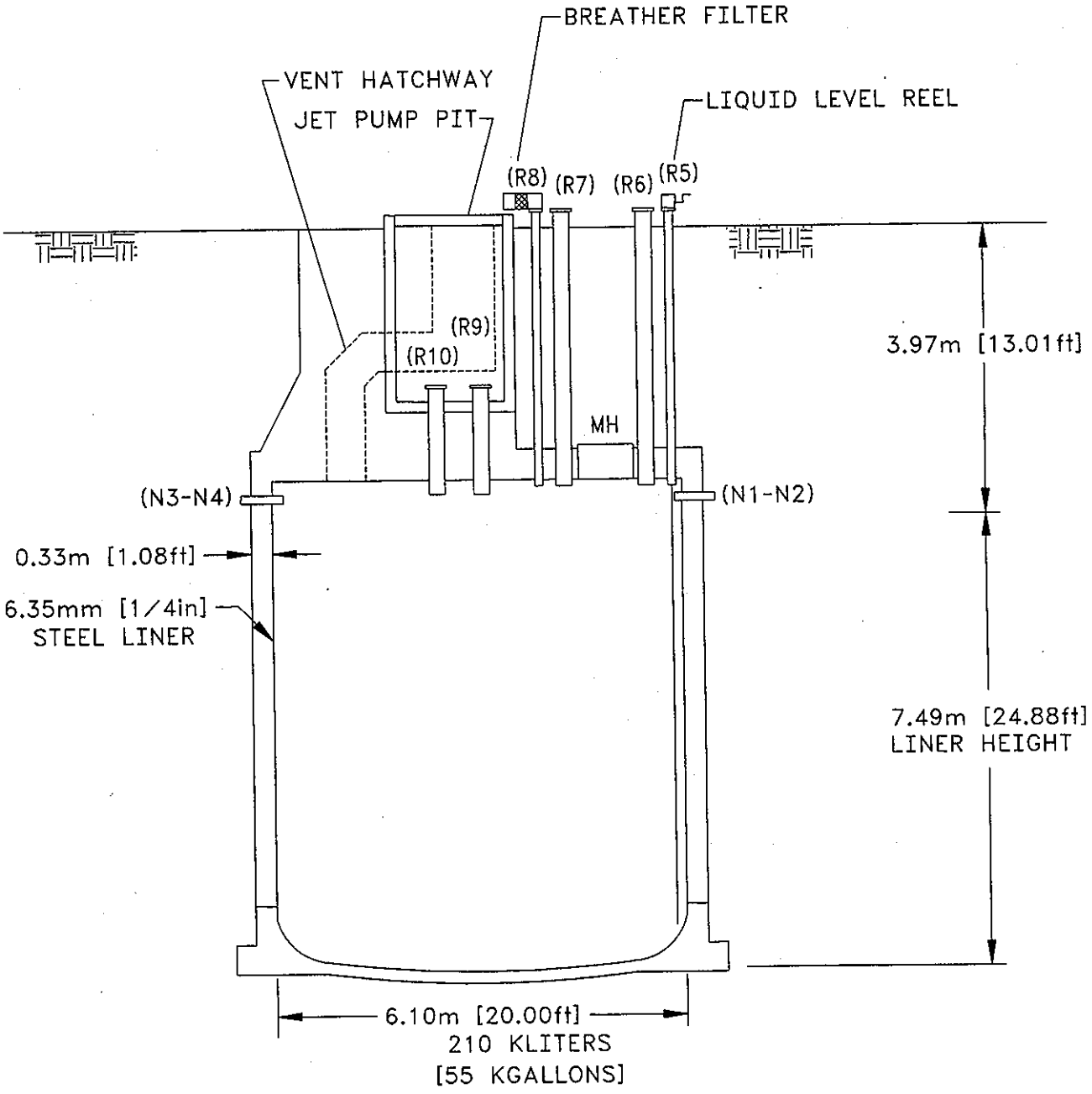

Figure C-3. Cross-Section View of C-200 Series Tanks.

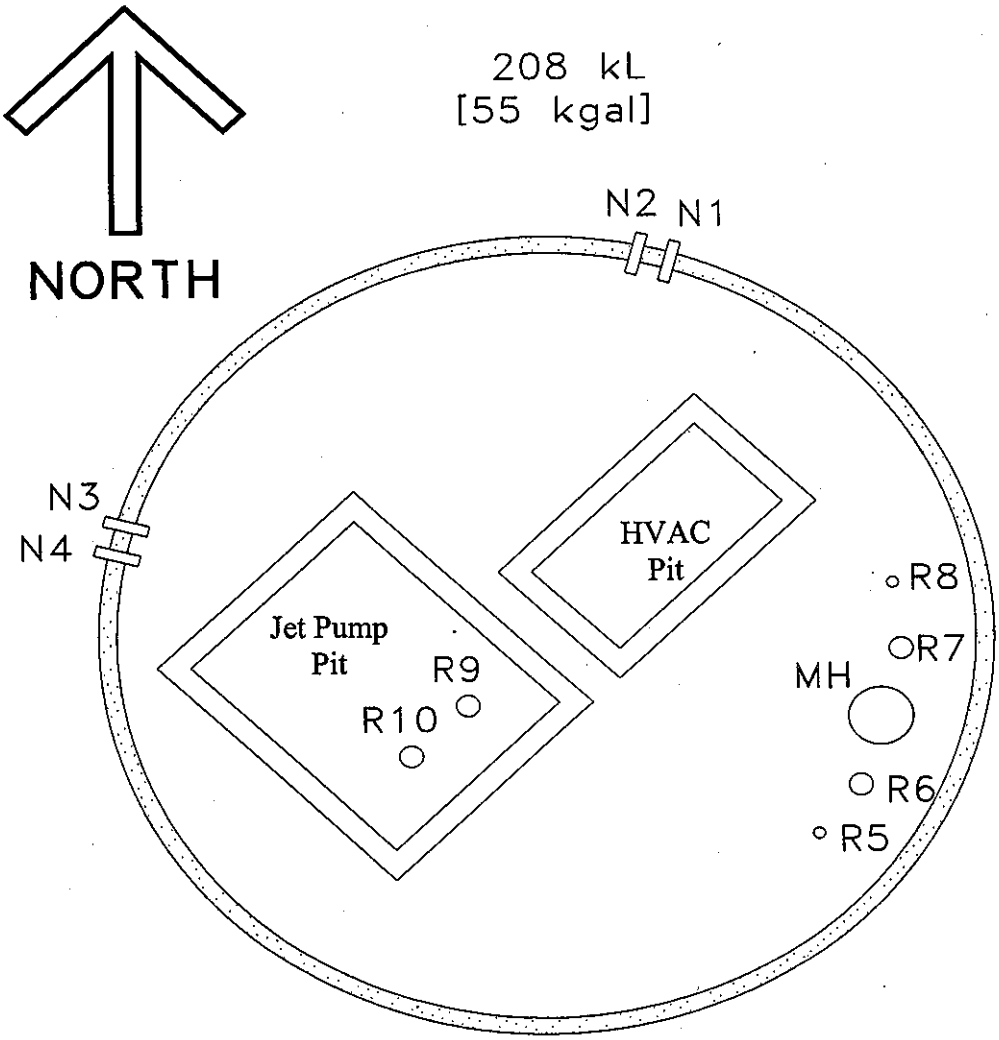

Figure C-4. Plan View of the C-200 Series Tanks.

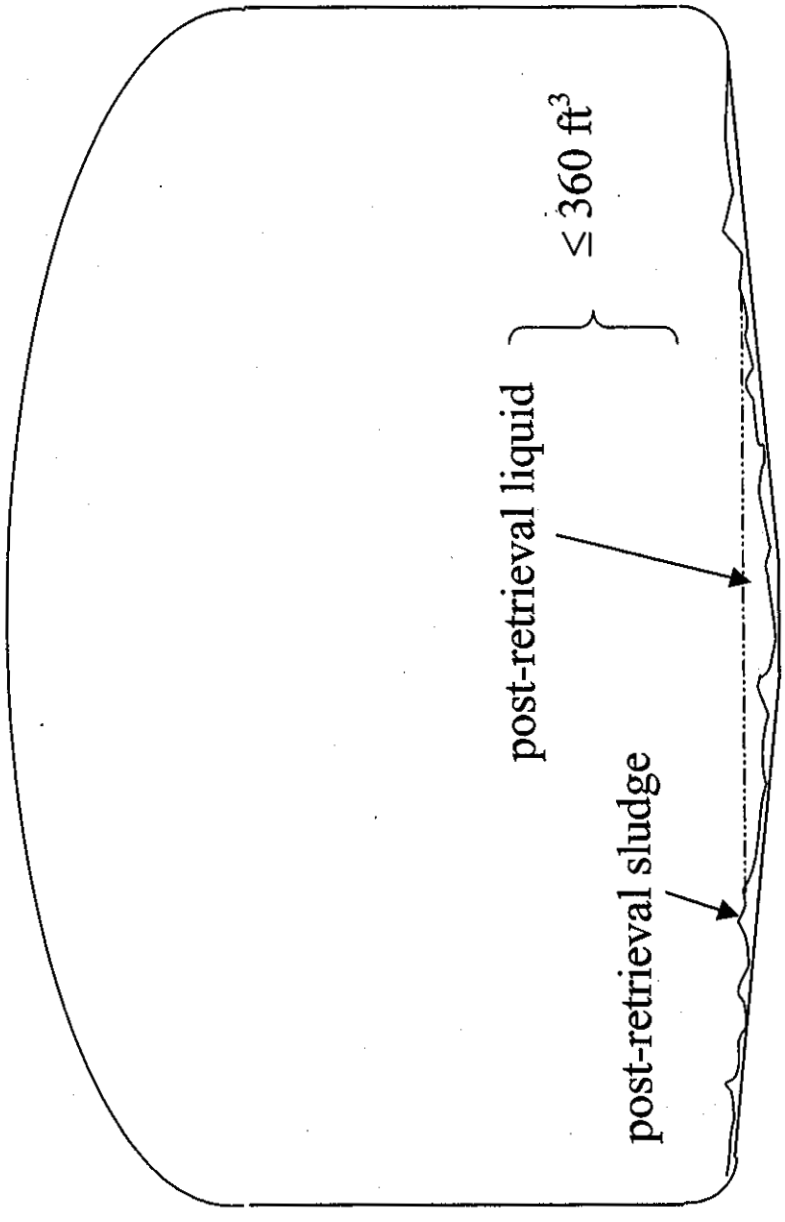

Figure C-5. Tank C-106 with 360 cu ft of Residual Waste Following Retrieval (assumed Initial conditions)

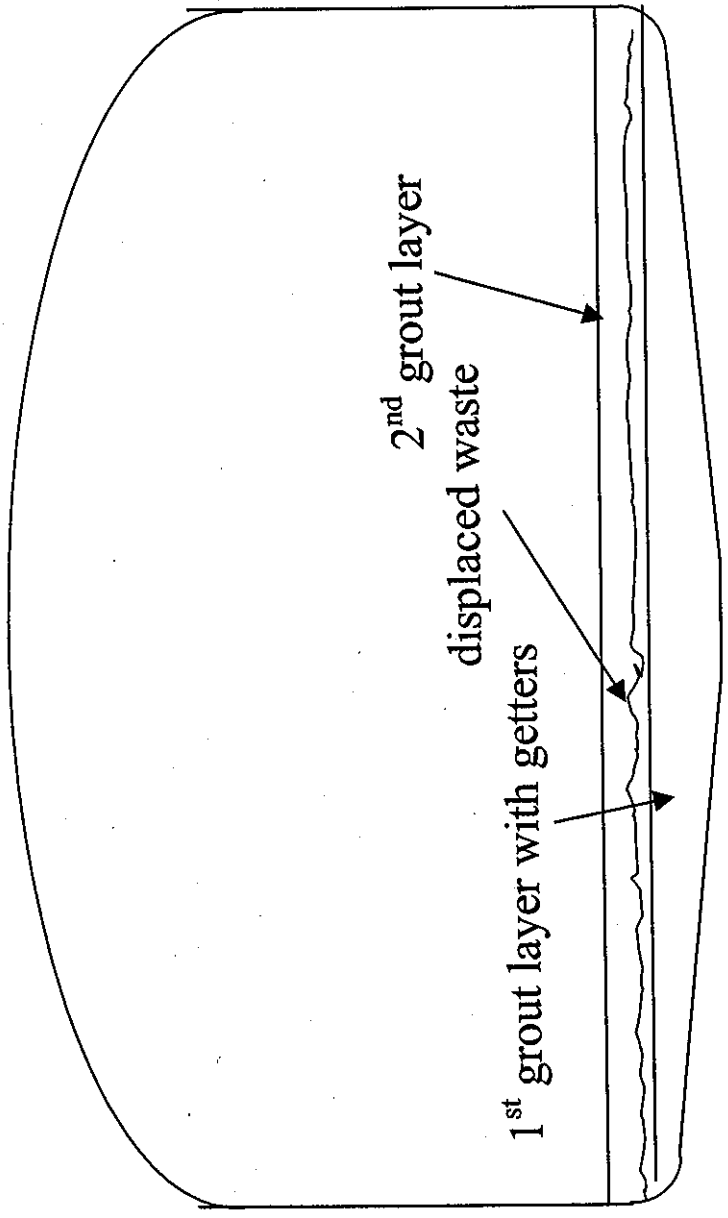

Figure C-6. Tank C-106 - Grout Waste Stabilization Layer Displaces Waste – Case 1

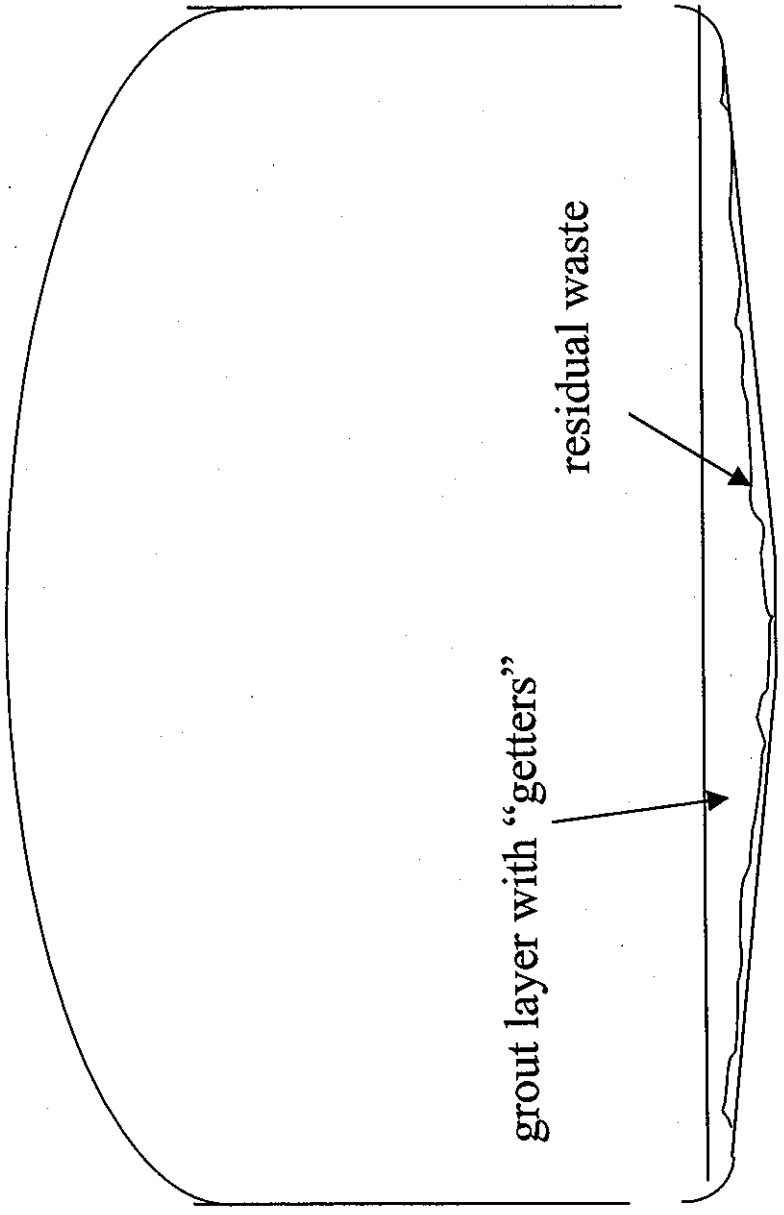

Figure C-7. Tank C-106 - Grout Waste Stabilization Layer Does Not Displace Waste – Case 2

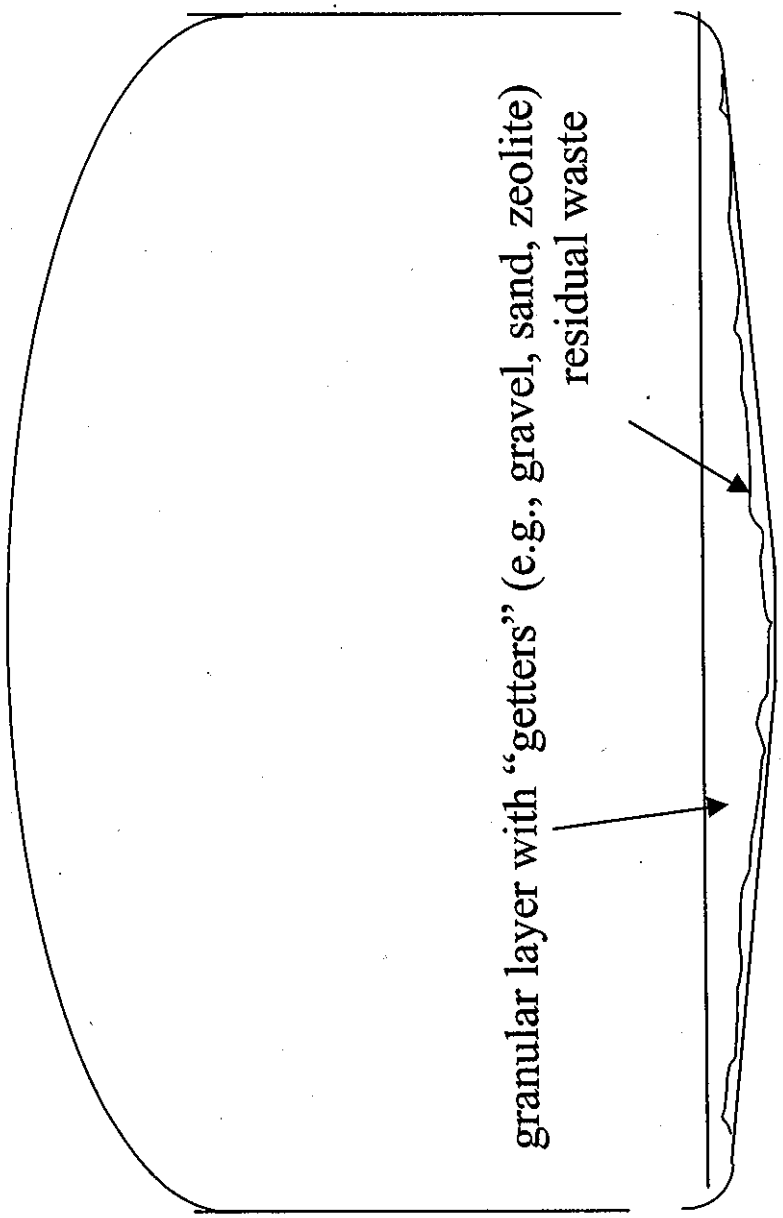

Figure C-8. Tank C-106 - Granular Waste Stabilization Layer.

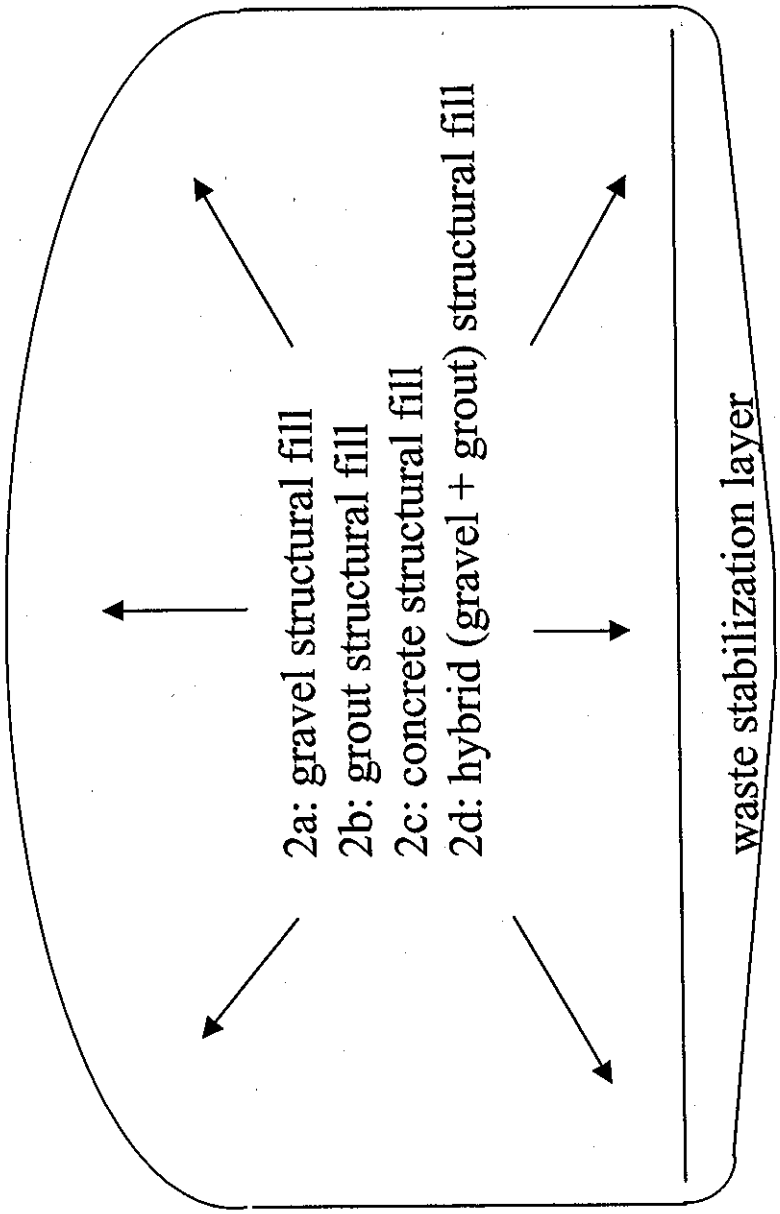

Figure C-9. Tank C-106 - Homogeneous Structural Fill.

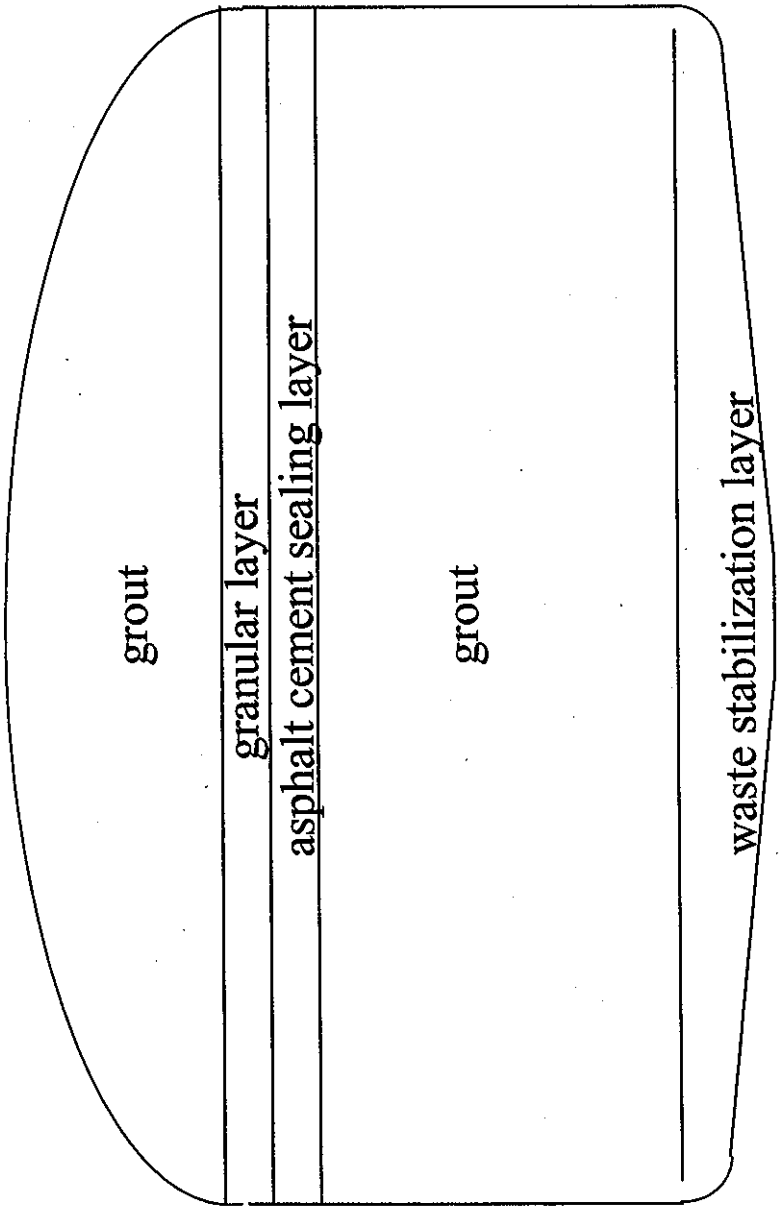

Figure C-10. Tank C-106 - Multi-Layered Structural Fill.

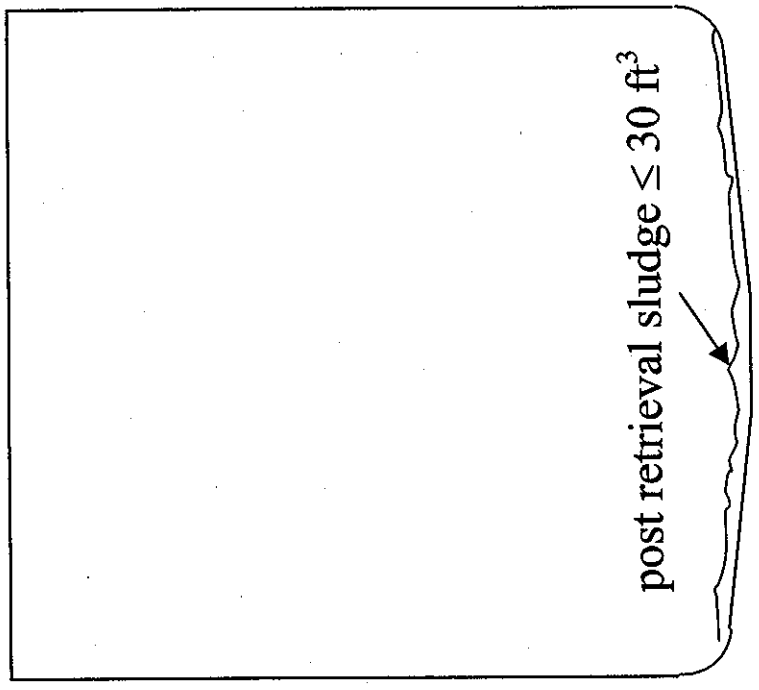

Figure C-11. C-200 Series Tanks with 30 cu ft of Residual Waste Following Retrieval (assumed initial conditions)

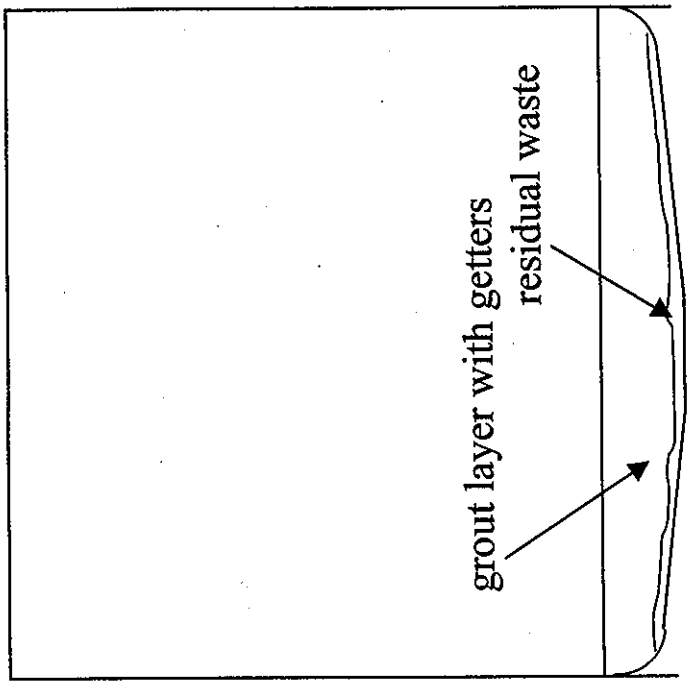

Figure C-12. C-200 Series Tanks - Grout Waste Stabilization Layer Displaces Waste – Case 1

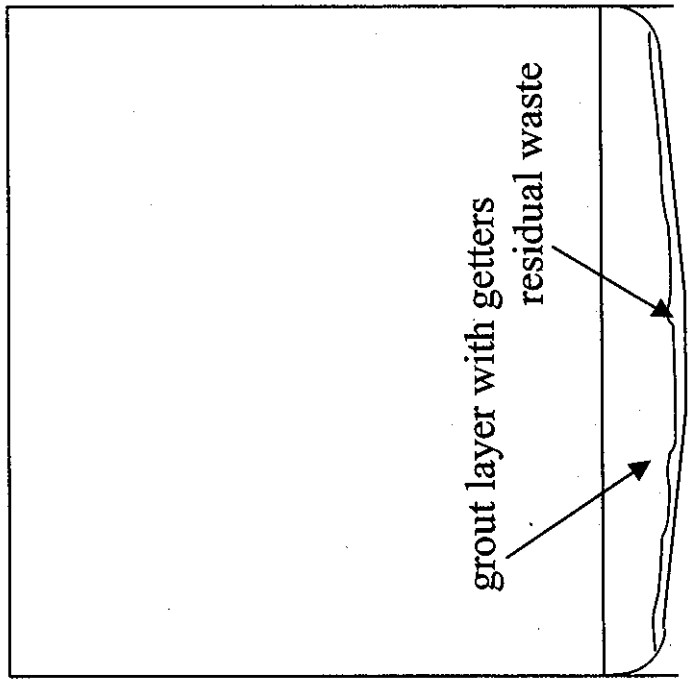

Figure C-13. C-200 Series Tanks – Granular Waste Stabilization Layer.

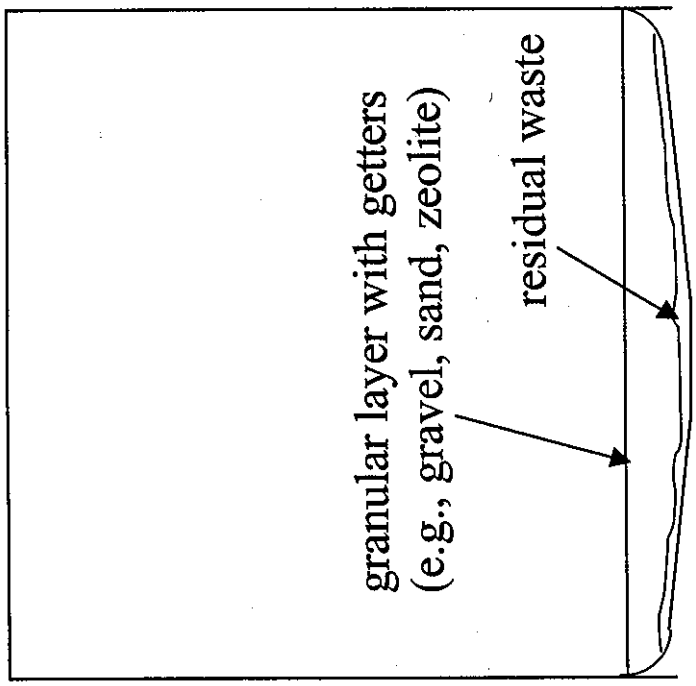

Figure C-14. C-200 Series Tanks – Granular Waste Stabilization Layer.

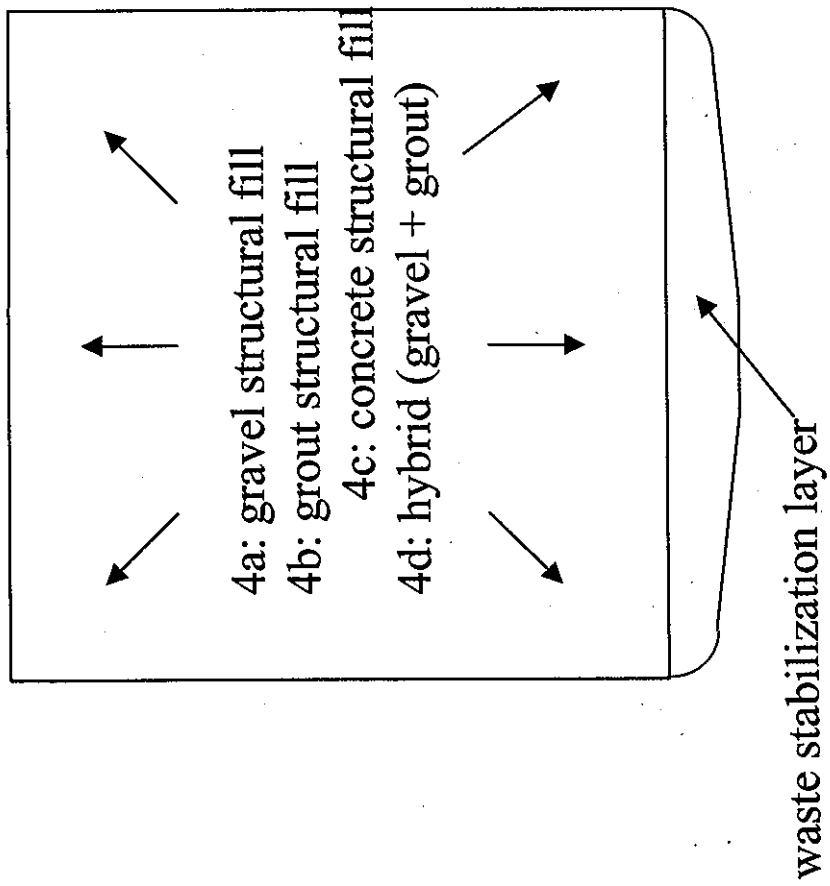

Figure C-15. C-200 Series Tanks – Homogeneous Structural Fill.

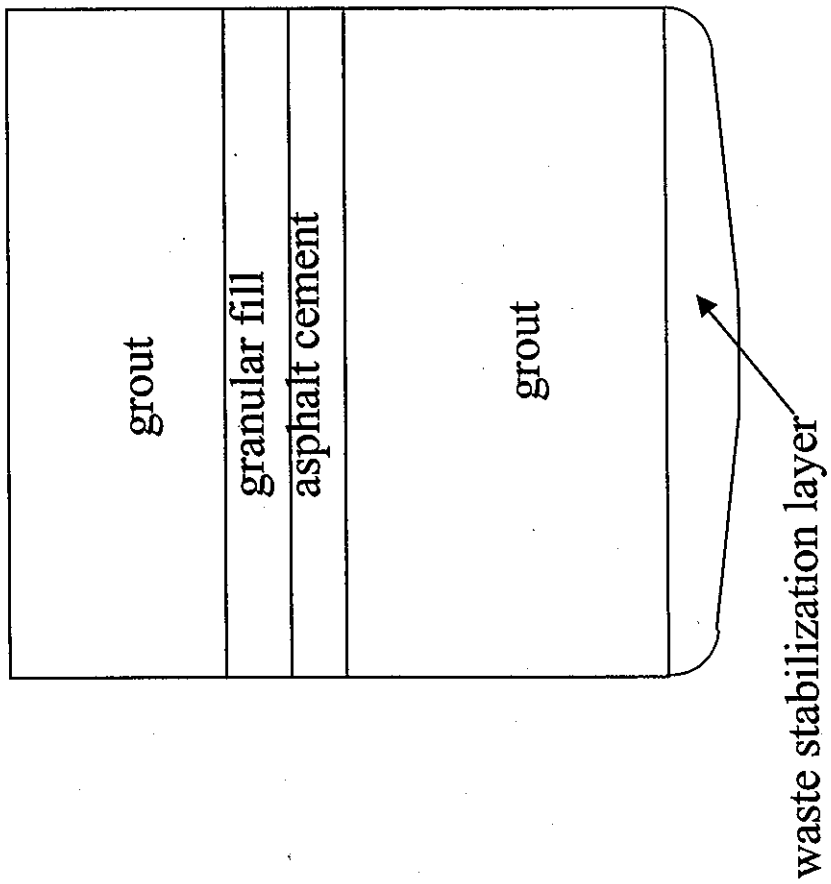

Figure C-16. C-200 Series Tanks – Multi-Layered Structural Fill.

Attachment 4

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Attachment 4

Appendix D

Meeting Attendees

Attachment 4

ATTENDANCE		
NAME	COMPANY	NUMBER
BRUCE GROTH	ARES	946-3300
Jerry Cammann	CHG – TF Closure Program	372-2757
Ed Fredenburg	CHG	372-0435
Craig Sump	CH2M Hill	375-0683 ext. 220
Gary Kelmel	CHG Const.	373-5898
Nathan R. Roe	ARES	946-3300
Chip Conselman	ARES	946-3300
John Winters	CH2M Hill	375-0683 ext. 212
Janet Badden	CHG	372-9698
Steve O'Toole	CHG	376-4284
Bill Deutsch	Battelle	376-3422
R. Jeff Serne	Battelle	376-8429
Grant McCallum	CBCG	947-0988
Mark Riess	CHG	373-2007
AJ Knepp	CHG	531-1563
Bill Grams	CHG	373-7308
Dave Strasser	CHG	531-9642
Stacey Callison	CHI	372-9601
Steve McKee	Jacobs	943-7257
Joe Cruz	DOE/CHP	372-2606
Dave Nichols	Columbia	946-7111
Paul Patterson	ARES	946-3300
Bob Fritz	ARES	946-3300

Attachment 4

Appendix E

Scoring Guidelines

Attachment 4

EVALUATION SCORING GUIDELINES

E1.0 LIMIT RELEASE OF CONTAMINANTS

	Points
Low	**0-30**

This alternative is expected to provide no reduction of contaminant mobility.

Medium	**31 – 60**

This alternative is expected to provide for reduction of either physical or chemical contaminant mobility.

High	**61 – 100**

This alternative is expected to provide for reduction of all contaminant mobility.

E2.0 LONG-TERM FUNCTION FOR STABILIZATION (INSTALLATION SYSTEM)

	Points
Low	**0-30**

This alternative is expected to have significant deterioration within the 1,000-year guideline (1,000 years expected useful life).

Medium	**31 – 60**

This alternative is expected to provide a reasonably stable system for 1,000 years.

High	**61 – 100**

This alternative is expected to exceed stability for up to 10,000 years.

E3.0 ESQ&H AND ALARA

	Points
Low	**0 – 30**

This alternative reduces or eliminates the risk of minor to moderate injury to facility personnel.

Selection of this alternative has no implications with respect to ALARA, OSHA requirements, AB compliance, fire concerns, and personnel injury.

Medium **31 – 60**

Selection of this alternative enhances safety for facility personnel.

Selection of this alternative has a reduced potential for radiological or toxicological harm to facility workers, and alternative workers, but does not impact public risk.

Selection of this alternative improves, but does not optimize, conditions with respect to ALARA, OSHA requirements, AB compliance, fire concerns, and personnel injury.

High **61- 100**

Selection of this alternative enhances safety to help prevent an accident causing the death of one or more facility worker.

Selection of this alternative reduces or eliminates the potential for radiological or toxicological harm to the public.

Selection of this alternative optimizes conditions with respect to ALARA, OSHA requirements, AB compliance, fire concerns, and prevention of personnel injury.

E4.0 SCHEDULE RISK

Schedule considerations include integrated, operating and construction, and accelerated shipping.

	Points
Low	**0-30**

Selection of this alternative does little or nothing to improve or maintain the ability to meet the project schedules.

Selection of this alternative provides a low probability (<50 percent) of meeting the project schedule.

Medium **31 – 60**

Selection of this alternative enhances the ability to meet the project schedules.

Selection of this alternative provides a medium probability (50-75 percent) of meeting the project schedule.

High **61 – 100**

Selection of this alternative results in significant improvement in the ability to meet the project schedules.

Section of this alternative provides a high probability (>75 percent) of meeting the project schedule.

E5.0 OPERATIONS

	Points
Low	**0-30**

This technology is difficult for operators to use.

The technology is difficult to deploy and setup on the tank.

The technology has a low compatibility with existing equipment

This approach requires extensive infrastructure modifications.

Medium **31 – 60**

This technology is of medium difficulty for operators to use.

The technology is moderately difficult to deploy and setup on the tank.

The technology is somewhat compatible with existing equipment

This approach requires moderate level of infrastructure modifications.

High **61 – 100**

This technology is easy for operators to use.

The technology is not difficult to deploy and setup on the tank.

The technology is very compatible with existing equipment

This approach requires very little infrastructure modification.

E6.0 COST

Cost considerations are life-cycle costs that include construction, operations and maintenance, startup/readiness testing and acceptance, environmental, and safety basis costs associated with each alternative. The alternative with the lowest cost is scored as 100 points. All other alternatives are scored according to the guidelines below based on the percent difference from the lowest cost alternative.

	Points
Low	**0-30**

This alternative has estimated life-cycle costs that are 50 percent to 500 percent higher than the lowest cost competing alternative.

Medium	**31 – 60**

This alternative has life-cycle costs that are 25 percent to 50 percent higher than the lowest cost competing alternative.

High	**61 – 100**

This alternative has life-cycle costs that are 0 percent to 25 percent higher than the lowest cost competing alternatives.

E7.0 REVERSIBILITY (ABILITY TO RETRIEVE MATERIAL IN THE FUTURE)

	Points
Low	**0-30**

Selection of this alternative would require a significant development effort to remove the installed material in a safe, environmentally friendly manner.

Medium	**31 – 60**

Selection of this alternative will allow material to be removed predominantly with existing systems and technology.

High	**61 – 100**

Selection of this alternative will allow all material to be removed with existing technology and equipment.

E8.0 MAXIMIZED FUTURE USE

	Points
Low	**0-30**

This technology is unlikely (<20 percent probability) to be useful for future closure operations of SSTs.

Medium **31 – 60**

This technology is moderately likely (20 percent - 70 percent probability) to be useful for future closure of SSTs.

High **61 – 100**

This technology is highly likely (>70 percent probability) to be useful for future closure of SSTs.

E9.0 PERFORMANCE VERIFICATION

	Points
Low	**0-30**

This verification method involves new technology or requires a need to perform in-tank sampling

Medium **31 – 60**

This verification method involves physical sampling outside of the tank or some other physical method to ensure the stabilization and fill material is providing (will provide) the intended function.

High **61 – 100**

This verification method involves simple visual or other readily available non-physical inspection.