S

AUG 13 2002 Sta. 15 (20)

ENGINEERING DATA TRANSMITTAL

1. EDT 634896

2. To: (Receiving Organization) Tank Farm Closure Program	3. From: (Originating Organization) Single Shell Tank Projects	4. Related EDT No.: 634896
5. Proj./Prog./Dept./Div.: HPA B0621 Accelerated Tank Closure Dem Proj	6. Design Authority/Design Agent/Cog. Engr.: NA/NA/S.W. Callison	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-10950		0	Accelerated Tank Closure	NA	1	1	
				Demonstration Data				
				Assessment				

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	M.J.Galgoul	MJ Galgoul	8/12/02	
1	1	Cog. Eng. S.W. Callison	SW Callison	8-12-02							
1	1	Cog. Mgr. M.J. Riess	MJ Riess	8/12/02		1	1	J.N. Winters	JN Winters	8/12/02	
		QA				1	2	E.A. Fredenburg	E Fredenburg	8/12/02	
		Safety				1	1	G.T. Wells	GT Wells	8/9/02	
		Env.						See Distribution List			

18.	19.	20.	21. DOE APPROVAL (if required)
S.W. Callison S. Callison Signature of EDT Originator — Date 8-12-02	M. Jarayssi Authorized Representative for Receiving Organization — Date 8/12/02	MJ Riess M.J. Riess Design Authority/ Cognizant Manager — Date 8/12/02	Ctrl No. ____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

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A-6000-135 (10/97)

Accelerated Tank Closure Demonstration Data Assessment

S. W. Callison
CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: 634896 UC: 2000
Cost Center: 7P300 Charge Code: 117169/AJ60
B&R Code: NA Total Pages: ~~178~~ ~~168~~ 178
JHa 8/13

Key Words: Tank Closure; Demonstration; SST; Accelerated; Single Shell Tank; Data Assessment; C-106; C-200 Series

Abstract:
This document summarizes and references available characterization information for the C-106 and the C-200 series (C-201, C-202, C-203, and C-204) closure demonstration tanks. Available C Tank Farm soil and groundwater information is summarized. A summary of other DOE site tank closures is presented. A brief overview of characterization approaches, technologies, and tank closure technologies is given.

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AUG
RELEASE ID: 20

Janis Aardal 8-13-02
Release Approval Date Release Stamp

Approved For Public Release

RPP-10950
Rev. 0

ACCELERATED TANK CLOSURE DEMONSTRATION DATA ASSESSMENT

August 2002

CONTACT
M. J. Riess
CH2M HILL Hanford Group, Inc.

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ABBREVIATIONS AND ACRONYMS

3-D	three dimensional
BBI	Best Basis Inventory
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act*
CFR	*Code of Federal Regulations*
CHG	CH2M HILL Hanford Group, Inc.
CMSA	calcium monosulfate aluminate
COC	contaminant of concern
COPC	contaminant of potential concern
CWP	coating waste (PUREX)
DAR	data assessment report
DOE	U.S. Department of Energy
DQO	data quality objective
DST	double-shell tank
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EMI	electromagnetic induction
EPA	U. S. Environmental Protection Agency
GPR	ground penetrating radar
HDW	Hanford Defined Waste
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HLW	high-level waste
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LDUA	Light Duty Utility Arm
LIBS	laser-induced breakdown spectroscopy
MDL	minimum detection level
MPI	multiple-point grout injection
MRS	Mobile Retrieval System
NEPA	*National Environmental Policy Act*
ORNL	Oak Ridge National Laboratory
ORP	Office of River Protection
ORR	Oak Ridge Reservation
PCBs	polychlorinated biphenyls
PNNL	Pacific Northwest National Laboratory
PQL	practical quantitation limit
PUREX	plutonium uranium extraction
RCRA	*Resource Conservation and Recovery Act*
ROD	Record of Decision
RPE	Retrieval Performance Evaluation
SGLS	Spectral Gamma Logging System
SIAC	silver impregnated activated carbon
SNL	Sandia National Laboratory
SRS	Savannah River Site
SST	single-shell tank
TMS	topographical mapping system

TOC	total organic carbon
TPA	Tri-Party Agreement
UPR	unplanned release
WAC	Washington Administrative Code
WIDS	Waste Identification System
WIR	waste incidental to reprocessing
WSRC	Westinghouse Savannah River Company

EXECUTIVE SUMMARY

The purpose of this Data Assessment Report (DAR) is to summarize and assess available characterization information and to present closure approaches and technologies for the C-106 and the C-200 series (C-201, C-202, C-203, and C-204) closure demonstration tanks. The scope of the closure demonstration project and this document are focused on the in-place closure of the five-closure demonstration tank structures including any remaining residual waste remaining after retrieval. Closure of soils and groundwater are not included with this demonstration. Closure of tank farm ancillary equipment with noted exceptions is not included with this demonstration. Closure of ancillary equipment inside the tank structure (e.g. cut off piping, transfer pumps, etc.) and ancillary equipment directly connected to the tank structure (e.g. overflow piping and risers) are addressed with this demonstration. Closure of groundwater is a 200 Area wide and Hanford site wide issue and is being addressed in those contexts. Closure of soil and tank farm ancillary equipment are C Tank Farm issues and will be addressed in that context during closure of the entire tank farm. Again this closure demonstration project and document are focused on the closure of the five-closure demonstration tank structures.

As a part of the data assessment, an assessment of the residual waste volumes of the closure demonstration tanks was conducted. The currently accepted operational residual waste volumes are included in the Best Basis Inventory (BBI) system. The BBI system is a database system used to track and establish tank waste inventories primarily for tank operational purposes. The generally accepted BBI waste volume for the C-106 tank is 115,000 L (30,000 gal) of liquid supernate and 23,000 L (6,000 gal) of solids or sludge. These volumes were primarily established following the 1999 sluicing activities and are based on mass transfer calculations and current tank waste levels. The total volume basis for the C-106 tank appears to be sound. From a closure perspective additional residual volume refinement of the solids will be necessary following the expected retrieval of the supernate and additional retrieval of solids. For the C-200 series tanks the BBI operational residual waste volumes are 4,000 L for the C-201 and C-202 tanks and 10,000 L for the C-203 and C-204 tanks. These volumes are entirely based on waste level measurements using conservative tank benchmark volumes and are also generally rounded up to the nearest 1,000 L. From a closure perspective this volume calculation method is too conservative. Through additional waste volume refinement the current residual waste volumes in the C-200 series tanks are more accurately represented for potential closure as 1,850 L (490 gals) for C-201, 2,080 L (550 gals) for C-202, and 7,100 L (1,880 gals) for both C-203 and C-204.

The available waste characterization data for the five closure demonstration tanks is generally contained in the BBI system. The BBI system is a database system that uses multiple sources to establish tank waste inventories. Inventories are based on analyses of waste samples from the subject tank, analyses of waste samples from other tanks with similar waste history, calculations based on isotopic distributions, and process knowledge modeling. For the C-106 tank inventory, the primary inventory basis is from analyses of waste samples collected from the AY-102 tank following the sluicing of waste from the C-106 tank to the AY-102 tank in 1999. A qualitative assessment of the C-106 inventory information indicated that the inventory information should be reasonably representative of the remaining tank waste and sufficient for initial closure planning. Depending on ongoing tank closure data quality objective (DQO) efforts, ongoing risk assessments, and waste retrieval efforts, the data may be suitable for some closure purposes.

However, additional waste characterization for closure is likely necessary. For the C-200 series tank inventories, the primary inventory basis is process knowledge models. With the higher than actual residual waste volumes used for calculating the BBIs, the expectation is that the BBIs for the C-200 series tanks are very conservative and are sufficient for initial risk-based conservative bounding closure planning. However, for closure decisions, especially those related to applicable waste disposal regulations the inventories for the C-200 series tanks are likely too conservative for purposes of this closure demonstration.

Although soil closure is not included in this document, available C Tank Farm soil characterization data is summarized. The available soil characterization data for the C Tank Farm is limited and generally only includes historical knowledge of known releases to soil and gamma logging of 70 C Tank Farm boreholes. The historical knowledge of known releases indicates that the majority of documented waste released to soil is near the south corner of the C Tank Farm and is associated with the C-101 tank, the 244-CR vault, and the CR-151 and 152 diversion boxes. It is estimated that up to 91,000 L (24,000 gals) of waste has leaked from the C-101 tank. From the referenced vault and diversion boxes it is estimated that about 206,000 L (54,400 gals) has been released to the soil. In addition, approximately 65,800 L (17,380 gals) of waste was released to soil from the C-151 diversion box located near the west corner of the tank farm. Gamma logging boreholes were only completed in the areas surrounding the twelve 100 series tanks. The borehole gamma logging indicates the presence of primarily of Cs-137 and Co-60 with indications of elevated contamination beneath the C-101, C-104, C-105, C-106, C-108, C-109, C-110, C-111 tanks. For the contamination beneath the C-104, C-105, C-106, and C-110, tanks the gamma logging generally indicates surface or near surface sources (e.g. surface spills or piping leaks). Because of their adjacent locations, contamination beneath the C-101, C-108, C-109, and C-111 tanks may be representative of the lateral and vertical migration of the near surface sources mentioned above or may be from other sources such as tank leaks or may be a combination of both. The C-101, C-110, C-111, and the four C-200 series tanks have been previously identified as assumed leaking tanks.

Although groundwater closure is not included in this document, available C Tank Farm groundwater characterization data is summarized. Groundwater information is a good characterization source for indications of soil contaminant sources. There are five monitoring wells surrounding the C Tank Farm. Detections of Tc-99 and nitrate are generally increasing in four of the wells. In two of the wells at the northeast and southeast boundary of the C Tank Farm, concentrations of Tc-99 have been greater than the drinking water maximum contaminant level of 900 pCi/L since 2001.

In addition, this Data Assessment Report (DAR) provides a summary of other complete or ongoing U.S. Department of Energy (DOE) site tank closures including the Savannah River Site (SRS), Oak Ridge Reservation (ORR), and Idaho National Engineering and Environmental Laboratory (INEEL). In brief, the SRS has closed two 1.3 million gal high level waste (HLW) tanks in-place by filling with a cementitious grout. These waste tanks were closed with about 3,800 L (1,000 gals, 134 cubic feet) of residual waste remaining in each tank. On a percentage basis the residual waste closed with the tank is less than 0.1 % of the total tank volume. ORR has closed all but 3 of 40 relatively small, low level waste tanks. Bulk wastes were removed to the extent practicable (approximately 95% of the radioactivity) prior to closure in-place using a cementitious grout. INEEL is pursuing closure of its 11 sound stainless steel HLW waste tanks

through extensive retrieval and decontamination. INEEL expects to fill two to five tanks with a cementitious grout by the end of FY 2004.

This DAR summarizes characterization approaches that are currently being used on the Hanford site and potential closure approaches that could be considered for closure of tanks, soil, and ancillary equipment. Characterization approaches range from conservative or graded approaches to extensive characterization approaches prior to closure. Tank closure approaches generally range from stepped closure approaches with decision points between steps to a full closure approach where decision criteria are well defined and facility conditions are well characterized and known.

Also discussed, is the sensitivity and uncertainty associated with the characterization data sets for closure. The characterization data sets include soil and residual waste information. Soil data can be divided into contamination from previous releases and potential contamination from waste retrieval leaks. The residual waste data sets can be divided into waste volumes and concentrations for residual tank wastes and residuals within ancillary equipment. Sensitivity assessments from the AX Farm RPE indicate that from a risk perspective the most influential characterization data sets associated with long-term risk are previous soil contamination and potential retrieval leakage. For these demonstrations the primary focus is the closure of the tank structure, the primary closure drivers include applicable waste disposal regulations, the impacts from waste retrieval activities and the assessment of risk from remaining residuals. On this basis the most influential and sensitive data set to closure of tanks currently appears to be residual tank waste volume and concentration.

Also included in the data assessment, is a brief overview of characterization technologies, sample collection technologies, waste volume calculation technologies, waste retrieval technologies, tank closure technologies including tank fill and residual waste stabilization technologies, and surveillance technologies. The technology discussions are generally limited to technologies that have been previously studied and identified as a reasonably implementable technology. The discussion is also limited to those technologies that have the potential to be implemented in the near term. Limited qualitative technology screening based on implementation and applicability to the closure demonstration tanks is also performed. The purpose of this limited screening is to provide a basis for initiation of preliminary engineering on a representative tank closure approach.

The limited screening tentatively identified cementitious grout as the preferred tank fill structural stabilization technology as well as the preferred residual tank waste stabilization technology. Contaminant specific chemical "getter" compounds beyond common grout additives (e.g. fly ash, slag, etc.), with the possible exception of hydroxyapatite, were screened out primarily for implementation, applicability, and technology maturity reasons. Hydroxyapatite is currently under development and study by Sandia National Laboratory (SNL) for use as a grout additive for tank closure. It must be noted that the project intends to complete further studies and evaluation including an Alternatives Generation and Analysis report.

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The primary purpose of this Data Assessment Report (DAR) is to summarize and assess available characterization information, present closure approaches and technologies, and to provide information for use in a closure Alternatives Generation and Analysis Report (AGA) for the C-106 and the C-200 series closure demonstration tanks (C-201, C-202, C-203, and C-204). This report also includes a summary of similar projects that have been completed at other Department of Energy (DOE) sites. Closure of the demonstration tanks is scheduled for calendar year 2004. These five single shell tanks are located on the Hanford Site in the 200 East Area within the C Tank Farm. The selection of these tanks for this accelerated tank closure demonstration (ATCD) project is summarized in Section 1.3. Additional tank specific information is summarized in Section 2.0.

The scope of this document supports in-place closure of the tank structures. The *Single-Shell Tank (SST) System Closure Work Plan* (DOE 2002) identifies landfill or in-place closure of the SSTs as the preferred closure approach. Closure of these tanks will be done in accordance with an approved Closure Plan.

This document does not address closure for groundwater, vadose zone soil (includes all soil from ground surface to groundwater including soil surrounding tanks), or final tank farm surface barriers. Groundwater is a 200 Area wide issue and is being addressed in that context.

However, this document does include an evaluation of available soil information and does address general soil characterization approaches for closure. Closure of vadose zone soil will be addressed in the context of the entire tank farm and will be addressed during C tank farm closure process. For this reason, soil remediation / closure technologies are not included in this document. With the exception of soil removal from beneath a tank, in-place closure of the tank structure would not necessarily preclude potential future corrective measures for soils. Removal of the tank structure and removal of soil beneath the tanks have generally been ruled out as closure/corrective measure options (DOE 2002). Final tank farm surface barriers are an entire tank farm issue and will be addressed during closure of the entire C Tank Farm. Vadose zone and surface barrier (both final and interim barriers) needs are currently being assessed in ongoing risk assessments. From the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement,* the current and future land use for the 200 Area has been designated as industrial-exclusive use relating to waste management activities for at least 50 years.

The focus of the closure demonstration project and this document are for the in-place closure of the demonstration tank structures.

1.2 REGULATORY AUTHORITY

Under the Hanford Federal Facilities Act and Compliance Order (HFFACO) (Ecology et al., 1989) SSTs are regulated as *Resource Conservation and Recovery Act* (RCRA) hazardous waste

storage and treatment 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 EPA is responsible for implementing the undelegated portions of the program. 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 *Atomic Energy Act* (AEA). Closure of the SSTs will occur under both WAC 173-303-610, per the HFFACO, and the AEA including DOE Order 435.1. Therefore the regulatory authority for closure demonstration activities is WAC 173-303 and AEA. Closure plans satisfying RCRA and DOE requirements are being prepared for the closure demonstration.

1.3 CLOSURE DEMONSTRATION TANK SELECTION

There has been ongoing discussions between Ecology and the DOE regarding the selection of the tanks for this closure demonstration. The tanks preliminarily selected by the DOE for this closure demonstration are the C-106, C-201, C-202, C-203, and the C-204 tanks.

Many of the concepts, approaches, and technologies presented in this report are relevant to any tank that is ultimately selected for this closure demonstration.

1.4 DOCUMENT ORGANIZATION

This document is organized into the following sections:

Section 1.0 Introduction
Section 2.0 Background and Supporting Information
Section 3.0 Characterization Information
Section 4.0 DOE Complex Wide Tank Closures
Section 5.0 Closure Demonstration Performance Objectives
Section 6.0 Contaminants of Concern for Closure
Section 7.0 Closure Approaches
Section 8.0 Characterization Approaches and Technologies
Section 9.0 Waste Retrieval Technologies
Section 10.0 Tank Closure Technologies and Screening Assessment
Section 11.0 Ancillary Equipment
Section 12.0 Surveillance and Monitoring
Section 13.0 Conclusions
Section 14.0 References

Appendices A, B, and C support the main text. Appendix A includes a DOE tank closure program cost summary. Appendix B contains residual waste volume spreadsheets for the C-200 series tanks. Appendix C contains a detailed tabulation of the ancillary equipment with referenced drawings for the closure demonstration tanks.

2.0 BACKGROUND, AND SUPPORTING INFORMATION

2.1 FACILITY BACKGROUND

The Department of Energy (DOE) operates the Hanford Site on approximately 1,450 square kilometers (560 square miles) of arid shrub-steppe in the southeastern part of Washington State (Figure 2-1). The isolated and sparsely populated location near the Columbia River was selected in 1942 as the site for the first industrial-sized operations to manufacture plutonium. From 1944 to the late 1980s the production of defense related materials at the Hanford Site has resulted in the large-scale generation of solid and liquid radioactive mixed waste. More than 1,510,000,000 L (400 million gals) of high-level waste have been generated by irradiated uranium fuel processing and reprocessing operations, of which more than 1,140,000,000 L (300 million gals) were directed to the site single-shell and double-shell underground waste tanks (Agnew, S.F., J. Boyer, R.A. Corbin, T.B. Duran, J.R. Fitzpatrick, K.A. Jergensen, T.P. Ortiz, B.L. Young, 1997). The tanks now contain a mixture of salt cake, liquid, and sludges with both radioactive and hazardous components.

2.2 C TANK FARM DESCRIPTION AND BACKGROUND

The C-Farm tanks were built during the initial 30-month war-time construction period (1941 to 1944), in the 200 East Area, near the location of the planned C Plant chemical processing facility. The C Tank Farm consists of twelve 100 series tanks and four 200 series tanks (Figures 2-2 and 2-3). The 100 series tanks are 22.9 m (75 ft) in diameter with capacities of 2,010,000 L (530,000 gal). The 200 series tanks are 6.1 m (20 ft) in diameter with capacities of 208,000 L (55,000 gal). Both types of tanks are constructed of reinforced concrete with welded carbon steel liners. These tanks were designed for non-boiling waste with maximum temperatures of 104 degrees Celsius (220 degrees Fahrenheit) and a pH of 8-10 (Simpson et al. 1994). A cross-sectional and plan view of the C-106 tank are included in Figures 2-4 and 2-5, respectively. A typical cross-sectional and plan view of the C-200 series tanks are included in Figures 2-6 and 2-7, respectively.

2.3 C-200 SERIES AND C-106 TANK BACKGROUND AND DESCRIPTION

2.3.1 Tank 241-C-106 Tank Waste Transfer History

Tank C-106 is the last tank in a three tank cascade beginning with tanks C-104 and C-105 (Schreiber, R.D. 1994). The C-106 tank was put into service in 1947, when it received metal waste from the cascade overflow from tank C-105. The metal waste was sluiced for uranium recovery in 1953, and the tank became the metal waste supernatant blend tank, receiving metal waste from tanks BY-102, C-104, C-105, C-202, C-203, and C-204 (Agnew, S.F., R.A. Corbin, T.B. Duran, K.A. Jurgensen, T.P. Ortiz, and B.L. Young, 1997). Metal waste slurry was sent to U-Plant for uranium recovery in 1953 and 1954, and uranium recovery waste was received into tank C-106 in 1954.

Liquid waste from tank C-106 was sent to tanks C-112 and C-109 for ferrocyanide scavenging in 1957, and during that same year tank C-106 received flush water, high-level plutonium uranium extraction (PUREX) waste from tanks A-101 and A-102, and organic wash water from tank A-102. Between 1958 and 1960, PUREX cladding waste was sent to tank C-106, and supernatant was sent from tank C-106 to tank BY-110. In 1963, supernatant was sent to tanks B-101 and B-107. Waste was received from and sent to tank A-102 in 1963 and 1964. Tank C-106 received decontamination waste from the CR Vault in 1965.

In 1968, most of the waste in tank C-106 was sent to tank C-105. Between 1968 and 1971 tank C-106 received washed PUREX waste from the 244-AR Vault. During this time, tank C-106 also received waste from tanks A-102, A-104, A-106, and C-103, and sent waste to tanks A-102, C-103, and C-105. In 1972, tank C-106 received waste from tank A-106.

Low-level waste from B-Plant and flush water was sent to tank C-106 between 1974 and 1976. During this time, waste was sent from tank C-106 to tanks AX-103, C-103, and C-104. Between 1976 and 1979 strontium recovery waste from B-Plant and complexed and evaporator waste were sent to and received from tank A-102. Waste was sent from tank C-106 to tank AZ-101 in 1978. Tank C-106 was declared inactive in 1979. A general waste transfer history and relative waste volume history through 1995 (with estimated waste forms) for tank C-106 are shown on Figure 2-8.

Detailed descriptions of the processes that generated the categories of waste (metal waste, PUREX cladding waste, and uranium recovery waste) can be found in (Sasaki, L.M. 2001), (Agnew, S.F., J. Boyer, R.A. Corbin, T.B. Duran, J.R. Fitzpatrick, K.A. Jergensen, T.P. Ortiz, B.L. Young, 1997), (GE 1944), and (GE 1951).

2.3.2 Tank 241-C-106 Release, Recent Retrieval History, and Retrieval Leak Monitoring

Tank C-106 is classified as a sound tank, as surveillance and historical data indicate no loss of liquid attributed to breach of integrity.

To resolve high heat safety issues, the C-106 tank was sluiced from November 1998 through September 1999. Approximately 97% of the waste was removed during sluicing activities (DeFigh-Price, C. 2000). From an electronic memo (Carothers 2000), three methods of leak detection were employed during sluicing. These methods are described in *Tank 241-C-106 Waste Retrieval Sluicing System Process Control Plan* (Carothers, 1998). The methods included 1) performing a cumulative engineering material balance for the process, 2) monitoring C-106 liquid levels, and 3) borehole measurements at six boreholes surrounding the tank. Using the project leak detection criteria for sluicing activities, the three methods did not indicate that a leak occurred during sluicing (Carothers 2000).

Using the material balance method, the criteria for stopping sluicing to conduct a leak evaluation was set at 8,000 gallons per the Project W-320 Environmental Assessment (DOE-RL 1995) and (Hertzel 1997). Using the 8,000 gallons as the definition of a leak, the mass balance method did not indicate the necessity for a leak evaluation. At the end of sluicing operations, the final material balance gave a negative volume of 6,184 gallons, indicating a 6,184 gallon loss. The volume was determined to be in the acceptable range of the sluicing project material balance

discrepancies. Following sluicing, potential material balance errors or discrepancies that could impact the accuracy of mass balance based retrieval leakage monitoring were presented to Ecology. For the C-106 sluicing project the potential discrepancies and associated volumes included:

- C-106 ENRAF level gauge (± 280 gallons)
- AY-102 ENRAF level gauge (± 280 gallons)
- C-106 tank radius tolerances (tolerances not shown on engineering drawings and therefore difficult to quantify, but could be potentially significant)
- AY-102 tank radius tolerances (+0 to –1,500 gallons)
- C-106 retained gas volume (-5,000 to –10,000 gallons)
- Flush water additions (±2,500 gallons)
- Caustic addition (-1,300 gallons)
- Sludge dissolution (±3,000 gallons)
- Exposed solids volume (±1,300 gallons)
- Other instruments

Using the liquid level monitoring method, leak monitoring was conducted for the sluicing project during periods when there was no active sluicing or pumping. The leak detection criteria for liquid level monitoring method was 1.3 cm (0.5 in.). There were no measurable drops in liquid levels during the periods of monitoring.

Leak monitoring using the borehole measurement method was performed in six boreholes around the C-106 tank. The gross gamma scans showed no detectible change in activity attributable to sluicing activities. Although differences in gross gamma response were observed in most of the boreholes, the differences were attributed to contaminant movement independent of sluicing activities, radon pumping, equipment setup issues, and expected scan variation.

As a part of leak detection activities the six boreholes were each logged monthly between February 1999 and December 1999 (total of 10 logging events for each drywell) (Barnes 2000). In borehole 30-06-03 (Hanford site designation 299-E27-84) the initial logging activities conducted in February 1999 identified about 20 feet of water at the bottom of the borehole. Borehole 30-06-03 is located 5 feet to the east of tank C-106 and was installed in 1974 with a 6-inch diameter casing to a depth of 100 feet below ground surface. The drilling report for the borehole does not indicate if the borehole casing was perforated or grouted. Succeeding monthly logging activities of the borehole indicated that the water level decreased from the initial 20 feet in February 1999, to 14 feet in March to 8 feet in May to 1.5 feet in July and was not present in August 1999. The source of the water in the borehole is not known.

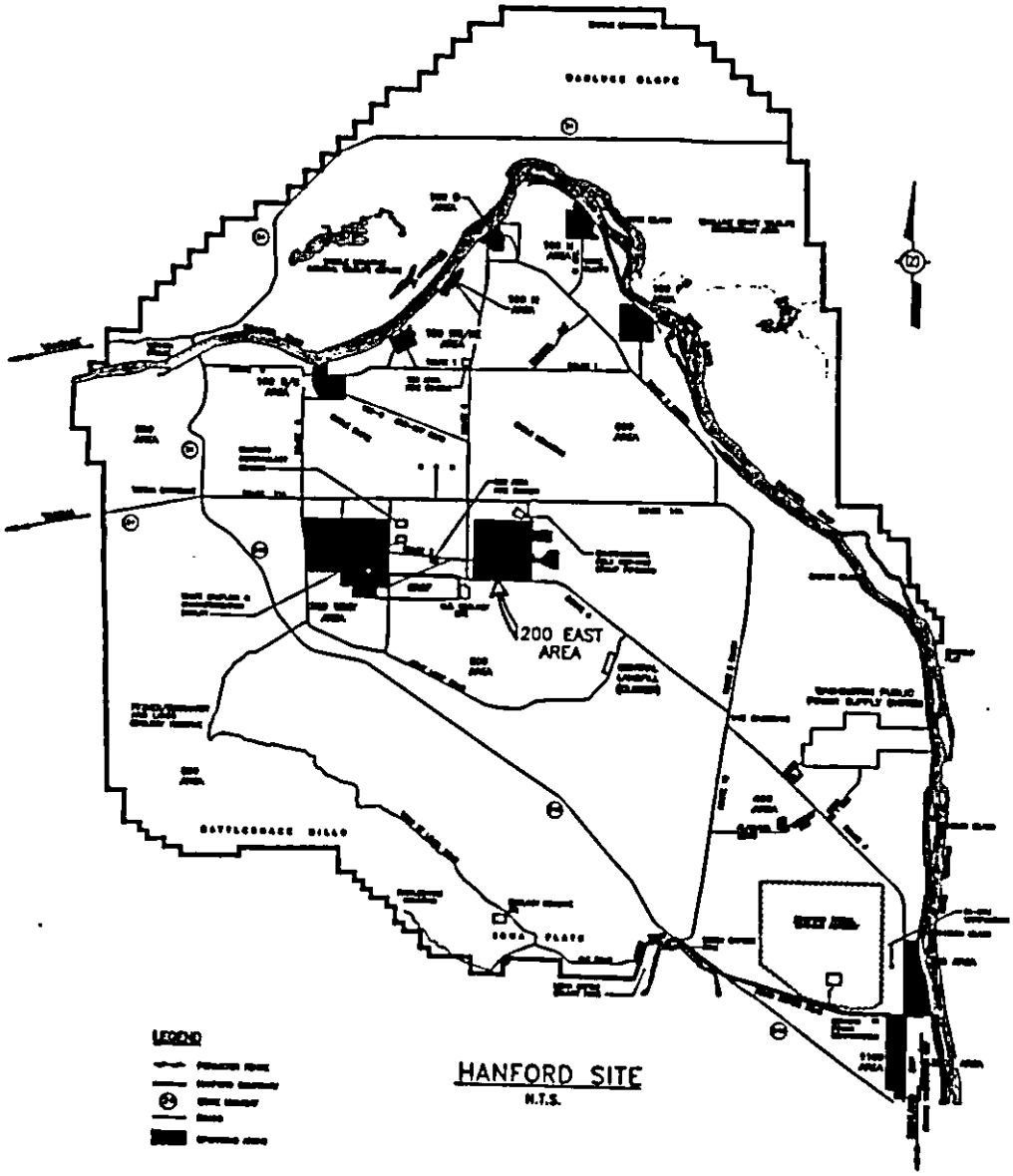
2.3.3 Tank 241-C-106 Residual Waste Form and Volume

Current estimates for the tank 241-C-106 inventory, with the effective date of January 1, 2001, include 23,000 L (6,000 gal) of solids (sludge), and 115,000 L (30,000 gal) of liquid (supernatant), as documented in the best-basis inventory (BBI). The sludge volume reported in (Carothers, K.G., L.A. Stauffer, J.W. Bailey, 1999) was the basis for the solids volume for the C-106 tank BBI estimate. The volume of 5,500 gal was rounded to 6,000 gal as the BBI reports the volume in kilogallon units. On the recent video (August 1, 2002), the solids volume estimate

of 23,000 L (6,000 gal) under-represents the actual sludge volume. Additional discussion regarding residual waste volume calculation methodology including assessment is in Section 3.2.

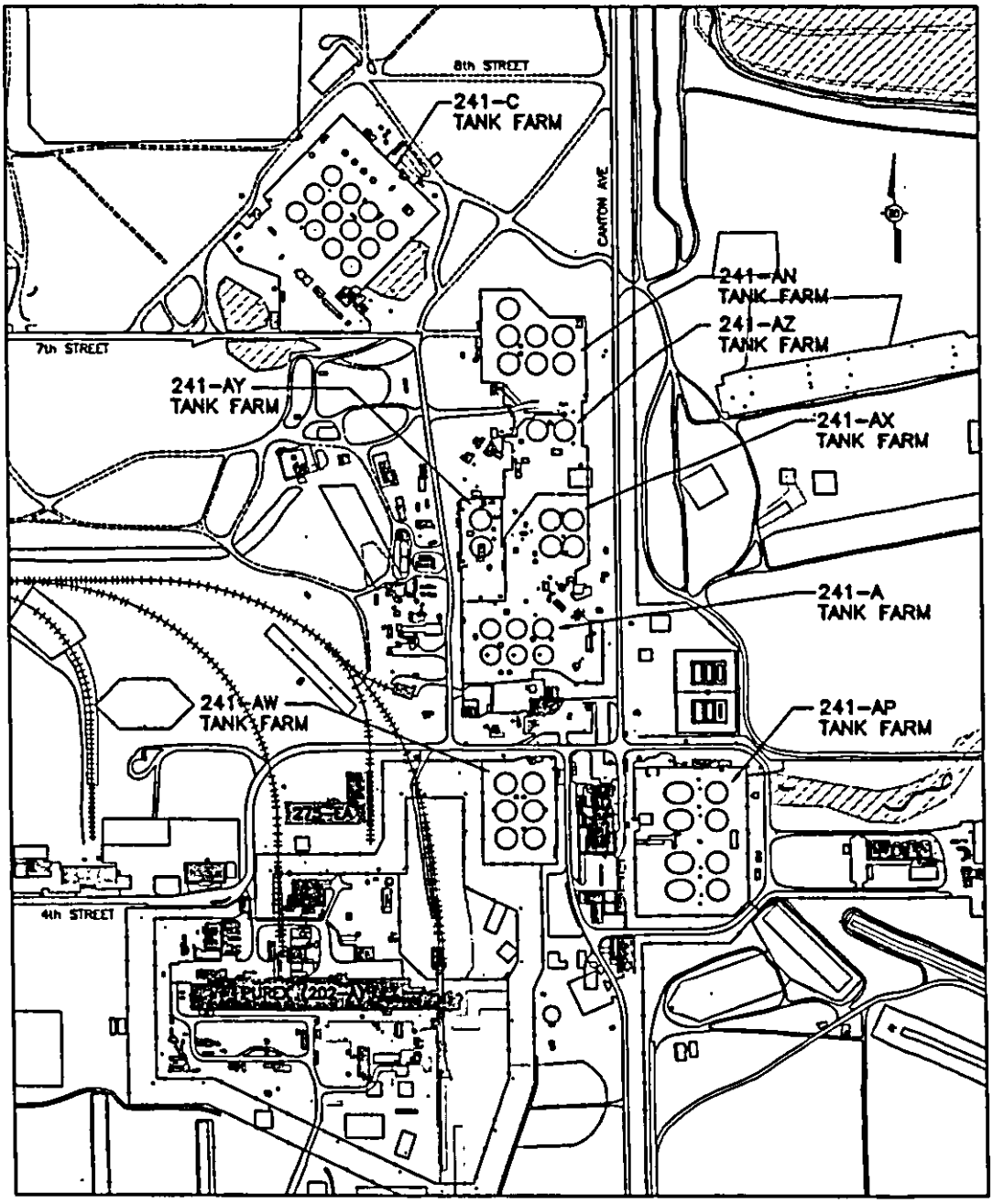
POOR QUALITY ORIGINAL

Figure 2-1. Hanford Site Map



POOR QUALITY ORIGINAL

Figure 2-2. C Tank Farm Location



POOR QUALITY ORIGINAL

Figure 2-3. C Tank Farm and Monitoring Well Location

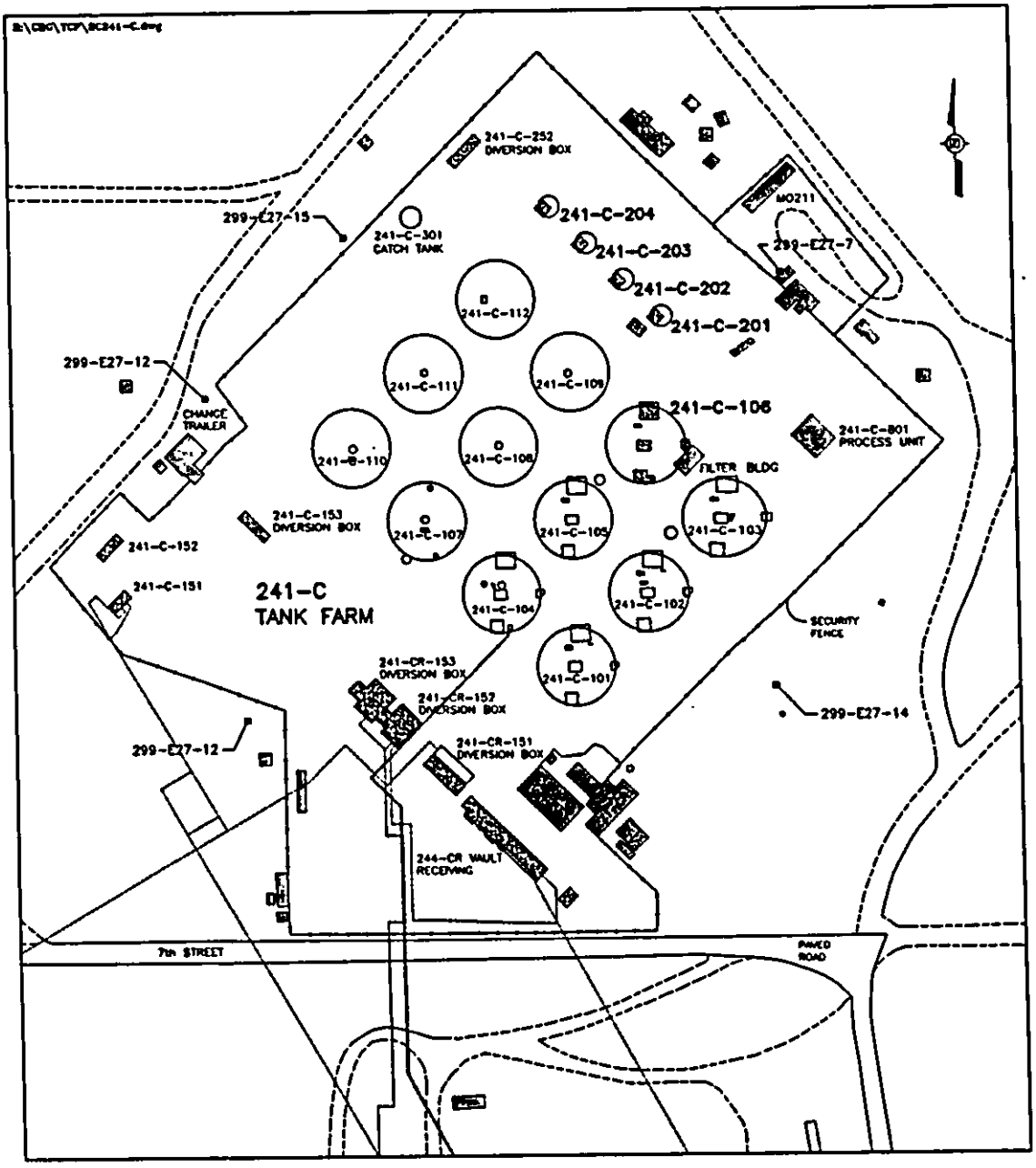


Figure 2-4. Generalized Cross-Sectional View of the C-106 Tank.

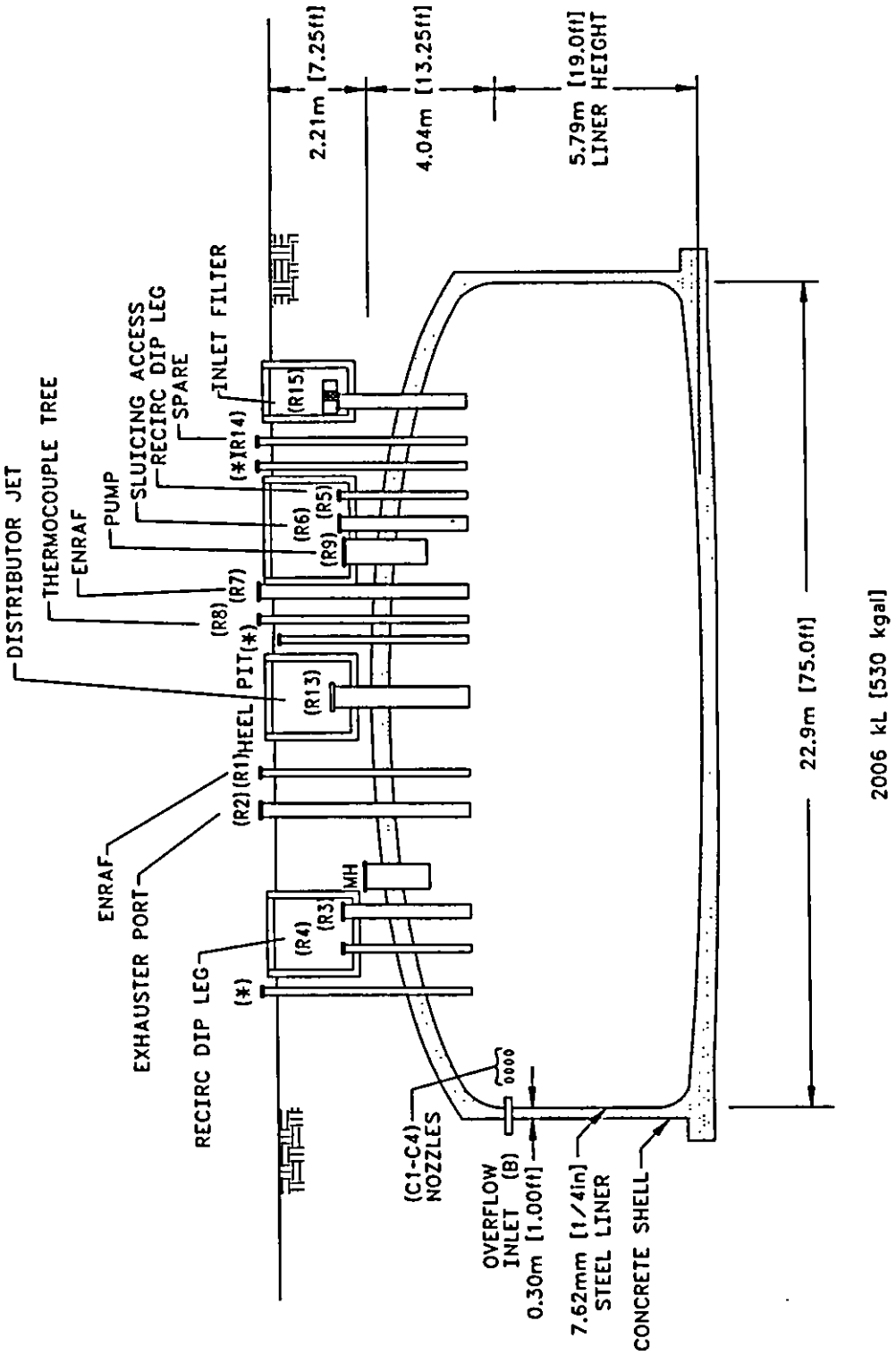


Figure 2-5. Plan View of the C-106 Tank

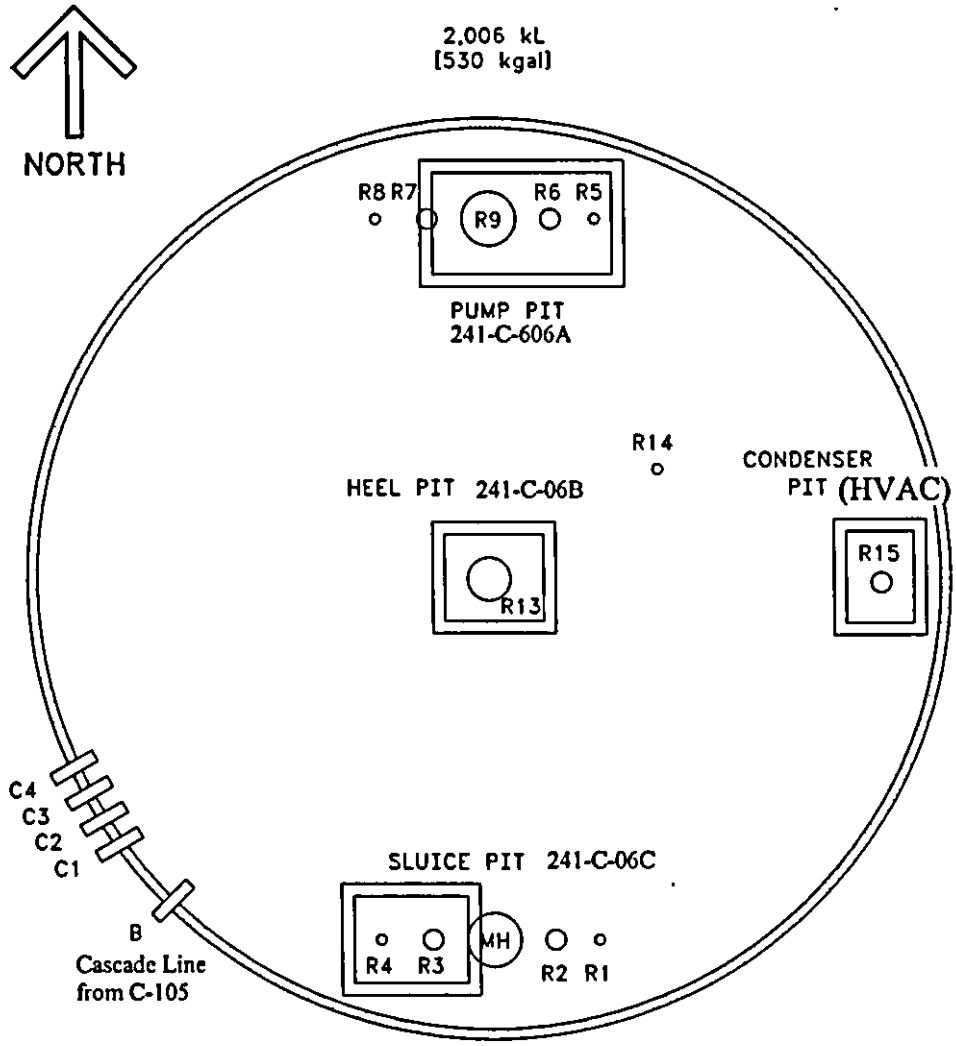


Figure 2-6. Generalized Cross-Sectional View of the C-200 Series Tanks

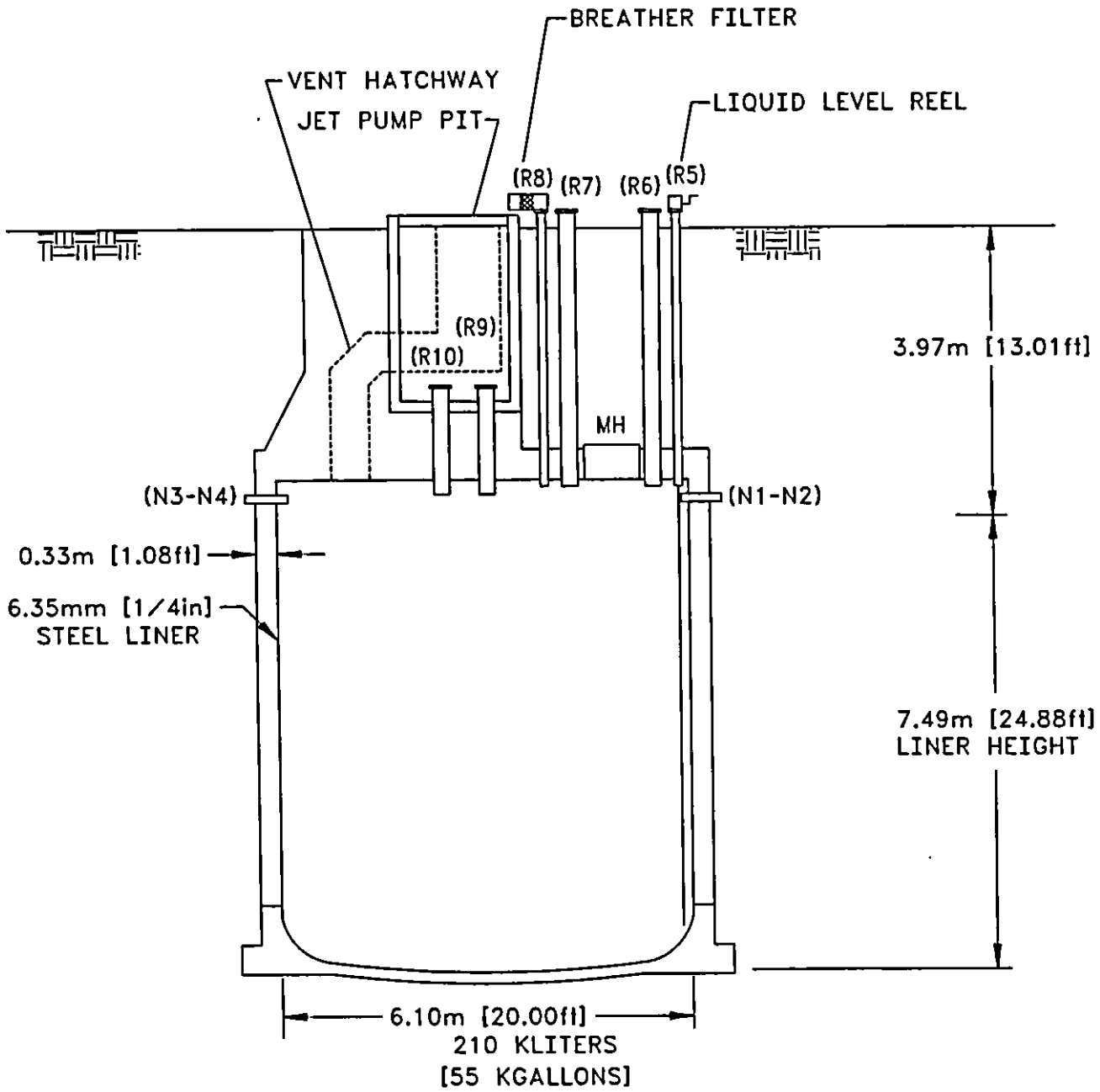


Figure 2-7. Plan View of the C-200 Series Tanks

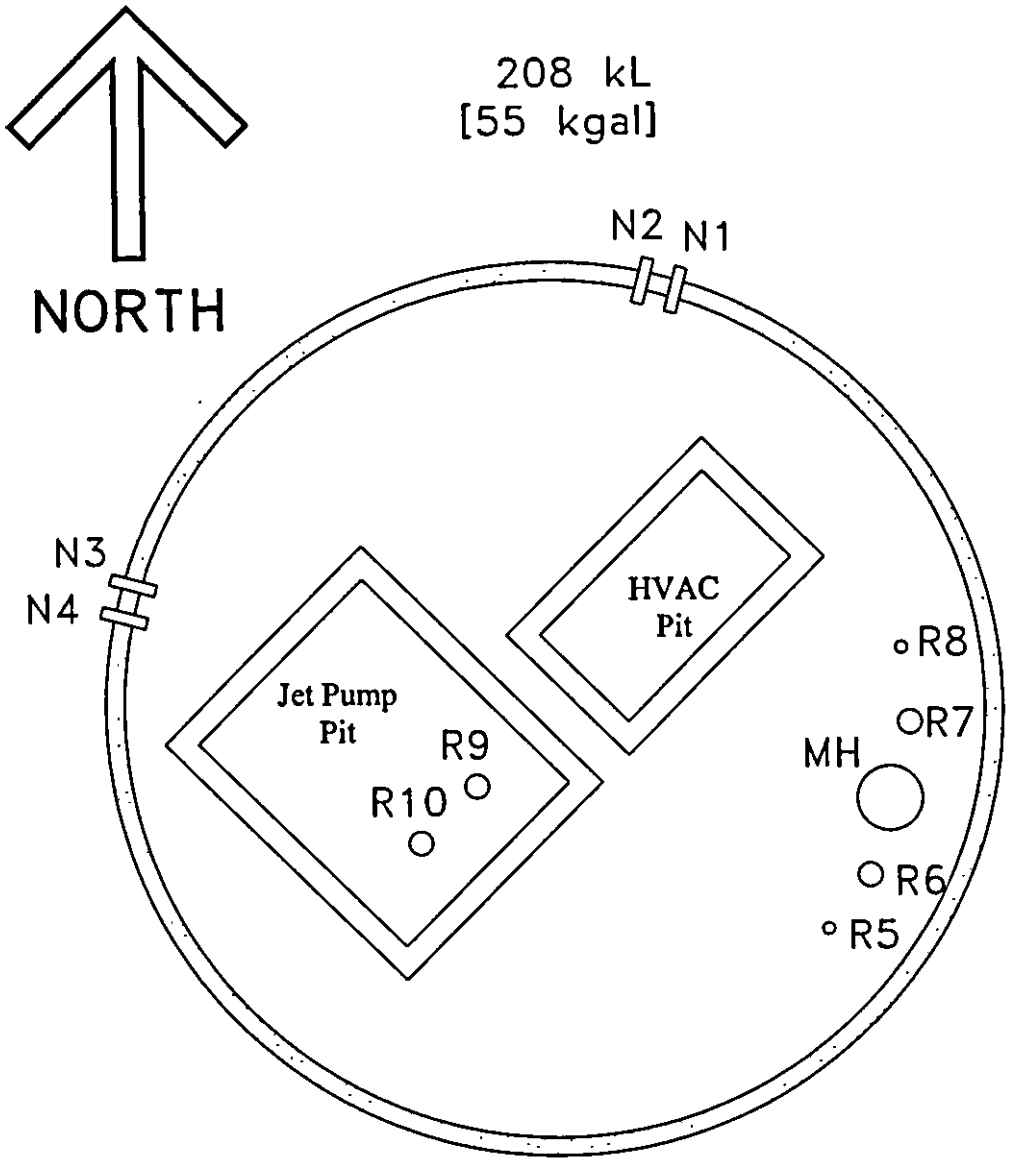
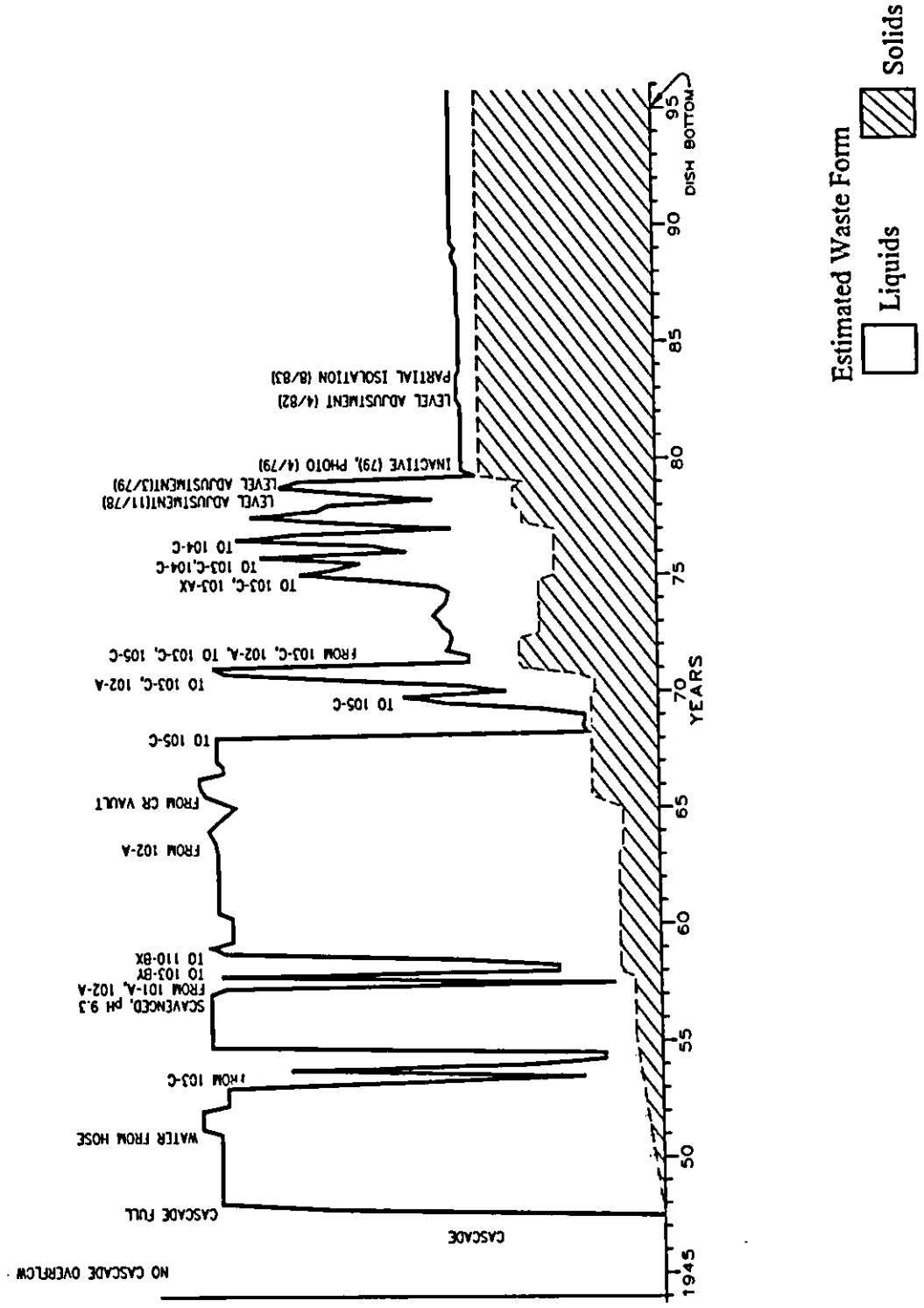


Figure 2-8. C-106 Waste Transfer History and Relative Waste Volume History (Does not include the 1999 sluicing waste retrieval)



2.3.4 C-200 Series Tanks Waste Transfer History

The four smaller 200 series tanks are not cascaded. Tanks C-201, C-202, and C-203 went into service in 1947, when they received B Plant metal waste. Tank C-204 began receiving waste from tank C-203 in 1948. The tanks were all sluiced for uranium recovery in 1953, and supernatant was transferred from tanks C-202, C-203 and C-204 to tank C-106 (Agnew et al. 1997b). The remaining sludge in tank C-201 was transferred to tank C-204 in 1954, and metal waste was sent from tank C-204 to uranium recovery operations in the 221-U building. Tanks C-201, C-202, and C-203 were declared empty in 1954. In 1955, tank C-204 was emptied with a transfer to the uranium recovery operations in the 221-U building.

In 1955 and 1956, all four tanks received hot semiworks waste generated during PUREX pilot plant studies conducted in the mid 1950s. Tank C-204 received waste in 1967 from the strontium recovery operations at the hot semiworks plant.

Waste was transferred from tank C-202 to tank C-109 during the first quarter of 1970. Supernatant was transferred to tank C-104 from each of the 200 series tanks, in 1970, as well. Tanks C-201, C-202, and C-203 were removed from service in 1976. Tank C-204 transferred waste to an unknown receiver in 1977, and was removed from service that same year. A general waste transfer history and relative waste volume history (with estimated waste forms) for the C-201, C-202, C203, and C-204 tanks are shown on Figures 2-9, 2-10, 2-11, and 2-12 respectively. The relative volumes are based on historical waste level measurements. The figures reflect information through 1995, which reflects the current information for the C-200 series tanks.

Detailed descriptions of the processes that generated the categories of wastes can be found in (Sasaki 2001), (Agnew, S.F., J. Boyer, R.A. Corbin, T.B. Duran, J.R. Fitzpatrick, K.A. Jergensen, T.P. Ortiz, B.L. Young, 1997), (GE 1944), (GE 1951), (GE 1963), and (GE 1965).

2.3.5 C-200 Series Tanks Release History

The C-200 series tanks are four of sixty-seven single-shell tanks (SSTs) currently listed as assumed leakers. Tank 241-C-203 was the first C-200 series tank to be declared an assumed leaker. In 1984, observed liquid level decreases in the tank gave an estimate of 1,500 L (400 gals) of liquid lost from tank 241-C-203. Tanks 241-C-201, 241-C-202, and 241-C-204 were declared assumed leakers in 1988, with the volume lost for each tank estimated at 2,100 L (550) gals, 1,700 L (450 gals), and 1,300 L (350 gals), respectively. Because of the low waste volumes in the C-200 series tanks, all four tanks were administratively interim stabilized.

A memorandum (Groth 1987) indicates that the C-201, C-202, and C-204 tanks leaked during the 1980s. The basis of the assumed leaker designation is not clear, but is likely due to measured decreases in waste levels. All four of the C-200 series tanks had intrusion prevention measures implemented in 1982. Intrusion measures primarily were in the form of applying a spray foam to the tank access pits. The waste levels would decrease at a faster rate because there would potentially only be waste mass exiting the tank in the form of evaporation and potential leakage. Prior to the intrusion measures, there would have been water infiltration, evaporation, and

potential leakage affecting the waste level. Water intrusion would have been a contributor to waste mass and waste level. The likelihood that these tanks developed leaks only during the 1980s after over 10 years with relatively low volumes of waste is probably low. The more likely statement is that the C-200 series tanks experienced waste level decreases following intrusion prevention conducted in 1982. Whether the waste level decreases are solely attributable to evaporation or evaporation and a previously unnoticed slow leak is not known.

Figure 2-9. C-201 Waste Transfer History and Relative Waste Volume History.

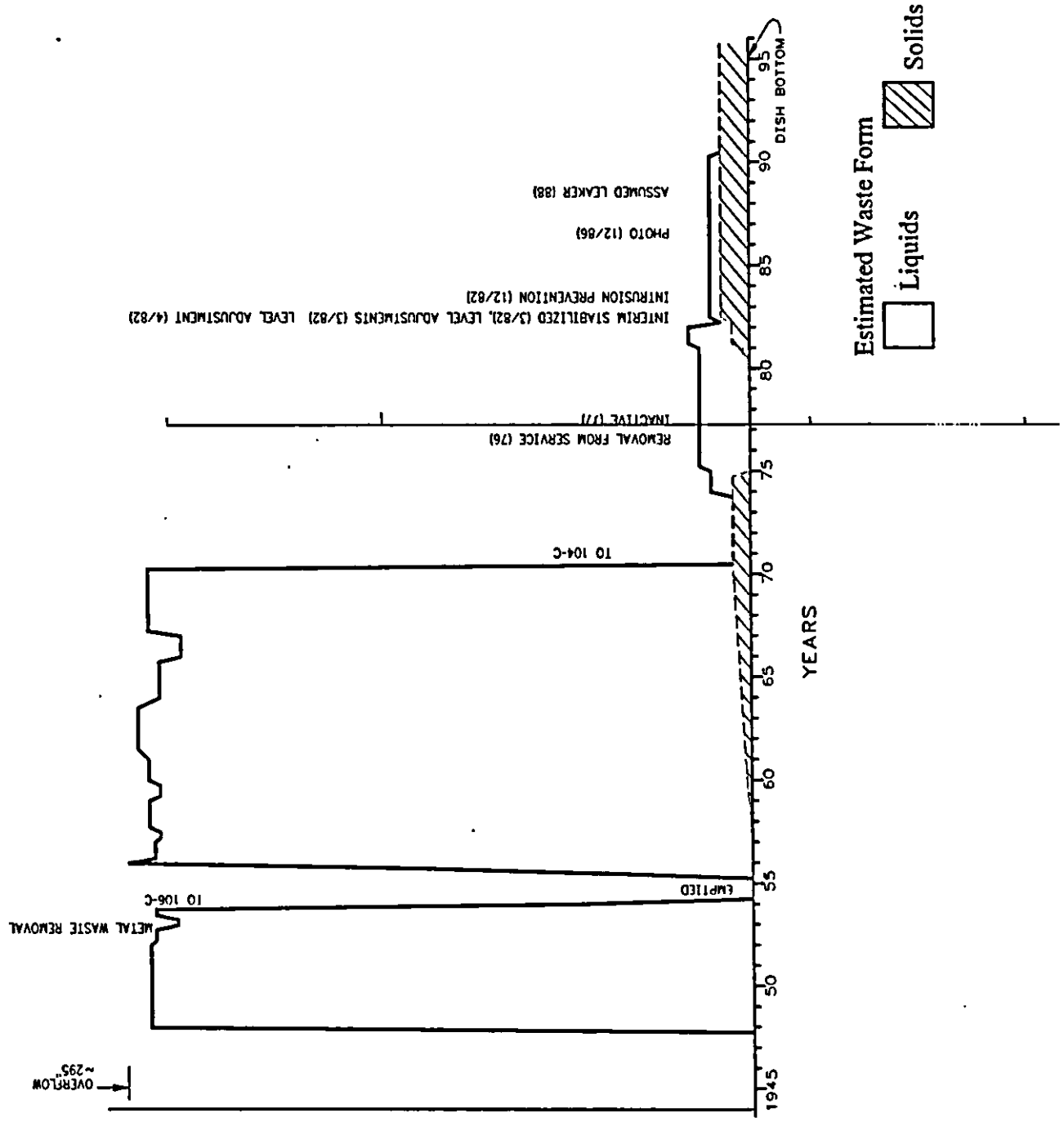


Figure 2-10. C-202 Waste Transfer History and Relative Waste Volume History.

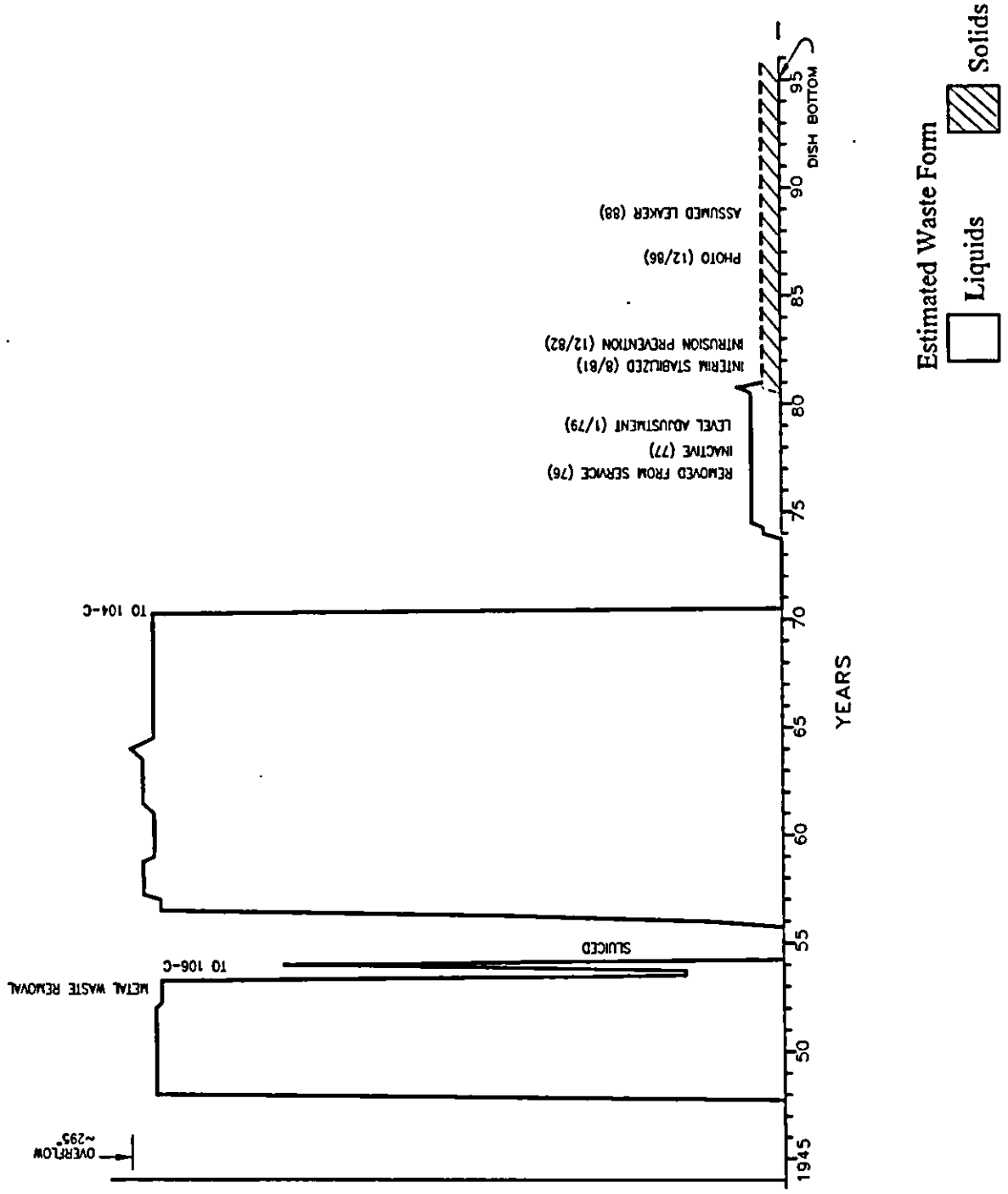


Figure 2-11. C-203 Waste Transfer History and Relative Waste Volume History.

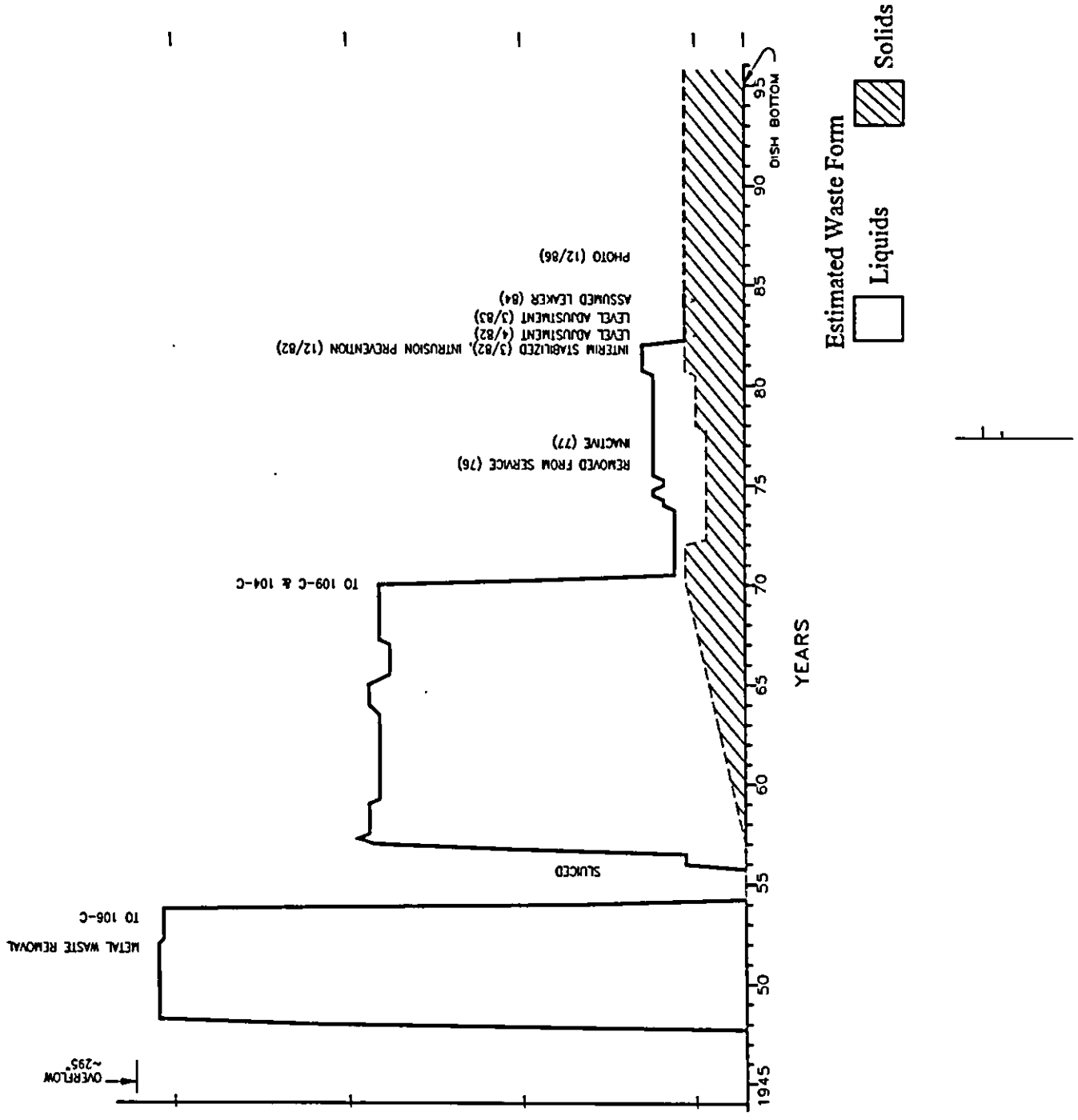
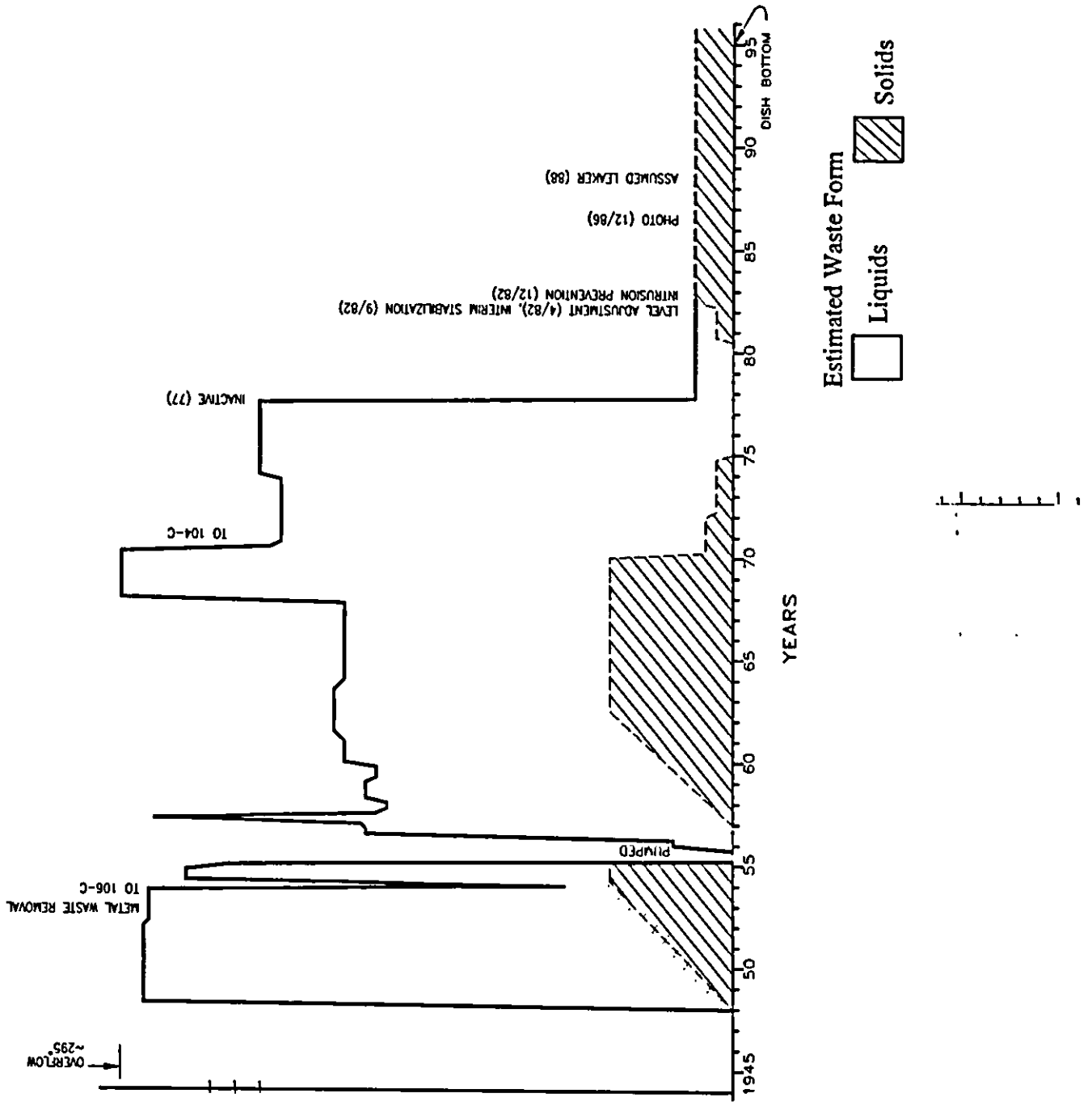


Figure 2-12. C-204 Waste Transfer History and Relative Waste Volume History.



2.3.6 C-200 Series Tank Residual Waste Form and Volume

Tanks C-201 and C-202 reportedly each contain 4,000 L (1,000 gal) of hot semiworks sludge, a volume calculated from manual tape readings of 7.5 inches and 8 inches respectively recorded for each tank in October 2000. The tank C-203 waste volume equals 10,000 L (3,000 gal) of hot semiworks sludge as calculated from manual tape readings showing a surface level reading of approximately 17 inches between 1999 and 2002. The tank C-204 waste volume equals 10,000 L (3,000 gal) of strontium semiworks sludge as calculated from manual tape readings showing a consistent surface level reading of approximately 17 inches between 1999 and 2002.

In tank photos and videos from the C-200 series tanks taken in the mid 1980s, in 1997, and in 2002 show a dry, relatively even, white to yellow to yellowish-black surface in each tank. Additional discussion of information gathered from the recent video surveys is included in Section 3.0.

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3.0 CHARACTERIZATION INFORMATION

This section summarizes and references the available characterization information and the ongoing characterization activities associated with the five closure demonstration tanks. Characterization information is summarized in terms of tank physical characterization, waste characterization (volume, concentration, waste form, and total inventory), and soil characterization. Following the waste characterization and soil characterization sections, a brief assessment of the information as related to tank closure is provided.

3.1 PHYSICAL TANK CHARACTERIZATION

General tank characterization information (e.g. tank volume, construction material, and history) was discussed in previous sections (Section 2.0). Presented below is tank specific information from previous and recent tank inspections. Also included, is a description of ongoing physical characterization activities. Appendix C includes a tank by tank summary table listing ancillary equipment with referenced engineering drawings.

3.1.1 Video Camera Surveys

3.1.1.1 Video Camera Survey of C-106 Taken in 2000. A video camera survey was conducted of the C-106 tank in July 2000 following the 1999 sluicing retrieval effort. The video generally showed the interior condition of the tank including in-tank ancillary equipment, tank sidewalls, and residual post-sluicing waste including miscellaneous debris. Viewable residual waste included liquid supernate and three relatively small piles or bergs of solid sludge type waste with a total estimated visible volume of approximately 6,000 gallons. This estimate does not include sludge below the liquid level that was not visible in the July 2000 video camera study.

The following equipment was visible in the video:

- Riser 1: ENRAF cable and float hanging in the riser
- Riser 2: nothing protruding into tank
- Riser 3: sluicer assembly
- Riser 4: old recirculating dip leg
- Riser 5: nothing protruding into tank
- Riser 6: presence of transfer pump PTX141 could not be confirmed due to the viewing angle and obstruction by the slurry pump in Riser 9, however, a floating pump suction and flexible line were visible in the video
- Riser 7: observation port from which the video was taken
- Riser 8: thermocouple tree
- Riser 9: slurry pump
- Riser 13: heel jet pump
- Riser 14: thermocouple tree
- Riser 15: nothing protruding into tank (condenser hatchway)

The existence of three additional 10 cm (4 inch) diameter risers shown on engineering drawings H-2-7352 and FCN-54902 could not be confirmed by the video. According to FCN-54902, the risers were installed for installation of thermocouple trees. The video showed that there are no thermocouple trees in the location where these risers were to be installed. A table listing tank ancillary equipment, risers, and referenced engineering drawings is included in Appendix C.

A section of pipe was visible on the bottom of the tank, partially resting on the slurry pump and extending past the thermocouple tree in Riser 8. The pipe is probably an old temperature probe and is estimated to be 2" in diameter and greater than 10' in length.

3.1.1.2 Video Camera Survey of C-106 Taken in 2002. A video survey of the C-106 tank interior has recently been completed. Video surveys of the C-106 valve and pump pits is planned. The in-tank survey was similar in scope to the post sluicing retrieval survey and provides an update of the current status of the tank and residual waste within the tank. A thorough assessment of the video has yet to be done, but in general, the video shows that a portion of the supernate has evaporated, revealing additional waste solids that were not viewable in the previous video.

3.1.1.3 Video Camera Surveys of the C-200 Series Taken in 1997. Video camera surveys from 1997 were done for the C-201 and C-202 tanks. These surveys showed the in-tank ancillary equipment, tank sidewalls, and residual tank waste. The C-201 and C-202 tanks to have small amounts of in-tank ancillary equipment. From the video, the residual waste in these tanks appears to be very dry sludge.

3.1.1.4 Video Camera Surveys of the C-201 and C-202 Tanks Taken in 2002. The recently completed video surveys of the C-201 and C-202 tank showed the same in-tank conditions as the surveys conducted in 1997.

The equipment configuration and residual waste levels for the C-201 and C-202 tanks are essentially the same, and are described together. The C-200 series tanks were originally constructed with 8 risers, a manhole, and two ventilation ports. Subsequent installation of the jet pump pit covered Risers 1 through 4 (two 4" diameter and two 12" diameter), installed two new 12" risers (Risers 9 and 10) and covered one of the ventilation ports. The covered risers and ventilation port extensions into the tank space were visible on the video from each of the 200 series tanks. The following equipment were visible in the C-201 and C-202 videos:

- Riser 5: nothing protruding into tank
- Riser 6: temperature probe
- Riser 7: observation port from which the video was taken
- Riser 8: nothing protruding into tank
- Riser 9: sludge jet pump and hoses
- Riser 10: nothing protruding into tank
- Manhole: unlined concrete access hole with concrete cover
- Ventilation port: nothing protruding into tank. There are two penetrations of this type in the ceiling. One of the penetrations should be blocked and the other provides access to the condenser hatchway.

A section of pipe was visible in both tanks, supported on its ends by the tank wall and the tank bottom. The pipe in each tank is probably an old temperature probe and is estimated to be 2" in diameter and greater than 20' in length.

The sludge jet pump has two flexible hoses (3" and 4" diameter) leading to the eductor and lay across the bottom of the tank. The top of the two hoses are visible in both tanks, suggesting that if the bottom of the hoses are resting on the tank bottom that the depth of residual waste is potentially no thicker than 3 to 4 inches. There are no visible free liquids in either of these tanks. Additional waste discussion is in Section 3.2. A table listing tank ancillary equipment, risers, and referenced engineering drawings is included in Appendix C.

3.1.1.5 Video Camera Survey of the C-203 Tank Taken in 2002. The following equipment was visible in the video from the C-203 tank:

- Riser 5: sludge level measuring assembly with the tape extended
- Riser 6: temperature probe
- Riser 7: observation port from which the video was taken
- Riser 8: nothing protruding into tank
- Riser 9: nothing protruding into tank
- Riser 10: nothing protruding into tank
- Manhole: unlined concrete access hole with concrete cover
- Ventilation port: nothing protruding into tank. There are two penetrations of this type in the ceiling. One of the penetrations should be blocked and the other provides access to the condenser hatchway.

The primary physical structure difference between the C-203 tank and the other C-200 series tanks is that the C-203 tank the jet pump hoses are not present in the C-203 tank (riser 9). Residual waste can be seen at the bottom of the tank. There are no visible free liquids. Additional waste discussion is in Section 3.2.

3.1.1.6 Video Cameral Survey of the C-204 Tank Taken in 2002. The following equipment was visible in the video:

- Riser 5: sludge level measuring assembly with the tape extended; additional tape is coiled in the waste below riser 5.
- Riser 6: nothing protruding into tank
- Riser 7: observation port from which the video was taken
- Riser 8: nothing protruding into tank
- Riser 9: sludge jet pump with corroded lines visible near the bottom of the riser extension
- Riser 10: appears to be a 4" multi-stage turbine pump; below the riser extension, a flanged connection is visible with plastic wrap and a fragment of dry Russian thistle draped on the flanged connection; according to drawings, a partial sluicer assembly was anticipated to be in this riser
- Manhole: unlined concrete access hole with concrete cover
- Ventilation port: nothing protruding into tank

A section of pipe was visible in the C-204 tank, supported on its ends by the tank wall and the tank bottom. The pipe is probably an old temperature probe and is estimated to be 2" in diameter and greater than 20' in length. Other miscellaneous items in the tank include what appear to be 3 or 4 rags and a block of unknown dimension or material.

The sludge jet pump has two flexible hoses (3" and 4" diameter) leading to the eductor and laying across the bottom of the tank. The top of the two hoses are partially visible. The residual waste level in the C-204 tank appears to be higher than the dish bottom knuckle joint. There are no visible free liquids in C-204. A table listing tank ancillary equipment, risers, and referenced engineering drawings is included in Appendix C.

3.1.2 Planned Dose Estimate Surveys

In conjunction with the planned video camera surveys dose estimating surveys will be performed for the valve pits, pump pits, access pits, and for the interior of the tanks. These surveys will provide a better basis for estimating worker exposure risks during implementation of closure activities.

Dose surveys were recently completed for the interior of the five closure demonstration tanks. Results from the surveys will be available later for design purposes, following the necessary USQ review as required by CHG procedures.

3.1.3 Planned Ground Penetrating Radar Subsurface Mapping

Ground penetrating radar (GPR) subsurface mapping surveys are planned for the areas above and immediately surrounding the five closure demonstration tanks. The GPR surveys are tentatively planned for the fall of 2002. The surveys will provide confirmation of historical engineering drawings, additional information regarding locations and status of subsurface ancillary equipment, and information on potential subsurface anomalies or characteristics that may impact tank closure.

3.2 WASTE CHARACTERIZATION

Presented in the following sections, is a summary of the current operational approach to waste characterization and the currently available waste characterization information for the five closure demonstration tanks. Also presented, is a general assessment of the available characterization information to support closure decision. In addition, there is a brief summary of ongoing waste characterization activities in support of this closure demonstration.

3.2.1 Waste Volume

Waste volume is an important component in calculating total contaminant inventory. As discussed in the following sections, tank waste volumes to date have been calculated for operational purposes for tracking volumes of tank waste. For closure purposes, where very small volume calculation is being evaluated (i.e. Topo system as described in TPA, M-45 series, Appendix H) of waste may be closed with a tank, the operational approach to tank waste volume is not sufficient. Because there may be discrepancies between the currently accepted operational

tank waste volume and a waste volume calculated for potential closure it is important to understand the bases of each.

For the purposes of clarity and because the design of the closure demonstration tanks is based on English units and because the extent of retrieval goal is based on English units, only English units are provided in this section.

3.2.1.1 Operational Waste Volume Methodology. Historical and current operational tank waste volumes are primarily based on tank waste level measurements. Historically the bottom dish of the C Tank Farm 100 series tanks has been given a rule of thumb volume of 12,500 gals. The bottom dish (tank floor) for the C Tank Farm 100 series tanks is typically 12 inches deep at the center. The top of the dish meets the bottom of the tank knuckle region. The knuckle region is the corner radius area of the tank where the tank walls meet the tank floor. The corner radius of the C Tank Farm 100 series tanks is 4 feet, therefore the knuckle region of the tank is 4 feet thick. In terms of tank volume, the knuckle region has historically been treated as a part of the 75 foot diameter tank cylinder, where 1 a inch thick waste thickness corresponds to 2,750 gal.

Historically for the 200 series tanks (20 foot diameter) the bottom dish has been given a volume of 590 gals. The corner radius of the C Tank Farm 200 series tanks is 3 feet, therefore the knuckle region of the tank is 3 feet thick. In terms of tank volume, the knuckle region has historically been treated as a part of the 20 foot diameter tank cylinder, where 1-inch thick waste thickness corresponds to 196 gals.

This volume calculation method is summarized in Supporting Document for Historical Tank Content Estimate for C Tank Farm (Consort, S.D., K.L. Ewer, J.W. Funk, R.G. Hale, G.A. Lisle, C.V. Salois, 1996).

3.2.1.2 Current Operational C-106 Waste Volume Estimate. The residual waste volume in the C-106 tank is calculated in the *Waste Retrieval Sluicing System* Campaign Number 3 Solids Volume Transferred Calculation (Carothers, K.G., L.A. Stauffer, J.W. Bailey, 1999) and is based on subtracting the volume of waste retrieved from the initial pre-sluicing waste volume.

The initial pre-sluicing waste volume of 197,000 gals was based on measured sludge levels in the tank. The calculation of this volume was revisited in (Carothers, K.G., L.A. Stauffer, J.W. Bailey, 1999) and the initial pre-sluicing volume revised downward to 192,000 gals. The initial pre-sluiced volume was revised downward because the respective assumed volumes for the dish bottom of the tank and the tank knuckle region of 12,500 gals and 132,000 gals respectively are not correct. From engineering drawings the calculated volumes of the dish bottom region and the knuckle region of the C Tank Farm 100 series tanks are actually 13,380 gals and 126,280 gals respectively. The 132,000 gal knuckle region volume is simply the tank corner radius of 4 feet multiplied by the 2,750 gals per inch for a 75 foot diameter circle. The volume does not take into account the corner radius. As a part of this tank volume refinement effort, the CHG Process Engineering group has developed a tank waste volume spreadsheet (see Section 3.2.1.4) that is specific to all of the Tank Farm tanks on the Hanford site. The spreadsheet tool is discussed below.

The sludge volume removed from the C-106 tank during sluicing was calculated using four methods of mass transfer measurement. The four methods of mass transfer measurement included direct measurement of mass transfer using a mass flow meter, mass transfer estimates using density profiles from an ENRAF densitometer, mass transfer estimates using sediment levels from an ENRAF densitometer, and mass transfer estimates from dissolved solid grab samples.

Based only on the initial pre-sluicing waste volume and the estimated volumes removed from the tank, using the different methods described above, the residual sludge volume in the tank ranged from 0 to 13,800 gals (0 to 1,840 cubic feet). After assessing other data from the AY-102 tank where the retrieved waste was stored and the post sluicing 2000 video, the residual sludge volume in tank C-106 from (Carothers, K.G., L.A. Stauffer, J.W. Bailey, 1999) and (DST Engineering, 200) was estimated to be approximately 5,500 gals (735 cubic feet). Supernatant volume was estimated at 30,000 gal using updated supernate level measurements.

The C-106 residual volume is currently being refined using the recent video camera survey. Additionally, following planned waste retrieval from C-106, the residual waste volume will be re-estimated as part of the closure process.

3.2.1.3 C-200 Series Waste Volume Estimate. The residual waste volumes in the C-200 series tanks are based on tank level measurements. Level measurements of these tanks have been performed using a manual tape. Tank waste level measurements in the C-200 series tanks have generally decreased since the last tank waste transfer activities were conducted in the 1970s.

As previously discussed, the BBI recognized residual waste volumes in these tanks are 1,000 gal for the C-201 and C-202 tanks and 3,000 gal for the C-203 and C-204 tanks. These waste volume estimates are based on waste level measurements from October 2000, which generally correspond to more recent measurements collected in 2002.

Waste level measurements and the in-tank video survey indicate 7.5 inches of waste in the C-201 tank. The 1,000 gal estimate from the BBI is a value rounded up from a calculated value of 884 gals (590 gals from 6 inch bottom saucer plus 294 gals [1.5 inches times 196 gals per inch]). The 884 gal calculated value does not consider the radiused corners of the tank.

Waste level measurements and the in-tank video inspection indicated about 8 inches of waste in the C-202 tank. Again the 1,000 gal estimate from the BBI is a value that was rounded up from an 8 inch waste thickness calculated value of 982 gal (590 gal dish volume plus 392 gal [2 inches times 196 gal per inch]). The 982 gal volume does not account for the radius corners of the tank.

Waste level measurements from the C-203 and C-204 tanks indicate about 17 inches of waste in each tank. The 3,000 gal volume estimates from the BBI were rounded up to the nearest 1,000 gal. The calculated volume is 2,750 gal (590 gal dish volume plus 2,156 gal [11 inches times 196 gal per inch]). Again this volume does not consider the radius corners of the tanks.

Following planned retrieval of waste from the C-200 Series tanks, the residual waste volumes will be re-estimated as part of the closure process.

3.2.1.4 Process Engineering Tank Volume Spreadsheet. CH2M HILL Hanford Group Process Engineering has recently developed a spreadsheet to more accurately calculate waste volumes. The spreadsheet was developed using tank farm specific engineering drawings. Using the spreadsheet, the specific design of the tanks is easily represented in calculating tank waste volumes. As discussed above, the dish area of the C Tank Farm 100 series tanks is 13,380 gal. For the 200 series tanks the dish area is 338 gal. The knuckle regions of C Tank Farm 100 series tanks are 126,000 gal. For the 200 series tanks the knuckle regions are 6,200 gal.

The spreadsheet tool also calculates fractions of the dish bottoms and knuckle regions. An example of the spreadsheet is included in Appendix B.

3.2.1.5 C-106 Volume Assessment. In terms of estimating residual volumes of waste for tank closure, the mass balance methods summarized above give a wide range of residual waste volumes. Considering the quantified HFFACO extent of retrieval goal for remaining residual tank waste for a 100 series tank of 360 cubic feet (2,693 gals) the estimated residual waste volume range (0 to 1,840 cubic feet) from the mass balance methods alone is not sufficient to assess whether the retrieval goal was met. If a risk-based approach to closure were the only concern (rather than meeting the volume-based requirements of the HFFACO), then a graded conservative approach to residual waste volume calculation for closure could be used. In a graded conservative approach, the conservative volume (high value) from the mass balance could be used to initially assess whether the residual waste met risk based closure criteria. If the conservatively high residual waste volume estimate met the risk-based closure criteria, then there would be no need for additional residual waste volume refinement.

As discussed above, the residual waste volume range from the mass balance methods was further refined using the tank video inspection. Given the known in-tank volume benchmarks, spreadsheet tool, and using the video inspection improves the ability to estimate residual waste volume for closure. However, dividing the total residual waste volume into estimated solid and liquid waste form volumes, is problematic in that the video camera can only see the surface liquid with a couple of sludge piles along the tank walls. The volume estimates are accurate enough to determine that the residual waste volume does not meet the TPA extent of retrieval goals both for the liquid as well as the sludge for closure.

The separate waste form (solids and supernatant) volumes are estimates and may or may not be representative of the individual waste form volumes. The waste volume estimate (total) should be representative because the liquid volume has been updated periodically since sluicing. Evaporation has occurred since sluicing.

The video survey recently completed, will provide additional refinement of the residual waste volume (for both total and individual waste forms).

Following planned additional waste retrieval from C-106, the residual volume will be re-estimated.

3.2.1.6 C-200 Series Volume Assessment. As discussed previously, the residual waste volumes of 1,000 gals for the C-201 and C-202 tanks and 3,000 gals for the C-203 and C-204 tanks were rounded up to the nearest 1,000 gals and are based on historical rule of thumb tank

region volumes. These historical rule of thumb tank region volumes may not be accurate enough for purposes of tank closure.

In terms of estimating residual volumes of waste for tank closure, the waste level measurement method with the process engineering spreadsheet tool and video camera confirmation is a method that can provide reasonable, conservative, and defensible residual waste volumes to support tank closure decisions. The residual waste volume for each of the C-200 series tanks was reassessed using the recent video surveys, waste level measurements, and the spreadsheet tool.

For the C-201 and C-202 tanks, the in-tank videos are consistent with the waste level measurements of 7.5 inches and 8 inches, respectively. For the C-201 and C-202 tanks, the videos indicate that the waste levels are at or just above the bottom of the transition from the bottom dish of the tank to the tank knuckle region (bottom of tank corner radius), which is consistent with waste level measurements from these two tanks. For the C-203 and the C-204 tanks the videos and waste level measurements generally indicate more waste than the C-201 and C-202 tanks, however, the video does not appear to indicate the 17 inch waste thickness that the level measurements do. For the C-203 and the C-204 tanks the videos indicate that the waste level is above the dish bottom transition and near the tank corner radius. The 17 inch waste level measurement appears to be conservative. From design drawings the dish bottom of the 200 series tanks are 6 inches deep. An aside, there is historical anecdotal photographic evidence indicating that some of the dish bottoms in the site wide tanks vary by up to 3 inches and possibly more for the 100 series tanks. As discussed in the video survey summary section this could potentially be the reason that the tops of the 3 to 4 inch diameter jet hoses are at the bottom of the C-202 and C-204 tanks.

Using the spreadsheet tool, the calculated residual waste volumes for each of the C-200 series tanks is below:

C-201 – 7.5 inches of residual waste is equivalent to 490 gals (65 cubic feet).
C-202 – 8.0 inches of residual waste is equivalent to 550 gals (74 cubic feet).
C-203 – 17.0 inches of residual waste is equivalent to 1,880 gals (251 cubic feet).
C-204 – 17.0 inches of residual waste is equivalent to 1,880 gals (251 cubic feet).

These values are significantly different from the currently accepted waste volumes reported in the BBI for these tanks. The difference is primarily because the BBI rounds the waste volumes to the nearest 1,000 liters and the nearest 1,000 gal. The volumes listed above are more accurate than the BBI volumes, however as with any calculation or measurement, there is always a level of uncertainty or precision. For example, the dry residual waste in the C-200 series tanks is not perfectly level. As the waste has dried over the past 30 years the waste near the corner tank wall radius likely has dried at a faster rate than the waste near the middle of the tank. As seen in the videos from the tanks, the surface of the residual waste mimics the tank dish bottom in that the surface of the waste near the middle of the tanks is at a lower elevation than the waste near the sides of the tanks. Tank waste level measurements for the C-200 series tanks were taken from manual measuring tapes located in risers near the tank wall, so the volumes stated would over or conservatively represent the residual waste volume, because there is actually less waste in the middle of the tank than the waste level measurement near the tank wall indicates. This is

consistent with the tank video surveys where the tops of 3 to 4 inch diameter jet hoses can be seen near the center of the tank bottoms.

Another consideration in the volume uncertainty is the potential depression of the manual measuring tape weight into the waste surface. The waste in the C-200 series tanks appears to be dry. Over the years of multiple waste level measurements the tape weight has the potential to compact or make a depression in the waste immediately beneath the level measuring tape. From the videos there did not appear to be any significant depressions in the waste surface from the level measurement weights.

In addition, the volumes above do not explicitly account for potential tank sidewall contamination. From the tank videos the walls of the C-201 and C-202 tanks appear relatively clean. The rusty oxidized steel including welded joints are visible. The C-201 tank does have a white ring of residual waste scale about two-thirds of the way down from the top of the tank. The ring is about 0.3 m (1 foot) in height. For the C-203 tank the entire height of the tank walls are intermittently covered with a white scale material. For the C-204 tank the top half of the tank walls appear to be generally clean. The rusty oxidized steel including welded joints are visible. The bottom half of the C-204 tank walls are covered with a mostly uniform white scale material.

This report does not quantify the level of uncertainty or precision associated with the residual volumes given above. However, these volumes appear to be conservative and defensible residual tank waste volumes. The expectation is that the actual residual waste volumes in the C-200 series tanks are less than those presented above, but greater than the HFFACO residual waste volume goal of 224 gal (30 cubic feet).

For comparison the BBI volumes and those presented above are included in Table 3-1.

Table 3-1. Waste Volume Comparison.

Tank	BBI volume (gal.)	CHG Spreadsheet (gal.)
C-201	1,000	490
C-202	1,000	550
C-203	3,000	1,880
C-204	3,000	1,880

3.2.2 Summary and Assessment of Tank Waste Inventory Information

The BBI system is the primary system used to track and maintain specific tank waste inventories. The BBI is a computer database system that is used to develop and maintain tank waste inventories comprising of 25 chemical and 46 radionuclide components in the 177 Hanford Site underground storage tanks. The BBI consists of sample-based and process knowledge-based tank waste inventory and concentration estimates, by waste phase. Waste inventories are generally calculated by the BBI using the following parameters:

•

- constituent concentration
- waste density, and
- waste volume.

With the exception of the inventory values with the C basis, the waste inventory of each constituent is calculated by the following formula:

*Inventory = Concentration * Density * Volume * Multiplier*

Additional discussion for the C basis is included under the discussion for each tanks inventory.

The multiplier is generally used to adjust concentrations to account for modification of a specific parameter such as density or water content.

Specific tank waste constituent concentrations are based on sample analyses or process knowledge which may include the Hanford Defined Waste (HDW) model, an average of multiple concentrations from multiple sources, or a combination of any or all of these. Concentrations based on process knowledge may be inferred by expert judgment and calculations based on an understanding of the processes that produced the waste. For a thorough detailed discussion of the BBI system see (Tran, T.T., S.F. Bobrowski, L.L. Lang, T.S. Olund, 2000), (Field, J.G., D.J. McCain, K.M. Bowen, L.M. Sasaki, 2002) and (Sasaki, L.M., 2001).

3.2.2.1 Summary of the C-106 Tank Waste Inventory Information. Table 3-2 contains the January 1, 2001, BBI inventory of C-106 tank, which is not comprehensive of all the constituents listed in the BBI for the closure demonstration tanks. For presentation purposes the tables are a general listing of the primary contaminants of concern from both a risk (short-closure implementation and long-groundwater) and a regulatory waste perspective. A complete list can be obtained from the BBI system.

Table 3-2a. Tank C-106 BBI. (2 Pages)

Sludge volume = 23,000 L (6,000 gal)						Supernate volume = 115,000 L (30,000 gal)				
Radio-nuclide	Sludge Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier	Supernate Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier
Am-241	2.25E+02	E	1.56	6.27E+00	1	5.36E-02	E	1.14	2.52E-04	1.62
C-14	8.28E-03	S	1.56	2.31E-04	1	4.91E-02	S	1.13	2.33E-04	1.62
Cm-242	3.42E-01	C	1.56	1.85E-03	1	1.43E-02	E	1.05	4.96E-05	2.39
Co-60	2.46E-01	E	1.3	3.44E-03	2.39	1.16E+00	S	1.13	5.48E-03	1.62
Cs-137	1.14E+04	S	1.56	3.17E+02	1	6.16E+03	S	1.13	2.92E+01	1.62
Eu-152	2.85E+00	E	1.3	3.99E-02	2.39	4.33E-01	E	1.05	1.50E-03	2.39
Eu-154	2.64E+02	S	1.56	7.36E+00	1	3.21E+00	S	1.13	1.52E-02	1.62
Eu-155	1.82E+02	S	1.56	5.08E+00	1	6.95E+00	S	1.13	3.30E-02	1.62
H-3	1.45E-01	S	1.56	4.04E-03	1	1.40E+00	S	1.13	6.66E-03	1.62

Table 3-2a. Tank C-106 BBI. (2 Pages)

Sludge volume = 23,000 L (6,000 gal)						Supernate volume = 115,000 L (30,000 gal)				
Radio-nuclide	Sludge Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier	Supernate Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier
I-129	8.28E-03	E	1.3	1.16E-04	2.39	8.73E-03	S	1.13	4.14E-05	1.62
Ni-3	5.71E+02	E	1.3	8.00E+00	2.39	3.70E+01	E	1.05	1.28E-01	2.39
Ni-59	6.13E+00	E	1.3	8.59E-02	2.39	3.99E-01	E	1.05	1.38E-03	2.39
Np-237	1.66E-01	S	1.56	4.62E-03	1	9.66E-02	S	1.13	4.58E-04	1.62
Pu-238	3.48E+00	C	1.56	4.44E-02	1	2.12E-02	C	1.13	4.44E-02	1
Pu-239	7.52E+01	C	1.56	9.07E-01		4.57E-01	C	1.13	9.07E-01	
Pu-240	1.54E+01	C	1.56	1.85E-01		9.33E-02	C	1.13	1.85E-01	
Pu-241	1.84E+02	E	1.56	5.14E+00	1	1.12E+00	E	1.14	5.28E-03	1.62
Pu-242	1.64E-03	C	1.56	1.98E-05	1	9.95E-06	C	1.13	1.98E-05	1
Se-79	2.77E-01	E	1.3	3.88E-03	2.39	1.09E-02	S	1.13	5.18E-05	1.62
Sr-90	2.82E+05	S	1.56	7.86E+03	1	3.43E+02	S	1.13	1.63E+00	1.62
Tc-99	1.03E+00	S	1.56	2.88E-02	1	2.11E+00	S	1.13	1.00E-02	1.62
U-232	1.65E-04	C	1.52	1.60E-05	1	3.64E-04	C	1.14	1.60E-05	1.62
U-233	6.81E-04	C	1.52	6.16E-05	1	1.50E-03	C	1.14	6.16E-05	1.62
U-234	1.34E-02	C	1.52	1.21E-03	1	2.96E-02	C	1.14	1.21E-03	1.62
U-235	5.73E-04	C	1.52	5.18E-05	1	1.26E-03	C	1.14	5.18E-05	1.62
U-236	2.39E-04	C	1.52	2.16E-05	1	5.27E-04	C	1.14	2.16E-05	1.62
U-238	1.37E-02	C	1.52	1.24E-03	1	3.03E-02	C	1.14	1.24E-03	1.62

C – Concentration based on calculation.
E – Concentration based on engineering estimates.
S – Concentration based on sample analyses.

Table 3-2b. Tank C-106 BBI (Non-Radionuclides). (2 Pages)

Sludge volume = 23,000 L (6,000 gal)						Supernate volume = 115,000 L (30,000 gal)				
Non-radio-nuclide	Sludge Inventory (kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier	Supernate Inventory (kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier
Cr	5.71E+01	S	1.52	1.63E+03	1	4.63E+00	S	1.14	2.18E+01	1.62
Hg	4.39E+00	S	1.52	1.26E+02	1	6.55E-02	S	1.13	3.11E-01	1.62
K	2.11E+01	S	1.52	6.03E+02	1	8.69E+01	S	1.14	4.09E+02	1.62
Na	2.45E+03	S	1.52	7.02E+04	1	9.51E+03	S	1.14	4.47E+04	1.62
Ni	1.06E+02	S	1.52	3.03E+03	1	6.23E-01	S	1.13	2.96E+00	1.62
NO_2	8.08E+01	S	1.52	2.31E+03	1	1.45E+03	S	1.14	6.80E+03	1.62

Table 3-2b. Tank C-106 BBI (Non-Radionuclides). (2 Pages)

Sludge volume = 23,000 L (6,000 gal)						Supernate volume = 115,000 L (30,000 gal)				
Non-radio-nuclide	Sludge Inventory (kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier	Supernate Inventory (kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier
NO_3	1.18E+01	S	1.52	3.36E+02	1	6.51E+01	S	1.13	3.09E+02	1.62
Pb	1.57E+02	S	1.52	4.50E+03	1	3.38E+00	E	1.05	1.17E+01	2.39
PO_4	3.75E+02	S	1.52	1.07E+04	1	5.64E+02	S	1.14	2.65E+03	1.62
SO_4	6.06E+01	S	1.52	1.73E+03	1	4.21E+02	S	1.14	1.98E+03	1.62
Sr	6.49E+00	S	1.52	1.86E+02	1	8.38E-03*	C	--	--	--
TIC as CO_3	3.25E+03	S	1.56	9.05E+04	1	9.98E+03	S	1.13	4.73E+04	1.62
TOC	1.67E+02	S	1.56	4.65E+03	1	3.58E+02	S	1.13	1.70E+03	1.62
U_{TOTAL}	4.11E+01	S	1.52	1.18E+03	1	9.07E+01	S	1.14	4.26E+02	1.62

C – Concentration based on calculation.
E – Concentration based on engineering.
S – Concentration based on sample analyses.
* - Sr inventory based on correlation with Sr-90 inventory.

S Basis. As indicated by the "S" in the basis column of the Table 3-1, the majority of the C-106 tank inventory is based on sample analysis. The samples are from a core sample collected from the AY-102 tank following retrieval and transfer of retrieved waste from the C-106 into tank AY-102. During the sluicing activity the supernatant from the AY-102 tank was used as the sluicing fluid. Because of the continuous reuse and mixing of the supernate during retrieval, the C-106 supernatant and the AY-102 supernatant were determined to be equivalent in the BBI. The sludge layer from the AY-102 tank that corresponded to the retrieved sludge from the C-106 tank was analyzed and is represented in Table 3-1 by the "S" basis.

The 1.62 multiplier applied to the sample based supernate concentrations accounts for the estimated concentration increase in the supernatant through evaporation between the sampling date and the BBI date of January 1, 2001. Evaporation was measured using liquid level measurements. A multiplier was not applied to the sample based sludge concentrations.

E Basis. The values with the "E" basis are primarily based on the process knowledge template "AR Solid or Liquid Template." The "AR" refers to a BBI waste template developed for liquids and solids that were generated during sludge washing operations in the 241-AR Vault from 1967 to 1976. Agnew et al. 1997 indicates that tank C-106 accumulated primarily AR sludge. There are multiple waste type templates in the BBI. The waste templates are created from sample data, process knowledge, and HDW model estimates. The AR template is based entirely on the HDW model.

The Am-241 concentrations presented in Table 3-2 are from the analysis of the core samples collected from the AY-102 tank following retrieval and transfer of retrieved waste from the C-106 tank into tank AY-102. The Am-241 concentrations were given an E basis because the value was adjusted from the measured result to account for second order decay before calculating

the tank inventory. For Pu-241 the inventory is also based on a decay chain isotopic distribution calculation using the Am-241 analytical result.

The 2.39 multiplier for the both the liquid and solid is a coincidence. The sludge multiplier is based on the measured density and water content from the core samples and is used to transform the template data to reflect the actual sludge density and water content. The liquid multiplier of 2.39 is based on a specific gravity estimate from sample data as well as the calculated water content and is also used to transform the template to reflect the supernatant content.

Constituents based on the HDW model AR template include I-129, Eu-152, Pu-241, Ni-59, Co-60, Ni-63, and Se-79. In the case of I-129, Eu-152, Pu-241, and Co-60 samples collected from the AY-102 tank (discussed above) were also analyzed for these constituents. However, the I-129, Eu-152, and Co-60 concentrations were below the detection limits for the analytes and the analytical detection limits were reported in the absence of detected results. The template concentrations for these constituents were lower than the analytical minimum detectable activities (MDA), therefore the inventory concentrations for these constituents defaulted to the template values.

The sole basis for the Ni-59, Ni-63, and Se-79 concentrations are the HDW model.

C Basis. The C basis qualifier indicates that the constituent inventory is based on a calculation. Constituents with the C basis include all of the uranium isotopes; Pu-238, 239, 240, and 242; and Cm-242.

Calculated inventory values for all of the C-106 "C" basis constituents are based on actual sample data collected following sluicing (discussed above) with HDW model isotopic distributions applied. For the uranium isotopes the calculation uses the sample based total uranium results and applies the HDW model uranium isotopic distribution to calculate individual uranium isotope inventories. The Pu-239 and Pu-240 inventory values are based on a sample analysis of the combination of the two plutonium isotopes with the HDW model plutonium isotopic distribution applied for the individual plutonium isotopes. The Pu-238 and 242 inventories are also based on the Pu-239/240 sample analysis and the HDW plutonium isotopic distribution.

The Cm-242 inventory is based on a HDW model isotopic distribution with the Am-241 sample analysis.

As mentioned previously, the inventory formula is not used for the C basis inventories. The C basis concentration in Table 3-2 are from the HDW model, without considering the isotopic distribution form the referenced analyses. A more representative waste concentration could be calculated by working backward using the isotopic distribution based inventory values.

Other Analytical Data not Included in the BBI. In addition to the BBI data summarized above, pre-sluicing samples were collected from the C-106 tank in 1996 to support the sluicing effort. Samples were collected from the tank supernate, a potential organic layer, and from the sludges. Various analyses were conducted on the samples including anions, radionuclides, metals, normal paraffin hydrocarbons, tributyl phosphate, and physical parameters. A detailed

listing of results from the 1996 effort are included in the *222-S Laboratory Analytical Report for Tank 241-C-106, Grab Samples 6C-96-1 Through 6C-96-16 & 6C-96-17* (WHC 1996).

The pre-sluicing results are generally consistent with the results collected from the post-sluicing samples included in the BBI discussion above. For example, in the case of Tc-99 the BBI sludge Tc-99 concentration is given as 1.45E-02 µCi/g. From the 1996 sampling, a total of 7 sludge samples plus 7 duplicates were analyzed for Tc-99. Tc-99 was detected in 6 of the 14 samples at concentrations ranging from 1.75E-02 µCi/g to 5.04E-01 µCi/g. Analytical detection limits ranged from 1.50E-02 µCi/g to 3.70E-02 µCi/g. The average concentration of the 14 analyses using the detection limit for undected analyses results is 6.50E-02 µCi/g. Given the detection limits the pre-sluicing Tc-99 sludge concentrations are consistent with the BBI concentration. The BBI supernate Tc-99 concentration is given as 1.00E-02 µCi/g. Transformed by the BBI multiplier based on evaporation of 1.62 and the density of 1.13 g/mL the supernate Tc-99 concentration is 1.83E-02 µCi/mL. From the 1996 sampling, a total of 2 supernate samples plus 2 duplicates were analyzed for Tc-99. Tc-99 was detected in all four samples at concentrations ranging from 8.52E-02 µCi/mL to 4.79E-01 µCi/mL, with an average of 2.04E-01 µCi/mL. The pre-sluicing supernate concentrations and the BBI supernate concentrations are not directly comparable because the BBI concentration is based on mixing with supernate from the AY-102 tank. However, the concentrations are consistent in that they are generally within a single order of magnitude difference.

The BBI does not include information for petroleum hydrocarbon / solvent based organics. The pre-sluicing potential organic layer was analyzed based on process knowledge for the primary organics of concern which included normal paraffin hydrocarbons and tributyl phosphate. The results of these analyses are summarized below in Table 3-3.

None of the constituents with exceptions of tetradecane and tridecane were detected above the analytical practical quantitation limit (PQL) of 50 µg/mL. The detections listed that are below the PQL are estimated concentrations below the PQL. With the exception of tributyl phosphate all of the compounds are typical compounds found in kerosene or normal paraffin hydrocarbons. As previously discussed kerosene or normal paraffin hydrocarbons and tributyl phosphate were process chemicals used in uranium recovery.

Table 3-3. Normal Paraffin Hydrocarbons and Tributyl Phosphate Analytical Results for the Potential Pre-Sluiced C-106 Tank Organic Layer. (2 Pages)

Constituent Name	February 23, 1996 – Riser 1 Sample		March 1, 1996 – Riser 7 Sample	
	Concentration (µg/mL)	Qualifier	Concentration (µg/mL)	Qualifier
Decane	<50	U	<50	U
Dodecane	10.1	J	27	J
Nonane	<50	U	<50	U
Pentadecane	2.37	J	6.27	J
Tetradecane	27.6	J	77	
Tributyl phosphate	31.9	J	48.8	J

Table 3-3. Normal Paraffin Hydrocarbons and Tributyl Phosphate Analytical Results for the Potential Pre-Sluiced C-106 Tank Organic Layer. (2 Pages)

Constituent Name	February 23, 1996 – Riser 1 Sample		March 1, 1996 – Riser 7 Sample	
	Concentration (µg/mL)	Qualifier	Concentration (µg/mL)	Qualifier
Tridecane	45.6	J	119	
Undecane	1.59	J	4.07	J

J = Estimated value below laboratory PQL of 50 µg/L.
U = Constituent was not detected at the laboratory PQL of 50 µg/L.

The pre-sluicing supernate and solids were also analyzed for total organic carbon (TOC) and oxalates. Conducting a simple comparison of the oxalate results to the TOC results for the same waste forms indicate that 100% of the TOC in the solids is in the form of the oxalates. For the liquid fraction oxalates appear to be make up from 30-40% of the TOC content.

3.2.2.2 Assessment of the C-106 BBI and Additional Data. The majority of the inventory and concentration information for the C-106 tank is based on sample analytical data (either direct analysis or isotopic distribution based on direct analysis) from waste retrieved during the 1999 sluicing effort. Although the samples were collected from the AY-102 tank and not directly collected from the remaining waste in the C-106 tank, the concentration values should adequately characterize and represent the remaining waste in the C-106 tank for closure planning and could potentially be used for some closure decisions, pending ongoing closure DQO efforts.

As discussed above, the constituents that have no inventory basis linked to sample analysis include Ni-59, Ni-63, and Se-79. The inventories of these constituents are entirely based on the HDW model template.

There is anecdotal evidence from comparison of HDW model results to actual waste analyses results that the HDW model based inventories are generally conservatively high. This is generally not the case for the C-106 sludge. For the C-106 sludge where there is enough information to compare sample analyses concentrations to template concentrations, the AR template indicates the highest concentration for 10 of 34 comparable constituents. Of the primary COCs, the long-lived mobile contaminants (see Section 6.0), the AR template estimated a higher concentration than the actual sample analyses for nitrite (22,600 µg/g-template versus 3,970 µg/g and 2,310 µg/g-sample analyses), C-14 (8.52E-03 µCi/g-template versus 2.31E-04 µCi/g and 2.50E-04 µCi/g-sample analyses), and Tc-99 (6.0E-02 µCi/g-template versus 2.88E-02 µCi/g and 1.11E-02 µCi/g-sample analyses). Of the other COCs only the uranium results from the template and sample analyses were comparable. The sample analyses for total uranium indicated a higher concentration than the AR template (360 µg/g-template and 2,020 µg/g and 1,180 µg/g-sample analyses). Also prior to January 1, 2001, BBI update, the Tc-99 inventory for the C-106 sludge inventory was based on B-Plant low level waste "BL" template, which gave a Tc-99 concentration of 4.60E-03 µCi/g. When the BBI was revised to reflect the AY-102 core sampling and analysis, the sludge Tc-99 concentration was revised to 2.88E-02 µCi/g with a resulting Tc-99 inventory increase.

The individual C-106 constituents that are based solely on the HDW model (Ni-59, Ni-63, and Se-79) are generally not the primary risk and/or regulatory waste drivers. These HDW model derived inventories should be adequate for closure planning, but may not be sufficient for closure decisions. DQO efforts for closure are ongoing.

The supernatant will likely be removed prior to closure and therefore, the characterization of the supernatant is generally not relevant to closure unless complete free liquid evaporation occurs in the C-106 tank and no additional waste retrieval is performed.

The organic results from the C-106 pre-sluicing grab samples indicate that the organic component of the tank waste is low and are not contaminants of concern for closure of the C-106 tank.

This is a brief general assessment of the available data for C-106 and its suitability for use in tank closure. For discussion of uncertainty and sensitivity of characterization data sets see Section 8.1.4. With the possible exceptions of Se-79, Ni-59, and Ni-63, the results of this assessment indicate that the available data for the C-106 tank waste may adequately represent and characterize residual waste for making some closure decisions. However, because the C-106 tank will be the first tank to be closed at Hanford and within C Tank Farm, additional characterization of residual waste through sample analysis is likely necessary. Again, there are ongoing DQO efforts for tank closure. When the closure DQOs are further developed the information summarized and referenced here can be reassessed using the objectives for potential closure application.

3.2.2.3 Summary of the C-200 Series Tank Waste Information. Table 3-3 contains the BBI inventory of four 200 series tanks. Tables 3-4 and 3-5 below are not comprehensive of all the constituents listed in the BBI for the closure demonstration tanks. For presentation purposes the tables are a general listing of the primary COCs from both a risk (short-closure implementation and long-groundwater) and a regulatory waste perspective. A complete list can be obtained from the BBI system. In addition, the inventory presented below is based on the current January 1, 2001, BBI residual waste volumes and not the volumes previously discussed in Section 3.2.

Table 3-4a. C-200 Series (C-201 and C-202) Tanks BBI.

C-201: Sludge volume = 4,000 L (1,000 gal)						C-202: Sludge volume = 4,000 L (1,000 gal)				
Radio-nuclides	Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier	Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier
Am-241	2.27E+01	E	1.5	3.79E+00	1	1.19E+01	E	1.5	1.98E+00	1
C-14	2.01E-03	E	1.45	2.06E-04	1.68	2.09E-03	E	1.45	2.06E-04	1.75
Cm-242	3.41E-02	E	1.5	5.68E-03	1	1.78E-02	E	1.5	2.97E-03	1
Co-60	8.42E-04	E	1.45	8.64E-05	1.68	8.77E-04	E	1.45	8.64E-05	1.75
Cs-137	7.87E+01	E	1.16	4.60E+00	3.69	8.22E+01	E	1.16	4.60E+00	3.85
Eu-152	4.05E-01	E	1.45	4.16E-02	1.68	4.22E-01	E	1.45	4.16E-02	1.75
Eu-154	1.91E-01	E	1.45	1.96E-02	1.68	1.99E-01	E	1.45	1.96E-02	1.75
Eu-155	1.42E+01	E	1.45	1.45E+00	1.68	1.48E+01	E	1.45	1.45E+00	1.75
H-3	9.80E-04	E	1.45	1.01E-04	1.68	1.02E-03	E	1.45	1.01E-04	1.75
I-129	2.74E-05	E	1.45	2.81E-06	1.68	2.85E-05	E	1.45	2.81E-06	1.75
Ni-59	7.52E-01	E	1.45	7.72E-02	1.68	7.84E-01	E	1.45	7.72E-02	1.75
Ni-63	7.00E+01	E	1.45	7.18E+00	1.68	7.29E+01	E	1.45	7.18E+00	1.75
Np-237	4.28E-05	E	1.45	4.39E-06	1.68	4.46E-05	E	1.45	4.39E-06	1.75
Pu-238	1.45E+00	E	1.5	2.42E-01	1	7.62E-01	E	1.5	1.27E-01	1
Pu-239	6.48E+01	E	1.5	1.08E+01	1	3.39E+01	E	1.5	5.65E+00	1
Pu-240	1.07E+01	E	1.5	1.78E+00	1	5.57E+00	E	1.5	9.28E-01	1
Pu-241	7.92E+01	E	1.5	1.32E+01	1	4.14E+01	E	1.5	6.90E+00	1
Pu-242	5.46E-04	E	1.5	9.10E-05	1	2.85E-04	E	1.5	4.75E-05	1
Se-79	8.79E-04	E	1.45	9.02E-05	1.68	9.16E-04	E	1.45	9.02E-05	1.75
Sr-90	4.13E+02	E	1.16	2.41E+01	3.69	4.31E+02	E	1.16	2.41E+01	3.85
Tc-99	1.41E-02	E	1.45	1.45E-03	1.68	1.47E-02	E	1.45	1.45E-03	1.75
U-232	4.15E-09	C	1.16	5.29E-07	3.69	2.60E-08	C	1.16	5.42E-11	3.85
U-233	2.66E-10	C	1.16	3.11E-08	3.69	7.31E-10	C	1.16	1.40E-12	3.85
U-234	3.75E-04	C	1.16	4.39E-02	3.69	3.99E-04	C	1.16	7.64E-07	3.85
U-235	1.69E-05	C	1.16	1.97E-03	3.69	1.68E-05	C	1.16	3.22E-08	3.85
U-236	2.39E-06	C	1.16	2.80E-04	3.69	9.28E-06	C	1.16	1.78E-08	3.85
U-238	3.80E-04	C	1.16	4.44E-02	3.69	3.96E-04	C	1.16	7.59E-07	3.85

C – Concentration based on calculation.
E – Concentration based on engineering.
S – Concentration based on sample analyses.

Table 3-4b. C-200 Series (C-201 and C-202) Tanks BBI (Non-Radionuclides).

C-201: Sludge volume = 4,000 L (1,000 gal)						C-202: Sludge volume = 4,000 L (1,000 gal)				
Non-radio-nuclides	Inventory (Kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier	Inventory (Kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier
Cr	2.29E+00	E	1.16	1.34E+02	3.69	2.39E+00	E	1.16	1.34E+02	3.85
Hg	0.00E+00	E	1.45	0.00E+00	1.68	0.00E+00	E	1.45	0.00E+00	1.75
K	6.85E+00	E	1.16	4.00E+02	3.69	7.15E+00	E	1.16	4.00E+02	3.85
Na	4.62E+02	E	1.16	2.70E+04	3.69	4.82E+02	E	1.16	2.70E+04	3.85
Ni	1.37E+02	E	1.16	8.00E+03	3.69	1.43E+02	E	1.16	8.00E+03	3.85
NO_2	4.18E+01	S	1.5	6.97E+03	1	2.14E+02	S	1.5	3.56E+04	1
NO_3	2.27E+02	S	1.5	3.78E+04	1	6.39E+02	S	1.5	1.07E+05	1
Pb	9.71E+02	E	1.16	5.67E+04	3.69	1.01E+03	E	1.16	5.67E+04	3.85
PO_4	1.00E+01	S	1.5	1.67E+03	1	1.10E+01	S	1.5	1.83E+03	1
SO_4	1.14E+01	S	1.5	1.90E+03	1	3.02E+01	S	1.5	5.04E+03	1
Sr	2.79E+01	E	1.16	1.63E+03	3.69	2.91E+01	E	1.16	1.63E+03	3.85
TIC as CO_3	6.52E+02	E	1.56	8.23E+04	1.27	6.66E+02	S	1.5	1.11E+05	1
TOC	2.50E+02	E	1.5	4.17E+04	1	2.15E+02	S	1.5	3.59E+04	1
U_{TOTAL}	1.14E+00	E	1.16	6.64E+01	3.69	1.19E+00	E	1.16	6.64E+01	3.85

C – Concentration based on calculation.
E – Concentration based on engineering.
S – Concentration based on sample analyses.

Table 3-5a. C-200 Series (C-203 and C-204) Tanks BBI.

	C-203: Sludge volume = 10,000 L (3,000 gal)					C-204: Sludge volume = 10,000 L (3,000 gal)				
Radio-nuclides	Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier	Inventory (Ci)	Basis	Density (g/mL)	Concentration (µCi/g)	Multi-plier
Am-241	5.95E+00	E	1.62	3.67E-01	1	1.21E-01	E	1.62	7.49E-03	1
C-14	4.00E-03	E	1.45	2.06E-04	1.34	2.58E-03	E	1.45	2.06E-04	0.863
Cm-242	8.93E-03	E	1.62	5.51E-04	1	1.81E-04	E	1.62	1.12E-05	1
Co-60	1.68E-03	E	1.45	8.64E-05	1.34	1.08E-03	E	1.45	8.64E-05	0.863
Cs-137	1.57E+02	E	1.16	4.60E+00	2.94	1.01E+02	E	1.16	4.60E+00	1.9
Eu-152	8.08E-01	E	1.45	4.16E-02	1.34	5.20E-01	E	1.45	4.16E-02	0.863
Eu-154	3.80E-01	E	1.45	1.96E-02	1.34	2.45E-01	E	1.45	1.96E-02	0.863
Eu-155	2.83E+01	E	1.45	1.45E+00	1.34	1.82E+01	E	1.45	1.45E+00	0.863
H-3	1.95E-03	E	1.45	1.01E-04	1.34	1.26E-03	E	1.45	1.01E-04	0.863
I-129	5.46E-05	E	1.45	2.81E-06	1.34	3.52E-05	E	1.45	2.81E-06	0.863
Ni-59	1.50E+00	E	1.45	7.72E-02	1.34	9.66E-01	E	1.45	7.72E-02	0.863
Ni-63	1.40E+02	E	1.45	7.18E+00	1.34	8.99E+01	E	1.45	7.18E+00	0.863
Np-237	8.53E-05	E	1.45	4.39E-06	1.34	5.49E-05	E	1.45	4.39E-06	0.863
Pu-238	3.81E-01	E	1.62	2.35E-02	1	7.76E-03	E	1.62	4.79E-04	1
Pu-239	1.70E+01	E	1.62	1.05E+00	1	3.47E-01	E	1.62	2.14E-02	1
Pu-240	2.79E+00	E	1.62	1.72E-01	1	5.69E-02	E	1.62	3.51E-03	1
Pu-241	2.07E+01	E	1.62	1.28E+00	1	4.23E-01	E	1.62	2.61E-02	1
Pu-242	1.43E-04	E	1.62	8.81E-06	1	2.92E-06	E	1.62	1.80E-07	1
Se-79	1.75E-03	E	1.45	9.02E-05	1.34	1.13E-03	E	1.45	9.02E-05	0.863
Sr-90	8.23E+02	E	1.16	2.41E+01	2.94	5.32E+02	E	1.16	2.41E+01	1.9
Tc-99	2.82E-02	E	1.45	1.45E-03	1.34	1.81E-02	E	1.45	1.45E-03	0.863
U-232	8.27E-09	C	1.16	8.10E-07	2.94	5.35E-09	C	1.16	6.88E-07	1.9
U-233	5.30E-10	C	1.16	4.77E-08	2.94	3.42E-10	C	1.16	4.05E-08	1.9
U-234	7.47E-04	C	1.16	6.72E-02	2.94	4.82E-04	C	1.16	5.71E-02	1.9
U-235	3.36E-05	C	1.16	3.02E-03	2.94	2.17E-05	C	1.16	2.57E-03	1.9
U-236	4.77E-06	C	1.16	4.29E-04	2.94	3.08E-06	C	1.16	3.64E-04	1.9
U-238	7.56E-04	C	1.16	6.80E-02	2.94	4.89E-04	C	1.16	5.78E-02	1.9

C – Concentration based on calculation.
E – Concentration based on engineering.
S – Concentration based on sample analyses.

Table 3-5b. C-200 Series (C-203 and C-204) Tanks BBI (Non-Radionuclides).

C-203: Sludge volume = 10,000 L (3,000 gal)						C-204: Sludge volume = 10,000 L (3,000 gal)				
Non-radio-nuclides	Inventory (Kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier	Inventory (Kg)	Basis	Density (g/mL)	Concentration (µg/g)	Multi-plier
Cr	4.57E+00	E	1.16	1.34E+02	2.94	2.95E+00	E	1.16	1.34E+02	1.9
Hg	0.00E+00	E	1.45	0.00E+00	1.34	0.00E+00	E	1.45	0.00E+00	0.863
K	1.36E+01	E	1.16	4.00E+02	2.94	8.82E+00	E	1.16	4.00E+02	1.9
Na	9.21E+02	E	1.16	2.70E+04	2.94	5.95E+02	E	1.16	2.70E+04	1.9
Ni	2.73E+02	E	1.16	8.00E+03	2.94	1.76E+02	E	1.16	8.00E+03	1.9
NO_2	2.45E+02	E	1.5	2.10E+04	0.779	1.58E+02	E	1.5	2.10E+04	0.503
NO_3	8.38E+02	E	1.5	7.17E+04	0.779	5.41E+02	E	1.5	7.17E+04	0.503
Pb	1.93E+03	E	1.16	5.67E+04	2.94	1.25E+03	E	1.16	5.67E+04	1.9
PO_4	2.04E+01	E	1.5	1.75E+03	0.779	1.32E+01	E	1.5	1.75E+03	0.503
SO_4	4.02E+01	E	1.5	3.44E+03	0.779	2.59E+01	E	1.5	3.44E+03	0.503
Sr	5.56E+01	E	1.16	1.63E+03	2.94	3.59E+01	E	1.16	1.63E+03	1.9
TIC as CO_3	1.30E+03	E	1.56	8.23E+04	1.01	8.51E+02	S	1.62	5.25E+04	1
TOC	4.54E+02	E	1.5	3.89E+04	0.779	2.93E+02	E	1.5	3.89E+04	0.503
U_{TOTAL}	2.26E+00	E	1.16	6.64E+01	2.94	1.46E+00	E	1.16	6.64E+01	1.9

C – Concentration based on calculation.
E – Concentration based on engineering.
S – Concentration based on sample analyses.

S Basis. As indicated by the "S" in the basis column of Table 3-4, only a small portion of the waste constituent inventory from the C-200 series tanks is represented by direct analysis of tank waste samples. Samples were collected from all four of the C-200 series tanks between 1978 and 1998.

E Basis. The values with the "E" basis are primarily from the process knowledge "HS Solids" template. The "HS" refers to a BBI waste template developed for Hot Semiworks. The HS waste template was developed entirely on the HDW model. Many of the metals inventories with the E basis for the four 200 series tanks are based on a 1978 sample analysis from the C-201 tank. The Am-241, plutonium and curium isotopes are based on total alpha sample analyses from samples collected from each tank in 1995 or 1997. The samples collected in 1995 and 1997 were generally only analyzed for total alpha. The majority of the other radionuclides are from the HS waste template. For these tanks additional refinement of the metals inventories was done based on Hot Semiworks flowsheets.

The density of 1.16 g/mL is a measured density from a tank C-201 sample collected in 1978. The 1.45 g/mL density is the HS template density. The 1.5 g/mL density was assumed for the tank C-201 1995 auger and 1997 core sampling event results. The 1.62 g/mL density is the

measured result from the tank C-203 1995 auger sampling. The 1.56 g/mL density associated with the tank C-201 and C-203 TIC is an average of the 1.5 g/mL and 1.62 g/mL densities.

The various multipliers are used to scale the template data to reflect the waste densities and the weight percent water of the representative samples.

C Basis. The values with the "C" basis are based on calculation. The inventories and concentrations for the uranium isotopes were calculated based on the HDW model isotopic distribution and the total uranium from the HS waste template.

As discussed previously, the inventory formula is not used for the C basis inventories. The C basis concentrations in Table 3-5 are from the HDW model, without considering the isotopic distribution from the referenced analyses. A more representative waste concentration could be calculated by working backward using the inventory values.

3.2.2.4 Other Analytical Data. In addition to the data summarized above, samples collected from the C-201 and C-202 tanks in 1997 have been analyzed for organic acids including chelating compounds such as ethylenediaminetetraacetic acid (EDTA) and N-(2-hydroxyethyl) ethylenediaminetriacetic acid (HEDTA) (Campbell, J.A., A.K. Sharma, S.A. Clauss, G.M. Mong, and D.L. Bellofatto, 1998). Analytical results are summarized in Table 3-5. None of the chelating compounds were detected. Low levels of acetate (acetic acid) and/or formate (formic acid) were detected with the primary organic acid in the form of oxalates (oxalic acid). The presence of primarily oxalic acid is consistent with numerous tank waste aging studies where the chelator compounds and other acids degrade with age, radiation exposure, and heat exposure to oxalic acid (Meacham, J.E., A.B. Webb, et.al. 1997) (Camaioni, D.M., W.D. Samuels, J.C. Linehan, S.A. Clauss, A.K. Sharma, K.L. Wahl, J.A. Campbell, 1996).

Table 3-6. Summary of Organic Acid and Chealator Data for Tanks C-201 and C-202.

Organic Acid	Tank	
	C-201 (µg/g)	C-202 (µg/g)
Oxalate (Oxalic acid)	7.94E+03	6.82E+03
Glycolate	2.22E+03	2.52E+03
Formate (Formic acid)	1.40E+02	2.00E+02
Iminodiacetic acid	ND	ND
Citric acid	ND	ND
Nitrilotriacetic acid	ND	ND
Ethylene	ND	ND
EDTA	ND	ND
HEDTA	ND	ND
s-EDDA	ND	ND

EDTA – ethylenediaminetetraacetic acid
HEDTA – N-(2-hydroxyethyl)ethylenediaminetriacetic acid
s-EDDA – symmetric ethylendiaminediacetic acid
ND – not detected (detection level unavailable)

The *Organic Complexant Topical Report* (Meacham, J.E., A.B. Webb, et.al. 1997) indicated that virtually all of the TOC content of the C-204 tank waste is in the form of tributyl phosphate. The purpose of the complexant report was to address organic complexant safety issues. Thus environmental analytical methods were not used for testing, however the safety testing did indicate waste differences between the two C-200 series tanks tested. The two C-200 series tanks tested were the C-201 tank and the C-204 tank.

The auger samples collected from the C-204 tank in 1995 were analyzed by the 222-S laboratory for safety screening purposes and by the Pacific Northwest National Laboratory (PNNL) for organic speciation. PNNL analyzed the samples for chelators, chelator fragments, organic acids, and organically soluble carbon. This effort indicated that 33% of the sample by weight was tributyl phosphate. Chelator compounds were not detected. Trace unquantifiable levels of butyric acid, toluene, benzoic acid, and normal paraffin hydrocarbons were also indicated in the sample. Results from this analysis are in *Final Report for Tank 241-C-204, Auger Samples 95-Aug-022 and 95-Aug-023,* (Conner, J.M., 1996a).

In 1996, PNNL conducted tank vapor characterization projects on the C-202 and the C-204 tanks. The projects are documented in the *Headspace Vapor Characterization of Hanford Waste Tank 241-C-202* (Pool, K.H., J.C. Evans, B.L. Thomas, K.B. Olsen, J.S. Fruchter, K.L. Silvers, 1997) and *Headspace Vapor Characterization of Hanford Waste Tank 241-C-204* (Thomas, B.L., J.C. Evans, K.H. Pool, K.B. Olsen, J.S. Fruchter, K.L. Silvers, 1997). These vapor characterization studies were thorough and included a large list of volatile and semi-volatile organic compounds. Analytical results on the vapor samples from the C-202 tank indicated the presence of non-methane organic compounds at a vapor concentration of 1.23 mg/m^3. There were no vapor detections for specific organic compounds from the C-202 tank.

Analytical results on the vapor samples from the C-204 tank indicated the presence of low vapor concentrations (less than 2 parts per million) of dodecane, tridecane, and 1-butanol. All of these are typical kerosene / petroleum hydrocarbon compounds. Detection of these compounds is likely indicative of the presence of tributyl phosphate in the waste. Tributyl phosphate and the normal paraffin hydrocarbons were generally used together in the uranium recovery process and were included together in the same waste stream. Also from organic waste aging studies, the hydrocarbon component of the waste stream typically degrades and evaporates at a faster rate than tributyl phosphate. For additional discussion regarding organic solvent waste aging see the *Organic Solvent Topical Report* (Conner, J.M., 1996).

3.2.2.5 Assessment of the C-200 Series Tank Waste Information. As discussed above, almost none of the BBI inventory of these four tanks is based on actual analytical analysis of tank waste. The majority is based on the HDW model. For the C-200 series tanks the model based contaminant concentrations pared with the very conservative BBI residual waste volumes likely provide a very conservative representation of the tank waste inventory. On these bases the BBI inventory likely provides a very conservative basis for initial closure planning.

Process knowledge has indicated that the waste in the C-200 series tanks should be very similar. However, some of the limited organic complexant and organic solvent data provide indications

that there may be differences between the C-204 and the C-201 and C-202 tanks. In addition, recent vapor space readings from the C-203 tank performed prior to the planned video inspection indicated the presence of low levels of organic vapors from the C-203 tank. Based on very the limited data it appears that the waste in the C-203 tank and the C-204 may be similar and that the waste in the C-201 and C-202 tanks are similar, but that the C-203 and C-204 tanks contain a organic solvent component that may not be present in the C-201 and C-202 tanks. The differences may simply be because the C-203 and C-204 tanks contain a greater volume of waste than the C-201 and C-202 tanks. A larger volume of organic solvent containing waste would produces a greater volume of vapor and would take a longer period of time for the organic components to degrade to more stable compounds. In addition, the total alpha analyses results from each tank are significantly different as well. The differences between the total alpha analyses is shown in Tables 3-4 and 3-5 in the plutonium and curium inventories.

The available organic complexant and organic solvent data do not indicate that organics are contaminants of concern from a tank closure prospective, however the differences in these constituents and the total alpha results indicate that there may be differences in the C-200 series tank wastes that are not adequately captured by the HDW model, which indicates that the wastes from tank to tank are similar.

Depending on the defensibility of the HDW model as conservatively high, the volume of post-retrieval residual waste, regulatory waste determinations, and risk assessments, the use of a conservative approach could potentially be an appropriate approach for closing the C-200 series tanks.

However, for these initial tank closure demonstrations, it is important to note that the full regulatory status of residual waste to be closed with a tank has not been determined, and because contaminate inventories of surrounding soil, other tanks, and ancillary equipment have yet to be fully addressed in terms of closure implications, this potentially conservative approach may be too conservative and is therefore considered not appropriate to support closure decisions. There is additional discussion regarding uncertainty and sensitivity of closure characterization data sets in Section 8.1.4.

As some of these statements indicate, this conservative approach could be implemented to support future tank closures. However, for this closure demonstration, the HDW model based waste characterization data generally does not adequately address or represent the remaining waste or the potential remaining waste following retrieval for purposes of making final closure decisions.

There are currently ongoing efforts for DQOs for purposes of tank closure.

3.2.2.6 Planned Waste Inventory Characterization. Waste samples collected in 1995 and 1997 from the C-200 series tanks were archived at the 222-S laboratory. These samples are scheduled for additional analyses during the summer of 2002. The samples are being analyzed for the long lived mobile radionuclides, radionuclides that pose potential short term worker risks, and radionuclides that are the primary regulatory waste designation determiners. The samples are also being analyzed for metals, anions, and polychlorinated biphenyls (PCBs). There is not an expectation that PCBs are a contaminant of concern (COC) for these tanks, however the PCB

analysis is supportive of commitments made by the double shell tank feed program and is being done on that basis. Analyses of these samples are being done in accordance with the amended Retrieval Performance Evaluation (RPE) DQO and tank analysis plan. Again, there are currently ongoing efforts to establish a DQO for tank closure.

The archived samples from the C-201 and C-202 tanks each contain a small mass of sample material from each tank, generally less than 60 grams. Archived samples from the C-201 and C-202 tanks were collected in 1997 using a core sampler. For the C-202 tank additional sample material was collected in 1997 from the waste surface using an auger and a grab sampler. Waste material from both tanks was described as dark brown to gray and dry and powdery to granular. Preliminary indications from the laboratory are that there is enough material to conduct the requested analyses.

The archive sample from the C-203 tank is of sufficient volume to conduct the requested analyses. The archived sample from the C-203 tank was collected in 1995 using an auger sampler and was described as solid with brown and yellow sludges.

The archived samples from the C-204 tank were collected in 1995 using an auger sampler and are comprised of a cloth rag in each of two vials. The laboratory is analyzing the cloth material for a modified set of analyses in accordance with a change control notice that was submitted to address the issues of analyzing a material other than tank waste. There is not an expectation that the results from the rag analysis will be used to establish a waste inventory for the C-204 tank. The results will provide qualitative information to compare against the results from the other tanks for making an assessment of the similarity of the wastes between the C-200 series tanks.

All of the archived C-200 series tank waste samples have been stored at room temperature since collection. For the primary COCs (long-lived mobile contaminants, see Section 6.0) the extended hold times should have little to no affect on the quality of the analytical data. The potential exception would be for nitrite where the addition of oxygen to the sample material from disturbance during actual sampling in conjunction with extended hold time allows the nitrite to react with the oxygen to form nitrate. This is expected to be minimal. The total nitrate-nitrite concentration should not be affected by the extended hold times.

The results from these additional analysis when available and as appropriate will be reflected in the BBI system. Again there are currently ongoing efforts for a tank closure DQO.

3.3 C TANK FARM AND CLOSURE DEMONSTRATION TANK VADOSE ZONE.

The following sections discusses the physical setting of the C Tank Farm and what is known about subsurface contamination associated with the tank farm. The physical setting includes a brief discussion of geologic and hydrologic information. More detailed information can be found in the references cited. Subsurface contamination information includes a review of documented releases of contaminated liquid to the soil. Also included is a discussion of gamma-ray logging and its use in assessing geologic subsurface contamination.

3.3.1 Geologic Setting

3.3.1.1 Regional. The Hanford site is located in the Pasco Basin, a structural and topographic basin within the Columbia Plateau. The Columbia Plateau is located in an intermountain basin extending from the Bitterroot Range to the Cascade Range. This area has been partially filled with a thick sequence of tholeiitic basalt flows called the Columbia River Basalt Group.

The thick basalt sequence is overlain by fluvial (river) and lacustrine (lake) sediments of the Miocene-Pliocene Ringold Formation and the Quaternary Hanford formation. These sediments, which consist of gravel, sand, silt, and clay, were deposited in rivers or lakes and constitute the unconfined aquifer beneath the Hanford Site (DOE-RL 1998).

3.3.1.2 200 East Area. The 200 Areas are developed on a gently sloping, low relief surface produced by two geomorphic processes: (1) Pleistocene cataclysmic flooding and (2) Holocene (Recent) eolian activity.

The stratigraphy of the 200 East Area has been strongly influenced by local basalt highs in the central part of 200 East. The Ringold Formation, which overlies basalt over most of the central Pasco Basin pinches out and is missing beneath the Waste Management Area B-BX-BY.

The Hanford formation in the 200 East Area is divisible into three units: Hanford lower gravel, Hanford sand, and Hanford upper gravel. Each of these units is highly variable. Clastic dikes have been observed crosscutting various units of the Hanford formation in the 200 East Area (DOE-RL 1998).

3.3.1.3 C Tank Farm. There are four sedimentary sequences overlying the basalt beneath the C Tank Farm (PNNL 2001). These are, from bottom to top:

Hanford formation lower gravel sequence and/or Plio-Pleistocene gravels. This sequence is described on borehole logs as cobble to pebble gravels, sandy gravels and gravelly sands with lesser amounts of muddy sandy gravel and sand.

Hanford formation sand sequence. This is described on borehole logs as variably bedded silty sand, sand and slightly gravelly to gravelly sand. It is the thickest of the four Hanford fm sequences averaging about 58 m (190 ft) based on the logs of the five RCRA groundwater monitoring wells.

Hanford formation upper gravel sequence. This sequence is dominated by gravels and is described on borehole logs as interbedded sandy gravels, gravelly sands, and sands. It averages about 10 m in thickness. This unit was excavated during tank farm construction and replaced with backfill.

Eolian sediments and/or backfill material. Within the tank farm, this material is mixed gravel, sand and silt excavated from the tank farm during construction (Narbutovskih et al, 1996). Areas outside the farm not disturbed by construction have a cap of up to 4.5 m (15 ft) of fine to medium grained, wind blown sand.

3.3.2 Hydrologic Setting

3.3.2.1 Vadose Zone Hydrology. The hydrology of the vadose zone is influenced by the textures of the geologic units in the Hanford and Ringold formations, the thickness of the unsaturated sequence, and the low precipitation, and high evaporation typical of the Hanford site. These factors significantly influence the time required for the contaminants to reach the water table. Perched water has been known to occur beneath a few active release sites, and is located above fine grained sediments (DOE-RL 1999).

3.3.2.2 Groundwater Hydrology. The unconfined aquifer generally occurs in the unconfined Hanford formation and the semi-consolidated silts, sands, and gravels of the Ringold formation. Beneath 200 East, the Ringold is locally absent, and the aquifer exists entirely in the Hanford formation. Because the Hanford formation sands and gravels are so much more permeable than the Ringold gravels, the water table is relatively flat in the 200 east area, but groundwater flow velocities are higher (DOE-RL 1999).

Aquifer recharge associated with Hanford site operations historically has produced major groundwater mounds in the 200 East Area. The reduction and cessation of waste disposal has resulted in decline of the water table elevations and is changing the contaminant plume characteristics (DOE-RL 1999). Based on March 1999 water levels in the C Tank farm, the gradient between 299-E27-7 and 299-E27-13 is nearly flat (PNNL 2001). Such a low gradient makes identification of groundwater flow direction uncertain (DOE-RL 1999). However, a general groundwater flow direction is indicated in the south and/or easterly directions.

3.3.3 C Tank Farm Subsurface Contamination Information

This section discusses subsurface soil contamination information for the C Tank Farm derived primarily from process knowledge of unplanned releases (UPR) and tank leaks of liquid to the soil, and gamma-ray logs from more than 70 boreholes installed in the C Tank Farm. Groundwater monitoring well information is also included in this section. No significant results from analytical testing of soil in the C-farm have been located in the historical data. Wind-blown releases have been documented inside the C Tank farm; however, they are not included in this discussion.

3.3.3.1 Process Knowledge of Subsurface Contamination. Six UPRs from piping or other sources other than the tanks have been identified. Sources of information presented below are from (Williams, J.C. 2001) and from the Waste Information Data System (WIDS). The referenced vaults, diversion box, and tank locations are shown on Figure 2-3.

- UPR-200-E-99. This site is associated with releases at or near the ground surface surrounding the 244-CR Vault during the numerous piping changes and activities associated with the vault. The contaminated surface soil has been stabilized or removed. The extent of subsurface soil contamination and volumes of releases associated with these activities are not known. The release site was identified in 1980. The date or dates of actual release(s) are not known.

- UPR-200-E-107. There is conflicting information regarding this release. Williams 2001, identifies this release as associated with the installation of a transfer pump in the 244-CR

vault in 1952. WIDS identifies the release from a 1953 incident report as from the 241-C-110 tank. The volumes associated with this release and the specifics associated with the release are not known.

- UPR-200-E-16. Sometime between 1956 and 1959 the overground transfer line from the C-105 tank to the C-108 tank broke and released approximately 190 L (50 gal) of PUREX coating waste (CWP) to the soil. The waste was a high concentration contaminant waste.

- UPR-200-E-81. The UPR-200-E-81 release is associated with the 241-CR-151 diversion box and occurred in the waste transfer line near the box. The release occurred on October 15, 1969, and released approximately 136,300 L (36,000 gal) of CWP waste to the soil. The release occurred near the ground surface. As a result of the release a puddle of liquid waste formed at the ground surface a few feet to the west of the 241-CR-151 diversion box. The puddle measured 1.8 meters by 12.2 meters (6 feet by 40 feet). The puddle was covered with about 18 inches of soil, the piping was rerouted and the CR-151 diversion box covered with spray foam.

- UPR-200-E-82. The UPR-200-E-82 release is associated primarily with the 241-C-152 diversion box. The release occurred in 1968 from a pipeline between the box and the C-105 tank. The liquid from the release reportedly flowed over the ground surface from or near the diversion box to the northeast, downgrade, until it pooled into an area outside the 241-C Tank Farm fence. Approximately 3,800 L (1,000 gals) of the total liquid released (estimated at 2,600 gals) collected on the ground surface. The area where pooling occurred is not clear. The contaminated soil areas were covered with clean gravel in December 1969.

- UPR-200-E-86. The UPR-200-E-86 release occurred from a buried transfer line near the southwest corner of C tank farm (near the 241-C-151 diversion box). The release was detected in 1971 through routine leak detection monitoring. The estimated release volume of PUREX supernate waste is 65,800 L (17,380 gals). The ground surface above the release area was covered with shotcrete in 1995.

- In 1971, eight wells were drilled around the leak to define the release area. Borehole 4 encountered contaminated soil reading 5 rad per hour between the depth of 1 and 2 meters (3 to 6 feet). No contamination was found below 6 meters (20 feet) in any of the boreholes. In 1972, three boreholes were drilled through the contaminated area to determine the depth of the contamination. Contamination was not found below the 6.1-meter (20-foot) level in any of the boreholes.

3.3.3.2 Process Knowledge of Tank Leaks. A total of seven tanks from the C tank farm have been identified with releases to soil. These tanks include C-101, C-110, C-111, C-201, C-202, C-203, and C-204. Only the C-101 and C-201 tanks have UPR WIDS sites associated with them (UPR-200-E-136 and UPR-200-E-137, respectively). From *Historical Vadose Zone Contamination from A, AX, and C Tank Farm Operations* (Williams 2001) each tank release is briefly discussed below. As previously discussed the C-200 series tanks were used for primarily for metal wastes from the Hot Semi-works.

- Tank C-101 (UPR-200-E-136). The tank was categorized as having questionable integrity in 1970 and was categorized as a confirmed leaker in 1980. The tank was pumped to a minimal waste volume in 1969. The tank was last pumped in April 1979 and did not yield any additional waste. Leakage (UPR-200-E-136) from the C-101 tank occurred over a period of time and was identified from liquid level decreases that were not attributable to other potential sources of liquid loss. It was estimated that between 64,600 and 91,200 L (17,000 and 24,000 gals) of waste has leaked from the 241-C-101 tank. The tank was active from 1946 through 1970 and received bismuth phosphate metal waste, tributyl phosphate process waste and PUREX CWP.

- Tank C-110. The C-110 tank received bismuth phosphate first cycle waste from 1946 to 1967. The C-110 tank was also used as primary settling tanks for in-farm scavenging for the uranium recovery process. The last documented waste transfer for this tank was in 1978. The C-110 tank was identified as an assumed leaker in 1984 with an estimated volume loss of 7,700 L (2,000 gals). The basis of the assumed leaker status is not clear, but is likely due to decreasing waste level measurements.

- Tank C-111. The C-111 tank followed the C-110 tank in a tank cascade line and like the C-110 received bismuth phosphate waste between 1946 and 1967 and was also used in the uranium recovery process. The last documented waste transfer for this tank was also in 1978. The C-111 tank was declared an assumed leaker in 1968 with an estimated volume loss of 20,800 L (5,500 gals). Again the basis of the assumed leaker status is not clear, but is likely due to decreasing waste level measurements.

- Tank C-201. The last documented waste transfer for the C-201 tank was in 1970. The C-201 tank was identified as an assumed leaker in 1988, with an estimated release volume of 2,100 L (550 gals). The basis of the assumed leaker status and estimated release volume is not clear, but is likely due to decreasing waste level measurements.

- Tank C-202. The last documented waste transfer for the C-202 tank was in 1970. The C-202 tank was identified as an assumed leaker in 1988, with an estimated release volume of 1,700 L (450 gals). The basis of the assumed leaker status and estimated release volume is not clear, but is likely due to decreasing waste level measurements.

- Tank C-203 (UPR-200-E-137). Over a period of two to three years, precipitation reportedly entered the tank, migrated through the residual waste, and either became entrained in the waste or leaked out. On this basis the tank was declared a leaker in 1984 with an estimated leak volume of 1,500 L (400 gals).

- C-204. The last documented waste transfer for the C-204 tank was in 1977. The C-204 tank was identified as an assumed leaker in 1988, with an estimated release volume of 1,300 L (350 gals). The basis of the assumed leaker status and estimated release volume is not clear, but is likely due to decreasing waste level measurements.

The largest known releases in the C Tank Farm have occurred in the vicinity of the 244-CR vault, CR-151 diversion box, and the CR-152 diversion box area. The total process knowledge estimated release volume in this area is 206,000 L (54,000 gals).

3.3.3.3 Soil Contamination Information from Gamma-Ray Logging. Soil contamination information includes gamma-ray logging in vadose zone boreholes in the C Tank Farm from 1973-1997 (DOE-GJO 1998). Until 1993, gamma-ray logs were generally measurements of total gamma radiation. Beginning in 1993, spectral gamma logs were collected in some boreholes. In 1997, a new, higher efficiency Spectral Gamma Logging System (SGLS) was introduced and has remained the primary tool for gamma ray measurements in the tank farms. Total gamma logs measure gamma radiation from all sources, natural and manmade. Spectral gamma logs record the energy of individual gamma rays, and thus can be used, in most cases, to identify specific radionuclides, natural or manmade. While total and spectral gamma logs are not directly comparable, some correlation between them has been done (DOE-GJO 1998).

Soil contamination is inferred in the gamma logs when the measured gamma radiation does not correspond to naturally occurring sources of radiation. Changes in the distribution of the gamma contamination with time can be used to infer migration of contamination. Since primarily gamma radiation is measured with this method, only gamma emitters can be detected and tracked. However, knowledge of waste stream inventories can be used to infer the presence of some undetected contaminates when certain gamma emitters are detected. In addition, migration of the detected sources can be used to predict migration of undetected species that are known to have similar migration behavior.

The concentration of individual gamma-ray emitting radionuclides in the sediments surrounding a borehole can be calculated from the activities in the gamma-ray energy spectra measured in the borehole using calibrated instruments (DOE-GJO 1998). Several factors control the accuracy of these calculated concentrations--the most important include making corrections for borehole casings of unknown thickness, and different moisture content in the formation around the borehole compared to the calibration location. In addition, statistical uncertainties in reported concentrations and the minimum detection level (MDL) for the individual radionuclides is directly related to the time spent counting gamma-rays at each depth. Procedures for performing gamma-ray logging have been developed to optimize the trade-off between accuracy/precision and counting time (i.e., cost). The standard count time has been set to 100 seconds per level (DOE-GJO 1998).

A list of selected detectable manmade gamma-ray emitting radionuclides and their MDL based on a 100 second counting time is given in Table 3-7. Source concentrations are given in picocuries per gram (pCi/g), even though the logging unit technically describes decay rate per unit mass of the sample rather than concentration. The use of decay rate per unit mass is widespread in environmental work where health and safety issues relate to radioactivity, not chemical concentrations (DOE-GJO 1998).

Table 3-7. Selected Manmade Radionuclides and Minimum Detection Levels with Spectral Gamma (DOE-GJO-1998).

Radionuclide	MDL* (pCi/g)
Cs-137	0.1-0.2
Co-60	0.15
Eu-154	0.2
U-238	0.2
U-235	0.2

* based on 100 second counting time.

For the C tank farm the primary gamma-emitting radionuclides detected in the vadose zone were cesium-137 and cobalt-60 (DOE-GJO 1998). Europium-154 was also detected in the subsurface but to a much less extent. Uranium-235, europium-152, and europium-154 were detected at the ground surface around several boreholes.

Interpretation of the spectral gamma logs requires consideration of potential logging anomalies that are not representative of actual vadose zone contamination. Some of the anomalies encountered include surface contamination near the borehole, direct gamma rays from nearby contaminated equipment, contamination that was dragged down during borehole construction, or contamination that entered into the borehole at the surface and fell to the bottom of the borehole (DOE-GJO 1997).

Based on analysis of spectral gamma logging, significant Cs-137 contamination, and to a lesser extent Co-60 contamination) is present in the vadose zone at the C tank farm. The majority of the contamination cannot be directly associated with specific tank leaks or specific leaks from ancillary piping and equipment.

Near Surface Contamination. Logging detected primarily Cs-137 in near surface soil (0 to 30 feet below ground surface). The highest levels of Cs-137 in near surface soils were detected in the vicinity of tanks C-105, C-106, and along the southwest portion of C-108.

Contamination at Depth. In the vicinity of the C-101 tank, logging has indicated elevated levels of Cs-137 along the south side of the C-101 tank near the bottom of the tank. Additional boreholes in the vicinity indicate elevated levels of Cs-137 beneath the C-101 tank to the depth of the deepest borehole at 100 feet below the ground surface.

In the vicinity of the C-110 tank elevated levels of Cs-137 were detected on the north side of the tank from the ground surface to about 60 feet below the ground surface.

Borehole logging has indicated elevated levels of Cs-137 and Co-60 beneath tanks C-104, C-105, and C-106. The contamination extends horizontally from the northeast side of tank C-104 to the north side of tank C-106. The plumes extend vertically about 120 feet below ground surface (80 feet below the base of the tanks).

Borehole logging has indicated Co-60 contamination beneath the C-108 and C-109 tanks with indications that the contamination begins near the bottom of the tanks and extends to approximately 100 feet bgs.

3.3.3.4 C-106 Tank Specific Soil Information. There are eight vadose zone monitoring boreholes around tank C-106. The boreholes were logged using the Radionuclide Logging System in April 1993. This system provides a spectral gamma ray log of the borehole. The results of the investigation are in *Assessment of Unsaturated Zone Radionuclide Contamination Around Single Shell Tanks 241-C-105 and 241-C-106*, (Brodeur, J.R, 1993).

The boreholes were logged again in 1997 using longer count times and the higher efficiency SGLS. The results of the 1997 SGLS investigation are summarized in *Vadose Zone Characterization Project at the Hanford Tank Farms, Tank Summary Report for Tank C-106* (DOE-GJO 1997).

Both logging efforts showed the highest levels of contaminants primarily Cs-137 at the ground surface, generally 0 to 3 feet below ground surface. The highest detected concentration of Cs-137 in these soils was 1,170 pCi/g from borehole 30-05-02. Below this near surface zone and extending to the bottom of the tank, Cs-137 detectable concentrations generally range from 1 to 20 pCi/g. Below the bottom of the tank extending to a depth of about 120 feet detectable concentrations ranged from the MDL up to 3 pCi/g. The general conclusions of the investigations are that there have been surface releases with Cs-137 contamination extending to 27 feet below ground surface. There are local Cs-137 spikes near the elevation of the bottom of the tank. There are also Co-60 spikes at a depth which may have migrated from another tank along lithologic boundaries, particularly changes in sediment size.

The C-200 series tanks do not have any boreholes in the immediate vicinity. There does not appear to be any soil characterization information specific to the C-200 series tanks.

3.3.3.5 C Tank Farm Monitoring Well Information. There are five groundwater monitoring wells around the 241-C tank farm. Four of the wells are RCRA compliant wells constructed in 1989 in accordance with WAC 173-160 standards. These wells are 299-E27-12, 299-E27-13, 299-E27-14, and 299-E27-15. The fifth well, 299-W27-7, was constructed in 1982, and is not RCRA compliant. Well locations are shown on Figure 2-3.

These wells are monitored quarterly under RCRA in accordance with interim status, indicator parameter evaluation requirements (WAC 173-303 and by reference 40 *Code of Federal Regulations* [CFR] 265.92). RCRA monitoring began in 1991.

Groundwater depths are monitored in the 241-C wells monthly. The general depth of goundwater beneath the C Tank Farm is approximately 76 m (250 feet) below ground surface. Results of a colloidal borescope investigation in 2001 indicated that groundwater flow in the 241-C tank farm area is generally flat with a general flow direction in the southerly and/or easterly directions. The gradient between 299-E27-7 and 299-E27-13 is 0.00021 based on March 1999 water levels. The total difference in elevation was 15 cm (6 inches) (PNNL 2001). This minimal gradient makes the identification of upgradient and downgradient wells and groundwater flow direction less certain.

As shown in PNNL 2001 Hanford Site Groundwater Monitoring Report, Tc-99 and nitrate concentrations are increasing in monitoring wells around the C Waste Management Area. Tc-99 reached a maximum concentration of 2,760 pCi/L in 299-E27-7 in January 2002, but dropped to 784 pCi/L in June 2002. Nitrate is also increasing in all of the 241-C monitoring wells with a maximum concentration of 27,400 µg/L in January 2002 in monitoring well 299-E27-7. The drinking water maximum contaminant level (MCL) for Tc-99 is 900 pCi/L and for nitrate is 45,000 µg/L. The C Tank Farm is located within a large 200 East Area wide nitrate and iodine-129 groundwater contaminant plumes. Groundwater contour maps of the 200 East area with contaminants that exceed the drinking water MCLs are shown on Figure 3-1 and 3-2. In addition, tables 3-7 through 3-11 list the historical groundwater concentrations for selected contaminants (see Section 6.0) from 1990 to the present for the five wells surrounding the C Tank Farm. Although not considered COCs for closure (see Section 6.0) groundwater concentrations for Cs-137 and Co-60 are provided for potential comparison with soil gamma logging information. As summarized in Tables 3-8 through 3-12, Cs-137 and Co-60 have not recently been detected in groundwater. Groundwater samples from these wells have not been analyzed for Se-79 and C-14, which have been identified as COCs (see Section 6.0).

Figure 3-1. Major Nonradiologial Groundwater Plumes in the Vicinity of 200 East Area (Modified from PNNL 2001)

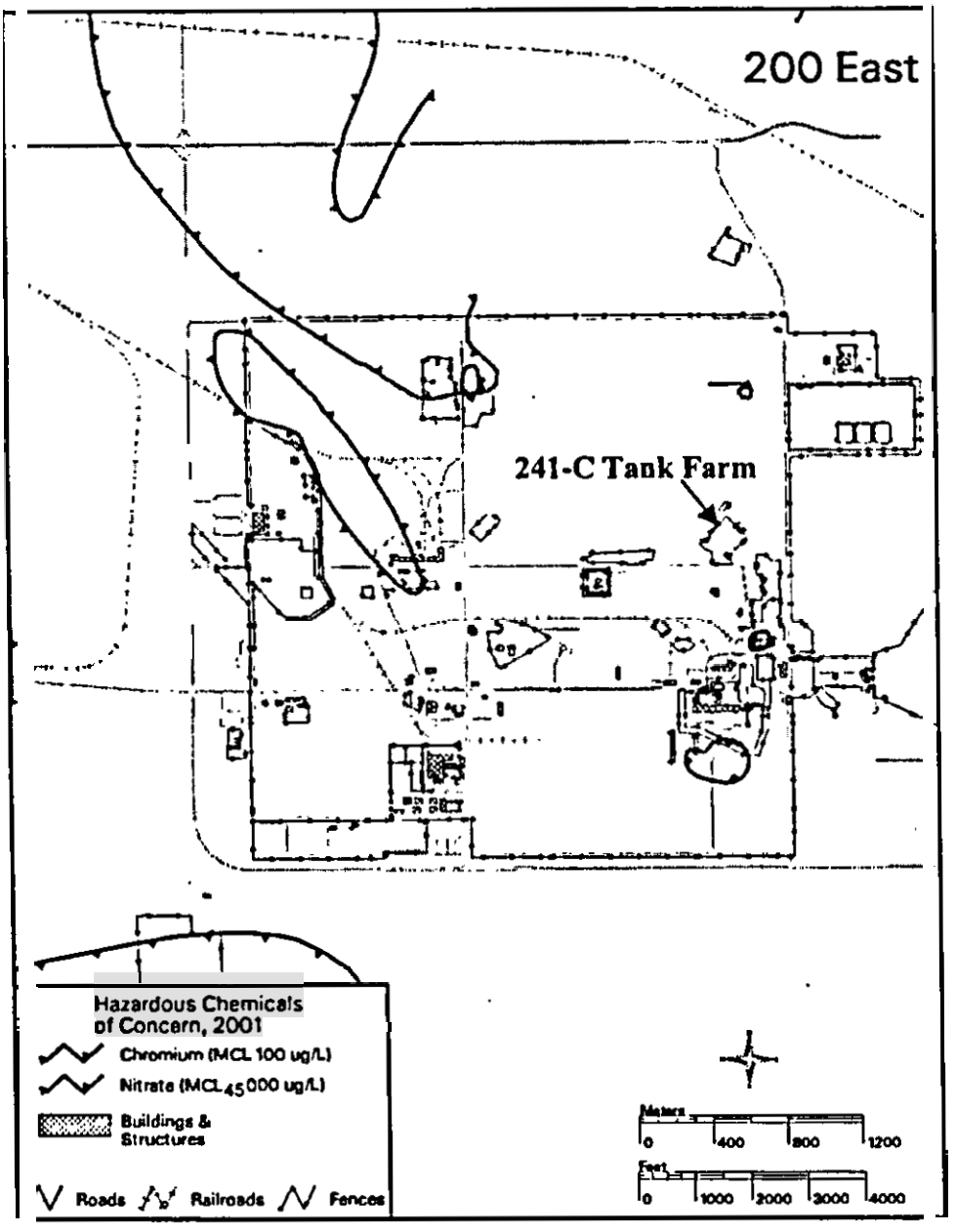

Figure 3-2. Major Radiological Groundwater Plumes in the Vicinity of 200 East Area (Modified from PNNL 2001)

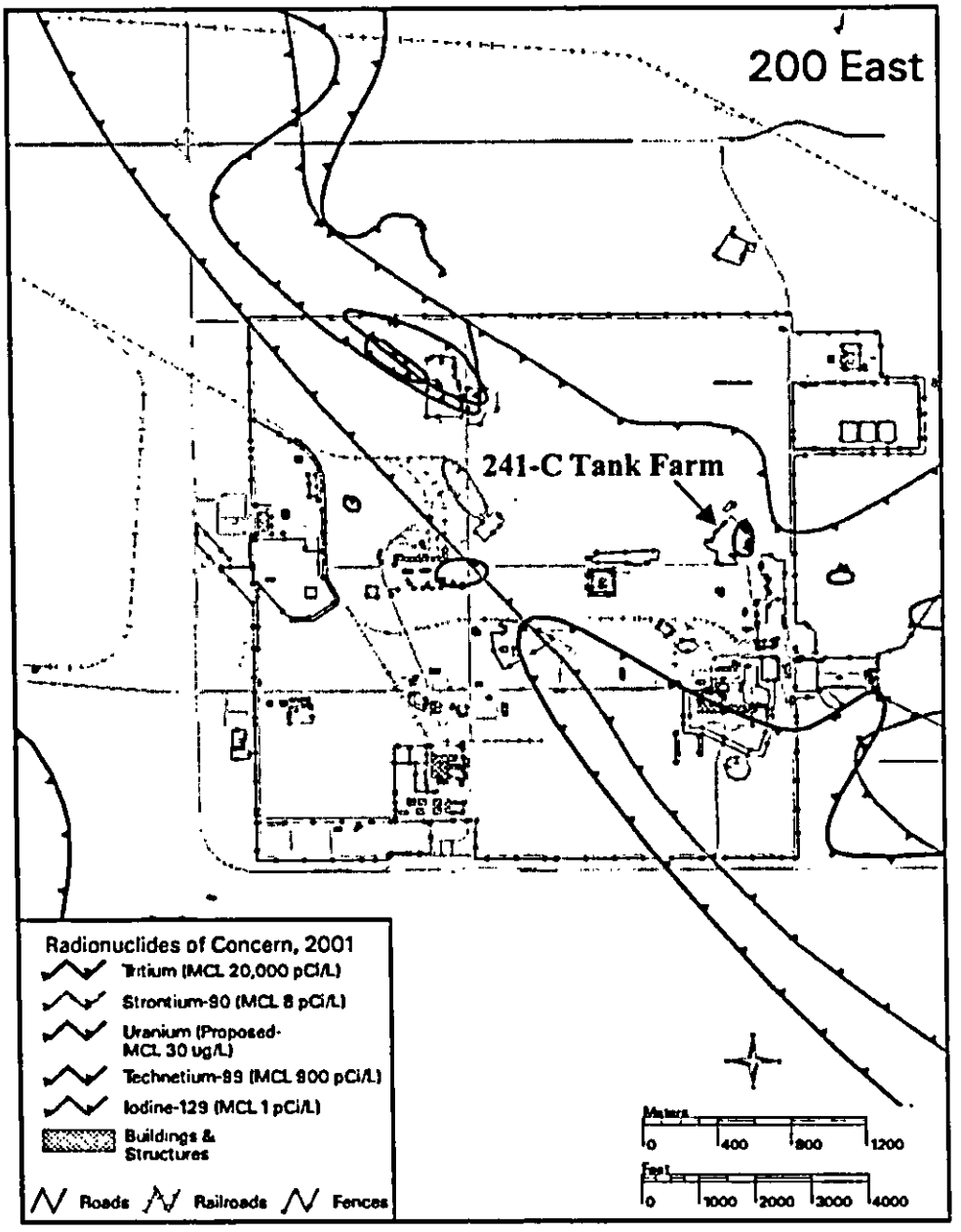

Table 3-8. Well 299-E27-12 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 pCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
H0008RF6	02/26/1990	-2.76 U	3.78 U	-	-	1,600	1,000 U	-	-
H00072D4	07/23/1991	-	-	1.85	2.74	2,030	-	1.57	20 U
B00MT3	11/18/1991	4.75	5.55	9.22	2.73	2,600	200 U	1.61	20 U
B01TR8	03/05/1992	-2.94	5.6	1.04	3.41	3,300	200 U	2.22	20 U
B06NJ7	05/15/1992	1.47	-1.75	1.96	3.33	4,700	200 U	1.97	20 U
B074T6	08/25/1992	2.33	10.4	1.37	4.11	4,900	200 U	2.06	20 U
B07LN3	11/09/1992	-0.43 U	-1.46	1.70 U	2.75	4,600	200 U	2.43	20 U
B087V5	03/09/1993	3.75 U	8.33	1.90 U	3.53	4,100	200 U	2.34	20 U
B08N29	06/15/1993	3.20 U	-5.59 U	2.92	2.88	3,500	200 U	1.83	20 U
B0BJK2	03/15/1994	-0.22 U	-0.12 U	1.60 U	3.42	3,100	38.3 U	1.77	-
B0CYN1	09/15/1994	0.61 U	0.75	1.06 U	3.02	-	-	-	-
B0DQB9	02/08/1995	-	-	1.98 U	2.62	11 U	18 U	-	-
B0G9T6	08/02/1995	-	-	4.18	3.92	-	-	-	-
B0H9R4	02/13/1996	-	-	2.74	3.42 U	3,500	140 U	-	-
B0J6Q7	08/05/1996	-	-	3.09	3.21	-	-	-	-
B0K1C9	02/11/1997	-	-	2.95 U	5.09	3,850	6.57 U	-	-
B0LD00 & 4	08/05/1997	1.85 U	1.16 U	7.35 U	4.13	-	-	-	-
B0MYT3	02/05/1998	0.12 U	-1.04 U	9.78 U	2.86	3,590	3.28 U	-	-
B0NWK5	06/08/1998	1.46 U	-0.30 U	15.7	3.84	3,670	3.28 U	-	-
B0T8H3 & 4	12/08/1998	0.36 U	0.78 U	32.9	4.27	3,940	55.80 U	2.07	-
B0TFL8 & 9	01/04/1999	-	-	29.3	-	3,910	23 U	-	1.59 U
B0VJ70 & 1	06/03/1999	-0.38 U	1.25 U	62.1	-	3,860	23 U	-	1.59 U

Table 3-8. Well 299-E27-12 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 pCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
B0X1V2 & 3	12/21/1999	-0.21 U	0.55 U	43.7	2.72	4,430 D	24.3 U	2.38	1.60 U
B0Y8X8 & 9	06/02/2000	2.44 U	-.99 U	33.4	-	4,430 D	24.30 U	-	1.60 U
B10N73 & 4	12/18/2000	-.31 U	-1.12 U	35.2	-	4,870 D	24.30 U	2.07	1.60 U
B11DR6 & 7	03/15/2001	.94 U	.85 U	25.4	-	4,870 D	6.57 U	2.33	1.60 U
B13J42 & 3	12/06/2001	.12 U	-1.57 U	29.2	-	5,310 D	6.57 U	2.5	2.50 U
B143F0 & 1	03/11/2002	-0.36 U	.23 U	39.9	-	5,310 D	36.10 U	-	2.50 U
B14NW8	06/05/2002	-0.37 U	-2.24 U	52.3	-	-	-	-	-
Drinking Water MCLs		200	100	900	1	45,000	10,000	30	200

D = Indicates that the sample was diluted prior to analysis, dilution is accounted for by the laboratory.
U = Indicates the constituent was not detected.
- = Sample not analyzed for indicated constituent.

Table 3-9. Well 299-E27-13 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
H0008RG0	02/26/1990	4.57 U	4.68 U	-	-	2,000	1,000 U	-	-
H00072D8	07/23/1991	-	-	40.6	8.04	1,750	-	2.25	20 U
B00MT7	11/15/1991	1.55	0.44	43.1	6.46	2,000	200 U	1.83	20 U
B01TS3	03/05/1992	-	-4.18	42.2	5.23	2,000	200 U	1.56	20 U
B06NK2	05/15/1992	0.86	2.91	62.3	4.41	4,600	200 U	1.81	20 U
B074V1	08/25/1992	4.66	3.77	77.8	4.55	2,000	200 U	1.66	20 U
B07LN8	11/09/1992	-2.00 U	-4.85	90.1	5.14	2,300	200 U	1.88	20 U
B087W0	03/09/1993	-5.26 U	-7.60 U	108	6.13	2,200	200 U	1.63	20 U
B08N34	06/15/1993	-3.74 U	3.69 U	127	4.89	2,600	200 U	2.53	20 U
B0BJL1	03/14/1994	11.9	-1.94 U	131	5.15	2,600	110 U	2.31	-
B0CYN5	09/21/1994	0.72 U	1.47	142	5.55	-	-	-	-
B0DQC4	02/13/1995	-	-	148	4.73	3,100	18 U	-	-
B0G9V5	08/03/1995	-	-	182	4.37	-	-	-	-
B0H9S6	02/13/1996	-	-	11.36	4.32	3,700	140 U	-	-
B0J6R1	08/14/1996	-	-	160.97	3.48	-	-	-	-
B0K1D4	02/13/1997	-	-	100	4.50 J	3,900	6.57 U	-	-
B0LD09 & 10	08/06/1997	0.67 U	1.63 U	123	4.42	-	-	-	-
B0MYT9	02/05/1998	1.80 U	-0.40 U	487	3.58	6,150 D	3.28 U	-	-
B0NWC0	06/08/1998	1.48 U	0.36 U	145	3.02 U	5,440 D	3.28 U	-	-
B0T8J0 & 1	12/10/1998	0.06 U	-1.06 U	77.3	3.93	5,440 D	55.80 U	1.96	-
B0VJ7 & 8	06/03/1999	2.41 U	-0.28 U	137	-	5,670 D	23.00 U	-	1.59 U
B0X1V9 & W0	12/20/1999	0.17 U	3.68 U	104	2.52	5,750 D	24.30 U	1.94	1.60 U

Table 3-9. Well 299-E27-13 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
B0Y8Y5 & 6	06/02/2000	0.06 U	0.14 U	155	-	5,750 D	24.30 U	-	1.60 U
B10N85 & 6	12/18/2000	0.32 U	0.90 U	176	-	6,200 D	24.30 U	1.94	1.60 U
B11DT3 & 4	03/15/2001	0.69 U	-1.19 U	263	3.06	6,200 D	6.57 U	2.05	1.60 U
B13J49 & 50	12/06/2001	0.77 U	2.08 U	472	-	6,640 D	6.57 U	2.29	2.50 U
B143F7 & 8	03/14/2002	-0.18 U	0.02 U	492	-	7,530 D	36.10 U	-	3.7
B14NX5	06/05/2002	3.29 U	0.81 U	769	-	-	-	-	-
Drinking Water MCLs		200	100	900	1	45,000	10,000	30	200

D = Indicates that the sample was diluted prior to analysis, dilution is accounted for by the laboratory.
U = Indicates the constituent was not detected.
- = Sample not analyzed for indicated constituent.

Table 3-10. Well 299-E27-14 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
H0008RG4	02/26/1990	-0.52 U	4.77 U	-	-	9,700	1,000 U	-	-
H00072G2	07/23/1991	-	-	140	9.63	7,270	-	2.13	20 U
B01TS8	03/04/1992	0.54	5.18	102	5.38	8,700	200 U	2.18	20 U
B06NK7	05/15/1992	-8.07	-0.44	195	4.53	7,400	200 U	1.85	20 U
B074V6	08/25/1992	-3.47	-0.58	160	4.86	7,600	200 U	1.79	20 U
B07LP3	11/09/1992	-3.11 U	0.44	139	3.77	7,600	200 U	1.77	20 U
B087W5	03/08/1993	3.29 U	9.61	88.7	4.71	8,000	200 U	1.92	20 U
B08N39	06/15/1993	-4.43 U	-8.94 U	65.8	4.53	7,700	200 U	2.26	5.0
B0BJM5	03/14/1994	1.18	-0.35 U	83.6	4.98	7,400	110 U	1.7	-
B0CYN9	09/21/1994	0.24 U	-2.75 U	64.2	3.64	-	-	-	-
B0DQC9	02/13/1995	-	-	84.8	4.87	11,000 D	18 U	-	-
B0H9V2	02/15/1996	-	-	86.4	4.95	9,600	140 U	-	-
B0J6R5	08/05/1996	-	-	88.7	2.7	-	-	-	-
B0K1G4	02/13/1997	-	-	124	4.15 J	9,210 D	6.57 U	-	-
B0LD15 & 9	08/06/1997	-1.33 U	2.67 U	141	2.74	-	-	-	-
B0MYN3	02/05/1998	1.35 U	0.29 U	184	3.89 U	8,410 D	3.28 U	-	-
B0NW84	06/04/1998	0.94 U	1.26 U	320	3.67	9,250 D	3.28 U	-	-
B0PR86	09/21/1998	-	-	672	-	22,000 D	55.80 U	-	-
B0T8J7 & 8	12/10/1998	-0.29 U	2.51 U	442	2.91	13,600 D	55.80 U	1.72	-
B0TF68 & 9	01/04/1999	-	-	479	-	13,800 D	23 U	-	1.59 U
B0VJ84 & 5	06/03/1999	0.60 U	1.76 U	455	-	12,800 D	23 U	-	1.59 U
B0X1Y0 & 1	12/20/1999	-0.59 U	1.73 U	709	3.97	17,300 D	24.30 U	1.72	1.60 U

Table 3-10. Well 299-E27-14 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
B0Y916 & 7	06/02/2000	-0.06 U	1.60 U	783	-	17,700 D	24.30 U	-	1.60 U
B10N76 & 7	11/14/2000	-0.52 U	1.39 U	857	-	31,000 DN	24.30 U	1.8	7.8
B11DV0 & 1	03/15/2001	-0.30 U	-0.11 U	1,010	2.96 U	32,300 D	6.57 U	2.17	1.60 U
B13J56 & 7	12/04/2001	-0.87 U	5.29 U	1,740	-	33,600 D	6.57 U	2.44	2.50 U
B143H4 & 5	03/14/2002	0.28 U	4.24 U	1,720	-	35,900 D	36.10 U	-	2.50 U
B14NY2	06/05/2002	0.89 U	3.20 U	2,050	-	-	-	-	-
Drinking Water MCLs		200	100	900	1	45,000	10,000	30	200

D = Indicates that the sample was diluted prior to analysis, dilution is accounted for by the laboratory.
U = Indicates the constituent was not detected.
- = Sample not analyzed for indicated constituent.

Table 3-11. Well 299-E27-15 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 pCi/L	Technetium-99 PCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
H0008RG8	02/26/1990	-0.13 U	1.58 U	-	-	1,800	1,000 U	-	-
H00072G6	07/24/1991	-	-	1.88	2.91	2,140	-	2.96	20 U
B00MV5	11/21/1991	1.92	0.46	-1.36	3.38	2,480	200 U	1.46	20 U
B01TT3	03/05/1992	6.4	2.65	4.16	3.55	3,100	200 U	2.42	20 U
B06NL2	05/15/1992	3.39	5.45	0.83	4.5	5,100	200 U	3.18	20 U
B074W1	08/25/1992	-4.39	4.16	1.77	5.11	5,600	200 U	2.61	20 U
B07LP8	11/10/1992	3.39 U	-0.29	.37 U	4.82	5,600	200 U	2.58	20 U
B087X0	03/09/1993	1.13 U	4.55 U	1.28 U	3.77	4,300	200 U	1.85	20 U
B08N44	06/16/1993	6.74	3.89	1.71 U	3.98	4,200	200 U	1.91	1.50
B0BJN0	03/16/1994	-0.33 U	0.49 U	381	5.78	19,000 D	38.30 U	2.2	-
B0CYP3	09/15/1994	-0.54 U	-0.62 U	0.11 U	2.96	-	-	-	-
B0DQD4	02/08/1995	-	-	0.95 U	3.71	3,000	18 U	-	-
B0H9X4	02/12/1996	-	-	2.24 U	3.79	3,500	140 U	-	-
B0J6R9	08/08/1996	-	-	1.1	4.01	-	-	-	-
B0K1F4	02/11/1997	-	-	1.02 U	4.04 J	4,030	6.57 U	-	-
B0LD20 & 4	08/05/1997	-0.31 U	0.74 U	1.44 U	2.81	-	-	-	-
B0MYN9	02/05/1998	-0.56 U	-0.45 U	4.93 U	2.64 U	4,050	3.28 U	-	-
B0NW92	06/08/1998	3.80 U	1.79 U	6.40 U	2.65	4,470 D	3.28 U	-	-
B0R008	10/05/1998	-	-	16.4	-	5,090 D	55.80 U	-	-
B0T8K4 & 5	12/08/1998	-0.68 U	-1.00 U	13.30 J	3.47	5,270 D	55.80 U	1.87	-

Table 3-11. Well 299-E27-15 Groundwater Monitoring Results for Selected Contaminants. (2 Pages)

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 pCi/L	Technetium-99 PCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
B0TF65 & 6	01/06/1999	-	-	17	-	4,870 D	23.00 U	-	1.59 U
B0VJ34 & 6	06/03/1999	0.79 U	0.73 U	37.3	-	6,200 D	23.00 U	-	1.59 U
B0X1W6 & 7	12/21/1999	-1.50 U	0.05 U	56.9	1.53 U	8,850 D	24.30 U	2.04	1.60 U
B0Y902 & 3	06/02/2000	2.73 U	1.81 U	88	-	10,600 D	24.30 U	-	1.60 U
B10N82 & 3	12/18/2000	-0.45 U	-0.35 U	71.4	-	12,400 D	24.30 U	2.2	5.1
B11DV7 & 8	03/19/2001	-1.99 U	1.40 U	99.2	3.61 U	11,100 D	6.57 U	2.39	1.60 U
B13J63 & 4	12/04/2001	-2.45 U	4.00 U	181	-	14,200 D	6.57 U	2.55	2.50 U
B143J1 & 2	03/11/2002	-0.02 U	1.10 U	148	-	14,600 D	36.10 U	-	4.50 B
B14P06	06/05/2002	0.40 U	2.76 U	196	-	-	-	-	-
Drinking Water MCLs		200	100	900	1	45,000	10,000	30	200

D = Indicates that the sample was diluted prior to analysis, dilution is accounted for by the laboratory.
U = Indicates the constituent was not detected.
- = Sample not analyzed for indicated constituent.

Table 3-12. Well 299-E27-7 Groundwater Monitoring Results for Selected Contaminants.

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
H0008RY1	02/27/1990	-3.29 U	0.30 U	-	-	1,400	1,000 U	-	-
H0008RY5	05/21/1990	-	-	-	-	1,500	1,000 U	-	-
H00072D0	07/25/1991	-	-	1.69	2.72	1,650	-	0.79	20 U
B01TT8	03/05/1992	1.4	1.44	0.16	3.66	5,800	200 U	2.61	20 U
B06NL7	05/15/1992	0.64	-0.46	0.72	5.7	6,000	200 U	2.42	20 U
B074W6	08/25/1992	-3.11	3.77	0.41	5.5	7,600	200 U	2.34	20 U
B07LQ3	11/09/1992	4.39 U	-5.56	1.10 U	4.37	4,900	200 U	2.13	20 U
B087X5	03/08/1993	2.74 U	-3.70 U	0.46 U	2.3	3,900	200 U	2.07	20 U
B08N49	06/15/1993	-4.79 U	-2.37 U	1.07 U	2.54	3,400	200 U	2.37	20 U
B096L0	09/21/1993	0.52 U	-4.67 U	0.63 U	2.5	3,000	38.30 U	1.75	1.24 U
B0BJP2	03/14/1994	0.54 U	0.15 U	-0.15 U	2.72	2,600	110 U	1.78	-
B0CYP7	09/15/1994	-0.04 U	0.42 U	0.28 U	2.95	-	-	-	-
B0DQF0	02/09/1995	-	-	0.02 U	3.19	2,700	18 U	-	-
B0GB01	08/02/1995	-	-	0.40 U	3.8	-	-	-	-
B0H9Z0	02/12/1996	-	-	-0.73 U	2.78 U	3,300	140 U	-	-
B0J6S3	08/20/1996	-	-	1.1	5.07	-	-	-	-
B0K1F9	02/11/1997	-	-	1.51 U	1.29 U	3,360	6.57 U	-	-
B0LD25 & 9	08/05/1997	-1.68 U	1.16 U	8.60 U	4.07	-	-	-	-
B0MYP5	02/18/1998	3.67 U	1.38 U	1.29 U	4.02	5,270 D	3.28 U	-	-
B0NWB2	06/04/1998	-0.98 U	3.82 U	27	5.2	6,060 D	3.28 U	-	-

Table 3-12. Well 299-E27-7 Groundwater Monitoring Results for Selected Contaminants.

Sample Number(s)	Sampling Date	Radionuclides				Nonradionuclides			
		Cesium-137 pCi/L	Cobalt-60 PCi/L	Technetium-99 pCi/L	Iodine-129 PCi/L	Nitrate µg/L	Nitrite µg/L	Uranium µg/L	Cyanide µg/L
B0R010	10/05/1998	-	-	49.9	-	7,660 D	55.80 U	-	-
B0T8L1 & 2	12/07/1998	-0.66 U	-0.47 U	28.2	4.54	7,220 D	55.80 U	2.36	-
B0TF62 & 3	01/04/1999	-	-	45.9	-	7,390 D	23.00 U	-	6.94
B0VJ46 & 7	06/03/1999	0.92 U	1.77 U	67.7	-	7,880 D	23.00 U	-	6.38
B0X1X3 & 4	12/20/1999	0.58 U	1.51 U	137	2.32 U	19,000 D	24.30 U	11.1	15.5
B0Y909 & 10	06/02/2000	1.81 U	3.10 U	336	-	13,700 D	24.30 U	-	17.1
B10N79 & 80	11/14/2000	1.24 U	2.59 U	363	-	17,300 DN	24.30 U	6.67	14.4
B111W9	12/18/2000	-	-	-	4.33 U	-	-	-	-
B11DR3 & 4	03/15/2001	2.61 U	1.85 U	789	2.81 U	16,800 D	6.57 U	4.71	10
B123L8 & 9	07/16/2001	-	-	2,190	-	25,200 D	6.57 U	6.29	2.50 U
B13J70 & 1	01/09/2002	-0.62 U	4.07 U	2,760	-	27,400 D	6.57 U	6.37	9.2
B143J8 & 9	03/11/2002	0.73 U	1.96 U	1,310	-	24,300 D	36.10 U	-	4.20 B
B14P13	06/05/2002	1.12 U	3.93 U	784	-	-	-	-	-
Drinking Water MCLs		200	100	900	1	45,000	10,000	30	200

D = Indicates that the sample was diluted prior to analysis, dilution is accounted for by the laboratory.
U = Indicates the constituent was not detected.
- = Sample not analyzed for indicated constituent.

3.3.3.6 Applicability of Soil Characterization Information. The available soil information from both process knowledge and gamma logging provide a good indication of the likely locations of the primary areas of soil contamination in C tank farm. The gamma logging gives a good indication and a general level of quantification for the extent and concentration of Cs-137 and Co-60 contamination in the tank farm. However, the primary COCs are the long lived and readily water mobile contaminants which are generally not measured with the logging instruments. The expectation is that where logging found the highest level of contamination that other contaminants not measured by logging would likely be at a high concentration depending on contaminant mobility. For example, where the logging found high levels of Cs-137 the expectation is that other contaminants would be at their high concentrations in that same vicinity depending on the mobility of the contaminant. Additionally, because Tc-99 is more mobile than Cs-137, its peak concentration would likely be at a greater depth than the peak Cs-137 concentration, but the high Cs-137 concentration should generally be indicative of the general lateral location of high contaminant concentration for all contaminants from the same generalized waste stream.

To quantify the more mobile contaminants in soil the process knowledge information and the gamma logging information could be used to focus a borehole sampling effort to get a representative or worst case assessment of the primary contaminants of concern for soil.

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4.0 DOE COMPLEX WIDE TANK CLOSURES

This section summarizes the recently prepared *U.S. Department of Energy Tank Closure Programs* (Luke 2002) document. The Luke 2002 report presents a summary-level comparison of the similarities and differences of tank closure programs at the four primary radioactive waste tank sites in the US Department of Energy (DOE) complex. A fifth DOE site, the West Valley Demonstration Project in New York State was not included in the DOE tank closure summary. The West Valley site was not included, because it has only two tanks that are regulated by the Nuclear Regulatory Commission. The two tanks are being thoroughly cleaned and decontaminated for closure. Based on these large differences it was determined that the West Valley closures were generally not relevant or comparable to the other DOE tank closures. Therefore West Valley was not included in the Luke 2002 report.

The depth of understanding of the closure programs varies with the amount of detailed information each of the four sites has provided to date. The Luke 2002 report was prepared using the best available information, including direct communications with key tank closure personnel at each of the sites. Many of the current schedules are under review for possible acceleration. A tank closure cost summary from the primary sites is included in Appendix A of this report.

The most prominent characteristic of the Hanford tank closure program is the relative enormity of the task. Hanford has 63% of all the DOE tanks (80% of all the single-shell tanks), 38% of the DOE waste volume, and 86% of the DOE failed tanks, including 98% of all the failed tanks which have leaked to the environment. The considerable subsurface contamination created by these leaks vastly complicates the technical and regulatory aspects of the Hanford tank closure program. By comparison, Oak Ridge Reservation (ORR) and Idaho National Engineering and Environmental Laboratory (INEEL) combined have less than 20% of the total tanks to be closed, less than 3% of the total volume of waste to be disposed, and no failed tanks.

There are other important differences in the physical systems to be closed.

- The estimated one million gals of contaminated liquid that has leaked from the Hanford tanks greatly complicates the closure of the tanks and tank farms and eventually the entire site.
- The Hanford waste is believed to be less characterized than at the other sites. This is primarily due to the complexity of the Hanford tank farms operations over six decades, such as the cascading between tanks and the extensive cesium and strontium recovery projects. At INEEL, the tanks are constructed of stainless steel (allowing more retrieval and decontamination options than Hanford tanks), contain mostly liquid waste (greatly simplifying waste characterization and retrieval), and are 50 feet in diameter (two-thirds the diameter of the larger Hanford tanks, which may also make waste sampling and retrieval easier).
- Similarly, at ORR many of the tanks are stainless steel, and have relatively small diameters (12 to 50 feet), although many of the tanks have a unique cigar shape with a horizontal orientation.
- The tanks and waste at the Savannah River Site (SRS) are similar to Hanford's, but the tanks' environments differ greatly. Hanford tanks reside far above the water table in mostly

unsaturated soil, while the majority of the SRS tanks are in direct contact with the groundwater, allowing greater regulatory flexibility in identifying closure requirements.

There are also important differences in the regulatory and stakeholder environments at the sites.

- Hanford appears to have the most restrictive waste retrieval requirements (99% of the total volume, or as much as is technically achievable).
- The INEEL individual tank retrieval goal is a 400-gal heel, and the tanks will be grouted to meet Class C requirements.
- At ORR none of the tank waste is categorized high level waste (HLW), the tanks are located within the ORNL which is approved in perpetuity for government/industrial use (negating the need for intruder analyses), and they reached early agreement with the regulators on key assumptions (such as risk criteria, modeling, grout dilution of heels, and sampling).
- The SRS tank closure plan currently assumes site intruder analyses are not required, and contains a rationale for WIR determination that allows tanks heels as low level waste (LLW).

Tank closure requirements for the four facilities are defined in their respective Federal Facility Agreements under the Federal Facility Compliance Act (the Tri-Party Agreement for Hanford). These agreements define the statutory authority that the regulatory agencies and DOE have determined will be used to close tanks.

- Hanford and INEEL will be closed under their States' Hazardous Waste Management Act, for compliance with the federal Resource Conservation and Recovery Act (RCRA).
- SRS and ORR are closing their tanks under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).
- SRS is using the Clean Water Act through CERCLA to establish cleanup goals.

These consent orders and agreements provide the regulatory framework for bringing these Sites into compliance through remediation and closure. CERCLA was created by Congress to respond to the release of hazardous substances and to investigate and respond to releases and potential releases from past-practice activities. RCRA and its authorized state programs were created to prevent releases at active facilities that generate, store, treat, transport, or dispose of hazardous wastes or hazardous constituents. RCRA, as amended by Hazardous and Solid Waste Amendment, also provides for corrective action for releases at RCRA facilities regardless of time of release.

Most importantly, the RCRA permit program requires a more prescriptive approach to remediation of a unit as compared to CERCLA or RCRA corrective action programs. These latter programs analyze cleanup alternatives using various criteria, such as long-term and short-term protection of human health and the environment, cost, and implementability, in order to determine an alternative that best balances the elements within all criteria. The RCRA permit program by contrast does not include an alternatives analysis and thus consideration of the merits of an alternative for risk reduction and overall cost-effectiveness.

Crucial to the success of the Closure Programs at both SRS and ORR were very effective public relations programs, developed to gain the trust and cooperation of their regulators and stakeholders. Hanford can benefit from a well-planned and well executed communications plan.

Tables 4-1 and 4-2 present a tabulated summary of the *U.S. Department of Energy Tank Closure Programs* (Luke 2002) document. Table 4-1 compares the physical systems to be closed. Table 4-2 provides the tank closure process and status for each site.

Table 4-1. Comparison of Site Physical Systems to be Closed. (2 Pages)

	Hanford Site	INEEL	ORR	SRS
Number of tanks/areas to close	177/18 tank farms	11a/1 tank farm	40/5 tank farms	51/2 tank farms
Tank types	2	2	6	4
Tank sizes, 10^3 gal	55-1,160	318	1.5-170	750-1,300
Tank ages, years	15-58	37-50	3-58	20-50
Tank conditions	67 confirmed and assumed leakers; est. 1 million gal. to soil; carbon steel liners	No leakers; stainless steel tanks	No leakers; carbon steel liners	11 leakers, 1 to soil; carbon steel liners
Tank maximum ages in years at closure	More than 75	More than 60	More than 60	More than 75
Site and tank specific considerations and uncertainties	In-tank hardware; arid climate; well above water table; contaminated vadose zone/ groundwater	Tanks are stainless steel; in-tank hardware; no secondary containment	Waste not classified as high-level; in-tank chunks of gunite; resin beads in 3 tanks	In-tank hardware; some tanks in water table; 2 tanks interim closed in 1997
Waste types	Viscous, alkaline liquid, sludge, salt cake	Acidic, liquid sodium waste, sludges; calcined powder	Liquids, sludges	Viscous, alkaline liquid, sludge, salt cake
Waste volumes, 10^6 gal	54	1.4	0.4	33
Waste radionuclides, 10^6 Ci	200	0.52	0.047	470
Retrieval schedule	SSTs complete by 2018b and DSTs by 2028b	HLW complete 1998; remaining liquid waste by 2012	37 of inactive tanks complete	2019 for Type I, II, and IV; 2024 for Type III

Table 4-1. Comparison of Site Physical Systems to be Closed. (2 Pages)

	Hanford Site	INEEL	ORR	SRS
Closure schedule	SSTs by 2024b and DSTs by 2032b	In six phases from 2005 to 2016; tank farms later	Remaining 3 inactive tanks will be closed as soon as funding is approved	2022 for Type I, II, and IV; Type III by 2028; tank farms later

[a] Plus an additional 7 calcine bin sets, containing 3.8 million L (24 million Ci) of calcined HLW, and four 30,000 gal stainless tanks in the tank farm facility
[b] Currently reevaluating retrieval and closure schedules
[c] Inactive tanks
DST = double-shell tank.
EIS = Environmental Impact Statement.
FFCA = Federal Facility Compliance Agreement.
HLW = high-level waste.
INEEL = Idaho National Engineering and Environmental Laboratory.
MOU = memorandum of understanding.
ORR = Oak Ridge Reservation.
SRS = Savannah River Site.
SST = single-shell tank.

Table 4-2. Tank Closure Process Status for Each Site. (4 Pages)

	HANFORD	SRS	INEEL	ORR
Closure Decision Status	Landfill closure established as baseline closure strategy in SST Closure Work Plan SST Closure Work Plan will be updated in 2002, 2004, and 2006 and will eventually evolve into closure plan DOE Closure Plans (Tier 1 and 2), Closure EIS, and closure performance assessments will be prepared for final closure decisions	Tier 1 Closure Plan completed and reviewed by HQ in 2001 but not yet approved Closure Plan approved by SCDHEC/EPA DOE/EIS-0303D DOE/EIS-0217 ROD: 60FR55249	Tier 1 Closure Plan submitted to HQ Draft Performance Assessment for INEEL Tank Farm Facility completed *Idaho Nuclear Technology and Engineering Center Tank Farm Facility Conceptual DOE and HWMA/RCRA Closure Approach* (INEEL/EXT-99-01066) completed and being reviewed by State of Idaho *INEEL HLW and Facility Disposition Draft EIS* completed	ROD for 3 remaining inactive resin tanks closure approved but rescinded due to funding uncertainty
Waste Retrieval Goal	Compliance agreement (HFFACO) contains interim retrieval goal of 99% retrieval from all tanks and also a process for seeking waivers from this goal	Based on density and concentration, by rad and non-rad component Estimated >1,000 gals of solids remain Heels described as "last several inches"	400 gals (1.52 cm3) 1 inch of solid heel	Waste is retrieved to "best ability" prior to tank grouting

Table 4-2. Tank Closure Process Status for Each Site. (4 Pages)

	HANFORD	SRS	INEEL	ORR
Compliance Boundary	State regulators currently indicating intent to use Waste Management Area boundary Multiple points being used for waste retrieval functions and requirements development (e.g., Waste Management Area boundary and 200 Area boundary) Multiple points between Waste Management Area boundary and Columbia River shoreline being used for corrective action decisions	Groundwater: seeplines of small rivers approx. 1 mile to north and 1 mile to south of the F and H tank farm areas Surface water: surface water quality standards applied in the receiving streams	First 100 years: INEEL Boundary for all but radon emissions, which is at surface of Tank Farm After 100 years: 100 m from Tank Farm, or maximum groundwater concentration	Drinking water standards in Clinch River
Compliance Timeframe	Likely to be 10,000 years for final closure 10,000 years being used for waste retrieval functions and requirements development 1,000 years being used for corrective action decisions	10,000 years	1,000 years or peak dose	Not yet determined
Institutional Control Period	Likely to be at least 100 years following final closure for the groundwater pathway Likely to be 500 years for final closure intruder dose calculations Prior Hanford performance assessments have used 500 years for intruder dose calculations	Institutional control for 100 years; F/H Areas industrial cat; outside F/H industrial/commerce for 10K years with deed restrictions on use of groundwater.	1,000 years or peak dose	Not yet determined

Table 4-2. Tank Closure Process Status for Each Site. (4 Pages)

	HANFORD	SRS	INEEL	ORR
Exposure Scenarios	Final closure groundwater pathway dose/risk calculations will likely be based on scenarios involving groundwater use. Actual scenarios to be applied for permitting are TBD. Inadvertent intruder dose calculations will likely be based on drilling and post-drilling resident scenarios.	Intruder scenario was not required. Tables B-4 thru B-6, Tier I Closure Plan summarize non-rad air, groundwater, surface water quality, and rad performance standards for tank closure	435.1 dose limit of 25 mrem; air pathway dose limit of 10 mrem Meet DOE M 435.1-1 Section III.P (disposal of TRU according to 40 CFR Part 191) or IV.P (LLW disposal facility requirements) or develop acceptable alternative performance objectives. 40 CFR Part 265 for hazardous components.	Groundwater only; intruder scenarios not required
Waste Incidental to Reprocessing Determination	Anticipate following WIR determination process as set out in DOE O 435.1	Using grout and alternative waste classification based on >10m depth Performance objectives in 10 CFR Part 61 must be met Goals for bulk waste removal Generated rationale for WIR determination to allow heels as LLW. Site-specific Class C limit (10x) because of depth of heel below surface.	· INEEL is following the three WIR criteria and utilizing grout averaging to classify residual tank waste as LLW	ORR waste did not fall under the Atomic Energy Act of 1954, as amended, definition of high level waste; therefore no WIR process was required
Tank Farm Closure Modeling Approach	Anticipate using for assessing risk through groundwater pathway at the tank farm or WMA boundary (STOMP).	Multimedia Environmental Pollutant Assessment System (MEPA) computer code. Details in Appendix C of Tier I Closure Plan.	DUST-MS; PORFLOW	DUST; FTWORK

Table 4-2. Tank Closure Process Status for Each Site. (4 Pages)

	HANFORD	SRS	INEEL	ORR
Cumulative Assessment Approach	Hanford Site Composite Analysis (PNNL-11800) completed, approved by EM-1; Disposal Authorization Statement issued *Future cumulative* assessments will be completed using System Assessment Capability suite of tools (STOMP, CFEST, MASS2, HUMAN, ECEM)	Three plumes (groundwater transport segments) treated separately for groundwater transport Sum over each *groundwater transport* segment separately All sources of potential contamination inside and outside F and H areas were considered in performance evaluations against objectives.	One plume, sum over all sources. At INEEL the calculated exposures from all radiation s[illegible] /y	Each geographic area containing tank systems evaluated separately

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5.0 CLOSURE DEMONSTRATION PERFORMANCE OBJECTIVES

Presented below are the generalized closure demonstration performance objectives. The purpose of this section is to provide closure objectives for discussion and screening of closure technologies in later sections.

The closure demonstration performance objectives are primarily for the period between individual tank closure and final tank farm closure. The closure demonstration performance objectives are closely linked to the final tank farm closure performance objectives in that the closure demonstration needs to be supportive and consistent with final tank farm closure. The primary factor determining final closure objectives is land use. The current and future land use for the 200 Area is generally industrial exclusive waste management.

- **Protect human health and the environment.** The closed tank will be protective of human health and the environment.

- **Minimize/eliminate waste to soil to groundwater contaminant pathway.** The closed tank will not impact groundwater in such a way as to exceed the human health based drinking water standards. Initial placements of fill material for purposes of stabilizing residual waste will be retrievable.

- **Prevent water infiltration into tank.** For the period between individual tank closure demonstration and final tank farm closure, the performance objective is to prevent water infiltration into the tank. For final tank farm closure extending into the long term the objective is to minimize water infiltration into the closed tanks as well as the entire tank farm soils, consistent with minimizing the waste to soil to groundwater contaminant pathway.

- **Maintain accessibility of surrounding tanks for future closure.** This objective is unique to the individual tank closure demonstration. When all tanks within a farm have been closed and the tank farm is ready for final closure implementation this will no longer be a closure objective.

- **Maintain/Stabilize tank structural integrity.** The structural integrity of the tank will be maintained or stabilized including necessary ancillary equipment to prevent tank dome failure and subsidence.

- **Comply with applicable waste retrieval/disposal/closure regulations.** Tank closure will be performed in accordance with applicable rules and regulations.

5.1 Current Tank Status Against Performance Objectives

All five closure demonstration tanks are currently under stringent institutional control and therefore meet the direct exposure protection of human health criteria performance objective.

The performance objective of protecting human health through the drinking water pathway (groundwater protection) or minimizing/eliminating the contaminant waste to soil to groundwater pathway performance objective appears to be currently met for all five tanks. The C-106 tank may currently have up to 30,000 gallons of liquid supernatant waste remaining in the tank, however the C-106 tank is currently considered to be a sound non-leaking tank and therefore is currently not an active source of contamination to groundwater. From waste descriptions from the C-200 series tanks, the residual waste in these tanks appears to be a relatively immobile sludge. The risers and vaults/valve boxes to these tanks are currently sealed from water intrusion. On this basis these tanks do not appear to currently be an active source of contamination to groundwater.

As stated above, currently as a part of routine surveillance and maintenance, tank risers and vaults are sealed against water intrusion. The five closure demonstration tanks are generally considered to be in good condition and do not appear to have water infiltrating through the dome lid, tank sidewalls, or through ancillary equipment into the tank space. Currently the water infiltration performance objective appears to be met for all five tanks.

Currently tanks adjacent and surrounding the five subject tanks are accessible.

Currently the tank void space has not been stabilized in any of the five tanks.

As previously discussed all five tanks contain residual waste that currently does not meet applicable or potentially applicable land disposal requirements for closing the waste in-place (in-tank).

5.2 Likely Status for Meeting Performance Objectives for the Future.

Near future (current to 50 years) land use of the 200 Area will likely continue to be characterized as industrial waste management. Long term land use of the 200 Areas including the tank farm areas has not been determined. The assumption of this report is that a level of control for the tank farms will be maintained in a manner that will be protective of human health and the environment for as long as necessary.

As the tank farms begin to close and institutional controls begin to ease, the ground surface above the closed tank farm may be appropriate for an undetermined use. The assumption under this section is that a level of control of the tank farms (both surface and subsurface) will be maintained ensuring that the undetermined land use is consistent with continuation of protection of human health and the environment. On this basis, protection of human health and the environment through the direct exposure pathways will continue to be met following tank farm closure and easing of land use controls.

The performance objective of protecting human health through the drinking water pathway (groundwater protection) or minimizing/eliminating the contaminant waste to soil to groundwater pathway performance objective for the future will be addressed by the selected closure demonstration closure alternative which could include additional waste retrieval, in-tank

waste stabilization/treatment, waste isolation with interim/final surface barriers, and institutional control.

The performance objective of preventing/minimizing water infiltration into the tank in the future will be addressed by the selected closure demonstration closure alternative which could include continuation of the surveillance and maintenance of the riser and vault sealing, tank void space stabilization, and/or interim/final surface barriers. The focus of this report will be for preventing water infiltration for the period between closure demonstration and final tank farm closure. The water infiltration performance objective in the context of post tank farm closure will likely be addressed through a final long term tank farm surface barrier.

The performance objective of maintaining the accessibility of adjacent and surrounding tanks is for the period between closure demonstration and final tank farm closure. The closure demonstration for these five tanks will not preclude closure actions for adjacent tanks. As stated previously the tanks adjacent to and surrounding the five subject tanks are currently accessible and will remain accessible following the closure demonstration on these five tanks.

The performance objective of stabilizing the tank void space will be addressed by the selected closure demonstration closure alternative.

The performance objective of complying with waste retrieval and potentially applicable waste disposal regulations is currently undergoing additional discussion. Compliance with waste retrieval goals will be addressed by the selected closure demonstration retrieval method. Compliance with potentially applicable waste disposal regulations will be addressed by the selected closure alternative.

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6.0 CONTAMINANTS OF POTENTIAL CONCERN FOR CLOSURE (RISK AND REGULATORY).

Presented below is a discussion of the tank closure contaminants of concern. For tank closure, COCs can be put into categories based on risk to human health and the environment and based on potential regulatory waste classification and disposal rules. Both categories of contaminants have the potential to significantly impact tank closure. These categories are similar, since the purpose and bases of the regulations are to protect human health and the environment. Generally, the requirements imposed by regulatory COCs if determined to be applicable to closure activities are less flexible than requirements from a risk based perspective.

6.1 RISK CONTAMINANTS

One of the assumptions of this report is that institutional control will be maintained as necessary to protect human health for the direct exposure pathway. Based on this assumption, the primary pathway of concern from a risk/human health standpoint is the groundwater pathway (groundwater protection). On this basis the contaminants of concern (COCs) for these tanks are the more mobile long-lived contaminants that could potentially migrate and impact groundwater at concentrations greater than the federal drinking water standards or MCLs.

For the C-106 tank a preliminary COC list was developed for the residual tank waste following the most recent sluicing event. The COC list is included in *Data to Support Tank C-106 Waste Retrieval Determination* (JEG 2000) and includes carbon-14, iodine-129, technetium-99, selenium-79, the uranium series, nitrite, nitrate, cyanide, and EDTA. The report indicated the same COC list identified in the *Retrieval Performance Evaluation Methodology for the AX Tank Farm* (DOE-RL 1999).

EDTA was a ligand or organic complexant acid used in chelating metals. Chelating is the process where a ligand chemical such as EDTA is used to bind metal ions for metals separation. EDTA by itself is generally not considered a COC from a groundwater protection standpoint. EDTA and other organic complexants do have the potential to affect contaminant transport in that the complexants influence contaminant solubility. Also from tank waste aging studies (Camaioni, D.M., W.D. Samuels, J.C. Linehan, S.A. Clauss, A.K. Sharma, K.L. Wahl, J.A. Campbell 1996) and complexant reports (PNNL 2001) and as indicated in the tank waste inventories and grab samples from the tanks, EDTA in the high dose environment of a tank generally quickly degrades to oxalates or oxalic acid. Again organics including organic complexants and organic solvents in the residual tank waste from the five closure demonstration tanks are not COCs for groundwater protection and have been omitted.

The COCs for the five closure demonstration tanks are the long lived relatively mobile contaminants and are listed below:

- Carbon-14
- Iodine-129
- Technetium-99

- Selenium-79
- Uranium
- Nitrite
- Nitrate
- Cyanide

Empirical information from Hanford site wide groundwater monitoring indicates that carbon-14, selenium-79, and cyanide may not necessarily be COCs for groundwater protection. These contaminants were however retained as COCs, because they are long lived and are generally considered to be mobile.

6.2 REGULATORY CONTAMINANTS

Based on the current BBI for the closure demonstration tanks and from a regulatory or potentially applicable regulatory standpoint of land disposal of residual tank waste, the regulatory COPCs are primarily the transuranics (plutonium and curium), the long lived mobile contaminants (Tc-99, C-14, and I-129) and to a lesser degree the short-lived and less mobile radionuclides (Cs-137, Co-60, Sr-90, and Ni-63). For the nonradionuclide metals, total chromium and lead are the primary regulatory COCs with arsenic, cadmium, and mercury also regulatory COCs, but to a lesser degree.

These are identified as regulatory waste COCs in that these are the waste constituents that will likely determine the necessity for additional waste retrieval and potentially the method of closure if the land disposal rules are determined to be applicable to the residual waste.

The applicability of these rules to residual waste for closure and the regulatory framework of the residual waste for closure are topics of ongoing discussion between Ecology, DOE, EPA, and other agencies including the Nuclear Regulatory Commission.

These discussions are expected to result in additional closure criteria that focus on key contaminants of interest within RCRA (Part A permit), Land Disposal Restriction and risk management.

7.0 CLOSURE APPROACHES

The objective of the Accelerated Tank Closure Demonstration (ATCD) Project is to close tanks from which waste has been retrieved to the extent technically and economically practical. It is assumed the tanks to be closed will still contain a small volume of residual waste. Thus tank removal (clean closure) is not viable and consequently tanks will be closed in-place. Approaches for closing the tanks in-place range from a partial closure approach, where closure decisions can be made between steps, to an approach where all of the closure decision criteria are well defined and closure proceeds as one free flowing process without need for interim decision points.

The stepped approach to closure is an approach that can be used when all of the closure criteria for a system or component of a system are not well defined or known or when the characteristics of the system to be closed are not understood to the extent necessary for full closure. This approach is similar to one currently being utilized for the 100 Area CERCLA soil remediation sites where a full detailed remedial investigation was not conducted for every site prior to remediation or closure implementation. The sites are being characterized and remediation decisions are being made as remediation or closure proceeds.

On a tank farm scale, the closure criteria are not currently well defined and the knowledge of the tank farm characteristics necessary to assess potential closure actions have yet to be agreed upon. Because of this, the initial closure demonstration is taking this stepped approach and focusing on closure of individual tank structures. Options for tank farm closure, including contaminated soil, ancillary equipment, and surface barriers were evaluated for a representative Hanford tank farm (DOE-RL 1999). Decisions on final tank farm closure actions will be made following evaluation of closure options via an Environmental Impact Statement.

The purpose of this section is to present and discuss the elements of closing tanks in a stepped manner.

Retrieval technologies preparatory for closing tanks are discussed in section 9.0. Closure technologies are discussed in section 10.0. Characterization technologies that support selection of appropriate retrieval and closure technologies and decisions on closure are discussed in section 8.0.

7.1 FULL TANK CLOSURE

As described here, full-tank closure would place a tank in an irretrievable state awaiting closure of the entire tank farm. The general elements include:

1. Retrieval of necessary waste
2. Isolating the tank structure as necessary to prevent potential tank fill material migration through piping and into other tanks and vaults
3. Stabilization of residual tank waste
4. Tank structural stabilization through filling
5. Tank isolation against water intrusion

For this closure demonstration, steps 2 through 5 generally define full tank closure. Below is a discussion of a partial tank closure approach where full tank closure is divided into additional steps.

7.2 PARTIAL TANK CLOSURE

The underlying assumption of this section is that the necessary waste has been retrieved from the tank to the extent technically and economically practical or a waiver is obtained (i.e. TPA Appendix H), and the tank is ready for closure. Under the partial closure approach, the steps would include:

1. Retrieval of necessary waste
2. Stabilization of residual tank waste
3. Tank isolation against water intrusion
4. Monitoring and maintaining the structural integrity of the tank structure for the period of time between the partial closure and full closure step.

The primary difference between partial closure and full closure of the tank is that permanent structural stabilization of the tank structure through filling is deferred to a later closure step. By deferring full tank filling, the step of tank isolation to prevent fill material migration could also be deferred to a later closure step. One of the primary benefits of the partial closure approach is that it does not take tank closure to a point that cannot be undone as would generally be the case if full tank stabilization were done. One of the drawbacks of the partial closure approach is that ultimately it will require the tank to be accessed by closure workers twice for complete tank closure rather than if tank closure were done all at once.

Through comparative risk assessments the Closure Demonstration AGA Report will explore the potential necessity of undoing a closure action. For example, if a tank to be closed only contributes 1% or 0.1% of risk to the total closure risk allocation budget for the entire C Tank Farm then the likelihood of needing to undo a closure action for that specific tank is low to non-existent. Under this example a full closure approach (full tank filling) may be more appropriate than an initial partial fill approach. There are other ongoing regulatory considerations for considering the necessity of undoing closure actions.

8.0 CHARACTERIZATION APPROACHES AND TECHNOLOGIES

General characterization approaches to support and tank closure actions are given below. Approaches range from very thorough complete detailed quantified characterization approaches to conservative, qualitative relative approaches. .

8.1 TANK CLOSURE CHARACTERIZATION APPROACHES

The characterization approaches given below for each media (i.e. waste to be retrieved, residual waste to be closed with the tank, and soil) generally range from a lower level to a higher level of characterization. The lower level generally does not require a lot of additional laboratory analysis of samples where the higher level requires additional tank specific waste and soil sampling as well as laboratory analyses. In order to be effective and appropriate, the lower level of characterization approach requires a level of conservatism is demonstrated in the following text.

Examples of characterization approaches at the Hanford site that could be used or adapted for tank closure include the current approach outlined in the *200 Areas Remedial Investigation/Feasibility Study Implementation Plan* (DOE-RL 1998). The primary characterization approach included in the 200 Area Implementation Plan is the analogous site approach where a thorough remedial investigation characterization effort is conducted on selected representative waste sites. The characterization data in terms of selection of the remedial action / closure action is then applied to all of the sites that are represented. Although not prepared for the purpose of tank closure or remediation the analogous tank and tank waste concept has previously been applied to the tank farm system in the *Clustering of Radioactive Tank Waste Data and Comparison with Historical Models* (Simpson 1998) and in the *Hanford Single-Shell Tank Grouping Study* (Simpson 1995).

The analogous characterization approach is in active use in the BBI system for tank waste. For example where sample analytical data may be available from one tank and not another, the BBI system applies the analytical data to another tank because the two tanks received the same waste streams. Also the BBI system divides the tanks into waste stream categories similar to the referenced methodology that the Implementation Plan does for the other 200 Area waste sites. The BBI also uses waste templates and process knowledge models for waste characterization. Additional discussion for each characterization media is given below. In addition there is a discussion of the uncertainty and sensitivity of the various closure data sets in Section 8.1.4.

8.1.1 Waste to be Retrieved

8.1.1.1 BBI System. The BBI as discussed in Section 3.0 is a tank waste inventory system based on the current best available information for each tank. The information is based on process knowledge, sample analysis, process models, calculations, and engineering estimates. Depending on the specific tank, the inventory may be based entirely on sample data from that tank or could be entirely based on process knowledge and engineering estimates. For waste that is to be retrieved, the BBI should be adequate for closure planning purposes.

Depending on the tank and the basis of the specific tank, the BBI may be adequate for making retrieval decisions. For a tank with a BBI that is based primarily on sample analyses of the tank waste, a definitive decision could be made regarding the necessity of waste retrieval. This assumes that the retrieval / closure criteria are known and defined.

As previously discussed, there are anecdotal indications that the tank waste BBIs based on the HDW model templates are conservatively high. However, this is not the case for the C-106 tank sludge where there are both process knowledge and sample based waste concentrations for comparison. If the conservative assessment of the BBI for a specific tank is defensible then retrieval decisions could be made using the BBI. The retrieval decision would be a conservative decision and could potentially result in retrieval where retrieval may not be necessary. For tanks with relatively low volumes of waste the BBI waste volume would likely need to be refined because of the current BBI practice of rounding waste volumes up to the nearest 1,000 liters and nearest 1,000 gallons.

8.1.1.2 Sampling and Analysis of Waste. Sampling and analysis of the waste to be retrieved may not be explicitly necessary for tank closure.

However, and as discussed below, actual laboratory sample analysis of the residual wastes to be closed with the tank may be necessary. In this context collecting a sample of the waste before waste retrieval or during retrieval would likely be simpler than conducting a sampling effort post-retrieval. This pre waste retrieval or during waste retrieval sample would then be used to represent the residual waste that is to remain in the tank for closure.

8.1.2 Residual Tank Waste (Ready for Closure)

8.1.2.1 BBI System. The BBI may be adequate for closure of a tank with residual waste if the argument of accuracy or conservatism can be made for the specific tank. If a reasonable argument that a specific tank BBI is accurate, or sufficiently conservative representation of the residual tank inventory and meets the closure/retrieved criteria then additional residual waste characterization for closure is not necessary.

For example, as stated earlier, the BBI estimate of the pre-retrieved tank waste inventory for the five closure demonstration tanks is a logical representation (may or may not be conservative) of the tank waste inventory. If ongoing risk assessments using the BBI data for the five closure demonstration tanks indicates that the pre-retrieved waste for these tanks does not pose an unacceptable risk to human health and the environment, then a reasonable argument would be that the post-retrieval residual waste, regardless of the remaining volume in the tank at closure, does not pose an unacceptable risk. This argument is dependent on the confidence of the initial pre-retrieval inventory information. For example, in the case of the C-106 waste, the BBI is primarily based on actual sample analysis during sluicing activities and therefore should be a good representative of the inventory for pre-retrieval as well as potentially for post-retrieval. In the case of the C-200 series tanks most of the inventory information is based on process knowledge models and therefore contains more uncertainty. If the level of uncertainty is greater than the difference between the pre-retrieved and post-retrieved inventory then relying on the BBI data is problematic. In this case, additional conservative risk assessment could be

conducted taking this uncertainty into account. If this conservative approach shows that closure criteria are met then additional characterization is not necessary.

It should also be noted that there needs to be a balance between conservatism and adequate characterization. Taking a conservative characterization approach for initial tank closures may require more stringent closure requirements for surrounding tanks, soils, and ancillary equipment, because the conservatism of the initial closures results in risk estimates that are higher than necessary. Also using a conservative inventory approach for risk assessments may present potential contradictions and problems for regulatory waste determinations of the residual waste. There is additional discussion regarding uncertainty and sensitivity of various closure data sets in Section 8.1.4.

8.1.2.2 Sampling and Analysis of Residual Waste. Sampling and analysis of residual waste that will be closed with the tank is the ideal and most representative method for determining the concentration and inventory of residual waste that will be closed with a tank (assuming that a representative set of samples can be obtained). As discussed above, sampling of residual waste for closure could be conducted in conjunction with waste retrieval as possibly the last step of the retrieval process.

Also, if it is determined that the land disposal criteria are applicable to all residual waste to be closed with a tank it will likely be necessary to collect representative samples of residual waste from each tank for meeting the regulatory disposal requirements.

8.1.3 Soil

8.1.3.1 Analogous Tank/Tank Farm Approach. Consistent with the analogous site characterization approach in the 200 Area Implementation Plan (DOE-RL 1998), individual tanks would be grouped together into representative (analogous) groups of tanks generally by waste type and leak status. From these groups an analogous tank could be selected and a thorough remedial / facility investigation be conducted. The results of this investigation for purposes of soil remedial action / corrective action / closure decisions would be applied to the tank group.

Alternatively, a remedial / facility investigation from a conservatively representative tank could be used to represent an entire tank farm or group of tank farms for purposes of remedial action / closure action selection for soil. A detailed discussion of the analogous site approach to characterization is in the 200 Area Remedial Investigation / Feasibility Study Implementation Plan (DOE-RL 1998).

8.1.3.2 Remedial/Facility Investigation. A more thorough approach to soil characterization is to conduct remedial / facility investigation sampling and analysis of vadose zone soil for each tank / tank farm. This would provide the most representative soil contaminant inventory depth profile, however it is also expensive, delays closure, and poses greater risks to investigation workers and does not accomplish timely risk reduction. In addition, the compilation of substantitive amounts of data may not greatly improve and/or compliment the final decisions affecting tank farm closure actions.

8.1.4 Uncertainty and Sensitivity of Closure Characterization Data Sets

From the *Retrieval Performance Evaluation Methodology for the AX Tank Farm* (DOE 1999) sensitivity assessment, the data sets that have the greatest affect on long-term risk in order of influence are the exposure parameters (land use) and source term parameters associated with past leaks and potential retrieval leakage loss.

The exposure parameters are associated with land use, (e.g. residential farmer, industrial worker, etc.) with the most sensitive parameters involving the consumption of food grown using groundwater as affected by the closed tank / waste site.

The tank closure characterization data set that is the most sensitive (has the greatest impact) to risk is the source term or contaminant inventory. Contaminant inventory can be further divided into characterization data sets: 1) residual tank waste to be closed with the tank, 2) residual waste to be closed with the ancillary equipment, 3) contaminated soil, and 4) waste retrieval leakage. The RPE sensitivity assessment indicated that the leak volume and contaminant concentration associated with past leaks (soil contamination) and retrieval leakage loss are the most influential specific parameters for long-term human health risk. The RPE indicated that the residual waste inventories associated with the closed tank and ancillary equipment (volume and concentration) are not the primary influential parameters for long-term human health risk. The residual tank waste and ancillary equipment inventories are not influential parameters because of the release mechanism. That is, as the volume of residual tank waste is increased, the only impact from the increase is to the contaminant release duration with little to no affect on the peak concentration impact to groundwater.

Because the material inside the tanks is a waste, there are not only risk considerations for closure but also a multitude of regulatory waste rules that provide specific quantified concentration and volume limits to the residual waste for closure, which implies that a low level of uncertainty for the residual waste characterization data set may be necessary for assessing compliance with regulatory waste closure criteria.

From a risk perspective the RPE indicates that the most influential closure characterization data set is soil contamination and potential retrieval leakage. From a regulatory perspective and a tank structure closure perspective, the most influential closure data set appears to be the residual tank waste data set.

Categorizing retrieval leakage as a closure characterization data set is problematic in that the goal for retrieval leakage is zero and establishing retrieval leakage criteria for closure purposes is difficult. Retrieval leakage as indicated by the RPE sensitivity assessment should be one of the primary retrieval method determining factors. Because there is very limited to no information characterizing actual waste retrieval leaks quantifying potential retrieval leaks to closure risk is difficult. Currently only qualitative assessments based on the RPE sensitivity assessment can be made that indicate prevention or minimization of retrieval leaks is very important for meeting long term risk closure criteria.

Information needed to characterize actual retrieval leakage includes leakage volume and leak concentration. The level of characterization for retrieval leakage is dependent on the method of retrieval and on tank integrity. That is, the level of characterization is dependent on the level of retrieval leakage uncertainty. For example a dry retrieval method would generally require no retrieval leakage loss characterization, because there generally is no uncertainty regarding retrieval leakage for a dry retrieval system. There generally would be no leakage loss for a dry retrieval system and therefore no uncertainty. For a retrieval system that uses large volumes of liquids such as sluicing on a tank with unknown integrity there is a relatively large uncertainty regarding retrieval leak volume. Therefore, given the sensitivity of the long term risk to retrieval leakage, characterization methods that can reduce the level of uncertainty and quantify retrieval leak volumes are likely necessary for retrieval methods that use large volumes of fluids and are conducted on tanks with unknown integrity.

This closure demonstration is focussing on the closure of the tank structure and the residual waste within the tank following waste retrieval. From the closure aspect of closing the tank structure independent of waste retrieval, the primary closure data set is the residual tank waste data set. Consistent with the RPE sensitivity assessment, if the residual tank waste meets the potentially applicable regulatory waste closure criteria including volume goal criteria, the impacts of the residual tank waste to long term risk will likely be minimal and supportive of final tank farm closure.

8.2 CHARACTERIZATION TECHNOLOGIES

8.2.1 Waste Characterization Technologies

8.2.1.1 BBI. The BBI technology or system is described in previous sections and is based on sampling and analysis of waste samples and process knowledge models. This is a single system based on multiple technologies and approaches to waste characterization.

8.2.1.2 Waste Screening / In-Situ Measurement. There are a large number of in-situ screening/measurement waste characterization technologies available or in stages of development. Technologies for in-situ screening and measurement of gamma and beta emitting radionuclides are currently in use for worker dose estimating purposes and could likely be adapted for purposes of closure if gamma emitting radionuclides were the driving contaminants of concern for closure. Although gamma emitters are present, the primary radiological COPCs for closure are primarily the long lived alpha emitters. There generally is not a well developed technology for measuring these radionuclides and differentiating specific radionuclides in-situ for purposes of closure.

For in-situ measurement of metals, technologies primarily based on x-ray fluorescence techniques have been developed. These technologies however have not been specifically developed or deployed for in-tank applications. In addition, although metals that could be measured using x-ray fluorescence are present in the waste, they are not the primary contaminants of concern for closure with the possible exception of uranium.

Fiber-optic technologies have been developed for in-situ measurement trichloroethylene. These technologies have been successfully deployed in vadose zone environments using a cone penetrometer, however have not been used in a tank environment. The fiber optic technology could be used for other organic applications, however additional development would be necessary to develop reagents specific to the organics of interest. Additional technologies using a gaschromatograph have been deployed as well.

Based on process knowledge and the limited organic data from safety screening analyses the primary petroleum hydrocarbon or solvent based organics that are present in the closure demonstration tanks appears to be kerosene / normal paraffin hydrocarbons. Kerosene and the individual organic kerosene compounds are not expected to be a significant waste component and are not considered as contaminants of concern for closure. Additional discussion is included in the characterization data section (Section 3.0)

There are additional in-situ screening / measurement technologies, however the primary and most developed technologies are discussed above. In general, none of the in-situ characterization technologies are suitable for sufficiently or conservatively quantifying the closure COCs for comparison to potential closure criteria.

8.2.2 Waste Sample Collection Technologies

Tank waste sampling technologies that have been developed and are in use at the Hanford site or have been developed and used at other DOE sites are summarized below. Most of these technologies and methods have generally been used for collecting samples from tanks with significant waste volumes. Many of these methods generally would not be suitable for collecting samples of waste from tanks with low volumes of residual waste. Also discussed are technologies for collecting residual waste samples from tanks with low volumes of residual waste.

8.2.2.1 Core Sampling. There are generally two types of tank waste core sampling methods in use at the Hanford site. These include a truck mounted system that has the capability to obtain samples with push core or rotary-auger core methods. These methods have been successful at collecting tank waste profile cores from tanks with significant volumes of waste (Kostelnik, A.J. 1998). For closure purposes of collecting samples of residual waste to be closed with the tank, these systems would likely not be adequate for collecting samples of waste where there is a low volume of residual waste.

8.2.2.2 Grab Sampling. There are and have been multiple grab sampling techniques used at the Hanford site. Some of these have included auger sampling, the finger-trap sampler, and the simple method of lowering a container into the tank. For application to the closure demonstration tanks, the auger sampler has previously been used on the C-200 series tanks. Depending on the residual volume of waste remaining the auger sampler may be applicable. Another tool following within this category but not used at the Hanford site is the Ponar Dredge.

8.2.2.3 Dip Filter Sampler. The dip filter sampler, developed and used at the SRS (Thomas, N.A.), filters the top layer of liquid or supernate, within a tank to obtain a sample of any existing floating organics on a special filter media. The sampler is lowered through a tank

riser into the tank supernate where the sampler collects a volume of the supernate surface. The sampler is lifted from the supernate and the collected volume drains through the filter media. The filter media is in a vial within the sampler. Following removal from the tank the vial is removed with the filter media for laboratory analysis. Floating organics are not associated with the closure demonstration tanks, therefore this sampling method is not applicable to the closure demonstration tanks.

8.2.2.4 Circle Scrape Sampler. The circle scrape sampler, developed and used at the SRS (Thomas, N.A.), is designed to obtain samples from a very thin waste material layer on a tank floor. The sampler is composed of a sampling head that is attached by a hinge to a sample mast. When the sampling head contacts the tank floor, the head swivels on the hinge and reorients parallel to the tank floor. The extension mast is then rotated causing the scrape head to travel in a circular path, sampling the material on the tank floor surrounding the extension mast. Following removal the sampling head is disconnected and transported to the laboratory for analysis. The circle scrape sampler would be appropriate if a sample of residual waste following thorough waste retrieval were necessary.

8.2.2.5 Vial Snapper Grab Sampler. The vial snapper sampler, developed and used at the SRS (Thomas, N.A.), is a pneumatic actuated grab sampler that is remotely operated and has a pair of jaws which open and close together in a clamshell fashion to obtain a sample. The sample jaws also detach from the actuator to allow shipment of the jaws with the sample to the laboratory for analysis. There are both horizontally and vertically oriented jaws depending on the thickness of the waste layer at the bottom of the tank. This sampling technique could be used for the closure demonstration tanks.

8.2.2.6 Light Duty Utility Arm (LDUA) or Modified (M). The LDUA is a remotely operated mechanical arm that is installed in a 12 inch diameter or larger tank riser and used for multiple purposes depending on the end effector tool installed on the arm (Kiebel, G.R. 1997 and Conrad, R.B. 1996). The arm is used to move the end effector tool within the tank for the tools intended purpose. End effectors that have been used or have been developed include in-tank sampling tools (summarized below), targeted retrieval tools, inspection tools, and gripper tools. The LDUA has had limited use on Hanford site tanks because of concerns over the LDUA capacity, stability, safety, and other issues. The LDUA offers the advantage of having the ability to sample waste that is not directly beneath a tank riser. Sampling end effector tools are summarized below.

- **Burnishing Sampler End Effector.** The burnishing sampler has been used at the West Valley DOE site to collect tank wall samples (Killough, S.). Using an end-mill-type milling machine bit, the sampler scrapes a small area of the tank walls and collects a metal shaving sample from the wall. The need for this level of sampling and tank characterization is not anticipated for the closure demonstration tanks.

- **Heel Sampling End Effector.** This heel sampler was developed for the INEEL Idaho Nuclear Technology and Engineering Center (INTEC) waste tanks (DOE 2000). The sampler was designed to sample shallow (less than 15 inches) heels containing liquids and soft solids. The heel sampler was successfully used at the INEEL tanks in 1999. The sample chamber detaches from the sampler for delivery to the analytical laboratory. This technology

may be suitable for the residual waste in the C-106, however given the dry appearance of the residual waste in the C-200 series tanks this sampling technology may not be suitable for the C-200 series tanks.

- **Extended Reach End Effector.** The extended reach end effector, developed for use at the Hanford Site adds 81 inches (6.75 feet) to the LDUA's reach, providing the system with the ability to reach over 20 feet (TFA 2002). This end effector allows the LDUA to obtain 50-mL surface samples from the tank walls and floor. The device is pneumatically actuated and has a unique detachable sampler with a clamping force of 50 to 300 pounds. This technology would likely be suitable for the closure demonstration tanks.

8.2.3 Soil

A good source of soil characterization technique and technology summaries are located in the 200 Area Implementation Plan in Section 6.2.5 (DOE-RL 1998) and in the *Phase I RCRA Facility Investigational Corrective Measures Study Work Plan for Single-Shell Tank West Management* in Section 6.3 (DOE-RL 2000). Technologies discussed and summarized below include characterization methods successfully used in previous Hanford Site investigations, or technologies that are in development and nearing field implementation. These technologies include borehole drilling, auger drilling, test pits and trenching, cone penetrometer and geoprobe, borehole geophysics, surface geophysical methods (such as GPR), and vadose zone monitoring, laser-induced breakdown spectroscopy (LIBS) system, ground-pentrating holography, and soil gas sampling.

8.2.3.1 Borehole Drilling. Borehole drilling is used to access the deeper vadose zone (9.1 m [30 ft] and beyond) to collect soil samples for direct analysis. Cable tool, air rotary and sonic, are commonly used drilling methods at the Hanford Site.

8.2.3.2 Auger Drilling. Auger drilling is recognized as an accepted method for collection of soil samples for direct analysis in the shallow vadose zone (0 to 12 m [0 to 40 ft]). A hollow stem auger capable of accepting a 10-cm (4-in.) split spoon can collect adequate sample volumes for analysis.

8.2.3.3 Test Pit Construction/Trenching. Test pits are shallow, concave-shaped excavations that can range from 7.6 to 9.1 m (25 to 30 ft) deep depending on the equipment used and the type of soil encountered. The pits are excavated using a back-hoe or track-hoe, depending on the required depth. Samples are collected directly from the bucket and can be representative of as little as 152 mm (6 in.) layers of contaminated soil. With proper care to minimize sloughing of material from above, this sample collection method can be as good as borehole samples.

The technique provides a direct visual confirmation of stratigraphy, allows optimum collection of samples, and is cost effective because it requires minimum site mobilization. For application to a tank farm control of airborne safety hazards would be problematic in soils with high levels of contamination when using backhoe or trackhoe methods.

8.2.3.4 Cone Penetrometer/Geoprobe. The cone penetrometer system consists of special drill rods that are hydraulically pushed into the subsurface. The geoprobe system drives the same

type of drill rods with a hydraulic vibratory hammer. Both methods differ from drilling in that soil is not excavated to advance the drill rods to depth. As the drill rod is driven into the ground, soil is forced aside to provide subsurface access. Both systems are very versatile. Depending on the type of rod selected, a wide range of data and/or samples can be collected. Capabilities include the following:

- Collection of soil gas samples
- Measurement of geophysical properties
- Collection of soil samples (limited volume)
- Measurement of gross gamma radiation
- Collection of perched groundwater samples.

In addition, because the cone penetrometer is basically a delivery system, it can accept new measurement techniques as they are developed. Currently fiber-optic sensors are under development for detecting Sr-90 and U-238 in soil (CMST 2002a) and for measuring pore pressure (CMST, 2002b).

Either the cone penetrometer or geoprobe can be a cost-effective tool for quickly defining the lateral and vertical extent of contamination. Each has a limited depth of penetration. The small-diameter/small-volume cores that are collected are not representative of the grain size and are of insufficient volume for extensive laboratory analysis. At the Hanford Site, the maximum depth of penetration is about 36.6 m (120 ft) under ideal conditions (e.g., sand with some gravel). The maximum depth of penetration in a gravel unit is less than 12.2 m (40 ft). Based on field experience, over 50% the cone pushes do not reach their target depths due to obstructions (e.g., rocks or compacted zones). Groundwater samples are generally of poor quality, and data from these samples are used mainly to support the placement of permanent monitoring wells. The mobilization cost is low and the systems can accomplish multiple rod replacements within a single day.

8.2.3.5 Borehole Geophysics. The use of borehole geophysics to investigate soil properties can provide valuable information about the site. Borehole geophysics is commonly used at Hanford to assess the distribution of gamma-emitting radioactive contaminants and to determine the moisture content in soils. A high resolution spectral gamma system can be used to determine the extent of radiological contamination in the soil column identifying both man-made (e.g., Cs-137 and Co-60) and natural (e.g., K-40) gamma-emitting radionuclides and determining lithology based on a known distribution of naturally occurring radionuclides in specific formations. Moisture content is determined using a neutron logging probe. These tools are used in conjunction with existing characterization boreholes or wells and provide a continuous reading of soil characteristics.

In addition, geophysical logging tools have been developed for use with driven soil probes. The use of a gross gamma and passive neutron (GG/PN) detector in the probe has the capability of detecting areas with elevated soil concentrations of Am-241 and plutonium.

8.2.3.6 Surface Geophysical Methods. Surface geophysical methods are nonintrusive tools used to locate shallow 0-6.1 m (0-20 ft) subsurface features or determine surface levels of radioactive contaminants. Methods commonly used at Hanford to determine subsurface features

include ground-penetrating radar (GPR), electromagnetic induction (EMI), and magnetics. These methods are commonly used to locate suspected disposal pits, buried materials, utilities, and pipelines. GPR is reliable in most situations and provides the most information of the nonintrusive methods. GPR can be time consuming if the site is very large and requires experienced personnel. EMI and magnetics are excellent reconnaissance tools that are easier to use than GPR.

Methods to measure radioactive contaminants include tractor-mounted beta-gamma detectors (that can be driven over large area sites and provide scale maps with radiation level contours), and portable systems carried by a single person that provide similar capabilities but are useful for small waste sites or where access is restricted. Either method provides a cost-effective alternative to soil sample collection and laboratory analysis.

Lysimetry techniques are also available to measure, in situ, the flow of liquids through a soil column and, potentially, the consequent movement of contaminants. The technique requires isolation of a representative disturbed or undisturbed soil mass from its surroundings. The isolated mass is then fitted to either collect liquids moving through the soil or monitor weight changes in the mass due to moisture additions and evaporation transpiration reductions. Lysimetry is a cumbersome, expensive process capable of providing accurate results at the expense of a considerable investment in time.

8.2.3.7 Other Characterization Technologies. The ongoing review and implementation of innovative characterization technologies is key to maintaining a cost-effective approach to the characterization of the hundreds of waste sites. The following technologies represent promising examples of innovative characterization tools currently in various stages of development and field implementation.

- An LIBS system, which can perform in-situ measurements of metals including selected radionuclides in soils, is under development. The LIBS is delivered by a cone penetrometer to the required depth and performs the in situ measurement from the bottom of penetration to the surface as it is being removed. Although a recent onsite demonstration for the collection of in situ information on lead, barium, and uranium was not successful, LIBS has been shown in principle to be a potentially viable tool.

- A ground-penetrating holography system enhances existing GPR technology by providing location and algorithm data that produce a volumetric image of objects beneath the ground surface. A single-channel system was successfully demonstrated at the 618-4 Burial Ground in the 300-FF-1 Operable Unit. The information gained from this demonstration will support the development of a multi-channel real-time system. The existing single-channel system is currently supporting cultural resource investigations at Hanford and can support other GPR activities.

- A pipe explorer system can transport characterization sensors into piping systems that are radiologically contaminated. The system deploys an air-tight membrane into the pipe being inspected. The characterization detector and its cabling enter the membrane and take measurements. Therefore, the potential for contamination of the equipment is minimized significantly. The system can be deployed through pipe constrictions, around

90° bends, vertically (up and down), and in wet conditions. Characterization tools that have been demonstrated with the system thus far include gamma detectors, beta detectors, and video cameras. Alpha measurement capability is also under development. The explorer system can be deployed in pipes as small as 50 mm (2 in.) in diameter and up to 76.2 m (250 ft) long.

- Soil gas sampling has been used to monitor changes in volatile and semivolatile organic compounds at selected waste sites, notably in the 200 West Area, as a means of measuring carbon tetrachloride in the vadose zone. A calibrated infrared photoacoustic spectrometer is being used either in a mobile laboratory or at boreholes to examine concentrations of volatile organic analytes. Sampling networks using existing boreholes and shallow soil probes can examine the volatile organic analyte concentration at desired depths in the soil column.

8.2.4 Waste Volume

Current operational tank waste volumes are based on tank level measurements, mass transfer measurements, visuals from video and photo inspections, and known tank area volumes.

There are a large number of technologies for measuring liquid waste levels (Weeks, G.E. 1998). Measuring the waste level is generally a good method for measuring operational waste volume when the tank contains a significant portion of liquid or semi-liquid waste, however these liquid level measurement methods are generally not by themselves adequate for measuring the residual volume of waste remaining following retrieval and for tank closure. On this basis the liquid level measurement technologies are not discussed in this report. Only those technologies that could potentially be used to measure relatively low volumes of residual waste for closure of the five closure demonstration tanks within the general near-term closure schedule are presented below. Additional low volume residual waste volume calculation technologies including the topographical mapping system (TMS) (discussed below) are included in *Residual Waste Volume Measurement for Hanford Underground Storage Tanks* (Evans M. 1996). The recommended technology from the report was the TMS.

8.2.4.1 Topographical Mapping System. The TMS is a three dimensional (3-D) mapping system that uses a laser range finder to project a laser plane on the surface to be mapped and a triangulation-based measurement technique. The intersection of the laser plane and the surface produces a contour line annotating the shape of the surface. The TMS has a camera that captures the laser plane contour line. The image from the camera is processed and a 3-D image of the tank interior surfaces is produced and residual waste volumes calculated. The TMS has a specified accuracy of +/- 6.35 mm (+/- 0.25 in.) over a range of up to 13.7 m (45 ft). The TMS mast is 3.5 inches in diameter and can be deployed in a 4-inch riser.

The TMS was first demonstrated in 1994 in a Hanford Site cold-test tank and was successfully deployed in the Oak Ridge Gunite tanks in 1996. Tank waste volume measurement capability was added and successfully demonstrated in 1997. Currently a TMS is installed in the U-107 tank, however the radiation sensitive components of the TMS are near or past their lifespan.

Through the former Tank Focus Area (TFA) Accelerated Site Technology Demonstration (ASTD) program a new volume measurement system using the same principle as the TMS system, but with updated technology is being acquired for the S-112 tank retrieval project.

8.2.4.2 Visual Observation with Video Cameras. This technique is based on engineering judgement and detailed knowledge of interior tank dimensions including tank volume benchmarks (e.g. concave and knuckle areas of the tanks) using the process engineering tank volume spreadsheet tool. This technique is not as quantitative as the TMS, however for most closure applications depending on the volume of waste and contaminant inventory of the residual waste, the visual observation technique should be adequate for calculating conservative residual waste volumes for closure purposes. If the conservative volume and inventory meet closure criteria then a more quantified volume estimate is not necessary for closure. If the estimate is too conservative the volume estimate could be further refined using the video camera observational method, using the TMS system, or additional waste could or may need to be retrieved to meet closure criteria.

Visual observation with video cameras is also the most effective technique for identifying and locating foreign objects within tanks. It is important to know the location of such objects during waste retrieval. In addition having a visual document of the residual waste prior to tank closure will be important.

9.0 WASTE RETRIEVAL TECHNOLOGIES

Waste retrieval strategies must account for the waste types (i.e., liquid, salt cake, sludge/hard heel, or a combination), whether a tank has leaked in the past or not, and the purpose of the retrieval effort. Retrieving waste for purposes of closing a tank and from tanks known to have leaked in the past without causing significant additional leakage of waste to the soil presents a major technological challenge.

There are a large variety of waste retrieval technologies. Retrieval technologies can generally be grouped into two categories: operational waste retrieval or waste retrieval for tank closure. Retrieval for closure is designed to support closure criteria objectives more so than an operational waste retrieval effort. An operational waste retrieval effort is generally for purposes of waste consolidation, safety, or transfer of waste for treatment or processing rather than for specific tank closure. There is technology overlap between the two retrieval categories. The level of overlap depends on the tank closure criteria. Technologies developed for tank closure could be used for operational waste retrieval, however depending on the closure criteria, technologies developed for operational retrieval may not be suited for tank closure retrievals.

There are upcoming Hanford site waste retrieval demonstrations discussed in the following sections and included in the HFFACO. The one important objective of these demonstrations is for technology demonstration that may lead to tank closure.

Below are sections describing the primary tank waste retrieval technologies that have been used or developed and tested in the DOE complex. Also discussed is the primary historical retrieval technology (past practice sluicing) used at Hanford as well as the three ongoing retrieval demonstration projects at Hanford. This section is not meant to be a thorough compilation of the many retrieval technologies that have been conceptualized or studied. The purpose of this section is to present retrieval technologies that are reasonably implementable in the near term. The technologies discussed below have at a minimum been demonstrated or are very near demonstration.

9.1 DST MIXER / MOBILIZATION TECHNOLOGIES FOR SLUDGE RETRIEVAL.

Pacific Northwest National Laboratory (PNNL) evaluated technologies that have been developed around the DOE complex primarily for sludge retrieval. The evaluation is documented in *An Assessment of Technologies to Provide Extended Sludge Retrieval From Underground Storage Tanks at the Hanford Site* (Bamberger, J.A. 2000). The purpose of the PNNL study was to identify sludge mobilization technologies that could readily be installed in double-shell tank (DST) along with mixer pumps to augment mixer pump operation when mixer pumps do not adequately mobilize waste alone. The supplementary technologies would be used to mobilize sludge that accumulate in tank locations out of reach of the mixer-pump jet and move the sludge into the mixer-pump range of operation.

As stated above, the purpose of the PNNL technology evaluation was not specific to tank closure, but it does provide a good sludge mixer / mobilization technology evaluation and description that could potentially be used as a component of a retrieval system for closing SSTs.

From the PNNL assessment report, mixer / mobilization technologies that have been deployed or demonstrated include a pulsed air mixer, pulsating mixer pump, fluidic pulse-jet mixer, the C-106 tank sluicer, the borehole-miner extendible-nozzle, waste-retrieval end effector, high-pressure scarifier, and Flygt mixer.

All of these technologies, with the exception of the Flygt mechanical mixer, are based on jet mixing. The jet fluid is air, slurry (supernate), or water. The jet pressure, duration, and pulse rate vary based on the technology. The pulsating mixer pump and fluidic pulse-jet mixer both create jets by using suction to draw slurry or supernate from the tank into a tube and pressure to expel the fluid jet back into the tank. The C-106 sluicer and the borehole-miner extendible-nozzle are both based on sluicing; however, the borehole miner operates at a higher pressure than the C-106 sluicer and has an increased jet range based on the extension of the nozzle away from the mast using its extendible arm. The waste-retrieval end effector and the high-pressure scarifier are both based on scarification – using a high-pressure, low-flow-rate jet to fracture and erode solids at high pressures.

The purpose of the PNNL technology assessment report was to identify the best technology for assisting in sludge retrieval from DST. On this basis the report identified the borehole-miner extendible-nozzle sluicer as the preferred mixer / mobilization technology for sludge retrieval.

The necessity for additional retrieval from the closure demonstration tanks has not been determined. Assessing the need for waste retrieval of the closure demonstration tanks is beyond the scope of this document. The decision for additional retrieval generally will be made based on risk and applicable of regulatory requirements.

The technologies discussed above generally would be coupled with a suitable retrieval pump and would require addition of significant volumes fluids to the tanks during retrieval. As discussed below, there are retrieval systems that are being developed that are more suitable to retrieval efforts specific to tank closure and specific to the closure demonstration tanks. Many of these technologies and other technologies not included in this document were considered when the SST retrieval demonstration technologies were formulated.

The preliminary and minimal retrieval for the closure demonstration tanks include the removal of the liquid supernate from the C-106 tank. Removal of the liquids will likely be done using a simple retrieval pump. Pump technologies are not presented in this document.

9.2 SST RETRIEVAL DEMONSTRATION PROJECT TECHNOLOGIES INCLUDING HISTORICAL SLUICING.

A large variety of waste retrieval technologies were considered when forming and planning the waste retrieval demonstration projects. The purpose of this section and report is not to revisit those individual technology evaluations. The purpose of this section is to discuss and present a brief assessment of the potential applicability of these retrieval systems to the closure demonstration tanks. This is not an assessment for the need for waste retrieval. It is simply an assessment of whether a retrieval demonstration technology system could be used on the closure demonstration tanks if necessary.

Waste retrieval from SSTs is planned using both fluid-based retrieval technologies and limited-fluid to dry retrieval technologies.

Hydraulic sluicing was used in the A and AX tank farms in the 1960s and 1970s to recover strontium and again in the first phase of tank C-106 waste retrieval (Milestone M-45-03B).

A low-water volume salt cake dissolution process is the planned baseline for tanks containing salt cake. This process will be deployed in a limited trial in tank U-107 to assess the optimal sprinkler configuration. The full tank demonstration of low-water volume salt cake dissolution will be applied to tank S-112 as defined by the HFFACO schedule (Milestone M-45-03C). Both of these tanks contain a high percentage of salt cake containing a significant amount of technetium-99, a primary COC for groundwater.

For tanks containing primarily sludge and with anticipated insoluble hard heels, a modified crawler system or similar combined mechanical-hydraulic system using localized water addition (as necessary) near the waste removal point will be deployed. The scheduled first demonstration of this technique will be in tank C-104. Tank C-104 has the highest amount of plutonium (estimated at 89 kg) of any SST and the waste is expected to be mostly insoluble sludge. Given the complexity of the proposed retrieval system, a large-scale demonstration is part of the HFFACO schedule (Milestone M-45-03G, due June 30, 2004).

The Mobile Retrieval System (MRS) currently envisioned for retrieving waste from C-104 consists of an articulated mast in the center of the tank and an in-tank vehicle. The articulated mast has the capability to remove liquid and solid waste in a 30-foot diameter region around the axis of the articulated mast. The in-tank vehicle would then be deployed to mobilize waste toward the center of the tank where it can be retrieved by the articulated mast (RPP-10829, Rev A). Cold testing of the MRS is scheduled for later in 2002.

For the first full-production retrieval (Milestone M-45-05a), a fluidics-type system is planned in tank S-102. This tank contains both salt cake and sludge and has a large inventory of technetium-99. Fluidics systems were successfully used in both Great Britain and Russia for similar applications. Two cold demonstrations were successfully completed in 2001 (TFA 2002) to test both the British and Russian systems on Hanford waste stimulants.

These three techniques (low-water volume salt cake dissolution, modified crawler system, and fluidics system) are new, in various stages of design and testing, and are now the basis for planning for future retrievals at the Hanford site. All three techniques use significantly less water or fluid and lower hydraulic head than was used in tank C-106 past-practice sluicing.

9.3 TECHNOLOGY APPLICATION TO C-106

As described in Section 3, tank C-106 is a 100 Series SST with a diameter of 23-m (75-ft) with approximately 30,000 gals of drainable liquid and 6,000 gals of sludge primarily contained in three piles (bergs) on the periphery of the tank.

Retrieval methods for C-106 will be evaluated and selected during the preliminary engineering phase of the waste retrieval project for this tank. Results and conclusions will be described in the AGA and preliminary engineering reports for the ATCD Project, by the end of FY 2002.

9.4 TECHNOLOGY APPLICATION TO C-201, -202, -203, -204

The 200 series C Farm tanks contain varying residual sludge waste revised volumes varying between 500 and 1,900 gals. These waste volumes exceed the HFFACO interim retrieval goal of 30 cubic feet (225 gals) for the 200 series tanks.

Retrieval methods for the C-200 series tanks will be evaluated and selected during the retrieval project for these tanks. Results and conclusions will be described in the AGA report and in preliminary engineering reports for the ATCD project by the end of FY 2002.

10.0 TANK CLOSURE TECHNOLOGIES AND SCREENING ASSESSMENT

In-place closure of tanks will involve placing a fill material in the tank. The purpose of filling the tank void spaces is to stabilize residual waste and provide structural stability of the tank. Waste stabilization can include both physical and chemical stabilization. Stabilizing the tank structure will ultimately be necessary to ensure that the tanks do not collapse under their own weight or added weight of a final tank farm surface barrier.

Tank filling has been studied and implemented at several DOE sites (see Section 4.0). Westinghouse Savannah River Company (WSRC) has completed the draft *State of the Art Report on High-Level Waste Tank Closure (*Langton, C.A., R.D. Spence, J. Barton 2001*)* that is intended to provide a review of in-place closure of waste tanks using various grout formulations. The primary focus of the WSRC 2001 document is on waste stabilization (physical and some chemical stabilization). The *Engineering Study of Tank Fill Alternatives for Closure of Single-Shell Tanks* (Skelly, W.A. 1996) and a closure Technical Data Package for the Tank Waste Remediation EIS (Kline, P.L., H. Hampt, W.A. Skelly 1995) provides descriptions and evaluations of four alternative concepts for filling and stabilizing SSTs with fill materials. The focus of (Skelly, W.A. 1996) is on both tank structural stabilization and on waste stabilization. Also the *Stabilization of In-Tank Residual Wastes and External-Tank Soil Contamination for the Tank Focus Area, Hanford Tank Initiative: Applications to the AX Tank Farm* (Balsley, S.D., J.L. Krumhansl, D.J. Borns, R.G. KcKeen 1998) contains a recommended tank fill and waste stabilization method. Brief summaries of the four tank fill alternatives from (Skelly, W.A. 1996) and the single alternative from Balsley 1998 are provided below. For the purposes of this report, the detailed grout alternatives from (Langton, C.A., R.D. Spence, J. Barton, 2001) are generalized into a single grout alternative included in the (Skelly, W.A. 1996) document. In terms of waste stabilization, the section below primarily focuses on physical waste stabilization. Discussion of chemical waste stabilization technologies are discussed in later sections. In addition, specifications for the tank fill system for the closure demonstration tanks have been issued (Davalle 2002).

10.1 TANK VOID SPACE STABILIZATION TECHNOLOGIES

The first four sections summarize the alternatives of gravel, grout, hybrid, and concrete fill from the (Skelly, W.A. 1996) tank fill assessment. The fifth section summarizes the multi-layer tank fill alternative from the Balsley 1998 assessment.

10.1.1 Gravel

Tanks would be filled with crushed aggregate using a rotating slinger apparatus installed in the central riser of the tank. The process is an adaptation of commercial materials-handling technology for storage and retrieval of granular solids. The essential equipment components consist of a metering hopper, belt conveyor, and a rotating "rock slinger" apparatus and associated support structure situated in and above the central riser of the tank.

The rock slinger concept was the subject of extensive prototype development activities at Hanford between 1983 and 1985. A centrifugal thrower mechanism was selected for placing and distributing crushed aggregate in SSTs. The specific mechanism used in the prototype tests was a 10-in. "swiveloader" manufactured by Stephens-Adamson Manufacturing Company of Aurora, Illinois. The unit provided material handling capacity of 50 tons/hr for materials with bulk densities of 50 lb/ft^3 or more.

The filling apparatus was designed for installation in a 42-inch diameter riser. The extendable fill tube was functional in risers varying from 4 to 12 in length. The system was designed so that no loads would be imposed on the riser. Throwing distance and trajectory were a function of the discharge angle and velocity of the slinger belt. In prototype tests, it was established that 75-foot diameter tanks could be uniformly and completely filled with crushed aggregate in approximately 100 operating hours, and that the process was readily controllable by varying belt speed and discharge angle within available limits.

10.1.2 Grout

Tanks would be filled with a pumpable, ex-situ mixed cementitious grout formulation that is self-leveling. The grout could be mixed in a portable batch plant set up in close proximity to the tank undergoing closure and grout tremies would be installed in each tank through existing riser penetrations. The grout will be placed in lifts. Because hydration of cement is an exothermic chemical process, placement in lifts is necessary to control temperatures and thermal strains within the grout as it cures. The maximum thickness of individual lifts is dependent on the heat of hydration property for a specific grout mixture design and on the capacity of grout batch delivery to the tank. The grout would be volume neutral (i.e., free of shrinkage or swelling during curing).

Because this closure demonstration is not generally characterized as a final closure measure, low strength grout (50 to 250 psi) will likely be required for this demonstration to ensure that the fill material can be retrieved at a later date if necessary. The grout can provide both for tank structural stabilization as well as residual waste stabilization. For residual waste stabilization the grout can provide for both physical as well as chemical stabilization. The waste stabilization properties of grout is discussed further in later sections.

There are various grout delivery methods to the interior of the tank. These range from a simple tremie to low-pressure, single-point grout injection for mixing with waste to a proprietary high pressure multiple-point grout injection (MPI) waste mixing system (Kauschinger, J.L. 2000). The simple tremie method was used at the SRS for the two large volume tank closures. The low-pressure injection method was studied by PNNL and is discussed in *Low-Pressure, Single-Point Grout Injection for Tank Heel Sludge Mixing and In Situ Immobilization* (Whyatt, G.A., C.R. Hymas 1998). The proprietary MPI system has been used on tanks at the Oak Ridge Tennessee site and is discussed in *Oak Ridge National Laboratory Old Hydrofracture Facility Tank-Closure Plan and Grout-Development Status Report for FY 1999* (Lewis, B.E., R.D. Spence, J.V. Draper, R.E. Norman, J.L. Kauschinger 2000).

10.1.3 Hybrid

This alternative would stabilize the tank by first filling the tank volume with coarse, uncrushed aggregate, followed by placement of grout. This grout would be injected into the void volume within the aggregate to create a stiff, low-permeability matrix of aggregate concrete. Any waste remaining in the tanks after retrieval would be stabilized by the grout. The aggregate used in this alternative would consist of coarse, uncrushed river gravels (i.e., rounded aggregate). The aggregate would not be crushed because angular material tends to achieve greater placement density (i.e., lower void volume and permeability) than material made up of rounded particles of similar size and shape.

A slinger mechanism similar to the one developed for the "gravel fill" alternative may be used. However, the mechanism tested at Hanford for gravel fill is limited to applications involving smaller particles (i.e., ¾-inch minus). With the larger particle size aggregate identified for this alternative, excessive mechanical abrasion and belt wear are predictable consequences. Off-the-shelf slinger units that can handle large particle sizes are too large to be installed in a 42-inch diameter riser. Consequently, it is likely that an alternate mechanical concept for aggregate placement would have to be developed.

10.1.4 Concrete

This alternative would utilize a highly flowable concrete formulation to fill (stabilize) nominally empty tanks. This alternative is very similar to the grout alternative, except that concrete would be used instead of grout. The concrete formulation would utilize both a super-plasticizer and rheological modifier. Super-plasticizers sorb onto the surfaces of cement particles and act as dispersing agents. This action contributes to enhanced flowability and workability and reduced water formation and particle segregation. Rheological modifiers, (water-soluble polymers), when added in small concentrations, can dramatically alter the viscosity of cement paste. A properly proportioned cement-based system that includes a super-plasticizer and a water-soluble polymer will provide greatly enhanced flowability and eliminates the undesirable effects observed when the super-plasticizer is used alone.

As with the grout alternative, the concrete mixture can be placed in lifts. Because hydration of cement is an exothermic chemical process, placement in lifts is necessary to control temperatures and thermal strains within the concrete as it cures. The maximum thickness of individual lifts is dependent on the heat of hydration property for a specific concrete mixture design as well as the capacity of the concrete delivery system.

10.1.5 Multiple Layer

The multiple layer tank fill alternative was developed by SNL and is very similar to the grout alternative in that the majority of the tank void space is filled with a cementitious grout. The differences between the alternatives is that the multiple layer alternative specifies grout placement in lifts of 16 inches and also contains a 2 foot thick bentonite grout "sealing" layer about eight feet from the top of the tank. This concept also utilizes an asphalt layer to seal cracks that might develop in the underlying grout as it cures, and to seal gaps that might develop between the grout and steel liner of the tank. The alternative also utilizes dry desiccant such as

unhydrated cement with getters (discussed in later sections) and gravel placement at the bottom of the tank for initial residual waste stabilization at the bottom of the tank. The purpose of the desiccant material would be to wick or adsorb any residual liquids remaining in the tank. The purpose of the gravel is to mix or sink into the residual waste and to prevent waste displacement during grout placement.

10.1.6 Comparison of Tank Fill Alternatives and Tentative Selection of Preferred Alternative

For application to the closure demonstration tanks, the general grout fill technology has been tentatively identified as the preferred tank fill and waste stabilization method. The purpose of this tentative selection is to provide a basis for initiation of preliminary engineering on a representative tank closure approach, pending impletion of an AGA for tank closure. This approach (initiation of preliminary engineering prior to completing the AGA) is justified since the principal elements affecting cost, schedule, environmental impacts, and worker health and safety relate to bulk materials storage, mixing and delivery; construction access; riser access; tank internal equipment disposition; and tank isolation which are for the most part common to all the alternatives. The waste stabilization aspect is briefly discussed here as it relates to tank fill but is discussed in greater detail in later sections.

The gravel alternative was not selected because of the difficulties associated with implementation of evenly distributing gravel in the entire void space of a tank. In addition, gravel offers no waste stabilization properties and may potentially settle over time creating additional void space near the dome peak that would require additional stabilization at a later date.

The hybrid alternative of placement of gravel with addition of grout in separate steps was not selected because it is redundant and requires separate steps and activities of placing gravel and then placing grout when the purpose of tank stabilization could potentially be done with either of the steps alone. This alternative does provide for waste stabilization through the grout however, the problems of gravel placement as discussed above remain for the hybrid technology.

The concrete alternative was not selected. The concrete and grout technologies are very similar, however the grout alternative is a simpler more easily implemented technology and was retained over the concrete technology. The primary differences between the two are that concrete contains gravel and the grout does not. Because of the gravel in the concrete, the concrete technology has gravel segregation issues associated with concrete pumping, delivery of the concrete to the interior of the tank, and distribution within the tank. None of these issues are insurmountable, however they are not present with the grout technology, therefore the grout technology is preferred over the concrete technology.

The multiple layer alternative was not selected. Many of the aspects of the multiple layer alternative are included in the selected grout alternative such as grout placement in lifts. The multiple layer alternative was rejected because implementation is unnecessarily complicated in that it requires the placement of gravel at the bottom of the tank to prevent waste floating, which is an important component of the grout alternative to achieve better waste stabilization of some of the residual waste. The multiple layer alternative also employs a bentonite grout layer and

asphalt layer. These extra layers could be implemented however they add an extra step to the implementation process without adding a definitive benefit other than potential additional water-intrusion sealing benefit. The added benefit is questionable and the added performance need is not anticipated for tank closure.

The grout alternative is tentatively selected for the closure demonstration tanks, pending completion of the AGA for tank closure. Grouts can be designed that are flowable and self leveling. The grout alternative would not require the installation of gravel slingers as some of the above technologies would. There are no complex placement issues associated with grout. Grout would simply be tremmied to the bottom of the tank and fill the tank (full closure) or just cover the tank bottom and the residual waste (partial closure). In-place tank closure precedents in the DOE complex have exclusively used grout. A refinement of the grout alternative similar to what occurred during placement of grout at the SRS tanks is to place an initial grout lift at the bottom of the tank to accomplish some waste displacement and floating of residual waste. Following curing or partial curing of the initial lift to immobilize the floating waste, another lift of grout would be placed over the first lift to encapsulate and provide additional waste stabilization of the waste that floated.

For the C-106 tank the simple tremie method of grout delivery is tentatively selected, because it is the simplest delivery method to implement and the mixing potential of the grout injection techniques is likely low for closure of C-106 tank. Because of the 75 foot diameter of the C-106 tank the MPI method would require multiple grout delivery points through multiple risers.

For the C-200 series tanks, the single point low-pressure grout injection technique may be appropriate depending on the amount of residual waste following retrieval. This method could provide for some additional waste and grout mixing beyond that achieved by the simple tremie method. The closure need for thorough and complete residual waste mixing is not anticipated, however the single point injection method appears to be implementable in the 20 foot diameter tanks from a single riser. Implementation of the single point low-pressure grout injection technique does not appear to be excessively complicated and could provide for additional waste / grout mixing beyond that of a simple tremie and would demonstrate a different grout delivery method for closure. However, a simple tremie for grout placement in the C-200 series tanks may be sufficient for displacing and stabilizing the residual waste, as is planned for C-106.

10.2 IN-SITU RESIDUAL TANK WASTE STABILIZATION TECHNOLOGIES

A volume of residual waste will remain in the tanks for closure therefore, physical stabilization of the residual waste is generally a preferred approach. In addition, chemical stabilization or contaminant sequestering may be beneficial and is evaluated in the following sections.

10.2.1 Physical Residual Waste Stabilization

Physical encapsulation or stabilization is intended to reduce contact between the waste and the environment by physical isolation of the contaminants and contaminated media. This can be accomplished on a macro-scale where the residual tank waste is encased, surrounded by, or sandwiched between solid media, such as grout. Although to a lesser extent of stabilization or

encasement than entirely surrounding a waste volume with grout, grout placement over residual waste with the tank bottom beneath is also a form of waste stabilization. Stabilization / encapsulation can also be accomplished on a micro-scale where contaminant particles are mixed with materials that form a matrix in which the waste is dispersed.

For the closure demonstration tanks, physical residual waste stabilization will be accomplished through the placement of two grout lifts at the bottom of the tanks. The initial lift will generally have a higher density than the residual waste, the rationale being that the higher density will result in some displacement or floating of residual waste. The initial grout lift will set / cure for initial waste stabilization. Following partial curing of the initial lift, the second lift of grout will be placed over the initial lift to cover the portion of the residual waste that was displaced with the initial lift. This approach will be utilized with both of the recommended grout delivery techniques (simple tremie for the C-106 tank and possibly low-pressure single point grout injection for the C-200 series tanks).

As mentioned previously the selected technology of grout for tank stabilization also has physical as well as chemical waste stabilization properties that make it an effective technology from both a tank structural stabilization as well as a residual waste stabilization perspective.

In addition, common grout components such as the primary cement slag, fly ash, and clay provide waste stabilization properties. Some or all of these may be included in the grout formulation used on the closure demonstration tanks. The specific grout formulation will be refined pending ongoing closure assessment and waste stabilization assessment.

10.2.2 Chemical Stabilization

This section discusses technologies considered for in situ stabilization of tank waste residuals. As previously discussed the primary COCs are the long lived mobile contaminants that pose the greatest potential long-term risk through the groundwater pathway. Those contaminants include carbon-14, iodine-129, technetium-99, selenium-79, uranium, nitrate, nitrite and cyanide. A discussion is provided below regarding available compounds that have the ability to stabilize each contaminant. A general screening level status of each compound as to maturity and likelihood for implementation for this closure demonstration is also given for each contaminant.

10.2.2.1 Carbon-14. Most likely present in residual tank waste as carbonate (CO_3^{2-}). Sodium carbonate (Na_2CO_3), the most likely carbonate in the tanks, is quite soluble in water. Other carbonates, such as calcium carbonate (calcite), are fairly insoluble with a solubility product of 10^{-8} (Weast, R. C. (ed.) 1980). The calcium hydroxide (portlandite) that is formed during the hydration of Portland cement based grouts (Glasser, F. P. 1993) would ensure precipitation and therefore provide C-14 stabilization. This technology is not so much retained but is an added benefit of using the Portland cement based grout for tank structural as well as physical waste stabilization. The performance of specific C-14 chemical stabilization by the grout is difficult to quantify because the residual waste will not likely be combined into the grout in a perfect mix.

10.2.2.2 Iodine-129. In aqueous environments, iodine exists predominantly as iodide (I^-), and iodate (IO_3^-). Iodide is easily converted to iodate in well-oxidized, high-pH solutions. Iodide and iodate form sparingly soluble salts with barium, calcium, copper, lead, mercury and silver

with solubility products ranging from 10^{-7} (cupric iodate) to 10^{-28} (mercurous iodide) (Weast, R.C. (ed.) 1980). Iodates are generally more soluble than iodides: the solubility product of silver iodate is 10^{-8} while that of silver iodide is 10^{-16} (Weast, R. C. (ed.) 1980). Calcium iodate has a solubility product of 10^{-8} and, similar to the precipitation of calcium carbonate discussed above, the calcium hydroxide (portlandite) that is formed during the hydration of Portland cement based grouts (Glasser, F. P. 1993) would ensure precipitation of the calcium iodate.

An alternative to precipitated salts is to absorb the iodide or iodates on activated carbon. Activated carbon is known to have an affinity for ionic iodine in water -- one measure of the porosity of activated carbon is the "iodine number" which is a measure of the adsorption of iodine from solution. Recently, silver impregnated activated carbon (SIAC) was found to have a greater affinity for iodine than activated carbon alone (Hoskins, J., T. Karanfil, and S. M. Serkiz, 2002). SIAC is commercially available and used where the anti-microbial properties of the silver are desirable to prevent biofouling of activated carbon water treatment systems. SIAC is not generally used for removal of iodine from wastewater streams or other applications that rely on the direct precipitation of waste stream constituents by reaction with silver.

The research by Hoskins, J., T. Karanfil, and S. M. Serkiz (2002) was performed on a small scale (50 mL batch sizes of stock solution) and does not provide sufficient information to evaluate the potential efficacy of the SIAC in solutions with many different anionic species present. The use of SIAC has only been tested on a small scale and could not be used for large-scale deployment without further development.

A wide variety of minerals (metal sulfides, copper oxides, hydrotalcites, lignite coal, etc.) were investigated as potential anion sorbers for iodide and pertechnetate (Balsley, S. D., P. V. Brady, J. L. Krumhansl, and H. L. Anderson, 1997). These experiments were performed on small (200 mL) batches. Experimental results suggested that calcium monosulfate aluminate (CMSA) might be highly selective for iodide at high pH. Scale-up to large tanks has not been performed.

Many of the technologies discussed above appear to be promising for the chemical stabilization of I-129 in the residual tank waste, however none of them have been retained with the general exception of the added I-129 stabilization benefit from the use of a cement grout for the tank structural stabilization as well as residual waste physical stabilization.

The other I-129 stabilization technologies appear promising, however their development and tank application including the physical tank application to the residual waste or as a component of the waste stabilizing grout are not well known and would require additional study. On this basis these other technologies were rejected for application to the closure demonstration tanks that are scheduled for closure during 2004.

10.2.2.3 Technetium-99. The most stable form of technetium under oxidizing conditions over a wide range of pH conditions is Tc(VII), which exists as the pertechnetate ion (TcO_4^-) (Pourbaix 1966). Various technetium species [Tc(V), Tc(IV), or Tc (III)] may be formed under reducing conditions, with Tc(IV) being the most stable. Reduced species are rapidly oxidized to the pertechnetate form under oxidizing conditions. Pertechnetate is quite soluble while Tc(IV) is much less soluble over a wide range of pH. Because of the presence of nitrate in the waste,

oxidizing conditions are expected, so the highly soluble pertechnetate species would predominate.

Metallic surfaces, including zinc, iron, and aluminum, adsorb technetium. However, adsorption onto metallic surfaces is limited to solutions that are mildly acidic to pH of less than 10. Highly acidic solutions tend to dissolve the metals and at higher pH, adsorption onto metal surfaces are less effective (Mushtaq, A. 1993). If oxidizing species, such as nitrite, are present, adsorption will be ineffective because the metallic surfaces will be oxidized and adsorption onto metallic surfaces would not be feasible for this reason.

Strontium, cesium, and heavy metals have been shown to form stable insoluble compounds by replacing calcium in the calcium hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$] structure (Elliott, J. C. 1994) and (Wronkiewicz, D. J., S. F. Wolf, and T. S. DiSanto 1995). Wronkiewicz, D. J., S. F. Wolf, and T. S. DiSanto (1995) suggest that technetium, among other elements, could be incorporated into the apatite structure. Laboratory scale experiments are proposed that use apatite with reducing agents such as stannous tin [Sn (II)] that result in the incorporation of technetium into the apatite structure (Marietta, M. 2002). The mechanism by which technetium would be incorporated is presently unknown [although, by analogy, it is known that many oxo anions including VO_4^{3-}, AsO_4^{3-}, MnO_4^{3-}, CrO_4^{3-}, GeO_4^{4-}, SiO_4^{4-}, SO_4^{2-}, SeO_4^{2-}, and ReO_5^{3-} partially or totally replace the phosphate ion (PO_4^{3-}) (Elliott 1994)]. Scale-up of the application in tanks is currently undergoing study.

An ion exchange resin (Reillex™ HPQ, a copolymer of divinylbenzene and 4-vinylpyridine subsequently methylated at the pyridine nitrogen) and a sorbent [ABEC 5000, a phase on the surface of resin beads (from Eichrom Industries)] were 93 and 91 %, effective, respectively, at removing technetium from double shell slurry feed (Blanchard, D. L, Jr., G. N. Brown, S.D. Conradson, S. K. Fadeff, G. R. Golcar, N. J. Hess, G. S.,000 Linger, and D. E. Kurath 1997). These studies were preformed ex situ in batch contacts. The use of these materials in situ was not tested, and the long-term stability of these materials was not tested.

The development of a new class of functionalized nanoporous sorbents with specific adsorptive characteristics, that selectively and irreversibly bind the pertechnetate ion from vadose zone pore waters and aquifer groundwater plumes has been proposed by Mattigod, S., G. Fryxell, J. Rustad, J. Serne, K. Kemner, S. Kelly, and T. Bitterwolf (2002). This class of sorbents is only in the development stage, and no data are available to judge the efficacy of in tank adsorption.

As discussed above, Balsley, S. D., P. V. Brady, J. L. Krumhansl, and H. L. Anderson (1997) investigated a wide variety of minerals as potential anion sorbers for iodide and pertechnetate. Experimental results suggested that CMSA might be highly selective for pertechnetate at high pH. Scale-up to large tanks has not been performed.

Many of these technologies for Tc-99 stabilization appear to be very promising especially hydroxyapatite. Additional study regarding hydroxyapatite is ongoing including study of

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combining the compound with grout for tank applications. The current expectation is that as additional study proceeds, if the studies form useable and implementable conclusions for tank closure, this closure demonstration could potentially use the apatite technology as a grout additive.

10.2.2.4 Selenium-79. Under slightly oxidizing conditions, selenite [Se(IV)] is the predominate ionic species. Under highly oxidizing conditions at high pH, selenate [Se(VI)] predominates. Selenite may form ion-pair species with Ca^{2+} (Kaplan, D. I., and R. J. Serne 2000). Solid phases in order of increasing solubility are $FeSe_2$, FeSe, and CuSe (Rai, D. and J. M. Zachara 1984).

Selenium (VI) (as SeO_4^{2-}) has substituted for phosphate in the apatite structure (Elliott 1994). Studies directed at the use of the apatite structure to immobilize selenium-79 have not been found.

10.2.2.5 Uranium. Uranium exists in the U(VI) as the uranyl (UO_2^{2+}) cation in oxidizing solutions. The uranyl cation forms strong complexes with inorganic oxygen-containing ligands such as hydroxide, carbonate, and phosphate (Kaplan, D. I., and R. J. Serne 2000). Cement based grouts have been shown to be effective at immobilizing uranium (Westrich, H. R., J L. Krumhansl, P. Zhang, H. L. Anderson, M. A. Molecke, C. Ho, B. P. Dwyer, and G. McKeen 1998).

Apatites containing uranium substituting for phosphorous are known to exist (Wronkiewicz, D. J., S. F. Wolf, and T. S. DiSanto 1995). Laboratory scale experiments are ongoing to study the uranium sequestration capability of apatite (Marietta, M. 2002). As previously discussed the apatite technology appears to be very promising. However, for application to this closure demonstration the technology is not retained until the results from the ongoing studies are more definitive.

10.2.2.6 Nitrate and Nitrite. Nitrate (NO_3^-), in the form of nitric acid, was used extensively in the chemical processing plants that discharged waste to tanks. Sodium hydroxide was used to adjust the pH, so the predominant species is sodium nitrate. Nitrates are in general quite soluble (Cotton, F. A., and Wilkinson, G.1972), so precipitation with a metal ion is not a viable option for stabilization of nitrate.

Nitrate and nitrite (NO_2^-) can be converted to ammonia and/or nitrogen by several different chemical or electrochemical reduction processes. Thermal processes convert nitrates and nitrites into nitrogen, oxides of nitrogen (NO_x), and sodium oxide and include calcination, plasma furnace, steam reforming and vitrification. Any process that would emit more than 40 tons of NO_x per year would require a prevention of significant deterioration permit. Thermal conversion is typically conducted at high temperatures (above 300°C) (Hobbs, D. T. 1997) and the amount of NO_x produced decreases with increasing temperature of the process.

Organic reductants (e.g., sugar) have been used to denitrate wastes. The plutonium-uranium extraction (PUREX) plant used sucrose to reduce nitric acid to carbon dioxide, water, and NO_x at temperatures of between 85 and 100°C (WHC 1989). Low-activity waste containing sodium nitrate has been denitrated with a similar process, but at a temperature of 300°C (Smith, H. D., E. O. Jones, A. J. Schmidt, A. H. Zacher, M. D. Brown, M. R. Elmore, and S. R. Gano 1999).

Electrochemical destruction of nitrates and nitrites on a laboratory bench-scale has been demonstrated (Elmore, M. R. and Lawrence, W. E. 1996), however, implementation inside a tank would be difficult.

Biodenitrification of groundwater has been demonstrated in bench-scale treatability studies in the 100 Area (BHI 1996). In biodenitrification, anoxic microbes use the oxygen from the nitrate to metabolize a carbon source (usually methanol or acetate). The treatability tests were conducted ex situ in a fluidized bed reactor. Implementation of a biological process inside of a radioactive waste tank would not be feasible because of the difficulties associated with maintaining optimum conditions for biological growth.

There do not appear to be any suitable in-tank chemical stabilization or treatment technologies for nitrates and nitrites.

10.2.2.7 Cyanide (CN^-). Forms salts with many cations, those of silver, mercury and lead are very insoluble (Cotton, F. A., and Wilkinson, G. 1972).

Free cyanide can be destroyed by alkaline hydrolysis using oxidants such as chlorine or hypochlorite (BHI 1996). However, if the cyanide is complexed with metals, it is not amenable to alkaline hydrolysis. Complexed cyanide can be destroyed by processes using ultraviolet light and oxidants such as ozone or hydrogen peroxide (BHI 1996). These processes are generally ex situ treatment process and would not be implementable inside a tank.

There do not appear to be any suitable in-tank chemical stabilization or treatment technologies for cyanide.

11.0 ANCILLARY EQUIPMENT

Ancillary equipment is the fixed equipment component of a tank farm or tank and generally includes every tank farm or tank fixture with the exception of the tank structure itself.

The accelerated closure demonstration is specific to the five identified tanks and their directly associated ancillary equipment. There is however other ancillary equipment that although will not be closed with this demonstration may need to be accessed for closure of the demonstration tanks. This limits the consideration of ancillary equipment to the in-tank equipment, the at-tank pits, the piping to and from the tanks or at-tank pits, the tank risers, and any other ancillary equipment that is located above or directly adjacent to the tanks.

11.1 ANCILLARY EQUIPMENT CLOSURE OPTIONS

The *AX Tank Farm Ancillary Equipment Study* (Skelly, W.A, D.L. Becker and DOE-RL, 1999), evaluated the following three ancillary equipment remedial or closure options: abandon in place as-is (no action); complete removal of ancillary equipment and disposal of all waste materials in the appropriate disposal facilities on the Hanford Site; and stabilization (by grouting) of the ancillary equipment in place. The study does not identify a preferred alternative. The currently proposed closure strategy for the SST system is to close the ancillary equipment, and contaminated soils in-place (landfill closure). Closure of the ancillary equipment and soils will be addressed in future documents.

Final landfill closure of the tank farm will likely include a surface barrier that limits water infiltration. Above grade ancillary equipment may need to removed for placement of the final surface barrier. As previously discussed decisions regarding surface barriers, contaminated soils, and tank farm ancillary equipment are not being made with this closure demonstration. This closure demonstration is focusing on the closure of the tank structure, however there are ancillary equipment related issues associated with the closure of the tank structures. This project will undertake administrative closure actions (e.g. procedural changes) pending final regulatory reviews and approvals in this area. PNNL is assisting in the development of long term strategies in this area.

11.2 ANCILLARY EQUIPMENT CLOSURE ISSUES

The primary closure issues associated with ancillary equipment on an individual tank basis are 1) tank isolation for tank filling to prevent potential migration of fill material during tank stabilization and 2) to prevent water infiltration into the tank. Additional ancillary equipment considerations include worker risks associated with closure implementation.

Ancillary equipment having a potential direct effect on the individual tanks include the in-tank equipment and the piping that directly enters into the tank space. That is equipment not in or directly entering into the tank space does not have a direct effect on tank closure and is therefore for purposes of this closure demonstration considered a component of the tank farm ancillary

equipment that will be addressed for final tank farm closure. For the purposes of this closure demonstration, equipment attached to or within the tank are addressed by this demonstration.

The tanks will be isolated to prevent migration of tank fill material and to help prevent water infiltration into the closed tank. Consistent with the partial closure approach where the tank stabilization/filling will likely be accomplished in a stepped approach of stabilization of the residual waste at the bottom of the tank followed by the next step at a later date of full tank stabilization/filling. Using this approach with a decision point between steps, tank isolation in terms of preventing potential migration of fill material during full tank stabilization may be deferred until the closure step of full tank stabilization/filling (see specific tank discussion below).

For the partial closure approach, the pipelines and risers entering into the tank space are currently isolated in terms of preventing water intrusion into the tank.

11.3 PRELIMINARY CLOSURE DEMONSTRATION TANK ANCILLARY EQUIPMENT

The discussion below is a general discussion regarding the status of the ancillary equipment specific to the closure demonstration tanks. A more detailed and thorough assessment will be performed during the design phase of closure. In-tank equipment not needing removal for the physical implementation of closure activities will be closed in-place.

11.3.1 Partial Closure

Under the partial closure approach where the residual tank waste at the bottom of the tank is stabilized, isolation of ancillary equipment is not expected to be a major engineering and construction effort.

11.3.2 Full Closure

Under the full closure approach (residual waste stabilization and full tank stabilization) the C-106 tank has only one preliminarily identified pipeline needing isolation from the tank. The pipeline is the cascade pipeline that drains from the C-105 tank to the C-106 tank. This pipeline may need isolation to prevent potential fill material migration into the C-105 tank during fill placement.

Preliminarily identified ancillary equipment for the C-200 series tanks needing isolation include a total of eight transfer lines from the 241-C-252 diversion box to the C-200 tanks (two transfer lines to each tank). Under the full closure approach these pipelines may need isolation to prevent fill material migration.

As a part of this data assessment effort a listing of available tank drawings has been developed. Included in the Appendix C is a summary table of the ancillary equipment and referenced drawings associated with the closure demonstration tanks.

12.0 SURVEILLANCE AND MONITORING

12.1 CURRENT OPERATIONAL SURVEILLANCE AND MONITORING

Currently the primary surveillance and monitoring activity for the C-106, C-201, C-202, C-203, and C-204 closure demonstration tanks includes quarterly monitoring for water / liquid intrusion into the tanks (Barnes, D.A. 2002). Monitoring is done using waste surface level measuring devices. These tanks are not currently being monitored for leak detection purposes. Leak detection is not being monitored, because the assumed tank waste surfaces have been characterized as "Dry" for purposes of surveillance and monitoring.

Tank integrity and structural stability is maintained and monitored through strict tank farm access requirements including specific tank dome load restrictions, detailed engineering assessments for dome loading, dome video inspections, and dome deflection surveys.

12.2 RETRIEVAL SURVEILLANCE AND MONITORING

The primary surveillance and monitoring activity associated with retrieval is for leak detection during retrieval. There are numerous technologies and approaches for leak detection during retrieval. To date the primary method for leak detection during retrieval has been liquid level and mass transfer monitoring and radiological monitoring using borehole logging instruments in the surrounding boreholes. This method has a large lag period between the leak and leak detection, because generally a large volume of liquid needs to leak or be lost prior to detection.

There are other methods of retrieval leak detection that have less of a lag period. Many of these technologies are being assessed as a part of the saltcake dissolution project. These technologies include electrical resistance tomography, high resolution resistivity, cross-borehole seismography, cross-borehole radar, and cross-borehole electro-magnetic induction. All of these technologies involve subsurface imaging and detection of leaks as the vadose zone beneath the tanks is wetted from retrieval leakage losses. These technologies involve installing various sensors in boreholes surrounding the tanks. Additional detail regarding each specific technology can be found in the following sections.

The need for and methods for monitoring leak detection during retrieval of waste from the five tanks in the ATCD project will be evaluated during the preliminary engineering phase of the waste retrieval project supporting the ATCD.

12.3 POST PARTIAL CLOSURE SURVEILLANCE AND MONITORING

Under the partial closure approach the current operational or very similar approach of monitoring for water intrusion with dome loading restrictions and dome integrity inspections and assessments for surveillance and monitoring would be maintained until full closure of the tank.

The need for partial closure surveillance and monitoring for the five demonstration tanks in the ATCD project will be evaluated during the preliminary engineering phase of the project and will be discussed further with the regulatory agencies as part of the closure plan/permitting process.

12.4 POST FULL TANK CLOSURE SURVEILLANCE AND MONITORING

For full tank closure, surveillance and monitoring of intrusion into the tank would not be necessary. Additional surveillance and monitoring for fill material settlement would be necessary following full tank stabilization, however this would likely be a component of a design specification and not necessarily a component of routine surveillance and maintenance. Following full tank stabilization and assurance of stabilization material performance through settlement monitoring, the tank dome load restrictions could be greatly eased and potentially removed entirely.

12.5 POST FINAL TANK FARM CLOSURE SURVEILLANCE AND MONITORING

Although not in the scope of this document routine surveillance and monitoring of a closed tank farm with final surface barrier would likely include site inspections, groundwater monitoring, aerial photography, and custodial maintenance and contingency repair of surface barriers. Surveillance and monitoring including maintenance guidance for uranium mill tailings remediation sites is included in *Guidance for UMTRA Project Surveillance and Maintenance* (UMTRA-DOE 1986).

Techniques are also available or under development that may be applicable to monitoring vadose zone concentration changes or moisture movement. These tools are considered appropriate for use after selection and installation of the chosen closure remedy, and would be implemented under an Operation and Maintenance plan or a post-closure monitoring plan. These technologies have also been considered for leak detection monitoring during waste retrieval activities. They are intended to show the adequacy of a remediation or closure technology selected to prevent movement of contamination already in place. These techniques require a previously constructed installation, typically a single or multiple borehole network, to examine fluid movement potential factors, moisture content, soil gases, or to sample pore liquids. Stephens, D.B. (1996) provides a good overview of vadose zone monitoring techniques and the data needs they can support.

Geophysical logging techniques are available to assess the soil volume around a borehole. Both gamma detection tools, such as the radionuclide logging system, neutron probes, acoustic velocity logs, and neutron density logging tools can be used to track soil moisture or radionuclides in the soil column. Analyses of repeated measurements will detect changes in moisture content or radionuclide movement over time.

Cross-hole techniques such as gamma ray attenuation, and tomography tools such as electrical resistance, nuclear magnetic resonance, and X-ray computed devices, offer the potential to detect minor changes in soil moisture in three dimensions with an appropriate borehole array. At the Hanford Site, electrical resistance tomography has been examined and field-tested for application around tank farms (Narbutovskih, S.M., R.K. Price, V.J. Rohay 1997). The system operates by

passing an electrical current through the soil column, which is monitored for changes in resistivity resulting from changes in conductivity, induced by soil moisture fluctuations.

Ground-based geophysical techniques are capable of measuring soil moisture using a combination of pre-installed subsurface sensors and surface-based interrogation or data collection systems. Electrical methods use electrodes to apply and receive a current through the soil and commonly measure resistivity changes. The method is best applied to delineate lateral extent over a target area or for depth profiling at a given point. EMI applies an electromagnetic pulse to the soil column and measures the response observed in soil depths from 3 to 60 m, depending upon the spacing of the transmitting and receiving coils. It can be used to measure apparent resistivity changes in the field at a site with uniform undisturbed features. GPR uses electromagnetic pulses in the radio frequency spectrum (10-1,000 MHz) to detect reflecting soil units and conditions. Moisture content and certain contaminated liquids may be detected by this method. Most surface-based systems are best used as a reconnaissance tool to detect relative moisture conditions and are affected by soil column layering and soil material types.

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13.0 CONCLUSIONS

The purpose of this Data Assessment Report is to summarize and assess available characterization information, present closure approaches and technologies, and to provide information for use in closure AGA report for the five closure demonstration tanks.

The focus of this closure demonstration project is on closure of the tank structure only. Decisions regarding soil and surface barriers will be addressed later. Ancillary equipment not directly affected by individual tank closure will be addressed later. These issues will likely be addressed during closure of the entire C tank farm.

The following conclusions were drawn as a result of this data assessment study.

1. The BBI tank waste inventories for the closure demonstration tanks are adequate for initial tank closure planning and in the case of the C-200 series tanks appear to be conservative. Pending ongoing DQO efforts and residual waste volume recalculation following retrieval the sample based inventory for the C-106 tank may be suitable for some closure decisions. However, because the C-106 tank will be the first tank to be closed at Hanford and within C Tank Farm, additional waste characterization for closure is likely necessary. The HDW model based inventories for the C-200 series tanks is likely not sufficient for making closure criteria driven decisions. In addition the C-200 series tanks residual waste volumes used in the BBI for inventory calculation appear to be conservatively high by up to 50% or possibly more for the C-200 series tanks. As the regulatory issues surrounding remaining tank waste are determined; and as tank, soil, and ancillary risk allocation issues are assessed; and as closure of additional tanks proceeds (following this demonstration) the use of model based inventories may be appropriate for making future closure decisions.

2. There is limited soil characterization information for the C Tank Farm and for the closure demonstration tank. There is gamma logging information for the C Tank Farm, that provides a general level and extent of soil contamination for gamma emitting radionuclides (primarily Cs-137 and Co-60). There is process knowledge soil information describing known releases and estimated release volume in the C Tank Farm. From the process knowledge information the majority of known releases have been associated with vaults and diversion boxes located at the south corner of the tank farm.

3. Tank closure alternatives will be explored in the closure demonstration AGA report. Those approaches include full tank closure (full tank structural stabilization through filling) and partial tank closure (residual waste stabilization at the bottom of the tank) using a cementitious grout.

4. For this closure demonstration, using video camera inspections and engineering judgement should be sufficient for calculating a residual waste volume remaining in the tanks for closure. This is consistent with a conservative graded approach to residual waste volume calculation. By using this approach, a more quantifiable residual waste volume measurement technique is not currently necessary for the closure demonstration tanks. Note HFFACO requirements will be met.

Tentatively, placement of cementitious grout for tank void space stabilization and physical tank waste stabilization for either the full tank closure (complete tank filling) or the partial closure (initial residual waste stabilization) approaches has been selected to provide a basis for initiation of preliminary engineering.

5. Sandia National Laboratories and others are currently studying hydroxy apatite for use as a grout additive for sequestering Tc-99, uranium, and other contaminants. The work to date appears to be very promising and results are anticipated to be available in time for this closure demonstration. However, until studies currently underway, and planned in FY 2003 are completed, no recommendations can be made on use of such chemical additives in the grout mix formulation for tank fill.

6. While data for other DOE site closures is discussed in this report, comparision of technical, cost, and schedule information is problematic as it is not clear that consistent assumption bases were used to produce this information.

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APPENDIX A

TANK CLOSURE COSTS AT U.S. DEPARTMENT OF ENERGY SITES

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The following data has been provided by the three primary sites where actual closure activities have commenced. The data is relative to the costs associated with each site's particular closure activities. The data does not allow direct site-to-site comparisons of closure costs for two reasons. First, the level of detail available, identifying the breakdown for the cited expenditures, is different with each site. For example, one site might have provided a comprehensive listing of all activities viewed as having comprised "closure" and, therefore, as having contributed to the cited cost, while another site might have provided only a total dollar cost with considerably less breakdown. Second, the scope of "closure" is different at each site. For example, at INEEL and ORNL, soil remediation costs are not included in the data because those costs are to be picked up by separate projects. At ORNL, costs associated with retrieval of tank waste and closing ancillary equipment are not included for the same reason. When adequate actual cost data becomes available to provide a more detailed and direct comparison of closure costs, this document will be revised.

POOR QUALITY ORIGINAL

INEEL – Tank Closure Costs & Activities

Fiscal Year		<2000	2000	2001
Tank WM-180				
Tank WM-181				
Tank WM-182		[redacted]	[redacted]	[redacted]
Tank WM-183				
Tank WM-184				
Tank WM-185				
Tank WM-186				
Tank WM-187				
Tank WM-188				
Tank WM-189				
Tank WM-190				
Tanks WM-103,104,105,106				
Project Management	15,889	750	500	443
Closure Plans	11,092	[redacted]	[redacted]	[redacted]
Baseline Heel Samples	5,232	[redacted]	[redacted]	
Final Heel Samples	6,650	[redacted]		
Conceptual/FS Design	2,911	[redacted]	[redacted]	
Mockup Facility**	300	[redacted]		
Design	6,145			[redacted]
GFE material	6,576		[redacted]	[redacted]
Site Preparation	6,440			[redacted]
Tank Isolation/decon lines	8,446			
ash Interior Walls				
Solidify Remaining Heel	7,856			
Fill Vault with Clean Grout	12,500			
Fill tank with Clean Grout *	8,060			
Project Request Budget	105,853	2,734	5,151	2,567
Approved Budget	14,834	1,650	5,145	2,534
* Tank fill material will be determined by EIS ROD				
Costs are for multiple tanks if clean grout is used.				
** TFA will fund mockup activities				

INEEL

- This will change to reflect acceleration goal of closing 4 tanks by 2004.
- Soil remediation costs to be picked up by a different project.

ORNL – Waste retrieval cost summary and responsible contractors for final clean out of the GAAT

	Cost ($M)										
	Responsible Contractors										
	MMES[a]		LMES[b]	LMER[c]		BJC/LMER[d]		BJC/UTB[e]		TOTAL	%
	Fiscal Year										
	1993	1994	1995	1996	1997	1998	1999	2000	2001		
Cost Category											
Project management	530	132	635	673	804	800	632	767	134	5,107	7.3
Preliminary design & technology selection	535	1,385	2,169	1,809	6,496	414				12,808	18.2
Final Design		237	987	1,461	1,285	243	435	293		4,941	7.0
Materials			50	3,256	1,141	90				4,537	6.5
Site Preparation		152	1,827	3,749	1,511	1,397	947	1,962		11,545	16.4
Operations		338	3,294	2,695	1,036	7,977	8,365	5,826	1,222	30,753	43.8
Closure							56	363	149	568	0.8
EM 50 Retrieval Systems										14,835	
Annual cost	1,065	2,244	8,962	13,644	12,273	10,921	10,435	9,211	1,502		
Cumulative cost	1,065	3,308	12,270	25,914	38,187	49,108	59,543	68,754	70,256	85,094	

[a] April 1, 1984 through March 31, 1994
[b] April 1, 1994 through December 31, 1995
[c] January 1, 1996 through March 31, 1998 for GAAT project. LMER remained the M&O contractor at ORNL through March 31, 2000
[d] April 1, 1998 through March 31, 2000. BJC has continued as the M&I contractor at ORNL.
[e] Beginning April 1, 2000

ORNL

- Does not include soil remediation
- Does not include ancillary equipment

SRS:Detailed Cost Calculations, in Millions of 1997 Dollars

Year	Tanks Operating	Tank Closure Costs
1997	24	4.30
1998	23	4.30
1999	22	4.30
2000	21	8.60
2001	19	4.30
Totals	109	25.8

APPENDIX B

RESIDUAL TANK WASTE VOLUME CALCULATION SPREADSHEETS

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POOR QUALITY ORIGINAL

Calculation Sheet - C-201

Farm e.g., "A", "TX", etc.	C
Series "100" or "200"	200
Depth of waste (in.)	7.5

distance to knuckle	r1 =	7.00 ft		
radius of knuckle	r2 =	3.00 ft		
radius of tank	R =	10.00 ft		
depth of dish	d =	0.50 ft		
radius of dish	rd =	55.14 ft		
total tank volume (inc. headspace)	Vtotal =	7,945 ft3		
depth of waste in dish region	hd =	0.50 ft		
volume of waste in dish region	*Vd =*	*43 ft^3*	*323 gal*	*1 m^3*
depth of waste in knuckle region	hk =	0.13 ft		
volume of waste in knuckle region	*Vk =*	*23 ft^3*	*169 gal*	*1 m^3*
depth of waste above knuckle	hc =	0.00 ft		
volume of waste above knuckle	*Vc =*	*0 ft^3*	*0 gal*	*0 m^3*
Total waste volume (Vd + Vk + Vc)	*Vwaste =*	*66 ft^3*	*492 gal*	*2 m^3*
Headspace volume (Vtotal - Vwaste)	*Vhead =*	*7,879 ft^3*	*58,939 gal*	*223 m^3*

POOR QUALITY ORIGINAL

Calculation Sheet - C-202

Farm e.g., "A", "TX", etc.	C
Series "100" or "200"	200
Depth of waste (in.)	8.0

distance to knuckle	r1 =	7.00 ft		
radius of knuckle	r2 =	3.00 ft		
radius of tank	R =	10.00 ft		
depth of dish	d =	0.50 ft		
radius of dish	rd =	55.14 ft		
total tank volume (inc. headspace)	Vtotal =	7,945 ft3		
depth of waste in dish region	hd =	0.50 ft		
volume of waste in dish region	*Vd =*	*43 ft^3*	*323 gal*	*1 m^3*
depth of waste in knuckle region	hk =	0.17 ft		
volume of waste in knuckle region	*Vk =*	*31 ft^3*	*230 gal*	*1 m^3*
depth of waste above knuckle	hc =	0.00 ft		
volume of waste above knuckle	*Vc =*	*0 ft^3*	*0 gal*	*0 m^3*
Total waste volume (Vd + Vk + Vc)	*Vwaste =*	*74 ft^3*	*553 gal*	*2 m^3*
Headspace volume (Vtotal – Vwaste)	*Vhead =*	*7,871 ft^3*	*58,878 gal*	*223 m^3*

POOR QUALITY ORIGINAL

Calculation Sheet - C-203 and C-204

Farm e.g., "A", "TX", etc.	C
Series "100" or "200"	200
Depth of waste (in.)	17.0

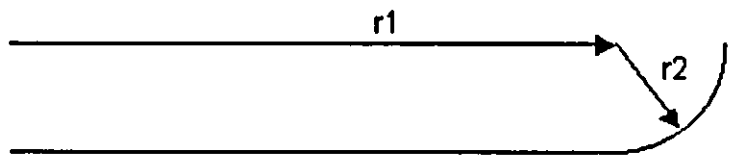
distance to knuckle	r1 =	7.00 ft		
radius of knuckle	r2 =	3.00 ft		
radius of tank	R =	10.00 ft		
depth of dish	d =	0.50 ft		
radius of dish	rd =	55.14 ft		
total tank volume (inc. headspace)	Vtotal =	7,945 ft^3		
depth of waste in dish region	hd =	0.50 ft		
volume of waste in dish region	*Vd =*	*43 ft^3*	*323 gal*	*1 m^3*
depth of waste in knuckle region	hk =	0.92 ft		
volume of waste in knuckle region	*Vk =*	*208 ft^3*	*1,558 gal*	*6 m^3*
depth of waste above knuckle	hc =	0.00 ft		
volume of waste above knuckle	*Vc =*	*0 ft^3*	*0 gal*	*0 m^3*
Total waste volume (Vd + Vk + Vc)	*Vwaste =*	*251 ft^3*	*1,881 gal*	*7 m^3*
Headspace volume (Vtotal - Vwaste)	*Vhead =*	*7,693 ft^3*	*57,550 gal*	*218 m^3*

POOR QUALITY ORIGINAL

Tank Dimensions

	knuckle radius (ft)	distance to knuckle (ft)	dish depth (ft)	dish radius (ft)	tank radius (ft)	total tank volume (gal)
A	0	0	0		37.5	1,315,972
AN	1	36.5	0		37.5	1,406,390
AP	1	36.5	0		37.5	1,406,254
AW	1	36.5	0		37.5	1,406,390
AX	0.5	37	0		37.5	1,331,879
AY	1	36.5	0		37.5	1,408,446
AZ	1	36.5	0		37.5	1,406,390
B	4	33.5	1	570	37.5	849,132
BX	4	33.5	1	569.59	37.5	849,119
BY	4	33.5	1	569.59	37.5	1,047,940
C	4	33.5	1	570	37.5	849,132
S	4	33.5	1	569.59	37.5	1,050,005
SX	0	37.5	1	874.9	37.5	1,295,192
SY	1	36.5	0	569.59	37.5	1,406,390
T	4	33.5	1	570	37.5	849,132
TX	4	33.5	1	569.59	37.5	1,047,940
TY	4	33.5	1	569.59	37.5	1,050,005
U	4	33.5	1	570	37.5	849,132
200	3	7	0.5	55.144	10	59,431

Cross-sectional of knuckle-region of waste tanks.
r1 = distance from tank center to bottom of knuckle
r2 = radius of knuckle



APPENDIX C

CLOSURE DEMONSTRATION TANK ANCILLARY EQUIPMENT SUMMARY TABLES

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Table C-1. Tank C-106 Piping (8 Pages)

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Diameter (in)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Diameter (in)	Material		
{cascade}	C-105	C-106	3	sch 80 stl	624.96	624.21	22'	22'-9"	9" (3%) to C-106	25'	none			8	sch 40 stl	H-14-104175 HW-72743 H-2-1744	
{cascade clean outs}	{cascade}	near grade	2	sch 20	624'-6"	644'-6"	approx . 21'	6"	n/a	approx 21'	1 @ 3' R	6" below grade	pipe cap	n/a	n/a	H-2-44006 H-2-2929	
2" M5	C-06B-U3	C-103	2	M5	644	638.53	1.5'	7'	Away from C-106	~105'	2 @ 90 2 @ obtuse	?	?	none	none	H-2-38599 H-14-104175 H-2-73346	Not shown on H-14-104175; part of saltwell program; need to confirm if saltwell or associated lines ever installed on C-106; believed to be capped spare # 8316
8232	CR-153-U6	C-06A-U2	6	P-93	659	640'-6"		4'-6"	to C-106	~433'	8 @ 90 1 @ obtuse	C-06A-U2 CR-153-U6	blank	trench size varies	concrete trench	H-14-104175 H-2-44502 H-2-41386 H-2-73346 H-2-36835 H-2-41413	6" line (8232) reduced to 4" nozzle (U-2)
8202	C-06A-U1	CR-153-L13	6	P-93	640'-6"	654'-6"	4'-6"		to C-106	~433'	9 @ 90 1 @ obtuse	C-06A-U1 CR-153-L13	blank	trench size varies	concrete trench	H-14-104175 H-2-44502 H-2-41386 H-2-73346	6" line (8202) reduced to 4" nozzle (U-1)

POOR QUALITY ORIGINAL

Table C-1. Tank C-106 Piping (8 Pages)

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Diameter (in)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Diameter (in)	Material		
SL-100	C-06A-U9	AY-02A-U11	4	M9	642'-7"	676'	2'-9"	3'-7"	to C-106	~1700'	21 @ 90 2 @ obtuse	C-06A-U9 AY-02A-U11	blank	6	M26a	H-14-104175 H-2-73346 H-2-818448 H-2-818536 H-2-818518	
ENC-100	SL-100	C-06A-U8	2	M26a	642'-7"	640'-7"	2'-9"	4'-9"	to C-106	5'-3"	2 @ 90	none	none	n/a	n/a	H-14-104175 H-2-73346 H-2-818448 H-2-818536 H-2-818522	encasement drain
8256	C-06B-U2	8202	3	P-93	644'-0"	641'-3-3/8"	1'	2'-9"	away from C-106	~50'	1@45 deg	C-06B-U2	yes	see notes	see notes	H-14-104175 H-2-44502 H-2-41386 H-2-73346	3" nozzle: H-14-104175 does not identify that this line is encased but pipe is in segmented 8' of concrete, ~3' of 8" cast iron, ~30' of 8" clay, and ~3' of 8" cast iron
8235	CR-153-U5	C-06C-U2	6	P-93	659'	640'-6"		4'-6"	to C-106	~310	4 @ 90 1 @ obtuse	C-06C-2 CR-153-U5	blank	trench size varies	concrete trench	H-14-104175 H-2-44502 H-2-41386 H-2-73346 H-2-41413	4" nozzle at C-06C-U2; H-2-73346 says 8235 is at U1 vs. U2 per H-2-44502

Table C-1. Tank C-106 Piping (8 Pages)

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Diameter (in)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Diameter (in)	Material		
8214	C-06C-U1	CR-153-L10	6	P-93	640'-6"	654'-6"	4'-6"		to C-106	~310	4 @ 90 1 @ obtuse	C-06C-1 CR-153-L10	blank	trench size varies	concrete trench	H-14-104175 H-2-44502 H-2-41386 H-2-73346 H-2-41414	4" nozzle at C-06C-U1; H-2-73346 says 8214 is at U2 vs. U1 per H-2-44502
SN-200	AY-02E-U2	C-06C-U6	4	M9	676'	641'-5"	3'-7"	4'	to C-106	~1700'	21 @ 90 2 @ obtuse	C-06C-U6 AY-02E-U2	blank	6	M26a	H-14-104175 H-2-73346	4" nozzle
ENC-200	SN-200	C-06C-U7	2	M26a	641'-5"	640'-5"	4'	5'	to C-106	6'-3"	2 @ 90	none	none	n/a	n/a	H-2-73346 H-2-41194	2" nozzle
DR-301	Process bldg floor drain	DR-302	3	M9	645	641'-5"	0	4'	to C-106	~70'-6"	2 @ 90 1 @ obtuse	C-06C-U8	blank isolation valve in drain	6	M26a	H-14-104175 H-2-73346 H-2-818526 ECN-649184	3" nozzle; DR-301 joins to DR-302 which ends at C-06C-U8
DR-302	metal filter drain	C-06C-U8	3	M9	645	641'-5"	0	4'	to C-106	~70'-6"	2 @ 90 1 @ obtuse	C-06C-U8	blank operations drain plug	6	M26a	H-14-104175 H-2-73346 ECN-649185 H-2-818521	3" nozzle; DR-301 joins to DR-302 which ends at C-06C-U8
ENC-302	DR-302	C-06C-U9	2	M26a	641'-5"	640'-5"	4'	5'	to C-106	5'-3"	2 @ 90	none	none	n/a	n/a	H-2-73346	2" nozzle
8348	C-06A	riser R-5	2		638'	638'	7'	7'	to riser	~5'	0	none	none	n/a	embed in pit floor	H-2-44502 H-2-73346 H-2-41190	Pit Drain
8347	C-06B	riser R-13	2		642'-10"	642'-10"	2'-2"	2'-2"	to riser	~3'-6"	0	none	none	n/a	embed in pit floor	H-2-44502 H-2-73346 H-2-41192	Pit Drain

POOR QUALITY ORIGINAL

Table C-1. Tank C-106 Piping (8 Pages)

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Diameter (in)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Diameter (in)	Material		
8346	C-06C	riser	2		638'	638'	7'	7'	to riser	~3'	0	none	none	n/a	embed in pit floor	H-2-44502 H-2-73346 H-2-41194	Pit Drain
8310	C-06A-U4	spare	6"	P	640'-6"	640'-6"	4'-6"	4'-6"	n/a	9'	0	C-06A-U4 stub	6" welded cap per H-2-41190	none	n/a	H-2-44502 H-2-41190 H-2-73346	spare 4" nozzle, 6" line
8316	C-06B-U3	spare	3	P	644'	644'	1'	1'	to C-106	9'-6"	0	C-06B-U3 stub	{capped outside of valve pit per H-2-73876 &H-2-73877}	none	n/a	H-2-44502 H-2-73346 H-2-73876 H-2-73877 H-2-38599 H-2-73973 H-2-41892	3" nozzle; this is believed to be correct configuration but see 2" M5 line
8260	C-06B-U1	gang valve south of pit	2	P12	644	645	1'	0	n/a	~20'	4 @ 90	at gang valve	cut and thd cap per H-2-71842, detail E	1' x 1'	concrete embed	H-2-44502 H-2-41847 H-2-73346 H-2-41846	steam; 2" nozzle
8322	C-06C-U3	spare	6	P	643'	643'	2'	2'	n/a	9'-6"	0	C-06C-U3 stub	welded cap per H-2-41194	none	n/a	H-2-44502 H-2-73346 H-2-41194	4" nozzle
Tank Nozzle 1	spare	n/a	4	sch 80 stl	624.33		22'-6"	n/a	1% into C-106	18" stub	none	at tank	loose cap per HW-72743	n/a	n/a	HW-72743 H-2-1744	
Tank Nozzle 2	spare	n/a	4	sch 80 stl	624.33		22'-6"	n/a	1% into C-107	18" stub	none	at tank	loose cap per HW-72743	n/a	n/a	HW-72743 H-2-1744	

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Table C-1. Tank C-106 Piping (8 Pages)

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Diameter (in)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Diameter (in)	Material		
Tank Nozzle 3	spare	n/a	4	sch 80 stl	624.33		22'-6"	n/a	1% into C-108	18" stub	none	at tank	loose cap per HW-72743	n/a	n/a	HW-72743 H-2-1744	
Tank Nozzle 4	spare	n/a	4	sch 80 stl	624.33		22'-6"	n/a	1% into C-109	18" stub	none	at tank	loose cap per HW-72743	n/a	n/a	HW-72743 H-2-1744	
8232(E)	C-06A-U5	blank conduit	3	E	640'-6"	640'-6"	4'-6"	4'-6"	n/a	1'-11"	0	at pit	grout per H-2-73450, detail 6	n/a	n/a	H-2-73346 H-2-73450 H-2-41190	
8301(E)	C-06A-U6	blank conduit	3	E	640'-6"	640'-6"	4'-6"	4'-6"	n/a	1'-11"	0	at pit	grout per H-2-73450, detail 6	n/a	n/a	H-2-73346 H-2-73450 H-2-41191	
8336(E) SP	C-06A-U7	spare conduit	3	E	640'-6"	640'-6"	4'-6"	4'-6"	n/a	1'-11"	0	at pit	grout per H-2-73450, detail 6	n/a	n/a	H-2-73346 H-2-73450 H-2-41192	
{RW@C-06A}		C-06A	2	P12								at concrete base outside of pit	cut and thd cap	n/a	n/a	H-2-73346	There are 4 RW supply lines servicing the following: to R-5, R-6, R-9, and near U1, U4, U6; also, line cut and capped near C-06A-U9 (SL-100)

Table C-1. Tank C-106 Piping (8 Pages)

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Diameter (in)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Diameter (in)	Material		
{RW@C-06B}		C-06B	2	P12								at concrete base outside of pit	Cut and 150# weld cstl weld cap per H-2-71842, det A	n/a	n/a	H-2-73346 H-2-71842	There are 2 RW supply lines servicing the following: to R-13, near U3, and between U1 and U2
8279	C-06C-U4	stub	3@1/2"	P12	643'	643'	2'	2'	n/a	~2'	0	Nozzle & stubbed lines	nozzle blank per H-2-73453, 125# brass thd cap per H-2-41194	n/a	n/a	H-2-73346 H-2-41194 H-2-73453	2" nozzle with three 1/2" air lines
8328	C-06C-U5	stub	3@1/2"	P12	643'	643'	2'	2'	n/a	~2'	0	Nozzle & stubbed lines	nozzle blank per H-2-73453, 125# brass thd cap per H-2-41195	n/a	n/a	H-2-73346 H-2-41194 H-2-73453	spare 2" nozzle with three 1/2" air lines
{RW@C-06C}		C-06C	2	P12								at concrete base outside of pit	cut and thd cap			H-2-73346	There are 3 RW supply lines servicing the following: to R-3, R-4 and on east and

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Table C-1. Tank C-106 Piping (8 Pages)

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Diameter (in)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Diameter (in)	Material		
																	west walls
VT-1001	HVAC Pit		6	M-42	n/a	n/a	n/a	n/a	n/a	n/a	yes	none	n/a	n/a	n/a	H-2-818470 H-2-818477	seal loop; above ground duct
VT-1002	HVAC Pit		6	M-42	n/a	n/a	n/a	n/a	n/a	n/a	yes	none	n/a	n/a	n/a	H-2-818470 H-2-818477	seal loop; above ground duct
VT-1010	HVAC Pit	Process Bldg C-91	10	M8	n/a	n/a	n/a	n/a	to C-106	~16'	2@90	none	n/a	n/a	n/a	H-2-818470	above ground duct
{air inlet and cooling water addition}	HVAC Pit, Riser 15		12	M8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	none	n/a	n/a	n/a	H-2-818470	above ground duct
VT-1022	Riser 2	Deentrainer and P-16 exhauster	8"	M8	n/a	n/a	n/a	n/a	from P-16 exh to C-106	n/a	n/a	none	n/a	n/a	n/a	H-2-93797 H-2-818470 H-2-818469	above ground duct to process building; and to deentrainer and P-16 exhauster that services both C-105 and C-106; 16" duct from P-16 to C-106 and 14" from P-16 to C-105

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Table C-2. Tank C-106 Risers. (3 Pages)

Riser ID	Dia. (in)	Material	Flange	Flange elev.	Location		Contents	Isolation	Reference	Notes
					Tank Rad.	Pit				
R-1	4	sch 40	150# std. flange	646.15'	33'-3"	none	LIT; Enraf per H-2-817634		H-2-73346 HW-72743 H-14-010613	benchmark
R-2	12	sch 40	150# std. flange	646.18'	32'-9"	none	16" dia above ground HVAC Duct with tie in from 8"VT-1022-M8		H-2-73346 HW-72743 H-14-010613	
R-3	12	sch 40	Adapter ring per H-2-41311	647.24'	32'-9"	C-06C sluice	sluicer/jumper assy. Per H-2-818549	air or steam line cut and capped per H-2-73346	H-2-73346 HW-72743 H-2-818549 H-2-41344 H-14-010613	
R-4	4	sch 40	Adapter ring per H-2-41319	638.21'	33'-3"	C-06C sluice	Old Recirculating Dip Leg riser per H-2-41318	Std vertical Isolation blank; see H-2-73453-5; air or steam line cut and capped per H-2-73346; isolation of the two 1" sch 80 dip tubes not identified	H-2-73346 HW-72743 H-2-41318 H-2-41344 H-14-010613	riser is 4"
R-5	4	sch 40	Adapter ring per H-2-41319	637.63'	33'-3"	C-06A pump	shield plug; old recirculating dip leg riser	RW line cut and capped per H-2-73346	H-2-73346 HW-72743 H-2-41343 H-14-010613	Pit drain connects to R-5
R-6	12	sch 40	Adapter ring per H-2-41311	646.01'	32'-9"	C-06A pump	Failed Transfer Pump PTX141		H-2-73346 HW-72743 H-2-37912 H-2-41343 H-14-010613	

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Table C-2. Tank C-106 Risers. (3 Pages)

Riser ID	Dia. (in)	Material	Flange	Flange elev.	Location		Contents	Isolation	Reference	Notes
					Tank Rad.	Pit				
R-7	12	sch 40	150# std. Flange modified to be flush with wall	646.48'	32'-9"	C-06A pump	Formerly housed in-tank imaging system		H-2-73346 HW-72743 H-2-41343 ECN-641247 H-14-010613	Plastic top hat, Flange T.B. Installed
R-8	4	sch 40	150# std. flange	645.66'	33'-3"	C-06A pump	thermocouple tree		H-2-73346 HW-72743 H-14-010613	
R-9	36		slurry pump adapter per H-2-41267	638.33'	32.5'	C-06A pump	slurry pump per H-2-818494		H-2-73346 H-2-818536 H-2-41343 H-14-010613	Riser installed at existing manhole; TWINS identifies it as a sludge pump
R-13	26 tapers to a 12"		adapter plate per H-2-41295	643.09'	0'	C-06B heel	distributor jet		H-2-73346 H-2-41318 H-2-41345 H-14-010613	Pit drain connects to R-13; heel jet
R-14	4	sch 40, cstl	150# 150# blind blue african asbestos	645.5'	11'-9"	none	H-2-34304 temp. probe		H-2-72352 H-2-73346 FCN-50547 H-14-010613	Benchmark; H-2-73346 shows location different from H-2-72352; H-2-73346 P/L indicates thermocouple tree
R-15	12 10 6 6		cover plate on concrete HVAC duct with multiple penetratio ns	645.14'	3.6'	HVAC	inlet filter per H-2-818470 on riser 15 (12" port); duct on 10" port; seal loop on south 6" port; breather filter on north 6" port		H-2-73346 H-2-818470 ECN-655466 H-14-010613	HVAC Pit also has duct to process bldg (C-91) and seal loops protruding from pit cover; TWINS indicate inlet filter per ECN-103653

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Table C-3. Tank C-201 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175

Pipe ID	Component ID				End Elevations		End Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
V156	C-252-L1	C-201-N4	3		634.61'	632.08'	11.86'	12.9'	into tank	230	3 @ obtuse	C-252-L1	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73352 H-2-73339 H-2-73338	4" sleeve to accept 3" pipe
V157	C-252-L2	C-201-N3	3		634.61'	632.08'	1 86'	12.9'	into tank	230	3 @ obtuse	C-252-L2	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73352 H-2-73339 H-2-73338	4" sleeve to accept 3" pipe
8552	CR-151-U2	C-201-U1	6	P-93 cstl, sch 80 smls, A-53	651'-6"	641'	13'-6"	4'	into tank	780	14 @ 90	C-201-U1 CR-151-U2	blank in diver-sion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73352 H-2-73339	4" nozzle; Lines 8400 & 8402 between 8552 and tank
8555	CR-151-U5	C-201-U2 C-201-U3	6	P-93 cstl, sch 80 smls, A-53	651'-6"	639'-9"	13'-6"	5'-3"	into tank	780	14 @ 90	CR-151-U5 8555 cut & capped South of C-104	blank in diver-sion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73352 H-2-73339	two 4" nozzle; Lines 8410 &8411 between 8555 and tank; H-2-44502, Sh 6 shows 8555 cut & capped
{spare inlet}	C-201 N1		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	loose cap per H-2-72742	n/a	n/a	H-2-72742 H-2-73352	4" sleeve to accept 3" pipe
{spare inlet}	C-201-N2		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	loose cap per H-2-72742	n/a	n/a	H-2-72742 H-2-73352	4" sleeve to accept 3" pipe

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Table C-3. Tank C-201 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175																	
Pipe ID	Component ID				End Elevations		End Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
RW@C-201 Jet Pump Pit		C-201 Jet Pump Pit	3@2"	P12	650'	644' 637'	above ground	10'	into tank			grade level	cut and 150# weld cap per H-2-71842 det A	n/a	n/a	H-2-41849 H-2-73352 H-2-71842	Three supply lines servicing the following: to R-9, R-10 and on wall above nozzles and opposite wall.
{1" conduit for leak detector}		C-201 Jet Pump Pit	1"	galv	643'-9"	637'	3'-3"	10'	n/a			el 643'-9"	1" scrd cap	n/a	n/a	H-2-41849 H-2-73352	
{Pit Drain}	Jet Pump Pit	R-9	2"	A-53, Gr A sch 40	637'-2"	636'-2"	10'-10"	11'-10"	12" drop into tank	~1'-6"	2 @ 90	blank per H-14-104175		n/a	n/a	H-2-41816 H-14-104175 H-2-41843	

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Table C-4. Tank C-201 Risers.

Riser ID	Dia. (in.)	Material	Flange Elevation	Location		Contents	Isolation	References	Notes
				Tank Rad.	Pit				
R-5	4		646.58'	8'	none	Breather filter	re-gasketed per H-2-73051 G/N 2	H-2-73352 H-2-73051 ECN-663406 H-14-010613	
R-6	12		646.60'	8'	none	Temperature probe	re-gasketed per H-2-73051 G/N 2	H-2-73352 H-2-73051 H-14-010613	
R-7	12		646.63'	8'	none	empty observation port	blind flange per H-2-93726	H-2-73352 H-2-93726 H-14-010613	
R-8	4		646.63	8'	none			H-2-73352 H-2-69748 ECN-663406 H-14-010613	Manual Tape
R-9	12		637.33'	4'	Jet Pump	Sludge Jet		H-2-41843 H-2-73352 H-14-010613	
R-10	12		637.33'	6'-1"	Jet Pump	none	blank	H-2-41843 H-2-73352 H-14-010613	Not seen in video
HVAC		concrete	grade	4'	HVAC	none	duct removed; access blanked	H-2-73352 HW-72742	There are 2 HVAC Hatchways; 1 was woodified, the other is still there
MH	42			8'	none	none		H-2-73352	manhole; original cover at top of tank

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Table C-5. Tank C-202 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175																	
Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
V158	C-252-L3	C-202-N4	3		634.61'	632.08'	11.86'	12.9'	into tank	185	3 @ obtuse	C-252-L3	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73353 H-2-73339 H-2-73338	4" sleeve to accept 3" pipe
V159	C-252-L4	C-202-N3	3		634.61'	632.08'	11.86'	12.9'	into tank	185	3 @ obtuse	C-252-L4	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73353 H-2-73339 H-2-73339	4" sleeve to accept 3" pipe
8552	CR-151-U2	C-202-U1 Jet Pump Pit	6	P-93 cstl, sch 80 smls, A-53	651'-6"	641'	13'-6"	4'	into tank	715	10 @ 90	C-202-U1 CR-151-U2	blank in diversion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73353 H-2-73339	4" nozzle; Lines 8400 & 8404 between 8552 and tank
8555	CR-151-U5	C-202-U2 C-202-U3 Jet Pump Pit	6	P-93 cstl, sch 80 smls, A-53	651'-6"	639'-9"	13'-6"	5'-3"	into tank	715	10 @ 90	CR-151-U5 8555 cut & capped South of C-104	blank in diversion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73353 H-2-73339	two 4" nozzle; Lines 8410 & 8415 between 8555 and tank; H-2-44502, Sh 6 shows 8555 cut & capped
{spare inlet}	C-202-N1		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	loose cap per H-2-7242	n/a	n/a	H-2-72742	4" sleeve to accept 3" pipe

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Table C-5. Tank C-202 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175																	
Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
{spare inlet}	C-202-N2		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	loose cap per H-2-7242	n/a	n/a	H-2-72742	4" sleeve to accept 3" pipe
RW@C-202Jet Pump Pit		C-202 Jet Pump Pit	3@2"	P12	650'	644' 637'	above ground	10'	into tank			grade level	cut and 150# weld cap per H-2-71842 det A	n/a	n/a	H-2-41849 H-2-73353 H-2-71842	Three supply lines servicing the following: to R-9, R-10 and on wall above nozzles and opposite wall.
{1" conduit for leak detector}		C-202 Jet Pump Pit	1"	galv	643'-9"	637'	3'-3"	10'	n/a			el 643'-9"	1" scrd cap	n/a	n/a	H-2-41849 H-2-73353 H-2-71842	
{Pit Drain}	Jet Pump Pit	R-9	2"	A-53, Gr A sch 40	637'-2"	636'-2"	10'-10"	11'-10"	12" drop into tank	~1'-6"	2 @ 90	blank per H-14-104175		n/a	n/a	H-2-41816 H-14-104175 H-2-41843	

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Table C-6 Tank C-202 Risers

Riser ID	Dia. (in.)	Material	Flange Elevation	Location		Contents	Isolation	References	Notes
				Tank Rad.	Pit				
R-5	4		646.48'	8'	none	Breather filter	re-gasketed per H-2-73051 G/N 2	H-2-73353 H-2-73051 ECN-663407 H-14-010613	
R-6	12		646.49'	8'	none	Temperature probe	re-gasketed per H-2-73051 G/N 2	H-2-73353 H-2-73051 H-14-010613	
R-7	12		646.5'	8'	none	empty observation port	blind flange per H-2-93726	H-2-73353 H-2-93726 H-14-010613	
R-8	4		646.48'	8'	none	Enraf per ECN-663407 & H-2-817634		H-2-73353 H-2-69748 ECN-663407 H-14-010613	Manual tape real currently has zip cord
R-9	12		637.33'	4'	Jet Pump	Sludge Jet		H-2-41843 H-2-73353 H-14-010613	
R-10	12		637.33'	6'-1"	Jet Pump	none	blank	H-2-41843 H-2-73353 H-14-010613	H-2-73353 G/N 5 requires removal of sluicer - need to confirm that this was performed
HVAC		concrete	grade	4'	HVAC	none	duct removed; access blanked	H-2-73353 HW-72742	There are 2 HVAC hatchways. 1 was modified the other is still there
MH	42			8'	none	none		H-2-73353	manhole; original cover at top of tank

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Table C-7. Tank C-203 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175																	
Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
V160	C-252-L5	C-203-N4	3		634.61'	632.08'	11.86'	12.9'	into tank	135	3 @ obtuse	C-252-L5	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73354 H-2-73339 H-2-73338	4" sleeve to accept 3" pipe
V161	C-252-L6	C-203-N3	3		634.61'	632.08'	11.86'	12.9'	into tank	135	3 @ obtuse	C-252-L6	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73354 H-2-73339 H-2-73338	4" sleeve to accept 3" pipe
8552	CR-151-U2	C-203-U1 Jet Pump Pit	6	P-93 cstl, sch 80 smls, A-53	651'-6"	641'	13'-6"	4'	into tank	750	14 @ 90	C-203-U1 CR-151-U2	blank in diversion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73354 H-2-73339	4" nozzle; Lines 8400 & 8406 between 8552 and tank
8555	CR-151-U5	C-203-U2 C-203-U3 Jet Pump Pit	6	P-93 cstl, sch 80 smls, A-53	651'-6"	639'-9"	13'-6"	5'-3"	into tank	750	14 @ 90	CR-151-U5 8555 cut & capped South of C-104	blank in diversion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73354 H-2-73339	two 4" nozzle; Lines 8410, & 8419 between 8555 and tank; H-2-44502, Sh 6 shows 8555 cut & capped
{spare inlet}	C-203-N1		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	Loose cap per H-2-7242	n/a	n/a	H-2-72742 H-2-73354	4" sleeve to accept 3" pipe

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Table C-7. Tank C-203 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
{spare inlet}	C-203-N2		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	loose cap per H-2-7242	n/a	n/a	H-2-72742 H-2-73354	4" sleeve to accept 3" pipe
RW@C-203Jet Pump Pit		C-203 Jet Pump Pit	3@2"	P12	650'	644' 637'	above ground	10'	into tank			grade level	cut and 150# weld cap per H-2-71842 det A	n/a	n/a	H-2-41849 H-2-73354 H-2-71842	Three supply lines servicing the following: to R-9, R-10 and on wall above nozzles and opposite wall.
{1" conduit for leak detector}		C-203 Jet Pump Pit	1"	galv	643'-9"	637'	3'-3"	10'	n/a			el 643'-9"	1" scrd cap	n/a	n/a	H-2-41849 H-2-73354 H-2-71842	
{Pit Drain}	Jet Pump Pit	R-9	2"	A-53, Gr A sch 40	637'-2"	636'-2"	10'-10"	11'-10"	12" drop into tank	~1'-6"	2 @ 90	blank per H-14-104175		n/a	n/a	H-2-41816 H-14-104175 H-2-41843	

POOR QUALITY ORIGINAL

Table C-8 Tank C-203 Risers

Riser ID	Dia. (in.)	Material	Flange El.	Location		Contents	Isolation	References	Notes
				Tank Rad.	Pit				
R-5	4		646.65'	8'	none		re-gasketed per H-2-73051 G/N 2	H-2-73354 H-2-73051 ECN-663408 H-14-010613	Manual tape
R-6	12		646.62'	8'	none	Temperature probe	re-gasketed per H-2-73051 G/N 2	H-2-73354 H-2-73051 H-14-010613	
R-7	12		646.63'	8'	none	spare		H-2-73354 H-2-93726 H-14-010613	
R-8	4		646.64'	8'	none	breather filter		H-2-73354 H-2-69748 ECN-663408 H-14-010613	
R-9	12		637.33'	4'	Jet Pump	Sludge Jet		H-2-41843 H-2-73354 H-14-010613	Nothing can be seen from the video
R-10	12		637.33'	6'-1"	Jet Pump	none	blank	H-2-41843 H-2-73354 H-14-010613	
2-HVAC		concrete	grade	4'	HVAC	none	duct removed; access blanked	H-2-73354 HW-72742	Same as 201
MH	42			8'	none	none		H-2-73354	manhole; original cover at top of tank

POOR QUALITY ORIGINAL

Table C-9. Tank C-204 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175																	
Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
V162	C-252-L7	C-204-N4	3		634.61'	632.08'	11.86'	12.9'	into tank	90	3 @ obtuse	C-252-L7	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73355 H-2-73339 H-2-73338	4" sleeve to accept 3" pipe
V163	C-252-L8	C-204-N3	3		634.61'	632.08'	11.86'	12.9'	into tank	90	3 @ obtuse	C-252-L8	blank per H-2-73339	n/a	None	H-14-104175 W-72742 H-2-73355 H-2-73339 H-2-73338	4" sleeve to accept 3" pipe
8552	CR-151-U2	C-204-U1 Jet Pump Pit	6	P-93 cstl, sch 80 smls, A-53	651'-6"	641'	13'-6"	4'	into tank	800	14 @ 90	C-204-U1 CR-151-U2	blank in diversion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73355 H-2-73339	4" nozzle; Lines 8400 & 8408 between 8552 and tank
8555	CR-151-U5	C-204-U2 C-204-U3 Jet Pump Pit	6	P-93 cstl, sch 80 smls, A-53	651'-6"	639'-9"	13'-6"	5'-3"	into tank	800	14 @ 90	CR-151-U5 8555 cut & capped South of C-104	blank in diversion box per H-2-73339	~2' x 2'	Yes	H-14-104175 H-2-44502 H-2-41389 H-2-41849 H-2-73355 H-2-73339	two 4" nozzle;Lines 8410, 8423, & 8429 between 8555 and tank; H-2-44502, Sh 6 shows 8555 cut & capped
{spare inlet}	C-204-N1		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	Loose cap per H-2-7242	n/a	n/a	H-2-72742 H-2-73355	4" sleeve to accept 3" pipe

POOR QUALITY ORIGINAL

Table C-9. Tank C-204 Piping. (2 Pages)

Weather Sealed and Isolated per H-14-104175

Pipe ID	Component ID				End Elevations		Burial Depth					Isolation		Encasement		References	Notes
	From	To	Dia. (in.)	Matl	From	To	From	To	Slope	Length	Bends	Location	Type	Size	Matl		
{spare inlet}	C-204-N2		4		632.08'	n/a	13'	n/a	into tank	1'-6" stub	0	stub at tank	Loose cap per H-2-7242	n/a	n/a	H-2-72742 H-2-73355	4" sleeve to accept 3" pipe
RW@C-204 Jet Pump Pit		C-204 Jet Pump Pit	3@2"	P12	650'	644' 637'	above ground	10'	into tank			grade level	cut and 150# weld cap per H-2-71842 det A	n/a	n/a	H-2-41849 H-2-73355 H-2-71842	Three supply lines servicing the following: to R-9, R-10 and on wall above nozzles and opposite wall.
{1" conduit for leak detector}		C-204 Jet Pump Pit	1"	galv	643'-9"	637'	3'-3"	10'	n/a			el 643'-9"	1" scrd cap	n/a	n/a	H-2-41849 H-2-73355 H-2-71842	
{Pit Drain}	Jet Pump Pit	R-9	2"	A-53, Gr A sch 40	637'-2"	636'-2"	10'-10"	11'-10"	12" drop into tank	~1'-6"	2 @ 90	blank per H-14-104175		n/a	n/a	H-2-41816 H-14-104175 H-2-41843	

POOR QUALITY ORIGINAL

Table C-10. Tank C-204 Risers. (2 Pages)

Riser ID	Dia. (in.)	Material	Flange Elevation	Location		Contents	Isolation	References	Notes
				Tank Rad.	Pit				
R-5	4		646.52'	8'	none	per 6/26/02 video, sludge level measuring assy with tape extended and donut in residual wsate at bottom of tank	re-gasketed per H-2-73051 G/N 2	H-2-73355 H-2-73051 ECN-663409 H-14-010613	Manual tape
R-6	12		646.58'	8'	none	spare	re-gasketed per H-2-73051 G/N 2	H-2-73355 H-2-73051 H-14-010613	
R-7	12		646.57'	8'	none	empty observation port		H-2-73355 H-2-93726 H-14-010613	
R-8	4		646.57'	8'	none	breather filter		H-2-73355 H-2-69748 ECN-663409 H-14-010613	
R-9	12		637.33'	4'	Jet Pump	Sludge Jet		H-2-41843 H-2-73355 H-14-010613	

POOR QUALITY ORIGINAL

Table C-10. Tank C-204 Risers. (2 Pages)

Riser ID	Dia. (in.)	Material	Flange Elevation	Location		Contents	Isolation	References	Notes
				Tank Rad.	Pit				
R-10	12		637.33'	6'-1"	Jet Pump	per 6/26/02 video, appears to be a 4" multi-stage turbine pump; a flanged connection is visisble with plastic wrap and russian thistle	blank	H-2-41843 H-2-73355 H-14-010613 H-14-010613	
2-HVAC		concrete	grade	4'	HVAC	none	duct removed; access blanked	H-2-73355 HW-72742	Same as 201
MH	42			8'	none	none		H-2-73355	manhole; original cover at top of tank

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