Preliminary Performance Assessment for Waste Management Area C at the Hanford Site, Washington

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EXECUTIVE SUMMARY

This preliminary performance assessment examines the long-term environmental and human-health effects of the planned closure of the Waste Management Area C (WMA C) to support the issuance of the *Tier 1 Closure Plan for Waste Management Area C, Hanford, Washington*[1] and Waste Incidental to Repossessing petition as required by the Department of Energy's (DOE's) order on *Radioactive Waste Management*[2] (DOE O 435.1, DOE 1999b). This document is prepared early in the life of the project, before any waste retrieval to support closure has been performed. Therefore, the emphasis of this document is to present methods, procedures, existing data, and analysis approaches.

WMA C (shown in Figure ES-1) is located along the eastern edge of Hanford Site's 200 East Area. Within the WMA C, the primary structures through which tank waste was stored, transported and discharge are the 12 primary tanks (C-101 through C-112) and four secondary tanks (C-201 through C-204). The primary tanks are 23 m (75 ft) in diameter and 4.9 m (16 ft) deep with a capacity of 2,000,000 L (530,000 gal). Each secondary tank is 6.1 m (20 ft) in diameter and 7.8 m (25.5 ft) deep with a capacity of 230,000 L (55,000 gal). The 12 primary tanks were divided into four sets of three tanks each (for example, tanks C-101, C-102, and C-103 form one set) with cascade lines attaching each set so that waste would flow from southwest to northeast by gravity feed. WMA C also contains an assortment of ancillary equipment used to move tank waste during operations. These include seven diversion boxes, the 244-CR process vault, and waste transfer lines.

This preliminary performance assessment builds on the work of many previous Hanford Site risk assessments. In particular, the *Field Investigation Report for Waste Management Area S-SX*[3] , the *Field Investigation Report for Waste Management Area B-BX-BY*[4], risk assessments performed for the second revision of the *Single-Shell Tank System Closure Plan*[5], and the

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[1] *Tier 1 Closure Plan for Waste Management Area C at the Hanford Site, Washington*, DOE-ORP-2003-17, Office of River Protection, Richland, Washington, September 2003.

[2] DOE O 435.1, "Radioactive Waste Management," DOE Order 435.1, U.S. Department of Energy, Washington, D.C., July 9, 1999.

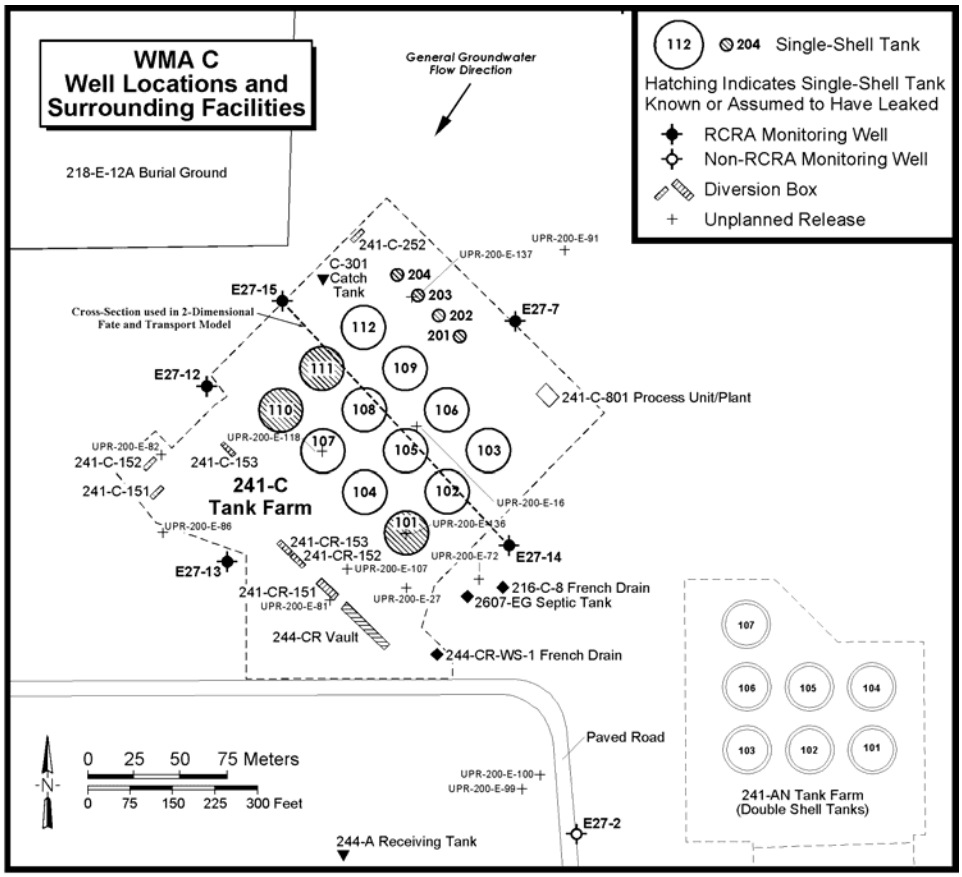
[3] A. J., Knepp, *Field Investigation Report for Waste Management Area S-SX*, RPP-7884, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, January 2002.

[4] A. J., Knepp, *Field Investigation Report for Waste Management Area B-BX-BY*, RPP-10098, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, December 2002.

[5] *Single-Shell Tank System Closure Plan*, RPP-13774, CH2M Hill Hanford Group, Inc. Richland, Washington, Rev. 1 was issued December 2002. Revision 2 is under review.

Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version[6] have been important sources for this document.

Figure ES-1. WMA C Tank Farm and Surrounding Facilities



Because of the long time frames involved in this analysis, estimates of impacts require computer simulations, rather than direct observations. The models used in the analyses are very flexible and should be adequate to describe the evolving features of the disposal system. However, because this analysis is performed early in the project life, many of the data are taken from related Hanford Site projects.

The major sources of information for the base analysis case are present in Table ES-1. Sensitivity cases were performed to determine the impact of uncertain data. Among the most important uncertain data were the following:

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[6] F.M. Mann, K.C. Burgard, W.R. Root, R.J. Puigh, S.H. Finfrock, R. Khaleel, D.H. Bacon, E.J. Freeman, B.P. McGrail, S.K. Wurstner, and P.E. LaMont, *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version*, DOE/ORP-2000-24, Revision 0, Office of River Protection, Department of Energy, Richland, Washington, August 2001.

- Amount of material leaked during past operations
- Amount of material remaining as residual waste in the tanks and ancillary equipment after retrieval
- Amount of material leaked from the tanks during retrieval
- Concentration of material in soils contaminated by past leaks, in residual waste left in the tanks and in ancillary equipment, and in leaked fluids during retrieval
- Release rates from residual materials
- Approach to filling the tank after waste retrieval
- Infiltration as a function of time.

Among the most important uncertainties in analysis approach are the following:

- Verification of non-overlapping plumes in Vadose zone
- Extrapolation from two- to three-dimensional analyses
- Groundwater flows in the future.

Table ES-1. Major Sources of Information for the Base Analysis Case. (2 pages)

Data Type	Major Source
Location	WMA C exists north of the PUREX Facility in the 200 East Area.
Analysis Approach	Four types of sources are modeled. These sources are 1) past releases presently in soils, 2) leaks during tank waste retrieval, 3) releases from residual waste in tanks, and 4) releases from residual waste in ancillary equipment. Releases are calculated separately from each source, assuming no overlap. Plumes from the various types of sources for each of the components in the tank farm are superimposed without any impact from other plumes. Verification runs have been made in the case of overlapping residual waste releases.
Waste Form	Waste will be in two forms: 1. dispersed in soil from past leaks and potential leaks during retrieval 2. residual waste stabilized by a yet-to-be determined process. The process will be determined based on future engineering studies.

Table ES-1. Major Sources of Information for the Base Analysis Case. (2 pages)

Data Type	Major Source
Volume of Material	Volume of past leaks is relatively well known. Retrieval is yet to occur; hence, the amount of residual waste and the potential volumes of retrieval leaks are to be determined. The volume of residual waste will be measured after retrieval is completed. The volume of potential leak volumes will be estimated based on monitoring data. The volume of residual waste used in this document is based on regulatory requirements. The volume of potential retrieval leaks is based on values normally assumed and each retrieval results in a leak. Volume of material in ancillary equipment is unknown, but can be estimated. Improved information will be obtained during remediation activities.
Inventory concentration	Concentrations of contaminants in past leaks are understood to varying degrees depending on knowledge of waste process history and previous characterization data. Further field characterization is planned for the major leak site. Concentration of contaminants in residual waste can be somewhat estimated based on waste process history. The concentration in residual waste will be measured after retrieval. Concentration of contaminants in potential leaks can be poorly estimated based on present estimates of inventories in each tank, the inventory of contaminants in the sluicing fluid used during retrieval, and knowledge of chemical reactions between the current inventory and the sluicing fluid. Concentration of contaminants in ancillary equipment is unknown, but can be estimated. Improved information will be obtained during remediation activities.
Long-term waste form performance	Past and potential retrieval leaks: entire amount is available for transport. Residual waste: Neither the release mechanism nor release parameters are known. Various release models with literature values are used in this analysis. Release rate parameters will be measured from residual waste samples taken after retrieval is complete.
Disposal facility design	Closure design has not yet been determined. For this analysis, no credit is taken for tank geometry, but a surface barrier with a design life of 500 years is used. Engineering studies are planned to optimize closure design.
Recharge	Estimates were derived from Hanford Site studies for both barrier and natural conditions.
Geotechnical	Taken from geotechnical measurements studies of locations in the Hanford Site 200 East Area. Geology is established from boreholes in C WMA.
Exposure	Taken from past Hanford Site documents and experience and DOE O 435.1 direction.

All of the estimated impacts meet the performance objectives[7] for the base case. Performance objectives were established for the following:

- Protecting the general public
- Protecting the inadvertent intruder

[7] F.M. Mann, A.J. Knepp, and J.W. Badden, *Performance Objectives for Tank Farm Closure Risk Assessments*, RPP-14283, Rev. 0, CH2M Hill Hanford Group, Inc. Richland, Washington, March 2003.

- Protecting groundwater
- Protecting surface water
- Protecting air resources
- Transuranic waste (TRU) requirements.

However, this conclusion rests upon decisions and implementations that have not been made.

The estimated all-pathways impacts are significantly lower than the performance objectives during the first 10,000 years as seen in Table ES-2. The DOE time of compliance is 1,000 years.

Table ES-2. Peak (during 10,000 Years) All-Pathway Exposure Scenarios for the Groundwater Pathway Impacts from WMA C at Key Locations

Impact	Performance Objective	WMA Fence Line (Fence Line Average)	Eastward Flow	
			Exclusion Boundary	Columbia River
All-Pathways - Farmer (mrem in a year)	25	0.172	0.027	0.010
ILCR[a] (Industrial) (Cr only)	10^{-5}	2.43×10^{-8}	3.41×10^{-9}	1.26×10^{-9}
Hazard Index (Industrial)	1	0.0075	0.0011	0.0004

[a]ILCR is the incremental lifetime cancer risk.

Table ES-3 compares the estimated impacts to the performance objectives for protecting the inadvertent intruder for Tank C-201, which is the tank providing the largest intruder impact. The time of compliance starts at 500 years after closure. The acute exposure performance objective is met by a factor greater than 100. The continuous exposure performance objective is met by a factor of approximately four for the base analysis case. The radionuclides ^{239}Pu, ^{240}Pu and ^{241}Am are the major contributors.

Table ES-3. Comparison of Estimated Impacts with Performance Objectives for Protecting the Inadvertent Intruder.

Performance Measure	Performance Objective	Estimated Impact at 500 years
Acute exposure [mrem]	500.0	1.46
Continuous exposure [mrem in a year]	100.0	0.39

Note: The time of compliance starts at 500 years. Results for Tank C-201 are given, the tank with highest impacts.

These results depend on the amount of contaminants left in the tanks. This amount depends on the volume of material left and the concentration of contaminants, which, of course, depends on the retrieval method used.

Table ES-4 compares the estimated impacts to the performance objectives for protecting the groundwater and surface water resources. At the DOE time of compliance (1,000 years) and the point of compliance (at the WMA fence line for groundwater protection or at the Columbia River for surface water protection), the impacts are not significant. At 10,000 years the estimated impacts are much lower than the performance objectives for beta-photon emitters, the alpha-emitting radionuclides, and the analyzed chemicals for the base analysis case. The concentration of radium is insignificant. The most important radionuclide drivers are the inventories of technetium and iodine, the infiltration rate, and the amount of mixing in the aquifer.

Table ES-4. Comparison of Estimated Peak Impacts with Performance Objectives for Protecting Groundwater and Surface Water Resources During First 10,000 Years.[a]

Impact	Performance Objective	WMA Fence Line (Fence-line Average)	Eastward Flow	
			Exclusion Boundary	Columbia River
Alpha-Emitters (pCi/L)	15	0[b]	0[b]	0[b]
Beta/gamma Emitters (mrem in a year)	4	0.172	0.027	0.010
Cr (μg /L)	50	0.16	0.00	0.00
NO_2 (μg /L)	1,000	5.22	0.08	0.02
NO_3 (μg /L)	10,000	11.32	0.17	0.06
U (μg /L)		2.95	0.04	0.01

[a]The point of compliance for groundwater is the eastern fence line of the C WMA, while for surface water, it is the Columbia River.

[b]The only alpha emitter explicitly calculated is uranium, which is not governed by standard. However, based on strong retardation of other alpha-emitters in Hanford soils (K_d > 1 ml/g), concentrations of regulated alpha emitters should not be present during the 10,000 years of analysis.

Table ES-5 compares the estimated impacts to the performance objectives for protecting air resources. The DOE time of compliance is 1,000 years, and the point of compliance is just above the disposal facility. The estimated impacts from radon are over four orders of magnitude lower than the performance objectives. The estimate for other radionuclides assumes that the entire inventory is released in a year. Even with this assumption, the performance objective is met.

Table ES-5. Comparison of Estimated Impacts with Performance Objectives for Protecting Air Resources.

Performance Measure	Performance Objective	Estimated Impact at 1,000 years
Radon [pCi m^{-2} $second^{-1}$]	20.0	<6x10-4
Other radionuclides (^{3}H and ^{14}C) [mrem in a year]	10.0	<2.8

Note: The DOE time of compliance is 1,000 years. The point of compliance is just above the disposal facility.

Table ES-6 presents the TRU cumulative release to groundwater during the first 10,000 years. The cumulative releases are below the performance objectives set by EPA. Iodine-129 is the radionuclide closest to the limit (a little over a factor of 10) for the base case inventory. Other radioisotopes have larger margins for the base case inventory. Because practically all of the mobile contaminants reach groundwater (92%), the results are insensitive to the release rate model.

Table ES-6. TRU-Weighted Cumulative Release (Ci) to Groundwater During the first 10,000 years for 1,000,000 Units of Source Material

Radionuclide	Performance Objective	Base Case	Radionuclide	Performance Objective	Base Case
^{90}Sr	1,000	2.79	^{235}U	100	0.00
^{99}Tc	10,000	65.76	^{236}U	100	0.00
^{126}Sn	1,000	35.01	^{237}Np	100	0.01
^{129}I	100	9.92	^{238}Pu	100	0.00
^{134}Cs	1,000	0.21	^{238}U	100	0.06
^{137}Cs	1,000	0.24	^{239}Pu	100	0.05
^{226}Ra	100	2.2E-05	^{240}Pu	100	0.01
^{232}Th	10	4.9E-03	^{241}Am	100	0.04
^{233}U	100	0.37	^{242}Pu	100	4.1E-07
^{234}U	100	0.07	^{243}Am	100	1.0E-06

However, the results are sensitive to the amount of waste left in the tanks. Thus, it is not possible to place a strict probabilistic uncertainty on the results. However, given the low results in Table ES-6 and that these results are based on quite conservative assumptions, if *Hanford Federal Facility Agreement and Consent Order* (HFFACO)[8], Ecology et al. 1989) commitments are met, it is very likely there is less than 1 chance in 10 that the performance objectives in Table 7-5 would not be met and there is less than 1 chance in 1,000 that values would exceed 10 times the performance objectives.

Performance assessments are iterative in nature and improve as data gaps are filled. Assessments are updated as data gaps are filled to reflect a greater understanding of the system. This process begins with using existing data and supplementing known data gaps with assumptions. For this assessment, although current site-specific data needed for this risk assessment are incomplete, enough relevant data from other sources were available that specific assumptions were made to satisfy the data gaps.

When made, these assumptions tended to be on the conservative side. Data gaps have been identified and are documented in the main body of the report

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

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ACRONYMS

amsl	above mean sea level
AMS	articulated mast system
ASTM	American Standards and Test Methods
BBI	Best Basis Inventory
bgs	below ground surface
BP	before present
BTC	break-through curve
CEC	cation exchange capacity
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CGS	Columbia Generating Station
COC	contaminant of concern
CRBG	Columbia River Basalt Group
CWP	cladding waste - PUREX
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DQO	data quality objectives
DST	double-shell tanks
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EDE	effective dose equivalent
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERDA	U.S. Energy Research and Development Administration
ERDF	Environmental Remediation Disposal Facility
FIR	field investigation report
FFTF	Fast Flux Test Facility
FLTF	Field Lysimeter Test Facility
HDW	Hanford Defined Waste
HFFACO	*Hanford Federal Facility Agreement and Consent Order*
HFSUWG	Hanford Future Site Uses Working Group
HMS	Hanford Meteorological Station
ILAW	immobilized low-activity waste
IP	intrusion prevention
IS	interim stabilized
ITS	in-tank solidification
ITV	in-tank vessel
K_d	distribution coefficient
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	low-level waste
MRS	mobile retrieval system
MUST	miscellaneous underground storage tank
NEPA	*National Environmental Policy Act*

NRC	Nuclear Regulatory Commission
ORP	Office of River Protection
OWW	organic wash waste
PA	performance assessment
PAS	PUREX acidified sludge
PAW	PUREX acid waste
PCB	polychlorinated biphenyl
PII	partially interim isolation
PNNL	Pacific Northwest National Laboratory
PSN	PUREX supernate waste
PTB	Prototype Hanford Surface Barrier
PUREX	plutonium-uranium extraction
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-Oxidation
RPP	River Protection Project
SCDR	subsurface conditions description report
SST	single-shell tank
TBP	tributyl phosphate
TRU	transuranic waste
TWINS	Tank Waste Information Network System
TWRS	Tank Waste Remediation System
UPR	unplanned release
UR	uranium recovery
VBR	vacuum-based retrieval
WAC	Washington Administrative Code
WIDS	Waste Information Data Base System
WMA	waste management area
WRF	waste receiving facility

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1.0 INTRODUCTION

1.1 PURPOSE

This preliminary performance assessment examines the long-term environmental and human health effects of the planned closure of the Waste Management Area C (WMA C), which is generally coincident with the 241-C tank farm area (C farm), to support the issuance of the *Tier 1 Closure Plan for Waste Management Area C, Hanford, Washington* (DOE-ORP-2003-17) and Waste Incidental to Repossessing petition as required by the Department of Energy's (DOE's) order on *Radioactive Waste Management* (DOE O 435.1). This document is prepared early in the life of the project, before any waste retrieval to support closure has been performed. Therefore the emphasis of this document is to present methods, procedures, existing data, and analysis approaches.

1.2 BACKGROUND

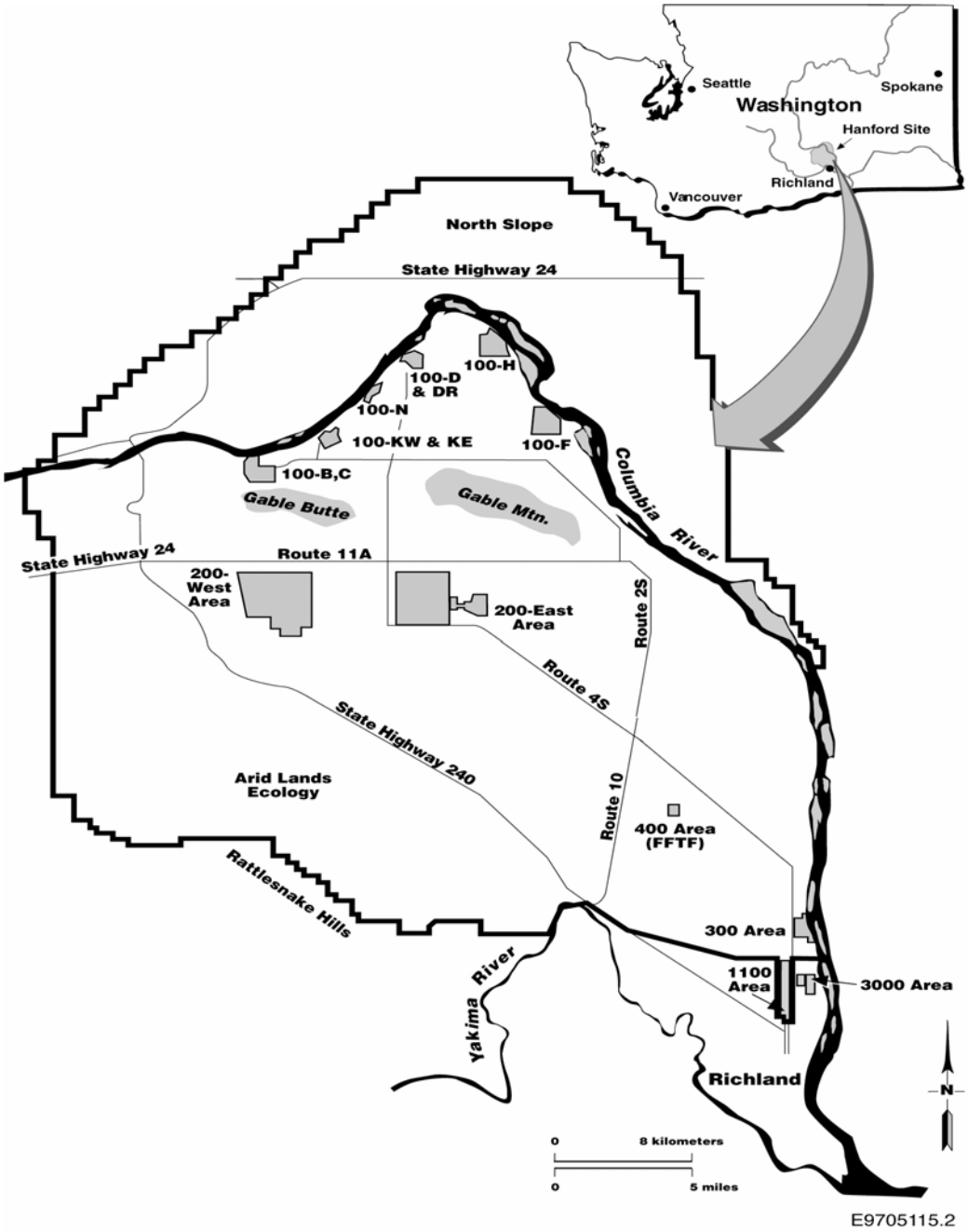
The Hanford Site, located in south-central Washington State (Figure 1-1), has been used extensively for the production of defense materials by DOE and its predecessors, the U.S. Atomic Energy Commission and the U.S. Energy Research and Development Administration. Starting in the 1940s, Hanford Site operations were dedicated primarily to producing nuclear weapons materials. In the 1960s, operations were expanded to producing electricity from a dual-purpose reactor, conducting diverse research projects, and managing waste. Termination in the late 1980s of the Site's original mission left a large inventory of radioactive and mixed waste (approximately 55 million gallons) stored in underground single- and double-shell tanks (SSTs, DSTs) in the Hanford Site 200 Areas.

Today, the Hanford Site's missions are environmental restoration, energy-related research, and technology development. As part of its environmental restoration mission, DOE is proceeding with plans to permanently dispose of the waste stored on site. These plans are based on Revision 6 of the *Hanford Federal Facility Agreement and Consent Order* (HFFACO, Ecology et al. 1989) and the *Record of Decision for the Tank Waste Remediation Systems Environmental Impact Statement* (DOE 1997). These documents call for the waste to be retrieved from the tanks, and treated to separate the low-level fraction (now called the low-activity fraction) from the high-level/transuranic fraction. Both fractions will then be immobilized and the two products will be disposed.

There are 177 large, underground storage tanks. These are grouped into 18 tank farms (SSTs: A, AX, B, BX, BY, C, S, SX, T, TX, TY, and U; DSTs: AN, AP, AW, AY, AZ, and SY). The SST farms are further grouped in seven WMAs (A-AX, B-BX-BY, C, S-SX, T, TX-TY, and U) for the purpose of groundwater monitoring.

After the tank wastes are retrieved, the tanks will be component closed. Once all tanks in a tank farm/WMA are component closed, the tank farm/WMA will be closed.

Figure 1-1. The Hanford Site Map and Location in Washington State.

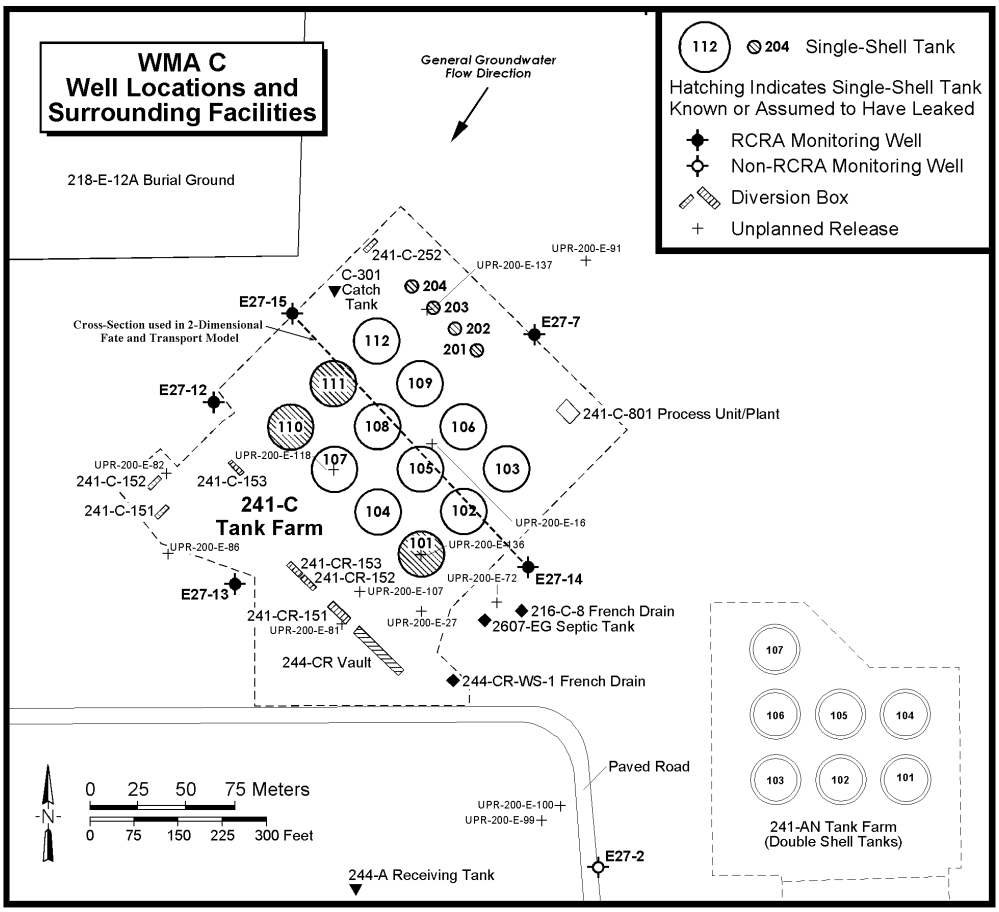


1.3 GENERAL DESCRIPTION OF THE FACILITY

This section provides a general description of WMA C. Section 2.1 describes the geology, hydrology, and geochemistry of the Hanford Site and the 200 East Area where the closed facility will reside. Section 2.3 provides much more information including figures showing the conceptual and pre-conceptual designs.

WMA C (see Figure 1-2) is located along the eastern edge of the 200 East Area. Within WMA C, the primary structures through which tank waste was stored, transported, and discharge are the 12 primary tanks (C-101 through C-112) and four secondary tanks (C-201 through C-204). The primary tanks are 23 m (75 ft) in diameter and 4.9 m (16 ft) deep with a capacity of 2,000,000 L (530,000 gal). Each secondary tank is 6.1 m (20 ft) in diameter and 7.8 m (25.5 ft) deep with a capacity of 208,000 L (55,000 gal). The 12 primary tanks were divided into four sets of three tanks each (for example, tanks C-101, C-102, and C-103 form one set) with cascade lines attaching each set so that waste would flow from southwest to northeast by gravity feed. The C farm also contains an assortment of ancillary equipment used to move tank waste during operations. These include seven diversion boxes, the 244-CR process vault, and waste transfer lines.

Figure 1-2. WMA C Tank Farm and Surrounding Facilities.



1.4 TANK CLOSURE PROGRAM

The Office of River Protection (ORP) is the DOE organization at the Hanford Site responsible for the safe underground storage of the liquid waste from previous Hanford Site operations presently stored in the Hanford Site tank farms, the retrieval of this waste, the treatment of this waste into immobilized waste forms, the storage and disposal of the immobilized tank waste, and the closure of the underground tanks. The contractors working for the ORP form the River Protection Project (RPP). As part of the RPP, the Tank Closure Project is responsible for the following:

- Performing *Resource Conservation and Recovery Act of 1976* (RCRA) Corrective Actions (which includes characterization of soils contaminated by past leaks)
- Preparing risk assessments and other regulatory documents to close the underground tanks
- Performing characterization of waste remaining after retrieval
- Performing interim and component closure of the tanks
- Performing final closure of the tank farms/WMAs.

Table 1-1 presents the schedule for closure of the C Farm tanks (RPP-13678).

Table 1-1. Schedule for WMA C Closure[a]

Description	Date
Retrieve waste from Tank C-106	November 2003[b]
Close Tank C-106	February 2004[b]
Close Tank C-201	September 2004
Close Tank C-202	October 2004
Close Tank C-203	March 2005
Close Tank C-204	June 2005
Close all tanks in WMA C	2018

[a] RPP-13678

[b] Present plans

1.5 RELATED DOCUMENTS

This section discusses the most important environmental assessments completed for the Hanford Site, as well as the documents used to provide guidance for preparing this document.

See Section 1.6 for documents supporting the setting of performance objectives.

See Sections 3.2 and 3.4 for documents justifying data used in this document.

1.5.1 Other Relevant Hanford Site Environmental Assessments

The WMA C Preliminary Performance Assessment builds on the many environmental assessments that have been performed at the Hanford Site. They can be classified as documents pertaining to the Hanford Site tank tarms, as documents fulfilling the requirements DOE O 435.1, or as more general documents.

1.5.1.1 Previous Work Related to Hanford Site Tank Farms. A number of reports have been published on risk assessments for the Hanford Site tank farms. They can be grouped into two classes: environmental impact statements (EIS) and documents supporting RCRA Corrective Actions.

The *Environmental Impact Statement for the Tank Waste Remediation System* (TWRS EIS) (DOE/EIS-0189) analyzed various options to manage the Hanford Site's tank waste with the Record of Decision, which was issued shortly thereafter (DOE 1997). Because of the scope of the TWRS EIS, the analyses relied on data less complete and less project-specific than the data on which this preliminary performance assessment is based. The TWRS EIS was preceded by the Hanford Defense Waste EIS, *Final Environmental Impact Statement: Disposal of Hanford Defense High-Level Transuranic and Tank Wastes* (DOE/EIS-0113).

Currently, DOE is preparing the *Environmental Impact Statement on Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, Washington.* Issuance of the draft EIS is planned for September 2003. To support this effort, a number of data packages with direct relevance to this document have been published:

- *Assessment Guidance Data Package* (DOE/ORP-2003-09)
- *Waste Retrieval and Storage Data Package* (DOE/ORP-2003-06)
- *Tank System Closure and Facility D&D Data Package* (DOE/ORP-2003-05)
- *Inventory and Source Term Data Package* (DOE/ORP-2003-02)

Washington State Department of Ecology (Ecology) has placed DOE under RCRA Corrective Action, because during tank farm operations, wastes from the tanks had leaked and impacted groundwater. As part of this activity, DOE is to gather all data that would be useful in estimating past leaks and their potential impacts; characterize the soils around the leaking tanks; perform experiments aiding the understanding of the transport of contaminants from the tanks to groundwater; and estimate future impacts. Among the many documents created for this activity, two sets are important for this document:

- Subsurface Conditions Description Reports (SCDRs)
- Field Investigation Reports (FIRs).

The SCDRs compile the data that would be useful in estimating past leaks and their potential impacts, to characterize the soils around the leaking tanks. SCDRs have been issued for all of the SST farms. The SCDR most relevant to this document is the *Subsurface Conditions Description of the C and A-AX Waste Management Areas* (Jones and Wood, 2003).

The FIRs document the characterization of the soils around the leaking tanks, the experiments that aided the understanding of the transport of contaminants from the tanks to groundwater, and the estimation of future impacts. The FIR for the WMA C is not expected to be published until 2007. However, the methods used in this preliminary performance assessment to estimate potential future impacts are heavily based on the *Field Investigation Report for Waste Management Area S-SX* (Knepp 2002a) and *Field Investigation Report for Waste Management Area B-BX-BY* (Kneep 2002b).

To support RCRA requirements for tank closure, a *Single-Shell Tank System Closure Plan* (RPP-13744, Rev. 1) was developed. Revision 1 of this document contains a risk assessment for the WMA C that forms the technical basis of this document.

1.5.1.2 Other Hanford Site Project-Specific Performance Assessments. This performance assessment also builds on previous performance assessments prepared for the Hanford Site, in particular the *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version* (ILAW PA; Mann 2001). The ILAW PA was prepared under DOE O 435.1. The other performance assessments were prepared under the requirements of the DOE Order 5820.2A, *Radioactive Waste Management*. The Hanford Site presently has a Disposal Authorization Statement (DOE 2001) covering disposal of wastes at the Solid Waste Burial Grounds, the Environmental Remediation Disposal Facility, and at the ILAW Disposal Site.

The 2001 ILAW PA deals with the disposal of packaged vitrified waste produced by the Hanford Waste Treatment and Immobilization Plant at a location 1.6 km (1 mi) southwest of WMA C. Because the ILAW PA was produced under DOE O 435.1 and was favorably reviewed by the Low-Level Waste Disposal Facility Federal Review Group (LFRG), the format and contents of this preliminary performance assessment are heavily based on the ILAW PA. The ILAW PA was approved by DOE (DOE 2001) and forms the current basis of the Hanford Site's Disposal Authorization Statement. A maintenance plan (DOE/ORP-2000-01), a monitoring plan (Horton 2000), and a closure plan (Burbank 2000) have been written and approved by DOE (French 2000, Boston 2000a, and Boston 2000b). The latest annual summary was issued in 2002 (Mann 2002).

The following performance assessments were developed under DOE Order 5820.2A, a predecessor to DOE Order 435.1.

1. The *Long-Term Performance Assessment of Grouted Phosphate/Sulfate Waste from N-Reactor Operations* (Stewart 1987) forms the basis of the environmental assessment (DOE/EA-0312 1986) for the disposal of low-level radioactive waste generated by decontamination operations and other activities associated with N Reactor operations. The grouted phosphate-sulfate performance assessment predates the DOE approval process for performance assessments. The DOE review was conducted by reviewing the environmental assessment.

2. The *Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford* (Kincaid 1995) dealt with the disposal of low-level liquid waste from the DSTs. The waste was to be combined with cement, fly ash, and clay to form a grout that would cure and solidify in large subsurface vaults located to the east of the 200 East Area. The Peer Review Panel approved (Wilhite 1994) the grout performance assessment in principle. DOE (Lytle 1995) found that the analysis performed in grout performance assessment was "technically adequate and provides reasonable assurance that the selected performance objectives would be met." However, noting that the grout project had been canceled, DOE also stated that a new or revised performance assessment would be needed for routine disposal of waste in the Grout Disposal Facility.

3. The *Environmental Remediation Disposal Facility Performance Assessment* (BHI-00169) was written to support disposal of waste generated by the cleanup of the Hanford Site. Most of this waste is expected to be contaminated soil. Trenches are planned to be the main means of disposal at the facility. Because the Environmental Remediation Disposal Facility (ERDF) is regulated under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), this performance assessment was not submitted to the Peer Review Panel. However, *A Remedial Investigation and Feasibility Study Report for the Environmental Restoration Facility* (DOE/RL 1994a) was prepared. A cross walk between this report and the requirements of DOE O 435.1 has been approved (DOE 2001).

4. The *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds* (Wood 1995a) dealt with the disposal of solid waste from operations at the Hanford Site and other DOE sites. This waste is placed into trenches in the western part of the 200 West Area then covered with a barrier. The Peer Review Panel found the performance assessment to be technically acceptable. The 200 West Area performance assessment has been "conditionally accepted" by DOE-Headquarters (Cowan 1996). The "conditions" referred to added documentation

5. The *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Waste Burial Grounds* (Wood 1996) addresses waste that is similar to that addressed in the 200 West Area performance assessment. However, the disposal trenches for this waste are in the northern part of the 200 East Area. The final performance assessment for this action also has been conditionally approved by DOE-Headquarters (Frei 1997).

A maintenance plan for the last two performance assessments listed has been written. Annual summaries also have been submitted to the LFRG, the latest in 2002 (Wood 2002). In addition, to satisfy the conditional requirements specified in the disposal authorization statement, a review of solid waste characterization practices has been completed and accepted by the LFRG. The review was conducted to determine whether these practices were adequate to support the evaluation of disposal facility performance relative to compliance with performance objectives. Waste characterization practices were found to be adequate and a report was issued to DOE Headquarters in June 2000.

1.5.1.3 More General Hanford Site Environmental Assessments. A series of general environmental assessments also have been prepared for Hanford Site activities. These

assessments look at the Hanford Site as a whole or address environmental impacts in a more general manner.

The *Composite Analysis for Low-Level Waste Disposal in the 200-Area Plateau of the Hanford Site* (PNNL-11800) was prepared in response to Recommendation 94-2 of the Defense Nuclear Facilities Safety Board (DNFSB) to the Secretary of Energy (DNFSB 1994). The recommendation noted the need for a risk assessment that investigates the environmental impacts of all radioactive waste disposal actions or leaks at a DOE site. The authors of the composite analysis are working with the authors of the previous performance assessments to maximize consistency in data and methods. The LFRG conditionally approved the Composite Analysis in "Disposal Authorization Statement for the Hanford Site Low-Level Waste Disposal Facilities" (DOE 1999a) with comments more fully documented in *Low-Level Waste Disposal Facility Federal Review Group Manual* (DOE 1999b).

The *Draft Hanford Remedial Action Environmental Impact Statement and Comprehensive Land Use Plan* (DOE, 1996c) analyzed the potential impacts associated with establishing future land-use objectives for the Hanford Site. These impacts will come primarily from remediation activities. The document also proposes a land-use plan for near-future activities. TWRS activities were not extensively considered. Based on comments, the draft EIS was rewritten and issued as a land use plan EIS (DOE 1999h) with an associated record of decision (DOE 1999e).

The *Revised Draft Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington* (DOE 2003) has recently been issued. This EIS deals with the disposal of non-CERCLA low-level waste (LLW) at the Hanford Site. Such waste includes low-level waste generated at the Hanford Site, melters from the Waste Treatment and Immobilization Plant, ILAW, and LLW imported from other DOE sites. The record of decision is planned for October 2003 issuance.

1.5.2 Regulatory Agreements and Documents

The HFFACO (Ecology et al. 1989) is an agreement between DOE, the U.S. Environmental Protection Agency (EPA), and Ecology concerning the cleanup of the Hanford Site. HFFACO contains legally enforceable milestones, many of which (the M45 series) cover SST closure:

M45-06A	Submit a Certified (Framework) SST System Closure Plan and C-106 Waste Retrieval and Closure Demonstration Plan, as an Application for the Modification of the Hanford Site-Wide Hazardous Waste Facility Permit to Ecology. 12/19/02 (plan was submitted, but not yet approved)	
M45-05M-T01	Submit C-106 Waste Retrieval Results, Analysis of Residual Waste(s), and (if appropriate) Request for Exception to the Criteria Pursuant to Agreement Appendix H.	2/27/04
M45-05H	Interim Completion of C-106 SST Waste Retrieval and Closure Demonstration Project.	4/30/04

M45-06D	Submit A Certified (Framework) SST System Closure Plan Modification and C-104 Waste Retrieval and Closure Demonstration Plan, as an Application for the Modification of the Hanford Site-Wide Hazardous Waste Facility Permit to Ecology.	6/30/07
M45-14	Interim Completion of C-104 SST Waste Retrieval and Closure Demonstration Project.	6/30/08
M45-00	Complete Closure of All Single-Shell Tank Farms.	9/30/24

DOE has written the *Hanford Site Ground Water Protection Management Plan* (DOE/RL 1995c) with Ecology's approval. However, the current version of the management plan does not address long-term protection of the groundwater resource.

1.5.3 Guidance Documents

The main document guiding the development of this performance assessment is *Format and Content Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments and Composite Analyses* (DOE 1999d). The 2001 ILAW PA (Mann 2001) was also used as an example of a document fulfilling the requirements of this guidance.

The following additional documents also were used as guidance in preparing this performance assessment:

- Critical Assumptions for Department of Energy Low-Level Waste Disposal Facility Assessments (Alm 1997)
- Issuance of Low-Level Waste Performance Assessment Guidance (Frei 1996)
- Performance Assessment Review Guide for Low-Level Radioactive Waste Disposal Facility (Dodge 1991)
- Proceedings of the Department of Energy Performance Assessment Briefing, Denver, Colorado, October 29, 1991 DOE/LLW-138 (NLLWMP 1992)
- Performance Assessment Task Team Progress Report (Wood 1994)
- A Compilation of DOE Performance Assessment Peer Review Panel Review Comments and Recommendations DOE/LLW-216 (RWTSP 1994).
- "DOE Headquarters Review of the Performance Assessment of Grouted Double-Shell Tank Waste at Hanford" (Lytle 1995)
- Implementation Plan, Defense Nuclear Facilities Safety Board Recommendation 94-2, Compliance with Safety Standards at Department of Energy Low-Level Nuclear Waste Sites (DOE 1996a)

Performance assessments from other DOE sites and the comments on those studies also have been reviewed to understand different approaches and methods.

1.6 PERFORMANCE OBJECTIVES

The performance objectives for WMA C closure are the same as included in the 2005 ILAW PA (Mann 2003a), with the added requirements under 40 CFR 191. Time of compliance is 1,000 years for groundwater pathways, although values at 10,000 years are presented. This analysis also includes chemicals. The most restrictive performance objectives are as follows:

1. Groundwater ($\beta\gamma$): 4 mrem in a year for 10,000 years

2. Intruder (continuous): 100 mrem in a year after 500 years.

1.6.1 Summary

The DOE's requirements for waste disposal (DOE 1999) can be summarized as follows:

- Protect public health and safety

- Protect the environment.

The requirements for this performance assessment are based on the performance objectives of the 2005 ILAW PA (Mann 2003a), with a few exceptions. The exceptions are that comparisons are performed at the tank farm fence line rather than at 100 m (328 ft) and the addition of the requirements from 40 CFR 191 for those tanks which may be closed with TRU in them.

For this preliminary performance assessment, the following methods were used to establish the quantitative performance objectives as explained in *Performance Objectives for Tank Closure Risk Assessments* (Mann 2003a):

- Investigate all potentially applicable regulations, as well as interpretations made by the Peer Review Panel and the LFRG (Section 1.6.2)

- Work with Tank Closure Project management to establish their needs (Section 1.6.3)

- Work with the Hanford Site stakeholders to understand the valuesof residents in the Pacific Northwest (Section 1.6.4).

- Add requirements for those tanks containing TRU from 40 CFR 191.

The manual (DOE M 435.1) for DOE O 435.1 describes the performance objectives for a performance assessment as follows:

(1)(a) “25 mrem in a year total effective dose equivalent from all exposure pathways”

(1)(b) “10 mrem in a year total effective dose equivalent “ via the air pathway

(1)(c) "Release of radon shall not exceed 10 mrem in a year total effective dose equivalent"

(2)(g) "Include an assessment of impacts to water resources"

(2)(h) "The intruder analysis shall use performance measures for chronic and acute exposures, respectively, of 100 mrem in a year and 500 mrem in a year total effective dose equivalent."

(2)(b) "The point of compliance shall correspond to the point of highest projected dose or concentration beyond a 100 meter buffer zone surrounding the disposal waste."

(2) "Include calculations for a 1,000 year period after closure"

The proposed closure action will also require consultation with the U.S. Nuclear Regulatory Commission (NRC) on the waste classification of the residual waste and a RCRA Part B permit. Therefore, additional constraints were considered in the establishment of the performance objectives used here.

According to DOE O 435.1, Chapter II, tank waste would be considered "incidental waste" and will be managed as LLW if the following three conditions are met:

1. Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical; and

2. Will be managed to meet safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C, Performance Objectives; and

3. Are to be managed, pursuant to DOE's authority under the *Atomic Energy Act of 1954*, as amended, and in accordance with the provisions of Chapter IV of this Manual, provided the waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration limits for Class C low-level waste as set out in 10 CFR 61.55, "Waste Classification"; or will meet alternative requirements for waste classification and characterization as DOE may authorize.

Or for waste to be managed as TRU, if the following three conditions are met:

1. Have been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical; and

2. Will be incorporated in a solid physical form and meet alternative requirements for waste classification and characteristics, as DOE may authorize; and

3. Are managed pursuant to DOE's authority under the *Atomic Energy Act of 1954*, as amended, in accordance with the provisions of Chapter III of this Manual, as appropriate.

NRC guidance for 10 CFR 61, Subpart C requires a time of compliance of 10,000 years. DOE O 435.1 Chapter 3 requires that the requirements of 40 CFR 191 be followed. 40 CFR 191 also requires a time of compliance of 10,000 years. Thus, independent of whether the waste is

managed as TRU or LLW, this assessment will use 10,000 years as the time of compliance, rather than the 1,000 years used in Chapter 4 of the DOE O 435.1.

Because tank closure will also be regulated under RCRA, the impacts from hazardous waste must also be considered. The inorganic chemicals selected are based on a data quality objectives (DQO) process. Because of the preliminary nature of this assessment, organic chemicals were not considered, even though tank waste are known to contain organic chemicals (Wiemers 1998).

A change from previous Hanford Site performance assessments is the point of compliance, which has be taken to be the point of maximal exposure, but no closer than 100 meters from the facility. RCRA requires that the point of compliance be the facility fence line. For the WMA C (as is true for most tank farms at Hanford), the fence line is 30 to 100 m (98 to 328 ft) down gradient from each tank. To reduce computation and acknowledging that the WMA C is more than 100 m (328 ft) wide, the difference in compliance points changes risk estimates minimally. Therefore, the more conservative point of compliance (the WMA C fence line) is chosen for the performance objective.

When closed, some tanks may contain TRU. Therefore the requirements of "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (40 CFR 191) must be met. The main differences are as follows:

- The all-pathways annual dose is limited to 15 mrem.
- The groundwater drinking requirements of 40 CFR 141 as of January 19, 1994, must be met.
- There are no separate requirements for protecting surface waters.
- There are no separate requirements for protecting inadvertent intruders
- There is a requirement for relative cumulative releases to the accessible environment.

The requirements have been merged into a unified set of performance objectives. Table 1-2 presents the performance objectives for radionuclides for LLW, while Table 1-3 presents the performance objectives for radionuclides for TRU. Table 1-4 presents the performance objectives for chemicals identified as most important.

Table 1-2. Radiological Performance Objectives for Low-Level Waste.

Protection of General Public and Workers [a, b]	
All-pathways dose from only this facility	25 mrem in a year [d, h]
All-pathways dose including other Hanford Site sources	100 mrem in a year [e, i]
Protection of an Inadvertent Intruder [c, f]	
Acute exposure	500 mrem
Continuous exposure	100 mrem in a year
Protection of Groundwater Resources [b, d, j]	
Alpha emitters	

Table 1-2. Radiological Performance Objectives for Low-Level Waste.

^{226}Ra plus ^{228}Ra	5 pCi/L
All others (total)	15 pCi/L
Beta and photon emitters	4 mrem in a year
Protection of Surface Water Resources [b, g]	
Alpha emitters	
^{226}Ra plus ^{228}Ra	0.3 pCi/L
All others (total)	15 pCi/L
Beta and photon emitters	1 mrem in a year [k]
Protection of Air Resource [b, f, l]	
Radon (flux through surface)	20 pCi m^{-2} s^{-1}
All other radionuclides	10 mrem in a year

[a] All doses are calculated as effective dose equivalents; all concentrations are in water taken from a well. Values given are in addition to any existing amounts or background.

[b] Evaluated for 1,000 and 10,000 years, but calculated to the time of peak or 10,000 years, whichever is longer.

[c] Evaluated for 500 years, but calculated to 1,000 years.

[d] Evaluated at the point of maximum exposure, but no closer than the fence line of the facility.

[e] Evaluated at the 200 East Area fence (assumed future boundary of the DOE site).

[f] Evaluated at the facility.

[g] Evaluated at the Columbia River, no mixing with the river is assumed.

[h] Main driver is DOE Order on *Radioactive Waste Management* (DOE 0 435)

[i] Main driver is DOE Order 5400.5, *Radiation Protection of the Public and the Environment*.

[j] Main driver is National Primary Drinking Water Regulations (40 CFR 141).

[k] Main driver is Washington State Surface Water Standards (WAC 173-201A)

[l] Main driver is National Emission Standards for Hazardous Air Pollutants (40 CFR 61H and 40 CFR 61Q).

Table 1-3. Radiological Performance Objectives for Transuranic Waste.

Protection of General Public and Workers [a, b]	
All-pathways dose from only this facility	15 mrem in a year [c,d,]
All-pathways dose including other Hanford Site sources	100 mrem in a year [e, f]
Cumulative Relative Release	
Less than 1 chance in 10 over 10,000 years that cumulative release to groundwater will exceed the following and less than 1 chance in 1,000 over 10,000 years that cumulative release to groundwater will exceeding ten times the following:	
^{230}Th, ^{232}Th	10 Ci/1,000,000 TRU
^{241}Am, ^{243}Am, ^{14}C, ^{129}I, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{226}Ra, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U	100 Ci/1,000,000 TRU
^{134}Cs, ^{137}Cs, ^{90}Sr, ^{126}Sn	1,000 Ci/1,000,000 TRU
^{99}Tc	10,000 Ci/1,000,000 TRU
Protection of Groundwater Resources [b, d,g]	
Alpha emitters	
^{226}Ra plus ^{228}Ra	5 pCi/L
All others (total)	15 pCi/L
Beta and photon emitters	4 mrem in a year

[a] All doses are calculated as effective dose equivalents; all concentrations are in water taken from a well. Values given are in addition to any existing amounts or background.

[b] Evaluated for 10,000 years.

[c] Main driver is "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (40 CFR 191)

[d] Evaluated at the point of maximum exposure, but no closer than fence line of the facility.

[e] Evaluated at the 200 East Area fence (assumed future boundary of the DOE site).

[f] Main driver is DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE 1993).

[g] Main driver is National Primary Drinking Water Regulations (40 CFR 141).

Table 1-4. Performance Goals for Inorganic and Organic Materials[a]. (2 pages)

Inorganics		
Chemical	**Groundwater**	**Surface Waters**
Ammonia (NH_3)	[b]	4.0 mg/L
Antimony (Sb)	0.006 mg/L	0.006 mg/L
Arsenic (As)	0.00005 mg/L	0.05 mg/L
Barium (Ba)	1.0 mg/L	2.0 mg/L
Beryllium (Be)	0.004 mg/L	0.004 mg/L
Cadmium (Cd)	0.005 mg/L	0.00077 mg/L
Chlorine (Cl)	250 mg/L	230 mg/L
Chromium (Cr)	0.05 mg/L	0.011 mg/L

Table 1-4. Performance Goals for Inorganic and Organic Materials[a]. (2 pages)

Copper (Cu)		1.0 mg/L	0.0078 mg/L
Cyanide (CN)		0.2 mg/L	0.0052 mg/L
Fluoride (F-)		4.0 mg/L	4.0 mg/L
Iron (Fe)		0.3 mg/L	[b]
Lead (Pb)		0.05 mg/L	0.0015 mg/L
Manganese (Mn)		0.05 mg/L	[b]
Mercury (Hg)		0.002 mg/L	0.000012 mg/L
Nickel (Ni)		[b]	0.115 mg/L
Nitrate as N (NO_3)		10 mg/L	10 mg/L
Nitrite as N (NO_2)		1.0 mg/L	1.0 mg/L
Nitrite plus Nitrate		10 mg/L	10 mg/L
Selenium (Se)		0.01 mg/L	0.005 mg/L
Silver (Ag)		0.05 mg/L	[b]
Sulfate (SO_4)		250 mg/L	[b]
Thallium (Tl)		0.002 mg/L	[b]
Zinc (Zn)		5.0 mg/L	0.072 mg/L
Organics			
CAS #	**Constituent (a)**	**Groundwater**	**Surface Waters**
56-23-5	Carbon tetrachloride	0.0003 mg/L	0.005 mg/L
67-66-3	Chloroform	0.007 mg/L	[b]
71-43-2	Benzene	0.001 mg/L	0.005 mg/L
71-55-6	1,1,1-Trichloroethane	0.003 mg/L	0.2 mg/L
75-09-2	Dichloromethane (Methylene Chloride)	0.005 mg/L	0.005 mg/L
79-00-5	1,1,2-Trichloroethane	0.005 mg/L	0.005 mg/L
79-01-6	1,1,2-Trichloroethylene	0.005 mg/L	0.005 mg/L
95-47-6	o-Xylene	0.7 mg/L	0.7 mg/L
Organics			
CAS #	**Constituent**	**Groundwater**	**Surface Waters**
100-41-4	Ethyl benzene	0.1 mg/L	0.1 mg/L
106-46-7	1,4-Dichlorobenzene	0.004 mg/L	0.075 mg/L
108-88-3	Toluene	1.0 mg/L	1.0 mg/L
127-18-4	1,1,2,2-Tetrachloroethene	0.005 mg/L	0.005 mg/L

[a]RPP-14283

[b]No limit was found.

1.6.2 Regulations and Other Performance Assessments

1.6.2.1 Introduction. Several federal and Washington State regulations potentially apply to how well the public health and safety and the environment must be protected. The following categories of requirements were reviewed for relevance to this proposed closure action:

- Protection of the general public
- Protection for workers
- Protection of the inadvertent intruder
- Protection of groundwater resources
- Protection of surface water resources
- Protection of air resources.

Appendix B of Mann (2003a) lists the regulations that were reviewed and judged to be potentially relevant to this proposed closure action. Some regulations and general environmental acts were judged not relevant to the performance assessment activity for one or more of the following reasons:

- Requirements are the responsibility of other participants in the Immobilized Waste Program (for example, ensuring compliance with the *National Environmental Policy Act* [NEPA]).
- Requirements are for different environmental actions (for example, the CERCLA).
- Requirements deal with general environmental concerns such as the protection of endangered species that are thought to be adequately covered for the long-term by the regulations presented here.
- Requirements are only at a preliminary stage and are likely to change, such as the "Radiation Site Cleanup Regulation" (proposed Title 40 CFR 196) and "Environmental Radiation Standards for Management and Disposal of Low-Level Waste" (proposed 40 CFR 193) from the EPA. The development of these requirements will be closely followed and the requirements will be incorporated as appropriate.

Performance assessments of LLW disposal in the DOE complex also were reviewed to identify any regulations relevant to this proposed closure action. These assessments provide "case law" interpretations.

1.6.2.2 Protection of the General Public. For this assessment, the performance objective for the protection of the general public is 25 mrem effective dose equivalent (EDE) in a year for LLW and 15 mrem (EDE) in a year for TRU. The LLW value is used consistently in LLW regulations (DOE O 435.1 and 10 CFR 61) and was used in previous performance assessments.

Although other methods are available for determining body dose, the EDE method was selected because regulations normally use this method. For TRU, the level of 15 mrem comes directly from "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (40 CFR 191).

The location for (or point of) compliance is at the point of maximal exposure, but not closer than the facility fence line. This is based on RCRA requirements. This is a change from previous Hanford Site performance assessments for the point of compliance, which used the point of maximal exposure, but no closer than 100 m (328 ft) from the facility. For the WMA C (as is true for most tank farms at Hanford), the fence line is 30 to 100 m (98 to 328 ft) down gradient from each tank. To reduce computation and acknowledging that the WMA C is over 100 m (328 ft) wide (and hence the impacts do not vary for points close to the facility), the difference in compliance points makes little difference in calculating impacts. Therefore, the more conservative point of compliance is chosen for the performance objective.

The Defense Nuclear Facilities Safety Board (DNFSB 1994) noted that a member of the public could receive exposures from several sources at a DOE site. Guidance from DOE Headquarters (DOE 1996) is that protection of the general public from multiple sources should be based on *Radiation Protection of the Public and the Environment*, DOE Order 5400.5. This order sets a limit of 100 mrem in a year from all sources. The interpretation of DOE Order 5400.5 places the point of compliance at the fence line of the future site. For the Hanford Site, this is considered to be a fence surrounding the present Hanford Site 200 Areas. The *Composite Analysis for Low-Level Waste Disposal in the 200-Area Plateau of the Hanford Site* (Kincaid, 1998) shows compliance with this requirement.

The compliance time for this performance assessment is 10,000 years. (The compliance time is the time starting 100 years from the present over which the predicted dose must remain below the performance objectives.) Although DOE guidance is that the time of compliance should only be 1,000 years, a longer time of compliance is driven by NRC and EPA requirements. This performance assessment supports the "waste incidental to processing" petition (which requires the use of methods comparable to those used in implementing 10 CFR 61.55 for LLW) and supports the closure of tanks that may have TRU (which requires that the standards of 40 CFR 191 be met). Thus, independent of how the waste is reclassified, a time of compliance of 10,000 years is mandated.

1.6.2.3 Protection for Workers. For this performance assessment, as for others performed under the DOE orders on radioactive waste management, no distinction is made between performance objectives for workers and for the general public. Because the protection requirements for the general public are more restrictive than those for the workers, the workers will be adequately protected. Protection for workers during construction and operations will be addressed in the safety analysis report that will be written for the Tank Closure Program.

1.6.2.4 Protection of the Inadvertent Intruder. The exposure limits for protecting a hypothetical inadvertent intruder are consistent with the regulations (DOE O 435.1 and 10 CFR 61) and with earlier performance assessments (Appendix Tables B-2 and C-2, respectively, in Mann 2003a provides details). These limits are 500 mrem (EDE) for a one-time (acute) exposure and 100 mrem (EDE) in a year for a continuous exposure. These limits are used in this performance assessment.

The compliance time for protecting an inadvertent intruder is defined differently from the compliance time for protecting the general public or the environment. The inadvertent intrusion compliance time differs slightly between regulations. Current DOE guidance (Alm 1997) is that active institutional control shall occur for at least 100 years, but notes that longer times can be used if justified. DOE intends to control the Hanford Site 200 Areas as long as necessary to protect the public. The Hanford Site grout performance assessment (Kincaid 1995) used the 500-year compliance time based on the assumption that passive barriers and markers would be present. The performance assessments for the disposal of solid radioactive waste on the Hanford Site (Wood 1995a and Wood 1996) also use a compliance time of 500 years. Similarly the performance assessment for the disposal of ILAW (Mann 2001) showed compliance for all times greater than 200 years. This is consistent with the NRC requirement for Class C waste that inadvertent intruders be protected for 500 years (10 CFR 61-1).

Following the precedent of the other Hanford Site performance assessments, the 500-year compliance time was used in this assessment because passive barriers and markers are planned for this proposed closure action. Therefore, protection of an inadvertent intruder shall be considered met if the exposure limits are met at 500 years after closure. Calculations were run and results shown from 100 years to 1,000 years after the time of disposal to obtain the doses as a function of time.

1.6.2.5 Protection of Groundwater Resources. The protection level for groundwater is the most complicated requirement to determine. The level of protection for groundwater usually is based on its intended use. However, predicting future groundwater use is highly subjective given the long time frames involved in a performance assessment. The type of quantities being limited (decay rate and dose) differs in the various regulations. Moreover, different regulatory agencies approach protecting groundwater resources using different metrics. In addition, earlier DOE performance assessments have taken different approaches. The guidance under DOE O 435.1 is to use the Hanford Site groundwater protection management plan. However, the Hanford Site plan (DOE/RL 1995c) does not discuss long-term protection of groundwater.

Previous performance assessments have generalized the requirements from the "National Primary Drinking Water Regulations," 40 CFR 141, for determining whether the disposal action met the groundwater protection requirement. The scenario used is based on a public drinking water system serving at least 25 people and located at least 100 m (328 ft) downstream from the disposal facility. The previous performance assessments set a limit for the total exposure at less than 4 mrem (EDE) in a year from all radionuclides for an individual drinking the water. However, National Primary Drinking Water Regulations (40 CFR 141) uses the limit of 4 mrem in a year, not for all radionuclides, but for just beta and gamma emitters. Four mrem EDE in a year was chosen for two reasons. First, the value corresponds to the risk-based limit found in the

40 CFR 141. Also, for most of the radionuclides, the value is more restrictive (see Table C-7 of Mann 2003a) than the decay rate concentration limits specified in WAC 173-200.

The requirements for alpha emitters are the same in both WAC 173-200 and 10 CFR 141. Both regulations limit alpha emitters by decay rate concentration limits, not annual dose. In addition, both sets of requirements limit the same subsets of alpha emitters (radium-226, total radium, and other) and set the same quantitative limits. These decay rate concentration limits (Table 1-2) are used for this performance assessment.

Washington State's requirements for beta emitters are based on screening levels previously set by the EPA. These screening levels were selected because the requirements are easily verified in the field. (The current EPA regulations are based on risk limitation.) The current state screening level ensures that, even for beta emitters emitting high-energy gamma radiation, the dose limit will be met. However, for low-energy beta emitters, the state screening level is overly conservative by a factor of about 100. This high degree of conservatism exists for radionuclides, such as technetium-99, that are important in this performance assessment.

For this preliminary performance assessment, the federal standards are used. This means that the current EPA regulation governing drinking water, 40 CFR 141, is used to protect groundwater. The "National Secondary Drinking Water Standards" 40 CFR 143 were not used because they are stated only as goals. This follows the precedent set in the TWRS EIS (DOE 1996b), a joint publication of the Ecology and DOE. Thus, the performance objective is an EDE of 4 mrem in a year for beta and photon emitters and a concentration of 15 pCi/L for alpha emitters other than uranium. The values are displayed in Table 1-2. A dose of 4 mrem (EDE) in a year for 70 years corresponds to an incremental health risk of 0.0001 (EPA 1989).

To ensure compliance with the intent of federal and state groundwater regulations, the limits shown in Table 1-2 are applied to a well 100 m (328 ft) downgradient from the disposal facility for 10,000 years after closure, the same time of compliance as for protection of the general public. The hypothetical well from which the water is drawn is sized to be the minimum public drinking water system to serve 25 people. Further information is given in Section 3.4.7.2 of this document. The effects of placing the well at other locations (including the Hanford Site 200 Area fence line) also are determined.

1.6.2.6 Protection of Surface Water Resources. The protection required is the same in both the federal (10 CFR 141) and state requirements (WAC 173-201A) for protecting surface water resources. The point of compliance is the point at which the groundwater is predicted to reach the Columbia River. The concentration of radionuclides in the groundwater at the point at which it enters the Columbia River should meet all the standards listed in Table 1-2.

The 1.0 mrem (EDE) dose in a year (one quarter of the EPA drinking water standard) value is selected because it meets WAC 173-201A while minimizing reporting requirements. WAC 173-201A mandates a dose limit that is the lesser of the EPA drinking water standard and the explicit limits for each radionuclide contained in the regulation. For the major radionuclides of interest, the explicit limits (when converted to dose) are greater than 1.3 mrem in a year. Therefore, using 1.0 mrem in a year for the sum of all beta and photon emitters is restrictive in meeting this standard.

The compliance time for protecting surface water resources is selected as 1,000 years, the same compliance time as for protecting groundwater resources. However, the calculations are carried out to 10,000 years or to the time of maximum impact, if the peak occurs after 10,000 years.

1.6.2.7 Protection of Air Resources. Air emissions limits were taken from Parts H and Q of the "National Emissions Standards for Hazardous Air Pollutants" (40 CFR 61). These limits are more restrictive than the Washington State requirements (WAC 173-480 and WAC 246-247). Based on these standards, emissions (except radon) are limited to 10 mrem (EDE) in a year with radon emissions limited to 20 pCi/m^2s.

1.6.2.8 Containment Requirements. The "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (40 CFR 191) adds a restriction on the cumulative relative release to the accessible environment. This restriction is placed as a result of a performance assessment that must show a likelihood of less than one chance in 10 of exceeding the standards set in the regulation and less than one chance in 1,000 of exceeding ten times those values. Depending on the waste (spent nuclear fuel, high-level waste, or TRU), the values are normalized. In the case of TRU, the values in Table 1 of 40 CFR 191 are normalized to "the amount of transuranic (TRU) waste containing one million curies of alpha-emitting transuranic radionuclides with half-life greater than 20 years." This normalization results in the numbers shown in Table 1-3. To ease calculational burden and to be conservative, the point of compliance is the point at which the radionuclides leave the vadose zone and enter groundwater.

1.6.2.9 Chemical Objectives. The DOE O 435.1 and its associated manual (DOE M 435.1) cover only the management of radioactive waste. However, Chapter 1, Section 1, item 10 of the manual notes that mixed waste also is subject to the RCRA as amended. Because tank waste contains some materials regulated under RCRA and because the RCRA Part B permit for closure will be based on this analysis, performance objectives for chemicals were established.

The determination of chemical objectives followed the same process as for radiological objectives (see HNF-EP-0828). That is, all relevant regulations were reviewed and the most restrictive limits were used. The chemicals included are those identified by a DQO process (Wiemers 1998). This DQO process included Ecology.

1.6.3 Programmatic Requirements

It is expected that some tanks may contain more than 100 nCi/g of alpha-emitting radionuclides with atomic numbers greater than that for uranium. The strategy for handling this waste is to petition the Secretary of DOE and the Administrator of EPA to establish Hanford tank farm-specific waste categories. Such a strategy is allowed by the "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," (40 CFR 191) and by DOE O 435.1 on the management of radioactive wastes .

To support such a petition, the performance objectives of 40 CFR 141 are included as performance objectives for these analyses. They are listed in Table 1-3.

1.6.4 Public Involvement

Giving Hanford Site stakeholders an opportunity to affect the performance objectives of this proposed closure action is important. These performance objectives are based on the performance objectives used in the ILAW PAs. Those performance objectives and scenarios (WHC-EP-0827) were summarized for the stakeholders. The summary was sent to each member and alternate of the Hanford Advisory Board, to selected Hanford Site contractor employees, and to selected members of the DOE's Peer Review Panel and Performance Assessment Task Team.

We received feedback from the stakeholders and have responded to their concerns. Copies of the performance objectives document (WHC 1994a) were sent to all who requested it. All comments received on either the summary or the performance objectives have been documented as an internal file.

A member of the Hanford Advisory Board, Todd Martin, also was a member of the external review board (see Appendix F.1 of Mann 1996a) that commented on the interim performance assessment and the performance assessment activity.

The public review of performance objectives will also occur during the public comment period associated with the RCRA permit associated with the *Single-Shell Tank System Closure Plan* (RPP-13744).

1.7 APPROACH AND MAJOR DATA SOURCES

This performance assessment is being performed early in the project life. Therefore the emphasis of this document is to present methods, procedures, existing data, and analysis approaches. As noted in Section 1.5.1, this performance assessment is built on the successes of earlier performance assessments (Mann 1995, 1998, 2001) and tank farm-related analyses (Knepp 2002a and 2002b, RPP-10098, Wood et. al. 2003, Connelly et. al. 2003).

Because of the long time frames involved in this analysis, estimates of impacts require computer simulations rather than direct observations. The models used in the analysis are very flexible and should be adequate to describe the evolving features of the disposal system. However, because this analysis is performed early in the project life, many of the data are taken from related Hanford Site projects.

The major sources of information for the base analysis case are present in Table 1-5. Sensitivity cases (See Section 3.5.5) were performed to determine the impact of uncertain data. Among the most important uncertain data were the following:

- Amount of material leaked during past operations
- Amount of material remaining as residual waste in the tanks and ancillary equipment after retrieval
- Amount of material leaked from the tanks during retrieval

- Concentration of material in soils contaminated by past leaks, in residual waste left in the tanks and in ancillary equipment, and in leaked fluids during retrieval
- Release rates from residual materials
- Approach to filling the tank after waste retrieval
- Infiltration as a function of time.

Among the most important uncertainties in analysis approach are the following:

- Verification of non-overlapping plumes in vadose zone
- Extrapolation from two- to three-dimensional analyses
- Groundwater flows in the future.

Table 1-5. Major Sources of Information for the Base Analysis Case. (2 Pages)

Data Type	Major Source
Location	The WMA C exists north of the PUREX Facility in the 200 East Area.
Analysis Approach	Four types of sources are modeled (past releases presently in soils, leaks during tank waste retrieval, releases from residual waste in tanks, releases from residual waste in ancillary equipment). Releases are calculated separately from each source, assuming no overlap. Plumes from the various types of sources for each of the components in the tank farm are superimposed without any impact from other plumes. Verification runs have been made in the case of overlapping residual waste releases.
Waste Form	Waste will be in two forms: 1. dispersed in soil from past leaks and potential leaks during retrieval 2. residual waste stabilized by a yet-to-be-determined process. The process will be determined based on future engineering studies.
Volume of Material	Volume of past leaks is relatively well known. Retrieval is yet to occur; hence the amount of residual waste and the potential volumes of retrieval leaks are to be determined. The volume of residual waste will be measured after retrieval is completed. The volume of potential leak volumes will be estimated based on monitoring data. The volume of residual waste used in this document is based on regulatory requirements. The volume of potential retrieval leaks is based on values normally assumed and that each retrieval results in a leak. Volume of material in ancillary equipment is unknown, but can be estimated. Improved information will be obtained during remediation activities.

Table 1-5. Major Sources of Information for the Base Analysis Case. (2 Pages)

Data Type	Major Source
Inventory concentration	Concentrations of contaminants in past leaks are understood to varying degrees depending on knowledge of waste process history and previous characterization data. Further field characterization is planned for the major leak site. Concentration of contaminants in residual waste can be somewhat estimated based on waste process history. The concentration in residual waste will be measured after retrieval. Concentration of contaminants in potential leaks can be poorly estimated based on present estimates of inventories in each tank, the inventory of contaminants in the sluicing fluid used during retrieval, and knowledge of chemical reactions between the current inventory and the sluicing fluid. Concentration of contaminants in ancillary equipment is unknown, but can be estimated. Improved information will be obtained during remediation activities.
Long-term waste form performance	Past and potential retrieval leaks: entire amount is available for transport. Residual waste: Neither the release mechanism nor release parameters are known. Various release models with literature values are used in this analysis. Release rate parameters will be measured from residual waste samples taken after retrieval is complete.
Disposal facility design	Closure design has not yet been determined. For this analysis, no credit is taken for tank geometry, but a surface barrier with a design life of 500 years is used. Engineering studies are planned to optimize closure design.
Recharge	Estimates were derived from Hanford Site studies for both barrier and natural conditions.
Geotechnical	Taken from geotechnical measurements studies of locations in the Hanford Site 200 East Area. Geology is established from boreholes in WMA C.
Exposure	Taken from past Hanford Site documents and experience and DOE O 435.1 direction.

Future performance assessments will be issued as new information about the waste form, its inventory, the design of the disposal facility, and site characterization is collected and as these factors are better understood.

1.8 STRUCTURE OF THIS PERFORMANCE ASSESSMENT

This performance assessment is divided into nine sections and eight appendices. The appendices provide additional detailed information about topics presented in the sections. This section summarizes the contents of each of chapter section and appendix.

- Section 2 describes the Hanford Site environment, the waste characteristics, and the waste disposal system.
- Section 3 covers the methods used to assess system performance, including the radionuclide transport pathways and exposure scenarios. It also discusses the assumptions used in modeling system performance.
- Section 4 presents and integrates results from the transport and exposure models used to estimate the potential consequences of long-term contaminant release from the disposal vaults.

- Section 5 presents the results from the inadvertent intruder analyses.
- Section 6 interprets disposal facility performance with respect to the performance objectives defined in Chapter 1, sets waste acceptance criteria and disposal facility requirements, shows that these requirements can be "reasonably expected" to be met, and discusses further work associated with the performance assessment activity.
- Section 7 outlines the quality assurance procedures used in the performance assessment activity.
- Section 8 contains brief resumes of contributors to the document.
- Section 9 lists the cited references
- Appendix A contains dosimetry data factors used in the analysis.
- Appendix B contains the equations used in the major codes.
- Appendix C presents detailed results of the analysis.
- Appendix D contains quality assurance information.

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2.0 WMA C FACILITY DESCRIPTION

2.1 OVERVIEW

This section explains the expected environment within the region and around WMA C, construction and operational history of WMA C, and likely closure concepts for WMA C facilities. It covers the following topics.

- **Hanford Site Characteristics** (Section 2.2). Regional and local geography, demography including future land use, climate, geology, hydrology, soils, ecological and biotic conditions, and natural background radiation.
- **Past and current Conditions at WMA C** (Section 2.3). Construction of facilities in the WMA C, current waste storage in underground tanks and plans for retrieving the waste.
- **Closure Technology** (Section 2.4). The current concepts for interim, component, and final closure of the tanks in the WMA C as well as final closure of the WMA C.

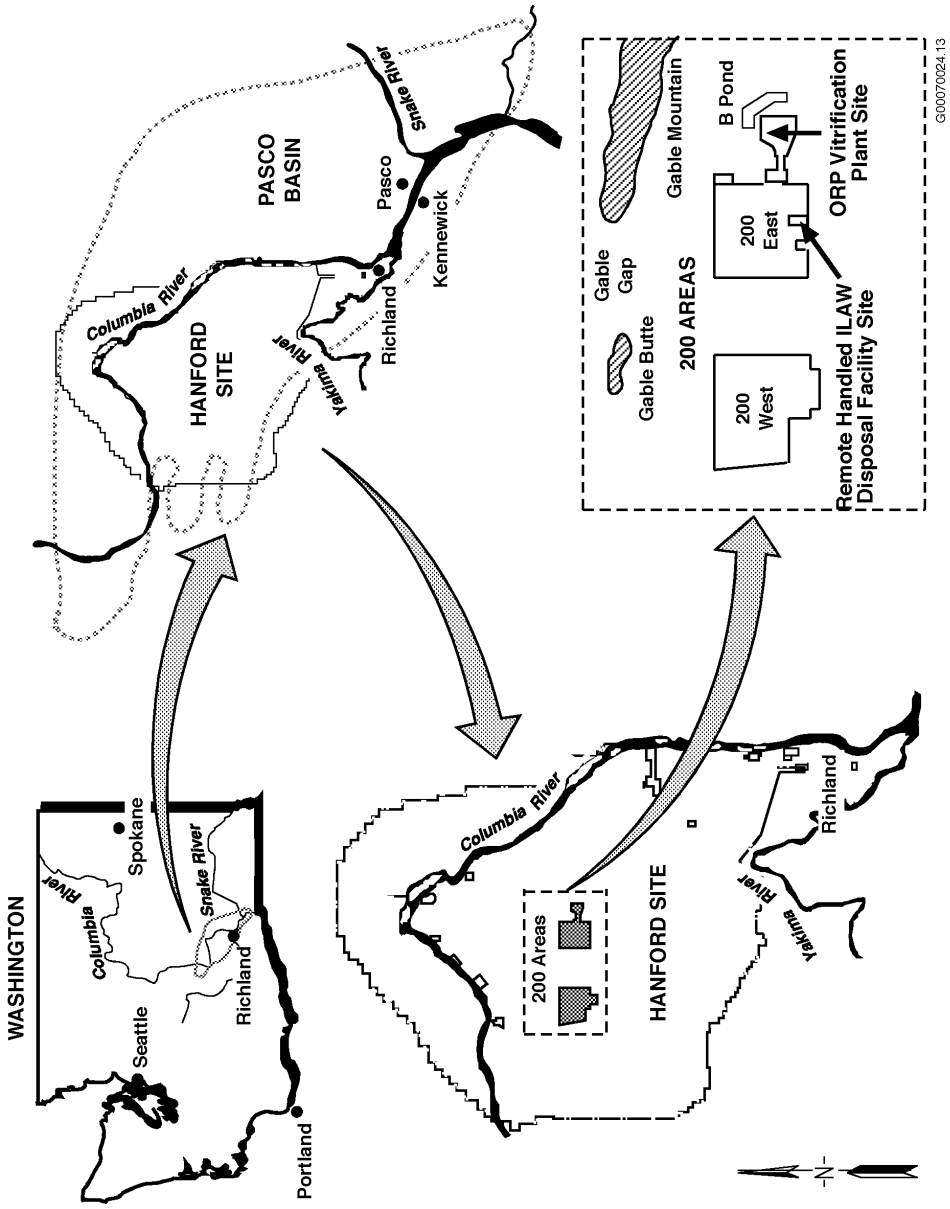
2.2 HANFORD SITE CHARACTERISTICS

This section describes the regional and local environment in which the WMA C is located. Extensive research has been done on the physical characteristics of the Hanford Site.

2.2.1 Geography of the Hanford Site

The Hanford Site is a 560-mi^2 (1,450-km^2) area of semiarid land located in south-central Washington State. The Hanford Site is owned by the U.S. Government and restricted to uses approved by the DOE. Figure 2-1 shows the Hanford Site in relation to the rest of the state, and identifies major cities in the region—Seattle, Portland, and Spokane—all of which are more than 100 mi (160 km) from the Hanford Site.

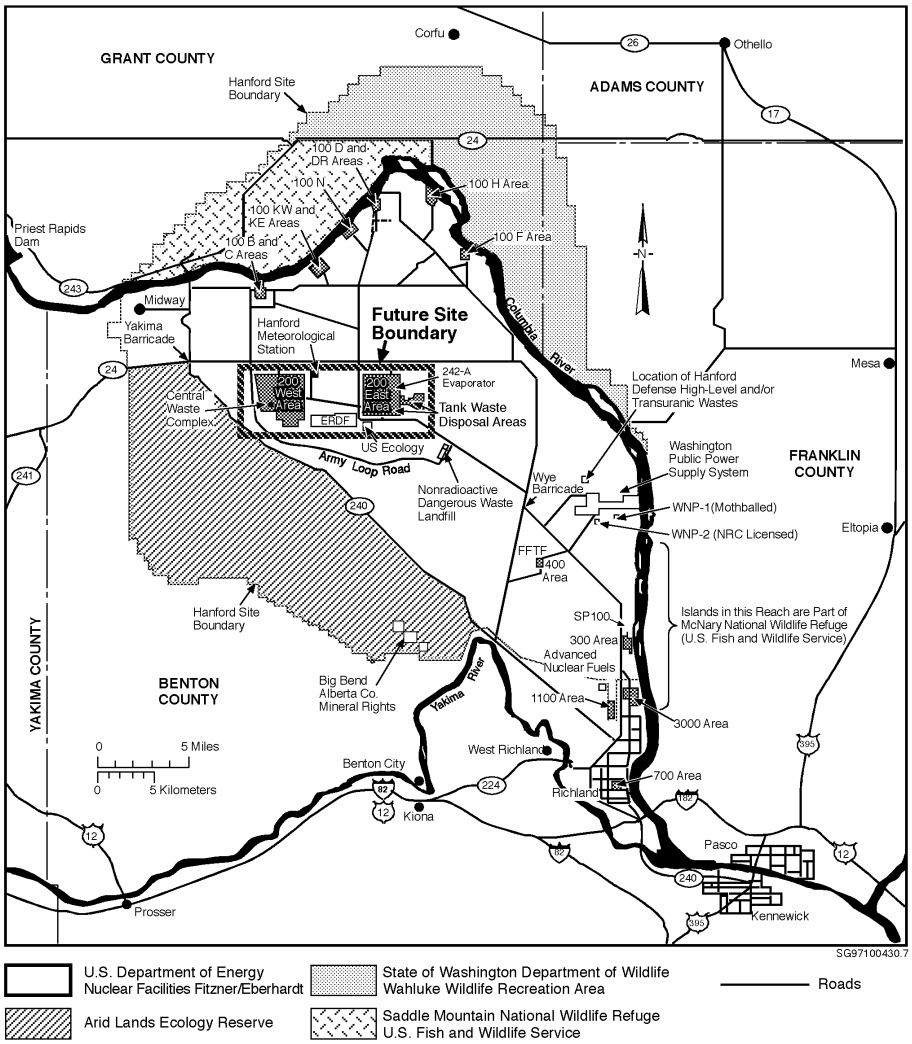
Figure 2-1. Hanford Site in Washington State.



The major features of regional geography are the nearby rivers and mountains. The Columbia River, which forms the eastern boundary of the Hanford Site, is an important source of water and hydroelectric power for the region. Other important rivers near the Hanford Site are the Yakima River to the southwest and the Snake River to the east. The Cascade Mountains, which are about 100 mi (160 km) to the west, have an important effect on the climate of the area, which is discussed in Section 2.2.5.

Figure 2-2 shows the Hanford Site. The DOE is planning to release some of the Hanford Site land for uses discussed in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Assessment* (DOE 1999h) and its associated record of decision (DOE 1999i). The areas planned for release are the area north of the Columbia River and the Fitzner/Eberhardt Arid Lands Ecology Reserve southwest of State Highway 240. This land now is part of the Hanford Reach National Monument (Clinton 2000).

Figure 2-2. Hanford Site Map Showing Public Highways and Future Site Boundary.



The 200 Areas, in which the tank waste is located, are in the center of the Hanford Site. Just south of the 200 Areas is land used by U.S. Ecology, Inc., for commercial low-level radioactive waste disposal.

As discussed more fully in Section 2.2.4.3, the *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* (DOE 1999h) has defined the future site boundaries as just outside of the 200 Area boundaries, as shown in Figure 2-2.

2.2.2 Location of the WMA C

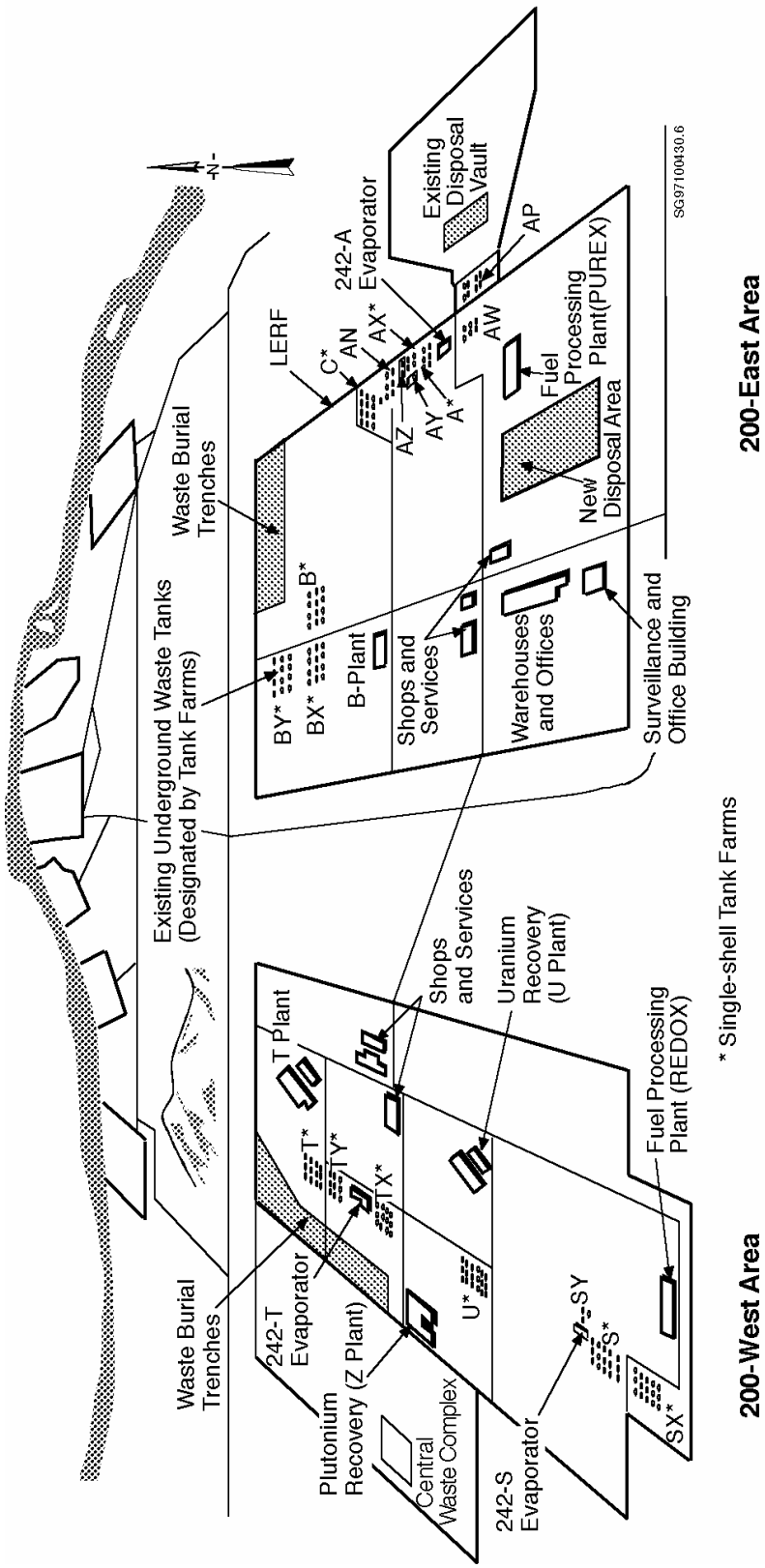
WMA C is in the middle of the eastern part of the 200 East Area of the Hanford Site. Figure 2-3 shows the major facilities in the 200 Areas, and the location of WMA C. WMA C is located at the north end of a series of tank farms (AN, AZ, AY, AX, A, AW, and AP). It is located south of the solid waste burial grounds covered by the *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Burial Grounds* (Wood 1996) and north of the proposed ILAW disposal facility (labeled "new disposal area in Figure 2-3) that is covered by *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version* (Mann 2001).

2.2.3 Demography

Demographic data are used in a performance assessment to help set the scenarios and select the dosimetry parameters. This section describes the current population database.

The major population centers within 50 mi (80 km) of the Hanford Site are identified in Figure 2-4, along with populations based on the 1990 U.S. Bureau of Census estimates (DOC 1991). This radius is centered on the Hanford Meteorology Station (HMS), located between the 200 East and West Areas. The Tri-Cities (Richland, Kennewick, and Pasco) area, southeast of the Hanford Site, is the largest population center close to the Hanford Site. Other major population centers include Yakima and the Yakima Valley towns and Moses Lake in Washington to the west and north, respectively, and Umatilla and Hermiston in Oregon to the south. The cities of Ellensburg and Walla Walla, Washington lie just beyond the 50 mi (80 km) radius. Portions of Benton, Franklin, Adams, Grant, Kittitas, Yakima, Klickitat, and Walla Walla counties in Washington and Morrow and Umatilla counties in Oregon lie within the 50 mi (80 km) radius.

Figure 2-3. Activities in the 200 Areas. WMA C is located at the northern end of a series of tank farms along the eastern edge of the 200 East Area.



Year 2000 population estimates for Washington State (OFM 2000), as summarized in *Hanford Site National Environmental Policy Act (NEPA) Characterization* (Neitzel 2000), were used. The population in Benton County was approximately 140,000 in 2000, compared to 112,560 in 1990. Approximately 37,190 people reside in Richland; 53,270 people reside in Kennewick; and 15,235 people reside in West Richland, Benton City, and Prosser. The approximate population in the unincorporated portions of the county is 35,005. The estimated population of Franklin County was 45,900 in 2000, compared to 37,473 in 1990, with 27,370 people living in Pasco, 15,110 people living in other incorporated areas, and 17,600 people living in unincorporated areas. Benton and Franklin Counties accounted for approximately 3% of Washington State's population (OFM 1999).

2.2.4 Land and Water Use

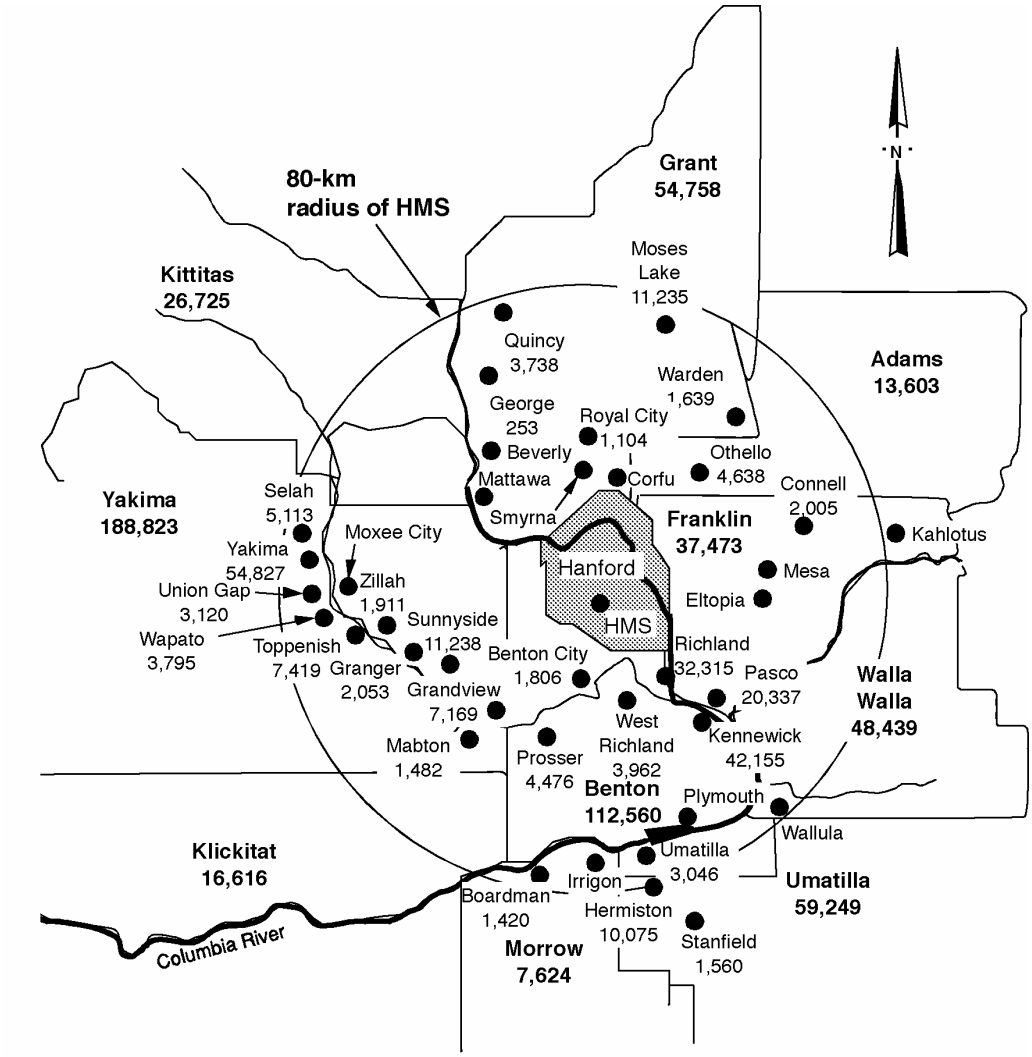
Land and water use information are used in a performance assessment to help set the scenarios and select the dosimetry parameters. This section describes area socioeconomics, past and planned DOE activities, and the results of an investigation of future uses conducted by the Hanford Future Site Uses Working Group (HFSUWG).

2.2.4.1 Socioeconomics. The major employers in the Tri-Cities area since 1970 have been the DOE and the Hanford Site contractors; Energy Northwest (formerly the Washington Public Power Supply System), which operates a nuclear power plant; agriculture; a large food-processing industry; plus several smaller industrial operations. Other than DOE activities, agriculture and food processing are the dominant industries. The socioeconomics of the area surrounding the Hanford Site are more fully described in Section 4.6 of Neitzel (2000-2).

Land use classifications around the Hanford Site vary from urban to rural. Most of the land south of the Hanford Site is urban, including the Tri-Cities, while much of the land to the north and east is irrigated crop land. Most of the irrigation water comes from the Bureau of Reclamation's Columbia Basin Project, which uses the water behind Grand Coulee Dam as the primary water source. The water is transported via canals to the areas north and east of the Columbia River. The land to the west of the Hanford Site is used for irrigated agriculture near the Yakima River and dry-land farming at the higher elevations.

The area's rivers are used as sources of irrigation and drinking water, as major sources of power production for the western United States, as primary salmon spawning grounds as well as for recreation. The Hanford Reach was designated as a national monument in 2000 (Clinton 2000).

Figure 2-4. Population Centers within an 80-km Radius of the Hanford Site. Populations shown are based on 1990 census (DOC 1991).



Note: If population not listed, less than 1,000

HMS = Hanford Meteorological Station

S9509085.2

2.2.4.2 Past and Future DOE Activities at the Hanford Site. In 1943, the U.S. Army Corps of Engineers created the Hanford Site from small farming areas along the Columbia River to locate facilities used to produce nuclear weapon materials for use during World War II. Since then, the major activities on the Hanford Site have been controlled by the DOE and its predecessors, the U.S. Atomic Energy Commission (1945 to 1975), and the Energy and Research Development Administration (ERDA) (1975 to 1976). Current major programs at the Hanford Site are dedicated to waste management, environmental restoration, long-term stewardship, and research and development.

The DOE nuclear facilities occupy about 6% of the Hanford Site's total available area. The major operating areas, as shown in Figure 2-2, are identified: 100 Areas, 200 Areas, 300 Area, and 400 Area. The activities conducted in these areas are described in the following paragraphs.

100 Areas. The 100 Areas, directly bordering the Columbia River (Figure 2-2), contain nine graphite-moderated plutonium production reactors, eight of which were shut down by the early 1970s. The ninth is the N Reactor, the first dual-purpose reactor built in the United States. N Reactor began operating in 1963 and was shut down in 1986.

200 Areas. Fuel reprocessing, plutonium and uranium separation, plutonium finishing, and waste management, including treatment, storage, and disposal activities, were conducted in the 200 Areas. Waste from the research and development activities and fuel fabrication activities in the 300 Area, reactor operation programs conducted in the 100 Areas, and the Fast Flux Test Facility (FFTF) in the 400 Area is sent to the 200 Areas for storage and disposal. Waste management activities are scheduled to continue until the mid 21st century. Waste management facilities are located in the 200 Areas, which are surrounded by security fencing (Figure 2-2). The following major facilities are located in the 200 Areas (see Figure 2-3):

- Burial trenches
- Eighteen underground storage tank farms (A, AN, AP, AW, AX, AY, AZ, B, BX, BY, C, S, SX, SY, T, TX, TY, and U)
- Very large fuel processing and recovery facilities (B, T, U, and Z Plants and the reduction-oxidation [REDOX] and plutonium uranium extraction [PUREX] facilities)
- Tank waste water evaporator facilities (the 242-A, -S, and -T)
- Office and warehouse buildings.

Many of these facilities are inactive. The Canister Storage Building was built recently just west of B Plant to store spent nuclear fuel from N Reactor. The Canister Storage Building will also be outfitted to store the immobilized high-level tank waste fraction.

Between and just south of the 200 East and West Areas is the Environmental Remediation Disposal Facility (ERDF) (see Figure 2-2). This trench system will hold most of the contaminated soil and materials from facility decontamination and decommissioning and Hanford Site remediation.

A 1.5 mi^2 (3.9 km^2) parcel located between the 200 West and East Areas is leased to Washington State. A portion of this land is subleased to U.S. Ecology, Inc., a private company, for the disposal of commercially generated low-level radioactive waste.

300 Area. Originally, the 300 Area was dedicated to fabricating fuel for Hanford Site reactors. Now, the 300 Area laboratories constructed over the last 30 years are used for research programs.

400 Area. The FFTF is located in the 400 Area. This facility contains a liquid-metal cooled fast reactor previously used for testing breeder reactor fuels, materials, and components. The FFTF operated until 1992 and now is in standby mode.

A 1.7 mi^2 (4.4 km^2) parcel northeast of the 400 Area is leased to Energy Northwest (formerly the Washington Public Power Supply System) for commercial nuclear power reactors. The Columbia Generating Station (CGS), a boiling-water reactor, currently is the only operating nuclear reactor on the Hanford Site. Construction of two pressurized-water reactors (WNP-1 and WNP-4) will not be completed.

2.2.4.3 Future Hanford Use. In 1992, DOE, EPA, and Ecology gathered a group of stakeholders to study potential future uses for the Hanford Site land. This Hanford Future Site Uses Working Group issued a summary (HFSUWG 1992a) and a detailed report (HFSUWG 1992b) of its findings. The *Final Hanford Comprehensive Land Use Plan Environmental Impact Statement* (DOE 1998h) is heavily based on the work of the HFSUWG. However, DOE's land use planning extends for only 50 years instead of the 100 years forecast by the working group.

The final report summary (HFSUWG 1992a) contains the following statements:

- Regarding near-term use of the 200 Areas, referred to as the Central Plateau in the report:

  > "The presence of many different types of radionuclides and hazardous constituents in various forms and combinations throughout the site poses a key challenge to the Hanford cleanup. To facilitate cleanup of the rest of the site, wastes from throughout the Hanford site should be concentrated in the Central Plateau waste storage, treatment, and disposal activities in the Central Plateau should be concentrated within this area as well, whenever feasible, to minimize the amount of land devoted to, or contaminated by, waste management activities. This principle of minimizing land used for waste management should specifically be considered in imminent near-term decisions about utilizing additional uncontaminated Central Plateau lands for permanent disposal of grout."

- Regarding future use options (HFSUWG 1992a-2):

  > "In general, the Working Group desires that the overall cleanup criteria for the Central Plateau should enable general usage of the land and groundwater for other than waste management activities in the horizon of 100 years from the decommissioning of waste management facilities and closure of waste disposal areas."

- Regarding waste management:

  Based on conversations of the working group, they could not agree on a definition of "general use." For the "foreseeable future" the working group developed options involving waste treatment, storage, and disposal of DOE low-level radioactive waste. The differences among the options are whether offsite waste (radioactive and/or hazardous) would be allowed to be disposed on the Hanford Site.

  "The working group identified a single cleanup scenario for the Central Plateau. This scenario assumes that future uses of the surface, subsurface and groundwater in and immediately surrounding the 200 West and 200 East Areas would be exclusive. Surrounding the exclusive area would be a temporary surface and subsurface exclusive buffer zone composed of at least the rest of the Central Plateau. As the risks from the waste management activities decrease, it is expected that the buffer zone would shrink commensurately."

For nearer term land use planning, the Record of Decision (DOE 1999i) for the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999h) identifies near-term land uses for the Hanford Site. The record of decision proscribes the use in the 200 Areas as exclusively industrial (primarily waste management) with much of the surrounding land having the use of preservation or conservation. The Hanford Reach National Monument (Clinton 2000) was established along the river corridor as well as in lands at the northern and western edges of the site.

However, no formal land use planning is expected to be accurate over the hundreds to hundreds of thousands of years covered in this analysis.

2.2.5 Climate and Meteorology

The information in this section is taken from *Hanford Site National Environmental Policy Act (NEPA) Characterization,* PNNL-64415, Rev. 12, Section 4.1 (Neitzel 2000-3.)

2.2.5.1 Summary. Local and regional climate patterns and projections must be considered when estimating the effect of water on the disposal system. Both total precipitation and seasonal frequency are important. Potential long-term climatic conditions must be projected to evaluate future climate changes that might cause higher precipitation rates or glaciation. Climate also affects the potential for flooding.

The climate of the Pasco Basin (in which the Hanford Site is located) can be classified as midlatitude semiarid or midlatitude desert, depending on the climatological classification system being used. Large diurnal temperature variations are common, resulting from intense solar heating and nighttime cooling. Summers are warm and dry with abundant sunshine. Daytime high temperatures in June, July, and August can exceed 104 °F (40 °C). Winters are cool with occasional precipitation that makes up about 44% of the yearly total. During the winter, outbreaks of cold air associated with modified arctic air masses can reach the area and cause temperatures to drop below 0 °F (-18 °C). Overcast skies and fog occur during the fall and winter months.

The Cascade Mountain Range greatly affects the temperature, wind, and precipitation in the region. Air masses that reach the Pasco Basin are changed as they pass over the region's relatively complex topography. The mountains limit the Pacific Ocean's maritime influence, making the climate of Eastern Washington drier and with greater temperature extremes than the coast. In addition to this rain shadow effect, the Cascades are a source of cold air drainage, which has a considerable effect on Hanford Site's wind regime.

The rest of this section summarizes the modern climate patterns in the Hanford Site area, the regional climate patterns of the recent past, and the possible future changes.

2.2.5.2 Current Data. Climatological data are available from the Hanford Meteorological Station (HMS), located between the 200 East and 200 West Areas at about 215 m (705 ft) elevation (see Figure 2-2). Data have been collected at this location since 1945. Temperature and precipitation data also are available from nearby locations for the period from 1912 through 1943. Data from the HMS are representative of the general climatic conditions for the region and describe the specific climate of the 200 Areas. The most recent summary is *Hanford Site Climatological Data Summary 1999 With Historical Data*, PNNL-13117 (Hoitink 2000).

Daily maximum temperatures vary from a normal maxima of 35 °F (2 °C) in late December and early January to 95 °F (35 °C) in late July. On the average, 52 days during the summer months have maximum temperatures of 90 °F (32 °C) or higher and 12 days with maxima of 100 °F (38 °C) or higher. From mid-November through early March, minimum temperatures average ≤(32°F (0 °C), with the minima in late December and early January averaging 21 F° (-6 °C). During the winter, on average, three days have minimum temperatures of 0 °F (18 °C) or lower; however, only about one in two winters experiences such temperatures. The record maximum temperature is 113 °F (45 °C), and the record minimum temperature is -23° F (-31 °C). The highest winter monthly average temperature at the HMS was 44 °F (6.9 °C) in February 1958, while the record lowest average temperature was 12 °F (-11.1 °C) during January 1950. The record maximum summer monthly average temperature was 82°F (27.9°C) in July 1985, while the record lowest average temperature was 63°F (17.2°C) in June 1953.

Between 1946 and 1998, annual precipitation at the HMS averaged 6.3 in. (16 cm) and varied between 3.0 in. (7.6 cm) and 12.3 (31.3 cm). The wettest season on record was the winter of 1996-1997 with 5.4 in. (141 mm) of precipitation; the driest season was the summer of 1973 when only (0.03 in. (1 mm) of precipitation was measured. Most precipitation occurs during the winter, with more than half of the annual amount occurring from November through February. Days with more than 0.5 in. (13 mm) precipitation occur on average less than once each year. Rainfall intensities of 0.5 in./hr (13 mm/h) persisting for 1 hour are expected once every 10 years. Rainfall intensities of 1 in./hr (25 mm/h) for 1 hour are expected only once every 500 years.

About 38% of the precipitation during December through February falls as snow. Winter monthly average snowfall ranges from 0.8 cm (0.3 in.) in March to 13.5 cm (5.3 in.) in January. Only one in four winters is expected to accumulate as much as 5.9 in. (15 cm) of snow on the ground. During these winters, four days, on average, have 6.0 in. (15.2 cm) or more of snow on the ground. However, the 1964-1965 winter had 35 days with snow on the ground, 32 of which

were consecutive. That winter also provided one of the deepest accumulations, with 12 in. (31 cm) of snow occurring in December 1964. The record accumulation of snow is 24.5 in. (62.2 cm) in February 1916.

Prevailing wind directions on the 200 Area Plateau are from the northwest in all months of the year. Secondary maxima occur for southwesterly winds. Summaries of wind direction indicate that winds from the northwest quadrant occur most often during the winter and summer. During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwest flow. Winds blowing from other directions (e.g., northeast) display minimal variation from month to month. Monthly average wind speeds are lowest during the winter months, averaging 6 to 7 mi/hr (10 to 11 km/hr), and highest during the summer, averaging 8 to 9 mi/hr (13 to 15 km/hr). Wind speeds that are well above average are usually associated with southwesterly winds. However, the summertime drainage winds are generally northwesterly and frequently reach 30 mi/hr (50 km/hr). These winds are most prevalent over the northern portion of the Hanford Site.

This climate profile suggests opportunities for moisture infiltration or recharge. This infiltration is centered around the frequency of precipitation during the winter months when evaporation is low and plant uptake and transpiration are minimal.

2.2.5.3 Historical Data. Historical climate data can provide insights into how future and current climate patterns may differ. Information on climate exists for the past few centuries and, in less detail, for the last 10,000 years.

Cropper and Fritts (1986) derived a 360-year regional reconstruction of seasonal and annual variations in temperature and precipitation from statistical relationships between meteorological records from Columbia Basin stations and tree-ring data from western North America. They calibrated the relationship between Columbia Basin weather records and a network of 65 tree-ring chronologies. The results suggest that the average temperature of the Columbia Basin for the past three centuries was slightly higher by 0.16 ^{o}F (0.09 ^{o}C) and more variable (4% higher standard deviation) than in the twentieth century. The increase was primarily attributed to warmer winters. This reconstruction also suggests that the past three centuries were wetter on the average by 0.3 in. (0.8 cm), primarily in the autumn. Furthermore, droughts were apparently more frequent starting in the second half of the seventeenth century and lasted longer than twentieth century droughts. Gramulich (1987) also used multiple regression models to reconstruct precipitation in the Pacific Northwest. The results indicate that the average precipitation in the eighteenth and nineteenth centuries was the same as the average precipitation in the twentieth century.

Chatters (1991) and Chatters and Hoover (1992) summarized proxy evidence for climatic change in the Columbia Basin for the past 10,000 to 13,000 years. They identify an environment for about 13,000 years ago that was kept cool and dry by masses of ice and glacial meltwater, supporting a mosaic of isolated plant and animal communities. This was followed between 10,000 and 8,500 years ago by a period of warmer than modern summers, colder than modern winters and low, but spring-dominant, precipitation. This climate supported extensive grasslands and their associated fauna. By 8,000 years ago, summers and winters were both relatively warm, and precipitation was at least 33% below current levels. This climate pattern resulted in reduced

stream flows, with late spring flow maxima, and extensive development of shrub-steppe vegetation throughout most of the region. Between 4,500 and 3,900 years ago, the climate evolved to wetter and cooler conditions. Rivers flooded frequently and forests expanded into steppe zones. From 3,900 to 2,400 years ago the climate was cool in the summer and cold in the winter, with winter-dominant precipitation at least 30% above current levels. Warmer, drier conditions returned between 2,400 and 2,000 years ago, reducing vegetation density and renewing flooding.

2.2.5.4 Long-Range Forecasts. Future long-range forecasts of climate are uncertain. Climatologists universally accept that global climates have undergone significant variation in the past and that such natural variations are expected to continue into the future. Berger (1991) reviewed 7 models of different complexity developed to predict the global climate for the next 10,000 to 100,000 years. All the models are in relatively good agreement. Without human disturbances, the long-term cooling trend that began some 6,000 years ago is expected to continue for the next 5,000 years. This trend should be followed by a stabilization at about 15,000 years, a cold interval centered at approximately 25,000 years, and finally a major glaciation at about 55,000 years. Although human disturbances (such as the green-house effect) could occur, their main effect will be to delay the onset of these trends.

2.2.5.5 Severe Weather. Severe weather events are not significant to the Hanford Site. According to the records of the HMS and the National Severe Storms Forecast Center's database, only 24 separate tornadoes have occurred between 1916 to 1994 within 100 mi (160 km) of the Hanford Site. Only one of these tornadoes was observed within the boundaries of the Hanford Site (at the extreme western edge), and no damage resulted. The estimated probability of a tornado striking a point at the Hanford Site is 9.6×10^{-6}/y. Hurricanes do not reach the interior of the Pacific Northwest.

Severe winds are associated with thunderstorms or the passage of strong cold fronts. The greatest peak wind gust was 81 mi/h (130 km/h), recorded at 50 ft (15 m) above ground level at the Hanford Meteorological Station. Extrapolations based on 35 years of observation indicate a return period of about 200 years for a peak gust in excess of 90 mi/hr (145 km/hr) at 50 ft (15 m) above ground level.

2.2.5.6 Climate Summary. The analyses of present and future climatic conditions at the Hanford Site and in the surrounding region suggest that conditions similar to the current climate will prevail for at least 10,000 years and probably considerably longer. However, because of the uncertainty inherent in any analysis of climate, wetter conditions and associated higher recharge or infiltration rates also will be considered. Scientists generally accept that, at about 50,000 years from now or later, major glaciation will occur, followed by possible flooding similar to that which occurred near the end of the last glacial stage.

2.2.6 Ecology and Biotic Conditions

The information in this section is taken from *Hanford Site National Environmental Policy Act (NEPA) Characterization,* PNNL-64415, Rev. 12, Section 4.4 (Neitzel 2000-4).

This section summarizes the ecology of the Hanford Site, emphasizing plant and animal activities that may affect exposure pathways. The primary impact would be through roots penetrating and animals burrowing through barriers into a disposal facility. Secondarily, the types of plants and animals and their density can affect net groundwater recharge, which is greatly influenced by surface vegetation and burrowing. Neitzel (2000-4) details both the terrestrial and aquatic ecology of the Hanford Site and presents extensive listings of plant and animal species. This section considers only terrestrial ecological effects because the proposed tank closure activities are not located near significant aquatic ecological systems.

The Hanford Site consists of mostly undeveloped land. Chemical processing facilities, shut down nuclear reactors, and supporting facilities occupy only about 6% of the site. Most of the Hanford Site has not experienced tillage or agricultural grazing since the early 1940s.

The Hanford Site is characterized as a shrub-steppe ecosystem that is adapted to the region's mid-latitude semiarid climate. Such ecosystems are typically dominated by a shrub overstory with a grass understory. In the early 1800s, the dominant plants in the area were big sagebrush (*Artemisia tridentata*) and an understory consisting of perennial Sandberg's bluegrass (*Poa sandbergii*) and bluebunch wheatgrass (*Pseudoregneria spicata*). Other species included threetip sagebrush, bitterbrush, gray rabbitbrush, spiny hopsage, bluebunch wheatgrass, needle-and-thread grass, Indian ricegrass, and prairie Junegrass.

With the advent of settlement, livestock grazing and agricultural production contributed to colonization by non-native vegetation species that currently dominate portions of the landscape. Although agriculture and livestock production were the primary subsistence activities at the turn of the century, these activities ceased when the Hanford Site was designated in 1943. Range fires that historically burned through the area during the dry summers eliminated fire-intolerant species (e.g., big sagebrush) and have allowed more opportunistic and fire resistant species to establish. Of the 590 species of vascular plants recorded for the Hanford Site, approximately 20% are non-native. The dominant non-native species, cheatgrass, is an aggressive colonizer and has become well established across the Hanford Site. Over the past decade, several knapweed species also have become persistent invasive species in areas not dominated by shrubs.

The plant community in the undisturbed areas of the 200 Areas is shrub-steppe dominated by big sagebrush, Sandberg's bluegrass, and cheatgrass. The WMA C itself is kept clear of vegetation; however, much of areas outside of the WMA C is vegetated. Appendix F of Fayer (1999) describes some of the data collected recently to characterize the plant community at these two sites.

Approximately 300 species of terrestrial vertebrates have been observed on the Hanford Site, including approximately 40 species of mammals, 246 species of birds, 4 species of amphibians, and 9 species of reptiles. Terrestrial wildlife includes Rocky Mountain elk, mule deer, coyote, bobcat, badger, deer mice, harvest mice, grasshopper mice, ground squirrels, voles, and black-tailed jackrabbits. The most abundant mammal on the Site is the Great Basin pocket mouse. Bird species commonly found in the shrub-steppe habitats at the Hanford Site include the western meadowlark, horned lark, long-billed curlew, vesper sparrow, sage sparrow, sage thrasher, loggerhead shrike, and burrowing owls.

Butterflies, grasshoppers, and darkling beetles are among the more conspicuous of the approximately 1,500 species of insects that have been identified from specimens collected on the Hanford Site. The actual number of insect species living on the Hanford Site may reach as high as 15,000.

The side-blotched lizard is the most abundant reptile species that occurs on the Hanford Site. Short-horned and sagebrush lizards are reported, but occur infrequently. The most common snake species includes gopher snake, yellow-bellied racer, and Pacific rattlesnake. The Great Basin Spadefoot Toad, Woodhouse's Toad, Pacific tree frog, and bullfrogs are the only amphibians found on the Site.

Wildlife species observed in the 200 Areas include mule deer, black-tailed jackrabbits, cottontail rabbits, coyotes, side-blotched lizards, gopher snakes, sage sparrows, shrikes, meadowlarks, and horned larks.

Wildfires are frequent on the Hanford Site. Three large wildfires in the past two decades have burned over 15% of the site. However, because of fire-control measures, no fire has occurred on the WMA C for at least 50 years.

No farming has occurred on the Hanford Site since the government took control of the Site. However, the Hanford Site has all the components that favor successful irrigated farming. Constraints to agricultural development are political and social, not economic or technical. A report prepared by Washington State University, *Evaluation of the Potential for Agricultural Development at the Hanford Site* (Evans 2000), provides many details on potential agricultural activities on the Site.

2.2.7 Regional Geology

The information in this section is based on *Geologic Data Packages for 2001 Immobilized Low-Activity Tank Waste Performance Assessment* (Reidel 1999).

2.2.7.1 Overview. Knowledge of the thickness and lateral distribution of the sediments and other geologic characteristics is required for the following reasons:

- To define a conceptual model for the flow of water and the transport of contaminants from the facility through the vadose zone (the zone between the surface and the groundwater that is not saturated with water) and from the unconfined aquifer (the uppermost groundwater layer) to the human environment
- To define hydraulic parameters
- To interpret modeling results.

The geology of the Hanford Site includes thick sequences of water-derived sediments varying in texture from cobbles and coarse gravels to fine silts and clays. These sediments overlay thick basalt flows. The top sequence or surface soil has been modified by wind. An unconfined aquifer exists in the lower part of the sedimentary sequence overlaying the uppermost basalt

flow. This relatively thin aquifer is considered the primary contaminant pathway for evaluating exposure scenarios. The aquifer intercepts infiltration from the vadose (unsaturated) zone above it, providing a pathway for water and contaminant transport to users or ultimately the Columbia River.

The geological and physical settings of the Hanford Site have been extensively characterized. This section summarizes the physical geology and environmental setting of the Hanford Site and of the WMA C. Emphasis is on the sedimentary sequence, which is the pathway to the groundwater. More detailed discussions of the geology of the Northwest and the Hanford Site are found in *Final Environmental Impact Statement: Disposal of Hanford Defense High-Level Transuranic and Tank Wastes* (DOE 1987), *Consultation Draft Site Characterization Plan* (DOE 1988b), *Geologic Studies of the Columbia Plateau: A Status Report* (Myers 1979), *Subsurface Geology of the Cold Creek Syncline* (Myers 1981), "Volcanism and Tectonism in the Columbia River Flood-Basalt Province" (Reidel 1989), and *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in WHC Documents and Reports* (Delaney 1991).

2.2.7.2 Topography and Physiography. The WMA C is on the Hanford Central Plateau, a Pleistocene flood bar most commonly referred to as the 200 Areas Plateau, near the center of the Hanford Site. The Hanford Central Plateau is approximately 650 ft (198 m) to 750 ft (229 m) above mean sea level (amsl). The plateau decreases in elevation to the north, northwest, and east toward the Columbia River. The plateau escarpments have elevation changes of 50 to 100 ft (15 m to 30 m).

The Hanford Site is situated within the Pasco Basin of south-central Washington State (Figure 2-5). The Pasco Basin is one of many topographic depressions located within the Columbia Intermontane Province (Figure 2-6), a broad basin located between the Cascade Range and the Rocky Mountains. The Columbia Intermontane Province is the product of Miocene continental flood, basalt volcanism, and regional deformation. The Pasco Basin is bounded on the north by the Saddle Mountains; on the west by Umtanum Ridge, Yakima Ridge, and the Rattlesnake Hills; on the south by the Horse Heaven Hills; and on the east by the Palouse Slope (Figure 2-5).

The physical geography of the Hanford Site is dominated by the low-relief plains of the Pasco Basin and anticlinal ridges of the Yakima Folds physiographic region. The surface topography of the Hanford Site is the result of the following events:

- Uplift of anticlinal ridges
- Pleistocene cataclysmic flooding
- Holocene eolian activity.

Uplift of the ridges began in the Miocene epoch (starting about 17 million years ago) and continues to the present. This uplift is occurring on geologic time scales (i.e., over tens of millions of years). The uplift is not incorporated into our conceptual model of the WMA C, which addresses a time scale of tens of thousands of years.

Figure 2-5. Geologic Structures of the Pasco Basin and the Hanford Site.

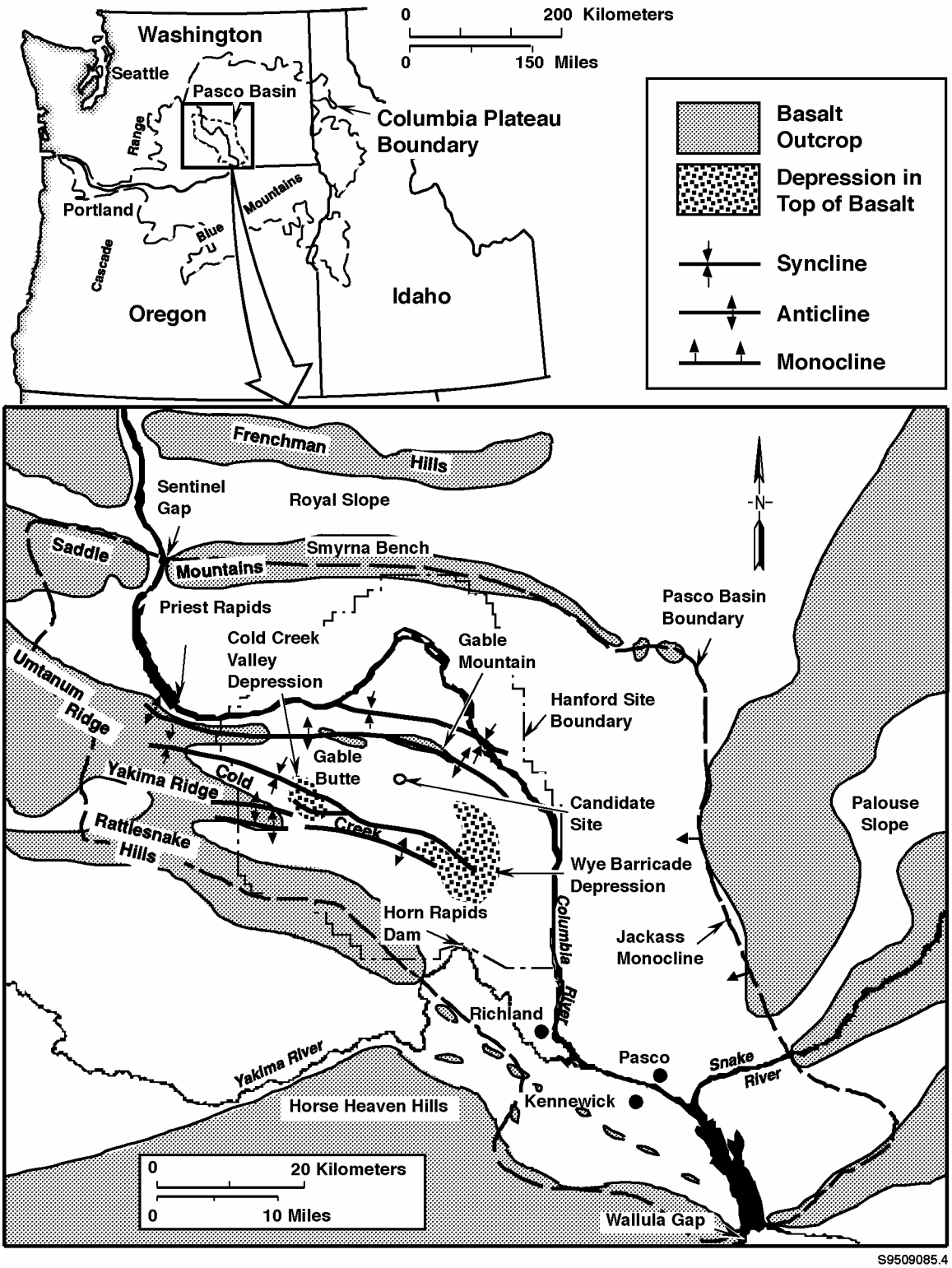
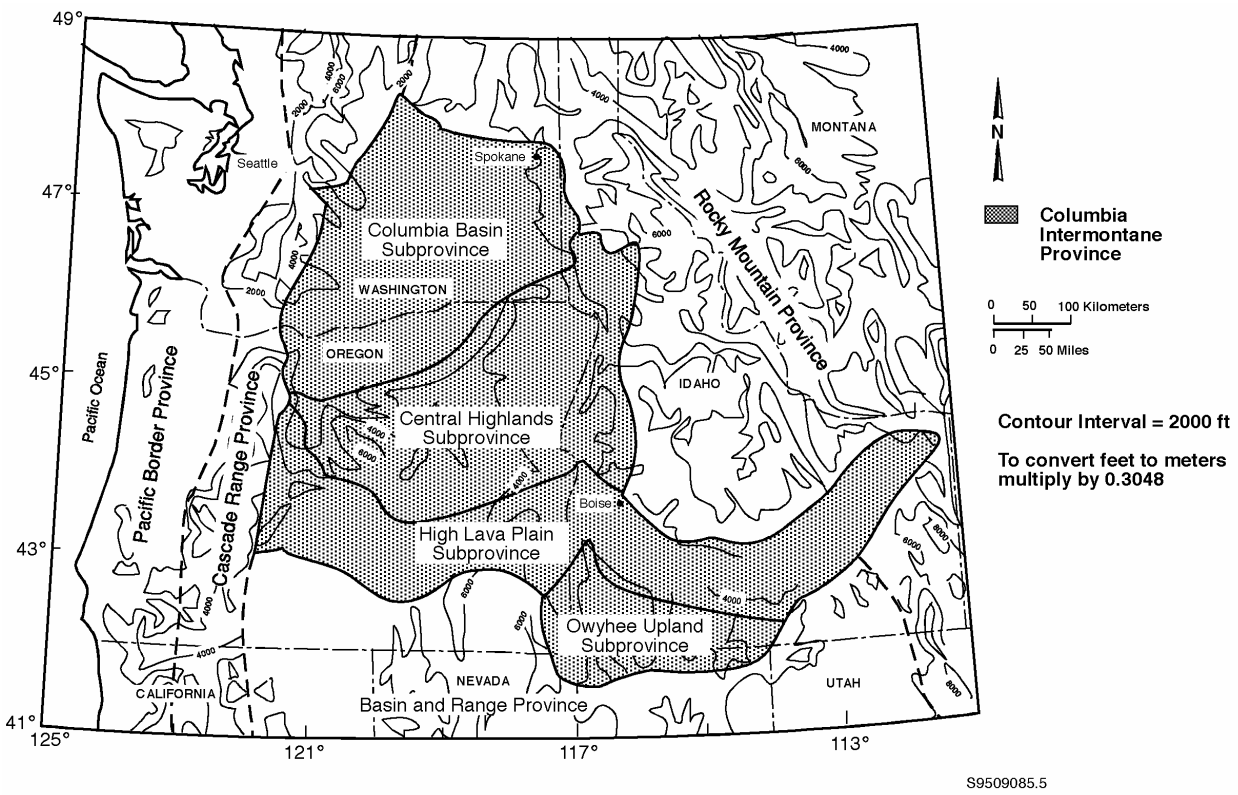


Figure 2-6. Divisions of the Intermontane Physiographic and Adjacent Snake River Plains Provinces.



Glacier-related flooding has had a major impact on the physical geography. Cataclysmic flooding occurred when ice dams in western Montana and northern Idaho were breached, allowing large volumes of water to spill across eastern and central Washington. The last major flood occurred about 13,000 years ago, during the late Pleistocene Epoch. Interconnected flood channels, giant current ripples, and giant flood bars are among the landforms created by the floods. These formations resulted in heterogeneous and discontinuous characteristics for sediments ranging in size from silts to coarse gravels. These sediments yield a wide range of vadose zone hydraulic properties.

Landslides have had a limited effect on physical geography. Previous landslide activity in the area generally is limited to the White Bluffs area east of the Hanford Site and Rattlesnake Mountain, on the western edge of the Hanford Site. No landslide activity is observed in the Hanford Central Plateau.During the Holocene Epoch (the last 11,000 years), winds have locally reworked the flood sediments. The winds deposited dune sands in the lower elevation and loess (very fine wind-blown silts) around the margins of the Pasco Basin. Generally, anchoring vegetation has stabilized sand dunes. However, they have been reactivated where vegetation has been disturbed. Most sand dunes on the Hanford Site are located southeast of the 200 East Area and are stabilized by vegetation.

The location of the Hanford Site in an intermontane basin helps maintain a semiarid climate with low recharge. Most topographical surface features that could disturb the near-surface hydraulic

characteristics affecting recharge, such as sand dunes and landslides, are not found at the location of the WMA C. Moreover, sand dunes are indicators of past, cumulative wind directions.

2.2.7.3 Stratigraphy. The stratigraphy or geologic layering is not extremely complex in the Hanford Site region. Late Miocene to Pleistocene suprabasalt sediments (2 to 5 million years old) and Miocene-aged basalt (16 to 17 million years old) of the Columbia River Basalt Group lie beneath the Hanford Site. Miocene-aged basalt is exposed at some locations, including Gable Mountain and Gable Butte. The basalts and sediments thicken into the Pasco Basin and generally reach maximum thickness in the Cold Creek syncline, which is southwest of the WMA C. Cenozoic (25 to 65 million years old) sedimentary and volcaniclastic rocks underlying the basalts are not exposed at the surface near the Hanford Site.

Table 2-1 delineates the general stratigraphy of the suprabasalt sedimentation that makes up the vadose zone sediments beneath the WMA C. This table illustrates the degree of heterogeneity and discontinuity in the sediments. The sedimentation is composed largely of Ringold Formation and Hanford formation sediments, with the Hanford formation above the Ringold Formation. At the WMA C, the Hanford formation makes up most of the vadose zone.

The suprabasalt sedimentary sequence at the Hanford Site is about 230 m (750 ft) thick in the west central Cold Creek syncline. This sedimentary sequence pinches out against the Saddle Mountains anticline, Gable Mountain/Umtanum Ridge anticline, Yakima Ridge anticline, and Rattlesnake Hills anticline. The suprabasalt sediments are dominated by laterally extensive deposits assigned to the late Miocene- to Pliocene-aged Ringold Formation and the Pleistocene-aged Hanford formation (Table 2-1). Locally occurring strata assigned to the informally defined Plio-Pleistocene unit and pre-Missoula gravels comprise the remainder of the sequence.

The following sections describe the geology of the Ringold Formation and the Hanford formation sediments in some detail. These sediments are the basis for determining vadose zone hydraulic and geochemical properties for contaminant transport modeling.

Table 2-1. Stratigraphy of the 200 East Area.

Nomenclature Used in this Report		Equivalent of Lindsey (1994a), Lindsey (1996), and Reidel (1992)	Equivalent of Reidel (1994a, 1994b)
Eolian			Qd
Hanford formation		H	Qfs and Qfg
Sandy Sequence	Layer 3	H2	Qfs_3
	Layer 2	H2	Qfs^2
	Layer 1	H2 and HZA	Qfs_1(?)
Basal Gravel Sequence		H3	Qfs_1(?)
Ringold Formation, Member of Wooded Island		Ringold Formation, Member of Wooded Island	P_L~~M~~
	Unit E	Unit E	P_L~~M~~cg
	Lower Mud	Lower Mud	P_L~~M~~c
	Unit A	Lower A	P_L~~M~~cg

? = an uncertain assignment

P_L = Pleistocene era

~~M~~ = Miocene

Q = Quarternary

Ringold Formation. The Ringold Formation varies in thickness throughout the Hanford Site. It is up to 600 ft (183 m) thick in the deepest part of the Cold Creek syncline south of the 200 West Area and 560 ft (170 m) thick in the western Wahluke syncline near the 100 B Area. It pinches out against the Gable Mountain, Yakima Ridge, Saddle Mountains, and Rattlesnake Mountain anticlines (Figure 2-5). It is mostly absent in the northern and northeastern parts of the 200 East Area and adjacent areas to the north near West Pond.

The Ringold Formation consists of fluvial and lacustrine sediments deposited by the ancestral Columbia and Clearwater-Salmon river systems between about 3.4 and 8.5 million years ago. Lindsey (1996) described the Ringold Formation in terms of three informal members: the member of Wooded Island, the member of Taylor Flat, and the member of Savage Island. Of these, only the member of Wooded Island is present beneath the 200 East Area.

The member of Wooded Island consists of five separate units dominated by fluvial gravels (conglomerate). The gravels are designated (from bottom to top) as units A, B/D, C, and E. Fine-grained deposits typical of overbank and lacustrine environments separate the gravel units. The lowermost of the fine-grained sequences is designated the lower mud unit. Only gravel units A and E are present beneath the 200 East Area and the Ringold Formation is entirely absent beneath the north and northeast parts of the 200 East Area (Lindsey 1992, 1994b).

The Ringold Formation conglomerate is a variably indurated clast- and matrix-supported, pebble to cobble gravels with a fine to coarse sand matrix (Lindsey 1996). The most common lithologies are basalt, quartzite, and intermediate to felsic volcanics. Interbedded lenses of silt and sand are

common. Cemented zones within the gravels are discontinuous and of variable thickness. In outcrop, the gravels are massive, planar bedded, or cross-bedded. Lying above the Ringold gravels are silts and sands of the upper Ringold, the member of Taylor Flats, which is not generally present beneath the 200 East Area.

Hanford Formation. The Hanford formation (an informal designation) is up to 210 ft (64 m) thick in the Cold Creek bar near the 200 Areas. It is absent on ridges approximately 1,180 ft (360 m) above sea level.

The Hanford formation overlies the Ringold Formation. The Hanford formation consists of glacio-fluvial sediments deposited by cataclysmic floods from Glacial Lake Missoula, Pluvial Lake Bonneville, and ice-margin lakes. Hanford formation sediments resulted from at least four major glacial events and were deposited between about 1 million years and 13 thousand years ago. The formation consists of pebble to boulder gravel, fine- to coarse-grained sand, and silt to clayey silt. These deposits are divided into three facies: gravel-dominated, sand-dominated, and silt-dominated (Reidel 1992; Lindsey 1992, 1994a, 1994b). These facies are referred to as coarse-grained deposits, plane-laminated sand facies, and rhythmite facies, respectively, in Bjornstad (1987) and Baker (1992). The Hanford formation is present throughout the Hanford Site and is as much as 380 ft (116 m) thick (Delaney 1991).

- **Gravel-Dominated Facies**. This facies generally consists of coarse-grained basaltic sand and granule to boulder gravel. These deposits display an open framework texture, massive bedding, plane to low-angle bedding, and large-scale planar cross bedding in outcrop. Silt content is variable and local interbedded silt and clay have been observed in outcrop. Clay and silt have been found as coatings on clasts but generally not filling open spaces between clasts. The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channelways.

- **Sand-Dominated Facies**. This facies consists of fine- to coarse-grained sand and granule gravel. The sands typically have high basalt content and are commonly referred to as black, gray, or salt-and-pepper sands (Lindsey 1992). They may contain small pebbles and rip-up clasts, pebble-gravel interbeds, and silty interbeds less than 3 ft (1 m) thick. The silt content of the sands varies, but where it is low, a well-sorted and open framework texture is common. The sand facies was deposited adjacent to main flood channelways during the waning stages of flooding. The facies is transitional between the gravel-dominated facies and the silt-dominated facies.

- **Silt-Dominated Facies**. This facies consists of thin bedded, plane-laminated, and ripple cross-laminated silt and fine- to coarse-grained sand. Beds are typically a few centimeters to several tens of centimeters thick and commonly display normal grading (Myers 1979; Bjornstad 1987; DOE 1988b). Local clay-rich beds occur in the silt-dominated facies and paleosols have been observed in cores from the 200 East Area. Sediments of this facies were deposited under slack water conditions and in back flooded areas (DOE 1988b).

Clastic Dikes. Clastic dikes are vertical to subvertical sedimentary structures that cross cut normal sedimentary layering and could effect the vertical movement of water and contaminants. Clastic dikes are a common geologic feature of Pleistocene flood deposits of the Hanford

formation although they also have been found in the underlying Ringold Formation and in Columbia River Basalt Group and intercalated sedimentary interbeds. Clastic dikes on the Hanford Site have been described in detail by Fecht (1998).

Clastic dikes typically occur in swarms and occur as regularly shaped polygonal patterns; irregularly shaped polygonal patterns; preexisting fissure fillings; and random occurrences. Regular polygonal networks resemble 4- to 8-sided polygons. Dikes in irregular-shaped polygon networks generally are crosscutting in both plane and cross-section, resulting in extensive segmentation of the dikes. Clastic dikes often occur in zones of preexisting weakness.

Clastic dikes typically show a wide range in widths, depths, and lengths. The vertical extent of clastic dikes has been observed to range from 12 in (30 cm) to greater than 180 ft (55 m). Clastic dike widths ranges from about 0.4 in (1 mm) to greater than 6.5 ft (2 m) and their length varies from as little as 1.0 ft (0.3 m) to more than 328 ft (100 m).

In general, a clastic dike is composed of an outer skin of clay with coarser infilling material. Clay linings are commonly 0.008 to 0.4 in. (0.03 mm to 1.0 mm) thick, but linings up to about 0.39 in (10 mm) are known. The clay skins may have a great influence on transport both within and adjacent to the clastic dikes. The width of individual infilling layers range from as little as 0.004 in (0.01 mm) to more than 12 in (30 cm) and their length can vary from about 8 in. (0.2 m) to more than 66 ft (20 m). Infilling sediments are typically poor to well-sorted sand, but may contain clay, silt, and gravel.

Clastic dikes have been noted in the Hanford formation sand sequence (Lindberg 1993). Clastic dikes have been found in numerous locations on the 200 Area Plateau where they occur primarily in polygonal networks with dimensions ranging from (98.5 to 787.4 ft) 30 to 240 m (Fecht 1998).

Surficial Deposits. Holocene surficial deposits consist of silt, sand, and gravel that form a veneer less than 16 ft (4.9 m) thick atop much of the Hanford Site. These sediments were deposited by wind and local flood processes.

2.2.7.4 Soils. Hajek (1966) lists and describes the 15 different soil types on the Hanford Site, varying from sand to silty and sandy loam. The following soils are found in the part of the 200 East Area around the WMA C:

- **Burbank Loamy Sand**. This soil is dark-colored, coarse-texture soil underlain by gravel. Surface soil is usually about 16 in. (40 cm) thick but can be 30 in. (76 cm) thick. Gravel content of the subsoil ranges from 20 to 80%.

- **Ephrata Sandy Loam**. The surface is dark colored and subsoil is dark grayish-brown medium-texture soil underlain by gravelly material, which may continue for many feet.

- **Rupert Sand.** This soil is brown to grayish brown coarse sand grading to dark grayish-brown at about 35 in. (90 cm). Rupert sand developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by wind-blown sand.

2.2.7.5 Earthquakes. Seismic events can accelerate the degradation of WMA C facilities and the materials (grout) used to close them.

Faults and History of Earthquakes. The Hanford Site lies in the Pasco Basin near the eastern limit of the Yakima Foldbelt. The Site is underlain by basalt of the Columbia River Basalt Group, which is covered by up to 700 ft (213 m) of relatively stiff sediments. It is in an area of low-magnitude seismicity and is under north-south compressional stress, which is reflected in the deformation of the Yakima folds. The following sources are major contributors to the seismic hazard in and around the Hanford Site:

- Fault sources related to the Yakima folds
- Shallow basalt sources that account for the observed seismicity within the Columbia River Basalt Group and are not associated with the Yakima Folds
- Crystalline basement source region
- Cascadia Subduction Zone earthquakes.

Earthquake activity at the WMA C is typical of the Hanford Site. Figure 2-7 shows the location of earthquakes that have occurred near the 200 East Area since monitoring began at the Hanford Site in 1969. Most of the earthquakes have been less than coda magnitude 3.0. Coda magnitude is a local magnitude and is an estimate of the Richter magnitude. Of the earthquakes shown on Figure 2-7, 33% occurred in the Columbia River Basalt Group (CRBG), 16 % in the subbasalt sediments, and 51% in the crystalline basement.

The principal geologic structures described in *Geologic Map of the Richland 1:100,000 Quadrangle, Washington*, Open File Report 94-8 (Reidel 1994a), are reproduced in Figure 2-7. Comparing the location of earthquakes to the geologic structures shows no apparent pattern.

The largest historical earthquake in the Columbia Plateau occurred in 1936 near Milton-Freewater, Oregon, approximately 90 km (54 mi) east of the site. The earthquake had a magnitude of 5.75 and was followed by a number of aftershocks. The ground motion from this event is estimated to have been less than 0.03 g at the Hanford Site.

A seismic monitoring network has been operated in and around the Site since 1969. The network, operated by DOE, can locate all earthquakes of magnitude 1.5 and larger on or near the Hanford Site, and those of magnitude 2.0 and larger throughout south-central and south-eastern Washington State. The largest recorded earthquake on the Hanford Site had a magnitude of 3.8 near Coyote Rapids in 1971 and was felt in the 100 N Area.

Seismic Hazard Assessment. This section explains the earthquake ground motions that the facility is expected to experience during the performance period. Deformation and cracking from earthquake ground motion may physically degrade the engineered system.

A probabilistic seismic hazard analysis was recently completed for the Hanford Site (Geomatrix 1996). Previous seismic hazard analyses were done for Energy Northwest's WNP-

1/4 and WNP-2, which also are located on the Hanford Site (Power 1981). Woodward Clyde Consultants (WCC 1989) later applied the Energy Northwest study to the Hanford Site areas under DOE control. The mean seismic hazard curves for the 200 West, 200 East, and 400 Areas are shown in Figure 2-8. The 200 West Area ground motion values are shown for the selected time period in Table 2-2. (See Geomatrix [1996] for details including response spectra.)

Figure 2-7. Map Showing the Location of Earthquakes Detected From 1969 to 1999.

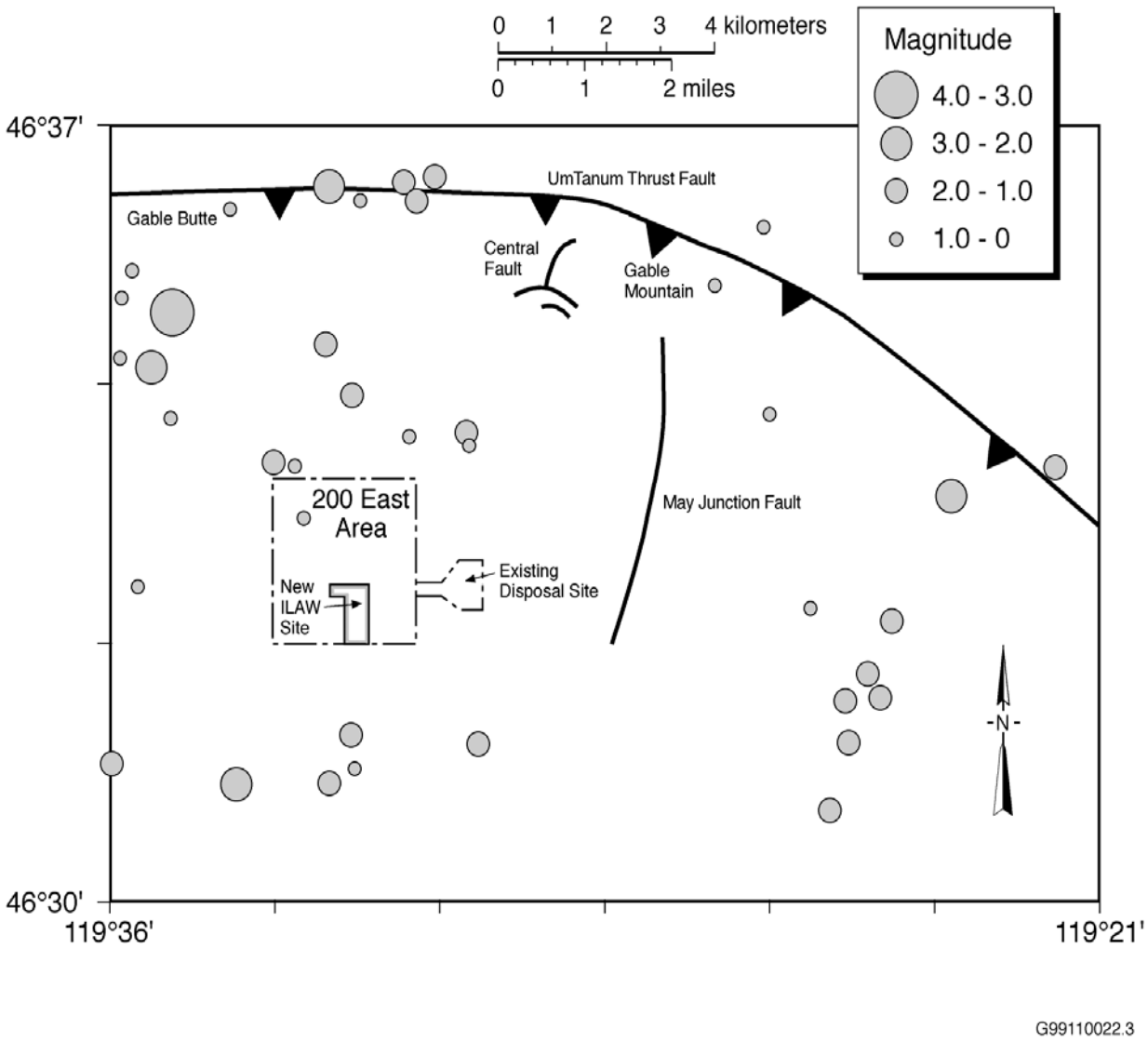


Table 2-2. Approximate Probability of Exceeding Given Ground Motions During Selected Time Periods.

Ground Motion (g)		Return Period (Years)	Annual Probability of Exceedence (p)	EP[a] over 50 years (%)	EP over 1,000 years (%)	EP over 10,000 years (%)
Horizontal	Vertical					
0.19	0.11	1,000.0	1×10^{-3}	5.0	63	100
0.26	0.16	2,000.0[b]	5×10^{-4}	2.0	39	99
0.37	0.25	5,000.0	2×10^{-4}	1.0	18	86
0.48	0.33	10,000.0	1×10^{-4}	0.5	10	63

[a]$EP = 1-(1-p)^n$

where:

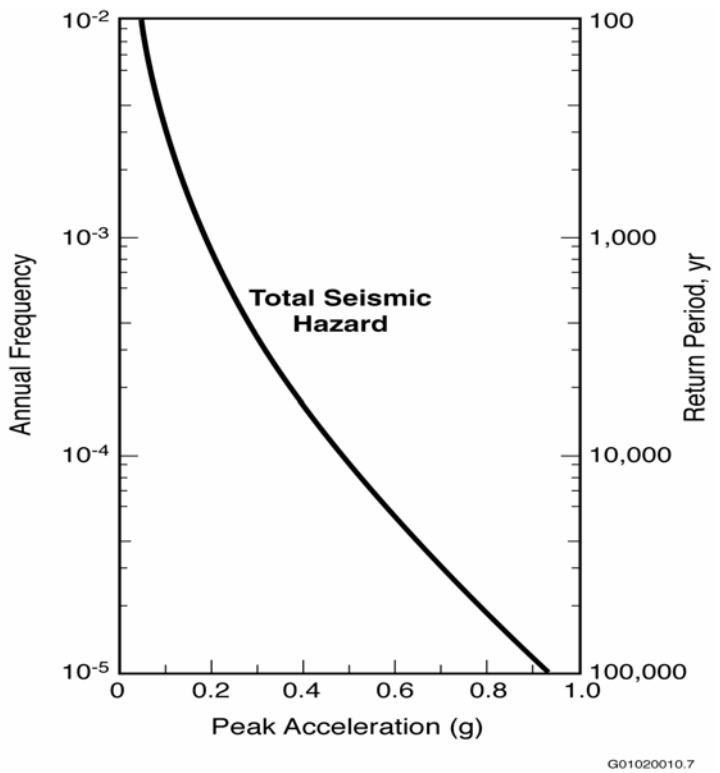
p = the annual probability of exceedence,

n = the performance life

EP = the probability of exceedence over the performance life.

[b]Performance Category 3, DOE Order 5480.28.

Figure 2-8. Total Mean Seismic Hazard for 200 Area Plateau, Hanford Site.



2.2.7.6 Volcanology. Several major volcanoes are located in the Cascade Range, west of the Hanford Site. The nearest volcano, Mount Adams, is about 100 mi (160 km) from the Hanford Site. The most active volcano, Mount St. Helens, is located approximately 136 mi (220 km) west-southwest of the Hanford Site. Because of the distance from the range, volcanic flows are not expected; the only effect of an eruption would be ash fall. The impacts of any such ash fall are not expected to have any long-term significance to contaminant movement.

2.2.8 Geology of the WMA C

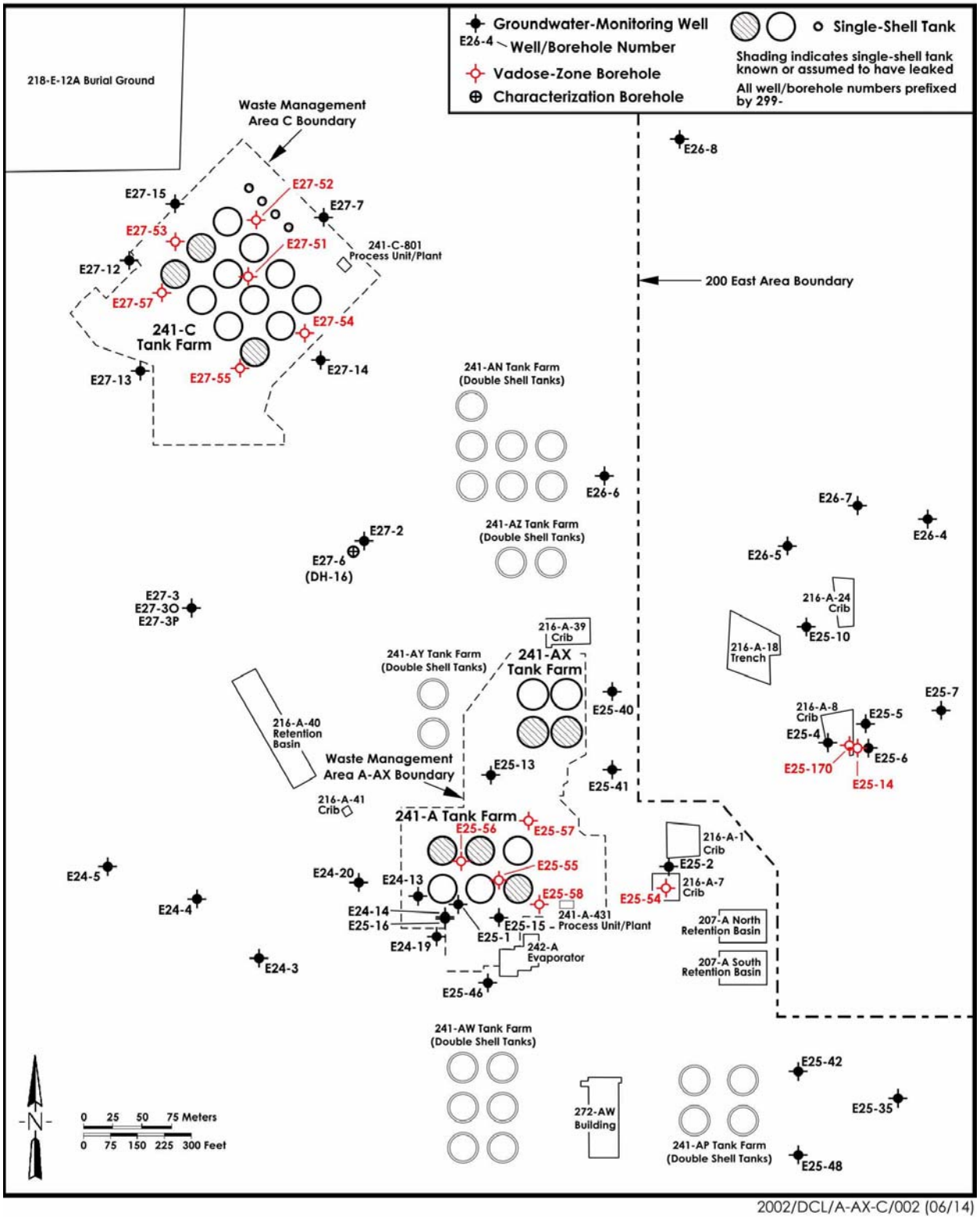
The information in this section is based on the *Subsurface Conditions Description of the C and A-AX Waste Management Areas* (Wood 2003). Information is given below for the area containing both WMAs A-AX and C.

2.2.8.1 Methodology. This analysis is based on a total of 49 boreholes located within 1,000 ft (305 m) of WMAs A-AX and C (Figure 2-9) and contains an update of previous geologic descriptions given for these areas (Caggiano and Goodwin 1991; Williams et al. 2000; Narbutovskih 2001; and Horton 2001). The resulting conceptual model was compared to regional studies to assure coherence within the larger framework of stratigraphic interpretations. The information in this section provides the framework for subsequent consideration of stratigraphic and structural controls on moisture and waste movement through the vadose zone to groundwater.

Borehole data consisting of driller's logs, geologist's logs, archived samples, and geophysical logs, as well as limited laboratory characterization data (grain-size distribution, calcite [$CaCO_3$], and moisture content), are the principal data sets used to interpret subsurface geology. In addition, numerous reports describing the geology of the area create the foundation from which the model has evolved (e.g. Tallman 1979; DOE 1988b; Last 1989; Lindsey 1992, Connelly 1992, Horton 2001, and Narbutovskih 2001). A summary of the types of data available for the boreholes within 1000 ft (305 m) of WMAs A-AX and C is presented in Table 2-1. Interpretations in this document are biased in favor of the higher-quality boreholes, which have one or more of the following characteristics: 1) recent installation, 2) available geologist logs, 3) available geophysical logs, and 4) available moisture, grain-size, and other characterization data.

Initially, well-site geologists logs or drillers logs were examined and compared to geophysical logs from boreholes. The quality of drilling logs differs because many wells and boreholes were drilled without a geologist present at the site; this is generally true for all boreholes drilled prior to the mid-1980s. Up until that time, driller's would collect sediment samples every 5 ft (1.5 m) and provide general descriptions of the formation materials and problems encountered during drilling. Most of the archived sediment samples from these early (pre-1980) borings were subsequently analyzed in the laboratory for grain-size distribution and $CaCO_3$ content; these results reside in a database called ROCSAN, which is available but no longer maintained. For this study grain-size distribution and wt% $CaCO_3$ plots were generated after manually reentering the data into Microsoft Excel™ spreadsheets from ROCSAN printouts.

Figure 2-9. Well/Borehole Location Map.



The quality of the grain-size distribution data largely depends on the drilling method used. Most boreholes were drilled using the percussion cable-tool method, either with a hard tool or a drive barrel. Those intervals drilled with a hard tool tend to produce more fines because of the pulverizing action of the solid hard-tool bit. The drive-barrel, on the other hand, better preserves the original grain-size distribution, but also can result in some pulverization. The suprabasalt sediments in only two boreholes within the study area were drilled by alternative methods (Table 2-1). Borehole 299-E25-48 was drilled using the air rotary method, which also has a pulverizing effect, and borehole 299-E27-6 (DH-16) was drilled using a diamond core below the 100 ft (30 m) depth (Webster 1977). Of all the methods, diamond core produces the best-quality samples from which to evaluate the subsurface geology.

Beginning in the mid-1980s, geologists were assigned the responsibility for providing lithologic descriptions during drilling, and samples were no longer routinely analyzed in the laboratory. Therefore, most boreholes drilled after the mid-1980s were not analyzed quantitatively in the laboratory for grain-size distribution and wt% $CaCO_3$; qualitative estimates of these parameters were provided on geologists logs, however.

Geophysical logs (e.g., gross-gamma ray), available for most of the boreholes, differ in quality but are useful for identifying some, but not all, stratigraphic contacts. Geophysical logs sometimes show lithologic differences because of differing amounts of natural gamma-ray emitters (most commonly ^{40}K). The proportion of ^{40}K generally increases with decreasing grain size. The gross-gamma log is often more useful than physical samples for accurately determining the depths of fine-grained layers, especially those more than about 3 ft (1 m) thick. However, very thin clay and/or silt layers commonly go undetected on gross gamma logs.

When available, the neutron-moisture log is useful for identifying zones of higher moisture, which are often associated with capillary boundaries including fine-grained intervals. Within the vadose zone, moisture content frequently increases along sedimentary interfaces between materials with contrasting grain size or lithology. Other geophysical logs listed in Table 2-1 (e.g., density, temperature, magnetic, caliper) have not proven particularly useful for stratigraphic interpretation.

2.2.8.2 Geomorphology. WMAs A-AX and C lie along Cold Creek bar, a large compound flood bar formed during Pleistocene ice-age floods (DOE 1988b, Wood et al. 2000). The upper surface of the bar in the 200 East Area forms a broad plain extending westward for several miles. The northern boundary of the bar is defined by a series of northwest-southeast trending flood channels. WMA A-AX is near the apex of the bar at an elevation of about 690 ft (210 m), whereas WMA C lies along the gently sloping, north flank of the bar at an elevation of about 650 ft (198 m).

2.2.8.3 Site Stratigraphy. A total of seven stratigraphic units lie within WMAs A-AX and C. These units are represented on hydrogeologic cross sections and isopach and structure-contour maps:

- Recent deposits
- Hanford formation - upper gravelly sequence (H1 unit)

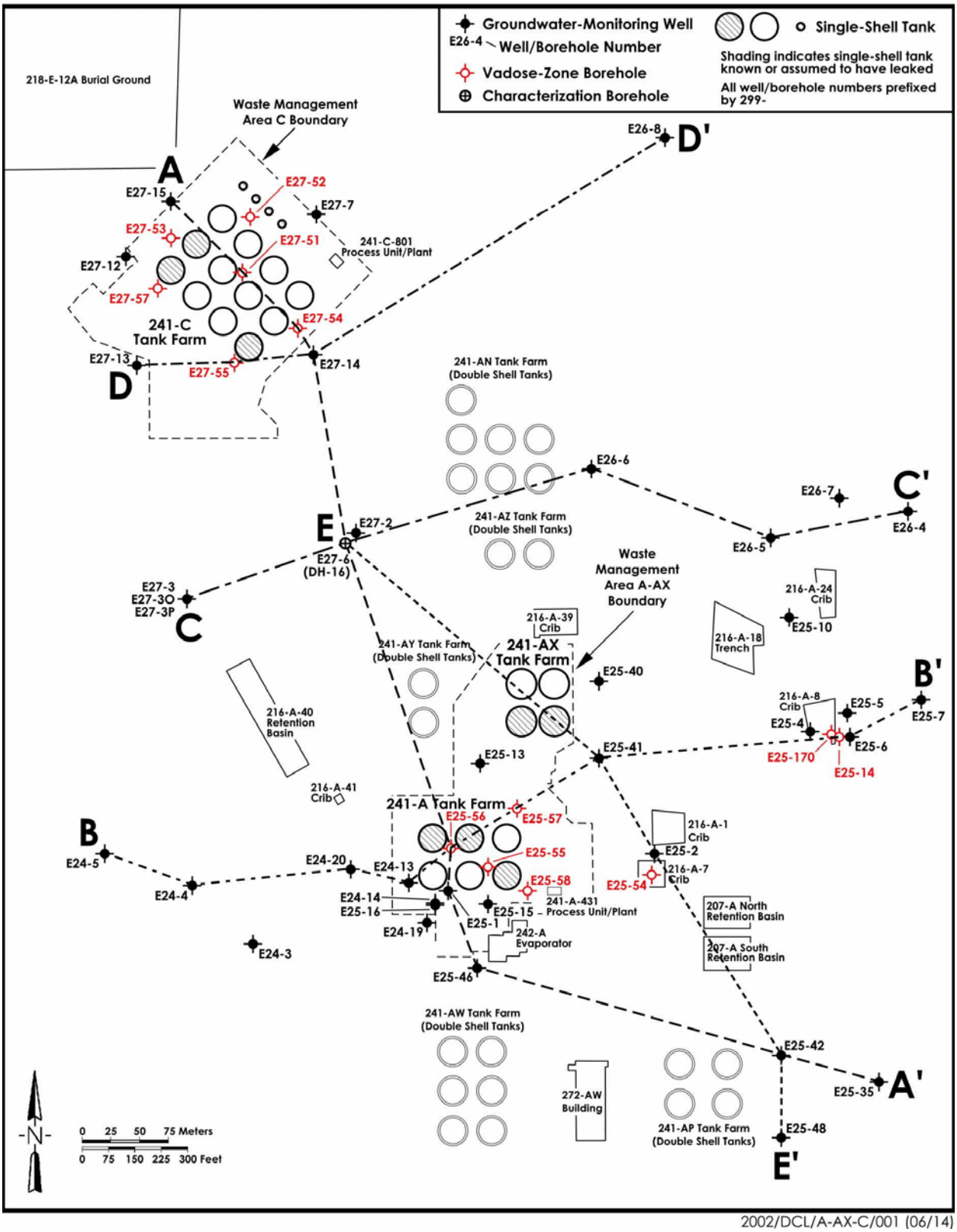
- Hanford formation – sand sequence (H2 unit)
- Hanford formation - lower gravelly sequence (H3 unit)
- Undifferentiated Plio-Pleistocene silt (PPlz) and/or Ringold Formation mud? (PPlz(R)?)
- Undifferentiated Plio-Pleistocene unit gravel (PPlg) and/or Ringold Formation UnitA? (PPlg/(R)?)
- Columbia River Basalt Group.

WMAs A-AX and C were constructed in the near-surface sediments that overlie the Columbia River Basalt Group (i.e., bedrock) on the north limb of the Cold Creek syncline. The oldest suprabasalt sediments in the vicinity of WMAs A-AX and C include, (1) a gravelly sequence belonging to undifferentiated Ringold Formation member of Wooded Island (Unit A) and/or younger fluvial gravel facies of the Plio-Pleistocene unit (PPlg), referred to in this report as PPlg/R(?), overlain by (2) undifferentiated Ringold Formation mud and/or Plio-Pleistocene silt (PPlz), abbreviated here as PPlz/R(?). These deposits predate Pleistocene cataclysmic flooding, which blanketed the area with mostly coarse sand and gravel. Cataclysmic flood deposits, collectively referred to as the Hanford formation, include a lower and upper gravelly sequence, separated by a sand-dominated sequence in the study area. Recent deposits of eolian silty sand and man-made backfill locally overlie flood deposits.

The thickness of the vadose zone beneath the study area ranges from 235 ft (72 m) in the vicinity of WMA C to 295 ft (90 m) around WMA A-AX (Narbutovskih 2001; Horton 2001). The unconfined aquifer is relatively thin (60 to 90 ft [18 to 27 m]) and resides mostly within the undifferentiated Plio-Pleistocene gravels/Ringold Formation Unit A sequence.

Five cross sections were constructed in the study area to include as many higher-quality boreholes as possible to best represent the study area and especially the tank farms. The location of these cross sections are given in Figure 2-10, while Figures 2-11 to 2-14 depict cross sections A-A', C-C', D-D' and E-E', respectively. Stratigraphic contacts for the various units and facies were identified on these cross sections. Elevations and thicknesses for the seven major stratigraphic units were calculated and plotted onto structure-contour and isopach maps, as a way to determine if the contacts are realistic and make sense geologically. If the interpreted depths of contacts are chosen correctly, the data should plot as relatively smooth surfaces transitioning from one borehole to another. Isolated, large, steep-gradient "bull's eyes" on contour maps indicate that the contact may be mislocated; in those cases the interpreted stratigraphic contact would be reevaluated and adjusted as necessary. Final selections for stratigraphic units are presented in the final isopach and structure-contour maps.

Figure 2-10. Cross Section Location Map.



2002/DCL/A-AX-C/001 (06/14)

Figure 2-11. Cross Section A-A'--Northwest to Southeast Section of Vadose Zone Underlying WMAs C and A-AX.

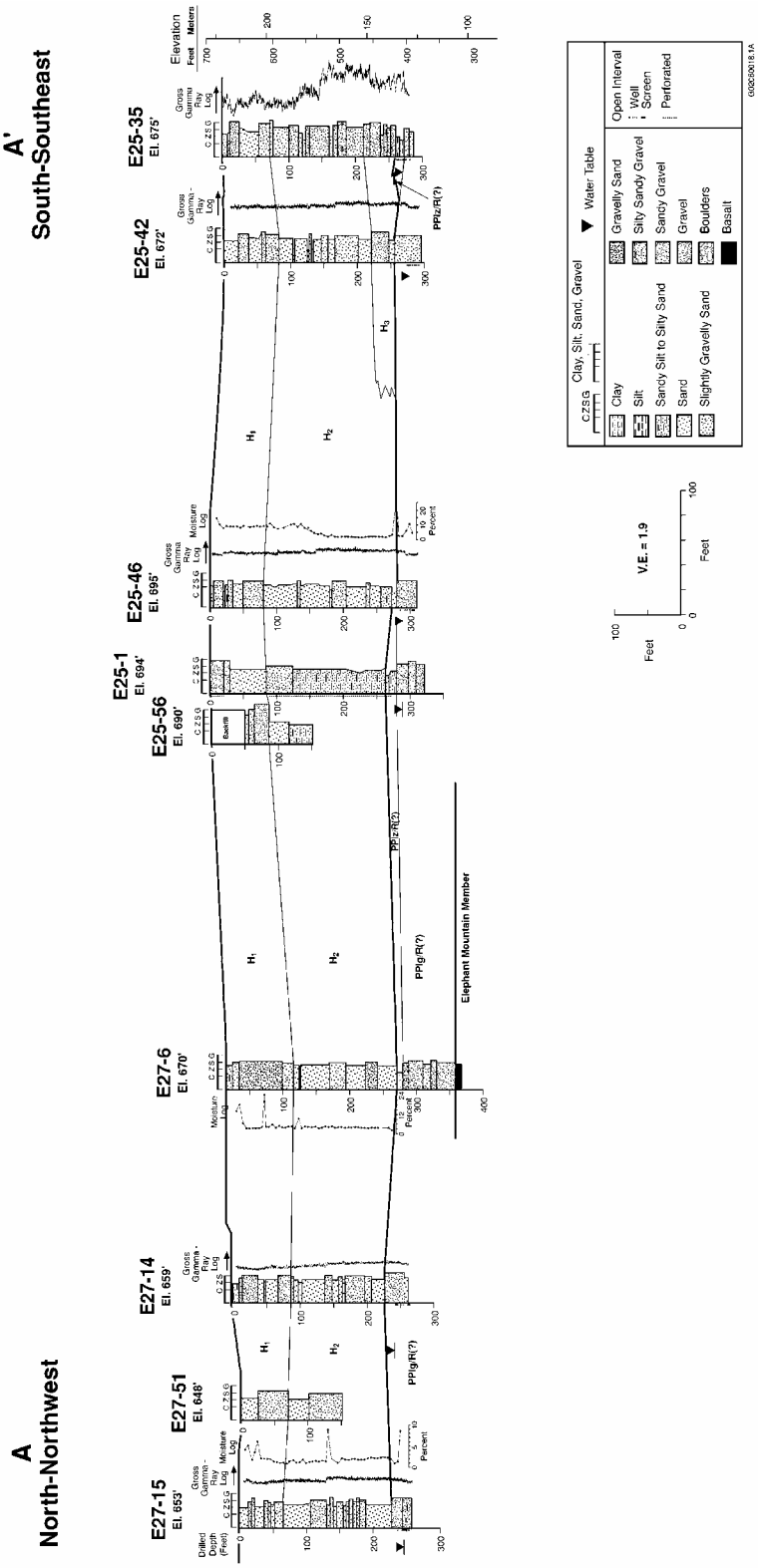


Figure 2-12. Cross Section C-C'--West to East Section of Vadose Zone Between WMAs C and A-AX.

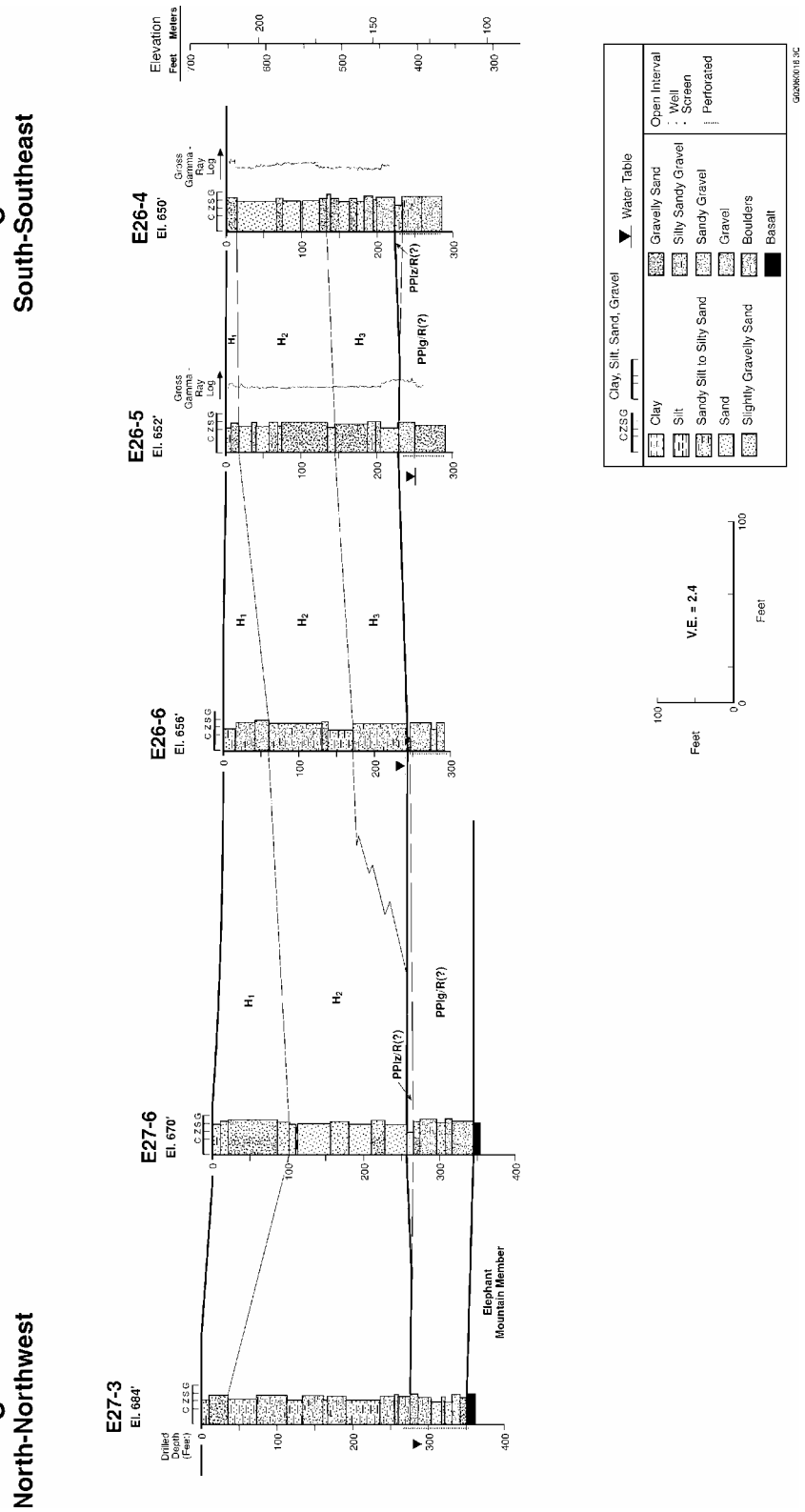


Figure 2-13. Cross Section D-D'--Southwest to Northeast Section of Vadose Zone Just South of WMA C.

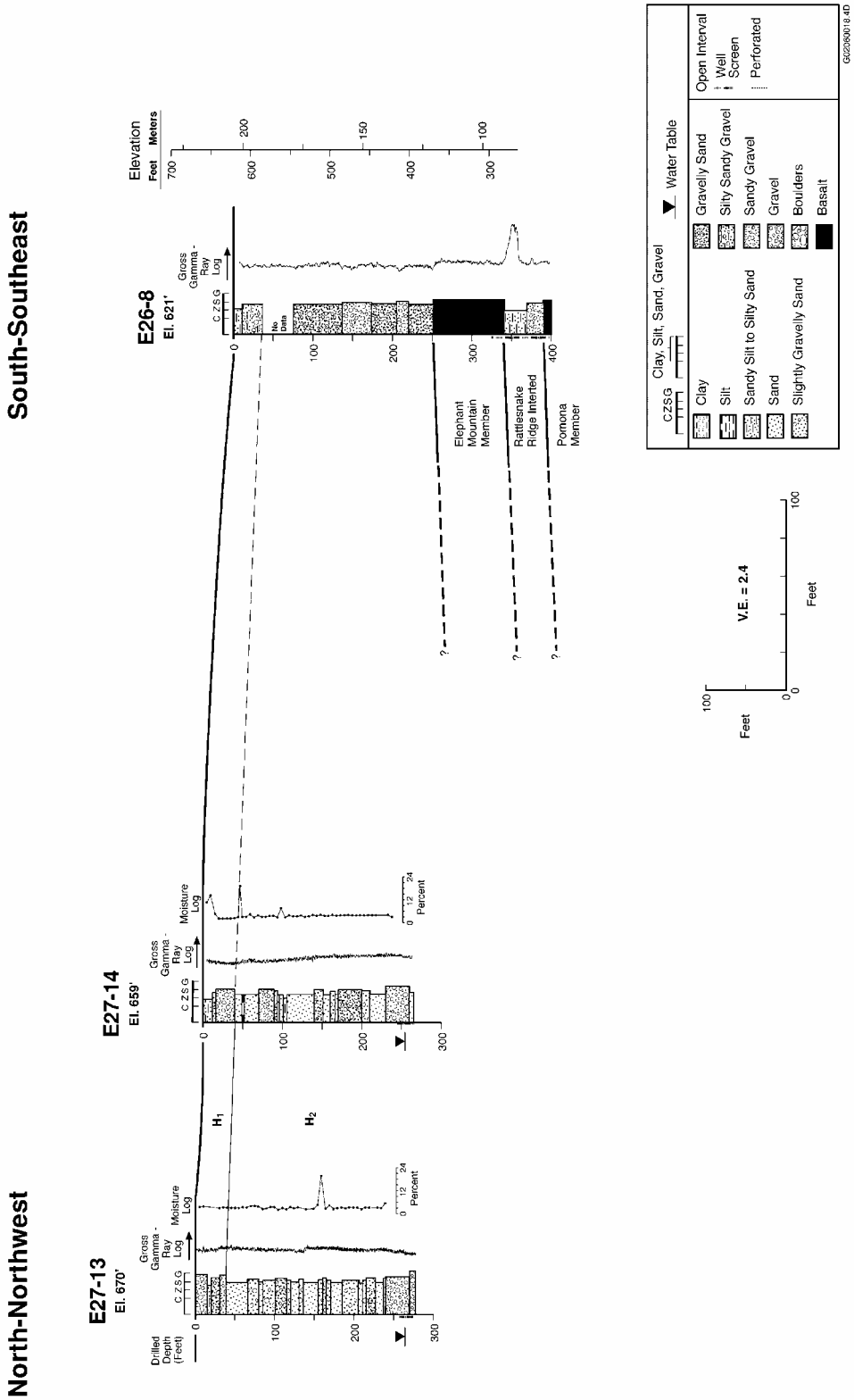
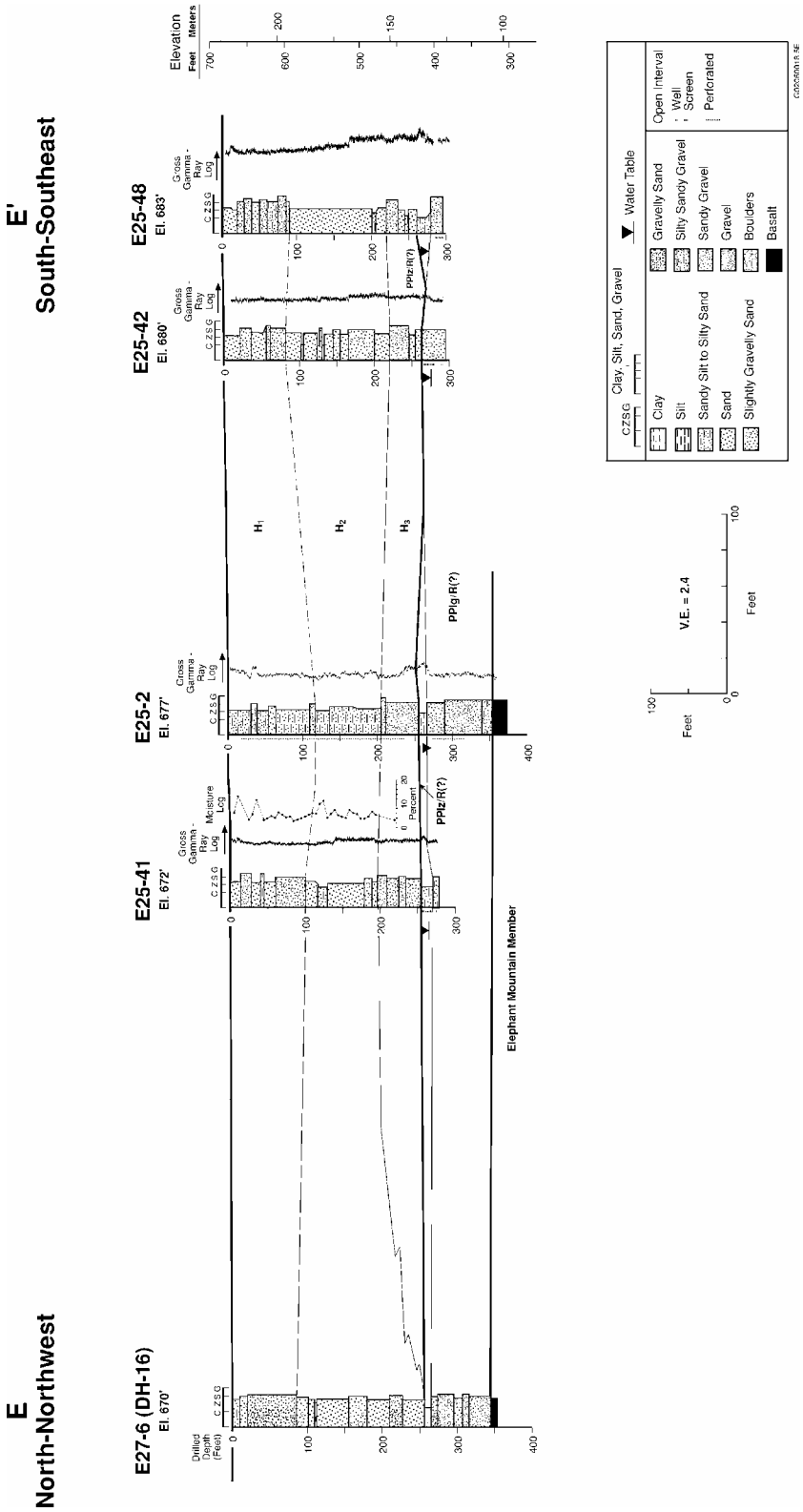


Figure 2-14. Cross Section E-E--Northwest to Southeast Section of Vadose Zone Underlying WMA A-AX.



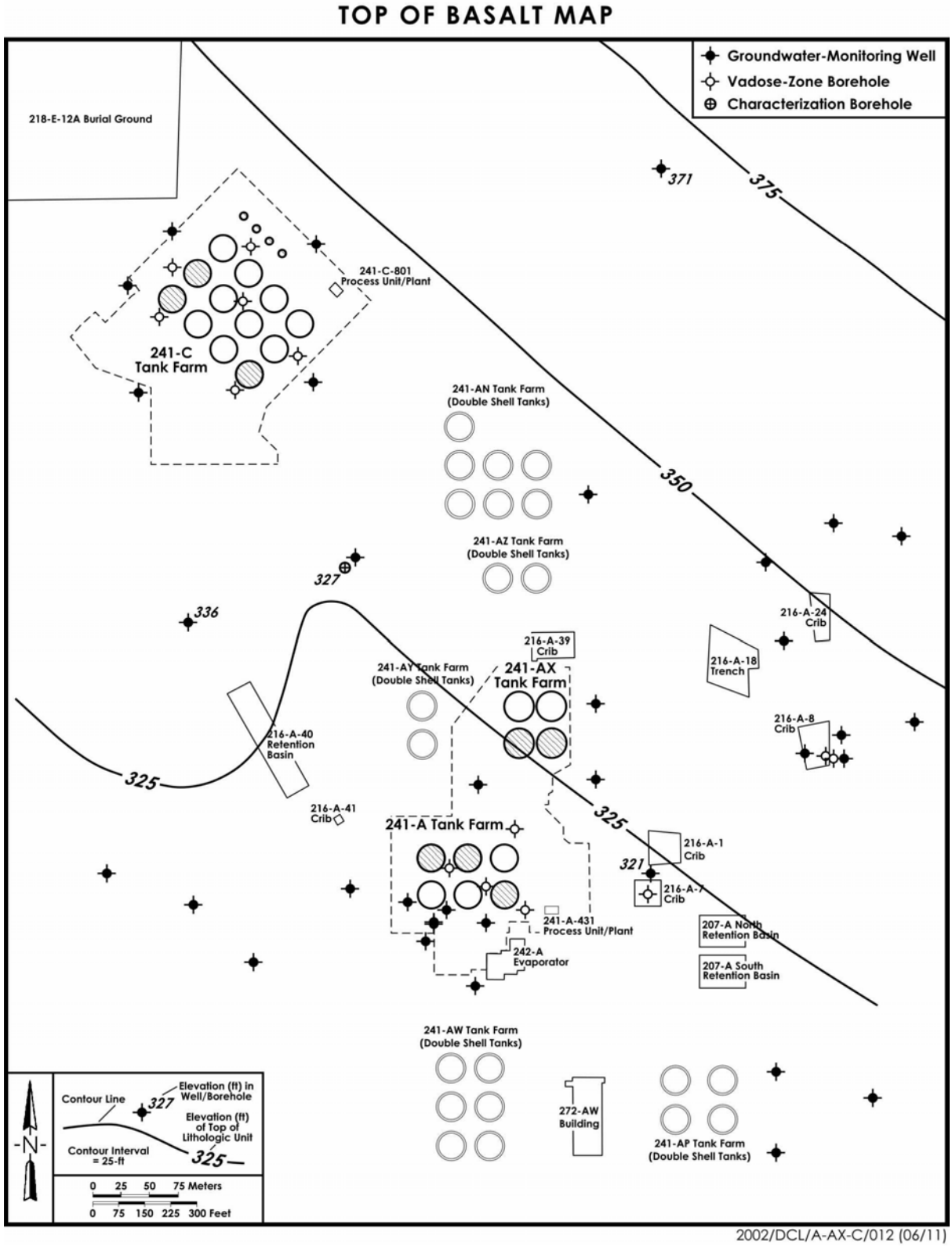
2.2.8.4 Columbia River Basalt Group. The Columbia River Basalt Group (CRBG) forms the bedrock base of the unconfined aquifer under WMAs C and A-AX. Sedimentary interbeds between CRBG flows belong to the Ellensburg Formation. The Elephant Mountain Member of the Saddle Mountains Basalt formation is a medium to fine-grained tholeiitic basalt with abundant microphenocrysts of plagioclase (DOE 1988b). The Elephant Mountain Member has been dated by the K/Ar method at 10.5 Ma (McKee 1977) and consists of two flows beneath the 200 East Area. The Elephant Mountain Member represent the youngest basalt flows in the study area; the top of the member lies at depths between 250 to 360 ft (75 to 110 m) below ground surface (bgs) within the study area. The top of basalt dips south toward the axis of the Cold Creek syncline (Connelly 1992). Up to 50 ft (15 m) of topographic relief (Figure 2-15) exists on the basalt surface as a result of tectonic deformation and/or erosion. In general, upper lava flows of the CRBG, as well as the Ellensburg Formation and overlying suprabasalt sediments, thicken to the south toward the axis of the Cold Creek syncline (DOE 1988b).

Only four boreholes (299-E25-2, -E26-8, -E27-3, and -E27-6) within the study area extend to the top of basalt. One borehole (299-E26-8) fully penetrated the Elephant Mountain Member and advanced through the first sedimentary interbed (Rattlesnake Ridge) into the underlying Pomona Member of the CRBG (Figure 2-13). In this borehole, the Elephant Mountain Member and the Rattlesnake Ridge Interbed were 90 ft (27 m) and 50 ft (15 m) thick, respectively.

2.2.8.5 Undifferentiated Plio-Pleistocene Unit/Ringold Formation. Where not eroded away, the Ringold Formation overlies Columbia River basalt in the central Pasco Basin (DOE 1998b). The Ringold Formation in this area consists of multilithic, clast-supported to matrix-supported, variably cemented and/or limonitic-stained, sandy gravel sequences. Ringold Formation gravel sequences are occasionally separated by thinner sequences of horizontally laminated, ripple laminated and/or massive, locally calcareous sand, silt, and clay in various shades of blue, olive, gray, and brown (Lindsey 1995). Sands are generally well-sorted and predominantly quartzo-feldspathic (i.e., light colored). The gravels represent fluvial channel-fill and braidplain deposits while intervening fine-grained deposits are interpreted as lacustrine and/or fluvial overbank-paleosol deposits.

It is uncertain how much, if any, of the Ringold Formation is present beneath WMAs C and A-AX. This area lies at or near the axis of a paleochannel that removed most or all of the Ringold Formation from the northern half of the 200 East Area (Williams et al. 2000). Thus, most or all the Ringold Formation may have been removed from beneath the study area, either by fluvial processes that postdate the Ringold Formation and/or by Ice-Age cataclysmic flooding. Some previous work, however, includes erosional remnants of the Ringold Formation beneath WMAs A-AX and C (Lindsey 1992, Connelly 1992, Narbutovskih 2001).

Figure 2-15. Structure Contour Map of the Top of Basalt.

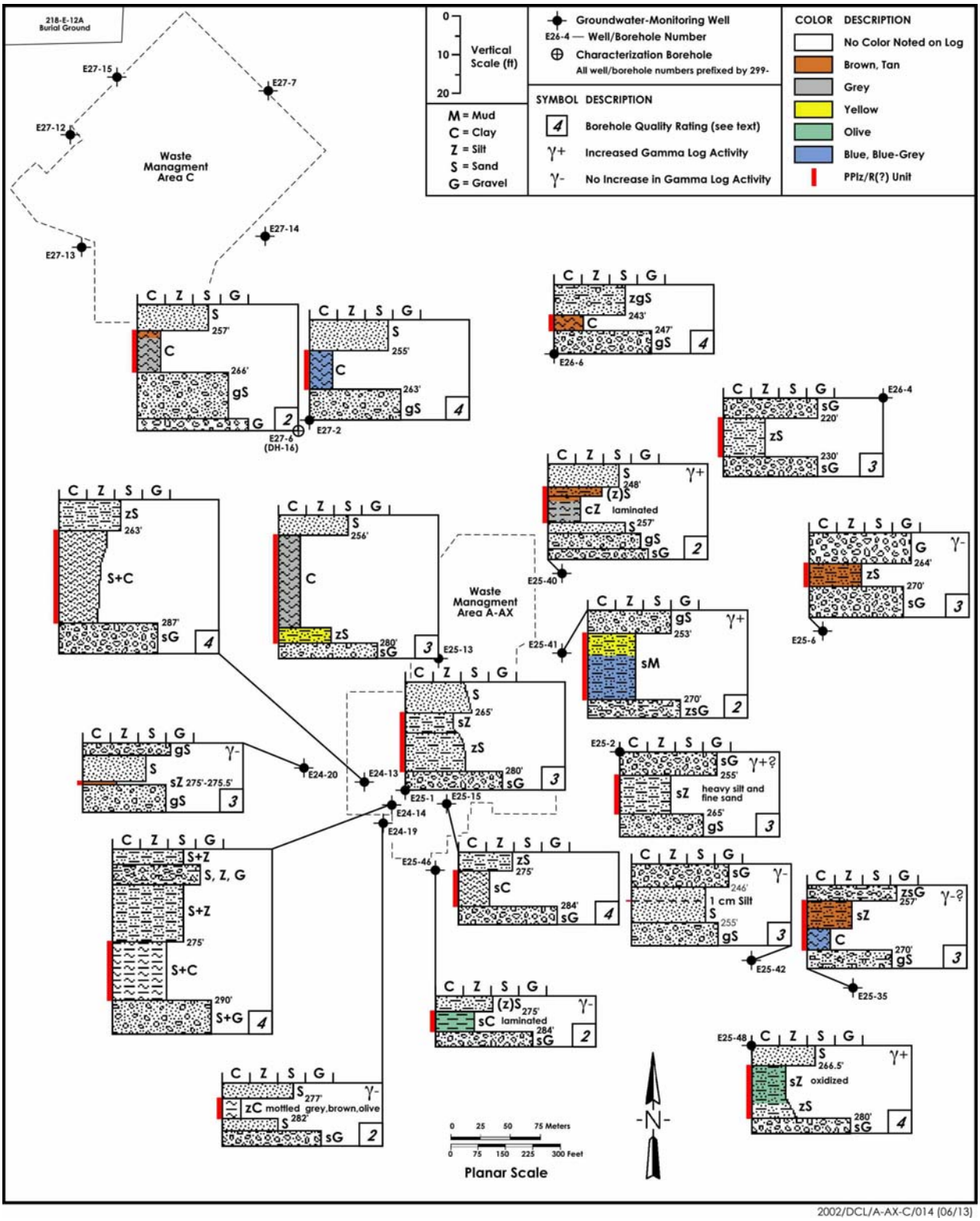


The southeast-trending paleochannel underlying WMAs A-AX and C postdates regional incision of the Ringold Formation and marks the path of the ancestral Columbia River as it flowed through a topographic low at Gable Gap starting sometime after 3.4 Ma (Fecht 1987). The shift of the Columbia River to its present path along the north side of Gable Mountain probably occurred at the onset of the Ice Age and associated cataclysmic flooding. These floods, which began about the beginning of the Pleistocene Epoch 1.5 to 2.5 million years ago as documented in "Long History of Pre-Wisconsin, Ice Age Cataclysmic Floods: Evidence from Southeastern Washington State (Bjornstad 2001), led to further erosion as well as development and progradation of flood bars over the former course of the river. Prior to the Ice-Age floods, however, there was a 1 to 2 million year period during which "normal" fluvial processes might have occurred within the central basin where the ancestral Columbia River continued to flow through Gable Gap and to the southeast. It is during this period that the Plio-Pleistocene unit deposits developed locally on either the eroded Ringold Formation or directly on top of basalt bedrock within the study area.

Similar to the Ringold Formation, Plio-Pleistocene unit deposits in the central basin consist of multilithic, clast-supported sandy gravel. These deposits, previously referred to as Pre-Missoula Gravels in *Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report* (PSPL 1982, Lindsey 1995), have more recently been included as a mainstream-alluvial facies of the Plio-Pleistocene unit (Lindsey 1994b). Unlike the Ringold Formation, mainstream facies of the Plio-Pleistocene unit are generally unconsolidated, have a "whitish" or "bleached" appearance and lack limonitic staining, characteristic of the Ringold Formation. Because the mainstream facies of the Plio-Pleistocene unit consists of essentially reworked fluvial sands and gravels of the Ringold Formation, it is often difficult to distinguish the two units from one another.

Another facies of the Plio-Pleistocene unit beneath the 200 East Area consists of a well-sorted silt to fine sand, which is locally up to 35 ft (10.5 m) thick beneath the B tank farm (Wood 2000). The thickness of this unit, referred to as the Hf/PPu(?) silt by Wood (2000), appears to be too great for the Hanford formation and thus is probably entirely of Plio-Pleistocene age. A fine-grained layer, at about the same relative depth, is also present beneath most of WMA A-AX. The fine-grained layer is discontinuous, however, between this area and northern portion of the 200 East Area as it is missing beneath WMA C. Some of the sample descriptions of the fine-grained unit from WMA A-AX are more like those for the lacustrine/overbank/paleosol facies of the Ringold Formation (i.e., gray-, blue-, or green-colored clay). In other boreholes, however, sample descriptions are more like those for the Plio-Pleistocene silty facies (brown silt to fine sand) (Figure 2-16). Therefore, it is uncertain at this time as to whether this fine-grained unit beneath WMA A-AX represents fine-grained facies of the Ringold Formation or Plio-Pleistocene unit, or both.

Figure 2-16. Heterogeneity within the Undifferentiated Plio-Plestocene Silt/Ringold Formation Mud? [PPlz/R(?)] Unit at Boreholes near the WMAs C and A-AX.



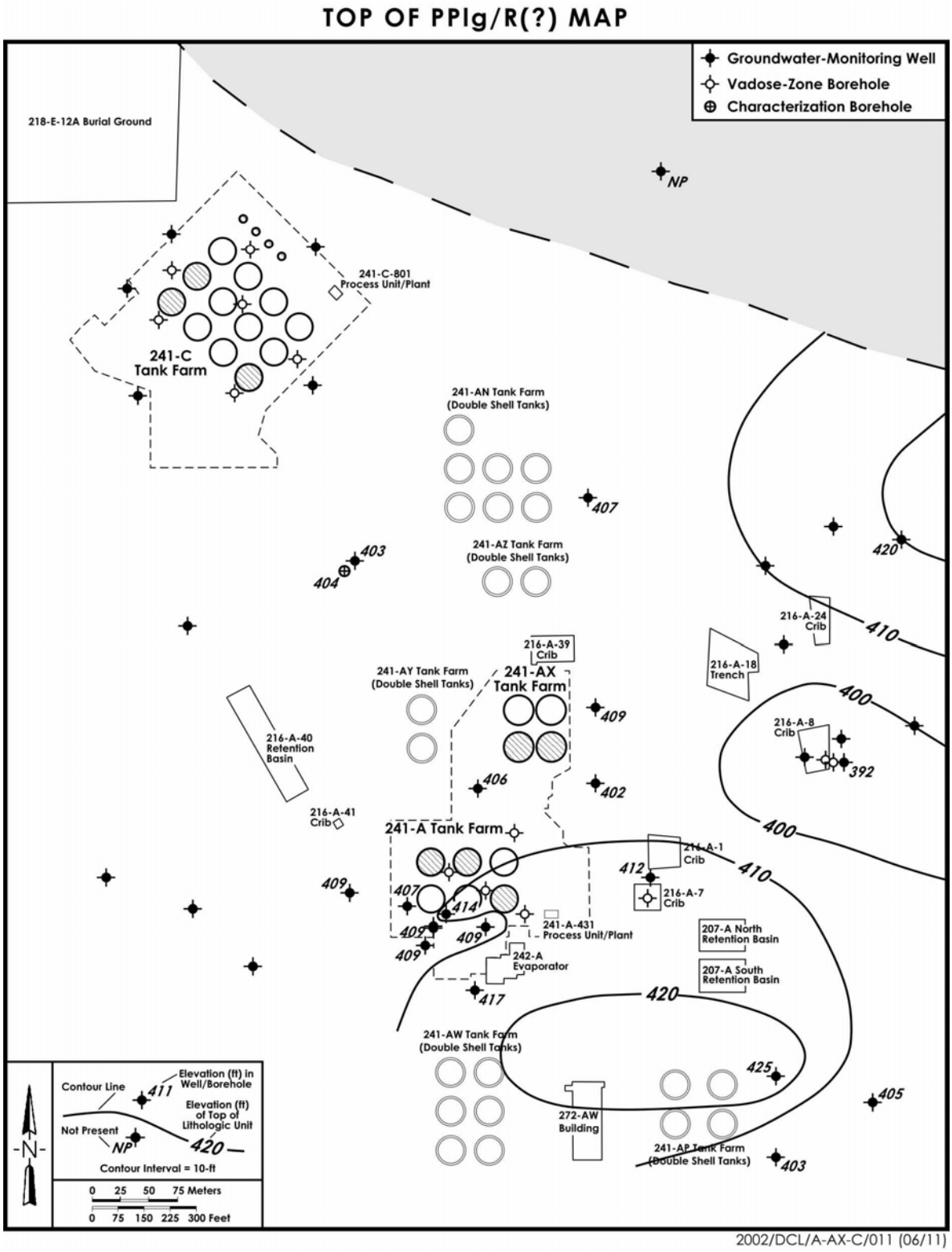
Where present, the top of the fine-grained unit, near the 250 ft (75 m) depth, defines the top of the undifferentiated PPlz/R(?) unit and the base of overlying flood deposits of the Hanford formation. Below the PPlz/R(?) unit is an undifferentiated sequence of Plio-Pleistocene gravel and/or Ringold Formation Unit A, designated PPlg/R(?). Where the fine-grained layer is missing, (e.g., beneath WMA C) it is not possible to differentiate between similar, coarse-grained facies of the Ringold Formation, Plio-Pleistocene unit, and flood gravels of the Hanford formation with the information available.

While these units have similar lithologic characteristics, their transport properties are believed to be very different. Whether this gravel sequence is Ringold, Plio-Pleistocene unit, and/or Hanford formation has important implications for the permeability and flow rate of groundwater in the unconfined aquifer. Overall, Hanford formation gravels are significantly (l0 to 100 times) more permeable than gravel sequences in the Ringold Formation. Plio-Pleistocene-age gravels are probably intermediate between the Ringold and Hanford formations. The differences in permeability are attributed mainly to the higher degree weathering and matrix cementation and induration common in the Ringold sediments (Wurstner 1995).

2.2.8.6 Undifferentiated Plio-Pleistocene Unit Gravel and/or Ringold Formation Unit A (PPlg/R(?)). Gravelly facies immediately overlying basalt within the study area belong to either the Ringold Formation Unit A and/or the Plio-Pleistocene unit. An exception is to the northeast in the vicinity of borehole 299-E26-8 (Figure 2-14), where the top of basalt rises above the depth of post-Ringold-age scouring by Ice-Age floods. It is probable that the PPLg/R(?) unit was completely removed during flooding so that flood deposits of the Hanford formation lie directly on top of basalt bedrock.

The PPLg/R(?) unit consists of predominantly sandy pebble- to cobble-sized gravel with occasional boulders. As a whole the unit shares characteristics of both coarse-grained facies of the Ringold Formation and the Plio-Pleistocene unit. In some boreholes the unit is described as tight, cemented, and brown colored with oxide coatings (characteristics of the Ringold Formation), whereas other boring logs describe the unit as loose, caving to heaving, losing water, gray colored, and clean/unweathered (more characteristic of the Plio-Pleistocene unit). Mineralogically, the sand fraction consists of 15 to 60% basalt grains with generally less than 1 wt% $CaCO_3$. The total thickness of this unit is $\leq$ 90 ft (27 m), based on a limited number of boreholes where the upper and lower boundaries are represented. The top of PPLg/R(?) unit ranges from about 390 to 425 ft (120 to130 m) elevation amsl (Figure 2-17).

Figure 2-17. Structure Contour Map of the Top of the Undifferentiated Plio-Pleistocene Gravels/Ringold Formation Unit A [Pplg/R(?)] Unit.



2.2.8.7 Undifferentiated Plio-Pleistocene Silt and/or Ringold Formation Mud? (PPlz/R(?)). A fine-grained unit, occurring at a depth of about 250 ft (75 m), is described for most boreholes beneath WMA A-AX (Figure 2-9). The fine-grained unit is described on borehole logs of cuttings and samples as clay, silt, sandy silt, and/or silty sand. Some gross gamma-ray logs show a reported increase in activity occasionally accompanied by an increase in moisture. No perched water was noted on top of the sequence (Caggiano 1991), but the water table was higher in the past. Thus, the increased moisture content may be a remnant of a higher water table.

The PPlz/R(?) unit is thickest (up to 24 ft (7.3 m]) in the vicinity of WMA A-AX (Figure 2-18). This unit disappears to the north and is absent beneath the WMA C. Descriptions of this unit on drilling and geologic logs vary significantly, which may be a result of: 1) different subjective descriptions/interpretations by different drillers and geologists, 2) heterogeneities within the unit, which may include multiple lithologic units (e.g., Plio-Pleistocene unit silts overlying Ringold Formation muds), or 3) a combination of these. Where present, this fine-grained unit is described in about half the boreholes as a blue-, gray- or olive-colored clay or mud; remaining boreholes describe the unit as a tan to brown sandy silt to "heavy" silt, which may display a laminated to mottled structure. The former description fits that of Ringold Formation paleosol facies (DOE 1998b), whereas the latter fits descriptions for the Plio-Pleistocene silt facies (Wood et al. 2000), interpreted as eolian-overbank in origin. Unlike most other fine-grained units in the 200 Areas, the PPlz/R(?) unit is generally noncalcareous, containing only a few weight percent or less $CaCO_3$.

The top of the PPlz/R(?) unit ranges from about 400 to 435 ft (122.9 to 132.6) elevation (Figure 2-19). The top of the PPlz/R(?) unit was probably scoured and eroded during Ice-Age flooding as suggested by a southeast-trending trough present at the top of this unit. The PPlz/R(?) unit may have extended further north prior to flooding but was subsequently removed during Ice-Age flooding in the vicinity of WMA C.

2.2.8.8 Hanford Formation. The Hanford formation (informal name) overlies the Ringold Formation and consists of glaciofluvial sediments deposited by Ice-Age cataclysmic floods from glacial Lake Missoula, pluvial Lake Bonneville, and perhaps other ice-margin lakes. Cataclysmic floods were released during major glacial events that occurred during the Pleistocene starting as early as 1.5 to 2.5 Ma (Bjornstad et al. 2001). The Hanford formation consists of pebble- to boulder-size gravel, fine- to coarse-grained sand, and silt (Baker et al. 1992). These deposits are generally divided into three facies associations: 1) gravel-dominated, 2) sand-dominated, and 3) interbedded sand and silt-dominated. The Hanford formation is present throughout the Hanford Site below elevations of about 1,000 ft (305 m). The Hanford formation reaches its maximum thickness of 300 ft (92 m) be 200 East and West Areas beneath the Cold Creek flood bar.

Figure 2-18. Isopach Map of the Undifferentiated Plio-Pleistocene Silt/Ringold Formation Mud? [Pplz/R(?)] Unit.

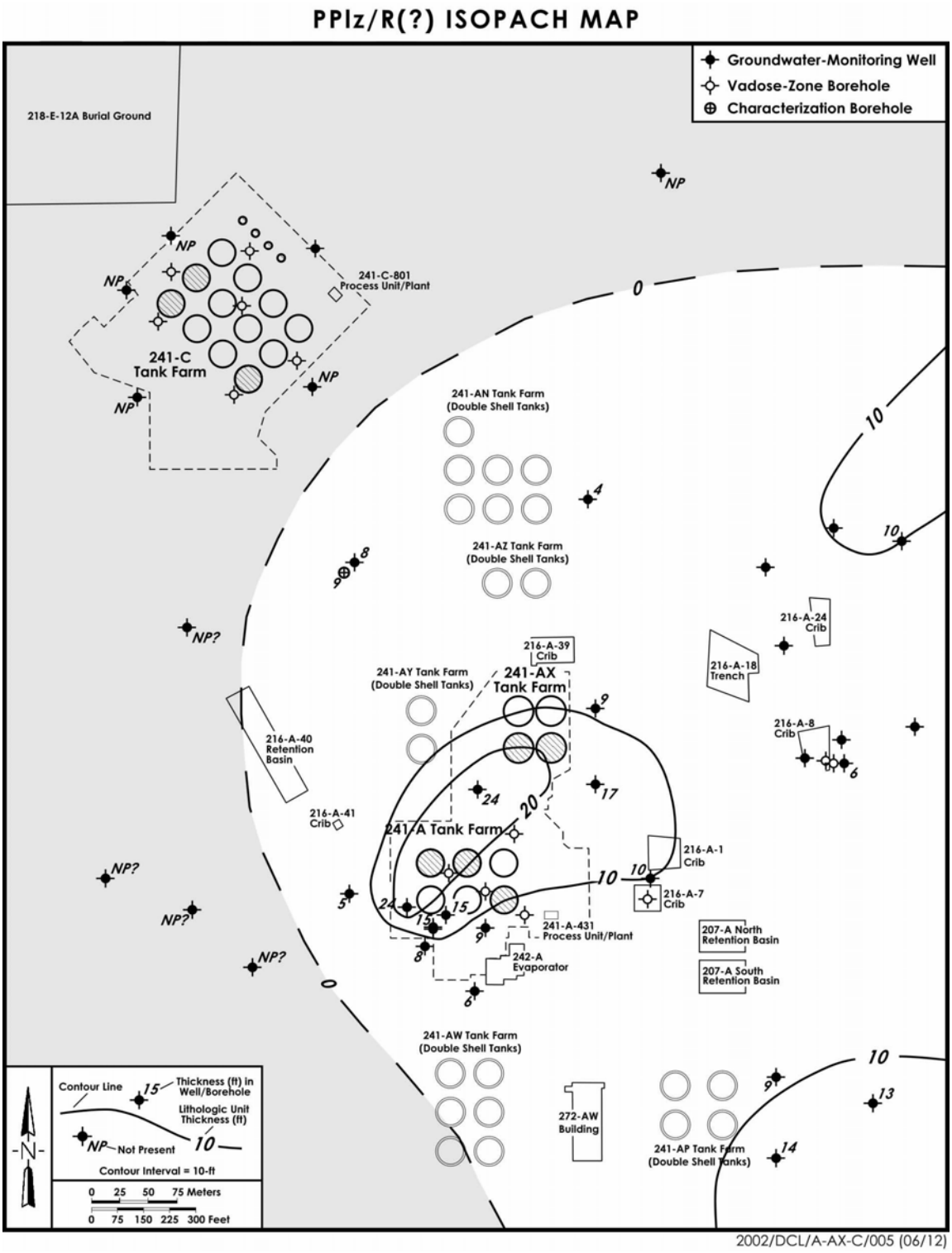
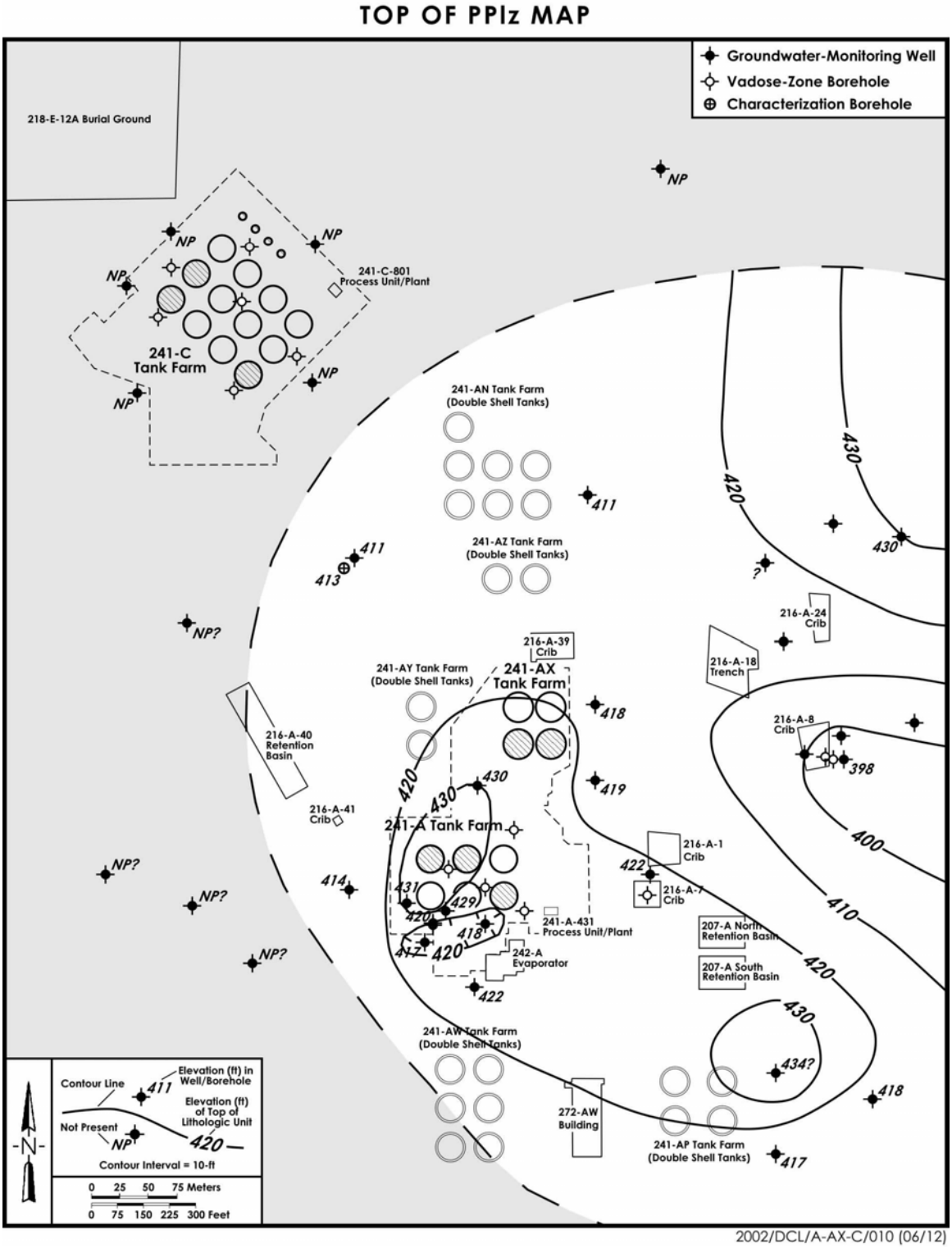


Figure 2-19. Structure Contour Map of the Top of the Undifferentiated Plio-Pleistocene Silt/Ringold Formation Mud? [Pplz/R(?)] Unit.



Coarser-grained sand and gravel fractions of the Hanford formation generally consist of about equal amounts of basaltic and quartzo-feldspathic material (Tallman 1979). This mineral assemblage gives the Hanford formation its characteristic "salt and pepper" appearance, often noted in driller's and geologist's logs. The non-basaltic component consists of predominantly quartz and feldspar with some samples containing greater than 10% pyroxene, amphibole, mica, chlorite, ilmenite and magnetite. The silt- and clay-sized fractions consist of mostly quartz, feldspar, mica and smectite.

The Hanford formation makes up the majority of the suprabasalt sedimentary sequence beneath WMAs C and A-AX, ranging in thickness from 140 to 240 ft (43 to 73 m). The Hanford formation has been divided into three informal units (H1, H2, H3) in the 200 East Area. The Hanford formation H1 and H3 units are gravelly units consisting of predominantly sandy gravel to gravelly sand. The H2 unit is predominantly sand, with occasional beds of slightly gravelly sand. The Hanford formation H1 and H3 units contain a higher percentage of flood gravel, associated with deposition within and along the main ice-age flood channelways. The sand-dominated H2 unit was deposited under less-energetic currents, perhaps further away from the main channelway. The third facies association of the Hanford formation, the interbedded sand and silt-dominated facies, are absent in WMAs C and A-AX.

Gravel-Dominated Facies. This facies generally consists of poorly sorted mixtures of pebble to boulder gravel, fine- to coarse-grained basaltic sand, with variable amounts of silt. Gravel-dominated facies may display massive bedding, horizontal to low-angle bedding, and/or large-scale, planar-tabular cross bedding in outcrop, as well as scour-and-fill channels. An open-framework fabric is also observed in outcrop, characterized by clast-supported basalt-rich gravel without little or no matrix-filling sand/silt. Discontinuous sand and silt beds may be interbedded throughout sequences of gravel-dominated facies. Gravel clasts are dominantly basalt with lesser amounts of reworked, Ringold Formation clasts such as granite, quartzite, and gneiss (Lindsey 1992). The gravel-dominated facies was deposited by high-energy floodwaters in or immediately adjacent to the main cataclysmic flood channels (Baker 1991).

Sand-Dominated Facies. This facies consists of fine- to coarse-grained sand and pebbly gravel. The sands typically display a high basalt content (30 to 70%) with color commonly described as black, gray, or “salt-and-pepper” like. Sand-dominated facies may contain isolated matrix-supported pebbles and rip-up clasts, as well as discontinuous beds of pebble-gravel and/or silty interbeds generally less than 3 ft (0.92 m) thick. The silt content of the sands is variable, but when low, the sands are clean and well-sorted. In outcrop this facies commonly displays horizontal to subhorizontal lamination and bedding. The sand-dominated facies was deposited adjacent to main flood channels during the waning stages of flooding (Baker 1991). The facies is transitional between the gravel-dominated and the interbedded sand and silt-dominated facies associations.

Interbedded Sand and Silt-Dominated Facies. This facies consists of thin-beds of interbedded, horizontal- to ripple cross-laminated fine- to coarse-grained sand and silt. Beds are typically a ≤ 3 ft (0.92 m) thick and commonly display normally graded-bedding. Unlike the other facies associations, in outcrop, individual “rhythmite” beds may be traced laterally for hundreds of

meters or more. Sediments of this facies were deposited under slack-water conditions and in back-flooded areas during cataclysmic flooding (DOE 1998b; Baker 1991). This facies association is generally absent within WMAs A-AX and C .

Lower Gravelly Sequence (H3 Unit). The Hanford formation lower gravelly sequence (H3 unit) locally overlies undifferentiated Plio-Pleistocene/Ringold deposits. This sequence is equivalent to the lower coarse-grained unit of the Hanford formation of Last et al. (1989) and the lower gravel sequence of Lindsey et al. (1992), the Hanford formation H3 sequence of Lindsey et al. (1994a) and the Quarternary flood gravels (Qfg) deposits of *Geologic Map of the Priest Rapids 1:100,000 Quadrangle, Washington* (Reidel 1994a).

The H3 unit consists of predominantly gravelly facies of clast-supported, sandy, pebble to boulder gravel to matrix-supported pebbly sand. The maximum $CaCO_3$ measured is ~2.5 wt%. The sand fraction ranges from 15 to 70% basalt grains, but most often is reported as 40 to 50% basalt. This unit appears to be present everywhere except within the central and southwest portions of the study area; it is generally missing from beneath most of WMA A-AX (Figure 2-20). The unit is probably absent from these areas because of lateral facies changes that take place between gravel-dominated facies to the north and sand-dominated facies to the south away from the primary flood channel that exists north and east of the study area. The greatest thickness (94 ft [28.7 m]) occurs several hundred feet east of WMA A-AX. The exact thickness of the Hanford formation H3 unit beneath WMA C, on the other hand, is uncertain because the underlying PPLz/(R)? unit, used to define the base of the unit, is missing.

A structure-contour map of the top of the Hanford formation H3 unit is shown in Figure 2-21. The surface of this unit slopes to the south and west with the highest elevations occurring in the northeast and east portions of the study area. Coarser-grained facies are more common to the east and north along the axes of flood channels. About 70 ft (20 m) of relief (420 to 490 ft [128 to 149 m] elevation) exists on the surface of the H3 unit beneath WMAs A-AX and C.

Sand Sequence (H2 Unit). The Hanford formation sand sequence overlies the lower gravel sequence (H3 unit). This sand sequence is equivalent to the middle sand unit of Last et al. (1989), the fine sequence of Lindsey et al. (1992), the sandy sequence of Connelly et al. (1992), the Hanford formation H2 sequence of Lindsey et al. (1994a), and to Quaternary flood sands (Qfs) of Reidel and Fecht (1994a).

Figure 2-20. Isopach Map of the Hanford Formation H3 Unit.

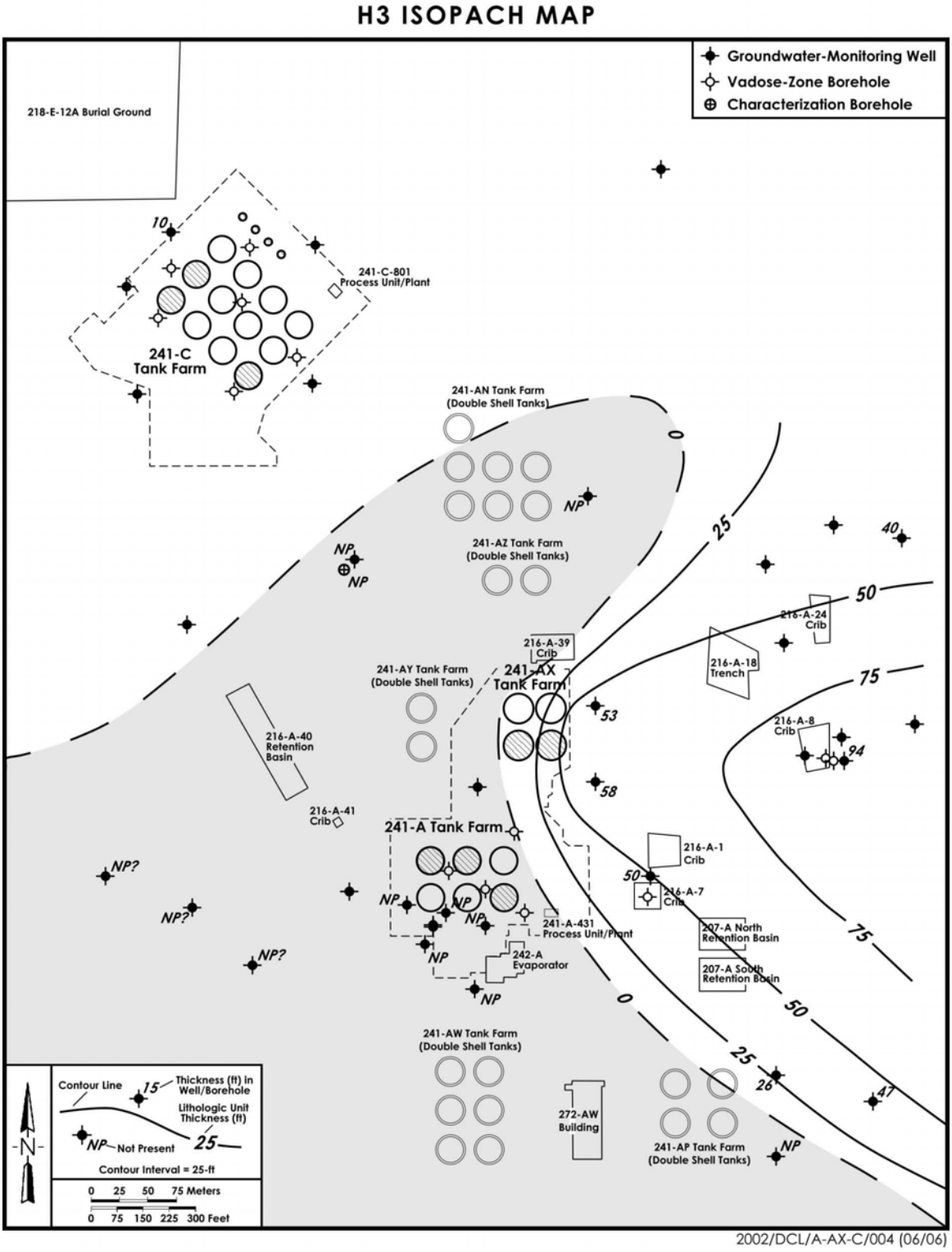
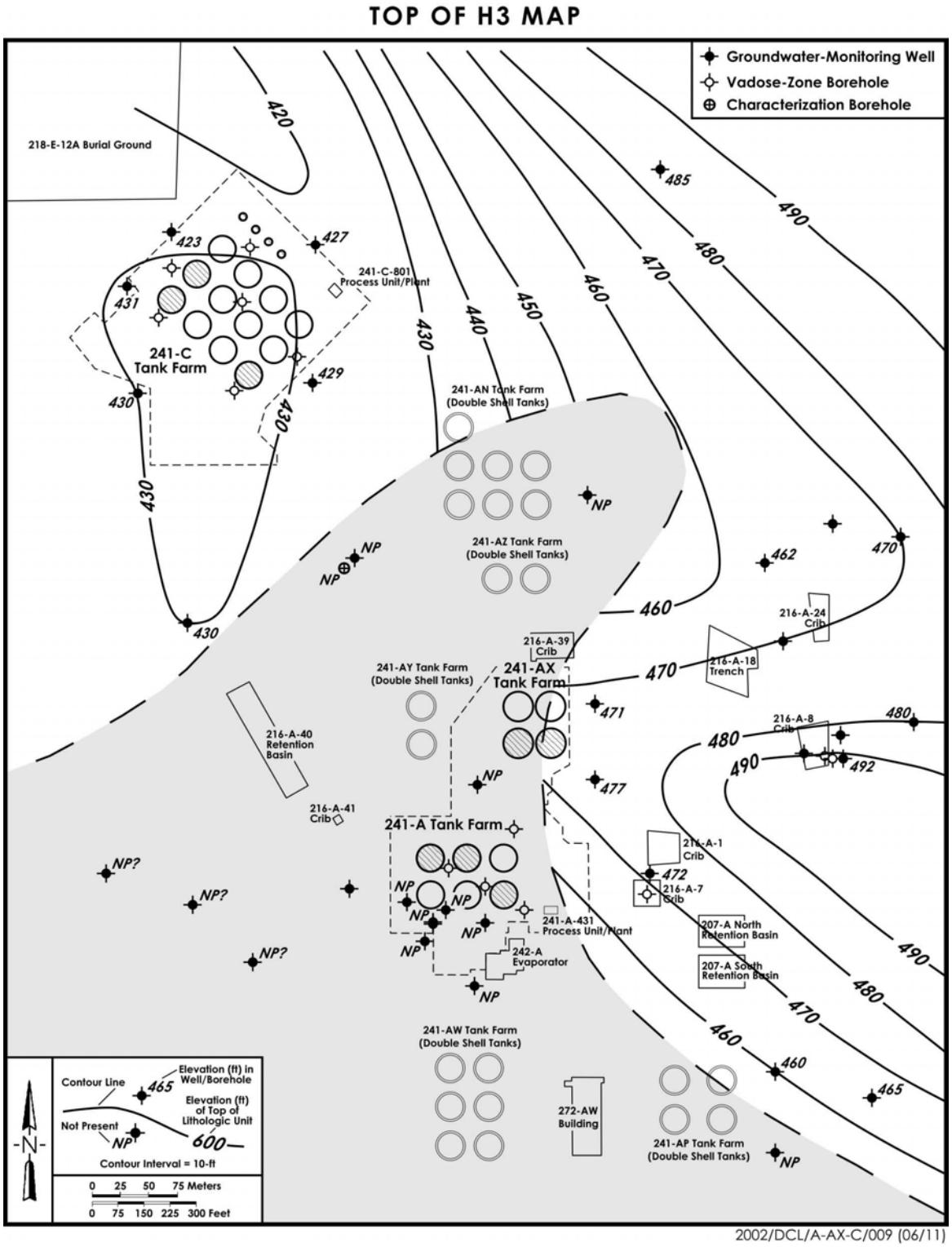


Figure 2-21. Structure Contour Map of the Top of the Hanford Formation H3 Unit.



The H2 unit consists of predominantly sand-dominated facies of the Hanford formation. Fine- to coarse-grained sand dominates with lenses of silty sand to slightly gravelly sand. Minor sandy gravel to gravelly sand beds occur sporadically. Consolidation ranges from loose to compact. Cementation is very minor or absent, and total $CaCO_3$ content is generally only a few weight percent or less. The sand fraction ranges from 10 to 70% basalt grains but most often a basalt content of 30 to 40% is reported. Silt lenses and thinly interbedded zones of silt and sand are common but are not abundant in the Hanford formation H2 unit. These thin (< 1ft [0.3 m]) fine-grained zones generally cannot be correlated among boreholes and are not reflected in the gross gamma-ray logs or moisture data. This is probably because moisture samples are normally collected every 5 ft (1.5 m) during drilling; this sampling interval is too large to detect most thin zones. The fine structure observed in some older gross gamma-ray logs may reflect changes in the silt content that were not detected during drilling.

The Hanford formation sand sequence (H2 unit) underlies the entire area beneath WMAs A-AX and C. The base of the H2 unit is identified as the top of gravelly H3 unit or the top of the fine-grained PPlz/R(?) unit, if the H3 unit is missing. The H2 unit thickens to south and west (Figure 2-22), except beneath WMA A-AX, where the upper portion may have been scoured by a southeast trending Ice-Age flood channel, perhaps associated with deposition of the overlying gravelly sequence (HI unit). This is indicated by a south to southeast-trending trough present at the top of the H2 unit (Figure 2-23). Furthermore, over 100 ft (30.5 m) of relief exists on top of the H2 unit along this trough.

Upper Gravelly Sequence (H1 unit). The Hanford formation upper gravel sequence overlies the Hanford formation sand sequence (H2 unit). This sequence is equivalent to the upper coarse-grained unit of Last et al. (1989), the upper gravel sequence of Lindsey et al. (1992), the Hanford formation H1 sequence of Lindsey et al. (1994a), and the Qfg of Reidel and Fecht (1994a).

The Hanford formation H1 unit consists of predominantly loose, sandy gravel to gravelly sand, with minor beds of sand to silty sand. Coarser beds may contain boulder-sized materials. Only a few weight percent or less $CaCO_3$ has been measured in this unit. Sand fractions range from 10 to 80% basalt, although 40 to 50% basalt is most commonly reported. The Hanford formation H1 unit consists of mostly high-energy, coarse-grained gravel and sand deposits. Occasional thin, discontinuous lenses of fine sand and silt may also be present.

The isopach map of the Hanford formation H1 unit (Figure 2-24) suggests the unit thickens along a northwest-southeast trending trough, which includes WMAs A-AX and C. The H1 unit appears to be missing in the northeast and extreme southwest portions of the study area. The maximum thickness (100 ft (~30 m]) of the H1 unit underlies WMA A-AX. The H1 unit is thinner in the immediate vicinity of the tanks because much of the Hanford formation H1 unit was removed and replaced with backfill during tank-farm operations.

Figure 2-22. Isopach Map of the Hanford Formation H2 Unit.

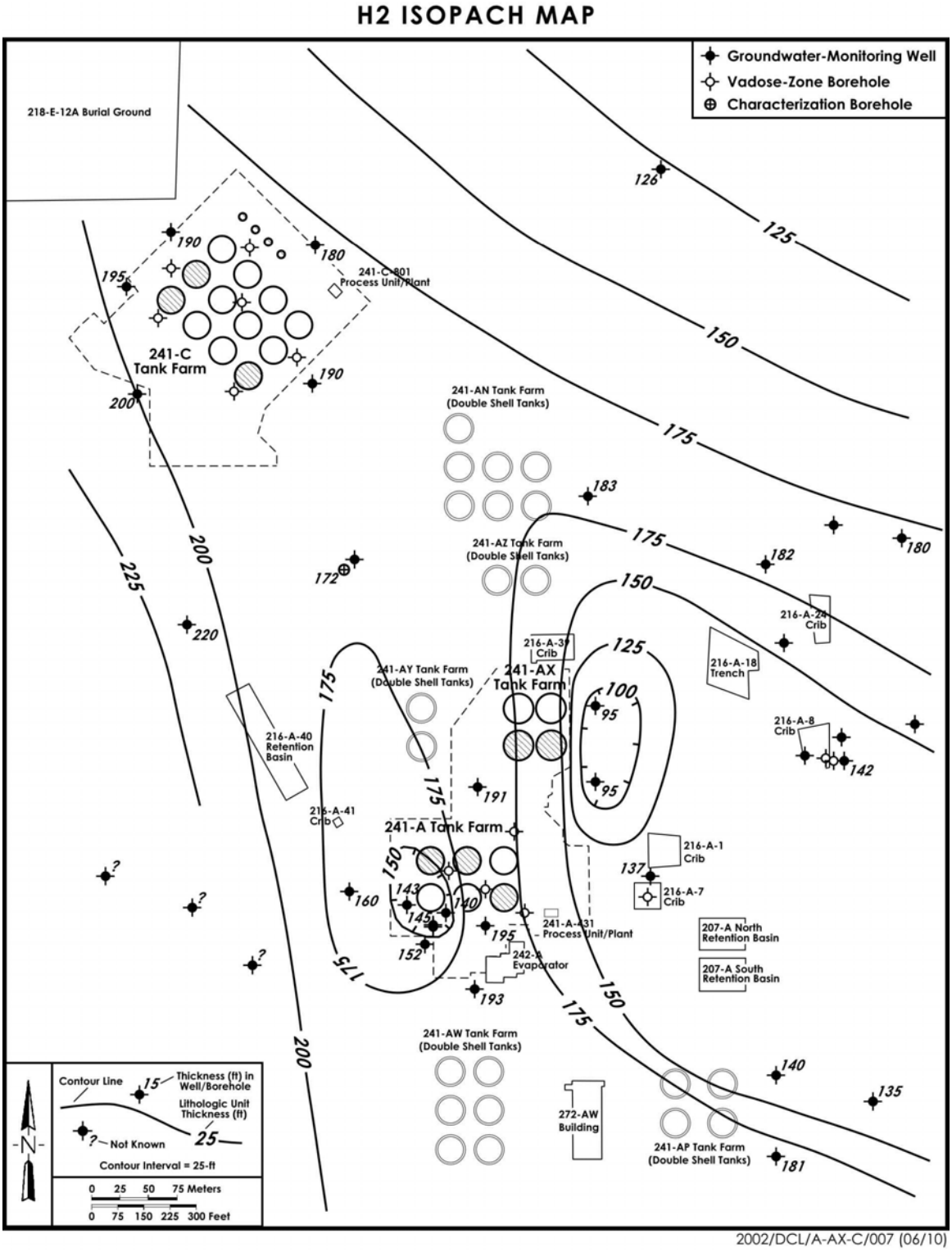


Figure 2-23. Structure Contour Map of the Top of the Hanford Formation H2 Unit.

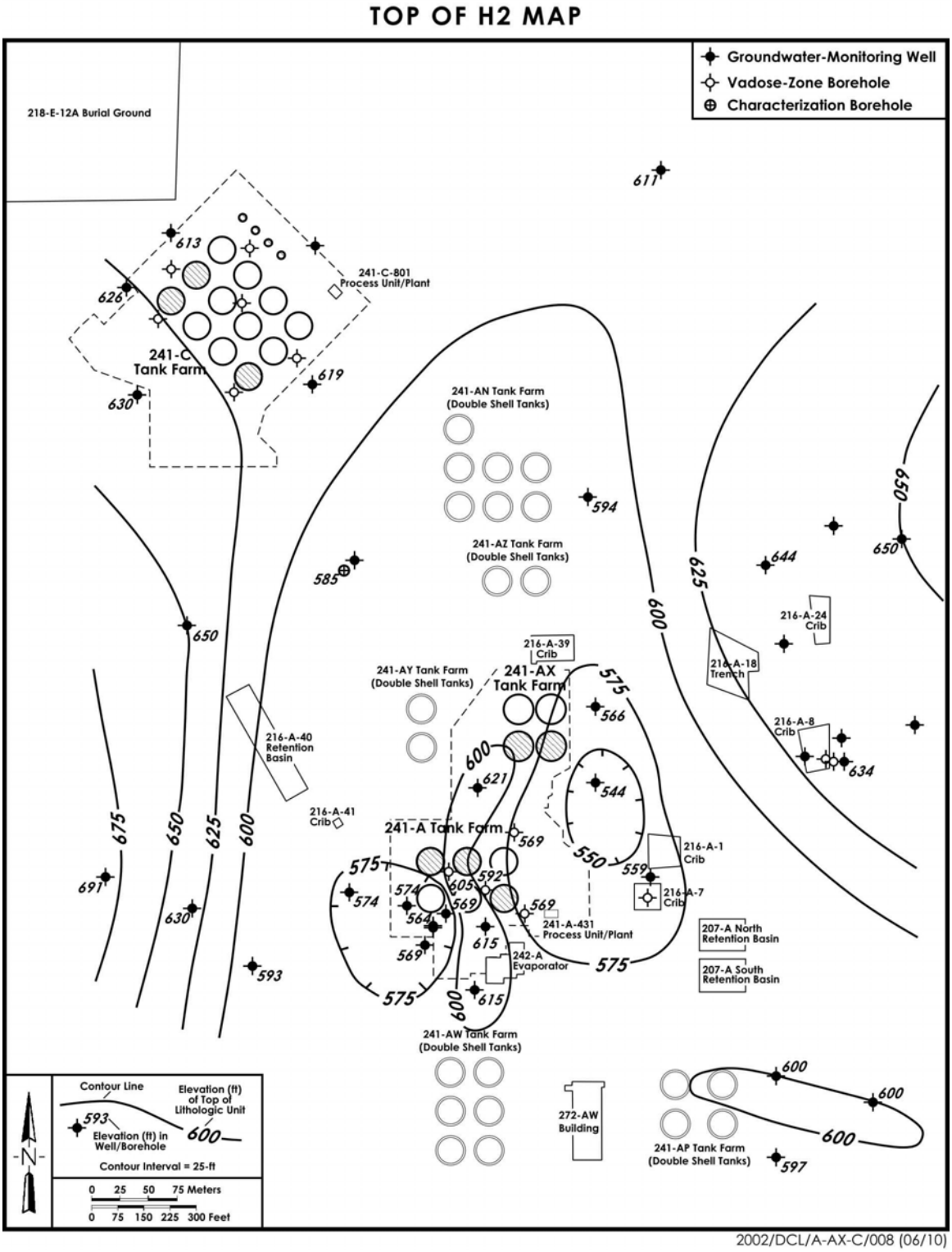
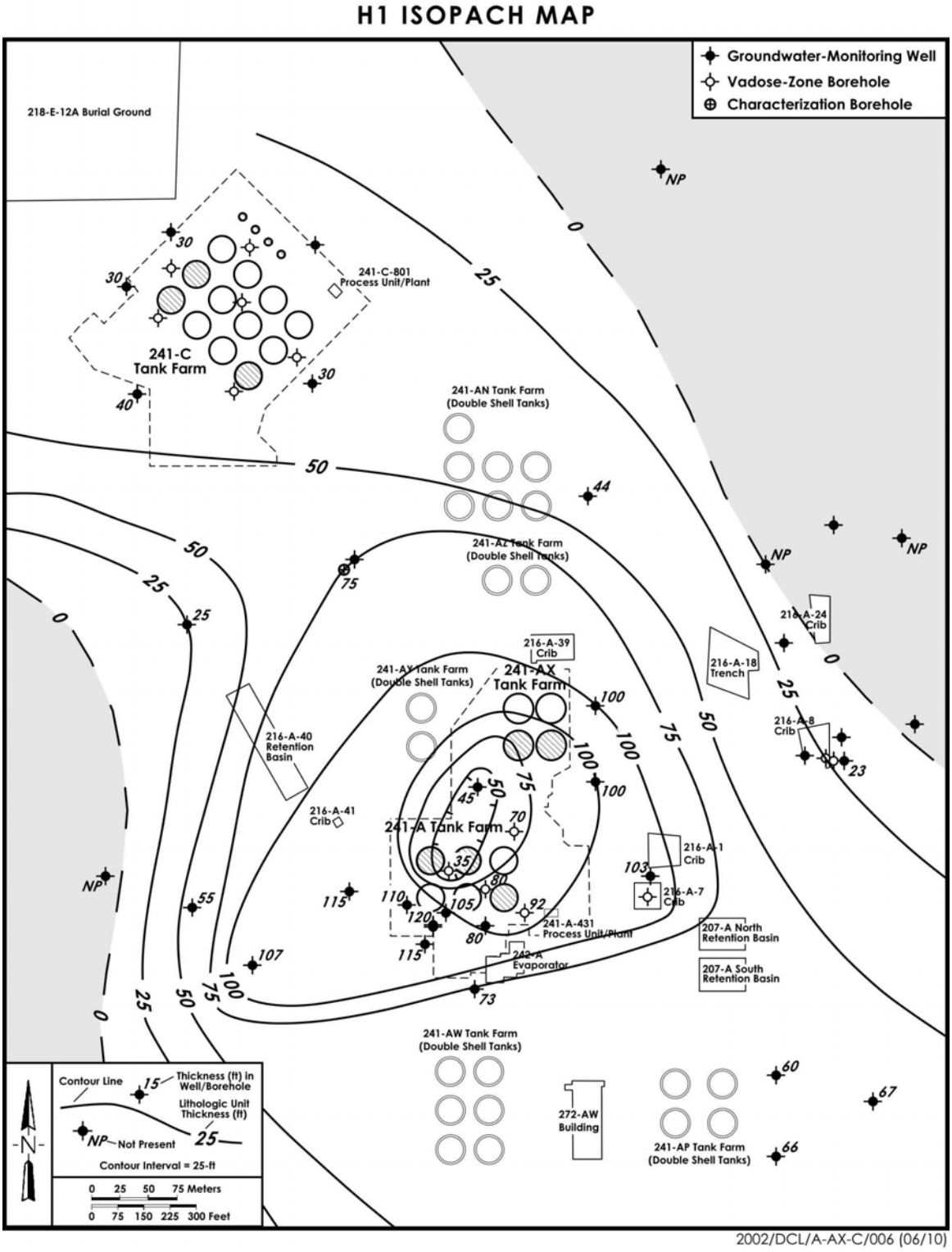


Figure 2-24. Isopach Map of the Hanford Formation H1 Unit.



2.2.8.9 Recent Deposits. Two types of recent deposits are present in WMAs C and A-AX: 1) eolian sand and silt, and 2) backfill material. Fine to medium sand to silty sand naturally caps the sedimentary sequence in the C and A-AX WMAs. These relatively fine-grained deposits are derived from the reworking of uppermost flood deposits by winds since the last Ice-Age flood (~13,000 years Before Present (BP). These poorly sorted eolian deposits contain up to 10 wt% $CaCO_3$ associated with recent soil development.

Eolian sand and silt, forms a relatively thin [up 20 ft (6.1 m)] blanket over the study area (Figure 2-25). The thickness of the eolian deposits appears greater along a northwest to southeast trend extending from the WMA AX toward the southeast (Figure 2-25). Most or all of the eolian material has been removed and replaced with backfill in the immediate vicinity of tank-farm operations. Backfill materials consist of unstructured, poorly sorted mixtures of gravel, sand, and silt removed during tank excavation, and then later used as fill around the tanks. Backfill materials extend to depths of 50 ft (15 m) bgs within the tank farms (Figure 2-25).

2.2.8.10 Clastic Dikes. Clastic dikes are vertical to subvertical sedimentary structures that crosscut normal sedimentary layering. Clastic dikes are a common geologic feature of the Hanford formation in the 200 Areas, especially in the sand- and silt-dominated facies. Clastic dikes are much less common in the gravel-dominated facies of the Hanford formation.

Clastic dikes occur in swarms and form four types of networks (Fecht 1999):

1. regular-shaped polygonal-patterns,
2. irregular-shaped, polygonal-patterns,
3. pre-existing fissure fillings, and
4. random occurrences.

Clastic dikes in WMAs A-AX and C probably occur randomly in the gravel-dominated facies (Hanford formation Units H1 and H3) and as regular-shaped polygons in the sand sequence (Hanford formation unit H2). Regular polygonal networks resemble 4- to 8-sided polygons and the dikes defining the polygons typically range from 1.2 to 39 in. (3 cm to 1 m) in width, from 6.7 ft to > 67 ft (2 m to >20 m) in depth, and from 5 to 330 ft (1.5 to 100 m) along strike. Smaller dikelets, sills, and small-scale faults and shears are commonly associated with master dikes that form the polygons.

In general, a clastic dike has an outer skin of clay with coarser infilling material. Clay linings are commonly 0.01 to 0.4 in (0.03 mm to 1.0 mm) in thickness, but linings up to about 3.9 in (10 mm) are known. The width of individual infilling layers ranges from as little as 0.004 in. (0.01 mm) to more than 12 in. (30 cm) and their length can vary from about 8 ft to > 66 ft (0.2 m to > 20 m). Infilling sediments are typically poor- to well-sorted sand, but may contain clay, silt, and gravel.

2.2.9 Regional Hydrology

This section describes the concept of recharge rate for the surface and subsurface hydrology of the Hanford Site region and the WMA C. The surface hydrology is important in determining possible surface pathways for dissolved or suspended contaminants, as well as for identifying sources of infiltration. The groundwater hydrology helps determine possible flow paths for contaminants released from the WMA C and provides a basis for determining vadose zone thickness.

2.2.9.1 Surface Hydrology. The hydrology of the Pasco Basin (Figure 2-25) is characterized by a number of surface sources and aquifers. Surface drainage enters the Pasco Basin from several other basins, including the Yakima River Basin, the Horse Heaven Basin, the Walla Walla River Basin, the Palouse/Snake Basin, and the Big Bend Basin. Within the Pasco Basin, major tributaries, the Yakima, Snake, and Walla Walla Rivers, join the Columbia River. Two intermittent streams, Cold Creek and Dry Creek, cut through the Hanford Site. Water drains through these pathways during wetter winter and spring months. No perennial streams originate within the Pasco Basin.

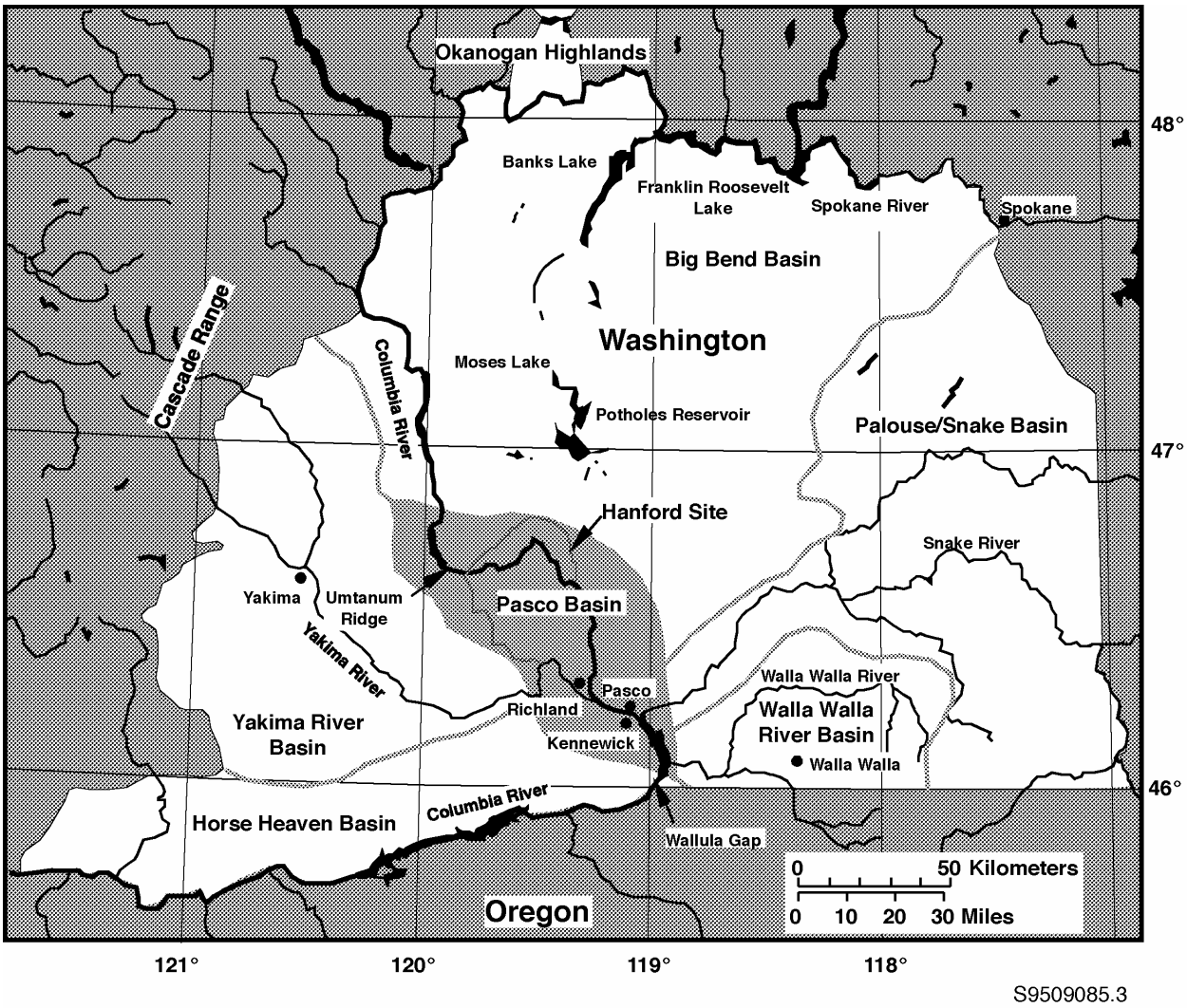
The total estimated precipitation over the basin averages 6.3 in./yr (16.0 cm/yr) (Section 2.2.5.2). Mean annual runoff from the basin is estimated to be less than 2.5×10^4 acre ft/yr (3.1×10^7 m^3/yr), or approximately 3% of the total precipitation. The remaining precipitation is assumed to be lost through evapotranspiration, with perhaps a few percent contributing to the recharging of the groundwater (DOE 1988b).

The Hanford Site has one pond, West Lake, and various water disposal ponds. West Lake, located 1.7 mi (2.7 km) north of the 200 East Area, is a shallow pond with an average depth of about 3 ft (1 m) and a surface area of 10 acres (4 hectares). While described as a natural lake, the source of recharge to the lake is groundwater that is locally mounded because of infiltration from 200 Area operations. The pond is a topographic depression that intersects the artificially elevated water table (DOE/RL 1993a-1). The 200 Area's disposal activities are scheduled to halt within a few decades. As this happens, the water table will drop and West Lake will become an intermittent seasonal pond (DOE/RL 1993b). Wastewater ponds, cribs, and ditches associated with nuclear fuel processing and waste disposal activities, although present on the Hanford Site, will not be an important source of water in the future.

No surface streams are near the WMA C, but current disposal ponds have an artificial influence on net contributions to the water table. These disposal ponds and related facilities are not expected to exist after current operations end, so their long-term influence is not considered in this performance assessment.

The surface drainage characteristics of the Hanford Site and regional area indicate that the Columbia River and its tributaries are the major surface drainage pathways. The Columbia River is the dominant pathway. The large volume of flow in the Columbia River (typically 35,000 ft^3/s to 106,000 ft^3/s (1,000 to 3,000 m^3/s) [Dirkes 1999-1]) through the Pasco Basin and downstream greatly dilutes any contaminants that reach the river.

Figure 2-25. Hydrologic Basins Designated for the Washington State Portion of the Columbia Plateau (DOE 1988b).



DOE conducts routine water-quality monitoring of the Columbia River for both radiological and nonradiological parameters. The Pacific Northwest National Laboratory (PNNL) has been reporting the water quality data since 1973. Ecology has issued a Class A (excellent) quality designation for Columbia River water from Grand Coulee Dam, through the Pasco Basin, to McNary Dam (*Washington Administrative Code* [WAC] 173-201). This designation requires that all industrial uses of this water be compatible with other uses, including drinking, wildlife habitat, and recreation. The Columbia River water is characterized by a low suspended load, a low nutrient content, and an absence of microbial contaminants (Dirkes 1999-1).

2.2.9.2 Flooding. Neitzel (2000-5) describes flooding potentials at the Hanford Site. Except for catastrophic glacier flooding, which is not expected for tens of thousands of years, no floods are expected to affect the Hanford Central Plateau.

The flows for the three largest probable Columbia River flood scenarios range from 600,000 to 21 million ft^3/s (17,000 to 600,000 m^3/s). The probable maximum flood on the Columbia River (DOE 1988b), based on natural conditions, has been calculated to be 1.4 million ft^3/s (40,000 m^3/s). This is greater than the 500-year flood. A landslide resulting in Columbia River blockage, followed by flooding could yield a maximum flow of 17,000 m^3/s (600,000 ft^3/s). The U.S. Army Corps of Engineers estimated that a 50% breach in the Grand Coulee Dam, the largest dam in the region, would yield flows of 21 million ft^3/s (600,000 m^3/s). None of these flow rates are large enough to cause the Columbia River waters to reach the Hanford Central Plateau.

A flood risk analysis of Cold Creek (west of the 200 West Area) was conducted to characterize a basaltic repository for high-level radioactive waste (Skaggs 1981). Based on this evaluation, the probable maximum flood would be at least 5 mi (8 km) to the west of the WMA C and its closest approach would be about 4.5 mi (7.5 km) to the south.

2.2.9.3 Groundwater Hydrology. The groundwater pathway is considered the most likely pathway for contaminants released from WMA C facilities for the following reasons:

- Low precipitation in the Pasco Basin
- Lack of surface transport pathways near the WMA C
- Subsurface location of the WMA C facilities
- Near-surface lysimeter measurements showing downward movement of water
- Samples showing the existence of radioactive contaminant plumes in the groundwater because of past Hanford Site operations.

Evaluating this pathway will require information about the types of aquifers present, depths to the water table, regional flow paths, and the net recharge rate.

The hydrology of the Pasco Basin is characterized by a multiaquifer system. This system consists of four hydrologic units corresponding to the upper three formations of the Columbia River Basalt Group (Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt) and the overlying suprabasalt sediments (the Hanford formation and Ringold Formation). The basalt aquifers consist of the tholeitic flood basalts of the Columbia River Basalt Group and relatively minor amounts of intercalated sediments of the Ellensburg formation. Confined zones in the basalt aquifers are present in the sedimentary interbeds and/or interflow zones that occur between dense basalt flows. The main water-bearing portions of the interflow zones are networks of interconnecting vesicles and fractures in the flow tops and bottoms (DOE 1988b).

The uppermost aquifer system consists of fluvial, lacustrine, and glaciofluvial sediments. Within the Pasco Basin, this aquifer is regionally unconfined and is contained primarily within the Ringold Formation and the Hanford formation. The main body of the unconfined aquifer usually occurs within the Ringold Formation. The water table in the southwestern Pasco Basin is generally within Ringold fluvial gravels. In the northern and eastern Pasco Basin, the water table is generally within the Hanford formation. Hydraulic conductivities in the Hanford formation are usually greater than in the gravel facies of the Ringold Formation (Graham 1981). However, fine-grained deposits in the Ringold Formation form locally confining layers for Ringold fluvial gravels.

The base of the uppermost aquifer system is defined as the top of the uppermost basalt flow. This aquifer system is bounded laterally by anticlinal basalt ridges and is about 152 m (500 ft) thick near the center of the Pasco Basin. Within the Hanford Site, this uppermost aquifer system lies at depths ranging from less than 1 ft (0.3 m) bgs near West Lake and the Columbia and Yakima Rivers, to more than 350 ft (107 m) in the central portion of the Cold Creek syncline.

Because the uppermost unconfined aquifer is considered the primary pathway for possible contaminant transport from WMA C facilities, it is especially important in this performance assessment.

Before the liquid waste disposal systems, such as B Pond, began operating, and before the onset of large regional irrigation projects, the groundwater table for the Hanford Site could be represented by a 1944 water table map (Figure 2-26) (ERDA 1975). This water map includes limited irrigation near the former towns of White Bluff and Hanford, but not the extensive irrigation now common in Cold and Dry Creeks. The 1944 water table contours suggest that groundwater flow is easterly toward the Columbia River with a relatively uniform hydraulic gradient (approximately 5 ft/mi [1.5 m/km]). Regional groundwater flow was generally toward the east-northeast, although flow north of Gable Mountain was more to the north.

Effluent disposal at the Hanford Site has altered hydraulic gradients and flow directions of the uppermost aquifer system, particularly near the 200 Areas. Figure 2-27 shows a recent water table map (Smith 1990) influenced by effluent disposal actions. Regional irrigation projects had a minor influence on the changes shown in Figure 2-27. Groundwater flow is still nominally easterly toward the Columbia River, but mounding occurs in the 200 East Area near B Pond. Groundwater flow north of Gable Mountain now trends in a more northeasterly direction as a result of mounding near reactors and northerly flow through Gable Gap between Gable Mountain and Gable Butte. South of Gable Mountain, flow is interrupted locally by the groundwater mounds in the 200 Areas. Some groundwater from the 200 Areas flows to the north between Gable Mountain and Gable Butte. For the time periods considered in this performance assessment, effluent disposal operations will have stopped.

Figure 2-26. Hindcast Water Table Map of the Hanford Site, January 1944 (ERDA 1975).

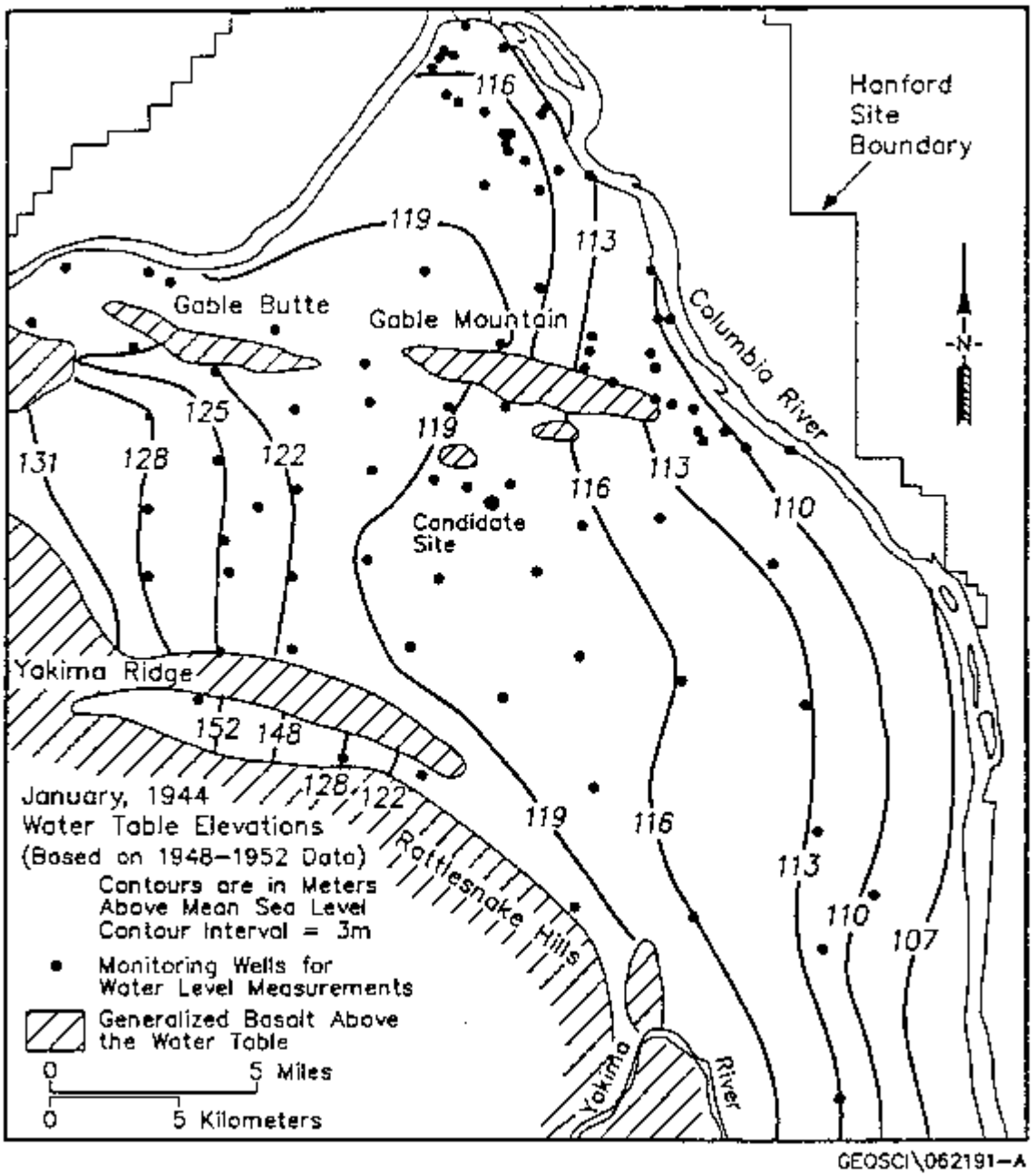
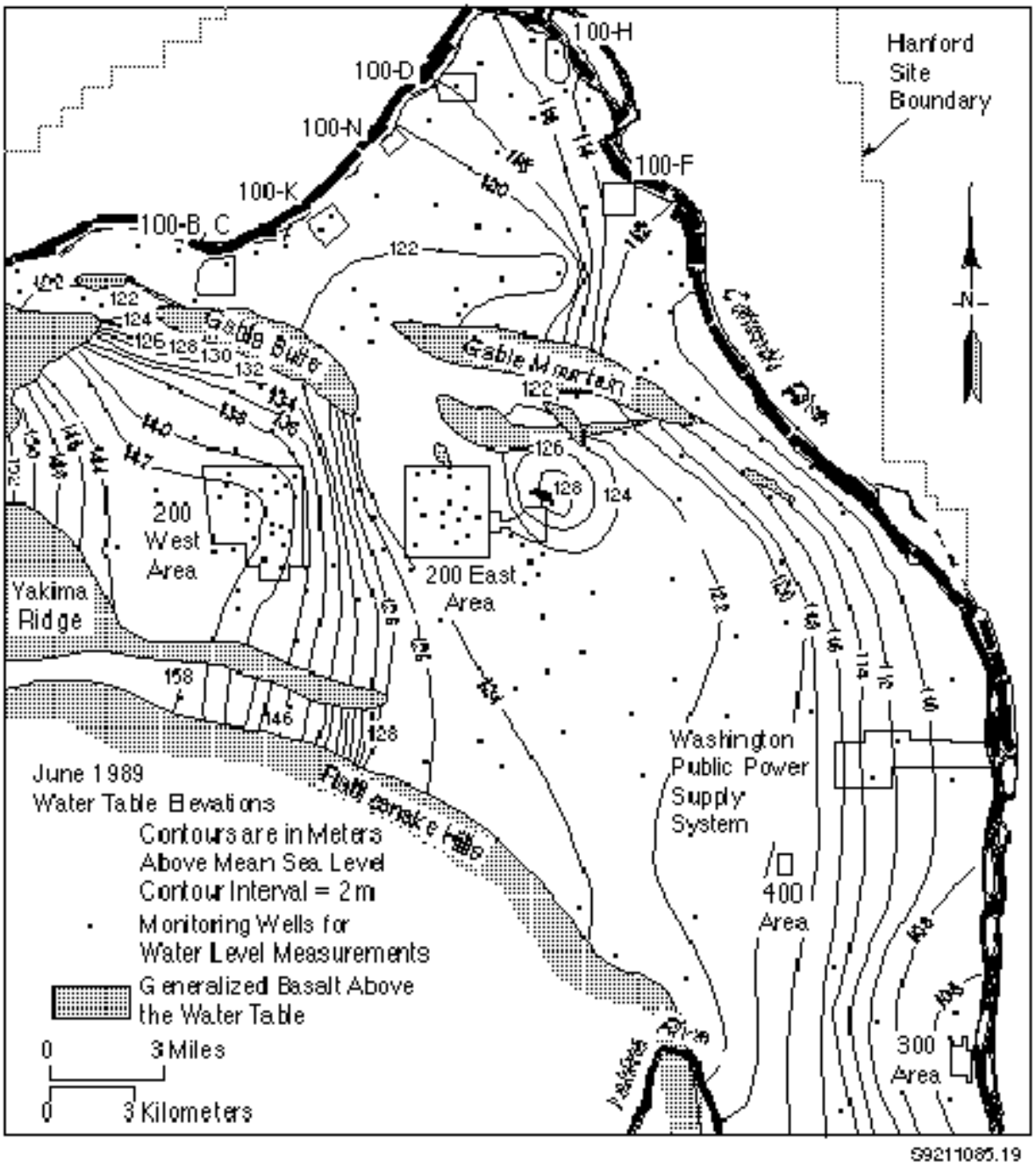


Figure 2-27. Hanford Site Water Table Map, June 1989 (Smith 1990).



2.2.9.4 Natural Recharge Rates. The information in this section is based on *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance* Assessment (Fayer 1999). Recharge is the amount of total precipitation that infiltrates into the unsaturated (vadose) zone after runoff, evaporation, and transpiration by plants have occurred. Recharge from rain and snow melt is a major hydrologic variable affecting contaminant transport from WMA C facilities.

Studies conducted over the last 25 years at the Hanford Site are summarized in the following paragraphs. These studies indicate that long-term recharge can vary greatly depending on factors such as climate, vegetation, land use, and soil texture. As noted in Section 2.2.5, most of the very small amount of precipitation at the Hanford Site falls in the winter and spring. Because of the dry conditions at the Site, most of the precipitation is stored in near-surface soils until used by plants or evaporates during the hot summer months. Native plants have adapted to use all the water in the near-surface zone. Because of the large storage capacity of the near surface soils, water rarely (on just a few days per decade) exits downwards from this near-surface zone. Such rare events typically occur following the rapid melting of a snow pack.

Most recharge rate data at the Hanford Site have been measured directly using a combination of drainage and weighing lysimeters (Rockhold 1995, Gee 1992). These lysimeters are vertical tubes as much as 16 ft (5 m) long placed in the ground and filled with various type of soils and covered with various types of vegetation. At the bottom of the lysimeters, the water that passed through the tube of soil is collected and measured (by volume or weight). The measurements can be used to determine the rate at which moisture escapes the near-surface part of the vadose zone. Because no mechanisms are known to exist that trap the moisture, the measured rate from the lysimeters is considered a good approximation for the recharge rate of the conditions (soil, vegetation, and precipitation) simulated by the lysimeter.

The recharge rate depends on the seasonal distribution of precipitation, type of surface soil and vegetation, and climatic conditions. Maximum recharge events occur following the wettest winter periods. Under normal conditions, the recharge rate is highest in coarse-textured soils without vegetation and is at the measurement threshold in fine-textured soil with or without vegetation. Coarse soil surfaces that are either vegetated with shallow-rooted species or bare exhibit recharge on the order of 50% of the precipitation.

Fayer and Walters (1995) estimated recharge rates based on measurements (lysimeters, tracers, and regional studies) and on numerical modeling. Estimates made using these methods were assigned to specific soil-vegetation combinations and distributed across the Hanford Site using a soil map and a vegetation-land use map. The long-term average rates varied from 0.1 in./yr (2.6 mm/yr) for several soil and vegetation combinations in the 200 Areas to 5.0 in./yr (127.0 mm/yr) for basalt outcrop with no vegetation at the crest of Rattlesnake Mountain (Fayer 1995).

For the sites of interest, surface soils are dominated by Rupert Sands and Burbank Loamy Sand. Fayer (1999), summarized in Section 3.4.6 along with the human influences on recharge, estimates that the natural recharge rate through the two types of soils are 0.035 in./yr (0.9 mm/yr) and 0.165 in./yr (4.2 mm/y), respectively. See Section 3.4.6 for a fuller description of recharge rates and the choice of values used in this performance assessment.

2.2.10 Geochemistry

The information in this section is taken from *Mineralogy of Selected Sediment Samples from Borehole 299-E17-21* (Mattigod 2000). This section discusses the mineralogy of the WMA C based on recently obtained samples from the borehole located at the southwest edge of the ILAW disposal site (Reidel 1998a). Information about geochemical methods and parameters used in the performance assessment analysis is given in Section 3.4.3.3.

The dominant minerals in the sand fractions of all samples were quartz (about 66 to 82% by mass) and feldspars (about 15 to 31%) (Table 2-3). These minerals (quartz and anorthite and orthoclase feldspars) constituted approximately 92 to 99% of the total mass of the sediment samples. Trace quantities of muscovite mica, chamosite (a type of chlorite) and ferrotschermakite (an amphibole mineral) also were detected in sand fractions. The silt fractions of these samples also were dominated by quartz (about 61 to 76%) and feldspars (about 19 to 44%). Compared to sand fractions, the silt fractions contained higher amounts of muscovite and chamosite (about 1 to 5%), and ferrotschermakite (1 to 10%). Illitic mica was the dominant mineral at about 42 to 60% by mass in clay fractions of all the sediment samples (Table 2-3). About 14 to 17% chlorite and about 21 to 28% kaolinite also were found in clay fractions. Minor amounts (3 to 12%) of smectite (a mineral important for its geochemical reactivity) also were detected in clay fractions of all samples. Overall, quartz and feldspars dominated the sand fractions, whereas the clay fractions were dominated by illitic mica and chlorite. These size-dependent mineral distributions are typical of primary (quartz and feldspars) and secondary (illite, chlorite, kaolinite, and smectite) mineral occurrence in soils undergoing chemical weathering. The mineralogy of these sediments was typical of published mineralogy of other Hanford formation sediments (Schramke 1988).

Layers of high $CaCO_3$ (calcite) are found in the 200 West Area. Calcite can affect the mobility of certain contaminants and tends to buffer pore moisture. However, Mattigod (2000) found less than 5% of calcite in any of the samples they analyzed from the ILAW disposal site. Moreover, such layers are readily visible in geologic logs, and they have not been seen in other boreholes near the ILAW disposal site.

Based on the semiquantitative mineralogy data and the mass distribution of particles in each size fraction (Table 2-3), the mineral distribution was computed on the bulk soil basis. As expected, in all samples (predominantly sandy in texture), the minerals that are dominant in sand and silt fractions, quartz and feldspars, also dominate the mineralogy of bulk soils at approximately 91 to 95%. All other minerals occur in minor to trace concentrations in these soils.

Although the mineralogy of these soils is dominated by quartz and feldspar minerals, other minerals such as illite, chlorite, smectite and kaolinite, which have characteristics such as high surface areas, ionizable exchange sites, and specific adsorption interlayer sites, significantly influence bulk soil chemical properties such as cation exchange capacity (CEC). Therefore, calculations were made to assess the contribution of each mineral to the overall CEC of the whole soil. The results show that although the minerals mica, chlorite, smectite, and kaolinite together constitute only about 5 to 9% of the total soil mass, they account for about 40 to 60% of the total exchange capacity of the whole soil. Only trace amounts (less than 0.6%) of smectite

were detected in these soils. However, because of this mineral's very high surface area, it accounts from about 4 to 17% of the CEC of the whole soil. Also, it is well established that minerals such as illitic mica in Hanford formation sediments specifically adsorb radionuclides such as ^{137}Cs (Mattigod 1994a, 1994b). Therefore, although constituting only about 3 to 5% of the soil mass, mica would significantly affect the specific adsorption of alkali cations such as cesium and potassium by the whole soil.

Also, the calculated CEC of the whole soil agreed reasonably well with the measured CEC values except in the case of samples 24A, 31A, and 35A. The measured CEC values for these samples were about twice as high as the calculated values. Because the mineralogy of these samples was not significantly different from other core samples, the anomalously high measured CEC values were attributed to the presence of trace amounts of carbonates present in these sediments.

Table 2-3. Semiquantative Estimates (wt%) of Minerals in Selected Sediments from ILAW Boreholes . (2 Pages)

Borehole		Fraction	Quartz	Feldspar	Mica	Chlorite	Amphibole	Smectite	Kaolinite
7A	Sand	0.921	62	12	1	1	--	--	--
	Silt	0.055	12	5	1	1	--	--	--
	Clay	0.024	--	--	3	1	--	Tr	1
	All		74	17	5	2	--	Tr	1
10A	Sand	0.821	63	21	1	1	--	--	--
	Silt	0.146	8	3	Tr	1	--	--	--
	Clay	0.033	--	--	2	Tr	--	Tr	1
	All		71	23	3	2	--	Tr	1
14A	Sand	0.794	59	28	1	1	1	--	--
	Silt	0.136	3	2	Tr	Tr	Tr	--	--
	Clay	0.070	--	--	3	1	--	Tr	1
	All		62	30	2	2	1	Tr	1
16A	Sand	0.947	66	19	1	1	1	--	--
	Silt	0.038	6	3	Tr	Tr	Tr	--	--
	Clay	0.014	--	--	2	Tr	--	Tr	1
	All		72	22	3	1	1	Tr	1
20A	Sand	0.090	65	18	1	1	1	--	--
	Silt	0.088	6	2	Tr	1	1	--	--
	Clay	0.012	--	--	2	1	--	Tr	1
	All		71	20	3	3	2	Tr	1

Table 2-3. Semiquantative Estimates (wt%) of Minerals in Selected Sediments from ILAW Boreholes . (2 Pages)

Borehole		Fraction	Quartz	Feldspar	Mica	Chlorite	Amphibole	Smectite	Kaolinite
24A	Sand	0.913	59	28	1	1	--	--	--
	Silt	0.061	5	2	Tr	Tr	Tr	--	--
	Clay	0.026	--	--	2	1	--	Tr	1
	All		64	30	2	2	Tr	Tr	1
31A	Sand	0.884	53	16	1	1	1	--	--
	Silt	0.100	17	5	Tr	Tr	Tr	--	--
	Clay	0.015	--	--	2	1	--	Tr	2
	All		70	22	3	2	1	Tr	2
35A	Sand	0.983	68	25	1	1	1	--	--
	Silt	0.011	1	--	--	--	--	--	--
	Clay	0.006	--	--	1	1	--	Tr	1
	Allk		69	25	2	1	1	Tr	1

Source: Mattigod 2000.

Tr = Trace quantity < 0.5%.

2.2.11 Natural Resources

The Central Plateau of the Hanford Site has no important natural resources. No major mining operations exist in the Hanford Site area. Oil and gas exploration have occurred; however, no economically viable accumulations were found. Some local gravel processing is being done in the area.

As noted in the hydrology section (Section 2.2.9), the unconfined aquifer is not a significant resource for water. Monitoring wells on the Hanford Site normally have screen lengths of 20 ft (6.1 m) (Evans 2000).

2.2.12 Regional Background Contamination and Hanford Site Monitoring

The Hanford Site has an extensive monitoring program. Studies have been directed at determining background levels of possible contaminants in the soil (DOE/RL 1994b and DOE/RL 1995b) and in the groundwater (Johnson 1993). Also, reports are issued annually covering general environmental conditions (Dirkes 1999) and groundwater monitoring (Hartman 2000).

2.2.12.1 Soil Background Levels. Low concentrations of ^{90}Sr, ^{137}Cs, and $^{239,240}Pu$ were measured in samples of soil and vegetation during 1998 (Dirkes 1999-2). The levels were similar to those measured in previous years. No discernible increase in concentration could be attributed to current Hanford Site operations. DOE/RL 1995b summarizes all the measurements taken to determine radionuclide background levels at the Hanford Site. Table 2-4 displays the average of the measurements.

Table 2-4. Activity of Radionuclides in Hanford Sitewide Background Data Set

Nuclide	Activity (pCi/g)	Nuclide	Activity (pCi/g)	Nuclide	Activity (pCi/g)
^{40}K	15.4	^{60}Co	0.00132	^{90}Sr	0.0806
^{137}Cs	0.417	^{154}Eu	0.0083	^{155}Eu	0.0234
^{226}Ra[a]	0.686	$^{232}Th+D$	0.687	$^{235}U+D$	0.0271
$^{238}U+D$	0.675	^{238}Pu	0.00158	$^{239/240}Pu$	0.00935

Source: DOE/RL 1995b.

[a] ^{226}Ra is part of ^{238}U decay chain and is included in that entry.

+D = indicates daughters are included.

2.2.12.2 Groundwater Background Levels. Sample results from environmental monitoring can vary depending on local operations, so a regional baseline study was conducted using these and other sitewide monitoring results (Johnson 1993). Groundwater background values and trigger threshold levels are shown in Table 2-5.

Table 2-5. Background Values for Hanford Site Groundwater [a]. (2 pages)

Constituent (Concentration)	Groundwater Background Values [b]	Provisional Threshold Values
Aluminum (ppb)	<2	<200
Ammonium (ppb)	<50	<120
Arsenic (ppb)	3.9 ± 2.4	10
Barium (ppb)	42 ± 20	68.5
Beryllium (ppb)	<0.3	<5
Bismuth (ppb)	<0.02	<5
Boron (ppb)	<50	<100
Cadmium (ppb)	<0.2	<10
Calcium (ppb)	40,400 ± 10,300	63,600
Chloride (ppb)	10,300 ± 6,500	NC
Chromium (ppb)	4 ±2	<30
Copper (ppb)	<1	<30
Fluoride (ppb)	370 ± 100	1,340, 775[c]
Iron-mid (ppb)	NA	291

Table 2-5. Background Values for Hanford Site Groundwater [a]. (2 pages)

Constituent (Concentration)	Groundwater Background Values [b]	Provisional Threshold Values
Lead (ppb)	<0.5	<5
Magnesium (ppb)	11,800 ± 3,400	16,480
Manganese (ppb)	7 ± 5	NC
Mercury (ppb)	<0.1	<0.1
Nickel (ppb)	<4	<30
Nitrate (ppb)	NA	12,400
Phosphate (ppb)	<1,000	<1,000
Potassium (ppb)	4,950 ± 1,240	7,975
Selenium (ppb)	<2	<5
Silver (ppb)	<10	<10
Silicon (ppb)	NA	26,500
Sodium (ppb)	18,260 ± 10,150	33,500
Strontium (ppb)	236 ± 102	264.1
Sulfate (ppb)	34,300 ± 16,900	90,500
Uranium (pCi/L)	1.7 ± 0.8	3.43
Vanadium (ppb)	17 ± 9	15
Zinc (ppb)	6 ± 2	NC
Field alkalinity(ppb)	NA	215,000
Laboratory alkalinity (ppb)	123,000 ± 21,000	210,000
Field pH	NA	(6.90, 8.24)
Laboratory pH	7.64 ± 0.16	(7.25, 8.25)
Total organic carbon (ppb)	586 ± 347	2,610, 1,610[c]
Field conductivity (µmho/cm)	NA	39
Laboratory conductivity (µmho/cm)	380 ± 82	530
TOX, LDL (ppb)	NA	60.8, 37.6[c]
Total carbon (ppb)	NA	50,100
Gross alpha (pCi/L)	2.5 ± 1.4	63, 5.79[c]
Gross beta (pCi/L)	19 ± 12	35.5, 12.62[c]
Radium (pCi/L)	<0.2	0.23

[a] From Tables 5-9 and 5-11 of DOE/RL 1992.

[b] Results shown are mean ± one standard deviation, unless only an upper limit is given.

[c] Potential outlier observation(s) were removed.

LDL = lower detectability limit

NA = not available

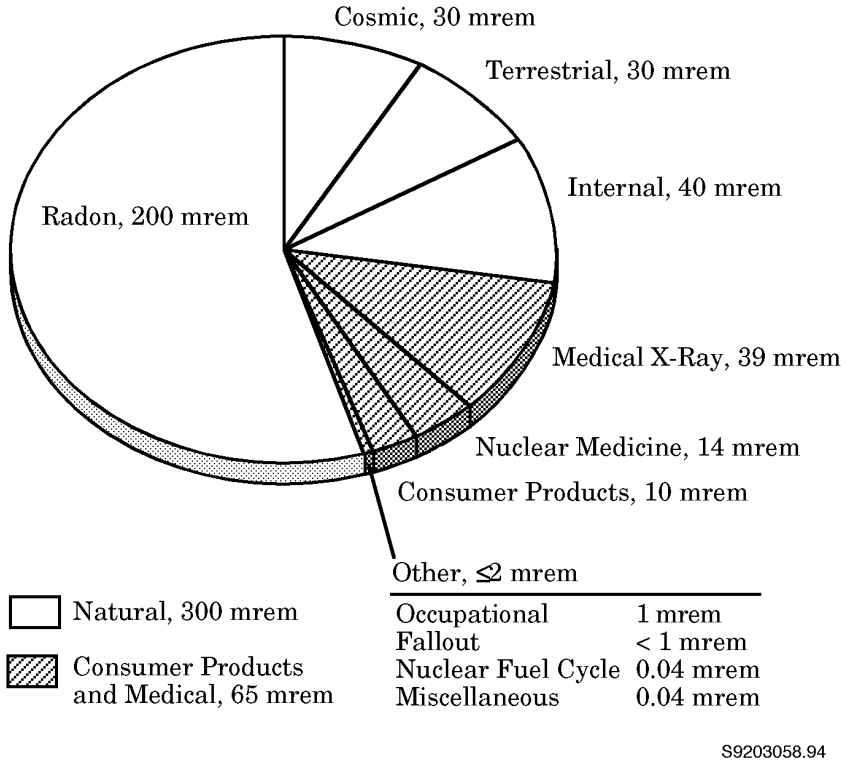
NC = not calculated

TOX = total organic halides

2.2.12.3 Radiation Background Levels. Various natural and human-produced sources contribute to radiation doses. These sources include natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural internal body radioactivity, and inhalation of naturally occurring radon. Figure 2-28 shows the national average dose from each of these sources to an individual. Of the contributions shown in Figure 2-28, natural background contributes 300 mrem to the estimated per capita annual dose to individuals living near the Hanford Site. Human-produced sources contribute an additional 65 mrem. In contrast, annual Hanford Site environmental reports (e.g., Dirkes 1999) estimate that the maximum annual dose to an individual from Hanford Site operations in 1998 was about 0.02 mrem. This is similar to values seen over the last 4 years.

The public is exposed to radiation at or near the Hanford Site from industrial sources other than DOE operations. These sources include the low-level radioactive waste burial site operated by U.S. Ecology, the nuclear generating station operated by Energy Northwest, the nuclear fuel production plant operated by Siemans Nuclear Power Corporation, the low-level waste compacting facility operated by Allied Technology Corporation, and a decontamination facility operated by Pacific Nuclear Services. Based on information gathered from these companies, Dirkes (Dirkes 1999-3) conservatively determined that the total 1998 annual dose for the hypothetical maximally exposed individual from those activities also was 0.02 mrem.

Figure 2-28. Averages for Natural and Human-Produced Sources of Radiation (NCRP 1987).



2.3 PAST AND CURRENT CONDITIONS AT WMA C

2.3.1 Overview

This section describes the construction of facilities in the WMA C, waste storage operations in the underground tanks, and plans for retrieving the waste. Particularly emphasis is placed on our knowledge of the current inventory of waste. Much of the information in this subsection comes from the *Subsurface Conditions Description of the C and A-AX Waste Management Areas* (Wood 2003) and *Inventory and Source Term Data Package* for the Tank Closure EIS (DOE/ORP-2003-02).

2.3.2 Facilities

This subsection presents an overview of Hanford tank farm facilities and WMA C in particular.

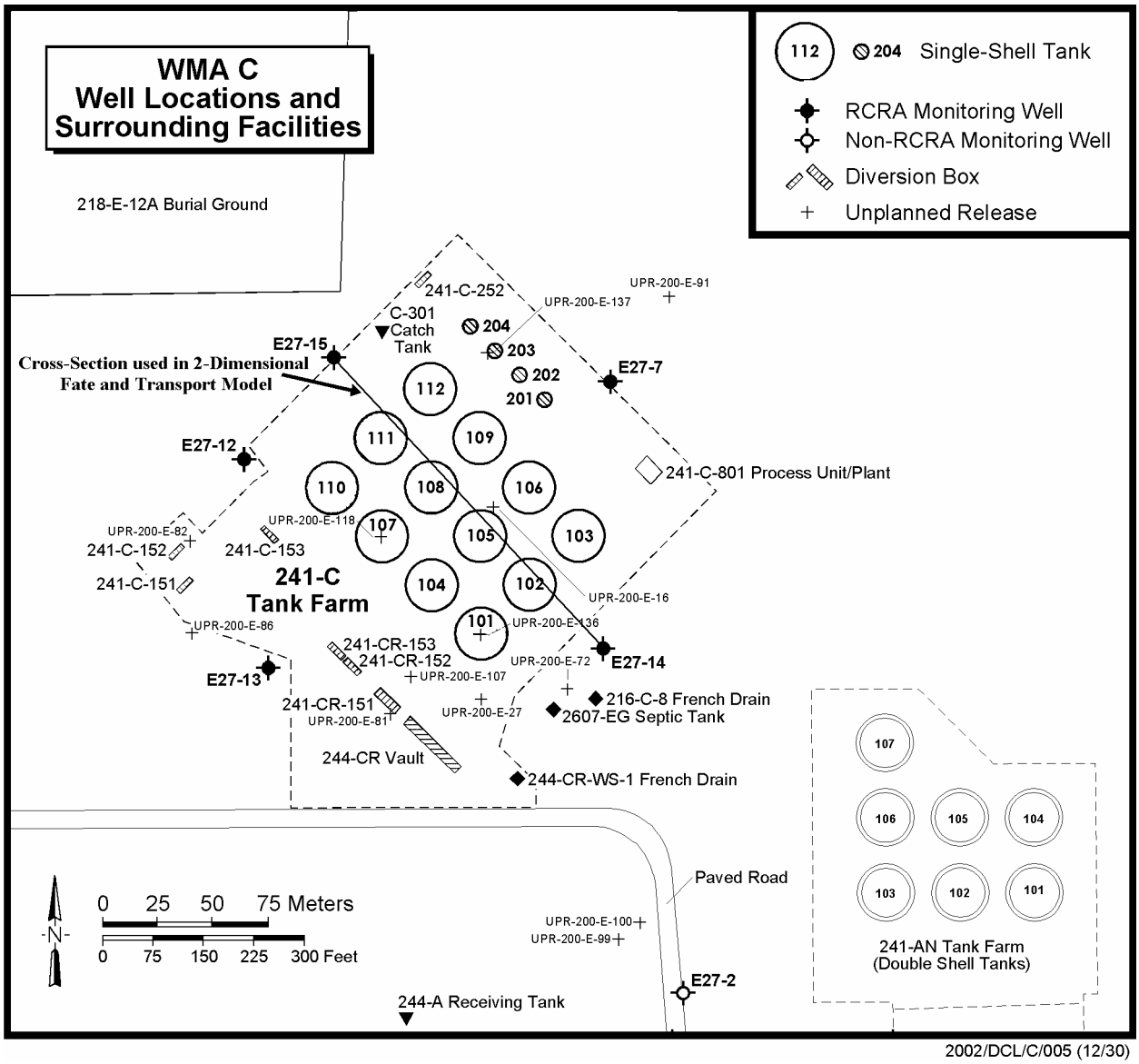
2.3.2.1 Hanford Tank Farm Overview. To store the liquid high-level radioactive waste generated by Hanford Site operations since 1944, 149 SSTs and 28 DSTs were built. The tanks are grouped into 18 tank farms containing more than 53.6 Mgal (204,000 m^3) [Hanlon 2000-1] of waste. The consistency of the tank waste ranges from dilute aqueous solutions to thick paste to hard solid.

Four basic chemical processing operations generated the radioactive waste solutions. These operations were the bismuth phosphate process, the REDOX process, the PUREX process, and the tributyl phosphate process. The first three processes recovered plutonium from irradiated reactor fuels. The last process recovered uranium waste generated in the bismuth phosphate process. Other specialized campaigns recovered ^{137}Cs, ^{90}Sr, and other special nuclear materials. The aqueous waste was made alkaline to control corrosion in the carbon-steel underground tanks. Anderson (1990) provides a history of the liquid waste generation and its subsequent handling and storage in the tank farms.

Most of the tank waste has undergone one or more treatment steps (for example, neutralization, precipitation, decantation, or evaporation). The neutralized waste contains sodium nitrate and nitrite, sodium hydroxide, sodium aluminate, sodium phosphate, various insoluble hydroxides and phosphates, usually small quantities of organic materials, and various radionuclides (approximately 250 MCi). The main effect of the treatment steps other than neutralization was to reduce the water content of the waste.

2.3.2.2 WMA C. WMA C encompasses the 241-C Tank Farm and is located in the east central portion of the 200 East Area. The WMA Ccontains twelve SSTs and four 200 series SSTs constructed in 1943 and 1944. WMA C also includes the 244-CR vault and eight diversion boxes (see Figure 2-29).

Figure 2-29. WMA C Tank Farm and Surrounding Facilities



The primary tanks are 75 ft (23 m) in diameter and 16 ft (4.9 m) deep operating depth with a capacity of 530,000 gal (2 million liters). The 200 series tanks are 20 ft (6.1 m) in diameter with a 17 ft (5.2 m) operating depth and each holds 55,000 gal (0.2 million liters). Tank configuration and dimensions are shown in Figure 2-30. The tanks sit below grade with at least 7 ft (2.1 m) of soil cover to provide shielding from radiation exposure to operating personnel. The inlet and outlet lines are located near the top of the liners (Figure 2-31). The tanks were constructed in place with carbon steel (ASTM A283 Grade C) lining the bottom and sides of a reinforced concrete shell. The tanks have slightly concave bottoms and a curving intersection of the sides and bottom. This curvature decreased the buildup of stress in the bottom corners of the tanks, reducing corrosive effects and thus reducing the chance of developing a leak in the tank bottom.

The 12 primary tanks were divided into four sets of three tanks each (for example, tanks C-101, C-102, and C-103 form one set) with cascade lines attaching each set so that waste would flow from southwest to northeast by gravity feed. The tanks in WMA C were removed from service between 1970 and 1980 (Hanlon 2000). The SSTs in WMA C were used to store waste primarily from the bismuth phosphate, PUREX, and uranium extraction processes.

Figure 2-30. Typical Configuration and Dimensions of Single-Shell Tanks in WMA C (Modified from Hanlon 2000).

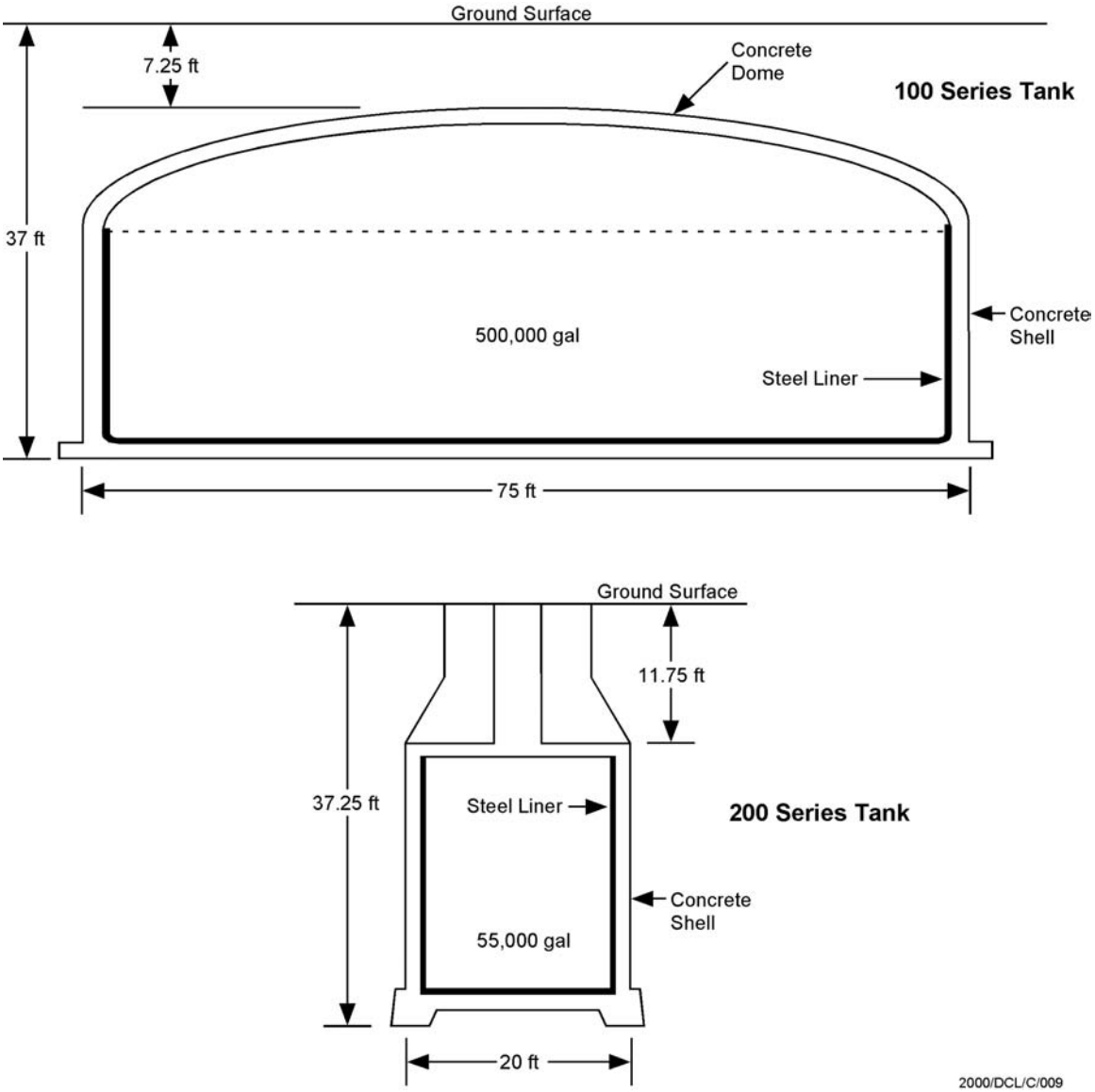
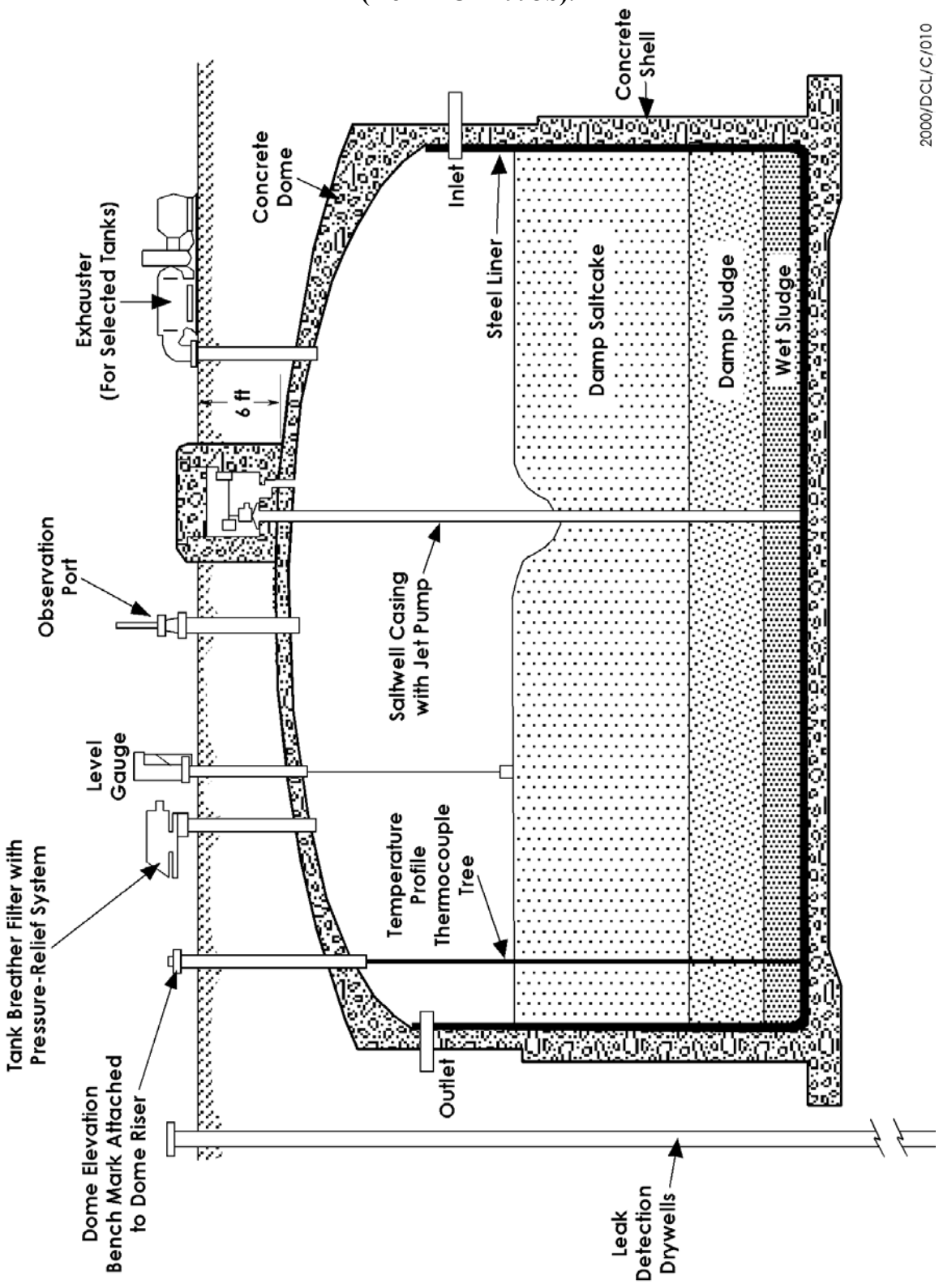


Figure 2-31. Typical Single-Shell Tank Instrumentation Configuration at WMA C (from DOE 1993b).



WMA C includes the 244-CR vault, which is south of the tanks. The vault is a two level, multi-cell, reinforced concrete structure constructed below grade (DOE 1993b). The 244-CR vault (Figure 2-32) contains four permitted underground tanks along with overhead piping and equipment. Two tanks (244-CR-001 and 244-CR-011) have diameters of 20 ft (6 m), are 19 ft (6 m) tall, and have a capacity of 45,000 gal (170,343 L) each. The other two tanks (244-CR-002 and 244-CR-003) are 14 ft (4 m) in diameter, 12 ft (3.7 m) tall, and have capacities of 14,700 gal (55,494 L) each. This vault was constructed in 1946 and ceased operating in 1988. It was used to transfer waste solutions from processing and decontamination operations (DOE 1993b). Only tanks 244-CR-003 and 244-CR-011 are listed in the Dangerous Waste Permit Application (DOE 1996b) as part of the WMA.

In addition to the tanks and vaults, there are eight inactive diversion boxes at WMA C that are designated as waste piles along with the transfer pipes to the DST systems and associated equipment (Figure 2-33). All diversion boxes used within the farms are inactive and presently isolated or covered from the weather. (As used here, "isolated" means exterior water intrusion has been restricted.) The diversion boxes are included in the RCRA permit application because they were an integral part of the waste transfer system. The boxes are important in the plan because some were the sites of contaminant releases to the subsurface. It is estimated that each box contains 50 lb (23 kg) of lead, and they are listed as waste piles (Hanlon 2000).

Ancillary equipment is defined as structures, piping, and equipment outside of the waste tanks but associated with tank farm operations. Evaluating ancillary equipment is an important component of the retrieval and closure strategy evaluation because the equipment could be a potential source term for either worker exposures, if the equipment were to be removed, or long-term risk, if the equipment were left in the tank farm. The ancillary equipment list includes the following categories:

- Surplus buildings and other surface facilities
- Drywells around WMA C and RCRA wells, if any
- Riser penetrations
- Leak detection pits
- Cribs and other liquid waste stream disposal sites within the WMA
- Direct buried piping, encased piping, and ventilation elements
- Pump pits, sluice pits, and valve pits associated with individual tanks
- Other facilities such as valve pits, jumper pits, diversion boxes, and structures

Figure 2-32. Schematic of the 244-CR Vault in WMA C.

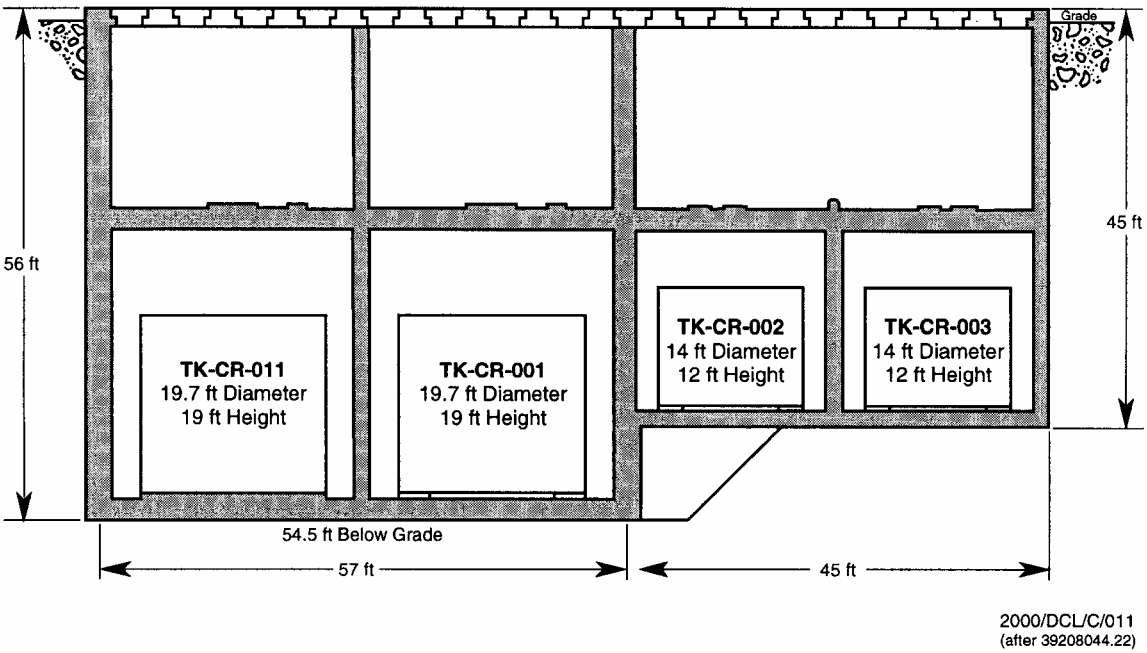
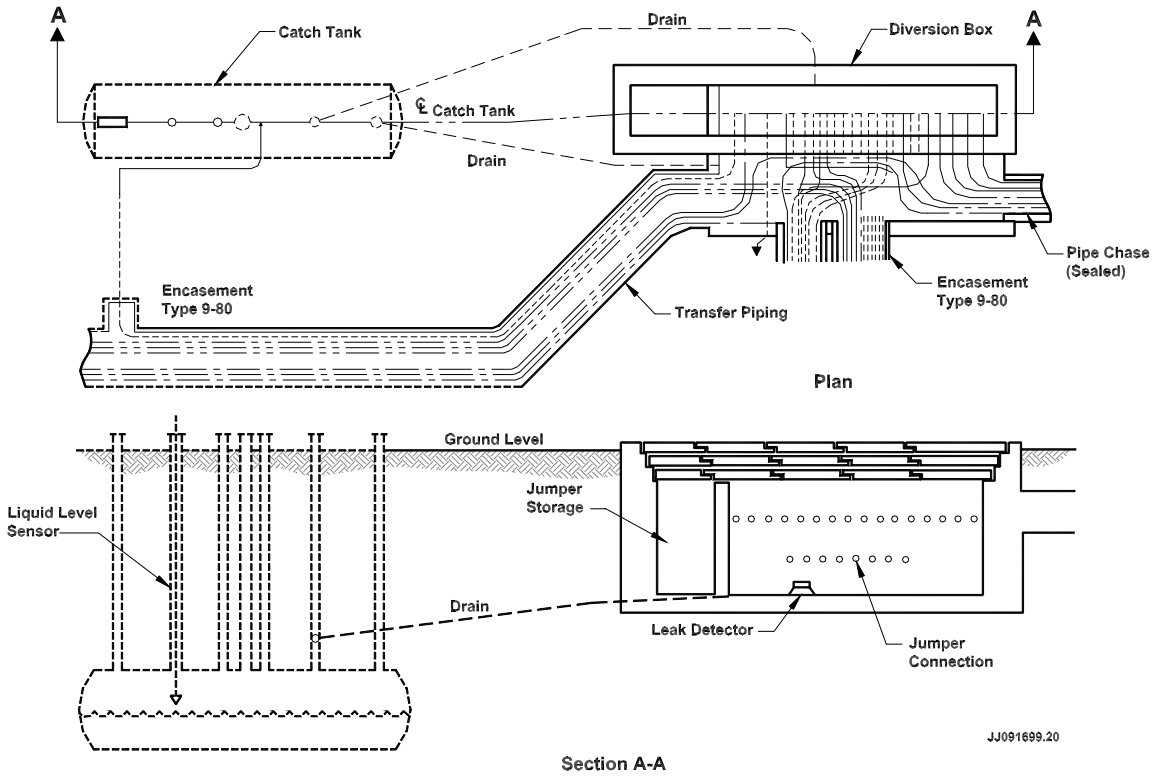


Figure 2-33. Schematic of a Typical Diversion Box Transfer System.



2.3.3 WMA C Operational History

2.3.3.1 Summary. The WMA C received waste generated by essentially all of the major chemical processing operations that occurred at Hanford including bismuth phosphate fuel processing, uranium recovery, PUREX fuel processing, fission product recovery and tank farm interim stabilization and isolation activities.

Documented information on the operational history of the SSTs, the waste transfer vault, and the diversion boxes that are part of WMA C is provided in Tables 2-6 and 2-7. Table 2-6 lists the tank, vault, and diversion box numbers; year of construction; year removed from service; and operating capacity or function. Tanks from which leaks are officially considered as confirmed or assumed are listed in Table 2-7 along with the estimated volume of leaked waste and date the tank was interim stabilized. Interim stabilized means that the tank now contains less than 50,000 gal (189,250 L) of drainable interstitial liquid and less than 5,000 gal (18,925 L) supernatant liquid (Hanlon 2000). Note that in the review of tank leaks in Section 3 of this document, the conclusions concerning tank status are not in agreement with Table 2-7. None of the tanks listed appear to have leaked although infrastructure around some of the individual tanks (e.g.,such as transfer lines) does seem to have leaked. Also, tank C-105, which does not appear in Table 2-7, is proposed in the *Subsurface Conditions Description of the C and A-AX Waste Management Areas* (Wood 2003) to have leaked.

2.3.3.2 Early Years (1943 - 1959). WMA C was constructed between 1943 and 1944 and first received metal waste and first-cycle waste from B Plant beginning in 1946. Ultimately, tanks C-101 through C-106 received metal waste and tanks C-107 through C-112 received first-cycle waste. All tanks were filled with bismuth phosphate waste by the end of 1948. The 200 series tanks also received metal waste. To free up tank space, first-cycle waste was transferred to the 242-B evaporator in 1952.

Metal waste was also removed from WMA C beginning in 1952 and transferred to U plant for uranium recovery. Ancillary equipment involved in the metal waste transfer included the 244-CR vault and diversion boxes 241-CR-151, -152 and –153. Subsequently, tributyl phosphate (TBP) waste, a byproduct of the uranium recovery process, was returned to WMA C. The 244-CR vault was modified in 1955 to scavenge TBP waste (that is, to separate cesium-137 from the supernate by precipitation) that was present in tanks C-107 through C-112. The scavenged slurry was redeposited in tanks C-109 and C-112 to settle and the resultant supernate was discharged to the BC cribs.

Several unintentional PUREX waste releases to the environment occurred during this time period. In 1969, cladding waste-PUREX (CWP) leaked from a transfer line (V051) near diversion box 241-CR-151 to which it was connected. CWP also leaked from a transfer line between tanks C-105 and C-108 some time between 1956 and 1959.

Table 2-6. Operating Period and Capacities for WMA C Facilities.

Facility	Constructed	Removed From Service	Operating Capacity (gal[L})
Single-Shell Tanks			
241-C-101	1943 - 1944	1970	530,000 [2,000,000]
241-C-102	1943 - 1944	1976	530,000 [2,000,000]
241-C-103	1943 - 1944	1979	530,000 [2,000,000]
241-C-104	1943 - 1944	1980	530,000 [2,000,000]
241-C-105	1943 - 1944	1979	530,000 [2,000,000]
241-C-106	1943 - 1944	1979	530,000 [2,000,000]
241-C-107	1943 - 1944	1978	530,000 [2,000,000]
241-C-108	1943 - 1944	1976	530,000 [2,000,000]
241-C-109	1943 - 1944	1976	530,000 [2,000,000]
241-C-110	1943 - 1944	1976	530,000 [2,000,000]
241-C-111	1943 - 1944	1978	530,000 [2,000,000]
241-C-112	1943 - 1944	1976	530,000 [2,000,000]
241-C-201	1943 - 1944	1977	208,000 [55,000]
241-C-202	1943 - 1944	1977	208,000 [55,000]
241-C-203	1943 - 1944	1977	208,000 [55,000]
241-C-204	1943 - 1944	1977	208,000 [55,000]
Diversion Boxes			**Function**
241-C-151	1946	1985	Interconnected 241-C-152, -153, and CR-151 diversion boxes
241-C-152	1946	1985	Interconnected 241-B-154 and -153 and 241-C Tank Farm, associated with the 241-C-301 Catch Tank
241-C-153	1946	1985	Interconnected 241-C-151 and -152 diversion boxes
241-C-154	1965	1985	Interconnected B-Plant to Hot Semi-Works locations. Box located at Hot Semi-Works
241-C-252	1946	1985	Interconnected 241-C-151 diversion box and 241-C Tank Farm
241-CR-151	1952	1985	Interconnected 241-C-151 and 241-C Tank Farms
241-CR-152	1946	1985	Interconnected 241-C-151 diversion box and 241-C Tank Farm
241-CR-153	1946	1985	Interconnected 241-CR-152 diversion box and 241-C Tank Farm
244-CR-Vault			**Function**
244-CR-011	1946	1988	Transfer of waste solutions from processes and decontamination operations.
244-CR-003	1946	1988	

Source: Data on SSTs are from Caggiano (1991) and Hanlon (2000). Data on diversion boxes and the 244-CR vault are from DOE (1993a) except for 241-C-154, which are from DOE (1993b).

Table 2-7. Tank Leak Volume Estimates.

Tank Number	Date Declared Confirmed or Assumed Leaker	Volume Leaked gal [L]	Interim Stabilized Date	Leak Estimate Updated
241-C-101	1980	20,000 [76,000]	11/83	1986
241-C-110	1984	2,000 [7,600]	5/95	1989
241-C-111	1968	5,500 [21,000]	03/84	1989
241-C-201	1988	550 [2,100]	03/82	1987
241-C-202	1988	450 [1,700]	08/81	1987
241-C-203	1984	400 [1,500]	03/82	1986
241-C-204	1988	350 [1,200]	09/82	1987

Source: Hanlon 2000

2.3.3.3 Isotope Recovery Programs: By the late 1950s, it was clear that a number of SSTs had likely leaked, and the long-term storage of large volumes of liquid radioactive wastes was untenable. Hanford Site contractors were directed to convert liquid radioactive waste to saltcake as soon as practicable. In the early 1960s, interest developed in recovering cesium-137 and strontium-90 from PUREX wastes. As treatment processes were developed and implemented, PUREX waste streams depleted in strontium-90 and cesium -137 were stored at various times in some WMA C tanks. Strontium-90 depleted PUREX acid waste (PAW) was stored in tanks C-107 through C-109 after Strontium Semiworks startup in 1961. In 1963, PUREX supernate waste (PSN) previously stored in tank C-103 was transferred to 241-C-801 facility for cesium-137 removal and subsequently returned to tank C-102. Eventually, this waste and commingled CWP in tank C-102 was transferred to BY tank farm. From 1963 to 1967, strontium-90 recovery processes were being developed at B plant and the depleted wastes were stored in WMA C and in tank AX-101.

Beginning in 1967, PUREX current acid wastes were processed through B Plant for cesium-137 and strontium-90 recovery, prior to the 3 to 5 year cooling-off period. Aged PUREX supernatants and sludges were recovered from the tanks and processed through the B Plant for strontium-90 and cesium-137 recovery. The aged REDOX supernatants were transferred to 200 East Area tanks and processed through B Plant for cesium-137 recovery. Tank C-105 was the receiver tank for all supernatants going to B Plant for Cs-137 recovery. After cesium-137 removal, REDOX supernatants were transferred back to the 200 West Area for saltcake production in the T and S Evaporators.

After the cesium-137 was removed (or at least greatly reduced) in the aged PUREX supernatants, the wastes were transferred to various tanks in the B/BX/BY and WMA Cs, leading to conversion of supernatants into saltcake using the BY farm in-tank solidification (ITS) process. In the ITS process, heater units were installed in three tanks in the BY tank farm. Waste supernatants were rotated through the ITS process tanks and out to the B-BX-BY tanks to

produce saltcake. The available tank space in the B-BX-BY farms was filled with saltcake using the BY ITS process.

By 1967, all cesium-137 and strontium-90 removal from PSN was being done at B Plant and the primary transfer sequence was initial storage of PSN in AX tank farm followed by transfer through tank C-105. In the late 1960s organic wash waste (OWW) was combined with CWP and stored in tank C-102 and subsequently transferred to BX tank farm for interim tank stabilization. PUREX sludges were also sluiced from A farm tanks (A-101 in 1968, A-104 in 1969 and A-106 in 1970) and transferred to 244-AR vault for acidification, then to 244-CR vault as PUREX acidified sludge (PAS) and B Plant. Tanks deemed to be sound in WMA C (primarily tanks C-103 and C-104) stored all variety of wastes not segregated by waste type.

Unintentional releases included PSN losses from transfer lines V122 near diversion box 241-C-152 in 1970 (UPR-200-E-82) and line 812 near diversion box 241-C-151 in 1971 (UPR-200-E-86).

2.3.3.4 Final Years. In the mid 1970s, a decision was made remove from service all the SSTs. At WMA C, saltwell jet pumping was employed to remove much of the liquid waste present in the tanks. Tank C-103 was designated as the receiver tanks for WMA C and pumping began in 1976. Currently, the majority of liquid wastes have been removed from these tanks. The most recent sluicing event occurred at tank C-106 in 1999.

Table 2-8 provides the current status of the SSTs in WMA C. Most of the pumpable liquid has been removed and transferred to DSTs as part of the interim stabilization project. Interim stabilized means that the tank now contains less than 50,000 gal (189,250 L) of drainable interstitial liquid and less than 5,000 gal (18,925 L) of supernatant liquid. However, two tanks (C-103 and C-106) are not yet interim stabilized, although tank C-106 has been sluiced. As used in Table 2-8, intrusion prevention is the administrative designation for the completion of the physical activities required to minimize the addition of liquids into an inactive storage tank. Electrical and other instrumentation devices are not disconnected during intrusion prevention. Partially interim isolated is the administrative designation for the completion of physical activities required for interim isolation except for isolation of risers and piping required for jet pumping or other stabilization methods (Hanlon 2000).

Table 2-8. Current Status by Tank.

Tank	Tank Integrity	Stabili-zation/ Isolation Status[a]	Total Waste (gal x 1000) [kL]	Total Pumped (gal x 1000) [kL]	Drainable Liquid Remaining (gal x 1000) [kL]	Pumpable Liquid Remaining (gal x 1000) [kL]	Sludge (gal x 1000) [kL]	Salt Cake (gal x 1000) [kL]
241-C-101	Assumed leaker	IS/IP	88 [333.1]	0 [0.0]	4[15.1]	0 [0.0]	88 [333.1]	0 [0.0]
241-C-102	Sound	IS/IP	316 [1196.1]	46.7 [176.8]	62 [234.7]	55 [208.2]	316 [1196.1]	0 [0.0]
241-C-103	Sound	/PII	198 [749.4]	0 [0.0]	83 [314.2]	83 [314.2]	119 [450.4]	0 [0.0]
241-C-104	Sound	IS/IP	295 [1116.6]	0 [0.0]	34 [128.7]	30[113.6]	295 [1116.6]	0 [0.0]
241-C-105	Sound	IS/PII	134 [507.2]	0 [0.0]	12 [45.4]	8 [30.3]	132 [499.6]	0 [0.0]
241-C-106	Sound	/PII	74 [280.1]	0 [0.0]	68 [257.4]	62 [234.7]	6 [22.7]	0 [0.0]
241-C-107	Sound	IS/IP	257 [972.7]	40.8 [154.4]	30 [113.6]	25 [94.6]	257 [972.7]	0 [0.0]
241-C-108	Sound	IS/IP	66 [249.8]	0 [0.0]	4 [15.1]	0 [0.0]	66 [249.8]	0 [0.0]
241-C-109	Sound	IS/IP	66 [249.8]	0 [0.0]	6 [22.7]	4 [15.1]	62 [234.7]	0 [0.0]
241-C-110	Assumed leaker	IS/IP	178 [673.7]	15.5 [58.7]	38 [143.8]	30 [113.6]	177 [669.9]	0 [0.0]
241-C-111	Assumed leaker	IS/IP	57 [215.7]	0 [0.0]	4 [15.1]	0 [0.0]	57 [215.7]	0 [0.0]
241-C-112	Sound	IS/IP	104 [393.6]	0 [0.0]	6 [22.7]	1 [3.8]	104 [393.6]	0 [0.0]
241-C-201	Assumed leaker	IS/IP	2 [7.6]	0 [0.0]	0 [0.0]	0 [0.0]	2 [7.6]	0 [0.0]
241-C-202	Assumed leaker	IS/IP	1 [3.8]	0 [0.0]	0 [0.0]	0 [0.0]	1 [3.8]	0 [0.0]
241-C-203	Assumed leaker	IS/IP	5 [18.9]	0 [0.0]	0 [0.0]	0 [0.0]	5 [18.9]	0 [0.0]
241-C-204	Assumed leaker	IS/IP	3 [11.4]	0 [0.0]	0 [0.0]	0 [0.0]	3 [11.4]	0 [0.0]

Source: Hanlon 2000

IP = Intrusion Prevention

IS = Interim stabilized or isolated

PII = Partially interim isolated.

2.3.3.5 Unplanned Releases. In addition to leaks historically attributed to tanks, twelve unplanned releases (UPRs) have been reported in and around the WMA C. The following are brief descriptions of these events:

- Unplanned release UPR-200-E-16 is a surface spill that resulted from a leak in an over ground transfer pipeline between tanks C-105 and C-108. The surface spill associated with this release is located approximately 60 ft (18 m) northeast of tank C-105 and occurred in 1959. The spilled liquid was classified as coating waste from the PUREX process.

- Unplanned release UPR-200-E-27 is located just east of the 244-CR vault and extends easterly beyond the tank farm fence line. DOE (1993) indicates the surface contamination was deposited in 1960, but does not specify the source or potential sources of the contamination.

- Unplanned release UPR-200-E-68 was wind-borne surface contamination spread from the 241-C-151 diversion box. The release occurred in 1985 and was subsequently decontaminated or covered with clean sediment.

- Unplanned release UPR-200-E-72 is located south of the WMA C and occurred in 1985. The source of the contamination was buried contaminated waste. The waste posed little release potential because the contamination was fixed in place. The source of contamination was stabilized and the area posted as a radiologically controlled area. The volume of the contamination was not specified.

- Unplanned release UPR-200-E-81 is located near the 241-CR-151 diversion box and the 244-CR vault. It occurred as a result of a leak in an underground transfer pipeline in October 1969. The waste leaked from the pipeline consisted of PUREX coating waste. The site was covered with gravel.

- Unplanned release UPR-200-E-82 is located near the 241-C-152 diversion box and was the result of a leak from an underground pipeline from the 202-A building to tank C-102 by way of the 241-CR-151 diversion box. The release occurred in December 1969. The leak spilled an estimated 2,600 gal (10,000 L) of waste. The contaminated site was covered with clean gravel.

- Unplanned release UPR-200-E-86 was a spill that resulted from a leak in a pipeline used to transfer waste from the 244-AR vault to the 241-C Tank Farm. The release was approximately 8 ft (2,4 m) bgs. It occurred in March 1971 and is located just outside the west corner of the tank farm. The spill was estimated to include 25,000 Ci of ^{137}Cs. The sediments surrounding the pipeline were sampled and it was determined the contamination had not penetrated below 20 ft (6 m). The contamination plume volume was estimated at 1,300 ft^3 (36.8 m^3)

- Unplanned release UPR-200-E-91 is located approximately 100 ft (30.5 m) from the northeast side of WMA C. It resulted from surface contamination that migrated from the WM A C. The date of the occurrence, its areal extent, and the nature of the contamination

are not specified. DOE (1993c) states that the contaminated sediment was removed and the area was released from radiological controls.

- Unplanned release UPR-200-E-99 was surface contamination that resulted from numerous piping changes associated with the 244-CR vault. It is located west of the 244-CR vault and was established as a release site in 1980 although the actual occurrence date is unknown. The site was decontaminated in 1981.

- Unplanned release UPR-200-E-100 was a surface spill of unknown proportions and constituents that occurred in 1986. It is located about 200 ft (60 m) south and east of WMA C and surrounds the 244-A lift station.

- Unplanned release UPR-200-E-107 was a surface spill located north of the 244-CR vault, inside WMA C DOE (1993c) states that a spill occurred on November 26, 1952 when a pump discharged liquid to the ground surface during a pump installation. The spilled waste was tributyl phosphate waste from 221-U building. The proportions of the spill and any cleanup actions were not documented.

- Unplanned release UPR-200-E-118 was located in the northeast portion of WMA C and extends north up to about 914 ft (300 m) beyond the fence line. It was the result of an airborne release from tank C-107 that occurred in April 1957. The highest exposure rate was estimated at 50 mrem/hr at the ground surface (DOE 1993c).

2.3.4 Current Inventory

Inventory in WMA C can be divided into the following categories:

- Waste in 100- and 200-series tanks

- Waste in infrastructure

- Waste in soil

2.3.4.1 Waste in 100 and 200 series tanks. The inventory of wastes in the large underground at the Hanford Site is maintained in the Best Basis Inventory (BBI). BBI includes "standard" chemical and radionuclide constituents that have been developed and published via the Tank Waste Information Network System (TWINS) at http://twins.pnl.gov/twins.htm. The constituents included are listed in Table 2-9.

The BBI is a process that was developed to more fully understand and use the available analytical data for tank samples and use the best available information to estimate tank compositions and inventories. The BBIs provide the official estimate of the SST and DST contents for 24 chemicals and 46 radionuclides.

Table 2-9. Standard Best-Basis Inventory Constituents

Analytes		Radionuclides		
Al	Na	^{3}H	^{134}Cs	^{234}U
Bi	Ni	^{14}C	^{137}Cs	^{235}U
Ca	NO_2	^{59}Ni	^{137m}Ba	^{236}U
Cl	NO_3	^{60}Co	^{151}Sm	^{237}Np
CO_3	Pb	^{63}Ni	^{152}Eu	^{238}Pu
Cr	PO_4	^{79}Se	^{154}Eu	^{238}U
F	Si	^{90}Sr	^{155}Eu	^{239}Pu
Fe	SO_4	^{90}Y	^{226}Ra	^{240}Pu
Hg	Sr	^{93}Zr	^{227}Ac	^{241}Am
K	TOC	^{93m}Nb	^{228}Ra	^{241}Pu
La	U-TOTAL	^{99}Tc	^{229}Th	^{242}Cm
Mn	Zr	^{106}Ru	^{231}Pa	^{242}Pu
		^{113m}Cd	^{232}Th	^{243}Am
		^{125}Sb	^{232}U	^{243}Cm
		^{126}Sn	^{233}U	^{244}Cm
		^{129}I		

TOC = total organic carbon

The BBI uses sample data, process knowledge, surveillance data, and waste stream composition information from the Hanford Defined Waste (HDW) computer model *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4* (Agnew 1997), hereafter referred to as the HDW model, to establish the inventory of the underground waste storage tanks. BBI values are updated on a quarterly basis to incorporate new data and waste transfer information. The BBI values in this document reflect the inventory estimates for the wastes in the tanks as of July 1, 2002. Sample data released after July 1, 2002 and waste transfers occurring after July 1, 2002 are not included.

Sample data, when they represent the current contents of the tank, are the preferred source of waste concentration information for the BBI. All of the DSTs and all but 23 of the SSTs have been sampled. All tanks in the WMA C have been sampled. However, a number of the sampled tanks were analyzed for a limited suite of analytes.

Consequently, a complete tank inventory cannot be determined based on samples only. Further, limited data are available for some of the key risk drivers for tank closure. Among these 23 SSTs are 13 of the 18 tanks in the TX tank farm and 6 of the 15 tanks in the SX tank farm.

Process knowledge concentrations may be derived from information such as historical tank sample data, sample data from other tanks, waste transfers, and chemical additions. Waste-type-template concentrations are used when other information is not available. Solid-waste-type templates are based on sample data for a particular waste type supplemented with

process knowledge and waste-type concentrations from the HDW model. Liquid-waste-type templates are primarily based on the waste type concentrations from the HDW model supplemented with adjustments based on process knowledge for mercury and water-insoluble metals. Templates are described in *Best-Basis Inventory Template Compositions of Common Tank Waste Layers* (Sasaki 2001).

Most of the chemical inventories in the BBI can be traced to sample data or template concentrations that are based on samples. However, aside from a few radionuclides such as cesium-137/barium-137m, strontium-90/yttrium-90, and the isotopes of plutonium, americium, curium, and uranium, the radionuclide inventories in the BBI are largely based on the HDW model. This is especially true for the SSTs.

The current HDW model is known to overestimate the inventories of certain radionuclides; therefore, the current best-basis global inventories may be biased high (*Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes*, Kupfer 1999). While the HDW model does account for releases to the environment from the tank farms via tank farm evaporators, tank leaks, and direct discharges to cribs, it does not account for the loss of constituents such as tritium and carbon-14 directly from the separation plants. Estimates for plant losses of tritium, carbon-14, technetium-99, and iodine-129 have been developed and are being incorporated into a revision of the HDW model. The HDW model may also underestimate global inventories. For example, the HDW model did not include the use of potassium permanganate at the REDOX facility and strontium nitrate for strontium-90 scavenging. Internal letter "Hanford Defined Waste Model Parameters for Manganese Used in the REDOX Process" (Higley 2002b) provides the quantity of potassium permanganate used in REDOX; internal letter "Strontium Modeling Parameters for the Hanford Defined Waste Model" (Higley 2002d) provides the relative amount of total strontium to strontium-90 for various processes. These estimates are being incorporated into the revision of the HDW model.

According to internal letter "Bismuth Phosphate Process Radionuclide Partition Factors for the Hanford Defined Waste Model" (Higley 2002a), the HDW model appears to have used information from the *Hanford Works Technical Manual Section C* (HW-10475 C) to distribute radionuclides among the bismuth phosphate process waste streams. Aside from strontium-90, cesium-137, and plutonium, all radionuclides were partitioned with 88.9% going into the metal waste stream, 10% to the first-cycle decontamination waste and coating waste, 1% to the second-cycle decontamination waste, and 0.1% to the final decontamination/concentration cycle waste. Recent draft laboratory simulations of the bismuth phosphate process have shown that this distribution is reasonable for some radionuclides but not for others. Based on the laboratory simulations, process flowsheets and process data, Higley (2002a) revised a number of the radionuclide partition factors for the bismuth phosphate waste streams.

A revision to the HDW model to reflect the new information that has become available is underway and will be completed in fiscal year 2003. In addition to incorporating the plant loss estimates and updated bismuth phosphate process partition factors, the revision of the HDW model will include updated source term estimates from ORIGEN2 and DKPRO runs from *Activity of Fuel Batches Processed Through Hanford Separations Plants, 1944 Through 1989* (RPP-13489), and updated solubilities from internal letter "Evaluation of Solubility Limits Based

[on] the Tank Characterization Database" (Place 2002b). After the model is revised, results will be compared with sample data to validate the model and assess the uncertainty in the results (see Section 6.8 of DOE/ORP-2003-02 for more information). Changes to key analytes (e.g., technetium-99, and iodine-129) are discussed below.

The BBI provides inventory estimates for 24 chemical and 46 radionuclide constituents for each of the 177 tanks. In addition, the BBI also contains supplemental analytes for which inventories are estimated only if sufficient sample data exists to provide an estimate of the tank content. These supplemental analytes are listed below:

- Ammonia/Ammonium
- Antimony
- Arsenic
- Barium
- Beryllium
- Boron
- Cadmium
- Cerium
- Cobalt
- Copper
- Cyanide
- Free Hydroxide
- Lithium
- Magnesium
- Molybdenum
- Neodymium
- Oxalate
- Palladium
- Plutonium
- Praseodymium
- Rhodium
- Rubidium
- Ruthenium
- Selenium
- Silver
- Tantalum
- Tellurium
- Thallium
- Thorium
- Titanium
- Tungsten
- Vanadium
- Yttrium
- Zinc

These analytes are not standard BBI analytes because they are not estimated by the HDW model (or, in the case of oxalate and ammonia, not adequately estimated by the HDW model) and no basis is readily available for estimating inventories except the sample data. Data for many of the supplemental analytes are now available for most DSTs as a result of sampling and analysis performed in support of waste feed delivery and retrieval.

The BBI does not provide inventory estimates analytes such as hexavalent chromium, pertechnetate, polychlorinated biphenyls (PCBs), and volatile and semi-volatile organics that may be of concern for retrieval, disposal, and closure purposes. Some data exist for these constituents and analytical results can be found at http://twins.pnl.gov/data/datamenu.htm. Key constituents not included in the BBI (e.g., pertechnetate) are discussed below.

Hanford Defined Waste Model Limitations and Improvements (HNF-3273) discusses the assumptions and limitations of the HDW model. As described in HNF-3273, uncertainty in the HDW estimates can be qualitative — expressed as subjective judgments about model accuracy and bias — or quantitative, as in scatter-plots that compare the HDW estimates to sample data. Because sample radionuclide data available for comparison are limited, the relative standard

deviations should be used in conjunction with qualitative assessments of the underlying HDW assumptions and limitations.

Technetium-99. The new ORIGEN2 runs resulted in a small (about 3%) increase in estimate of technetium-99 in the fuel as a result of updates to fission product yields and decay half-lives.

The HDW model assumes that all the technetium-99 present in the fuel exited the separation plants in waste streams that were sent to the tank farms. The model does not account for technetium-99 that was sent offsite in the uranium product. Based on an evaluation of the levels of technetium in uranium oxide products, uranyl hydrate hexahydrate products, and high-level waste supernatants in the tanks, internal letter "Recommended Separation Factors for Technetium-99" (Kirch 2003) estimates the fraction of technetium-99 that went into the tank waste streams; these fractions are shown in Table 2-10. The revised estimates will result in a reduction of about 24% in technetium-99 sent to the tank farms.

Table 2-10. Partition Factors for Technetium-99

Process	Fraction of Technetium-99 Sent to Tank Farms	Tank Farms Receiving Waste from Plant
Uranium Recovery	0.72	BX, BY, C, T, TX, TY
REDOX	0.87	S, SX, T, U
PUREX	0.72	A, AN, AP, AW, AX, AY, AZ, C

Source: Kirch, 2003.
PUREX = Plutonium-Uranium Extraction Facility
REDOX = Reduction Oxidation

Iodine-129. The new ORIGEN2 runs incorporate updated fission product yields for iodine-129. As a result of this change, the estimate of iodine-129 in the fuel is 49.4 Ci, about 77% of the previous estimate.

The HDW model assumes that all the iodine-129 present in the fuel exited the separation plants in waste streams that were sent to the tank farms. However, a significant portion of the iodine-129 is believed to have been lost from the plants as discharges to the atmosphere and to the soil as a result of iodine liberation during fuel dissolution. Table 2-11 provides the partition factors estimated by "Iodine-129 Partition Factors for the Hanford Defined Waste Model" (Higley 2002c). Because the alkalinity of the solutions used to remove aluminum and zirconium cladding would not cause iodine to be evolved, Higley (2002c) estimates that the iodine-129 present in the cladding will partition entirely to the cladding waste streams. Incorporation of these partition factors will result in about 80% of the iodine-129 in the fuel being discharged to the tank farms (Higley 2002c)

Table 2-11. Partition Factors for Iodine-129 Generated in Uranium Metal

Process	Fraction of Iodine-129 Sent to Tank Farms	Tank Farms Receiving Waste from Plant
T and B Plant 1944-1949	0.336	B, C, T, U
T and B Plant 1950-1956	0.933	BX, BY, C, T, TX, U
REDOX 1952-1958	0.9875	S, SX, T, U
REDOX 1959-1966	0.95	S, SX, U
PUREX 1956-1967	0.901	A, AX, C
PUREX 1968-1972	0.45	A, AX, AY, C
PUREX 1983-1988	0.45816	AN, AP, AW, AY, AZ

Source: Higley 2002c
PUREX = Plutonium-Uranium Extraction Facility
REDOX = Reduction Oxidation

Pertechnetate. Laboratory methods for measuring pertechnetate concentrations in tank wastes are not currently available. Free technetium-99 has been measured in some samples as a means of estimating the pertechnetate. As of December 24, 2002, free technetium-99 and technetium-99 analyses have been performed on liquid samples from nine tanks; no free technetium-99 analyses have been performed on solid samples. Results are shown in Table 2-12. Results for five of the tanks indicate that greater than 90% of the technetium-99 in the liquids exists as free technetium-99; results for the other four tanks range widely, indicating that from 13% to 76% of the technetium-99 in the liquids exists as free technetium-99.

Table 2-12. Comparison of Technetium-99 and Free Technetium-99 Concentrations in Liquid Samples

Tank	Free Technetium-99	Units	Technetium-99	Units	Free Technetium-99: Technetium-99
241-AP-101	4.72E-02	µCi/mL	4.90E-02	µCi/mL	96%
241-AP-104	5.77E-02	µCi/mL	2.03E-01	µCi/mL	28%
241-AW-103	2.04E-02	µCi/mL	2.23E-02	µCi/mL	91%
241-AY-101	5.31E-03	µCi/mL	4.23E-02	µCi/mL	13%
241-AY-102	9.72E-03	µCi/mL	1.29E-02	µCi/mL	76%
241-AZ-101	3.81E-01	µCi/mL	3.98E-01	µCi/mL	96%
241-AZ-102	2.37E-01	µCi/mL	2.17E-01	µCi/mL	109%
241-C-107	5.78E-02	µCi/mL	5.72E-02	µCi/mL	101%
241-SY-102	9.68E-02	µCi/mL	1.66E-01	µCi/mL	58%

Source: *Tank Waste Information Network System* (TWINS), [Best-Basis Calculation Detail Report], available at http://twins.pnl.gov/data/datamenu.htm.

Additionally, examination of technetium-99 analysis of water leaches and fusion digests of solids samples and comparisons of technetium-99 analysis of both liquids and solids from a tank indicate that not all technetium-99 exists in a water-soluble form.

2.3.4.2 Waste in Infrastructure.

Presently, there is no information to quantify the inventory that exists in the WMA C infrastructure (e.g. buried pipelines).

2.3.4.3 Waste in Soil. Subsurface contamination has been generated by tank farm operations in the WMA C over the course of a long operating period from the mid-1940s until 1980. The primary data sources are gamma ray logging data, tank waste chemistry records and tank farm operations records. Because the gamma logging data are so important to this discussion, an overview of these data is provided below. A summary of characteristics for tank wastes that are the probable sources of subsurface contamination is also provided. In addition, data are described by specific area of contamination. Although no WMA C sources are known to have caused local groundwater contamination, groundwater characteristics are provided to complete the description of subsurface contaminant characteristics in and around the WMA Cs.

Gamma Ray Logging Information. Two types of gamma ray logging data (spectral gamma logging data and gross gamma logging data) were collected in the WMA C. As part of a tank leak detection program (Isaacson and Gasper 1981), gross gamma logging was conducted from the early 1960s through 1994. Recently, the gross gamma logging data from WMA C were evaluated to assess potential movement of gamma-emitting radionuclides in the vadose zone (Randall 2001a). More recently, spectral gamma logging data were collected for the WMA C (DOE-GJO 1998).

Spectral Gamma Logging Data. The spectral gamma logging database is the most comprehensive database available that quantifies the nature and extent of subsurface contamination in the WMA C. Specific spectral gamma data that identify the most contaminated areas within WMA C are discussed below. In some cases, the spectral gamma data provide information that can be correlated with time-dependent waste transfer and storage records for specific tanks. This allows identification of specific waste types. The spectral gamma data also provide an independent means of evaluating the veracity of reported tank leaks.

Some limitations are associated with the gamma logging methods:

- Gamma logging interrogates only about 12 to 18 in. (30 to 45 cm) of the soil around the well.
- Uncertainties associated with distinguishing gamma contamination in the well or on the well casing from gamma activity originating in the soil may make data inaccurate.
- Gamma activity monitored by these methods provides little information about the tank waste-related non-gamma-emitting radionuclides and chemicals.

These limitations must be considered in evaluating the referenced data reports.

The relationship between the leak status of SSTs and spectral gamma logging data in nearby drywells is qualitative. However, both the depth of gamma activity and its intensity provide some ability to distinguish between failure of the tank and losses associated piping or tank overfills. Most easily distinguished are the cases where significant waste volumes engulf a section of the drywell. In these cases, Cs-137 activity is aproximately $1x10^7$ pCi/g. Depending on the waste type present, there are frequently other gamma emitters at much lower concentrations. This concentration of Cs-137 appears to represent the sorption capacity of the soil. If the high Cs-137 activity zones appear at or near the levels of the waste transfer lines or spare inlet ports then this is considered to be strong evidence for a piping leak or tank overfill event as being the origin of the contamination. High Cs-137 activity (>10,000 pCi/g) beginning near the base of the tank provides strong evidence for a leak from the tank. Other situations are much more difficult to interpret.

Low levels of Cs-137 contamination are ubiquitous in drywells around most SSTs. It appears that open boreholes provided a pathway for contamination to enter the well casing and in some cases the unsealed boreholes provided a pathway for contamination to move downward. In addition, the compacted base on the original tank farm excavation provided a region for liquids to pond and move laterally. The Cs-sorption chemistry predicts that the Cs-137 is held in a highly concentrated plume with sharp activity drops at the edge. Thus, when low Cs-137 activity is reported in one of the drywells, it appears there are only two reasonable explanations. Either the drywell is sitting on the edge of a high-activity Cs-137 plume or the contamination was the result of a nuisance contamination spread. Distinguishing between the two options requires an assessment of other information such as waste transfer and waste level records, waste type in the tank, documented leak history, and data from nearby drywells.

Gross Gamma Logging Data and Synthesis with Spectral Gamma Logging Data. Because gross gamma logging was conducted over two decades, evaluating these data provides information on the time-dependent behavior of the gamma-emitting radionuclides in the subsurface. The concentrations of the individual gamma-emitting isotopes that contributed to the gross gamma curves over time were estimated using the recently collected spectral gamma data (concentrations of specific gamma-emitting radionuclides) from the drywells used to collect gross gamma data. By factoring in decay, these calculated curves were propagated over time and compared with the gross gamma curve histories. Using this process, changes in the curves caused simply by decay can be distinguished from decay plus changes in gamma radionuclide concentrations at a given location over time.

Of particular interest are the drywells indicating a change in radionuclide concentrations at a given location over time that cannot be attributed solely to radioactive decay. These conditions are referred to as unstable events. For each location, the borehole number, the depth below the surface, the radionuclide present, the time over which changes in concentration were deduced, and the concentration increase or decrease over that period is listed.

Near-surface changes are attributed to tank farm operations and are broken out separately from changes that occur at greater depths. Changes at depth are attributed to tank and transfer line leaks of tank waste. These changes occur within 30 ft (9 m) of the surface and generally occurred from 1975 to 1985 over most of the tank farm areas. This observation is consistent

with a common drywell spectral gamma pattern in which a maximum radionuclide concentration (usually Cs-137) of 10 pCi/g to 100 pCi/g or occasionally higher near the surface diminishes with depth to about 1 pCi/g with depth. We consider this pattern to be consistent with surface or near-surface leaks of contaminated fluid.

The remainder of the radionuclide migration events (e.g., referred to as unstable zones) occurs at depths near the tank bottoms or lower. Over the time during which measurements were taken, unstable conditions were observed in 19 drywells in WMA C. The majority of unstable zones in the WMA C are associated with the transfer line leaks between tanks C-104 and C-105 and between tanks C-108 and C-109. Most involve movement of Co-60 after leakage from the transfer lines.

Tank Waste Chemistry and Leak Characteristics Overview. Environmental impacts of leaks from SSTs or other waste loss events are closely linked to the type of waste lost to the soil column. Waste types stored in WMA C tanks covered the complete range of waste types produced in the 200 Area chemical process facilities.

The WMA C tanks began receiving wastes from the B Plant bismuth phosphate process in 1946. The high activity waste stream coming from the bismuth phosphate process consisted essentially of the uranium by-product and the vast majority of the fission products (Serne and Jones 2003). This stream was called "metal waste". The first six tanks in the WMA C were filled with metal waste. The metal wastes were later recovered from the tanks and processed for uranium recovery in the U Plant in 200 West Area. The other six tanks in the WMA C were filled with so-called first-cycle waste, a much more dilute waste stream coming from the first plutonium dissolution/re-precipitation purification step. Cladding wastes were also added to these tanks. The cladding waste stream originated from the dissolution of the aluminum cladding from the fuel rods with a caustic nitrate solution and was a low activity stream. The first-cycle waste carried approximately 10% of the beta activity but a much lower fraction of fission products (Serne and Jones 2003). The cladding waste would have been a high aluminum, high hydroxide stream with low activity levels.

The uranium recovery process produced a waste stream at twice the volume of the metal waste recovery processed. This waste stream, called TBP (tributyl phosphate) or UR (uranium recovery) waste, was transferred back to a number of the WMA C tanks. To free up tank space, the first-cycle waste from C tanks was transferred to the B Evaporator. At a later date, the TBP wastes stored in WMA C tanks was processed through for reduction of Cs-137 in the C Vaults. After allowing some time in WMA C tanks for precipitation of resulting solids, the scavenged TBP waste was sent to the BC cribs and specific retention trenches. The first-cycle wastes were later transferred to the B Evaporator. As WMA C tank space became available, it was used to support pilot-plant studies at the Hot Semiworks and for low activity waste streams from PUREX. By the mid 1960s, WMA C tanks were being used to store aged PUREX high-level supernatants. As the B Plan isotope recovery process came online in 1968, several WMA C tanks were used as feeder tanks supporting specific B Plant operations. Thus, many of the WMA C tanks had very large volumes of wastes moved through them.

The transfers of wastes through the C tanks are well documented (Agnew 1997), and tank waste compositions are available from a number of sources (Agnew 1997, Buckingham 1967, Larson 1967). When tank waste loss events are well defined in terms of timing and volume, the inventory estimates for the lost materials are reasonably straightforward. However, the volumes of waste lost to the WMA C vadose zone in various events are highly uncertain or unknown. Thus, inventory estimates for most waste loss events associated with WMA C involve considerably uncertainty.

WMA C Tank Waste Losses Events. Hanlon (2000) lists three primary tanks and all four secondary tanks in the C tank farm as "confirmed or assumed leakers." Estimated leak volumes vary from 350 gal (1,300 L) in secondary tank C-204 to a possible 20,000 gal (80,000 L). None of estimated leak volumes are well constrained. Each of the listed leaks is discussed below to determine the severity of the contamination. Also, the validity of the leak designations was critically reviewed to determine whether the observed contamination is significant enough to support the leaker designation and warrant further characterization. A number of tanks are listed as confirmed or suspected leakers by Hanlon (2000), but neither the waste transfer record nor the gamma logging data support the designation.

Some additional locations were also considered because spectral gamma logging data indicates sufficient contaminant concentrations to warrant evaluation. These sites have not been clearly identified in the past as vadose contamination zones.

In addition to tank leaks, leaks from other infrastructure and tank farm activities occurred. An overall assessment of the spectral gamma logging data from WMA C drywells indicates that most vadose zone contamination originated from surface or near surface sources. This is demonstrated by relatively high concentrations of Cs-137 near surface and a general decrease in Cs-137 activity with depth. Cobalt-60 is found near the bottom of many of the drywells with near surface Cs-137 contamination. This indicates that "mobile" Co-60 was driven down from recharge. These ubiquitous contamination events were not generally associated with particular recorded events and are not considered to be significant sources of vadose zone contamination.

Tank Waste Losses from WMA C Tanks. Hanlon (2000) lists tank C-101 as a known or suspected leaker with a leak volume estimate of 20,000 gal (80,000 L). Decreases in waste levels were documented in the late 1960s, a time when this tank contained aged PSN. A 20,000 gal (80,000 L) loss of this waste type would have released ~127,000 curies of Cs-137 (Simpson 2001), more than all of the Cs-137 projected to have been lost from all of the SX tank farm leaks (Jones 2000). The spectral gamma logging data from drywells around tank C-101 show little evidence of any leaks and certainly nothing of that order of magnitude. A far more likely scenario is the liquid level drops in the late 1960s were associated with evaporation caused by the continuing high heat load of the aged PSN. The waste loss in the late 1970s appear to have been associated with saltwell pumping (Agnew 1997). Although the waste transfer records indicate that tank C-101 was filled above the 530,000 gal (2 million L) fill limit from 1964 through 1969, there is no evidence of leaks from the spare inlet ports in this tank.

Spectral gamma data in two drywells around tank C-101 suggest small waste loss events may have occurred. In drywell 30-01-09, a Cs-137 peak (about 600 pCi/g) occurs about 28 ft 8.5 m

bgs along with traces of Co-60, Eu-152 and Eu-154. The position of this peak suggests a small isolated leak from piping or a spare inlet port at this location. Tank waste chemistry suggests that Cs-137 in tank waste would sorb readily on the soil; therefore, the leak location should be near the drywell. Because the peak value is low, it is concluded a substantial inventory was not associated with this leak. A second small tank leak may be indicated near drywell 30-01-06 where an apparent Cs-137 peak (about 50 pCi/g) around 40 ft (12 m) bgs occurs, a depth that coincides with the tank bottom. Randall and Price (2001) identified some instability in the gross gamma logs from 1979 to 1980 in this drywell at 30 to 41 ft (9 to 12 m) bgs and interpreted the data as an indication of Cs-137 movement.

Hanlon (2000) lists tank C-110 as a known or suspected leaker. However, a detailed analysis of the history of WMA C (Agnew 1993) attributed liquid level decreases in 1969 to measurement errors and recommended the "leak statue" of this tank be revisited. This analysis reaches similar conclusions. The spectral gamma logging data and historical waste transfer records provide no definitive evidence of leaks from this tank. The simplest explanation of spectral gamma logging in drywells around this tank is that the widespread surface contamination found its way down the inside or outside of well casings, likely from additions of water to control airborne transport of radionuclides.

At tank C-110 small concentrations of Cs-137 are found almost continuously in drywell 30-10-02 between the surface and 63 ft (19 m) bgs. The shallow contamination likely represents surface spills or shallow pipeline leaks (the cascade line between tanks C-110 and C-111 plugged in 1952 [Brevick 1994]), but the contamination between 44 and 63 ft (13 and 19 m) bgs may indicate the occurrence of a small leak. Cs-137 contamination was measured when the drywell was constructed in 1974, indicating the occurrence of a leak prior to this date. If a small leak did occur, the low Cs-137 concentration (maximum of 20 pCi/g) and the historical record of relatively dilute tank waste (first cycle waste, PUREX coating waste, organic wash waste) indicate that little contamination would have been released to the vadose zone. Very small concentrations of Cs-137 (< 1 pCi/g) were also measured on the west side of tank C-110 in drywell 30-10-09 between 17 and 38 ft (5 and 12 m) bgs. Contamination at this depth range may indicate a small transfer line leak. Also, historical gross gamma records for 30-10-09 show a decrease of Ru-106 between 1975 and 1978 followed by an increase between 1978 and 1980 at tank bottom depth (40 to 60 ft [12 to 18 m] bgs). These data may be another indicator of this leak.

There are no spectral gamma data or well documented historical record data suggesting leaks occurred at primary tank C-111 and secondary tanks C-201 through C-204. Welty (1988) reported a liquid level drop in 1968 as the basis for questioning the integrity of tank C-111. However, the reliability of this claim was not well documented (DOE-GJO 1998) and no spectral gamma data from drywells around the tank indicate loss of tank waste. No drywells are present near the secondary tanks; therefore, no means of identifying leaked tank waste is available. Also, no clear indication of tank leakage has been reported. However, given their small volume, it is concluded that no significant tank waste loss from these tanks has occurred.

Spectral gamma data strongly indicate that tank C-105 did leak, at least temporarily and the leak event is indicated by contamination observed at drywell 30-05-07 where two high Cs-137

concentration zones occur at and below the tank bottom. Between 34 and 44 ft (10 and 13 m) bgs and 48 and 62 ft (15 and 19 m), maximum Cs-137 values (10^7 pCi/g and 10^5 pCi/g, respectively) were recorded (DOE-GJO 2000). The general location and profile of the spectral gamma logging data indicate that tank C-105 likely leaked near the bottom on the southwest side very near drywell 30-05-07. The gamma contamination was encountered when drywell 30-05-07 was drilled in 1974. The historical gross gamma data analysis indicates no changes in location or intensity of Cs-137 activity. Thus, if tank C-105 did leak then the leak occurred prior to 1974 and apparently self-sealed because tank C-105 was used as an active Cs-137 recovery feeder tank until 1974. The Cs-137 recovery wastes were aged PUREX and REDOX high-level wastes so any waste losses would have contributed radionuclides to the soil column.

Concerns about the integrity of tank C-105 are supported by the historical record of large liquid level drops (3 ft [~0.9 m]) in tank C-105 between 1963 and 1967 (DOE-GJO 1998). However, during the time tank C-105 stored aged PSN and liquid losses to evaporation are noted in the historical records (Agnew 1997). The contamination in the region between tanks C-104 and C-105 has been of interest (Brodeur 1993, Agnew 1993). Both cascade line and spare inlet port waste loss events have been suggested as sources of contamination in this region.

An alternate explanation for the high activity in drywell 30-05-07 is that Cs-137 in this drywell has origins in the cascade line between tanks C-104 and C-105 (Broduer 1993, DOE-GJO 2000). However, the likely waste, PSN, does not appear to have the appropriate chemical makeup to mobilize Cs-137 in the soil column. Therefore, a leak source at the tank wall 2 ft (0.6 m) from the contaminated zone compared to the cascade line more than 30 ft (9 m) away is much more plausible. The two high Cs-137 zones may indicate two leak events.

In addition to Cs-137 contamination at the tank bottom, isolated occurrences of Co-60, Eu-152 and Eu-154 are present. The true extent of these contaminants at this drywell location is difficult to determine. The very high Cs-137 concentrations may mask the occurrence of these isotopes at the same depth. Also, the drywell ends at about 68 ft (21 m) bgs and additional contamination at greater depth cannot be determined.

Two other drywells may indicate the outer edges of the proposed tank C-105 leak. In drywell 30-05-05 just south of drywell 30-05-07, a Cs-137 peak (about 70 pCi/g) occurs between 60 and 65 ft (18 and 20 m) bgs and a Co-60 peak occurs at 70 ft (21 m) bgs. Proximity of the two drywells and consistent Cs-137 peaks with depth suggest the same leak source. Similarly a Cs-137 peak (15 pCi/g) occurs at 47 ft (14 m) bgs in drywell 30-05-08. Co-60 is also present between 35 and 50 ft (11 and 15 m) bgs

Other Contamination Zones in the WMA C. Near surface contamination events are indicated at other locations within the WMA C by historical records, field investigations and drywell spectral gamma data. Unplanned releases in the WMA C, near surface transfer line leaks and generalized surface contamination are all indicated by this information. The most contaminated sources are discussed in greater detail below. Three significant unplanned releases that occurred to the west of WMA C farm but still within the WMA are described in this section. Within WMA C, spectral gamma measurements have been recorded at many drywells in the eastern half of C farm, particularly the southeastern segment. Cesium-137 and Co-60 are the most prominent

contaminants. Given the relative concentrations of these constituents, two locations appear to be the primary source of this contamination: the areas between tanks C-104 and C-105 and between tanks C-108 and C-109.

Unplanned Releases in the WMA C. Williams (2002) identifies a number of unintentional near-surface losses and windblown contamination events in the WMA C farm. The Waste Information Data Base System (WIDS) summarized these UPRs, and Maxfield (1979) also discusses some events. Two of the UPRs (UPR-200-E-82, and UPR-200-E-86) involved PSN and contributed significant inventory to the soil column. A third UPR involved the loss of CWP. These three events occurred on the southwest side of WMA C and made relatively significant contributions to vadose zone contamination. WIDS also identifies a number of other waste loss events but these involve either small (<100 gal [380 L]) volume losses, airborne contamination spreads, or tank leak information mirroring the information in the monthly Hanlon report (Hanlon 2000). There is small overland piping leak (50 gal [190 L]) involving the loss of PUREX cladding waste between tanks C-105 and C-108, documented in UPR-200-E-16. The spectral gamma logging data (DOE-GJPO 1998 and 2000) for WMA C farm indicates widespread low-level Cs-137 contamination across much of this farm.

Report UPR-200-E-81 describes a 1969 waste loss event that occurred near the 241-CR-151 Diversion Box and involved the loss of 36,000 gal (136,000 L) of CWP (Williams 2001, Maxfield 1979). A puddle of contaminated liquid measuring 6 by 40 ft (1.8 to 12 m) was formed. The puddle was backfilled with clean dirt in 1969. The CWP was a reasonably low activity waste stream produced from the caustic dissolution of the aluminum fuel rod cladding. The origin of the radioactive contamination in this waste stream was congruent dissolution of the uranium fuel during the de-cladding operation. It was estimated that 720 Ci of Cs-137 were lost to the soil.

Report UPR-200-E-82 describes the loss of Cs-137 recovery process feed solution being pumped from tank C-105 to the B Plant. The leak occurred near the 241-C-152 Diversion Box and involved the loss of approximately 2,600 gal (9,800 L) of liquids (Tanaka 1971). Approximately 100 gal (380 L) of this fluid surfaced. Surface contamination was covered with clean gravel in 1969. This waste loss event was thoroughly investigated and results are available (Tanaka 1971). It was estimated that 11,300 Ci of Cs-137 were lost to the soil. Additional inventory estimates of vadose contamination from this event are discussed in Section 4.

Report UPR-200-E-86 describes a waste loss event associated with a pipeline break near the southwest corner of WM A C. Fluids were being pumped from the 244-AR Vault to WMA C. Approximately 17,400 gal (65,860) of fluid that contained approximately 25,000 Ci of Cs-137 were lost to the soil (Maxfield 1979). Based on the ratio of Tc-99 to Cs-137 in the irradiated fuel ($\sim 3 \times 10^{-4}$ Ci Tc-99/Ci Cs-137), approximately 7.5 Ci of Tc-99 were lost. This waste stream most likely originated from the water washing of PUREX sludge intended to remove Cs-137 (and other waste soluble components) from the sludge prior to acidification and Sr-90 recovery.

Near Surface Contamination in the WMA C. Generalized near-surface contamination occurs across WMA C. About a dozen of the drywells in the farm have Cs-137 gamma activity that peaks at or above 100 pCi/g in the upper 15 ft (4.6 m) of the soil column; however, most

contaminated drywells are around 10 pCi/g. Two of these higher concentration zones, between tank C-104 and C105 and between C-108 and C-109, apparently are caused by small transfer leaks.

Between tank C-104 and C-105, a Cs-137 (531 pCi/g) peak at about 24 ft (7 m) bgs in drywell 30-04-03 indicates a transfer line leak. Apparently the Cs-137 was present before 1974 (Welty 1988). Below the Cs-137 peak, a Co-60 contamination zone (3–6 pCi/g) occurs from 26 ft (8 m) bgs to the bottom of the drywell (about 50 ft (15 m) bgs). Drywell 30-04-02 also includes Cs-137 and Co-60 contamination at similar depth ranges but the Cs-137 peak is not evident, suggesting that drywell 30-04-03 is closest to the source. Also, Co-60 appears at a slightly greater depth interval between 40 and 60 ft (12 and 18 m) bgs in drywell 40-04-02. Historical gross gamma data indicate Co-60 movement for at least 10 years beginning in 1975 when well-documented measurements were first taken. Drywell 30-04-01, which contains Cs-137 contamination almost continuously between the surface and the drywell bottom at 50 ft (15 m) bgs, may also have seen contaminant movement since 1975.

A Cs-137 and Eu-154 peak (about 70 and 20 pCi/g, respectively) occurs in drywell 30-05-08 at 17 ft (5 m) bgs. This may or may not be the same transfer line that leaked near drywell 30-04-03. However, the fact that Eu-154 is present in this drywell and not in drywell 30-04-03 suggests somewhat different waste stream chemistry. No other contiguous drywells show this pattern.

Between tanks C-108 and C-109, a transfer line leak source is indicated by contamination in drywell 30-08-02. High Cs-137 concentrations occur between 20 to 22 ft (6.1 to 6.8 m) bgs and peak at 1,100 pCi/g in this zone. A Eu-154 peak (24 pCi/g) is coincident with Cs-137 and the more mobile Co-60 is present between 50 and 80 ft (15 and 24 m) bgs at concentrations up to 10 pCi/g. These contaminants were present when the drywell was installed in 1974. This contaminant plume appears to extend at least to drywell 30-06-10 where a similar Co-60 plume occurs between 86 and 115 ft (26 and 35 m) bgs at lesser concentrations (up to 1 pCi/g). Co-60 also occurs to a lesser degree in drywell 30-09-01 at 90 to 95 ft (27 to 29 m) bgs. This location may represent the eastern extent of this contaminant plume. Other nearby drywells may also contain contamination that has migrated from this transfer line. These drywells (30-09-06, 30-09-07 and 30-09-02) along with drywells 30-08-02 and 30-06-10 contain mobile Co-60 that migrated in the 1980s between 40 and 115 ft (12 and 35 m) bgs according to the gross gamma record. The apparent lag time between initial discharge to the vadose zone before 1974 and the observed Co-60 migration in the 1980s may indicate additional leakage or enhanced migration instigated by artificial discharge.

Numerous drywells in the east and southeast part of WMA C other than those listed above contain Cs-137 primarily between the surface and tank bottom depth of about 40 ft (12 m) bgs and Co-60 that is located well below tank bottoms (80 ft [24 m] bgs and deeper) and has migrated during the course of the gross gamma logging program between 1975 and 1994. Generally speaking it appears that Co-60 migrates towards the east or southeast in the WMA C vadose zone, judging by the overall Co-60 distribution in the WMA C drywells. The source of contaminants in may be related to the transfer line leaks, the proposed tank C-105 leak or unidentified leaks. However, when the transfer lines and tank C-105 are postulated as sources of

the Co-60, contamination at specific drywells cannot be connected readily to these specific sources.

One other possible source is a tank C-103. Two drywells (30-03-01 and 30-03-07) show small Cs-137 peaks around 50 ft (15 m) bgs that might indicate a tank leak. Also, extended Co-60 contamination zones (20 ft [6 m]) occur in drywells 30-03-01 and 30-03-09 below 80 ft (24 m) bgs. However, these data do not clearly indicate a leak event. The Cs-137 data at drywell 30-03-01 is ambiguous because this drywell was completed in two stages and substantial Cs-137 contamination existed near the surface. During the second stage deepening of the drywell an opportunity presented itself for dragdown contamination in the depth range containing elevated Cs-137 concentrations. In drywell 30-03-07, the lack of a Co-60 contamination zone below the Cs-137 is unexpected if a tank leak occurred here and other surrounding drywells include Co-60 as a contaminant deeper in the vadose zone.

Finally, a small pipeline leak on the north side of tank C-112 is indicated by a thin high Cs-137 concentration zone at 8 ft (2 m) bgs in drywell 30-12-13. Lesser concentrations of Cs-137 (about 1 pCi/g), Co-60 and Eu-154 are found lower in the soil column (down to 50 ft [15 m] bgs).

Groundwater Contamination. This section covers the current state of contamination surrounding the WMA C, including historic constituent trends that depict the temporal and spatial distribution of contaminants. Several distinct suites of contaminants are recognized, based on spatial relationships and on identifying associations of co-contaminants or aqueous chemical parameters. Given the complicated history of waste discharge to the subsurface in the last 50 years combined with artificial reversals in the natural flow direction and the ambiguities and dynamics in the current flow direction, identifying sources at this time is not possible. However, there is no indication that WMA C is the source of any significant groundwater contamination.

During fiscal year 2001, critical means (or range for pH) were not exceeded for the three indicator parameters of pH, total organic carbon, and total organic halides. However, the critical mean for conductivity (553.3 uS/cm) was exceeded in well 299-E27-14 at the end of FY2001. An averaged value of 614 uS/cm was reported for this cross gradient well for the September 2001 sampling event. The increase in conductivity is due primarily to rising sulfate and calcium along with nitrate and chlorine (Figure 3.4). Sulfate was 135 mg/L while nitrate was 29 mg/L for July 2001. The September 2001 sulfate data is abnormally low and is under review. The nitrate value for September 2001 is 43.8 mg/L, very close to the drinking water standard (DWS) of 45 mg/L.

Technetium-99 concentrations continue to increase in all wells at WMA C. This technetium-99 contamination correlates to the rising anionic chemistry. Although downgradient well 299-E27-13 had a pulse of technetium-99 (487 pCi/L) seen in 1998, the recent technetium-99 contamination began to increase in the mid-1990s in well 299-E27-14, current value in July FY2001 of 1190 pCi/L. The greatest increase in FY2001 was detected in well 299-E27-7, which had a maximum value of 2190 pCi/L in July 2001 (DWS 900 pCi/L). Nitrate is greater in well 299-E27-14 while technetium-99 is higher in well 299-E27-7. These differences in concentration levels may be due to chemical differences within a larger, regional plume.

These increases in well 299-E27-14 are part of a contaminant plume that may be moving into the area from upgradient areas in recent years (1995 to the present). Although the source of this contamination is presently unknown, it may be related to past discharges that moved through the area when the B Pond was in full operation or from the upgradient 216-B-3-1 ditch. As part of a continuous ditch system connected to the 216-B-63 Trench, this ditch was decommissioned in 1964 after an accidental release of mixed fission products from the PUREX Plant was discharged directly to the 216-B-3-1 Ditch (DOE/RL-89-28 1993).

The technetium-99 level in well 299-E27-7 has risen sharply indicating a short travel time and thus a short travel distance in the groundwater from the point of entry into the groundwater to the well. Therefore, the 216-B-3-1 Ditch is probably not the source of this groundwater contamination. Results from well 299-E27-7 have, in the past 2 years, shown low levels of cyanide with a maximum value of 17 µg/L in June 2000. Ferrocyanide scavenging was conducted in the 244-CR Vault with storage in selected tanks at WMA C (Kupfer 1997). Although well 299-E27-7 is the upgradient well for this WMA, the only known source for cyanide is the waste stored in WMA C. However, cyanide concentrations decreased during FY2001, and presently it is not detected in this well or any other network monitoring well.

There does not appear to be other tank-related waste in WMA C groundwater. Tritium levels are low, generally less than 1,500 pCi/L, except at well 299-E27-7 where values rose from about 600 to 2,500 pCi/L during the late 1990s. Currently, the trend remains steady near 2,480 pCi/L.

2.3.5 Tank Waste Retrieval

As noted above in the operational history of WMA C, there have been many transfers to and from the tanks. Liquids have been removed from most of the the primary tanks (in an activity called interim stabilization). At this point, only tanks C-103 and C-106 have liquids remaining. The secondary tanks (200 series) have contained insignificant amounts of liquids since the late 1980s.

Formal retrieval is just beginning. According to HFFACO (Ecology 1989), as much waste as possible, given current technology, must be removed from the tanks for treatment and immobilization. Unless limited by waste retrieval technology, the SST waste residues must not exceed approximately 360 ft^3 (10.2 m^3) in each 200-series tank, which can hold 55,000 gal (208 m^3) of waste. For the 100-series tanks, which have volumes above 500,000 gal (2,000 m^3), the limit is approximately 30 ft^3 (1 m^3). On a tank-by-tank basis, the DOE can request that the EPA and Ecology approve a higher residue limit.

Three basic retrieval methods are expected (DOE/ORP-2003-06) to be used:

- Modified sluicing
- Mobile retrieval system (MRS)
- Vacuum-based retrieval (VBR)

2.3.5.1 Modified Sluicing.

Modified sluicing is the introduction of liquid into the waste at low-to-moderate pressures and volumes. Pressures of 50 to 200 psi and flows from 80 to 240 gpm (300 to 900 L/min) are typical (*Process Hazards Analysis for the S-112 Saltcake Waste Retrieval Technology Demonstration Project Preconceptual Design* [RPP-9014]). At lower pressures and flow rates, the retrieval action is primarily related to dissolution and retrieval of soluble species. At higher pressures and flow rates, the retrieval action is related to both dissolution of soluble species and the breaking apart of solid materials and suspension into a waste slurry. A transfer pump inside the tank pumps the waste to a receiver tank.

Modified sluicing differs from past-practice sluicing in the following ways:

- Past-practice sluicing introduces sluicing liquid from a single sluice nozzle in bulk fashion by a flooding-type action. Modified sluicing introduces sluice liquid in a controlled fashion using two to three sluicing nozzles, and pumps out the resultant waste slurry at approximately the same rate as the sluice liquid is introduced. This operating strategy maintains minimal liquid inventories within the tank at all times.

- Modified sluicing uses two to three in-tank sluice nozzles as opposed to the single nozzle used by past-practice sluicing. The use of two to three sluice nozzles allows for a more thorough distribution of sluicing liquid over the tank contents.

- The modified sluicing system has been tested in a non-radioactive environment and is being fabricated for installation into tank S-112.

Modified sluicing is selected for 100-series SSTs that are not classified as assumed leakers. This technology is representative of other fluid-based retrieval technologies (i.e., past practice sluicing, saltcake dissolution, and fluidic mixing). Deployments are limited to those tanks that are not classified as assumed leakers because of concerns regarding the potential for leakage to occur during retrieval. It is recognized that a number of tanks classified as assumed leakers may be candidates for deployment of modified sluicing after further evaluation of historical leak data (or lack thereof). Based on current design information modified sluicing is expected to be capable of retrieving waste to both 90% and 99%, but is not expected to be capable of achieving 99.9% retrieval.

2.3.5.2 Mobile Retrieval System. The MRS uses two major pieces of equipment to retrieve waste: an articulated mast system (AMS) and an in-tank vehicle (ITV). The AMS is located in the central region of the tank because the required relatively large access riser does not exist in other locations of the tank. The mast contains a waste vacuum system on an articulated arm that can be rotated to reach the central portion of the tank. The mast can also support a sluice nozzle. The ITV can be moved around the entire tank, and can be used to physically push the waste, carry a sluice nozzle, and carry a vacuum hose and nozzle assembly. The waste is physically removed from the tank by first mobilizing it either physically with the ITV or sluice liquid, and then pumping it out of the tank with a vacuum hose and nozzle assembly. At the end of the retrieval campaign, the ITV can be used for rinsing the tank walls and in-tank equipment.

The MRS has been designed, built, and tested in the Cold Test Facility at the Hanford Site (*Project W-523, 241-C-104 Waste Retrieval System Preliminary Design Report: Section 1-9* [RPP-10829] and *Tank 241-C-104 Retrieval and Closure Project – Mobile Retrieval System Performance Test Report* [RPP-15805]).

The MRS is selected for 100-series SSTs that are classified as assumed leakers. This technology provides for waste retrieval using lower liquid volumes, thereby reducing the potential volume of a retrieval leak, should one occur. Based on current design information the MRS is expected to be capable of retrieving waste to both 90% and 99%, but not expected to be capable of achieving 99.9% retrieval.

2.3.5.3 Vacuum-Based Retrieval

VBR is selected for retrieving waste from the 200-series tanks, miscellaneous underground storage tanks (MUSTs), and waste receiving facilities (WRFs). This technology is flexible in that it can be operated as a dry-vacuum retrieval method or liquid can be introduced near the vacuum head depending on the type of waste to be retrieved. This technology is well suited for deployment in small tanks and would minimize the potential for leakage in a number of the 200-series tanks that are classified as assumed leakers. Based on current design information the VBR system is expected to be capable of retrieving waste to both 90% and 99%, but not expected to be capable of achieving 99.9% retrieval.

Vacuum-based technologies have been deployed to retrieve tank waste at Oak Ridge National Laboratory (ORNL).

2.4 CLOSURE TECHNOLOGY

2.4.1 Summary

No tanks or other facilities in any Hanford Site tank farm have yet been closed. The *Single-Shell Tank System Closure Plan* (RPP-13744), which is intended to begin the meet the RCRA process, has been issued. Most of the information in this section comes from the *Tank System Closure and Facility D&D Data Package* for the Tank Closure EIS (DOE/ORP-2003-05).

In its guidance for the Tier 1 High-Level Waste Facility Closure Plan, DOE headquarters recognizes three phases that a facility may undergo:

1. Operational closure
2. Final facility closure, and
3. Institutional Closure.

The next four subsections define these events and discuss the timetables for each. Following those subsections are the assumptions currently being used for closure activities.

2.4.2 Operational Closure

For the Hanford single-shell tank system, operational closure is defined as the closure of a tank farm component (i.e., tank, pipeline, junction box, etc.). Operational closure occurs when the following steps have been completed:

1. Retrieval of as much waste as is technically and economically feasible from the tank, pipeline, or other tank farm component
2. Isolation of the component from other tank farm components
3. Filling of the component to minimize void space and hence subsidence.

The schedule for operational closure of the components of the WMA C has not yet been determined. However, C-106 and the C-200 series tanks are expected to be the first tanks operationally closed.

2.4.3 Final Closure

For the Hanford SST system, final closure is defined as the entire WMA is closed. Final closure of a WMA occurs when the following steps have been completed:

1. Operational closure of all components within the WMA
2. Remediation of all soils within the WMA
3. Completion of any additional actions that are needed to treat facilities/soil near the WMA so that a surface barrier can be installed.
4. Placement of a surface barrier and start of post-closure monitoring.

Final closure of the WMA C is expected by the end of 2018 (RPP-13678).

2.4.4 Institutional Closure

For the Hanford SST system, institutional closure is defined as the final closure of all SST farm WMAs. This is expected by the end of 2018 (RPP-13678). It is expected that the DST farm would still be operational during the 2020s.

2.4.5 Closure Assumptions

The *Tank System Closure and Facility D&D Data Package* for the Tank Closure EIS (DOE/ORP-2003-05) lists the following assumptions.

2.4.5.1 Tank-Dome-Fill Assumptions.

- Based upon previous studies (e.g. Riess 2002), gravel and grout dome fill are the preferred recommended technology. Other fill materials (like sand) are similar to gravel fill.
- Installed in-tank equipment (following waste retrieval operation) will remain in the tank.

2.4.5.2 Soil Removal and Barrier Assumptions.

- All contaminated soils and ancillary equipment to at least 15 ft (4.6 m) bgs would be removed or treated and disposed of onsite. The excavations would be backfilled with 15 ft (4.6 m) of clean soil from an onsite borrow source.
- Contaminated soils that will not be under surface barriers under the tank farm closure technology will be handled under the CERCLA Record of Decision process.
- Because of their proximity to other Hanford facilities, a number of engineered, near-field liquid waste sites and associated contaminated soils are assumed to be within the footprint of the barriers. Decisions associated with these facilities need to be integrated with tank farm closure decisions. These sites are currently managed under CERCLA. It is important that waste sites not being cleaned up under RCRA corrective action have a proper planning path forward under CERCLA and vice versa when applicable.
- The slope of surface barriers can be up to 3%, so additional resource material will not be required to fill low areas (200-BP-1 Prototype Barrier Treatability Test Report [DOE/RL 1999]).

2.4.5.3 Surface Barrier Assumptions.

- Contaminated soils that will not be under surface barriers under the tank farm closure technology will be handled under the CERCLA Record of Decision process
- Because of their proximity to other Hanford facilities, a number of engineered, near-field liquid waste sites and associated contaminated soils are assumed to be within the footprint of the barriers. Decisions associated with these facilities need to be integrated with tank farm

closure decisions. These sites are currently managed under the CERCLA regulation. It is important that waste sites not being cleaned up under RCRA corrective action have a proper planning path forward under CERCLA and vice versa when applicable.

- The slope of surface barriers can be up to 3%, so additional resource material will not be required to fill low areas (200-BP-1 Prototype Barrier Treatability Test Report [DOE/RL 1999]).

- The barrier will extend at least 100 ft (30.5 m)eyond the edges of tanks and other significant source terms.

2.4.5.4 Post-Closure Monitoring Assumptions.

- Post-closure monitoring will be required for at least 30 years after closure under landfill technologies, as required by RCRA regulation.

- After the required monitoring period, it is assumed that monitoring would shift to a long-term stewardship program.

- The federal government will maintain institutional controls for at least 150 years (50 years treatment and 100 years post-closure). For controls up to 1000 years, the data set can be scaled lineally.

- Individual RCRA post-closure monitoring plans associated with WMAs will be provided in the closure plan.

- Tank farm systems closed to meet clean closure standards and future use on an unrestricted basis may not require post-closure monitoring. This determination would be made in the closure/post-closure plan.

2.4.5.5 Decontamination and Decommissioning Assumptions

- Aboveground facilities within the scope of this data package would be decontaminated and decommissioned in a manner similar to previous Hanford Site programs (e.g., remove the most significant source terms, demolish and/or other steps required to place in a long-term protective condition).

- Below ground facilities would be handled in the same manner as ancillary equipment.

- LLW will be disposed of onsite. Remote-handled waste will be treated or shielded before disposal.

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3.0 ANALYSIS OF PERFORMANCE

3.1 OVERVIEW

This section describes the models, computer codes, and input data used to analyze the long-term performance of the proposed closure of WMA C. For the analyses, the information discussed in Section 2 is translated into a conceptual physical model, then into a numerical model. This section also provides justification for the translations.

The strategy for this preliminary assessment was to define and analyze both a base analysis case and sensitivity cases bracketing the base analysis case. The base analysis case was developed using best available information for the environmental conditions, the WMA C facilities, and the plans to close the WMA C. Sensitivity studies focused on various release mechanisms. For the interpretation of results discussed in Section 6, the results of these simulations are supplemented by other Hanford Site studies.

This section shows how the physical systems presented in Section 2 are translated into the numerical models that produce the results presented in Sections 4 and 5. The section covers the following topics:

Inventory Source (Section 3.2) describes the radionuclide inventories.

Pathways and Scenarios (Section 3.3) explains the pathways and scenarios that were analyzed.

Values and Assumptions (Section 3.4) presents the assumptions use in the analyses, including the actual data.

Performance Assessment Methodology (Section 3.5) presents methodology used in the analyses, including the actual data used, respectively.

3.2 INVENTORY SOURCE

Because this is a preliminary performance assessment, only a few radioactive and chemical contaminants of concern (COCs) are followed. Subsequent assessments will use a formal screening process.

3.2.1 Relevant Contaminants of Concern

Both radionuclides and chemicals are treated in this performance assessment. Because this is a preliminary performance assessment, only a limited number of COCs are considered.

As part of the C-106 Closure Demonstration project, Callison, in *Accelerated Tank Closure Demonstration Data Assessment* (2002), identified the primary pathway of concern from a

risk/human health standpoint as the groundwater pathway. On this basis, the COCs for these tanks are the more mobile long-lived contaminants that could potentially migrate and impact groundwater at concentrations higher than the federal drinking water standards or MCLs. For the groundwater pathway, Callison (2002) listed the following contaminants:

- Carbon-14
- Iodine-129
- Technetium-99
- Selenium-79
- Uranium
- Nitrite
- Nitrate
- Cyanide

The risk-based COCs listed by Callison (2002) are also consistent with previous performance assessments (Mann 2001, Wood 1995, and Wood 1996), as well as groundwater monitoring of the unconfined aquifer. Those previous performance assessments have shown that environmental conditions and waste inventory limit the type of radionuclides that could provide significant dose to the all-pathways farmer scenario. These radionuclides are long-lived and non-sorbing (technetium-99, iodine-129, carbon-14, and uranium).

Since both carbon-14 and uranium are moderately retarded, only the radiological dose contribution from technetium-99 and iodine-129 was examined in detail. However, at the end of the long-term simulation, the radiological dose for all radionuclides was calculated for the all-pathways farmer scenario to ensure that an important radionuclide was not missed. This calculation showed the relative contribution from technetium-99 and iodine-129 to the total dose. The result of this calculation shows that technetium-99 contributes 63% of dose, iodine-129 contributes 35% of the dose, and all other radionuclides contribute 2% of the dose.

For the COCs identified by Callison (2002), this analysis addresses the following COCs for this assessment.

- Technetium-99
- Iodine-129
- Chromium^{+6}
- Nitrate
- Nitrite
- Total Uranium (moderately retarded K_d = 0.6 mL/g)

Note that carbon-14, selenium-79, and cyanide have been dropped from the Callison (2002) list, and chromium has been added. The basis for changing the list is that empirical information from the Hanford site-wide groundwater monitoring indicates that chromium is a COC for groundwater protection, but that carbon-14, selenium-79, and cyanide may not be.

Because of the inadvertent intruder scenario and because some of the tanks in the WMA C may have concentrations of transuranic isotopes above 100 nanoCuries per gram, the following radioisotopes are also considered in this assessment: Carbon-14, Strontium-90, Tin-126, Cesium-134, Cesium-137, Radium-226, Thorium-230, Thorium-232, Uranium-233, Uranium-234,

Uranium-235, Uranium-236, Uranium-238, Neptunium-237, Plutonium-238, Plutonium-239, Plutonium-240, Plutonium-242, Americium-241, and Amercium-243.

Subsequent performance assessments will perform a formal screening process, based on risk. In order to facilitate these subsequent performance assessments, this analysis used multiple distribution coefficients (K_d) categories to address a wide range of contaminants at a later date.

3.2.2 Decay Data

Decay data (particularly half lives) are needed both for inventory estimates and for dosimetry calculations (see Section 3.4.7). The nuclear data used in this assessment are presented in *Dosimetry Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (Rittmann 1999), and Appendix O of Mann/Puigh (2000a).

3.2.3 Inventory

Four sources of contaminants are considered in this assessment:

- Past leaks
- Potential retrieval leaks
- Residual waste in tanks
- Residual waste in infrastructure.

The following subsections treat each of these sources separately as different information sources drive the inventory values. Table 3-1 provides the sources that have been explicitly included in these analyses. Section 3.2.2.5 defines the base analysis case inventory.

Table 3-1. Sources Included in WMA-C Risk Assessment Conceptual Model. (2 Pages)

Source Type	Individual Sources	Inventory	Included in Risk Assessment
Past Leaks from Tanks	1 Confirmed leak from Tank 241-C-105	Yes – Estimated→Table 3-2	Yes
Past Leaks from Tank Ancillary Equipment	UPR-200-E-81	Yes – Estimated→Table 3-2	Yes
	UPR-200-E-82	Yes – Estimated→Table 3-2	Yes
	UPR-200-E-86	Yes – Estimated→Table 3-2	Yes
	UPR-200-E-16	No – Small Leak (50 gal)[a]	No, unplanned release was much, much smaller than UPRs 200-E-81, 200-E-82, and 200-E-86.
	UPR-200-E-107	No – Small Leak (4 gal)[a]	
	UPR-200-E-27	No – Airborne Release[a]	No, Airborne releases not considered.
	UPR-200-E-68		
	UPR-200-E-99		
	UPR-200-E-100		

Table 3-1. Sources Included in WMA-C Risk Assessment Conceptual Model. (2 Pages)

Source Type	Individual Sources	Inventory	Included in Risk Assessment
	UPR-200-E-118		
	UPR-200-E-72	No – Solid waste located outside of WMA C[a]	No, release is nearby, but outside the WMA. It is solid waste consisting of miscellaneous trash and debris.
	UPR-200-E-91	No – Contaminated soil remediated[a]	No, site has been remediated.
	UPR-200-E-136	No – Reported 24,000-gal leak from tank C-101[a]	See discussion in Jones and Wood (2003)
	UPR-200-E-136	No – Reported 400-gal leak from Tank C-203[a]	
Intentional Discharge Sites	216-C-8	Yes – System assessment capability has estimated Tc-99 and I-129, but not the inorganics	No, reported inventory for Tc-99 and I-129 are much smaller than UPRs 200-E-81, 200-E-82, and 200-E-86.
Residual Waste in Tanks and Ancillary Equipment	12 100-Series Tanks	Yes –TWINS/BBI → Tables 3-4 and 3-5	Yes
	4 200-Series Tanks		
	300-Series Catch Tank	Yes – Assumed Inventory based on TWINS/BBI →Table 3-6	Yes
	4 244-CR Vault Tanks		
	3 CR-150 Series Diversion Boxes	No[a]	No, diversion boxes are designed to drain to catch tank. Contamination is mainly surficial. Residual in catch tank is examined
	3 C-150 Series Diversion Boxes		
	1 C-252 Diversion Box		
	Bldg. 801-C	No[a]	No, building is expected to be decontaminated and decommissioned.
Minor ancillary equipment	Pipes and valves, associated the Waste Management Area	Yes – Assumed inventory based on TWINS/BBI →Table 3-6	Yes
Potential Leaks during Waste Retrieval	2 100 Series Tanks (C-106 and C-107) are scheduled for liquid retrieval, all others scheduled for dry retrieval	Yes –TWINS/BBI →Table 3-3	Yes

[a] Waste Information Data System (WIDS) Report

UPR = Unplanned Release

3.2.3.1 Past Leaks There are known past leaks in WMA C. These have arisen from surface activity, pipeline breaks, and tank leaks.

As part of the effort to understand past leak and losses in SST farms, the Tank Farm Vadose Zone Project performs a systematic analysis of such leaks and loses. The analysis begins with the collection of all known data on the WMA, and continues with a plan to obtain new, significant data and then obtaining that data. The analysis ends with a simulation of estimated

impacts from past leaks, an interpretation of the estimates, and recommendations for additional work. The project has completed its initial efforts on WMAs B-BX/BY and S-SX, which are documented in the *Field Investigation Report for WMA B-BX-BY* (Knepp 2002b) and *Field Investigation Report for S-SX* (Knepp 2002a). A similar effort is ongoing in the WMAs T and TX/TY where additional data are being gathered. The effort has just started in the WMA C, where all known data has been recently published in the *Subsurface Conditions Description of the C and A-AX Waste Management Areas* (Wood 2003). The source for the follow paragraphs is Wood 2003.

The inventory is given in Table 3-2. The uncertainty for the total inventory for the COCs is thought to be about a factor of 2 to 3 for the key contaminants, but should be refined once the field investigation effort for WMA C is complete.

Table 3-2. Tank Leak and Unplanned Releases Inventory Estimates for WMA. (3 pages)

Tank	**C-105**	**UPR-200-E-81**	**UPR-200-E-82**	**UPR-200-E-86**
Leak Volume	**1,000 gal (3,785 L)**	**36,000 gal (136,260 L)**	**2,600 gal (9,841 L)**	**17,400 gal (65,860 L)**
Analyte	**kg**	**kg**	**kg**	**kg**
Na	4.49E+2	5.10E+3	1.17E+3	2.14E+3
Al	1.52E+1	2.32E+3	3.96E+1	3.93E+1
Fe	2.69E+0	1.53E+1	6.99E+0	7.41E+0
Cr	9.82E+0	2.18E+1	2.55E+1	5.88E+1
Bi	9.66E-2	0.00E+0	2.51E-1	1.60E-1
La	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Hg	1.85E-3	2.75E-1	4.82E-3	4.84E-3
Zr	7.57E-4	0.00E+0	1.97E-3	4.27E-4
Pb	2.94E-1	4.54E+1	7.65E-1	8.14E-1
Ni	2.53E+0	1.23E+1	6.59E+0	6.99E+0
Sr	0.00E+0	0.00E+0	0.00E+0	0.00E+0
Mn	2.72E-1	0.00E+0	7.06E-1	9.67E+0
Ca	8.70E+0	4.93E+1	2.26E+1	2.38E+1
K	2.97E+0	1.34E+1	7.72E+0	1.98E+1
NO_3	3.15E+2	5.79E+3	8.18E+2	1.21E+3
NO_2	2.69E+2	1.82E+3	6.98E+2	1.45E+3
CO_3	6.46E+1	7.40E+1	1.68E+2	5.79E+2
PO_4	1.64E+0	0.00E+0	4.25E+0	1.48E+2
SO_4	8.64E+1	1.66E+2	2.25E+2	5.19E+2
Si	1.84E+1	0.00E+0	4.79E+1	1.71E+2
F	4.41E-1	0.00E+0	1.15E+0	4.89E-1
Cl	1.14E+1	5.59E+1	2.95E+1	4.46E+1
DBP	4.33E+1	0.00E+0	1.12E+2	0.00E+0
Butanol	1.52E+1	0.00E+0	3.96E+1	0.00E+0
TBP	0.00E+0	0.00E+0	0.00E+0	0.00E+0
NPH	0.00E+0	0.00E+0	0.00E+0	0.00E+0

Table 3-2. Tank Leak and Unplanned Releases Inventory Estimates for WMA. (3 pages)

Tank	C-105	UPR-200-E-81	UPR-200-E-82	UPR-200-E-86
Leak Volume	**1,000 gal (3,785 L)**	**36,000 gal (136,260 L)**	**2,600 gal (9,841 L)**	**17,400 gal (65,860 L)**
U-Total	7.06E+0	1.30E+2	1.83E+1	3.73E+1
Radionuclide	**Ci**	**Ci**	**Ci**	**Ci**
H-3	6.62E-1	9.95E-2	1.72E+0	3.89E-1
C-14	2.76E-1	1.40E-2	7.17E-1	8.86E-1
Ni-59	3.50E-2	3.93E-3	9.11E-2	9.59E-2
Ni-63	3.39E+0	3.96E-1	8.81E+0	9.39E+0
Co-60	1.95E-1	2.03E-2	5.08E-1	8.99E-1
Se-79	3.84E-2	3.10E-3	9.99E-2	1.32E-1
Sr-90	6.55E+2	3.29E+2	1.70E+3	2.25E+3
Y-90	6.53E+2	3.29E+2	1.70E+3	2.25E+3
Zr-93	1.91E-1	1.45E-2	4.97E-1	6.61E-1
Nb-93m	1.34E-1	1.06E-2	3.48E-1	4.63E-1
Tc-99	1.93E+0	1.02E-1	5.01E+0	6.22E+0
Ru-106	6.76E-6	3.36E-5	1.76E-5	3.31E-4
Cd-113m	1.05E+0	7.07E-2	2.74E+0	3.97E+0
Sb-125	4.94E-1	1.11E-1	1.28E+0	3.37E+0
Sn-126	5.76E-2	4.74E-3	1.50E-1	1.98E-1
I-129	3.73E-3	1.97E-4	9.69E-3	1.20E-2
Cs-134	1.54E-2	7.34E-3	3.99E-2	1.53E-1
Cs-137	6.33E+3	3.79E+2	1.65E+4	2.08E+4
Ba-137m	5.97E+3	3.58E+2	1.55E+4	1.96E+4
Sm-151	1.34E+2	1.12E+1	3.48E+2	4.63E+2
Eu-152	3.03E-2	2.56E-3	7.89E-2	1.49E-1
Eu-154	4.29E+0	4.01E-1	1.12E+1	1.92E+1
Eu-155	1.71E+0	1.84E-1	4.46E+0	9.79E+0
Ra-226	1.19E-6	2.01E-7	3.10E-6	1.32E-6
Ra-228	1.34E-6	2.11E-4	3.48E-6	1.67E-6
Ac-227	7.22E-6	4.93E-5	1.88E-5	2.38E-5
Pa-231	4.00E-5	2.74E-4	1.04E-4	1.32E-4
Th-229	6.09E-7	9.51E-5	1.58E-6	7.74E-7
Th-232	2.87E-6	4.51E-4	7.46E-6	7.14E-6
U-232	9.18E-5	8.82E-3	2.39E-4	4.19E-3
U-233	3.59E-4	3.43E-2	9.33E-4	1.62E-2
U-234	2.33E-3	4.62E-2	6.06E-3	1.29E-2
U-235	9.90E-5	1.89E-3	2.57E-4	5.35E-4
U-236	4.55E-5	1.38E-3	1.18E-4	3.55E-4
U-238	2.36E-3	4.36E-2	6.13E-3	1.24E-2

Table 3-2. Tank Leak and Unplanned Releases Inventory Estimates for WMA. (3 pages)

Tank	C-105	UPR-200-E-81	UPR-200-E-82	UPR-200-E-86
Leak Volume	**1,000 gal (3,785 L)**	**36,000 gal (136,260 L)**	**2,600 gal (9,841 L)**	**17,400 gal (65,860 L)**
Np-237	7.70E-3	7.63E-4	2.00E-2	1.94E-2
Pu-238	2.80E-3	2.88E-2	7.28E-3	1.24E-1
Pu-239	1.77E-1	1.20E+0	4.61E-1	5.24E+0
Pu-240	2.68E-2	2.14E-1	6.97E-2	8.60E-1
Pu-241	2.08E-1	2.30E+0	5.41E-1	8.93E+0
Pu-242	7.69E-7	6.49E-6	2.00E-6	4.37E-5
Am-241	5.75E-1	8.70E-2	1.50E+0	1.98E+0
Am-243	5.81E-6	9.18E-7	1.51E-5	4.36E-5
Cm-242	6.06E-4	3.70E-5	1.58E-3	3.56E-3
Cm-243	1.61E-5	1.02E-6	4.19E-5	2.00E-4
Cm-244	5.00E-4	3.49E-5	1.30E-3	6.61E-3

3.2.3.1.1 General Observations. Multiple vadose zone contamination events have occurred in WMAs C and A-AX. Evidence for these events is provided by the historical record, and historical gross gamma and spectral gamma data. Outstanding characteristics of contaminant occurrences in these WMAs include the following:

- The primary gamma emitting radionuclides measured in WMA C are Cs-137, Co-60, and Eu-154. Antimony (Sb)-125 is occasionally measured and historical gross gamma evaluations indicate the presence of Ru-106 in the 1970s, which has since decayed to negligible quantities.

- Cesium-137 contamination is found from the surface down to as much 30 ft (9 m) bgs in the majority of drywells in WMA C. Typically, Cs-137 concentrations are < 10 pCi/g and are at maximum value just below the surface. This contamination is attributed to surface spills from tank farm activity.

- Cesium-137 is most highly concentrated in drywell 30-5-7 next to the southwest part of tank C-105 where two zones at and just below the tank bottom (between 34 and 44 ft [10 and 13 m] bgs and 48 and 62 ft [15 and 19 m]) contain maximum concentrations of 10^7 and 10^5 pCi/g, respectively.

- Historical gross gamma data indicate Co-60 migration in the late 1970s and early 1980s in WMA C drywells near presumed transfer line leaks between tanks C-104 and C-105, between tanks C-108 and C-109, and around tank C-103.

- Unintentional releases of tank waste occurred sporadically during tank farm operations. From a vadose zone contamination perspective, the most significant losses occurred from two transfer lines at the west and southwest edge of WMA C (UPR-200-E-82 and UPR-200-E-86). In both cases, high-activity PUREX waste leaked into the vadose zone.

- Unintentional releases of raw water in the tank farms do not appear to have been common.

3.2.3.1.2. Conceptualization of Primary Vadose Zone Contamination Events. Three types of vadose zone contamination events occurred in WMA C. These include surface spills attributed to various unspecified tank farm activities, waste transfer line leaks, and tank leaks. Conceptual models are provided in the following sections for those leaks that have discharged the largest inventories into the vadose zone. Several assumed leaks are not discussed further because neither the historical record nor the field evidence supports a substantive tank waste loss to the vadose zone. These include assumed tank leaks from tanks C-110 and C-111. At tank C-101, two potential tank bottom leaks can be inferred from Cs-137 peaks at about 37 ft (11 m) bgs. One is on the west (drywell 20-1-9) and the other is on the south (drywell 30-1-6) side of tank C-101. In both cases, peak concentrations are lower than 1,000 pCi/g. The isolated contamination at this depth and the small peak concentrations could indicate a very small leak. Another possibility is the accumulation of activity at the compacted base of the tank farm excavation.

Several small transfer line discharges are indicated by peak concentrations of gamma emitting radionuclides in a single drywell that occur between 5 and 40 ft (2 and 12 m) bgs. Usually, the indicator radionuclide is Cs-137 and the high concentration depth interval is small, about 2 ft (1 m) thick. These factors lead to the conclusion that the areal extent of the discharge is small and the contaminant concentrations in the discharged fluid are low. Apparent transfer line leaks with these characteristics in WMA C include the following:

- An apparent discharge on the north (drywell 30-7-11) side of tank C-107 indicated by an above detection concentration zone between1 and 5 ft (1 and 2 m) bgs, which is interpreted as contaminants contained in a nearby saltwell transfer line rather than a leak (DOE-GJO 1998).

- A discharge on the north (drywell 30-12-13) of tank C-112 indicated by peaks of unidentified radionuclides exceeding the detection limit at about 10 ft (3 m) bgs.

The remaining contamination areas that are considered to be the largest inventory contributors to the vadose zone in WMA C are tank leaks from tanks C-105 and unplanned releases from transfer lines at the west and southwest edge of WMA C. Smaller discharges also occurred from transfer lines between tanks C-104 and C-105 and between tanks C-108 and C-109.

3.2.3.1.3 Tank C-105 Data Integration and Interpretation. Tank C-105 has not been identified as a leaker in the past; however, it has been proposed as a possible leaker (Brodeur 1993). Two observations suggest that C-105 did leak. First, the spectral gamma data in drywell 30-05-07 on the southwest side of the tank contain two high Cs-137 zones near and just below the tank bottom, which indicates a past occurrence of a tank leak at the tank bottom. Second, a liquid level drop of 36 in. (0.9 m) was noted between 1963 and 1967. During this time and into the early 1970s, C-105 was being used as a transfer tank for high-activity PUREX waste being sent to B Plant for Cs-137 separation. This waste created high-heat conditions in tank C-105 for several years. It is proposed that the high-heat load in tank C-105 caused tank failure from rupture of the tank liner at a point of weakness (such as the weld between the sidewall and the bottom). Subsequently, a small loss of tank waste into the vadose zone occurred. This combination of tank history and environmental characteristics are similar to other tanks that are known to have leaked (such as tank T-106).

Alternative explanations for tank leaks as causes for these observations have been proposed. The Cs-137 source has been attributed to a nearby leaking transfer line between tanks C-104 and C-105, about 20 ft (6 m) from the tank bottom. This explanation seems unlikely because a temporary in situ chemical condition that enhanced Cs-137 mobility was needed to allow transport of Cs-137 at high concentrations a distance of more than 20 ft (6 m) away from the source. Previous SST leak characterization studies indicate that enhanced mobility has only occurred during the tank SX-108 leak when extremely high sodium concentrations in the waste successfully competed with Cs-137 for sorption sites, allowing Cs-137 to be non-reactive with soils temporarily and migrate more than a few feet from the source location (Knepp 2002a). The PUREX waste stream presumed lost from tank C-105 does not appear to have the correct chemistry (e.g highly concentrated sodium or other competing cations) to enhance Cs-137 mobility even temporarily. The observed liquid level drop is less convincing. The high waste heat load could certainly have induced evaporation and at least part of the liquid level drop. Nevertheless, some liquid loss due to tank failure is plausible.

The Cs-137 contamination was encountered when drywell 30-05-07 was drilled in the early 1970s. Therefore, the postulated leak would have occurred previously, probably in the late 1960s. It is hypothesized that the leak was small and self-sealed after a short time. Tank C-105 continued as a feeder tank to B Plant into the 1970s showing no obvious indication of leaking. An analysis of historical gross gamma logging data from this dry well indicates there have been no changes in the level or location of the Cs-137 contamination in the vadose zone since the drywell was installed. Also, additional liquid level drops after 1967 were not observed. The waste volume released from tank C-105 is unknown and it is feasible that some areas underneath tank C-105 may be highly contaminated. Two distinctly separate high Cs-137 contamination zones with markedly different concentration levels (about 10^7 pCi/g in the upper zone at tank bottom depth versus 10^5 pCi/g in the lower zone) may indicate two leak events. Another option is that the lower zone indicates a dragdown effect because the contamination was in place at the time of drilling. The 36-in (0.9m) liquid level drop in a 75 ft (23 m) diameter tank corresponds to about 100,000 gal, but evaporation because of high internal tank temperatures was likely responsible for most if not all of the liquid loss. The high Cs-137 vadose zone contamination area at tank T-106 (Wood 2001) can be used as a qualitative measuring stick for the size of the tank C-105 leak. At tank T-106, 115,000 gal of tank waste leaked into the vadose zone. During the T-106 leak approximately 40,000 Ci of Cs-137 was lost resulting in a high Cs-137 (approximately 10^7 pCi/g) plume extending over a 75 ft (23 m) diameter area. The area of the C-105 high Cs-137 concentration zone is much smaller as it is expressed by only one borehole. Given the uncertainty about contamination underneath the tank, a leak involving the loss of approximately 10,000 Ci of Cs-137 is feasible. The Cs-137 activity in the PUREX supernatant in tank C-105 at the time of the potential leak was in the range of 5 to 30 Ci/gal Cs-137. Thus, a leak volume could be could a small as several hundred gallons up to 2,000 gal. A leak inventory estimate was developed for a nominal 1,000-gal leak volume.

Since the timing of the waste loss event resulting in the Cs-137 activity in drywell 30-05-07 can only be constrained by the time of the drywell installation (early 1970s), waste stream identification, and thus leak inventory, are somewhat problematic. Tank C-105 was first used to store bismuth phosphate metal waste. From 1954 through 1955, it was used to story uranium recovery waste. The spectral gamma logging data from drywell 30-05-07 are inconsistent with a leak from either of these two waste types. From 1956 until 1963, tank C-105 was used to store PUREX cladding waste. The concentrations of radionuclides in CWP were three to four orders

of magnitude lower than in the high-level waste supernatants passing through this tank from 1963 until 1978. Thus, if PUREX cladding waste were the source of the Cs-137 found in drywell 30-5-7, then a much large leak volume would be required. However, the leak inventory would remain relatively constant.

Contaminant migration from drywell 30-05-07 to surrounding drywells is not clearly indicated by the spectral gamma data in these surrounding drywells. Two other nearby drywells, 30-05-08 and 30-05-05, show Cs-137 peaks at depths corresponding to the high concentration zones at drywell 30-05-07. In these drywells, maximum Cs-137 concentrations are < 100 pCi/g, much reduced relative to those at drywell 30-5-7. If this Cs-137 is from a tank C-105 leak, the rapid reduction in Cs-137 concentrations is consistent with the expected high Cs-137 reactivity with vadose zone soils. At drywell 30-05-05, Co-60 also appears to peak just below Cs-137 (at 70 ft [21 m]) bgs versus 60 to 65 ft (18 to 20 m) bgs). If Cs-137 and Co-60 at this drywell location are both from the tank C-105 leak, Co-60 is nearly as reactive as Cs-137.

From this minimal data set, it is concluded that the proposed tank C-105 leak is largely constrained to the area southwest of tank C-105. However, a more mobile constituent such as Tc-99 probably migrated over a larger area that cannot be predicted with the available data.

3.2.3.1.4 WMA C Transfer Line Leak Data Integration and Interpretation. Numerous transfer line leaks have occurred in the WMA C. Among the tanks, spectral gamma data suggest that the most contaminating leaks occurred between tanks C-104 and C-105 and between tanks C-108 and C-109. Also, three transfer line leaks near three diversion boxes (241-CR-151, 241-C-151 and 241-C-152) have been reported as unplanned releases in WMA C. Of these, the two near diversion boxes 241-C-152 (UPR-200-82) and 241-C-151 (UPR-200-86) are the most significant sources of contamination. Other unplanned releases were also reported, but their descriptions suggest a minimal vadose zone contamination outcome.

While there are individual differences in the occurrence, extent, and waste type discharged to the vadose zone, the conceptual model for the various transfer line discharges of tank waste to the vadose zone and subsequent contaminant migration in the vadose zone is basically similar. Typically, waste leaked from transfer lines for some time before the leak was discovered, either through nearby drywell gamma data or observed collection of water at the near surface. At that point, the transfer line was repaired or abandoned.

Contaminants proceed to migrate according to their reactivity with soils and natural infiltration rates. At WMA C the common gamma-emitting contaminants are Cs-137, Co-60, Eu-154 and Eu-152. Of these, the most reactive and therefore slowest moving contaminant is Cs-137. When drywell spectra gamma data are available, the leak location is assumed to be near a drywell exhibiting a sharp high concentration Cs-137 peak at depths consistent with transfer line depths. Cobalt-60 tends to be the least reactive and fastest moving gamma-emitting radionuclide in WMA C. Spectral gamma data suggest that contaminant migration generally has been limited to an area whose size is on the order of a tank diameter (75 ft, [23 m]) or two. However, at C farm, the extent of Co-60 migration may be greater because Co-60 is measured in numerous tanks as much as 250 ft (76 m) away from the two primary transfer line leaks between tanks C-104 and C-105 and between tanks C-108 and C-109. On the other hand when all the Co-60 spectral gamma data are considered in WMA C, logical patterns linking this Co-60 contamination to these two transfer line locations are not readily discernable. It is plausible that additional leak

sources are involved that cannot be clearly identified by the available data (e.g., a tank C-103 leak).

3.2.3.1.5 Tank Leak and Transfer Line Inventory Estimates. The approach used in developing quantitative leak inventory estimates is the same as that used in previous tank leak inventory estimates (Jones 2000 and 2001). The best estimates of actual leak volumes are combined with waste composition estimates at the suspected time of the waste loss events. The uncertainty of the inventory estimated depends mainly on the volume estimates and time of the leak. At least for the major constituents of the tank wastes, reasonable composition estimates are available as long as there has not been major commingling of waste types.

Except for tank C-105, there is essentially no evidence to support listing any of the C farm tanks as known or suspected leakers. An inventory is provided in Table 3-2 for a nominal 1,000-gal leak volume from tank C-105. If results for future investigations indicate a different leak volume, the reported results can be scaled appropriately.

Outside WMA C, the most significant contamination comes from two transfer line leaks of PUREX high-activity waste at the western edge of WMA C, identified in the Waste Information Data Base System (WIDS) as UPR-200-E-82, and UPR-200-E-86. Report UPR-200-E-82 describes the loss of Cs-137 Recovery Process feed solution being pumped from tank C-105 to the B Plant. The leak occurred near the 241-C-152 Diversion Box and involved the loss of approximately 2,600 gal of liquids (Tanaka 1971). The inventory estimate was developed assuming a PUREX high-level waste supernatant template. These results are listed in Table 4-1. Report UPR-200-E-86 describes a waste loss event associated with a pipeline break near the southwest corner of WMA C. Fluids were being pumped from the 244-AR Vault to C farm. Approximately 17,400 gal of fluid that contained approximately 25,000 Ci of Cs-137 were lost to the soil (Maxfield 1979). The inventory estimate was developed using the "AR waste type" template (Agnew 1997). These results are listed in Table 3-2. The large estimated Tc-99 inventory from these events is a primary contributor in the WMA C to long-term risk estimates.

Two other transfer line leaks involved the loss of PUREX cladding waste. First, report UPR-200-E-81 describes a 1969 waste loss event that occurred near the 241-CR-151 Diversion Box and involved the loss of 36,000 gal (136,000 L) of PUREX cladding waste (Williams 2001, Maxfield 1979). The PUREX cladding waste was a reasonably low activity waste stream produced from the caustic dissolution of the aluminum fuel rod cladding. The origin of the radioactive contamination in this waste stream was congruent dissolution of the uranium fuel during the de-cladding operation. Inventory estimates for the waste loss event use the PUREX cladding waste composition used in the Hanford Defined Waste (HDW) model for PUREX cladding waste (CWP2) (Agnew 1997). These inventory estimates are given in Table 3-2. Second, there is also a small overland piping leak (50 gal) involving the loss of PUREX cladding waste between tanks C-105 and C-108, documented in UPR-200-E-16. A negligible inventory is associated with this leak.

The final contamination source in WMA C is generalized near-surface contamination across WMA C where Cs-137 contaminates the vadose zone between the surface and 15 ft (5 m) bgs to levels of about 10 pCi/g. About a dozen of the drywells in the farm have Cs-137 gamma activity that peaks at or above 100 pCi/g in the upper 15 ft (14.6 m) of the vadose zone, with the most contaminated zones occurring between tanks C-104 and C-105 and between tanks C-108 and

C-109. Inventory estimates of near surface contamination can be made for a generalized level of contamination and for transfer line 'hot spots'.

An inventory estimate based on the generalized level of Cs-137 (10 pCi/g) contamination is insignificant when compared to other Cs-137 inventory estimates in this tank farm. For example, if one assumes a surface area of 400 ft by 400 ft (122 m x 122 m) down to a depth of 15 ft (4.6 m) with a soil density of 1.7 g/ml and a Cs-137 contamination level of 10 pCi/g, the estimated inventory of Cs-137 is 1.1 Ci. Assuming a PUREX high-activity waste or B Plant isotope recovery source, other constituents can be scaled from the Cs-137 estimate. For example, a Tc-99 inventory estimate can be made assuming the Cs-137 is 1,000 to 10,000 times more abundant than Tc-99 in the discharged waste. Even if this Cs-137 inventory estimate increased by two or three orders of magnitude, both Cs-137 and other constituent inventories would still be insignificant compared to that from other losses in WMA C.

A similar calculation can be done for smaller contamination zones affected by transfer line leaks with somewhat high Cs-137 concentrations distributed over a depth interval of a few feet. For example, at the transfer line leak between tanks C-104 and C-105, the maximum Cs-137 concentration approaches 1,000 pCi/g for a 1 ft (0.3 m) depth interval. Assuming contamination in the area between four tanks (roughly a 25 ft ([8 m]) square down to about 20 ft ([7m]) bgs, a Cs-137 inventory of < 0.1 Ci Cs-137 is calculated. Based on these calculations, it is clear that near-surface contamination inventories from small transfer line leaks are also insignificant compared to the high-activity waste loss events from tank C-105, UPR-200-E-82 and UPR-200-E-86.

3.2.3.2 Potential Retrieval Leaks. It is difficult to ascertain what the inventory for retrieval leaks should be. Retrieval leak inventory can be calculated by multiplying the concentration in the leaked fluid by the number of gallons that leaked. However, the concentration of the leaked fluid is unknown and is dependent on the retrieval method. Much waste has been transported among the tanks comprising the Hanford Tank System. Some of the SSTs clearly have leaked, but none has a leak date past 1994. Obviously, these tanks could leak again during retrieval. Also, structural weaknesses may have developed in other "sound" tanks because of former waste processing activities (e.g., high internal heat loading created by storage of highly radioactive waste streams) that could lead to leakage during retrieval.

Over the past few years, the Interim Stabilization Program has pumped over 3 million gal of liquids from the SSTs to DSTs to lessen the impacts from any SST leaks (Aromi 2003). There are no reported significant leaks from this activity.

As discussed in section 2.3.5, three major retrieval methods are being considered (DOE/ORP-2003-6):

- Modified sluicing
- Mobile retrieval system
- Vacuum-based retrieval.

Since most waste volume measurements are based on the level of liquids in the tanks, the transfer of liquids has made the determination of tank integrity difficult. Thus, when liquid is

added during retrieval, it is now difficult to estimate the volume of waste that could be leaked during retrieval.

Historically, risk assessments (e.g. the *Retrieval Performance Evaluation Methodology for the AX Tank Farm* [DOE/RL-1998]) used an estimate of 8,000 gal as the volume of tank waste that could leak during retrieval of a tank.

For this preliminary risk assessment, the inventory for leaked fluids was calculated by multiplying the inventory values given in Table 3-3a by the number of gallons leaked (0 gal, 8,000 gal and 20,000 gal) and then dividing by the estimated number of gallons used for the retrieval process (250,000 gal). This estimate was for tank C-106 and was applied also to C-107 and shown in Table 3-3b. *Hanford Tank Waste Operations Simulator (HWTOS) Model Run Results for the Proposed Baseline Change Request (BCR) Case* (RPP-15588) identifies tanks C-106 and C107 as the only tanks in WMA C scheduled for wet retrieval. All other tanks in WMA C are scheduled for dry retrieval. The inventory calculated by this methodology is conservative because it assumes all of the BBI inventory will go into solution.

Table 3-3a. Best Basis Inventory for WMA C. (2 Pages)

Tank	^{129}I	^{99}Tc	Cr	Nitrite	Nitrate	Uranium (Total)
	Ci	Ci	kg	kg	kg	kg
C-101	1.34E-3	0.697	299	9,180	61,400	9,610
C-102	2.74E-3	1.32	735	16,900	73,200	8.150
C-103	0.0662	34.2	690	16,300	1,380	5.960
C-104	0.754	58	1,460	36,500	19,600	35.300
C-105	0.093	81.4	413	8,420	8,140	9,840
C-106	0.017	3.14	61.8	1,530	76.9	132
C-107	4.83E-2	37.9	930	35,300	47,800	9,290
C-108	1.32E-3	6.19	232	8,740	15,700	153
C-109	2.00E-3	32.3	118	12,200	18,000	4,060
C-110	1.10E-3	31.8	420	6,530	98,000	1,970
C-111	2.01E-3	2.7	85.2	9,490	17,300	4,250
C-112	4.26E-3	61.1	139	27,800	37,200	24,100
C-201	2.74E-5	0.0141	2.29	41.8	227	1.14
C-202	2.85E-5	0.0147	2.39	214	639	1.19
C-203	5.46E-5	0.0282	4.57	245	838	2.26
C-204	3.52E-5	0.0181	2.95	158	541	1.46
Totals	0.993	350.8221	5,595.2	189,548.8	400,041.9	112,821.05

Table 3-3b. Inventory for Potential 8,000-Gal Retrieval Leaks.

Tank	^{129}I	^{99}Tc	Cr	Nitrite	Nitrate	Uranium (Total)
	Ci	Ci	kg	kg	kg	kg
C-106	0.00054	0.100	2.0	49	2.5	4.2
C-107	0.00154	1.218	29.8	1,129	1,529.6	297.3
Total	0.00209	1.313	31.7	1,178	1,532	301.5

3.2.3.3 Residual Waste in Tanks. None of the tanks in WMA C meet the HFFACO limits for waste left in a tank (360 ft^3 [2,690 gal or 10,200 L] for 100-series tanks and 30 ft^3 [224 gal or 829 L] for 200-series tanks. Therefore, there is no experience on which to base how much waste will remain in a tank after retrieval is complete.

The *Inventory and Source Term Data Package* for the Tank Closure EIS (DOE/ORP-2003-2) assumes that the HFFACO limits will be met and analyzes three cases for the residual inventory:

- Simple Volume Ratio (Table 3-4a) - Multiply the existing total tank inventory by a ratio of the final tank volume to the current tank volume (not including retained gas).

- Volume Ratio based on selected phase removal (Table 3-4b) - This is similar to the simple volume ratio, but modified to take into account removal of selected phases of waste during liquid retrieval.

- Computer Simulation (Table 3-4c) - Hanford Tank Waste Operation Simulator (HTWOS) Model Output (*Single-Shell Tank Retrieval Sequence and Double-Shell Tank Space Evaluation* – Hohl 2001) adjusted to the same final volume as the other two methods. This method represents HTWOS assumptions for water additions and incorporates wash/leach factors. The residual inventory is generally lower due to leaching of mobile constituents.

Comparing the inventory for the COCs for WMA C tanks shows there is very little difference between the simple volume ratio and the selected phase removal. The largest differences were for I-129 and chromium, with the total inventory for those constituents being 21%, and 28% higher for selected phase removal. However, comparing the residual inventory between selected phase removal and the HTWOS model, shows the HTWOS modeled total residual inventory for WMA C to be four to six times lower for all COCs except for uranium. For uranium, it was orders of magnitude less.

The inventory chosen for this risk assessment will be appropriate for the selected retrieval technology. It is expected that as the tank is retrieved, the tank residuals will be sampled and analyzed with resulting residual inventory being updated. That is, for C-106 and C-107, the computer simulation results are used, while for the remaining tanks, the volume ratio based on selected phase removal results are used. The inventory assumed for the base case is shown in Table 3-4d.

Inventories for actinides and other radionuclides important for inadvertent intrusion are presented in Tables 3-5a and 3.5b (corresponding to dry retrieval [vacuum and mobile retrieval system] methods and wet retrieval [modified sluicing retrieval] respectively). These inventories were established using the same methods as used for the contaminants important for the groundwater pathway displayed in Tables 3-4a, b, and c.

Table 3-4a. Summary of Final Inventory Estimates Based on Simple Volume Ratio following Retrieval with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks.

Tank	^{129}I	^{99}Tc	Cr	Nitrite	Nitrate	Uranium (Total)
	Ci	Ci	kg	kg	kg	kg
C-101	4.10E-5	0.0213	9.15	281	1,880	294
C-102	2.34E-5	0.0113	6.27	144	624	69.5
C-103	8.83E-4	0.456	9.21	218	18.4	79.5
C-104	7.84E-3	0.603	15.2	380	204	367
C-105	1.90E-3	1.66	8.42	172	166	201
C-106	1.26E-3	0.232	4.57	113	5.68	9.75
C-107	5.24E-4	0.411	10.1	383	518	101
C-108	5.38E-5	0.252	9.46	356	640	6.24
C-109	8.50E-5	1.37	5.01	518	765	172
C-110	1.66E-5	0.481	6.35	98.8	1,480	29.8
C-111	9.44E-5	0.127	4	446	813	200
C-112	1.11E-4	1.59	3.61	721	965	625
C-201	5.82E-6	0.00299	0.486	8.88	48.2	0.242
C-202	6.05E-6	0.00312	0.508	45.5	136	0.253
C-203	4.64E-6	0.0024	0.388	20.8	71.2	0.192
C-204	2.99E-6	0.00154	0.251	13.4	46	0.124
Totals	0.0128	7.22	93	3,920	8,380	2,160

Table 3-4b. Summary of Final Inventory Estimates Based on Selected Phase Removal (SPR) following Retrieval with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks.

Tank|	^{129}I	^{99}Tc	Cr	Nitrite	Nitrate	Uranium (Total)
	Ci	Ci	kg	kg	kg	kg
C-101	4.09E-5	0.0213	9.15	281	1,880	294
C-102	2.34E-5	0.0113	6.26	145	623	69.5
C-103	1.13E-3	0.583	14.7	244	23.7	100
C-104	7.84E-3	0.602	15.2	380	204	368
C-105	1.90E-3	1.66	8.43	172	166	201
C-106	3.67E-3	0.457	25.3	35.8	5.23	18.2
C-107	5.24E-4	0.411	10.1	384	518	101
C-108	5.37E-5	0.252	9.47	356	641	6.22
C-109	8.46E-5	1.37	5.02	519	765	172
C-110	1.67E-5	0.484	6.38	99.1	1,490	30
C-111	9.47E-5	0.127	4	446	811	200
C-112	1.11E-4	1.59	3.61	720	963	626
C-201	5.82E-6	2.99E-3	0.486	8.88	48.2	0.242
C-202	6.05E-6	3.12E-3	0.508	45.5	136	0.253
C-203	4.64E-6	2.40E-3	0.388	20.8	71.2	0.192
C-204	2.99E-6	1.54E-3	0.251	13.4	46	0.124
Totals	0.016	7.58	119	3,870	8,390	2,190

Table 3-4c. Summary of Final Inventory Estimates Based on HTWOS Predictions following Retrieval with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks.

Tank	^{129}I	^{99}Tc	Cr	Nitrite	Nitrate	Uranium (Total)
	Ci	Ci	kg	kg	kg	kg
C-101	5.17E-6	0.0027	1.16	35.5	238	0
C-102	6.44E-6	0.0031	1.72	39.8	171	0
C-103	8.29E-5	0.0428	1.25	20.3	1.98	0
C-104	1.03E-3	0.0791	1.99	49.9	26.7	0.167
C-105	1.43E-4	0.125	0.633	12.9	12.5	0
C-106	1.08E-3	0.199	3.91	97	4.87	0
C-107	7.95E-5	0.0681	2.15	76.7	116	7.65E-3
C-108	1.34E-5	0.0628	2.36	88.6	160	0
C-109	1.58E-5	0.256	0.937	96.8	143	0
C-110	8.43E-6	0.243	3.2	49.8	747	3.25E-5
C-111	1.47E-5	0.0197	0.622	69.3	126	0
C-112	2.85E-5	0.408	0.929	186	248	0
C-201	6.15E-7	3.17E-4	0.0514	0.938	5.1	2.54E-5
C-202	6.33E-7	3.27E-4	0.0531	4.75	14.2	7.66E-5
C-203	6.31E-7	3.26E-4	0.0528	2.83	9.69	0
C-204	6.29E-7	3.23E-4	0.0527	2.82	9.67	0
Totals	2.51E-3	1.51	21.1	834	2,030	0.175

Table 3-4d. Summary of Final Inventory Estimates Based on Projected Retrieval Techniques with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks.

Tank	Inventory	^{129}I	^{99}Tc	Cr	Nitrite	Nitrate	Uranium (Total)
		Ci	Ci	kg	kg	kg	kg
C-101	**SPR**	4.09E-5	0.0213	9.15	281	1,880	294
C-102	**SPR**	2.34E-5	0.0113	6.26	145	623	69.5
C-103	**SPR**	1.13E-3	0.583	14.7	244	23.7	100
C-104	**SPR**	7.84E-3	0.602	15.2	380	204	368
C-105	**SPR**	1.90E-3	1.66	8.43	172	166	201
C-106	**HTWOS**	1.08E-3	0.199	3.91	97	4.87	0
C-107	**HTWOS**	7.95E-5	0.0681	2.15	76.7	116	7.65E-3
C-108	**SPR**	5.37E-5	0.252	9.47	356	641	6.22
C-109	**SPR**	8.46E-5	1.37	5.02	519	765	172
C-110	**SPR**	1.67E-5	0.484	6.38	99.1	1,490	30
C-111	**SPR**	9.47E-5	0.127	4	446	811	200
C-112	**SPR**	1.11E-4	1.59	3.61	720	963	626
C-201	**SPR**	5.82E-6	2.99E-3	0.486	8.88	48.2	0.242
C-202	**SPR**	6.05E-6	3.12E-3	0.508	45.5	136	0.253
C-203	**SPR**	4.64E-6	2.40E-3	0.388	20.8	71.2	0.192
C-204	**SPR**	2.99E-6	1.54E-3	0.251	13.4	46	0.124
Totals		0.0125	6.98	89.9	3,620	7,990	2,070

Table 3-5a. Summary of Final Radionuclide Inventory Estimates (Post Retrieval) Based on Selected Phase Removal following Retrieval with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks (2 Pages)

Tank	Units	241-C-101	241-C-102	241-C-103	241-C-104	241-C-105	241-C-106	241-C-107	241-C-108	241-C-109	241-C-110	241-C-111	241-C-112	241-C-201	241-C-202	241-C-203	241-C-204	All Tanks
Current Tank Radionuclide Inventory Based on BBI	Ci	6.44E+5	1.26E+6	6.30E+6	1.19E+6	1.12E+6	6.12E+5	5.29E+6	1.76E+5	8.36E+5	3.58E+4	1.82E+6	1.85E+6	1.28E+3	1.24E+3	2.23E+3	1.41E+3	2.11E+7
Estimate at Closure Total	Ci	1.97E+4	1.07E+4	1.35E+5	1.24E+4	2.28E+4	2.65E+5	5.75E+4	7.17E+3	3.55E+4	5.43E+2	8.55E+4	4.81E+4	2.71E+2	2.63E+2	1.90E+2	1.20E+2	7.01E+5
3H	Ci	1.45E-2	8.90E-3	2.87E-2	5.84E-1	1.19E-2	6.43E-2	3.24E-1	1.58E-2	5.72E-2	1.03E-2	2.64E-2	1.88E-1	2.08E-4	2.17E-4	1.66E-4	1.07E-4	1.33E+0
14C	Ci	3.07E-3	2.41E-3	8.27E-2	1.93E-2	1.03E-2	3.67E-3	4.12E-2	5.35E-3	6.91E-4	5.05E-3	7.63E-3	9.37E-2	4.27E-4	4.44E-4	3.40E-4	2.19E-4	2.77E-1
59Ni	Ci	8.66E-4	3.85E-4	8.26E-1	4.76E-2	7.19E-4	2.72E+0	3.49E+0	4.45E-2	2.36E-1	3.62E-4	2.32E-1	2.17E-1	1.60E-1	1.67E-1	1.27E-1	8.21E-2	8.35E+0
60Co	Ci	5.56E-4	1.17E+0	1.54E+1	2.83E+0	1.76E+0	1.09E-1	2.68E+0	3.72E-4	8.18E-4	1.12E-4	8.51E-4	1.12E-1	1.79E-4	1.86E-4	1.43E-4	9.18E-5	2.41E+1
63Ni	Ci	7.70E-2	3.60E-2	7.68E+1	4.46E+0	6.49E-2	2.53E+2	3.26E+2	3.79E+0	2.12E+1	3.10E-2	2.07E+1	1.97E+1	1.49E+1	1.55E+1	1.19E+1	7.64E+0	7.76E+2
79Se	Ci	6.48E-5	4.00E-5	3.72E-2	6.66E-2	5.38E-5	1.23E-1	1.94E-1	8.66E-5	2.27E-4	2.69E-5	2.86E-4	1.44E-2	1.87E-4	1.95E-4	1.49E-4	9.60E-5	4.37E-1
90Sr	Ci	8.75E+3	5.06E+3	6.47E+4	5.04E+3	9.70E+3	1.25E+5	2.43E+4	3.44E+2	1.07E+4	5.66E+1	4.18E+4	1.68E+4	8.77E+1	9.15E+1	6.99E+1	4.52E+1	3.13E+5
90Y	Ci	8.75E+3	5.06E+3	6.47E+4	5.04E+3	9.70E+3	1.25E+5	2.43E+4	3.44E+2	1.07E+4	5.66E+1	4.18E+4	1.68E+4	8.77E+1	9.15E+1	6.99E+1	4.52E+1	3.13E+5
93mNb	Ci	2.66E-3	1.40E-3	1.46E+0	1.03E-1	2.17E-3	4.79E+0	7.57E+0	3.67E-3	1.18E-2	1.14E-3	1.16E-2	7.53E-3	7.33E-3	7.63E-3	5.85E-3	3.76E-3	1.40E+1
93Zr	Ci	3.06E-3	1.69E-3	1.57E+0	1.21E-1	2.53E-3	5.14E+0	8.41E+0	4.12E-3	1.33E-2	1.28E-3	1.31E-2	8.48E-3	8.24E-3	8.58E-3	6.57E-3	4.23E-3	1.53E+1
99Tc	Ci	2.13E-2	1.13E-2	5.83E-1	6.02E-1	1.66E+0	4.57E-1	4.11E-1	2.52E-1	1.37E+0	4.84E-1	1.27E-1	1.59E+0	2.99E-3	3.12E-3	2.40E-3	1.54E-3	7.57E+0
106Ru	Ci	1.25E-10	5.34E-8	7.77E-7	1.88E-6	1.51E-10	2.56E-6	1.23E-4	3.11E-12	2.54E-8	8.93E-13	2.19E-8	2.47E-11	2.89E-8	3.02E-8	2.30E-8	1.49E-8	1.28E-4
113mCd	Ci	6.94E-3	5.03E-3	7.88E-1	2.01E-1	6.39E-3	2.59E+0	1.29E+1	7.19E-3	2.47E-2	2.21E-3	2.41E-2	1.51E-2	1.53E-2	1.59E-2	1.22E-2	7.85E-3	1.66E+1
125Sb	Ci	4.57E-4	1.88E-3	5.42E-2	1.84E+0	5.11E-4	1.78E-1	8.05E-2	1.49E-4	6.19E-4	4.40E-5	5.89E-4	1.01E-2	2.99E-4	3.12E-4	2.39E-4	1.54E-4	2.17E+0
126Sn	Ci	3.97E-4	2.25E-4	2.43E-1	1.79E-2	3.32E-4	8.02E-1	6.91E-1	5.22E-4	1.82E-3	1.61E-4	1.78E-3	1.08E-3	1.19E-3	1.24E-3	9.52E-4	6.13E-4	1.76E+0
129I	Ci	4.09E-5	2.34E-5	1.13E-3	7.84E-3	1.90E-3	3.67E-3	5.24E-4	5.37E-5	8.46E-5	1.67E-5	9.47E-5	1.11E-4	5.82E-6	6.05E-6	4.64E-6	2.99E-6	1.55E-2
134Cs	Ci	6.21E-6	9.09E-5	1.36E-3	4.68E-4	7.27E-6	4.43E-3	5.32E-3	2.69E-5	5.91E-5	9.77E-7	6.80E-5	6.86E-3	1.58E-7	1.65E-7	1.27E-7	8.15E-8	1.87E-2
137Cs	Ci	1.11E+3	2.54E+2	1.79E+3	9.93E+2	1.67E+3	5.05E+3	6.89E+2	3.33E+3	7.26E+3	2.19E+2	9.20E+2	7.39E+3	1.67E+1	1.75E+1	1.33E+1	8.58E+0	3.07E+4
137mBa	Ci	1.05E+3	2.40E+2	1.70E+3	9.39E+2	1.58E+3	4.79E+3	6.52E+2	3.14E+3	6.87E+3	2.07E+2	8.71E+2	6.98E+3	1.58E+1	1.65E+1	1.26E+1	8.15E+0	2.91E+4
151Sm	Ci	2.23E+0	1.13E+0	1.36E+3	9.77E+1	1.83E+0	4.48E+3	6.90E+3	3.06E+0	1.03E+1	9.51E-1	1.01E+1	6.29E+0	6.63E+0	6.90E+0	5.28E+0	3.41E+0	1.29E+4
152Eu	Ci	3.95E-3	6.58E-3	3.84E-1	2.53E-2	2.90E-3	1.26E+0	1.27E+0	5.33E-3	8.48E-2	2.48E-4	7.53E-2	1.33E-2	8.60E-2	8.96E-2	6.86E-2	4.42E-2	3.42E+0
154Eu	Ci	1.74E-2	2.82E-1	1.18E+2	1.14E+1	1.85E-2	1.17E+2	1.74E+1	2.36E-2	5.71E-2	2.18E-2	5.49E-2	5.73E+0	4.06E-2	4.23E-2	3.23E-2	2.08E-2	2.70E+2
155Eu	Ci	1.35E-1	2.23E-1	7.05E+1	8.37E+0	8.74E-2	8.07E+1	1.13E+1	1.16E-1	8.05E-1	1.64E-2	2.69E+0	3.97E+0	3.02E+0	3.14E+0	2.40E+0	1.55E+0	1.89E+2
226Ra	Ci	1.03E-7	6.37E-6	5.29E-5	6.53E-5	5.74E-8	1.74E-4	2.34E-4	2.39E-7	1.25E-5	7.73E-8	1.09E-5	4.75E-7	1.38E-5	1.44E-5	1.10E-5	7.11E-6	6.04E-4
227Ac	Ci	6.71E-7	1.71E-1	2.97E-4	1.13E+0	3.85E-7	9.80E-4	1.53E-3	1.51E-6	4.96E-5	4.87E-7	4.34E-5	3.02E-6	5.44E-5	5.65E-5	4.33E-5	2.79E-5	1.31E+0
228Ra	Ci	6.66E-12	2.24E-2	3.31E-6	2.35E-1	2.89E-12	1.09E-5	5.25E-4	1.48E-11	5.67E-11	9.10E-13	5.59E-11	3.57E-11	3.78E-11	3.93E-11	3.01E-11	1.94E-11	2.58E-1
229Th	Ci	2.52E-9	1.38E-3	2.84E-6	9.79E-3	1.04E-9	9.31E-6	2.63E-5	5.65E-9	2.14E-8	2.89E-10	2.12E-8	1.38E-8	1.41E-8	1.47E-8	1.12E-8	7.24E-9	1.12E-2
231Pa	Ci	1.22E-6	2.53E-1	3.81E-4	2.49E+0	7.22E-7	1.25E-3	2.08E-3	2.65E-6	5.21E-6	8.54E-7	5.56E-6	5.28E-6	1.84E-6	1.91E-6	1.47E-6	9.43E-7	2.75E+0
232Th	Ci	7.68E-13	2.76E-4	6.60E-7	5.80E-2	5.93E-13	1.12E-3	7.90E-4	1.17E-12	1.78E-12	3.68E-13	2.01E-12	2.39E-12	1.02E-13	1.06E-13	8.11E-14	5.22E-14	6.02E-2
232U	Ci	3.65E-6	1.94E-3	3.65E-4	2.01E-1	3.22E-6	7.31E-5	5.91E-5	2.28E-8	2.40E-6	1.10E-7	2.21E-6	3.74E-3	8.81E-10	5.52E-9	7.03E-10	4.55E-10	2.07E-1
233U	Ci	1.41E-7	8.17E-3	1.50E-3	4.30E+0	1.15E-7	3.02E-4	2.45E-4	1.46E-9	1.07E-7	7.03E-9	8.65E-8	1.55E-2	5.65E-11	1.55E-10	4.50E-11	2.91E-11	4.32E+0

Table 3-5a. Summary of Final Radionuclide Inventory Estimates (Post Retrieval) Based on Selected Phase Removal following Retrieval with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks (2 Pages)

Tank	Units	241-C-101	241-C-102	241-C-103	241-C-104	241-C-105	241-C-106	241-C-107	241-C-108	241-C-109	241-C-110	241-C-111	241-C-112	241-C-201	241-C-202	241-C-203	241-C-204	All Tanks
234U	**Ci**	9.61E-2	2.32E-2	3.26E-2	2.16E-1	6.55E-2	5.94E-3	6.11E-3	2.05E-3	6.13E-2	9.89E-3	6.56E-2	2.07E-1	7.97E-5	8.47E-5	6.35E-5	4.10E-5	7.92E-1
235U	**Ci**	4.17E-3	1.00E-3	1.39E-3	6.27E-3	2.79E-3	2.54E-4	1.48E-3	9.23E-5	2.44E-3	4.46E-4	2.87E-3	9.07E-3	3.59E-6	3.57E-6	2.85E-6	1.84E-6	3.23E-2
236U	**Ci**	1.37E-3	3.80E-4	5.79E-4	7.12E-3	1.13E-3	1.06E-4	9.67E-4	1.31E-5	8.87E-4	6.31E-5	8.68E-4	2.56E-3	5.08E-7	1.97E-6	4.05E-7	2.62E-7	1.60E-2
237Np	**Ci**	1.36E-4	8.00E-5	1.85E-3	4.57E-2	1.14E-4	7.36E-2	8.75E-4	1.76E-4	4.16E-3	5.46E-5	3.04E-4	1.95E-2	9.09E-6	9.47E-6	7.25E-6	4.66E-6	1.47E-1
238Pu	**Ci**	3.20E-1	7.84E-1	1.42E+0	2.37E+0	6.21E-1	1.54E+0	7.39E-1	4.82E-4	6.60E-2	3.12E-3	6.49E-2	2.08E-1	3.08E-1	1.62E-1	3.24E-2	6.59E-4	8.63E+0
238U	**Ci**	9.83E-2	2.32E-2	3.34E-2	1.22E-1	6.71E-2	6.07E-3	3.36E-2	2.08E-3	5.76E-2	1.00E-2	6.67E-2	2.09E-1	8.07E-5	8.41E-5	6.42E-5	4.15E-5	7.29E-1
239Pu	**Ci**	1.64E+1	2.88E+1	9.03E+1	5.69E+1	4.19E+1	3.33E+1	2.34E+1	1.30E-1	2.58E+0	1.03E+0	6.14E+0	2.12E+0	1.38E+1	7.20E+0	1.44E+0	2.95E-2	3.26E+2
240Pu	**Ci**	2.74E+0	5.28E+0	1.39E+1	1.12E+1	6.41E+0	6.83E+0	4.27E+0	8.40E-3	4.38E-1	6.09E-2	6.76E-1	3.38E-1	2.27E+0	1.18E+0	2.37E-1	4.83E-3	5.59E+1
241Am	**Ci**	2.54E-1	9.87E+0	6.73E+1	6.60E+1	2.42E+1	9.97E+1	7.32E+1	2.68E-1	1.98E+0	5.96E-1	1.00E+1	1.23E+1	4.82E+0	2.53E+0	5.06E-1	1.03E-2	3.74E+2
241Pu	**Ci**	1.87E+1	4.56E+1	7.74E+1	1.54E+2	3.42E+1	8.16E+1	4.05E+1	8.07E-3	2.58E+0	2.77E-2	2.89E+0	2.09E+0	1.68E+1	8.79E+0	1.76E+0	3.59E-2	4.87E+2
242Cm	**Ci**	1.10E-4	1.84E-2	8.43E-2	5.60E-2	7.77E-3	1.52E-1	5.83E-2	5.60E-3	3.44E-3	6.86E-4	1.45E-1	3.93E-2	7.24E-3	3.78E-3	7.59E-4	1.54E-5	5.82E-1
242Pu	**Ci**	8.14E-5	2.43E-4	4.35E-4	9.87E-4	1.82E-4	7.27E-4	2.97E-4	4.42E-8	3.85E-5	1.19E-7	1.86E-5	1.06E-5	1.16E-4	6.05E-5	1.21E-5	2.48E-7	3.21E-3
243Am	**Ci**	5.70E-8	3.11E-5	1.55E-3	3.25E-3	6.64E-6	8.95E-4	3.77E-3	1.85E-6	4.64E-5	1.77E-6	9.12E-5	3.12E-4	1.12E-4	5.84E-5	1.16E-5	2.38E-7	1.01E-2
243Cm	**Ci**	2.24E-6	5.79E-4	4.71E-3	4.48E-3	1.60E-4	1.21E-2	4.57E-3	1.00E-4	1.51E-4	8.89E-6	2.79E-3	1.30E-3	3.46E-4	1.81E-4	3.62E-5	7.39E-7	3.16E-2
244Cm	**Ci**	1.63E-6	5.67E-3	2.95E-2	1.56E-1	2.45E-4	2.58E-1	1.69E-1	3.35E-5	7.43E-5	2.07E-5	2.50E-3	5.54E-4	1.53E-4	7.99E-5	1.60E-5	3.26E-7	6.22E-1

Table 3-5b. Summary of Final Radionuclide Inventory Estimates (Post Retrieval) Based on HTWOS Modeling with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks (2 Pages)

Tank	Units	241-C-101	241-C-102	241-C-103	241-C-104	241-C-105	241-C-106	241-C-107	241-C-108	241-C-109	241-C-110	241-C-111	241-C-112	241-C-201	241-C-202	241-C-203	241-C-204	All Tanks
Current Tank Inventory Based on BBI	Ci	6.44E+5	1.26E+6	6.30E+6	1.19E+6	1.12E+6	6.12E+5	5.29E+6	1.76E+5	8.36E+5	3.58E+4	1.82E+6	1.85E+6	1.28E+3	1.24E+3	2.23E+3	1.41E+3	2.11E+7
Estimate at Closure Total	Ci	2.49E+3	2.95E+3	1.15E+4	1.63E+3	1.71E+3	3.88E+4	1.04E+4	1.78E+3	6.63E+3	2.72E+2	1.33E+4	1.24E+4	2.86E+1	2.75E+1	2.58E+1	2.52E+1	1.04E+5
3H	Ci	1.84E-3	2.45E-3	1.39E-3	7.66E-2	8.96E-4	9.79E-2	4.89E-2	3.93E-3	1.07E-2	5.15E-3	4.11E-3	4.83E-2	2.20E-5	2.27E-5	2.25E-5	2.25E-5	3.02E-1
14C	Ci	3.88E-4	6.64E-4	6.07E-3	2.53E-3	7.77E-4	3.64E-3	6.31E-3	1.33E-3	1.29E-4	2.54E-3	1.19E-3	2.41E-2	4.51E-5	4.64E-5	4.62E-5	4.61E-5	4.99E-2
59Ni	Ci	1.10E-4	1.06E-4	6.15E-2	6.25E-3	5.40E-5	4.14E-1	5.27E-1	1.11E-2	4.39E-2	1.83E-4	3.61E-2	5.59E-2	1.69E-2	1.74E-2	1.73E-2	1.73E-2	1.22E+0
60Co	Ci	7.03E-5	3.21E-1	1.32E+0	3.71E-1	1.32E-1	8.91E-2	4.94E-1	9.24E-5	1.52E-4	5.62E-5	1.32E-4	2.90E-2	1.89E-5	1.95E-5	1.94E-5	1.93E-5	2.75E+0
63Ni	Ci	9.73E-3	9.89E-3	5.73E+0	5.85E-1	4.87E-3	3.85E+1	4.92E+1	9.44E-1	3.95E+0	1.56E-2	3.23E+0	5.07E+0	1.57E+0	1.62E+0	1.62E+0	1.61E+0	1.14E+2
79Se	Ci	8.19E-6	1.10E-5	2.77E-3	8.74E-3	4.04E-6	1.83E-2	2.93E-2	2.15E-5	4.23E-5	1.54E-5	4.45E-5	3.72E-3	1.97E-5	2.04E-5	2.02E-5	2.02E-5	6.30E-2
90Sr	Ci	1.11E+3	1.39E+3	5.52E+3	6.61E+2	7.29E+2	1.79E+4	4.56E+3	8.56E+1	1.99E+3	2.84E+1	6.50E+3	4.34E+3	9.27E+0	9.58E+0	9.52E+0	9.50E+0	4.49E+4
90Y	Ci	1.11E+3	1.39E+3	5.52E+3	6.61E+2	7.29E+2	1.79E+4	4.56E+3	8.56E+1	1.99E+3	2.84E+1	6.50E+3	4.34E+3	9.27E+0	9.58E+0	9.52E+0	9.50E+0	4.49E+4
93mNb	Ci	3.36E-4	3.85E-4	1.09E-1	1.35E-2	1.63E-4	8.06E-1	1.14E+0	9.13E-4	2.20E-3	5.75E-4	1.81E-3	1.94E-3	7.74E-4	7.98E-4	7.95E-4	7.91E-4	2.08E+0
93Zr	Ci	3.86E-4	4.66E-4	1.17E-1	1.59E-2	1.90E-4	9.10E-1	1.27E+0	1.02E-3	2.48E-3	6.45E-4	2.04E-3	2.19E-3	8.71E-4	8.98E-4	8.94E-4	8.90E-4	2.32E+0
99Tc	Ci	2.70E-3	3.10E-3	4.28E-2	7.91E-2	1.25E-1	1.99E-1	6.81E-2	6.28E-2	2.56E-1	2.43E-1	1.97E-2	4.08E-1	3.17E-4	3.27E-4	3.26E-4	3.23E-4	1.51E+0
106Ru	Ci	1.58E-11	1.47E-8	5.73E-8	2.46E-7	1.14E-11	1.08E-6	1.84E-5	7.73E-13	4.74E-9	4.48E-13	3.40E-9	6.35E-12	3.05E-9	3.16E-9	3.13E-9	3.13E-9	1.99E-5
113mCd	Ci	8.78E-4	1.38E-3	5.82E-2	2.64E-2	4.80E-4	1.12E+0	1.94E+0	1.79E-3	4.61E-3	1.11E-3	3.76E-3	3.89E-3	1.62E-3	1.67E-3	1.66E-3	1.65E-3	3.17E+0
125Sb	Ci	5.78E-5	5.16E-4	3.83E-3	2.42E-1	3.84E-5	1.79E-1	1.22E-2	3.70E-5	1.15E-4	2.21E-5	9.16E-5	2.60E-3	3.17E-5	3.27E-5	3.25E-5	3.23E-5	4.41E-1
126Sn	Ci	5.02E-5	6.17E-5	1.81E-2	2.34E-3	2.49E-5	1.36E-1	1.88E-1	1.30E-4	3.39E-4	8.13E-5	2.77E-4	2.77E-4	1.26E-4	1.30E-4	1.29E-4	1.29E-4	3.46E-1
129I	Ci	5.17E-6	6.44E-6	8.29E-5	1.03E-3	1.43E-4	1.08E-3	7.95E-5	1.34E-5	1.58E-5	8.43E-6	1.47E-5	2.85E-5	6.15E-7	6.33E-7	6.31E-7	6.29E-7	2.51E-3
134Cs	Ci	7.85E-7	2.50E-5	8.76E-5	6.14E-5	5.46E-7	4.48E-3	8.01E-4	6.70E-6	1.10E-5	4.90E-7	1.06E-5	1.77E-3	1.67E-8	1.73E-8	1.72E-8	1.71E-8	7.25E-3
137Cs	Ci	1.33E+2	6.61E+1	1.43E+2	1.23E+2	1.19E+2	1.05E+3	8.19E+1	7.82E+2	1.28E+3	1.04E+2	1.35E+2	1.80E+3	1.67E+0	1.73E+0	1.71E+0	1.71E+0	5.83E+3
137mBa	Ci	1.41E+2	6.99E+1	1.51E+2	1.30E+2	1.25E+2	1.11E+3	8.64E+1	8.28E+2	1.35E+3	1.10E+2	1.43E+2	1.90E+3	1.77E+0	1.83E+0	1.82E+0	1.80E+0	6.16E+3
151Sm	Ci	2.83E-1	3.10E-1	1.01E+2	1.28E+1	1.38E-1	7.56E+2	1.04E+3	7.62E-1	1.93E+0	4.79E-1	1.58E+0	1.62E+0	7.00E-1	7.22E-1	7.19E-1	7.16E-1	1.92E+3
152Eu	Ci	5.00E-4	1.81E-3	2.86E-2	3.32E-3	2.18E-4	2.08E-1	1.92E-1	1.33E-3	1.58E-2	1.24E-4	1.17E-2	3.43E-3	9.09E-3	9.38E-3	9.34E-3	9.29E-3	5.04E-1
154Eu	Ci	2.21E-3	7.74E-2	1.01E+1	1.50E+0	1.39E-3	1.69E+1	3.19E+0	5.87E-3	1.07E-2	1.09E-2	8.53E-3	1.48E+0	4.29E-3	4.42E-3	4.39E-3	4.38E-3	3.33E+1
155Eu	Ci	1.71E-2	6.12E-2	6.01E+0	1.10E+0	6.57E-3	1.20E+1	2.08E+0	2.88E-2	1.50E-1	8.24E-3	4.19E-1	1.02E+0	3.19E-1	3.29E-1	3.27E-1	3.25E-1	2.42E+1
226Ra	Ci	1.31E-8	1.75E-6	3.94E-6	8.57E-6	4.32E-9	2.60E-5	3.54E-5	5.95E-8	2.33E-6	3.91E-8	1.69E-6	1.22E-7	1.46E-6	1.51E-6	1.50E-6	1.50E-6	8.58E-5
227Ac	Ci	8.48E-8	4.70E-2	2.22E-5	1.49E-1	2.89E-8	1.46E-4	1.82E-4	3.76E-7	9.25E-6	2.46E-7	6.75E-6	7.77E-7	5.75E-6	5.91E-6	5.90E-6	5.86E-6	1.96E-1
228Ra	Ci	8.42E-13	6.16E-3	2.46E-7	3.08E-2	2.17E-13	2.00E-6	5.38E-6	3.67E-12	1.06E-11	4.56E-13	8.69E-12	9.19E-12	4.00E-12	4.11E-12	4.09E-12	4.07E-12	3.70E-2
229Th	Ci	3.18E-10	3.80E-4	2.11E-7	1.28E-3	7.83E-11	1.53E-6	4.80E-6	1.41E-9	4.00E-9	1.45E-10	3.30E-9	3.56E-9	1.49E-9	1.54E-9	1.53E-9	1.52E-9	1.67E-3
231Pa	Ci	1.54E-7	6.95E-2	2.82E-5	3.27E-1	5.43E-8	2.14E-4	3.22E-4	6.60E-7	9.71E-7	4.31E-7	8.65E-7	1.36E-6	1.94E-7	2.00E-7	2.00E-7	1.98E-7	3.97E-1
232Th	Ci	9.72E-14	7.60E-5	4.93E-8	7.62E-3	4.45E-14	1.61E-4	4.94E-7	2.92E-13	3.32E-13	1.86E-13	3.13E-13	6.17E-13	1.07E-14	1.11E-14	1.10E-14	1.10E-14	7.85E-3
232U	Ci	4.62E-7	5.34E-4	2.71E-5	2.64E-2	2.42E-7	3.35E-5	8.51E-6	5.68E-9	4.47E-7	5.50E-8	3.44E-7	9.64E-4	9.32E-11	5.78E-10	9.56E-11	9.56E-11	2.80E-2
233U	Ci	1.79E-8	2.25E-3	1.12E-4	5.64E-1	8.67E-9	1.38E-4	3.32E-5	3.63E-10	2.00E-8	3.53E-9	1.35E-8	4.00E-3	5.97E-12	1.62E-11	6.13E-12	6.11E-12	5.71E-1

Table 3-5b. Summary of Final Radionuclide Inventory Estimates (Post Retrieval) Based on HTWOS Modeling with 360 ft^3 (10.2 kL) remaining in 100-Series Tanks and 30 ft^3 (0.8 kL) in 200-Series Tanks (2 Pages)

Tank	Units	241-C-101	241-C-102	241-C-103	241-C-104	241-C-105	241-C-106	241-C-107	241-C-108	241-C-109	241-C-110	241-C-111	241-C-112	241-C-201	241-C-202	241-C-203	241-C-204	All Tanks
234U	**Ci**	1.22E-2	6.38E-3	2.77E-3	2.84E-2	4.92E-3	2.73E-3	3.49E-3	5.10E-4	1.14E-2	4.96E-3	1.02E-2	5.33E-2	8.42E-6	8.87E-6	8.64E-6	8.61E-6	1.41E-1
235U	**Ci**	5.28E-4	2.75E-4	1.18E-4	8.23E-4	2.09E-4	1.16E-4	1.44E-4	2.30E-5	4.55E-4	2.24E-4	4.46E-4	2.34E-3	3.79E-7	3.73E-7	3.88E-7	3.88E-7	5.70E-3
236U	**Ci**	1.73E-4	1.04E-4	4.90E-5	9.34E-4	8.51E-5	4.86E-5	1.56E-4	3.27E-6	1.65E-4	3.17E-5	1.35E-4	6.60E-4	5.36E-8	2.06E-7	5.51E-8	5.50E-8	2.55E-3
237Np	**Ci**	1.72E-5	2.20E-5	1.36E-4	6.00E-3	8.59E-6	1.66E-2	1.34E-4	4.39E-5	7.75E-4	2.75E-5	4.72E-5	5.02E-3	9.61E-7	9.91E-7	9.86E-7	9.81E-7	2.89E-2
238Pu	**Ci**	4.04E-2	2.16E-1	1.21E-1	3.11E-1	4.67E-2	2.22E-1	6.74E-2	1.20E-4	1.23E-2	1.56E-3	1.01E-2	5.37E-2	3.25E-2	1.69E-2	4.40E-3	1.39E-4	1.16E+0
238U	**Ci**	1.24E-2	6.37E-3	2.84E-3	1.60E-2	5.04E-3	2.79E-3	3.08E-3	5.17E-4	1.07E-2	5.03E-3	1.04E-2	5.39E-2	8.53E-6	8.80E-6	8.74E-6	8.74E-6	1.29E-1
239Pu	**Ci**	2.07E+0	7.92E+0	7.70E+0	7.47E+0	3.15E+0	4.80E+0	2.55E+0	3.23E-2	4.81E-1	5.17E-1	9.54E-1	5.47E-1	1.45E+0	7.53E-1	1.97E-1	6.20E-3	4.06E+1
240Pu	**Ci**	3.46E-1	1.45E+0	1.19E+0	1.47E+0	4.82E-1	9.82E-1	4.03E-1	2.09E-3	8.17E-2	3.05E-2	1.05E-1	8.70E-2	2.40E-1	1.24E-1	3.23E-2	1.02E-3	7.03E+0
241Am	**Ci**	3.21E-2	2.71E+0	5.74E+0	8.67E+0	1.82E+0	1.43E+1	7.49E+0	6.68E-2	3.69E-1	2.99E-1	1.56E+0	3.17E+0	5.10E-1	2.64E-1	6.88E-2	2.16E-3	4.70E+1
241Pu	**Ci**	2.36E+0	1.25E+1	6.60E+0	2.02E+1	2.57E+0	1.17E+1	3.46E+0	2.01E-3	4.82E-1	1.39E-2	4.50E-1	5.39E-1	1.78E+0	9.20E-1	2.39E-1	7.56E-3	6.39E+1
242Cm	**Ci**	1.39E-5	5.05E-3	7.19E-3	7.35E-3	5.84E-4	2.26E-2	8.14E-3	1.39E-3	6.42E-4	3.44E-4	2.25E-2	1.01E-2	7.65E-4	3.96E-4	1.03E-4	3.23E-6	8.72E-2
242Pu	**Ci**	1.03E-5	6.67E-5	3.71E-5	1.30E-4	1.37E-5	1.05E-4	2.84E-5	1.10E-8	7.17E-6	5.96E-8	2.89E-6	2.74E-6	1.23E-5	6.33E-6	1.65E-6	5.22E-8	4.23E-4
243Am	**Ci**	7.20E-9	8.55E-6	1.32E-4	4.26E-4	4.99E-7	1.40E-4	3.75E-4	4.61E-7	8.65E-6	8.85E-7	1.42E-5	8.03E-5	1.18E-5	6.11E-6	1.58E-6	5.00E-8	1.21E-3
243Cm	**Ci**	2.83E-7	1.59E-4	4.02E-4	5.89E-4	1.21E-5	1.78E-3	4.99E-4	2.49E-5	2.81E-5	4.45E-6	4.33E-4	3.34E-4	3.66E-5	1.89E-5	4.93E-6	1.55E-7	4.33E-3
244Cm	**Ci**	2.06E-7	1.56E-3	2.51E-3	2.05E-2	1.84E-5	3.82E-2	1.65E-2	8.33E-6	1.39E-5	1.04E-5	3.89E-4	1.43E-4	1.62E-5	8.35E-6	2.17E-6	6.86E-8	7.99E-2

3.2.3.4 Residual Waste in Infrastructure. Although DOE/ORP-2003-2 provides estimates of ranges of volumes that may reside in infrastructure, such information is insufficient for risk assessment as the waste streams are not known. The assumed inventory was calculated using the following methodology:

- The present waste volume in ancillary equipment tanks is given in Table 3-6. It is assumed that the waste in ancillary equipment tanks (that is, four tanks in the 244-CR vault and the C-301 catch tank) will be retrieved. Since these tanks are smaller than the 200 series tanks, the ancillary tank residual was calculated by multiplying the residual of the 200-series tanks by the ratio of the volume of the ancillary equipment tank to the 200-series tanks.

- The volume of pipes within the WMA was estimated by scaling off the drawings presented in *Historical Vadose Zone Contamination from A, AX, and C Tank Farms,* Williams et al. (2001). A total of four layers of pipe have been added to the WMA, the first layer of pipe was installed from 1943 to 1945 and were gravity fed to support filling the tanks, the second layer was added to support bismuth phosphate and uranium recovery operations and was installed from 1946 to 1957, the third layer was installed for waste fractionation operations from 1961 to 1978, with the last layer was installed from 1975 to 2001 to support interim stabilization and isolation. Table 3-6 shows estimated total length of piping for each of these layers. For the residual volume estimate, it is assumed that none of the piping in the last layer is blocked since this piping is still being used. For the previous three layers of pipe, the total estimated length of pipe is approximately 20,000 ft (6,000 m). The typical diameter of pipe used in the WMA is 3 in. The total volume of pipe that may contain blockages is:

  $$20{,}000 \text{ ft (length)} \times 0.05 \text{ ft}^2 \text{ (cross-sectional area)} = 1{,}000 \text{ ft}^3$$

  It is further assumed, that of the 1,000 ft of piping only 25% is blocked or has residual waste left in it. The pipelines in WMA C were drained and flushed after use; therefore, the amount of residual remaining in the pipelines is expected to be much smaller the 25% used in this estimate.

- The material left in the tank is assumed to be similar in nature to what is left in the 100- and 200-series tanks. Therefore, to estimate the inventory left in the 244-CR vaults, the C-301 catch tank and the pipes, the total residual inventory for each contaminant of concern (Selected Phase BBI) was divided by the total residual volume (12×360 ft^3 [100-series tanks] + 4×30 ft^3 [200-series tanks] = 4,400 ft^3) to come up with an average inventory per cubic foot. The expected residual volume for the ancillary equipment was then multiplied average inventory per cubic foot.

Table 3-6 provides the assumed inventory using these calculations.

Table 3-6. Assumed Inventory for Ancillary Equipment

Equipment	Total Volume	Current Waste Volume	Assumed Residual Volume	^{129}I	^{99}Tc	Chromium	Nitrite	Nitrate	Uranium (Total)
	gal[a]	gal[a]	ft^3	Ci	Ci	kg	kg	kg	kg
Average Inventory per ft^3 of Residual →				3.60E-6	0.001707	0.026859	0.87173	1.8896	0.49324
CR-244[b] TK-CR-01	50,000	2000 (s)	27	9.73E-5	0.046	0.725	23.54	51.0	13.32
CR-244[b] TK-CR-02	15,000	1,500 (s)	8	2.88E-5	0.014	0.215	6.97	15.1	3.95
CR-244[b] TK-CR-03	15,000	4,200 (s)	8	2.88E-5	0.014	0.215	6.97	15.1	3.95
CR-244[b] TK-CR-11	50,000	35,000 (l)	27	9.73E-5	0.046	0.725	23.54	51.0	13.32
C-301[c]	35,000	9,016 (s) 1,470 (l)	19	6.85E-5	0.032	0.510	16.56	35.9	9.37
Pipes Layers 1 - 3	1,000 ft^3	NA	250	0.0009	0.43	6.7	217.9	472.4	123.3
Totals				1.22E-3	0.579	9.1	295.5	640.5	167.2

[a] Units are in gallons for tanks, and in cubic feet for pipes

[b] CR-244 current waste volume from Waste Information Data Systems Report

[c] C-301 current waste volume from *Engineering Study of 50 Miscellaneous Inactive Underground Waste Tanks Located at the Hanford Site*, (Freeman-Pollard et al. 1994)

(s) = solids

(l) = liquids

3.2.3.5 Definition of Base Analysis Inventory. The inventory left in WMA C after closure is very uncertain. Not only has closure not taken place for any component of the WMA, but current inventories are uncertain. For the base case, the following assumptions are made:

1. The past leak from tank C-105 and the leaks from the pipelines form the bulk of the leaked inventory from all past leaks.

2. Only tanks C-106 and C-107 will leak during retrieval (the other tanks having minimal liquid inventory during retrieval). Each of these two tanks will leak 8,000 gal, fully diluted from the use of 250,000 gal during liquid retrieval.

3. Tanks will be retrieved to meet HFFACO milestones. The residual waste inventory will depend on the method of retrieval.

4. Residual waste in infrastructure can be crudely estimated.

3.2.3.6 Inventory Summary. The inventory of key contaminants is quite uncertain. This is not only because of our uncertainty of what is currently in the WMA C, but also because the residual inventory will be determined based on decisions yet to be made and implemented. However, as seen from Table 3-7, the inventory for contaminants other than uranium currently in the vadose zone will be comparable to the inventory left in the tanks.

Table 3-7. Summary of Assumed Inventory.

Type	^{129}I	^{99}Tc	Cr	Nitrite	Nitrate	Uranium (Total)
	Ci	Ci	kg	kg	kg	kg
Past Leaks	0.0256	13.3	116.0	4,240	8,130	193
Potential Retrieval Leaks	0.0021	1.3	31.7	1178	1,532	301
Residuals in Major Tanks	0.0125	6.98	89.9	3,620	7,990	2,070
Residuals in Ancillary Facilities	0.0012	0.58	9.1	295	640	167
Totals	0.0414	22.2	246.7	9,333	18,292	2,731

3.2.4 Release Rates

The source term used in the transport calculations is based not only on the inventory, but also on the release rate. The release rate is a function of the waste composition and the closure design, which affects water transport and the resulting chemical environment in the closed facility. For an accurate determination of the source term, the chemical and physical processes controlling contaminant release from the residual wastes must be explicitly modeled. Because the various sources in a closed WMA C facility have different release rates, the release rate for the sources are discussed in groups having similar release mechanisms.

3.2.4.1 Releases from Past Leak and Potential Retrieval Leak Sources. For the cases of past leaks and potential retrieval leaks, the contaminants are released to the soil as a result of a liquid discharge. Therefore, for these sources, it is assumed that all contaminants are immediately available for transport.

3.2.4.2 Releases from Tank Residual Waste. Very little is known about the physical form of residual waste remaining in the tanks after retrieval. It may be sludge, saltcake, flakes, a complex set of minerals, or something else. In the absence of post-retrieval tank waste characterization data and a lack of information of the controlling processes, a series of scenarios are assumed for contaminant release from tank wastes and tank ancillary equipment such that the modeling results include the range of possible outcomes.

To understand how various release scenarios would affect the estimated environmental impacts, various controlling processes (i.e., advection, diffusion, or solubility) are modeled. The advection-dominated release model is used to simulate the processes of release of contaminants from unstabilized wastes (i.e., a waste material covered with backfill sand and gravel). The diffusion-dominated release model is used to simulate the contaminant release from stabilized, contained wastes (i.e., a waste form covered with grout or cementatious grout). The solubility-dominated release model represents a waste form bound in a material that releases risk-driving contaminants congruently with the dissolution of the material. Details are presented in Section 3.3.

3.2.4.3 Releases from Infrastructure Residual Waste. For the case of residual waste in infrastructure, there is next to no information on the physical form of the waste. For this analysis, the diffusion-dominated release model is used as the infrastructure is likely to be filled with cementious materials.

3.3 PATHWAYS AND SCENARIOS

This section covers the selection criteria, the pathways chosen and not chosen, and the exposure pathways chosen and not chosen. Special emphasis is given to justifying the choices. In this discussion, "pathways" refers to the environmental paths (e.g., groundwater) by which contaminants move from the waste form to the human environment. Scenarios are the environmental and human-caused events (e.g., human intrusion or irrigation) that influence how contaminants move or affect humans.

3.3.1 Selection Criteria

Relevant pathways and scenarios for these analyses were selected mainly based on pathways and scenarios used in earlier Hanford Site long-term environmental analysis documents (see Section 1.5). As noted in Section 1.5.1, six Hanford Site performance assessments for the disposal of low-level waste have already been done (Kincaid 1995, Mann 1998, Mann 2001, Wood 1995, and Wood 1996) as well as two field investigation reports (Knepp 2002a and 2002b). The most important EISs have been the Hanford Defense Waste EIS (DOE 1987), the Tank Waste Remediation System EIS (DOE 1996b), and the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999h) and its associated Record of Decision (DOE 1999i). Two EISs, *Hanford Site Solid (Radioactive and Hazarous) Waste Program Environmental Impact Statement* and the *Accelerated Retrieval, Treatment, and Disposal of Single-Shell Tank (SST) Waste and Closure of Tanks at the Hanford Site Environmental Impact Statement*, are being prepared. These documents have been fairly consistent in their choice of pathways and scenarios.

After reviewing the relevant documents, reviews, and guidance, pathways and scenarios were selected for the current performance assessment (Mann 1999b). Selection was based on the relevance of the pathway or scenarios to the current disposal action and performance objectives.

3.3.2 Pathways

The most important pathways are through the use of contaminated groundwater and inadvertent intrusion. The pathways remain unchanged from the 1998 ILAW PA.

The selection of pathways for this performance assessment is covered more fully in *Scenarios of the TWRS Low-Level Waste Disposal Program* (Mann 1999b). Possible scenarios were suggested by analyzing the performance objectives introduced in Section 1 and determining which pathways could lead to a level of exposure that could equal or exceed the specified performance objective. Postulated land use also was studied to determine possible additional pathways. Finally, likely natural events were identified (such as catastrophic glacial age flooding).

3.3.2.1 Release Mechanism. In previous Hanford Site performance assessments and EISs, the dominant pathway was through groundwater. Infiltration of moisture from precipitation entered the engineered system, where the moisture could cause the contaminants to be released or could simply carry away already-released contaminants. The moisture and released contaminants travel downward through the vadose zone until the contaminants reach the unconfined aquifer where humans can encounter the radioisotopes through recovery of the groundwater resource for use in residential and agricultural settings.

3.3.2.2 Future Land Use. In 1992 the HFSUWG was charged to determine potential future uses of the various parts of the Hanford Site. This group consisted of local, state, and federal officials, representatives of affected Indian tribes, and agricultural and labor organizations, as well as members of environmental and other special interest groups. The efforts of the HFSUWG form the basis of the Hanford Site Comprehensive Land Use plan (DOE 1999h). The HFSUWG summary report (HFSUWG 1992a-2) states:

"In general, the Working Group desires that the overall cleanup criteria for the Central Plateau should enable general usage of the land and groundwater for other than waste management activities in the horizon of 100 years from the decommissioning of waste management facilities and closure of the disposal areas."

The following four general land uses can be envisioned for the Central Plateau over the time of interest to a performance assessment.

- Industrial or commercial
- Dry-land farming
- Irrigated farming
- Natural.

The present land use is heavy industrial. If this use is maintained, records of past activities, particularly those for the disposal of nuclear materials, are likely to be kept. In addition, in an industrial area, liquid discharges to the ground would be highly regulated and kept small.

Like the Central Plateau, the Horse Heaven Hills, south of the Hanford Site, are near the Columbia River, but are at a significantly higher elevation. Although the amount of irrigation is increasing at certain locations, comparatively little irrigation occurs in the Horse Heaven Hills because of the relatively high energy (hence economic) cost of bringing water to the surface. Dry-land farming continues to be the main use for the land of the Horse Heaven Hills.

East of the Central Plateau, across the Columbia River, irrigated farming is extremely common. The water, however, does not come from the nearby stretches of the Columbia River. The water comes from the Columbia Basin Project, which uses water stored behind the Grand Coulee Dam, over 322 km (200 mi) upstream of the Hanford Site. The water is gravity-fed to the farms. The regional geography makes such a water delivery system unlikely for the Central Plateau.

Finally, west of the Central Plateau is the Fitzner/ Eberhardt Arid Lands Ecology Reserve, a nature preserve area. This area now is part of the Hanford Reach National Monument (Clinton 2000).

For the base analysis case, the land use assumption was that knowledge of the disposal activities has been retained and that water discharges to the ground are minimized. These assumptions are consistent with the assumptions of the HFSUWG, the DOE (DOE 1999h), and the local planning authorities, all of which are using a 50- to 100- year planning horizon.

3.3.2.3 Land-Use-Driven Scenarios. The pathways described here assume that some controls remain in place to prevent public intrusion into the disposal site. That is, the barriers and markers that are to be left will effectively prevent open use of the land over the disposal site. The land surrounding the marked area, however, could be farmed and could contain wells.

Based on previous analyses at the Hanford Site, the main exposure pathway is expected to be the contamination of the underground aquifer leading to various exposure scenarios. Other pathways include upward diffusion through the engineered system into the air.

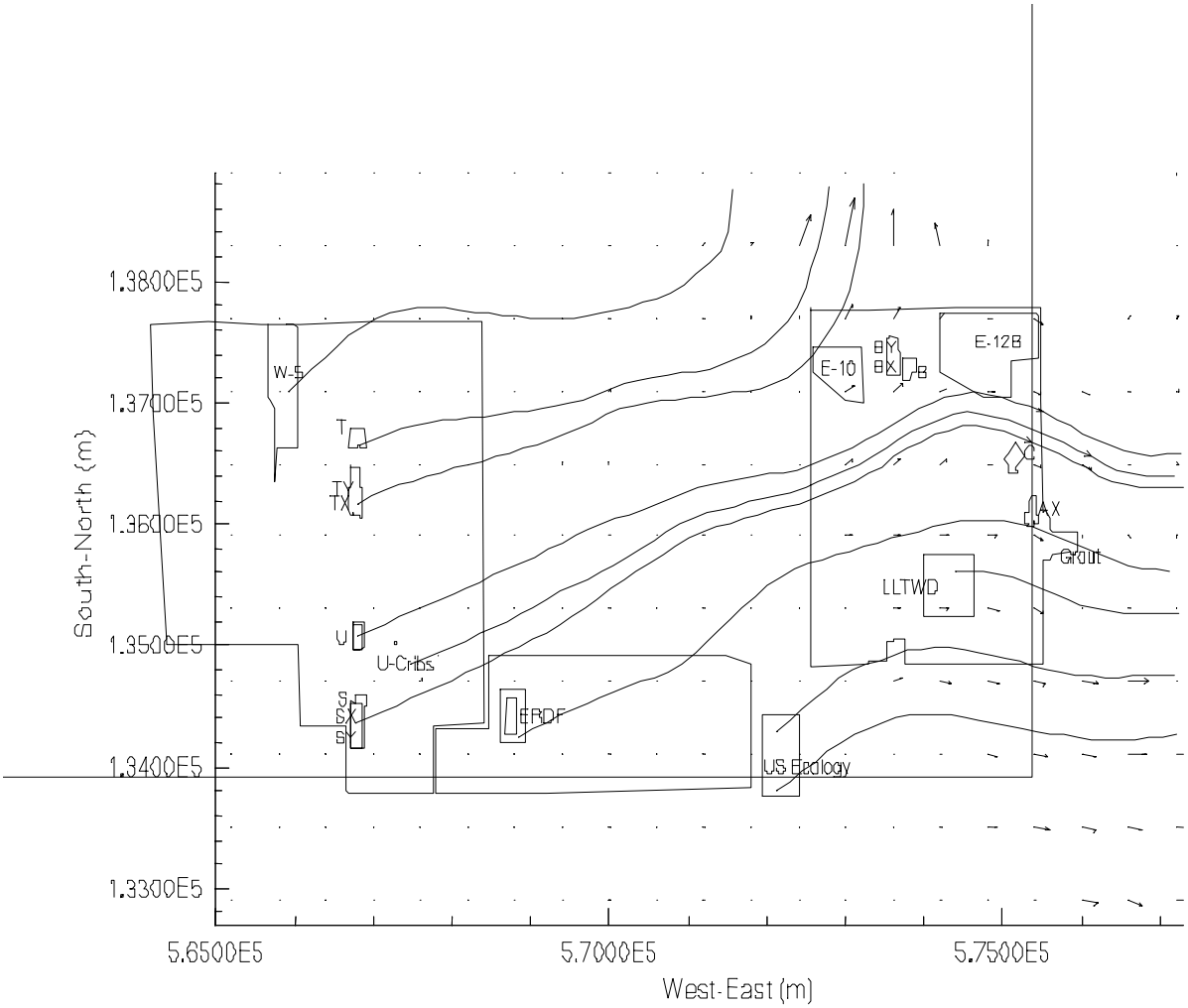
3.3.2.3.1 Unconfined Aquifer Contamination. Contamination of the unconfined aquifer is caused by water (natural or human-introduced) penetrating through the ground surface layer, interacting with the engineered structure (including the waste), then transporting contaminants down through the unsaturated sediments to the unconfined aquifer.

The main effects of land use on the analyses presented in this performance assessment are as follows:

- The amount of water penetrating through the ground surface layer above the closed facility
- The direction and magnitude of flow of the unconfined aquifer from regional irrigation
- The amount of well water pumped to the surface.

Because the site of the closed facility is assumed to be known to the surrounding population, it was assumed that the surface immediately above the closed facility will not be used. Thus, the only source of water would be natural rain or snowfall. The infiltration rate, the rate at which water actually penetrates through the surface layer and enters the sand-gravel capillary barrier, is described in Section 3.4.6 and is expected to be small (less than 5 mm/year).

Figure 3-1. Predicted Groundwater Flowlines for Post Hanford Conditions in the 200 East Area.



Note: WMA C is the diamond shaped area midway down along the eastern border of this map.

The second major consequence of land use is on the flow of groundwater in the unconfined aquifer. Analysis (ERDA 1975) of groundwater flow before the start of Hanford Site operations shows a predominantly west-to-east flow (Figure 2-26). Current calculations for post-operation conditions (Bergeron 2000) predict a similar flow (Figure 3-1). These groundwater calculations form an important part in this analysis.

The creation of ponds and the large amount of water discharged to the ground have altered the natural flow of groundwater (Dirkes 1999). Possible irrigation on the Central Plateau that also would affect groundwater must be considered. No irrigation was assumed for the base analysis case because the energy requirements for irrigation in the Central Plateau are significantly higher than for other nearby regions and no known irrigation rights exist. However, irrigation on the plateau was considered in sensitivity cases to determine the effects of selected irrigation on the regional flow of the groundwater in the unconfined aquifer. Irrigation on the 200 Areas was considered unlikely because this area will be dedicated to waste disposal and irrigation would be considered an inadvertent intrusion.

The main impact of irrigation would be to change the water table and potentially the flow direction. Sensitivity cases chosen to investigate this effect were set up to change the regional recharge by a factor of three.

The last major effect is the amount of water being taken from a well. At the locations of the proposed disposal facilities, the unconfined aquifer contains only a limited amount of water. Because the amount of water is so limited, either only a small amount would be pumped from the unconfined aquifer or the well would extend much deeper and tap the confined aquifer instead of the unconfined aquifer. Thus, minimum distortion of the groundwater flow field in the unconfined aquifer was assumed for the base analysis case. Sensitivity cases were considered, however, to determine the effect of the amount of pumping on the groundwater flow field and the calculated doses.

3.3.2.3.2 Surface Water. The major surface water source in the region is the Columbia River. Here the main impact of land use is possible irrigation of land near the river. The Columbia River is a more likely source of water than the unconfined aquifer for irrigating farmland near the river because of the land's low elevation and nearness to the river. The current plan (DOE 1999i) is preservation land use along the river. This is reinforced by the recent establishment of the Hanford Reach National Monument, which contains much of Hanford Site land near the Columbia River. For the base analysis case, the assumption was that no irrigation would occur downgradient from the plateau.

3.3.2.3.3 Air Resources. Gases and vapors could travel upward from the facility through the soil to the ground surface. This pathway is maximized with minimum downward water movement. No water flow is considered in the calculations for the protection of air resources.

3.3.2.4 Natural Event Scenarios. The main natural events to be expected are as follows:

- Wind erosion of the surface above the closed facility
- Earthquakes
- Flooding caused by post-glacial events.

Wind erosion and earthquakes are considered drivers for changes in the engineered structure as a function of time. They are described in Section 3.4.5.7. Massive regional flooding has occurred many times during the past 50,000 years (see Section 2.2.7.2). The flood in the scenario, which is caused by the release of water during glacial retreat from a receding ice dam removes ~100 ft (30 m) or more of ground, including the tank units. In this scenario, the waste is assumed to be uniformly redeposited over an area equivalent to the Hanford Site. Seasonal flooding or flooding caused by collapsed dams would not affect the disposal site (see Section 2.2.9.2).

3.3.3 Contaminant Release Scenario

Two types of contaminant releases are considered: instantaneous release (e.g., from past leaks or from potential retrieval leaks) and releases driven by a complex chemical, physical process (e.g., from residual waste). In the first case, the entire inventory is available for contaminant transport immediately. In the second, the contaminants are available for transport only slowly, and the

complete inventory may not be available for thousands of years. A variety of release scenarios are possible, depending on the waste in the tanks. Section 3.3.3.1 gives a general description of the contaminant release scenario. Sections 3.3.3.2 through 3.3.3.4 focus on advection-dominated release, diffusion-dominated release, and solubility-controlled dominated release, respectively. The contaminant release rate used in the base analysis case calculations is described in Section 3.3.3.5.

3.3.3.1 Conceptual Model of Source Term Release. The actual process of contaminant (radionuclides and hazardous chemicals) release for residual wastes from a tank cannot be modeled precisely because of the variability of chemical and physical reactions that occur between the waste material and the infiltrating water. In the real system, contaminants are distributed in a heterogeneous manner within the tank. These contaminants are released into solution at different rates because of the variability in waste material. Finally, variable types and quantities of contaminants are dissolved into the infiltrating water over time, depending on which waste material contacts a particular fluid volume. Therefore, averaging concepts are used in modeling to simplify the mathematical representation of the real system. These concepts must be justified, however, as being a conservative representation of the real system.

The following assumptions are made for the source-term release estimates.

- The release of contaminants from tank residuals is evaluated assuming that the structural integrity of the tanks degrades, allowing recharge (infiltrating) water to enter the tank, and dissolve contaminants from the residuals. The release of contaminants occurs by dissolution of the waste material contaminants into the infiltrating water migrating into and out of tanks through cracks.

- For both stabilized (grouted) and unstabilized (not grouted) residual wastes in tank and tank ancillary equipment, it is assumed that the contaminant inventory will be available for release into the infiltrating solution via an advection-dominated or a diffusion-dominated or a solubility-controlled release model.

- Unit quantities are assumed for various modeling runs. Because risk estimates are directly proportional to total inventory, the modeling runs with unit quantities can be scaled to calculate risk for any initial inventory.

- Three radionuclides (Tc-99, I-129 and U-238) are considered for the three release models (i.e., advection-, diffusion-dominated, and solubility-controlled) described below.

- For those stabilized waste materials that are incorporated into a waste form that controls radionuclide release by diffusion (i.e., grout), it is assumed that the diffusion coefficient remains constant over time for the diffusion-dominated release model.

- Contaminant inventories are assumed to be homogeneously distributed among the wastes. For the stabilized, grouted wastes, it is assumed that the contaminants are uniformly distributed in the residual wastes only in the bottom of the tank.

3.3.3.2 Advection-Dominated Release Model. The advection-dominated release model (mixing-cell cascade model) is used to simulate the processes of releases from stabilized (grouted tank or tank ancillary) wastes. For stabilized wastes, the radionuclides exit the facility

at a rate determined by the flow of water and the amount of dispersion (mixing) within the tank. The mixing-cell cascade model (Kozak 1989; Wood 1995) is based on the dispersion analysis of chemical reactors and allows the analysis to incorporate the effects of dispersion in the tank in a simplified manner. In this model, the tank interior is considered to be composed of a cascade of N equal-sized, well-stirred cells in series. The total volume of the N cells is equal to the volume of the tank residual waste.

The mixing-cell cascade model for N equal-sized cells is described by the following equation:

$$Q(t) = q\,A\,C_o\,e^{-\alpha Nt} \sum_{n=1}^{N} \frac{(\alpha Nt)^{n-1}}{(n-1)!} \tag{3-1}$$

where:

Q = release rate (Ci/yr)
t = time (yr)
q = vertical Darcy flux (m/yr)
A = horizontal (planar) area of the tank interior
$\alpha = q/(\theta dR)$
θ = volumetric moisture content in the residual waste
d = vertical depth of the residual waste material (m)
R = retardation factor in the waste material (assumed R=1).

The initial concentration of contaminant in the interstitial water can be determined from the following equation:

$$C_0 = \frac{m}{\theta VR} \tag{3-2}$$

where m equals total facility inventory (assumed unity) of the radionuclides in the tank and V equals total volume of the residual waste (i.e. 360 ft^3 [10.2 kL] for 100 series tanks and 30 ft^2 [850 L] for 200 series tanks or 1% residual following HFFACO goal). The spatially variable velocities, V, and moisture contents, θ, which are obtained via flow modeling within the tank, will be used to determine C_0. For most cases, backfill was used as the tank fill material. Two cases use grout as the tank fill material.

The mixing-cell cascade model provides results equivalent to the one-dimensional, convective-dispersion equation with varying values of the dispersion coefficient (Kozak 1989). In the limit, as N approaches infinity, the model represents flow through a system with zero dispersion, whereas for N equal to one, the model represents flow with an infinite dispersion coefficient. A value of N = 10 will be used reflecting moderate dispersion.

3.3.3.3 Diffusion-Dominated Release Model. The diffusion-dominated release model is used to simulate the release of contaminants from stabilized (e.g., grouted tank or tank ancillary) wastes. In the absence of little or no advection through the waste container, the release can be modeled as a diffusion-limited process. The diffusion from cylindrical containers leads to an expression for flux that contains infinite series (Kozak 1989). The series converges slowly for small diffusion coefficients for short times, and even for relatively long times. As a result, a one-dimensional diffusion solution can be adopted (Crank 1975). The solution, for a semi-infinite

medium with the concentration C_0 throughout, initially, and with zero surface concentration, is given by:

$$C = C_0 \, erf \frac{x}{2\sqrt{(D_e t)}} \tag{3-3}$$

where:

erf = standard error function
D_e = effective diffusion coefficient of the radionuclides in the waste form
t = time

The rate of loss of diffusing substance per unit area from the semi-infinite medium when the surface concentration is zero, is given by:

$$\left(D_e \frac{\partial C}{\partial x} \right)_{x=0} = C_0 \sqrt{\frac{D_e}{\pi t}} \tag{3-4}$$

The above equation has the form of diffusion mass transfer based on leaching theory. This simplified release model leads to the following form:

$$q = A \, C_0 \sqrt{\frac{D_e}{\pi t}} \tag{3-5}$$

where:

q = release rate from a single waste cell (Ci/yr)
A = effective surface area of a single cell
C_0 = concentration in a cell

Because the residual waste is likely contained in various cells with differing sizes and shapes, the diffusive release rate, Q, from all residual waste in the tank can be determined by the following equation:

$$Q = C_0 \sqrt{\frac{D_e}{\pi t}} \sum_{i=1}^{n} A_i$$

$$= C_0 A_t \sqrt{\frac{D_e}{\pi t}} \tag{3-6}$$

where n is the number of cells, A_i is the surface area of individual cells, and A_t is total surface area of a tank.

By assuming that the cells are constant, i.e.,:

$$I = C_0 \sum_{i=1}^{n} V_i = C_0 V_t \tag{3-7}$$

where I is the total inventory, V_i is the volume of i-th cell, and V_t is the total volume of all cells.

Combining the preceding equations, we obtain:

$$Q = I \frac{A_t}{V_t} \sqrt{\frac{D_e}{\pi t}} \tag{3-8}$$

The ratio A_t/V_t can be replaced by a ratio of a surface area over volume of a tank (only the portion of the tank containing waste will be used to obtain the ratio).

The model calculation is conservative in two aspects. First, the surface area of a tank might not be completely exposed to a moving stream of water. Second, the radionuclides reaching the tank surface area are assumed to be released into the water stream and instantaneously reach the bottom of the tank for release. Two different diffusion coefficient values will be used: 6×10^{-7} cm^2/sec based on Kincaid et al. (1995) and 5×10^{-8} cm^2/sec based on *Hanford Waste-Form Release and Sediment Interaction* (Serne 1990).

3.3.3.4 Solubility-Controlled Dominated Release Model. Solubility-controlled dominated release models assume that a known solid is present or rapidly forms, and controls the solution concentration in the aqueous phase of the constituents being released. Solubility models are thermodynamic equilibrium models and do not consider kinetics (time required to dissolve or completely precipitate) (Serne 1990). When identification of the likely controlling solid is difficult, empirical solubility experiments are performed to gather data that can be used to generate an empirical solubility release model. Such empirical models assume a controlling solid, and fix the chemistry of all constituents to derive a fixed value for the concentration of specific contaminants. No solubility empirical models presently exist for modeling contaminants from residual tank wastes. However, a solubility-controlled release model (i.e., "cake" model) has often been postulated in previous risk assessments.

The cake model consists of a very simple mathematical formulation containing a recharge rate term, a term for waste solid solubility, and a term for the cross-sectional area of the waste source (SST footprint).

The contaminant release mechanism of the cake model is the dissolution of the "structural matrix." As the matrix dissolves, all the contaminants are assumed to leach congruently at the same rate. When applied to the residual tank wastes, the term "cake" applies to the sludge and hard-heel residual in the tanks, which comprise the "structural matrix." The release rate for a given contaminant (Tc-99, I-129, and U-238) is given by:

$$dM / dt = -M_o \, A \, Q_w \, C_{wo}^{sol} / M_{wo} \tag{3-9}$$

where M_{wo} = the original mass of cake (kg). M_{wo} can be derived by the product of tank waste volume ((i.e. 360 ft^3 [10.2 kL] for 100 series tanks and 30 ft^2 [850 L] for

200 series tanks or 1% residual following HFFACO goal)) and waste density (1.7 g/cm^3)

Mo = the original quantity of the contaminant in Ci embedded in the cake

M = M(t) is the current quantity of the contaminant contained in the cake (Ci or kg) at time t

A = the surface area of the cake exposed to the release mechanism

C_{wo}^{sol} = the aqueous solubility of the cake simulated as a nitrate salt (g/cm3); the concentration most commonly used is 360 mg/L

Q_w = the recharge rate in cm/yr, also termed "infiltration rate"

dM/dt = the rate of loss of contaminant from the cake waste form per unit time t (the rate at which the contaminant enters the vadose zone).

3.3.3.5 Base Case Release Scenario. In contrast to releases from past leaks and retrieval losses, releases from residual waste generally are expected occur over a long time period. For residual tank wastes and residual ancillary equipment wastes, actual release mechanisms are unknown at this time. For an accurate determination of the source term, the chemical and physical processes controlling contaminant release from the residual wastes must be explicitly modeled. In the absence of post-retrieval tank waste characterization data and a lack of information of the controlling processes, the diffusion-dominated release scenario with an effective diffusion coefficient of 6×10^{-7} cm^2/sec is assumed. This choice recognizes that grout is likely to be used as a stabilization layer in the tanks and that pipelines and other infrastructure are also likely to be filled with grout.

3.3.4 Contaminant Transport

Contaminant transport is treated as an extension of moisture movement using the K_d model. Previous analyses (Kincaid 1995, Knepp 2001, Knepp 2002, Mann 1998, Mann 2001,Wood 1995a, Wood 1995b, and Wood 1996) have shown that contaminants are transported mainly by their movement in the aqueous phase. Contaminant transport can occur as contaminants move with the water and diffuse through water. Other transport mechanisms involve vapor-phase transport of the gaseous contaminations and massive movements caused by catastrophic events such as glacial-age flooding. Sections 3.3.4.1 through 3.3.4.4 describe how the contaminant transport mechanisms were modeled. Appendix B contains the equations actually used in the models.

3.3.4.1 Moisture Movement. Two distinct moisture-content regimes are present during contaminant transport: the unconfined aquifer and the vadose zone. In the unconfined aquifer, all the pore space of the porous sediment matrix is filled with water; the matrix is water saturated. In the vadose zone, the pore space is only partially filled with water; the vadose zone is unsaturated.

Water flow through a saturated porous medium, such as the unconfined aquifer, is governed by the empirical relationship described by Darcy's Law (Freeze 1979) and by the conservation of mass. Darcy's Law defines the discharge of water through a cross section of a porous medium.

However, in contaminant transport, the average velocity of water flowing through the pores of the medium is needed. The average velocity of the pore water is determined by dividing the discharge, or Darcy velocity of the water by the water-filled porosity of the medium. Total porosity is defined as the ratio of void space to total volume.

In an unsaturated medium, the pores are not completely filled with water. For such a medium, moisture content is defined as the ratio of water-filled void space to the total volume, and the average velocity of the pore water is determined by dividing the Darcy velocity by the moisture content. Additional effects (capillary forces, the dependence of hydraulic conductivity on moisture content, etc.) must be considered when analyzing an unsaturated medium. The Richards equation (Richards 1931) becomes the governing equation.

The important parameters in these equations are the following:

- Matric potential (or pressure head) as a function of moisture content (water retention function)
- Hydraulic conductivity as a function of moisture content (relative permeability function)
- The source or sink of moisture.

Under extremely dry conditions, water vapor diffusion may be important. Water vapor diffuses through porous media along vapor pressure gradients. The presence of water-soluble components (in the waste form, for example) depresses the water vapor potential and causes the water vapor to diffuse from the surrounding soils. This water then could condense at the location of the water-soluble material and leach contaminants from that surface. Important factors in this process are the level to which the water vapor pressure is depressed and the effective diffusion coefficient of water vapor.

Since the tanks contained large volumes of radioactive material, the heat generated by the decay of those radioactive materials also heat the surrounding soil. These analyses ignore the affect of heat based on simulations performed for the Hanford RCRA Corrective Action Program and documented in Appendix D of the *Field Investigation Report of the WMA S-SX* (Knepp 2001). Steve Yabusaki and his colleges performed temperature-dependent and temperature-independent simulations of vadose zone moisture flow and contaminant transport for what is thought to be one of the hottest thermal regions in the tank farms. Their results show clearly that for simulations before 2000, temperature effects are very important, even leading to the creation of heat pipe-type moisture flows. However, their results also show that for simulations beginning in 2000, the differences between temperature-dependent and temperature-independent simulations are small compared to most other uncertainties.

3.3.4.2 Advective, Dispersive, and Diffusive Transport. The equation for the advective, dispersive, and diffusive transport of contaminants can be viewed as a mass balance on a differential volume. The parameters important in this equation are as follows:

- The pore water velocity
- The dispersion coefficient

- The effective porosity of the soil layer
- The retardation factor that depends on the soil's density and wetted porosity and chemical distribution coefficient
- The effective diffusion coefficient.

An increase in the retardation factor increases the time for the contaminant to reach the aquifer. In the absence of an advective component, the diffusion process could bring water-soluble contaminants to the land surface via diffusion in a continuous liquid pathway.

Because of the very dry conditions present in Hanford Site soils and expected in the disposal facility, diffusive transport may be more important than advective movement in some cases. Because of the large storage capacity of the surface soils, the effect of large transient storms is confined to the top few feet of soil.

3.3.4.3 Vapor Transport. Some contaminants may move upward from the disposal facility to the surface in the vapor phase. In this document, gaseous contaminants are analyzed. Fick's law governs such movement.

3.3.4.4 Solid Transport. If another glacial-age catastrophic flood (such as the Missoula floods) occurs, the contaminants will be widely dispersed. For this case, the entire inventory is assumed to be mixed with soil to a depth of 20 m (66 ft) (the depth of the disposal facility) over the Hanford Site south of the Columbia River (an area of 906 km^2 [350 mi^2]). Glacial-age catastrophic floods have deposited soils over a far greater area (to the extent of carrying most of the soil all the way to the Pacific Ocean) and mixed the soil to greater depths than assumed here. Solid transport is not calculated in this preliminary performance assessment.

3.3.5 Exposure Scenarios

Two major exposure scenarios considered are drinking contaminated water and exposures via all-pathways while living on a small farm (the all-pathways dose). The details of these scenarios and the justification for all the parameters used in them are found in Rittmann (2003). The expected characteristics of potential future agricultural activities at the Hanford Site are given in *Evaluation of the Potential for Agricultural Development at the Hanford Site*, (Evans 2000). Values for the parameters used in these scenarios are discussed in Section 3.4.7 and are given in Appendix B.

3.4 VALUES AND ASSUMPTIONS

This section describes and justifies the conceptual models and data for those models that were used in the analyses. It covers the selection criteria and key assumptions for the conceptual models; describes the models and their associated data, the waste form, release rate, disposal facility, and moisture and moisture infiltration rate. It also covers the dosimetry parameters. The models actually used in the computer simulations were derived from these conceptual models and are described in Section 3.5. Sensitivity cases are gathered together in Section 3.5.5 and illustrate both uncertainty and bounding conditions.

3.4.1 Selection Criteria

The following criteria are used to select between the alternatives:

- The ability to justify the choice
- The availability of experimental evidence
- The use of best calculational methods.

The overriding criteria were the ability to justify the data and the calculational methods selected. The justification process requires that all data, assumptions, and processes be questioned for applicability. *Does each selection realistically portray probable situations?* This process quickly identifies errors, misunderstandings, and false assumptions that can be corrected. It also provides insight into the true requirements for methods and the true need for data.

Whenever possible, direct experimental evidence is the basis for selecting data or approaches for the conceptual models. However, in most cases, collecting direct experimental evidence is not possible. Sometimes collecting all the evidence could take too long (observing the behavior of glass for 10,000 years, for example). Sometimes the amount of data is too large to obtain (e.g., determining hydrologic parameters for the entire vadose zone).

When direct experimental evidence is limited, the available data are used to support analytical simplifications. This approach has two major facets. The first is extrapolating laboratory-measured data to field conditions, as in the case of hydrologic parameters. The second is measuring various effects of the total process to form a complete picture, as was done to determine the infiltration rate. The infiltration rate was determined by combining short-term lysimetry with mid- and long-term tracer measurements and moisture movement simulation studies.

Much experimental and analytical effort has been spent collecting information and producing the understanding needed for this analysis. This effort has been documented in *Modeling Data Package for an Initial Assessment of Closure for C Tank Farm* (Khaleel 2003).

Analytical and calculational studies are a major part of the effort to provide data for processes that will be evolving over thousands of years. Analytical and computational tools were selected with the intention of using them to provide the most insight and accurate simulations of these processes.

3.4.2 Key Assumptions

Although much information exists on a Hanford Site basis, the information specific to WMA C is much less abundant. The key assumptions are as follows:

- Each source can be modeled separately and not impact the consequences of the others (see Section 3.5.1).

- For each source, one simulation sufficiently models the consequences of position and time. That is, the results can be time- and/or spatially shifted to provide the consequences (see Section 3.5.1).
- Transport is independent of the concentrations of contaminants other than the one being modeled (see Section 3.5.1).
- The inventory for each of the sources is approximately that used here.
- The amount of waste left in infrastructures is small compared to the amount of waste left in tanks.
- The fill material in the tanks will not greatly affect the flow patterns used here.
- The various tank residual waste release models provide the envelope surrounding actual release rate performance.
- Closure of the tanks (e.g.,such as with surface barriers) will not be significantly different than used here.

The analysis in this assessment relies heavily on the assumption that the systems can be modeled as linear systems. That is, the impacts from a given contaminant from a particular source (including individual tanks and leaks) are linearly proportional to the inventory of that contaminant in that source and do not depend on the inventory of that contaminant from other sources or the inventory of any other contaminant from any source. Moreover, the moisture flow (which drives contaminant transport) depends only on the individual tank and leak. These are common assumptions in systems with fewer components (tanks, leaks, infrastructure) than used here. As will be seen in Section 4.2.2, a series of calculations were provided to verify these assumptions.

As noted in Section 3.1.3, final retrieval has not occurred for any tank nor is the inventory in the infrastructure known. Thus, inventories for potential retrieval leaks, residual waste in tanks, and residual waste in infrastructure are simply estimates.

The material that will be used to fill the tanks has not yet been determined. This assessment assumes that whatever the material, it will not have a great impact on the moisture flow into the tanks. Future assessments will obviously model the various materials that will be under consideration as well as the effect that the tank itself has on moisture flow patterns.

As noted in Section 3.3.3, it is presently unknown how the contaminants will release from the residual waste. The three models used (advection-dominated, diffusion-dominated, and solubility-controlled dominated) as well as sensitivity cases should bracket the release. However, experimental data from actual residual waste is obviously needed.

Finally, the time and method of final WMA C closure is not yet established. The type and size of surface barriers has not been determined. Currently, a modified RCRA C barrier over the entire WMA is thought to be likely. Other options are certainly possible.

3.4.3 Site

This section translates the geology, hydrogeology, and geochemistry described in Khaleel (2003) into a conceptual model and values that can be used in the analyses supporting this performance assessment. The location and stratigraphy of the disposal site are discussed first. Next, the hydrologic and geochemical properties of the vadose zone are addressed. Finally, the properties and structural features of the unconfined aquifer are examined.

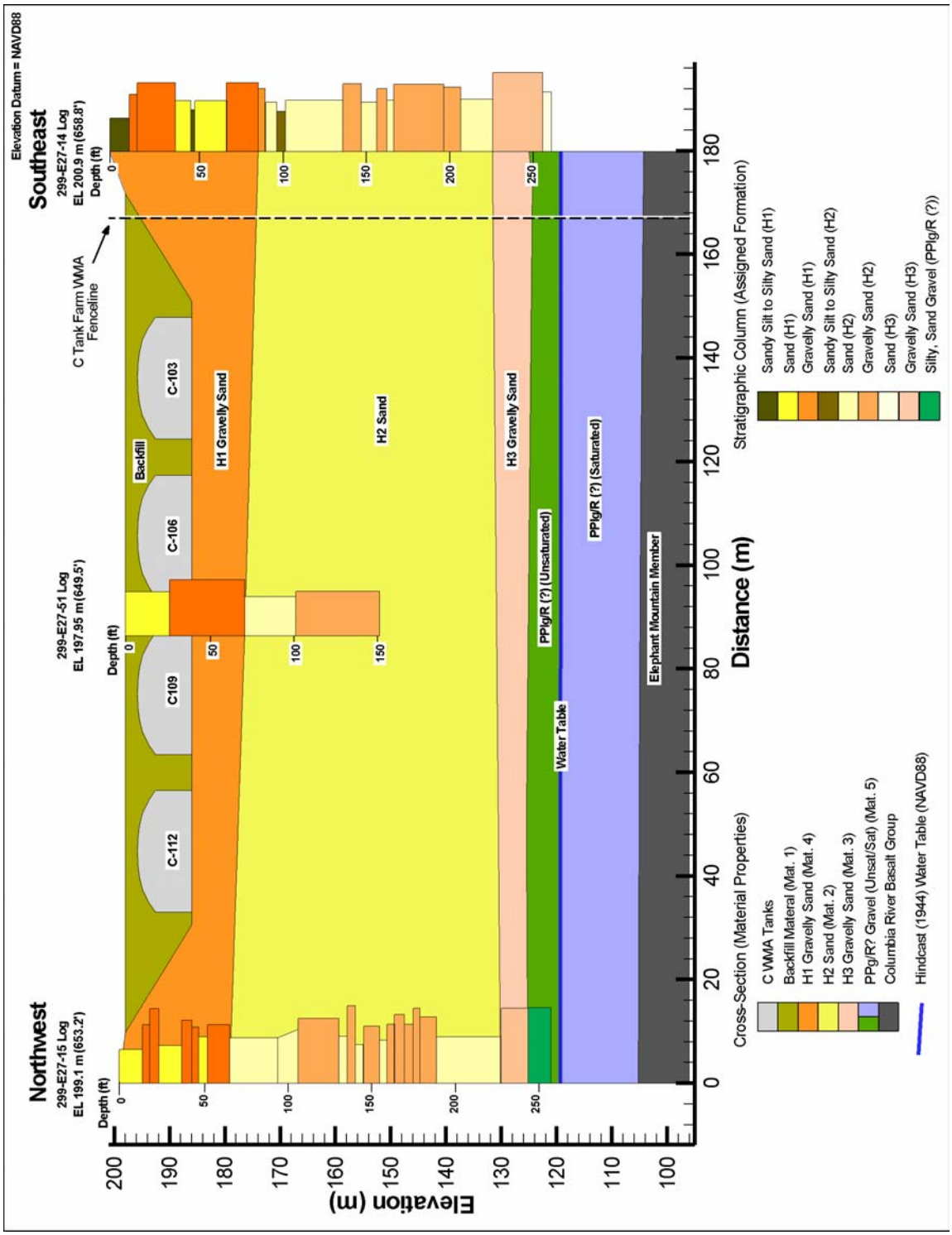
3.4.3.1 Location and Stratigraphy. As noted in Section 2.2.2 of this report, the location of the WMA C is in the middle of the eastern edge of the 200 East Area of the Hanford Site. The main strata at this location are the Hanford formation and the Ringold Formation.

The WMA C lies along the gently sloping, north flank of Cold Creek bar, a large compound flood bar formed during Pleistocene ice-age floods (DOE 1988, Wood et al. 2000) at an elevation of about 650 ft (198 m). The present thickness of the vadose zone measures about 250 ft (76 m) in the vicinity of WMA C (Narbutovskih 2001; Horton 2001). The geohydrologic model of the area in the vicinity of WMA C is based on boreholes located within 1,000 ft (305 m) of the WMA and contains an update of previous geologic descriptions given for these areas (Caggiano 1991; Williams 2000; Narbutovskih 2001; and Horton 2001). A total of five stratigraphic units lie within the WMA C. The stratigraphic units are represented on the northwest-southeast cross section (Figure 3-2) and are described as follows:

- **Backfill (material type 1, sandy gravel)**: Backfill materials consist of unstructured, poorly sorted mixtures of gravel, sand, and silt removed during tank excavation, and then later used as fill around the tanks. Backfill materials extend to depths of 50 ft 15 m) within the tank farms. Most or all of the recent deposit eolian sand and silt material found elsewhere across the Hanford Site has been removed and replaced with backfill in the immediate vicinity of the WMAs.

- **Hanford formation - upper gravelly sequence (H1 unit, material type 4, gravelly sand)**: Hanford formation H1 unit consists of predominantly loose coarse-grained gravel and sand deposits, with minor beds of sand to silty sand. Coarser beds may contain boulder-sized materials. Only a few weight-percent or less $CaCO_3$ (calcite) has been measured in this unit. The isopach map of the Hanford formation H1 unit suggests the unit thickens along a northwest-southeast trending trough. The maximum thickness (~100 ft (30.5 m]) of the H1 unit underlies WMA A-AX, but the H1 unit is thinner in the immediate vicinity of the tanks in WMA C because much of the Hanford formation H1 unit was removed and replaced with backfill during tank-farm construction.

Figure 3-2. Northwest-Southeast Cross-Section Through WMA C.



- **Hanford formation – sand sequence (H2 unit, material type 2, sand)**: Hanford formation H2 unit consists of predominantly fine- to coarse-grained sand with lenses of silty sand to slightly gravelly sand. Minor sandy gravel to gravelly sand beds occur sporadically. Consolidation ranges from loose to compact; cementation is very minor or absent, and total calcite content is generally only a few weight-percent or less. Silt lenses and thinly interbedded zones of silt and sand are common but not abundant in the Hanford formation H2 unit. These thin (<1 ft [0.3 m]) fine-grained zones generally cannot be correlated among boreholes and are not reflected in the gross gamma-ray logs or moisture data. The Hanford formation sand sequence (H2 unit) underlies the entire area beneath WMA C. The H2 unit thickens to south and west.

- **Hanford formation - lower gravelly sequence (H3 unit, material type 3, gravelly sand)**: Hanford formation H3 unit consists of predominantly gravelly facies of clast-supported, sandy, pebble-to boulder-sized gravel to matrix-supported pebbly sand. The maximum calcite measured is ~2.5 wt%. The exact thickness of the Hanford formation H3 unit beneath WMA C is uncertain.

- **Undifferentiated Plio-Pleistocene unit gravel (PPlg) and/or Ringold Formation UnitA? [PPlg/(R)? unit, material type 5]**: The PPLg/R(?) unit consists of predominantly sandy pebble- to cobble-sized gravel with occasional boulders. As a whole, the unit shares characteristics of both coarse-grained facies of the Ringold Formation and the Plio-Pleistocene unit. In some boreholes, the unit is described as tight, cemented, and brown colored with oxide coatings (characteristics of the Ringold Formation), whereas borings describe the unit as loose, caving to heaving, losing water, gray colored, and clean/unweathered (more characteristic of the Plio-Pleistocene unit). The total thickness of this unit is < 90 ft (27.5 m), based on a limited number of boreholes where the upper and lower boundaries are represented. The top of PPLg/R(?) unit ranges between (341-407 ft [104-124 m] elevation amsl. The water table lies within this unit.

- **Columbia River Basalt Group**: The Columbia River Basalt Group forms the bedrock base of the unconfined aquifer under WMA C. The top of unit ranges from about 312 to 344 ft (5 to 105 m) elvation amsl.

3.4.3.2 Vadose Zone Hydrologic Parameters. Hydrologic processes describe how moisture moves through the subsurface. Hydrologic parameters (volumetric moisture content and hydraulic conductivity) for these analyses come from laboratory analyses of samples from construction materials and from strata found near the disposal site. Field samples were taken from locations in the 200 Area. Corrections were made for the gravel content and for primary drainage. This resulted in moisture-retention data. A detailed discussion of the data and methods used to derive them can be found in the work of Khaleel (1999). The following paragraphs summarize the methods and data.

Hydraulic Conductivity and Moisture Retention. The moisture retention data can be described in an empirical relationship following the methods of van Genuchten 1980. The moisture retention function is

$$\theta(\psi) = \theta_r + [\theta_s - \theta_r] * \{1 + [\alpha\psi]^n\}^{-m} \qquad (3\text{-}10)$$

where

$\theta(\psi)$ = the volumetric moisture content [dimensionless]
ψ = the matric potential or pressure head [m]
θ_r = the residual moisture content [dimensionless]
θ_s = the saturated moisture content [dimensionless]
α = a fitting parameter (m^{-1})
n = a fitting parameter [dimensionless]
m = 1 - 1/n.

Using the Mualam 1976 model and this form for moisture retention, the hydraulic conductivity is

$$K(S_e) = K_s * S_e^n * \{1 - [1- S_e^{1/m}]^m\}^2 \quad (3\text{-}11)$$

where

$K(S_e)$ = the unsaturated hydraulic conductivity [m/t]
K_s = the saturated hydraulic conductivity [m/t]
S_e = effective saturation = $(\theta - \theta_r) / (\theta_s - \theta_r)$
n = the pore-connectivity parameter [dimensionless], estimated by Mualam to be about 0.5 for many soils. In this work, n is taken to be 0.5.

The RETC code (van Genuchten 1991) was used to determine values for θ_r, θ_s, α, and n. Values for K_s were determined by fitting laboratory data to a lognormal distribution.

Table 3-8 lists the composite, fitted van Genuchten-Mualem (van Genuchten 1980; van Genuchten 1991) parameters for various strata. Estimates for the equivalent horizontal and vertical hydraulic conductivities are presented in Section 4.3.

Table 3-8. Composite van Genuchten-Mualem Parameters for Various Strata.

Strata	Number of samples	θs	θr	α (1/cm)	n	ℓ	Fitted K_s (cm/s)
Backfill (1)	10	0.1380	0.0100	0.0210	1.374	0.5	5.60E-4
Sand H2 (2)	12	0.3819	0.0443	0.0117	1.6162	0.5	9.88E-5
Gravelly Sand H3 (3)	8	0.2688	0.0151	0.0197	1.4194	0.5	5.15E-4
Gravelly Sand H1 (4)	11	0.2126	0.0032	0.0141	1.3730	0.5	2.62E-4
Plio-Pleistocene/ Ringold Sandy Gravel (5)	10	0.1380	0.0100	0.0210	1.374	0.5	5.60E-4

Anisotrophy. Tension-dependent anisotropy provides a framework for upscaling small-scale measurements to the effective (upscaled) properties for the large-scale vadose zone. A stochastic model (Polmann 1990) is used to evaluate tension-dependent anisotropy for sediments at WMA C. Note that Polmann parameters (Table 3-9) will only be used to assign anisotropy ratios for various strata within the vadose zone.

$$
\begin{aligned}
&< LnK > = < LnK_s > - A < \psi > - \sigma^2_{LnKs} \lambda [p - p^2 < \psi > - \zeta^2 < \psi >] / (1 + A\lambda) \\
&\sigma^2_{LnK} = \sigma^2_{LnKs} [(1 - p < \psi >)^2 + \zeta^2 < \psi >^2] / (1 + A\lambda) \\
&K_h^{eq} = \exp[< LnK > + (\sigma^2_{LnK} / 2)] \\
&K_v^{eq} = \exp[< LnK > - (\sigma^2_{LnK} / 2)]
\end{aligned}
\tag{3-12}
$$

Table 3-9. Macroscopic Anisotropy Parameters, Based on Polmann (1990) Equations for Various Strata.

Strata	Number of samples	$<LnK_s>$	$\sigma^2_{LnK_s}$	p	ζ	λ (cm)	A
Backfill (1)	10	-15.76	3.56	-1.1E-4	1.84E-4	30	0.00371
Sandy H2 (2)	12	-14.59	1.50	-7.2E-4	6.55E-4	50	0.00620
Gravelly Sand H3 (3)	8	-15.30	1.83	-5.6E-4	5.16E-4	50	0.00415
Gravelly Sand H1 (4)	11	-14.85	1.94	-2.6E-4	2.50E-4	30	0.00368
Plio-Pleistocene/ Ringold Sandy Gravel (5)	10	-15.76	3.56	-1.1E-4	1.84E-4	30	0.00371

3.4.3.3 Effective Transport Parameters. Base case effective transport parameter (bulk density, diffusivity, and dispersivity) estimates are presented in this section. Because of natural variability, the transport parameters are all spatially variable. The purpose is again, similar to the flow parameters, to evaluate the effect of such variability on the large-scale transport process.

Bulk Density and Bulk Distribution Coefficient. Both bulk density (ρ_b) and bulk distribution coefficient (K_d) estimates are needed to calculate retardation factors for different species. The effective, large-scale estimate for the product [$\rho_b K_d$] is the average of the product of small-scale laboratory measurements for bulk density and K_d (Gelhar 1993). Table 3-10 provides the effective, large-scale estimates for U. The average ρ_b, E[ρ_b] (Table 3-10) estimates are based on data for various strata. The K_d estimates (Table 3-10) for U are based on Kaplan and Serne (1999) data for undisturbed sediments. No other species are included, because the K_d for Tc-99 and I-129 are estimated to be zero.

Table 3-10. Effective Parameter Estimates, $E[\rho_b K_d]$, for U for the Product of Bulk Density (g/cm^3) and K_d (cm^3/g) at WMA C.

Strata/Material Type	K_d	$E[\rho_b]$	$E[\rho_b K_d]$
Backfill (1) and Plio-Pleistocene/ Ringold Gravels (5)	0.6	2.13	0.59
Sandy H2 (2)	0.6	1.76	1.04
Gravelly sand H3 (3)	0.6	1.94	1.17
Gravelly sand H1 (4)	0.6	2.07	1.24

Retardation factors (and hence K_d values) are also needed for the radionuclides that are part of the TRU analyses. K_d values are obtained from the *Geochemical Data Package For The Immobilized Low-Activity Waste Performance Assessment* (Kaplan 1999) and are displayed in Table 3-11. Although cesium can be mobile in Hanford soils, as shown by the *Field Investigation Report for WMA S-SX* (Knepp 2002a), such mobility requires extremely large quantities of accompanying sodium ion, which is highly unlikely in the case of transport of contaminants from residual waste sources. Because explicit calculations are not done for $K_d > 1$ mL/g, the transport of those radionuclides with $K_d > 1$ mL/g are modeled as those they have a K_d of 1 mL/g.

Table 3-11. Effective K_d Values (Based on Kaplan 1999).

Element	K_d (mL/g)	Element	K_d (mL/g)
Americium	350	Radium[a]	0.6
Carbon	5	Strontium	10
Cesium	80	Thorium	300
Neptunium	0.8	Tin	80
Plutonium	200		

[a] Because radium is a decay product of uranium, the lower K_d of uranium is used.

Diffusivity. It is assumed that the effective, large-scale diffusion coefficients for all strata at WMA C are a function of volumetric moisture content, θ, and can be expressed using the Millington-Quirk (1961) empirical relation:

$$D_e(\theta) = D_0 \frac{\theta^{10/3}}{\theta_s^2} \tag{3-13}$$

where $D_e(\theta)$ is the effective diffusion coefficient of an ionic species, and D_0 is the effective diffusion coefficient for the same species in free water. The molecular diffusion coefficient for all species in pore water is assumed to be 2.5×10^{-5} cm^2/sec (Kincaid 1995).

Macrodispersivity Estimates for Non-Reactive Species. The Gelhar and Axness equation can be used to estimate asymptotic values of macrodispersivity. However, to account for the effects of unsaturated flow, a modified version is used for C modeling:

$$A_L(<\psi>) = \sigma^2_{LnK}\lambda \tag{3-14}$$

where the longitudinal macrodispersivity depends on the mean tension $<\psi>$. To apply equation (3-14), an estimate of the vertical correlation scale for unsaturated conductivity is needed. As discussed earlier, a correlation length of the order of about 50 cm was used for sediments at the C tank farm. However, compared to the saturated conductivity, an increase in the variance of log conductivity is expected to be compensated in part by a decrease in the correlation scale of log unsaturated conductivity. A correlation length of 30 cm is assumed for log unsaturated conductivity for all five strata. Table 3-12 provides the log unsaturated conductivity variances and the estimated longitudinal (A_L) and transverse (A_T) macrodispersivities for various strata. The transverse dispersivities are estimated as 1/10th of the longitudinal values (Gelhar et al. 1992).

Table 3-12. Non-reactive Macrodispersivity Estimates for Various Strata

Strata	σ^2_{LnK}	Correlation length, λ (cm)	A_L (cm)	A_T (cm)
Backfill (1) and Plio-Pleistocene/Ringold Sandy Gravel (5)	4.54	30	~150	15
Sandy H2 (2)	4.60	30	~150	15
Gravelly sand H3 (3)	4.95	30	~100	10
Gravelly sand H1 (4)	3.19	30	~100	10

Heterogeneous Sorption Enhanced Macrodispersivities for the Reactive Species. As expected, the net effect of sorption is to retard the velocity of the contaminant. Because sorption for specific contaminants may be a function of soil properties, as the soil properties experience spatial variability, the sorption also varies (Gelhar 1993; Talbott and Gelhar 1994). Stochastic analysis results for macrodispersivity enhancement for various strata are given in the modeling data package (Khaleel et al. 2003).

3.4.3.4 Unconfined Aquifer Properties and Boundaries. The approach to model contaminant transport in the unconfined aquifer follows that of the Field Investigation Reports for the WMA B-BX-BY WMA and for the WMA S-SX WMA (Knepp 2002a and -2002b). Instead of the Hanford Site-wide groundwater model, an analytical/streamtube approach was used to model groundwater flow and transport. The analytical solution in Domenico and Schwartz (1990) model was used to model saturated transport. Flow and transport information needed for the analytical/streamtube model was based on VAM3D Site-wide groundwater model (Law 1996). Figure 3-3 shows the VAM3D-generated water table map at steady state (post-Hanford conditions) used to generate the streamlines/pathlines, and Figure 3-4 shows a streamline/pathline originating in the vicinity of WMA C.

Information on groundwater velocity distribution is needed for the analytical/streamtube model. Figure 3-5 prescribes the material property numbers for various regions within the flow domain of the Site-wide model. Using Darcy's law, Figure 3-4 combined with Figure 3-5 and

Table 3-13, which provides the saturated hydraulic conductivity and porosity for each material type, will be used to perform necessary velocity calculations. Note that a steady-state simulation is being used for the saturated media. In doing so, we can estimate the gradient using the data in Figure 3-3. Note that the water table gradient in the vicinity of WMA C is relatively flat and the aquifer is relatively thin. However, the aquifer resides primarily in the PPlg/(R)? unit formation with a relatively high saturated conductivity of 0.43×10^5 m/y. The anisotropy ratio (horizontal to vertical) for the saturated media conductivity is a factor of 10.

The streamtube analysis assumed that flow directly under WMA C occurs in a southeast direction. Caggiano and Goodwin (1991, see Figure 4 in that document) depicted the generalized flow direction as being due west. More recently (June 2002) results of borescope analysis indicate that the flow direction has shifted to the southwest (Figure 3-6). The change in direction is most likely caused by the decline in the hydraulic mound that resulted from the discharges to 216-B-3 Pond (B Pond). As the mound continues to decline, the gradient in the aquifer is expected to continue shifting in a counterclockwise direction until it reestablishes the natural gradient to the southeast that existed before the onset of Hanford discharges altered the regional hydraulics. As contaminants released from the closed tanks are not expected to reach the groundwater for several hundred years, it appears reasonable to assume that the groundwater will have reestablished the natural flow direction by the time they could conceivably do so. A gradient of 4.5×10^{-4} (m/m) will be used, based on pre-Hanford water table map (assumed to be representative of post-closure conditions). Because of the uncertainty with the direction of groundwater flow in the vicinity of the WMA, streamlines for travel northward through the Gable Mountain/Gable Butte Gap also will be considered, in addition to streamlines to the southeast. Other parameters needed for groundwater transport modeling are listed in Table 3-13. The aquifer is relatively thin in the vicinity of WMA C, so for the streamtube model application in the unconfined aquifer, a mixing depth of 16 ft (5 m) will be used.

Figure 3-3. VAM3D-Generated Steady-State Hydraulic Head (m) Distribution for the Hanford Site for Post-Hanford Conditions (after Lu 1996).

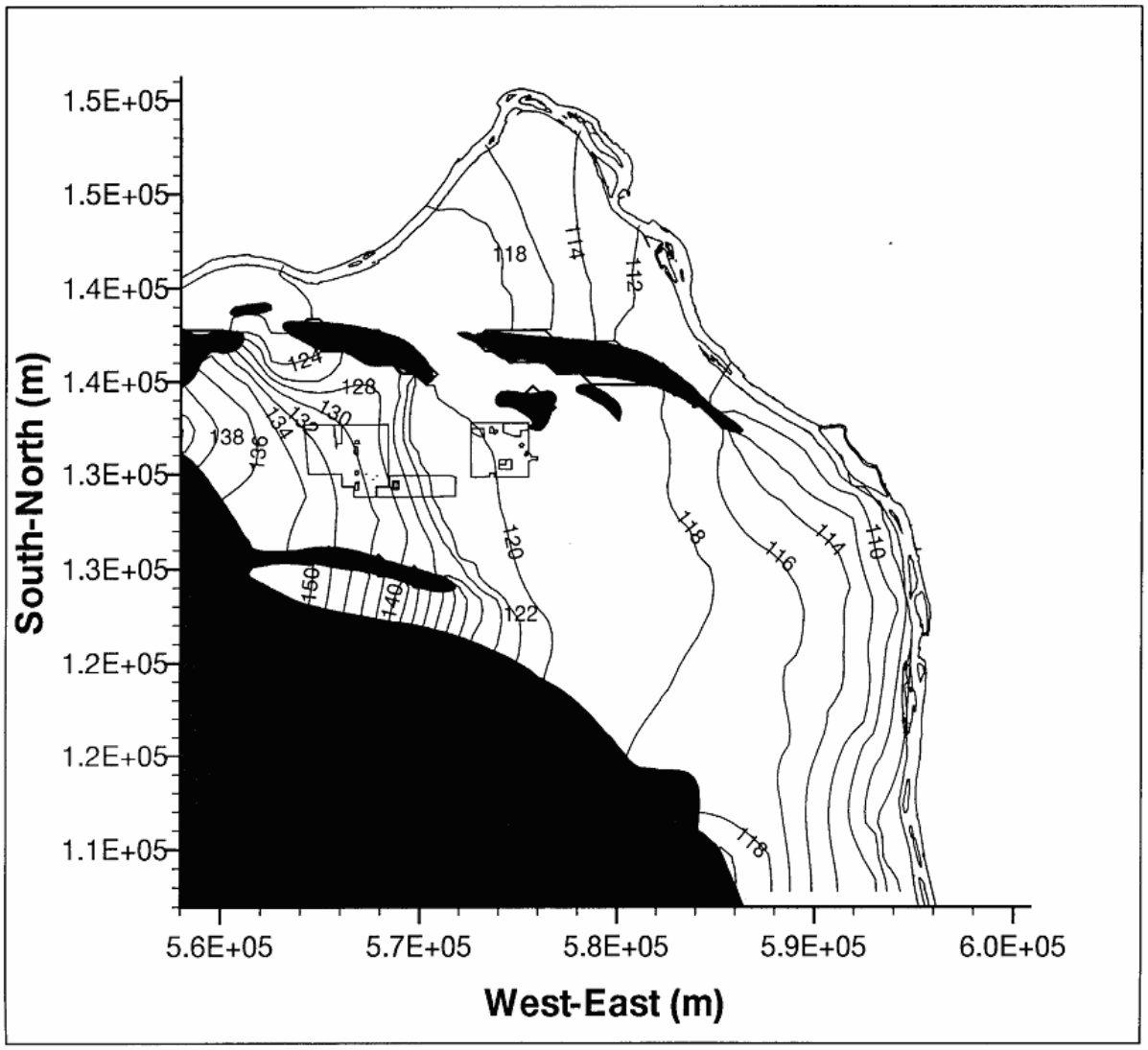


Figure 3-4. VAM3D-Generated Pathline Distribution at Steady-State for Post-Hanford Conditions (after Lu 1996).

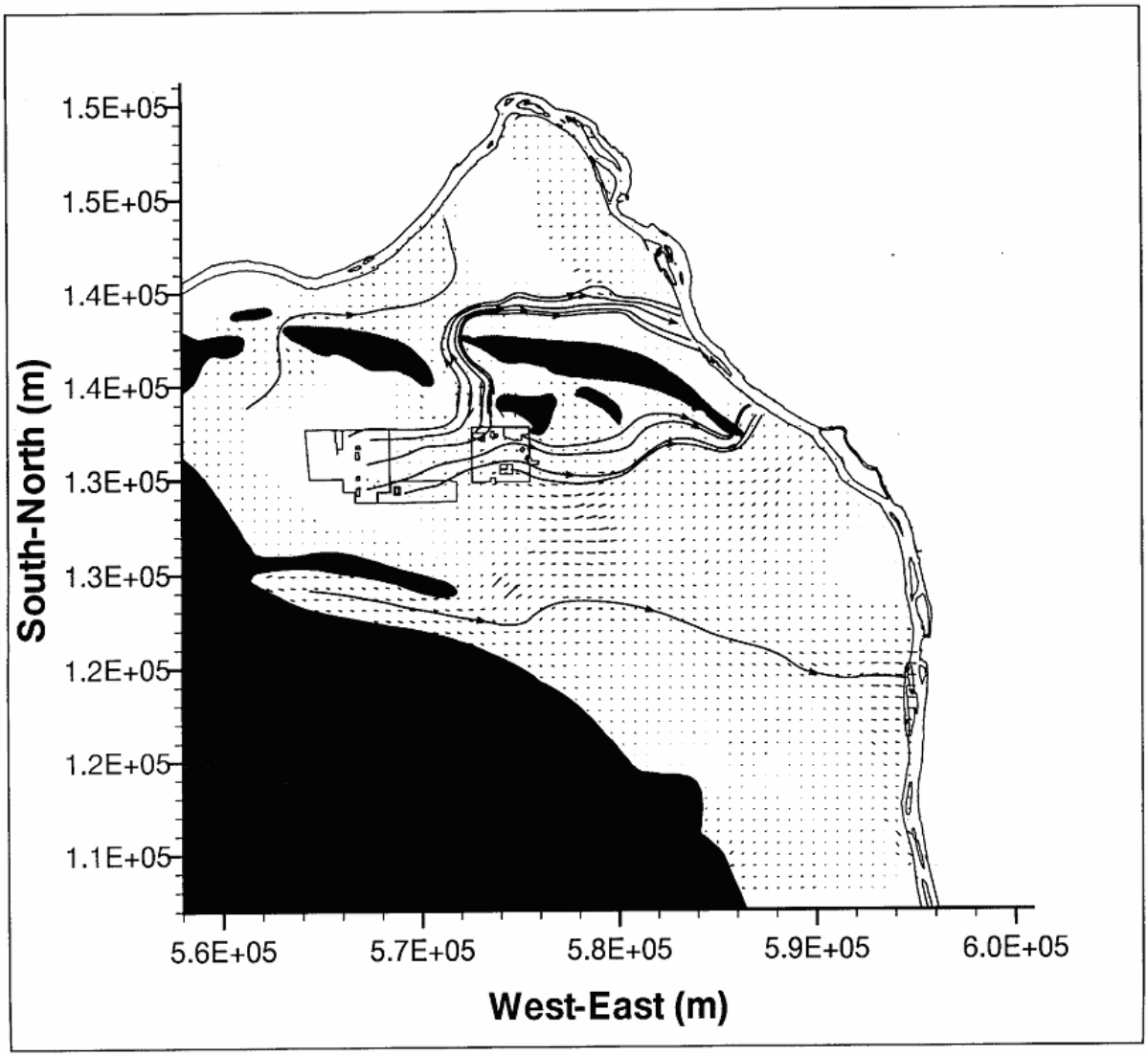


Figure 3-5. Material Property Distribution for the Upper Three Elemental Layers for VAM3D Site-wide Groundwater Model (after Law et al. 1996).

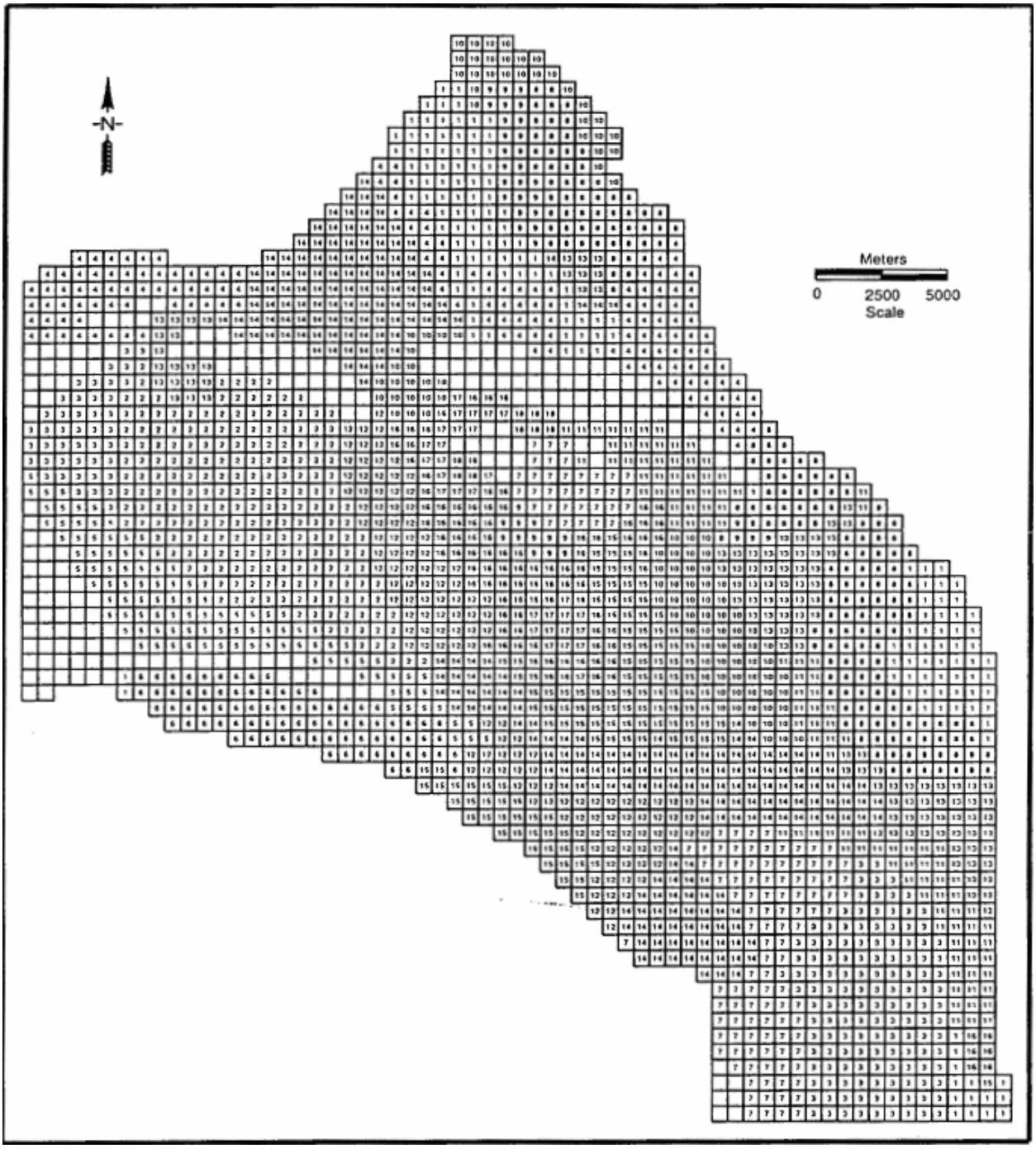


Figure 3-6. Results of Borescope Analysis for Groundwater Flow Direction at WMA C.

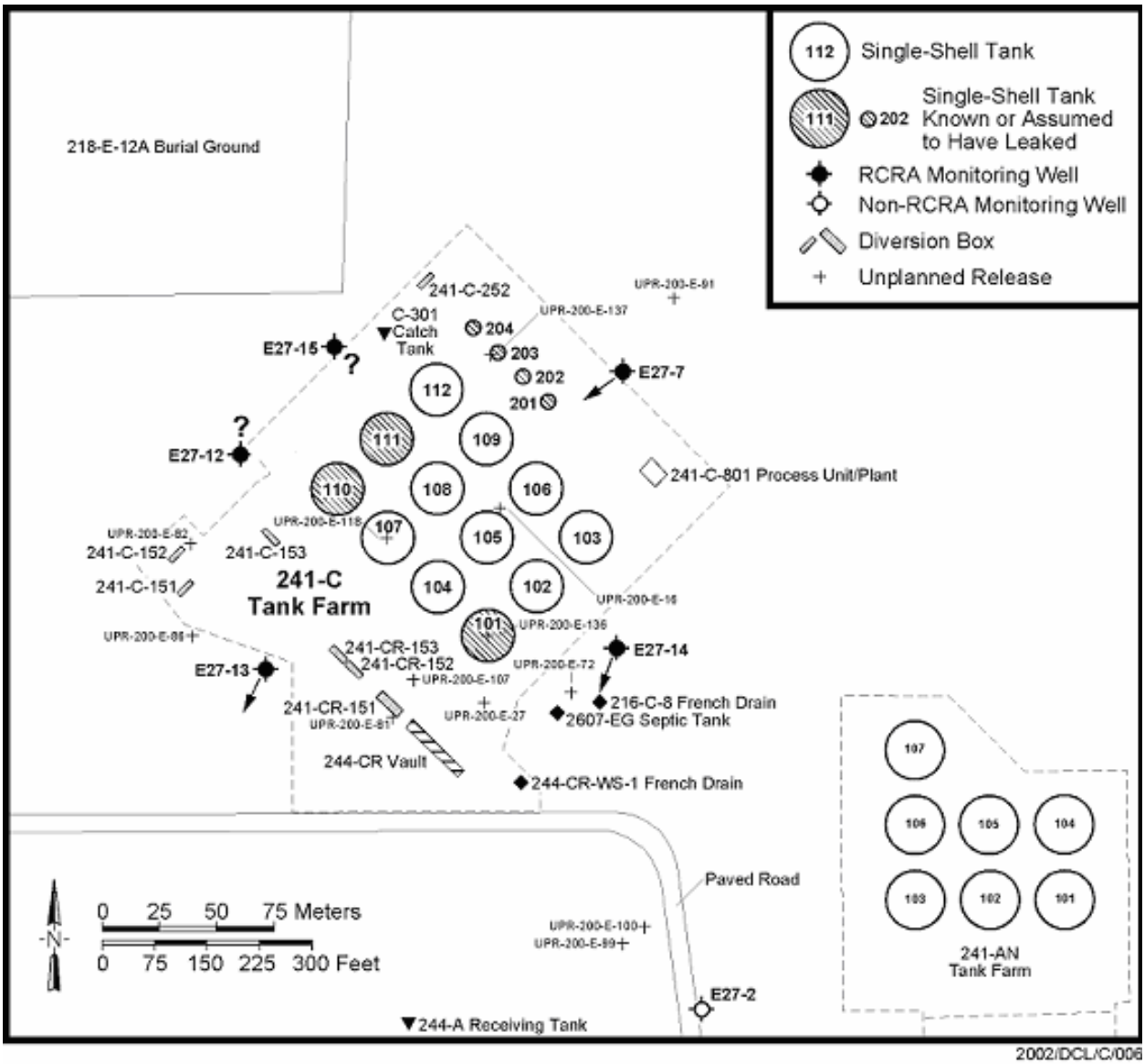


Table 3-13. Hydraulic Properties For Various Material Types for Site-wide VAM3D Groundwater Model (after Law 1996).

Zone	K_{xx} (m/y)	K_{yy} (m/y)	K_{zz} (m/y)	S_s (1/m)	Porosity (Percent)
1	.800E+03	.800E+03	.800E+02	.100E-05	10
2	.190E+04	.190E+04	.190E+03	.100E-05	25
3	.500E+04	.500E+04	.500E+03	.100E-05	10
4	.650E+04	.650E+04	.650E+03	.100E-05	10
5	.140E+05	.140E+05	.140E+04	.100E-05	25
6	.720E+05	.720E+05	.720E+04	.100E-05	25
7	.260E+05	.260E+05	.260E+04	.100E-05	10
8	.300E+05	.300E+05	.300E+04	.100E-05	25
9	.430E+05	.430E+05	.430E+04	.100E-05	25
10	.055E+06	.055E+06	.055E+05	.100E-05	25
11	.770E+05	.770E+05	.770E+04	.100E-05	25
12	.899E+05	.899E+05	.899E+04	.100E-05	25
13	.140E+06	.140E+06	.140E+05	.100E-05	25
14	.300E+06	.300E+06	.300E+05	.100E-05	25
15	.750E+06	.750E+06	.750E+05	.100E-05	25
16	.113E+07	.113E+07	.113E+06	.100E-05	25
17	.183E+07	.183E+07	.183E+06	.100E-05	25
18	.213E+07	.213E+07	.213E+06	.100E-05	25

K_{xx} = Hydraulic conductivity in the North-South direction
K_{yy} = Hydraulic conductivity in the East-West direction
K_{zz} = Hydraulic conductivity in the vertical direction
S_s = Specific storage
m/y = meters per year
1/m = 1 per meter

Table 3-14. Transport Parameters for the Site-wide Groundwater Model.

Parameter	Estimate
Longitudinal macrodispersivity, cm	3050
Lateral macrodispersivity, cm	305
Vertical macrodispersivity, mm	10
Diffusion coefficient, cm^2/sec	2.5×10^{-5}
U K_d, cm^3/g	0.6

3.4.4 Residual Waste

Residual waste in the tanks are assumed to meet HFFACO requirements, be homogeneous, and lay uniformly along the bottom of the tank.

3.4.4.1 Residual Waste Geometry Since no retrievals have taken place, the geometry of the residual waste in the tanks is unknown. For this assessment, the volume of waste left in the tanks is assumed to meet HFFACO requirements 360 ft^3 (10.2 kL) for 100-series tanks and 30 ft^3 (850 L) in 200-series tanks). Moreover, the residual waste is assumed to be homogeneous and lay along the bottom of the tank. Given the dimensions of the tanks and the above assumptions, the height of the residual waste in a 100-series tank would be 1.0 in (2.54 cm)., while the height in the 200-series tanks would be 1.4 in (3.6 cm).

3.4.4.2 Residual Waste Release Rate. Three relatively simple mechanistic release models (advection-dominated, diffusion dominated, and solubility-controlled dominated) as well as five temporally defined models are used. The mechanistic release models are described in Section 3.3.3. The parameters for these models are given in the following sections.

Advection-Dominated Diffusion Release Model. The mixing-cell cascade model described in Section 3.3.3.1 provides results equivalent to the one-dimensional, convective-dispersion equation with varying values of the dispersion coefficient (Kozak 1989). In the limit, as the number of cells (N) approaches infinity, the model represents flow through a system with zero dispersion, whereas for N equal to one, the model represents flow with an infinite dispersion coefficient. A value of N = 10 will be used reflecting moderate dispersion. Other values needed come from flow calculations.

Diffusion-Dominated Diffusion Release Model. The key parameter in this model is the effective diffusion coefficient of the radionuclides in the waste. Two different diffusion coefficient values will be used: 6×10^{-7} cm^2/sec based on Kincaid et al. (1995) and 5×10^{-8} cm^2/sec based on Serne (1990).

Solubility-Controlled Dominated Release Model. The key parameter here is the aqueous solubility of the cake simulated as a nitrate salt (g/cm^3); which is taken as 360 mg/L, a commonly used number.

Temporarily-Defined Waste Release Model. The last five release rates make the assumption that release rate is proportional to water flow rates, and noting (Section 3.4.6) that the flow rate will be 100 times higher after the surface barrier degrades then during the useful life of the barrier. Thus, the release rate for the first 500 years (the life estimated for the barrier) would be 0.01 times the release rate after 500 years. The five cases are shown in Table 3- 15.

Table 3-15. Parameters for Temporarily Defined Release Models

Case	Release rate first 500 Years	Release Rate after first 500 Years
1	0.001 /year	0.1 /yr for 5 years
2	0.0001 /year	0.01 /yr for 95 years
3	0.00001 /year	0.001 /yr for 995 years
4	0.000001 /year	0.0001 /yr for 9,995 years
5	0.0000001 /year	0.00001 /yr for 99,995 years

3.4.5 Closed Facility

With the exception of the surface barrier, facility structures are basically ignored in this analysis. The effect of the surface barrier is accounted for by changing the infiltration rate (see Section 3.4.6). The presence of other facility structures (e.g., the tank structures) disappear after 50 years. Thus, during the near term, the tanks act like umbrellas diverting moisture flow. In later years, the tanks do not divert the moisture away from the residual waste.

3.4.6 Infiltration Rate

The term recharge is used to denote the rate at which moisture flows past the root zone (that is, very near surface) into a region where moisture flow follows simpler models. Long-term estimates are needed of moisture flux through a fully functional surface cover, the cover side slope, and the immediate surrounding terrain, as well as for degraded cover conditions. These estimates were derived from lysimeter and tracer measurements combined with a modeling analysis.

WMA C ground surface is covered with gravel to prevent vegetation growth and provide radiation shielding for site workers. Bare gravel surfaces, however, enhance net infiltration of meteoric water, compared to undisturbed naturally vegetated surfaces. Infiltration is further enhanced in tank farms by the effect of percolating water being diverted by the impermeable, sloping surface of the tank domes. This umbrella effect is created by the 75 ft (23-m) inside diameter of buried tank domes. Water, shed from the tank domes, flows down the tank walls into the underlying sediments. Sediments adjacent to the tanks, while remaining unsaturated, can attain elevated moisture contents. Enhanced infiltration from a gravel-covered tank dome can provide potential for faster transport of contaminants to the water table.

Infiltration (recharge) can vary greatly depending on factors such as climate, vegetation, surface condition, and soil texture. Studies conducted over the last decade at the Hanford Site suggest that recharge rates can vary from less than 0.1 mm/y (0.004 in/y) on a variety of soil and vegetative combinations to greater than 130 mm/y (5.1 in/yr) on bare basalt outcrops or bare, gravel-covered waste sites (Gee 1992). Data from experimental sites such as the Field Lysimeter

Test Facility (FLTF) and the Prototype Hanford Barrier (PTB), both in the 200 Area, suggest that recharge through gravels can vary from 15 to 70 percent of precipitation, with the lower amount occurring under vegetated conditions (Gee 1996; Fayer 1995; Fayer 1996). With a long-term annual average precipitation of 160 mm (6.3 in.), the higher percentage translates into a recharge rate of about 100 mm/y (3.93 in./y) and was observed on clean gravels that were kept free of vegetation (Fayer 1999). Drainage from bare sands is about 55 mm/y (2.2 in/y) (Fayer 1995) to about 70 mm/y (2.8 in./y)under Hanford climatic conditions (Ward 1997). However, there has been no direct measurement of recharge on tank farm gravels, which are known to contain a larger amount of fines than the clean gravels. Thus, it is entirely possible that the tank farms experience a recharge rate that ranges between that observed for bare sand and gravels (Ward 1997). For the purpose of this modeling exercise, a base case infiltration estimate of 100 mm/y (3.93 in./y) will be used prior to closure (Table 3-16).

For simulations involving tank farms with an interim barrier, a recharge rate of 0.5 mm/y (0.02 in./y) will be used. This is based on experimental data from a prototype Hanford barrier that has been designed and built in 200 Area to limit recharge to ≤ 0.5 mm/y (0.02 in./y) (Wing 1994). This is also supported by the numerical simulation results of Smoot et al. (1989), who showed that with a relatively impermeable barrier over the tank farm, the drainage to a 6 ft (2-m) backfill depth decreased to less than 0.5 mm/y (0.02 in./y) after 8 years for cases of either a backfill or a clean graveled surface.

The closure barrier for tank farms is assumed to be an enhanced RCRA Subtitle C Barrier with a design life of 500 years; the recharge for such a barrier is estimated to be 0.1 mm/y (0.004 in./y) (Fayer 1999). For a degraded closure barrier, recharge rates are expected to return to predevelopment conditions (shrub-steppe ground cover), with a recharge estimate of 3.5 mm/y (0.14 in/y). Such an estimate is within the range of values reported in Fayer and Walters (1995).

Table 3-16 summarizes the timeline estimates for barrier emplacement at the WMA C and the corresponding recharge estimates.

For the tank farm cross-sections, the numerical simulation cases identified shall commence calculations on January 1, 2000 and continue for 10,000 years. It is assumed that a closure barrier will be in place by 2050. In cases where credit is taken for barrier integrity, it is assumed that a closure barrier will have a design life of 500 years.

Table 3-16. WMA C Infiltration (Recharge) Estimates for Pre-construction Period, Current Conditions, and Following Emplacement of Closure Barrier.

Condition Simulated	Recharge Estimate (mm/y) [in./y]	Duration	Comment
Before construction of WMA C, the construction period being 1943 to 1944	3.5[a] [0.14]	Until steady state moisture conditions are achieved for the year 1945	Vadose zone flow simulated at the recharge rate of 3.5 mm/y to develop initial moisture conditions for subsequent simulations
Current conditions	100 [3.93]	1945 to 2050	Recharge is assumed to increase from the pre-construction period estimate of 3.5 mm/y to the current value of 100 mm/y[b]. During this period, the ground cover is gravel with no vegetation. An enhanced RCRA Subtitle C barrier is assumed to be in place by 2050.
Transition to conditions of restricted recharge due to enhanced RCRA Subtitle C barrier	0.5 [0.02]	2050 to 2550	Recharge is assumed to decrease from a current estimate of 100 mm/y to the barrier design value of 0.5 mm/y. The barrier is assumed to function to its design estimate of 500 years[b].
Degraded barrier condition	3.5 [0.14]	2550 to 12000	The barrier is degraded and recharge increases from 0.5 mm/y to 3.5 mm/y until the end of simulation at 12,000 years[b].

[a]Based on 8-yr lysimeter data for graveled surface (Fayer 1999)

[b]Appropriate transition periods, as needed, can be used to accommodate the sharp breaks in individual recharge estimates.

For numerical simulations, the initial moisture contents (and the initial matric suctions) for the flow domain will be established by allowing the vadose zone model to equilibrate with an infiltration rate representative of natural infiltration for tank farm location.

3.4.7 Exposure Parameters

Dosimetry scenarios and parameter values are based on the discussion and values presented in *Exposure Scenarios And Unit Dose Factors For Hanford Tank Waste Performance Assessments* (Rittmann 2003). A variety of human health and dose estimates will be completed as part of this risk evaluation. Specific exposure scenarios, summarized below and described in greater detail

in Rittman (2003), are constructed to estimate human-health impacts from exposure to radionuclides and harmful chemicals present at a waste site that allows comparison with specific regulatory requirements (e.g., the performance objectives in Table 1-4). These scenarios have been evaluated in numerous performance and risk assessment activities completed previously at the Hanford Site and have been extensively reviewed by the Hanford Site regulatory community.

Exposure scenarios are organized as a function of water infiltration and receptor location. Water infiltration is divided into two basic categories. The first category assumes very limited contact between water and waste, thereby preventing groundwater contamination from the waste source in question (e.g., the no water infiltration case). Typically, an engineered barrier system is assumed to limit waste/water interactions. The second category assumes sufficient water infiltration to leach waste and drive contaminants into the underlying aquifer. In this analysis, infiltration from natural sources is assumed and effective infiltration rates are determined from the combination of average precipitation rates mitigated by engineered cover infiltration controls (e.g., the low water infiltration case). Potential receptors are either at the waste site (i.e., an onsite receptor) or at least 328 ft (100 m) away from the waste site (i.e., an offsite receptor). The onsite receptor is an inadvertent intruder who is deterred from entering the site for at least 100 years and is exposure primarily by contact with the waste. The offsite receptor can be exposed anytime after site closure and is exposed primarily by using contaminated groundwater.

Table 3-17 is a general summary of exposure scenarios that have been analyzed in Hanford Site risk and performance assessments in terms of onsite versus offsite receptors. Table 3-18 summarizes exposure scenarios for no water infiltration cases. The first two receptors do not directly exhume waste but are exposed in various ways to radionuclides that reach the surface by vapor migration. The second two receptors are exposed when they exhume waste. Table 3-19 summarizes exposure scenarios for low-water infiltration cases. Only offsite receptors are considered and all exposures stem from the use of contaminated groundwater. Both individuals and area populations can be considered in offsite receptor calculations.

Depending on the scenario, up to three types of health impacts are calculated. These include dose from radionuclide exposure, incremental lifetime cancer risk (ILCR) from radionuclide or carcinogenic chemical exposure, or toxic health effects (quantified as hazard index) from exposure to noncarcinogenic chemicals. Dose from radionuclide exposure (mrem/yr) is compared to performance objectives defined in DOE O 435.1 (the DOE order for *Radioactive Waste Management)*. ILCR from carcinogenic chemicals and the hazard index from noncarcinogenic chemicals are compared to the health standards (cancer risk of 10^{-5} and a unit value of 1, respectively) in WAC 173-340, *Washington State Model Toxics Control Act*. Dose, ILCR, and hazard index are calculated as the product of waste concentrations in soil, air, or water (as appropriate) and the appropriate unit conversion factor (e.g., mrem per pCi/L for dose).

Table 3-17. General Features of Performance Assessment Exposure Scenarios.

Feature	Onsite Receptor	Offsite Receptor
Time delay following site closure	Not less than 100 years	Any time after site closure
Receptor location	Directly over the waste disposal site	No closer than 100 m (328 ft) from the edge of the buried waste
Sources of exposure	(1) Gases & vapors that migrate upward from the waste (2) Direct radiation exposure (3) Well water (4) Exhumed waste	(1) Gases & vapors carried by the wind to the offsite location (2) Well water
Exposure scenarios	(1) Well Driller - person actually drilling through the waste (2) Suburban Residential - person living near the well with a garden (3) Rural Resident - person living near the well with a cow for milk (4) Commercial Farmer Resident - person living near the well commercially growing food (5) basement excavation - person lives in a dwelling with a foundation directly over the waste	(1) Industrial - people working at some commercial enterprise (2) Recreational - people who spend time near the site doing typical recreational activities (3) Residential - person living near the well (4) Farmer - subsistence farming operation that provides a portion of the individual diet (5) Native American Indian

Table 3-18. Exposure Scenarios for the No Water Infiltration Case.

Offsite Farmer -- gas/vapor emanations from the disposal site are carried downwind to a subsistence farm
‣ inhalation of plume ‣ ingestion (plants & animals) ‣ external radiation exposure from plume ‣ dermal absorption from air
Onsite Resident -- gas/vapor emanations into the basement of a residence located over the disposal site
‣ inhalation (higher concentrations in a dwelling) ‣ external radiation exposure (from buried waste and air) ‣ dermal absorption (from air)
Intruder -- individual present while a well is being drilled through the waste disposal site
‣ inhalation (resuspended dust & gaseous emissions) ‣ ingestion (trace amounts of soil) ‣ external radiation exposure ‣ dermal absorption (contact with soil)
Post-intrusion Suburban Resident -- spreads the exhumed waste into a vegetable garden
‣ inhalation (resuspended dust & gaseous emissions) ‣ ingestion (trace amounts of soil & garden produce) ‣ external radiation exposure (working in garden) ‣ dermal absorption (contact with soil)
Post-intrusion Rural Resident -- spreads exhumed waste on pasture with cow
‣ inhalation (resuspended dust & gaseous emissions) ‣ ingestion (trace amounts of soil & cow's milk) ‣ external radiation exposure (while present in the pasture or hay field)
Post-intrusion Commercial Farmer -- spreads the exhumed waste into area used for dry-land farming
‣ inhalation (resuspended dust & gaseous emissions) ‣ ingestion (trace amounts of soil, no food consumption) ‣ external radiation exposure (while working the crops)

Note: "Dermal absorption" refers to materials on the skin being absorbed into the body by passage through the skin. The offsite farmer scenario applies any time after site closure, while the other three require a delay of at least 100 years before they can occur.

Table 3-19. Exposure Pathways for the Low Water Infiltration Case

(1) Drinking the well water (also cooking with it)
‣ ingestion
(2) Showering and bathing with the well water
‣ inhalation (sprays) ‣ ingestion (small amounts) ‣ external radiation exposure (immersion) ‣ skin absorption (contact with water)
(3) Irrigating a garden
‣ inhalation (sprays & resuspended dust) ‣ ingestion (produce & trace amounts of soil) ‣ external radiation exposure (while in garden) ‣ skin absorption (contact with soil)
(4) Drinking water for house pets and livestock
‣ ingestion (eggs, poultry, milk) ‣ external radiation exposure (proximity to animal)
(5) Irrigating livestock pastures
‣ inhalation (sprays & resuspended dust) ‣ ingestion (beef & milk) ‣ external radiation exposure (while in pasture)
(6) Sleeping on soil contaminated by irrigation
‣ inhalation (resuspended dust) ‣ external radiation exposure (while on ground) ‣ skin absorption (contact with soil)
(7) Sweat lodge/wet sauna
‣ inhalation (steam) ‣ skin absorption (contact with steam) ‣ external radiation exposure (soil, walls, steam)

To provide a comprehensive estimate of potential human-health effects that addresses all performance objectives in Table 1-4, a total of eight scenarios have been considered in this analysis. The scenarios and type of human-health effects considered include:

Onsite Receptors-Five scenarios are considered, the Well Driller, the Post-Intrusion Suburban Resident, Post-Intrusion Rural Resident, and Post-Intrusion Commercial Farmer Resident. The driller and all four post-intrusion residents are exposed to contaminated soils resulting from drilling a well within the WMA. Dose by radionuclide exposure is calculated for comparison with DOE O 435.1 inadvertent intruder performance objectives.

Offsite Receptors-Six scenarios are considered. The All Pathways Farmer lives 100 m (328ft) downstream of the waste site and uses contaminated well water. Dose by radionuclide exposure is calculated for comparison with General Public Protection performance objectives in DOE O 435.1. The Native American uses contaminated well water at the tank farm fence line or Columbia River water and additional cultural activities increase exposure for the same amount of environmental contamination compared to the non Native American resident. Dose, ILCR, and hazard index are calculated for comparison with General Public Protection performance objectives in DOE O 435.1 and WAC-173-340. The final four scenarios are defined in DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*, and include the industrial worker (Industrial Scenario), the recreational shoreline user (the Recreational Scenario), the resident (the Resident Scenario), and the subsistence farmer (the Agricultural Scenario). Of these, risk calculations are not presented in this analysis for the recreational user. Dose, ILCR, and hazard index to the receptor are calculated for radionuclides and chemicals that contaminate groundwater.

Table 3-20 provides the unit dose factors for the intrusion scenarios (well driller and a post-intrusion residents). Table 3-21 provides the total unit dose factors for five exposure scenarios where the exposure includes contamination of the groundwater. Finally Table 3-22 provides conversion coefficients for chemicals from groundwater concentration to incremental lifetime cancer risk and to hazard index. Appendix A contains a complete set of values.

In the *Evaluation of the Potential for Agricultural Development at the Hanford Site* (Evans 2000), well screen heights were surveyed in the 3 counties in which the Hanford Site is located . The continued use of the 15-ft (4.6-m) well screen height is justified, given that most screen heights are larger than this value.

Table 3-20. Annual Unit Dose Factors for Intruders.

Radionuclide	Well Driller	Post-Intrusion Suburban Resident	Post-Intrusion Rural Resident	Post-Intrusion Commercial Farmer
	mrem per Ci/kg	mrem per Ci	mrem per Ci	mrem per Ci
H-3	3.25E+01	3.19E+00	1.08E-01	9.46E-03
Se-79	4.41E+03	9.98E+01	2.35E+00	1.02E-03
Sr-90+D	1.13E+05	3.57E+04	9.66E+02	3.21E-02
Tc-99	9.61E+02	5.06E+03	2.54E+01	2.49E-04
Sn-126+D	1.61E+07	9.74E+03	3.88E+02	5.97E+00
I-129	1.59E+05	2.88E+03	2.89E+02	4.14E-02
Cs-137+D	4.62E+06	6.63E+03	2.62E+02	1.69E+00
Pa-231	1.18E+07	2.15E+04	3.80E+02	4.34E+00
U-233	1.85E+05	1.47E+03	1.19E+01	5.31E-02
U-234	1.80E+05	1.44E+03	1.16E+01	5.14E-02
U-235+D	1.29E+06	2.02E+03	3.72E+01	4.55E-01
U-236	1.71E+05	1.37E+03	1.10E+01	4.86E-02
U-238+D	3.44E+05	1.47E+03	1.50E+01	1.11E-01
Np-237+D	6.42E+06	3.44E+04	1.91E+02	2.31E+00
Pu-239	3.85E+06	7.02E+03	1.21E+02	1.38E+00
Pu-240	3.85E+06	7.02E+03	1.21E+02	1.38E+00
Am-241	4.04E+06	7.24E+03	1.27E+02	1.45E+00

Notes: The nuclides with "+D" have short half-life progeny in secular equilibrium.

All doses (mrem or person-rem) are the 50-year committed EDE from the first year of intake. All risks are the lifetime averages.

Well Driller dose factor is mrem per Ci/kg. The Ci/kg is the total Ci exhumed divided by the total mass of soil & waste removed from the well.

Table 3-21. Total Annual Unit Dose Factors for Low-Water Infiltration Cases.

Nuclide	All Pathways Farmer -- Ground Water Only	All Pathways Farmer -- Columbia River	Columbia River Population Total	Native American -- Ground Water Only
	mrem per pCi/L	mrem per pCi/L	person-rem per pCi/L	mrem per pCi/L
H-3	4.75E-5	4.77E-5	2.36E-1	1.05E-4
C-14	4.85E-3	3.49E-1	2.19E+1	1.15E-2
Se-79	1.28E-2	1.77E-2	5.58E+1	2.80E-2
Rb-87	8.40E-3	4.08E-2	3.60E+1	2.43E-2
Sr-90+D	1.55E-1	1.85E-1	6.97E+2	3.93E-1
Tc-99	1.70E-3	1.80E-3	7.48E+0	4.15E-3
I-129	5.74E-1	6.11E-1	2.42E+3	1.46E+0
Cs-137+D	1.17E-1	4.53E-1	5.10E+2	2.54E-1
Pa-231	6.76E+0	7.13E+0	3.27E+4	7.33E+1
U-233	2.03E-1	2.13E-1	9.67E+2	8.16E-1
U-234	1.99E-1	2.08E-1	9.47E+2	8.01E-1
U-235+D	1.89E-1	1.99E-1	9.00E+2	7.51E-1
U-236	1.89E-1	1.98E-1	9.00E+2	7.59E-1
U-238+D	1.88E-1	1.98E-1	8.98E+2	7.41E-1
Np-237+D	2.91E+0	3.23E+0	1.40E+4	3.10E+1
Pu-239	2.26E+0	2.51E+0	1.09E+4	2.45E+1
Pu-240	2.26E+0	2.51E+0	1.09E+4	2.45E+1
Am-241	2.32E+0	2.58E+0	1.12E+4	2.54E+1

Notes: The nuclides with "+D" have short half-life progeny in secular equilibrium.

All doses (mrem or person-rem) are the 50-year committed EDE from the first year of intake. All risks are the lifetime averages.

Population numbers are the total for 5 million persons. All other dose/risk factors are per pCi/L in the water used.

Table 3-22. Scenario Dose/Risk Factors for Chemicals

	All Pathways Farmer -- Ground Water Only		All Pathways Farmer -- Columbia River		Columbia River Population Total		Native American -- Ground Water Only		Native American -- Columbia River	
Chemical Name	**Haz Indx per mg/L**	**Risk per mg/L**	**Haz Indx per mg/L**	**Risk per mg/L**	**Haz Indx per mg/L**	**Risk per mg/L**	**Haz Indx per mg/L**	**Risk per mg/L**	**Haz Indx per mg/L**	**Risk per mg/L na**
Nitrite[a]	2.29E-1	na	2.38E-1	na	1.18E+6	na	4.57E-1	na	1.06E+0	na
Chromium (III) (insoluble salts) [a]	4.44E-2	na	3.32E-1	na	3.91E+6	na	1.82E-1	na	9.14E+0	na
Chromium (VI) (soluble salts)[b]	1.81E+1	9.13E-5	2.88E+1	9.13E-5	9.84E+7	6.91E+2	8.28E+2	7.53E-2	1.40E+3	7.53E-2
Uranium (soluble salts) [a]	9.04E+1	na	9.65E+1	na	4.73E+8	na	2.78E+2	na	9.06E+2	na

[a]The RfD for inhalation is not available; the RfD for ingestion was used in its place.

[b]The slope factor for ingestion is assumed zero due to the observed cancer induction in humans.

na - not applicable

3.5 PERFORMANCE ASSESSMENT METHODOLOGY

This section describes how the performance of the system was determined. That is, this section explains how the data and conceptual models presented in Sections 3.2 through 3.4 are translated into a numerical model suitable for computer simulation. First, the strategy of the computer simulation is introduced. Then, the computer code selection criteria are summarized. The codes used are then described and their selection justified. Next, the process of translating the disposal facility concepts and the natural system into computer models is described. Finally, the parameters used in the computer simulations are given.

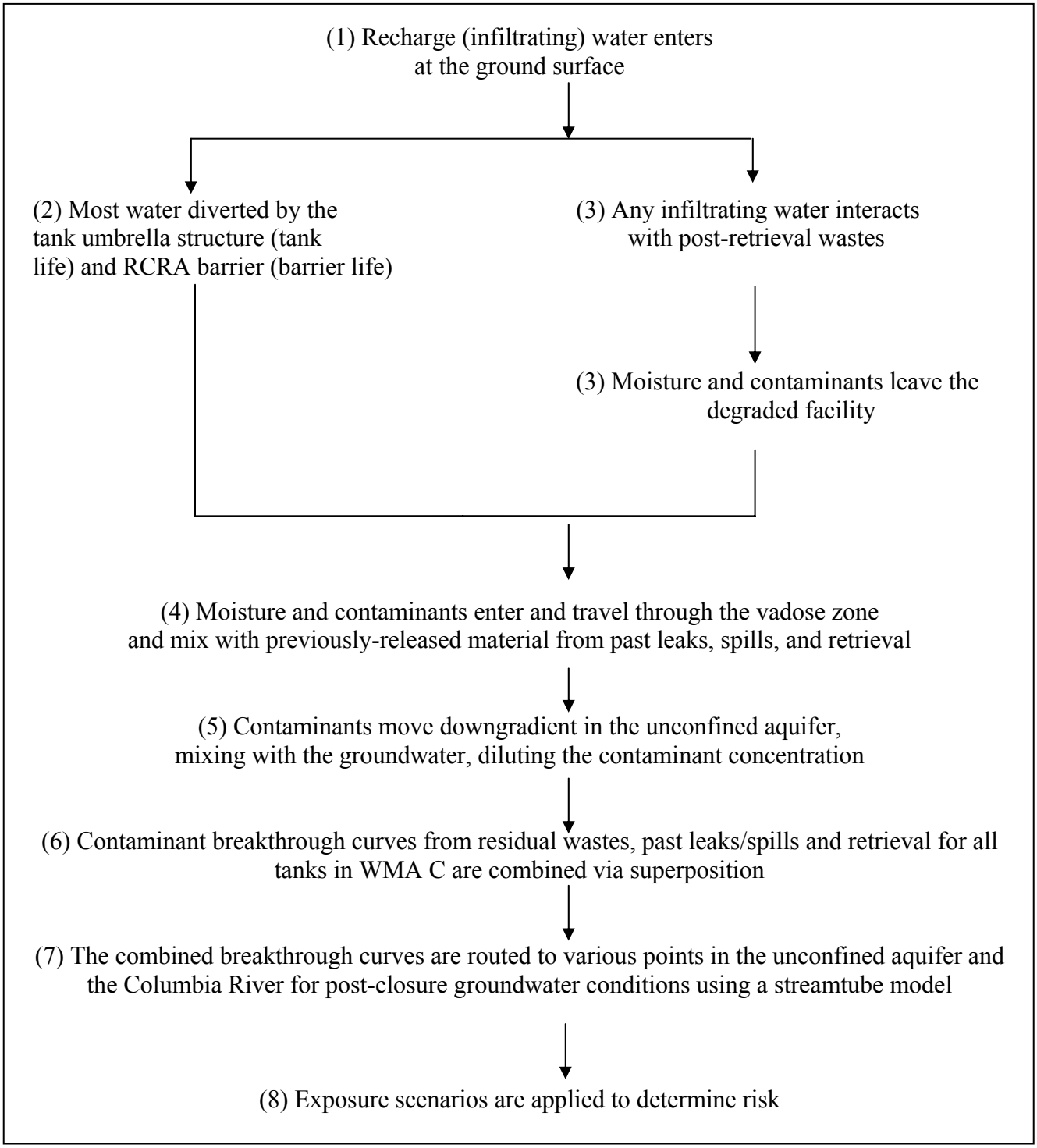
Calculations of relatively simple equations (for example, gaseous diffusion) were done by hand. These equations will be treated in Section 4, where the results are discussed.

3.5.1 Integration

3.5.1.1 Groundwater Pathway Strategy. Previous long-term environmental assessments at the Hanford Site have consistently shown that the groundwater pathway is the most important. This pathway also requires the most calculations. The conceptual model used for this and earlier Hanford Site performance assessments take the following eight steps:

The overall modeling approach is illustrated in Figure 3-7. The dominant pathway is through groundwater, as indicated by previous Hanford Site performance assessments and environmental impact statements (e.g., Mann 2001). Following closure, it is assumed that infiltration of moisture from precipitation eventually enters the tank facility (Step 1), most water is diverted by the tank structure or the barrier (Step 2), and contaminants are released into the vadose zone from the degraded tank structure (Step 3). The released contaminants then travel through the vadose zone where they meet and mix with already-released contaminants, if any, from past leaks, spills, and retrieval (Step 4). The contaminants travel through the vadose zone until they reach the water table and the unconfined aquifer (Step 5). The contaminant breakthrough curves (BTC) from residual wastes, past leaks, and retrieval for all tanks in WMA C are combined via a spatial and temporal superposition (Step 6). The combined BTCs are then routed to various locations within the unconfined aquifer and the Columbia River, using an analytical solution (i.e., streamtube model) (Step 7). In the final step, the exposure scenarios are applied to determine risk (Step 8).

Figure 3-7. Overall Modeling Approach for Risk Assessment



Calculations were not done for all facilities. Rather, the principle of spatial and temporally superposition was used. All calculations are performed for tank C-112 (Figure 5-3) and for unit Curie (or unit mass) as a source term for each of the four sources (i.e., past leaks and spills, retrieval, residual tank wastes, and ancillary equipment). To obtain concentrations at the WMA fence line, because facilities are at different distances from the fence line, the values from the C-112 calculation were spatially transposed to the proper location. Because travel times in the groundwater are so short (less than a year), the time translation is not performed.

Verification tests for all simulation cases (Section 4.2.2) are performed in which sources are present at all four tank locations (i.e., the row containing tanks C-112, C-109, C-106, and C-103) and compared against the case with source for tank C-112 only.

The two-dimensional cross-sectional simulations yield the contaminant mass flux and BTCs at the tank farm fence line along the tank centerlines for the selected cross-section. To account for three-dimensional aspects, the tank centerline mass flux and BTCs are transformed to average values across the tank farm fence line using two translations *FY00 Initial Assessment for S-SX Field Investigation Report (FIR): Simulations of Contaminant Migration and Surface Barriers*, (White 2001). In the first translation, the centerline quantities are converted to average quantities on the tank farm fence line boundary as the cross-sectional projections. The length of the cross-sectional projection equals the mean inventory diameter, where the mean inventory diameter is computed for each source inventory. The inventory diameter is not necessarily the tank diameter. In the second translation, the cross-sectional average mass flux or BTCs for various cross-sections are translated to a single average mass flux or BTC across the entire tank farm fence line length using a length-weighted averaging scheme (White 2001).

3.5.1.2 Base Analysis Case. The base analysis case provides the "best" information on how the system may evolve given the information available. The base analysis case is not necessarily representative of the way the system will behave. As more information concerning the waste form, the disposal facility design, and disposal site location is gathered, the definition of the base analysis case is expected to evolve. The approach used in the base analysis case is conservative, but reasonable.

The details of the models and related data for the base analysis case are presented in Sections 3.5.3 and 3.5.4, respectively. The major features of the base analysis case are as follows:

- The future land use of the 200 Areas is as a protected area, without artificial recharge (for example, no irrigated farming occurs).
- Because the release mechanism for tank residuals is not known, the three different release models (Section 3.3.4) are treated as equally likely.
- For potential retrieval leaks, a 8,000-gal leak from each tank is assumed.

The data for the natural system are those collected and interpreted for this performance assessment (Section 3.4.3).

3.5.1.3 Sensitivity Cases. The purpose of the sensitivity cases is to determine the uncertainty from the use of various parameters and the sensitivity of various assumptions. The sensitivity

cases actually simulated for this assessment focus on the uncertainty of release rates from tank residual waste and the location and liquid volume of leaks (past and potential retrieval leaks). Based on the linearity assumption, a number of sensitivity cases can be calculated for different inventory assumptions. Finally, a number of sensitivity cases can be inferred from recent Hanford Site work (Knepp 2002a, Knepp 2002b, Mann 2001, and Mann 2003b).

Note that the largest uncertainties come not from uncertainties of the natural system, but from human decisions or actions (e.g., amount of waste retrieved, amount of waste leaked during retrieval, tank closure parameters).

3.5.2 Computer Codes

This section discusses the computer codes used for this performance assessment and justifies their technical adequacy. The computer code STOMP (*STOMP Subsurface Transport Over Multiple Phases, Version 2.0, Theory Guide*, White and Oostrom 2000) was chosen to model transport through the vadose zone and groundwater out to the WMA fence line. STOMP was chosen because it meets the requirements of *Computer Code Selection Criteria for Flow and Transport Code(s) To Be Used in Vadose Zone Calculations for Environmental Analyses in the Hanford Site's Central Plateau* (Mann 1999c) and has been used for a number of risk assessments on the Hanford (Knepp 2002a and Knepp 2002b).

An analytical/streamtube approach is used to model groundwater flow and transport away from the WMA. The analytical solution in *Physical and Chemical Hydrogeology* (Domenico 1990) is used to model saturated transport. Spreadsheets were used in the analysis of STOMP data and in the calculations for other pathways.

Commercial spreadsheets were used in determining inadvertent intrusion doses. The Microsoft Excel™ was used for developing the spreadsheet cells and the calculations. The spreadsheet calculations were compared with manual calculations documented in Rittmann 1999 and verified as part of the review by the Hanford Environmental Dose Oversight Panel (HEDOP).

3.5.3 Computer Models

This section describes the 12 numerical models used in this performance assessment. As discussed earlier, the source terms for the risk assessment consist of four separate sources that include (a) leakage during retrieval, (b) past leaks and spills, (c) residual waste leakage from the tanks following closure, and (d) residual waste leakage from the tank ancillary equipment following closure. Table 3-23 lists the release scenarios and numerical cases considered. A rationale for the selection of individual cases is presented below.

Table 3-23. Release Scenarios and Numerical Cases Considered

Retrieval Leak	
Case 1:	**Retrieval leaks, 8,000 gallons**. A retrieval leak of 8,000 gal on the tank corner with start of leakage on January 1, 2000 and continuing for 14 days, with the leak occurring at the bottom east corner of tank C-112.
Case 2:	**Retrieval leaks, 20,000 gallons**. A retrieval leak of 20,000 gal on the tank corner with start of leakage on January 1, 2000 and continuing for 14 days, with the leak occurring at the bottom east corner of tank C-112.
Past Leak	
Case 3:	**Past leaks**. A past leak with its vadose zone inventory at a depth of 80 ft (24.5m) (based on drywell data) bgs and an inventory diameter of 25 ft (7.6 m) (based on drywell data) as of January 1, 2000, with the inventory distributed between tanks C-112 and C-109.
Case 4:	**Past leaks from ancillary equipment**. A past leak with its vadose zone inventory at a depth of 30 ft (9.1 m) bgs (based on drywell data) and an inventory diameter of 25 ft (7.6 m) (based on drywell data) as of January 1, 2000, with the inventory distributed between tanks C-112 and C-109.
Residual Waste Leak	
Case 5:	**Residual tank waste; release rate R_0**. Residual tank waste source with a release rate R_0 (10^{-3} Ci/yr for 500 yrs and 0.1 Ci/yr for 5 yrs), a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.
Case 6:	**Residual tank waste; release rate R_1**. Residual tank waste source with a release rate R_1 (10^{-4} Ci/yr for 500 yrs, 10^{-2} Ci/yr for 95 yrs), a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.
Case 7:	**Residual tank waste; release rate R_2**. Residual tank waste source with a release rate R_2 (10^{-5} Ci/yr for 500 yrs, 10^{-3} Ci/yr for 995 yrs), a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.
Case 8:	**Residual tank waste; release rate R_3**. Residual tank waste source with a release rate R_3 (10^{-6} Ci/yr for 500 yrs, 10^{-4} Ci/yr for 9,995 yrs), a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.
Case 9:	**Residual tank waste; release rate R_4**. Residual tank waste source with a release rate R_4 (0.1 Ci/yr for 10 yrs), a release start date of January 1, 2500 (i.e., date tank integrity is lost) and release over the tank bottom.
Case 10:	**Residual tank waste; advection-dominated release**. Residual tank waste source with advection-dominated release, a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.
Case 11:	**Residual tank waste; diffusion-dominated release**. Residual tank waste source with a diffusion-dominated release rate (diffusion coefficient $=6 \times 10^{-7}$ cm^2/s; Kincaid et al. 1995), a release start date of January 1, 2050 and release over the tank bottom.
Case 12:	**Residual tank waste; solubility-controlled dominated release**. Residual tank waste source with a solubility-controlled dominated release; a release start date of January 1, 2050 (i.e., date tank integrity is lost) and release over the tank bottom.
Case 14:	**Residual tank waste; diffusion-dominated release**. Residual tank waste source with a diffusion-dominated release rate (diffusion coefficient $=5 \times 10^{-8}$ cm^2/s; Serne and Wood 1990), a release start date of January 1, 2050 and release over the tank bottom.
Ancillary Equipment Waste Leak	
Case 13:	**Residual ancillary equipment waste.** Residual tank ancillary equipment waste source with inventory located at a depth of 20 ft (6.1 m) bgs, a release start date of January 1, 2050, and a diffusion-dominated release (diffusion coefficient =6 × 10-7 cm2/s; Kincaid et al. 1995) over an inventory diameter of 25 ft (7.6 m) for the grouted residual waste.

3.5.3.1 Retrieval Leak Loss. There is considerable uncertainty regarding the performance of retrieval technologies and the ability to respond to a retrieval leakage loss event. This initial assessment used the assumption that hydraulic sluicing will be used to retrieve waste and if a leak were to occur, all tanks would experience an equal volume of leakage loss of 8,000 gal per tank (Case 1). Such an estimate of 8,000 gal per tank has been used in earlier RPE analyses (e.g., JEG 1999). However, a higher leakage loss of 20,000 gal per tank was also used as a sensitivity case (Case 2).

3.5.3.2 Past Leaks And Spills. As stated earlier, the simulated cases for past leaks (Case 3) and spills (Case 4) do not attempt to model a waste release, instead they model the potential risk posed by their existing vadose zone contamination footprint. Information on contamination footprint and their location within the vadose zone for Cases 3 and 4 is based on spectral gamma data for drywells in the vicinity of tank C-106.

3.5.3.3 Residual Waste Leakage. Residual waste leakage is considered for both tank (Cases 5 through 12 and Case 14) and tank ancillary equipment (Case 13). As discussed before, a series of post-closure scenarios is assumed for contaminant release from tank wastes and tank ancillary equipment such that the modeling results include the range of possible outcomes.

One set of scenarios assumes uniform release rates over specified release periods, with the unit source inventory released over the entire release duration (Cases 5 through 9). The other set of release scenarios allows the release duration to vary on the basis of various controlling processes (i.e., advection, diffusion, or solubility) that are active during release (Cases 10 through 12 and Case 14). In effect, Cases 5, 6, 7, 8 and 9 arbitrarily release half of the unit inventory in the first 500 years, with the remaining inventory released in 5-yr, 10-yr, 100-yr, 1,000-yr and 10,000-yr release periods, respectively.

Cases 10 through 12 and Case 14 recognize whether the tank wastes are stabilized or unstabilized. The stabilized tank wastes (Cases 11 and 14) correspond to a waste form covered with grout or cementitious grout (diffusion-dominated release), whereas the unstabilized wastes (Case 10) refer to a waste form covered with backfill sand and gravel (advection-dominated release). Case 12 represents a waste form bound in a material that releases risk-driving contaminants congruently with the dissolution of the material (solubility-controlled dominated release). Although both Cases 11 and 14 use diffusion-dominated release, Case 11 uses a diffusion coefficient of 6×10^{-7} cm^2/sec, whereas Case 14 uses almost an order of magnitude lower diffusion coefficient of 5×10^{-8} cm^2/sec.

The waste in the tank ancillary equipment, following closure, is assumed to be stabilized (i.e., in grouted waste form). Therefore, Case 13 for residual waste release from ancillary equipment considers only diffusion-dominated release.

3.5.4 Initial Conditions

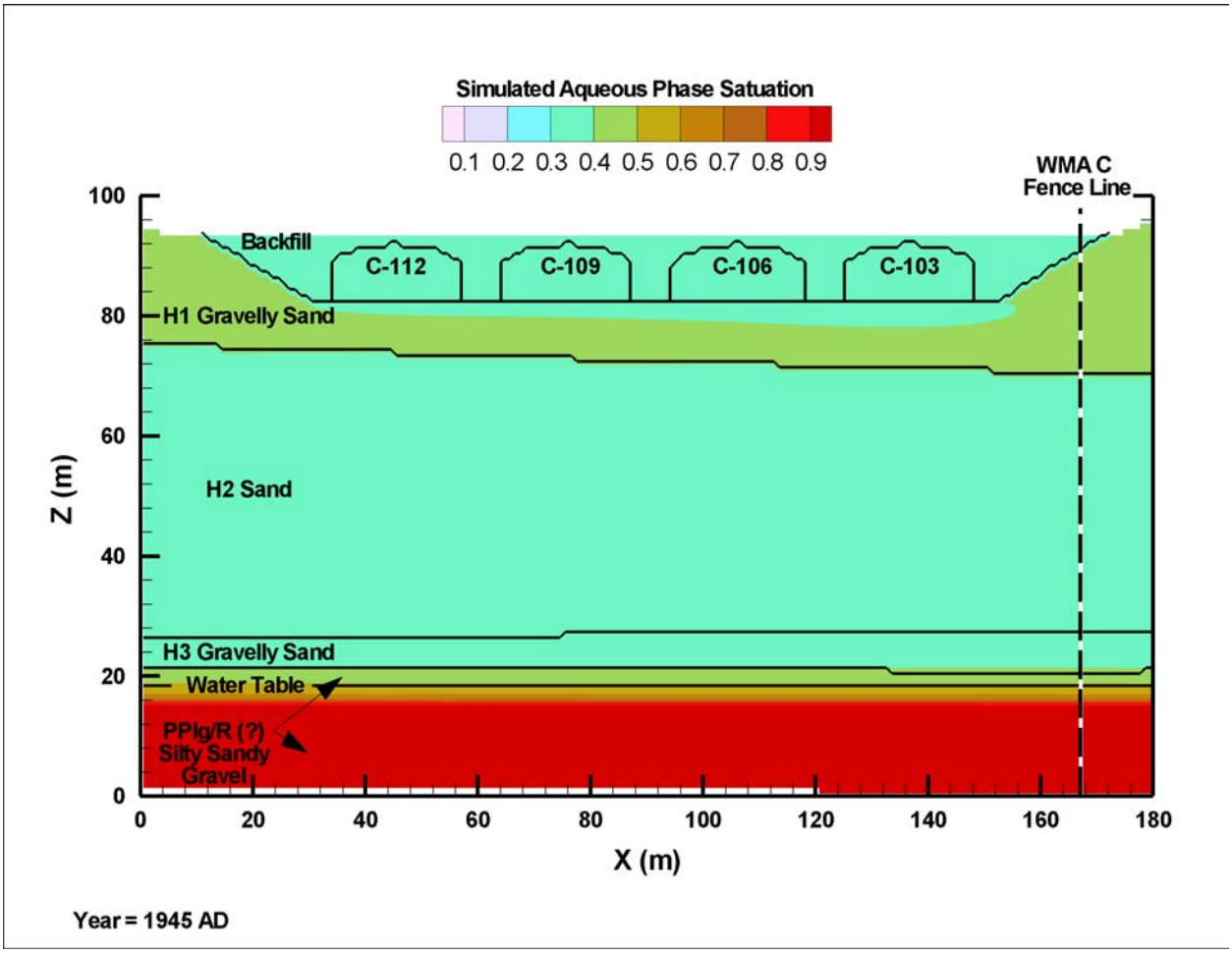
The simulations are comprised of steady-flow and transient components, where flow fields developed from the steady-flow component are used to initialize the transient simulation. Steady-state initial conditions are developed by simulating from a prescribed unit hydraulic gradient condition to a steady-state condition, dictated by the initial meteoric recharge at the

surface, water table elevation, water table gradient, no flux vertical boundaries, variation of hydrologic properties, and location of impermeable tanks.

The steady-flow simulation, representing flow conditions for the year 1945 (i.e., completion of WMA C tank construction), is used as the initial condition for all subsequent flow and transport simulations. The initial moisture condition at 1945 for all cases was achieved by running a simulation for the cross section using a recharge rate of 0.14 in/yr (3.5 mm/yr) for 1,000 years. Because this period of time represents the preconstruction period of the WMA C tanks, the simulation was run without the four tanks in place and the H1 gravelly sand unit extended to the surface. These conditions yielded a mean water content in the vadose zone of 0.121 m^3/m^3 (see Figure 3-8).

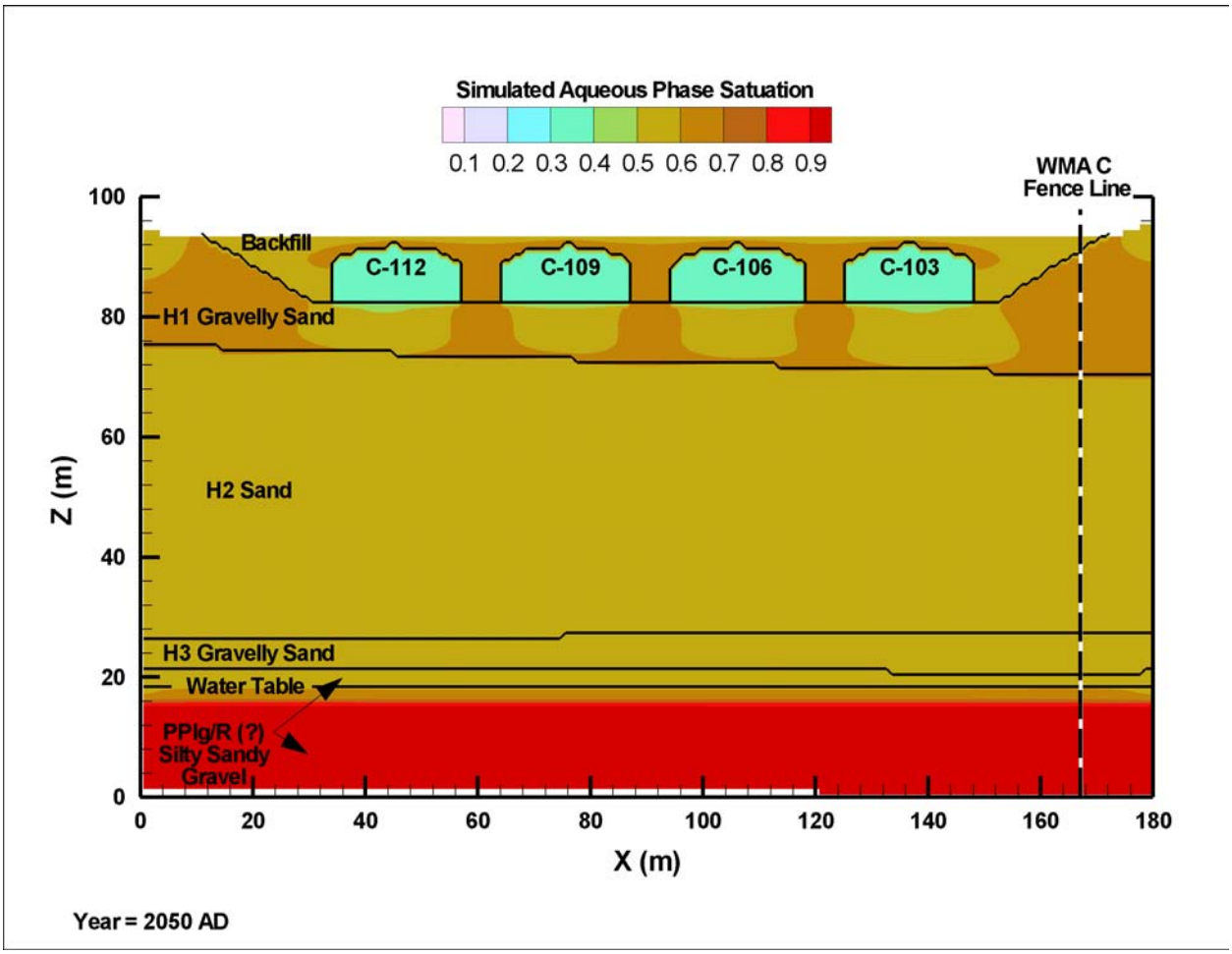
From 1945 to 2050, the recharge rate was assumed to increase from the preconstruction period estimate of 3.5 mm/yr to the current value of 100 mm/yr. This change is due to the replacement of the H1 gravelly sand layer at the top of the domain with a porous backfill material used for all subsequent calculations. This resulted in a nearly 50% increase in mean water content (0.179 m^3/m^3) in the vadose zone in the year 2050 (see Figure 3-9).

Figure 3-8. Estimated Aqueous Saturation Prior toTank Construction. (Figure A-1a of Zhang 2003.)



(The tanks are shown to orient the reader.)

Figure 3-9. Estimated Aqueous Saturation in Year 2050. (Figure A.21a of Zhang 2003)



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4.0 RESULTS OF ANALYSES

4.1 INTRODUCTION

This chapter presents the results of the analyses described in Section 3. It also discusses the data and methods affecting those results. This section emphasizes understanding the suite of analyses rather than the computational results as such. The detailed results and additional information on the calculational results can be obtained from *2003 Initial Assessments of Closure for the C Tank Farm: Numerical Simulations* (Zhang 2003).

This section is divided into four parts, organized by scenario:

- The results from the groundwater scenarios, including the impact on surface water (Sections 4.2 through 4.11)
- The results from the releases to air (Section 4.12)
- The results from biotic pathways (Section 4.13)
- The results of catastrophic events (Section 4.14)
- The as low as reasonably achievable (ALARA) analysis (Section 4.15).

For each scenario, the contaminant concentrations in drinking water and the all-pathway dose are calculated. Section 7 provides comparisons with performance objectives.

4.2 COMMENTS ON GROUNDWATER SCENARIOS CALCULATIONS

4.2.1 Overview

This subsection describes how the results will be presented for each major subset of calculations:

- Contaminant release from the waste form and into the vadose zone
- Moisture flow and contamination transport in the vadose zone
- Moisture flow and contaminant transport in the groundwater
- Integration of calculations.

The presentation will flow from the surface of the closed facility (where moisture enters), through the facility (where contaminants are released), and through the vadose zone and groundwater (where contaminants are transported), to the receptor (where impacts occur).

The groundwater scenario calculations are based on the use of a unit inventory and the principle of spatial and temporal superposition. That is, the calculations take advantage of impacts being proportional to the inventory causing the impacts. Since in most cases, the inventory causing the impacts is directly proportional to the initial inventory, unit inventory calculations are valid. The exception (solubility release calculations), however, still provides useful information.

The principle of spatial and temporal superposition is used to calculate the impacts from one region of the WMA C (the region around tank C-112) and extrapolate the results to the other regions of the WMA. Since departures for key parameters (moisture content, contaminant concentrations) from the natural state are estimated to be relatively small, such a superposition is a good assumption, as demonstrated by the test calculations presented in Section 4.2.2.

Because the details of the filling of the tanks and the placement of surface barriers are not known, the infiltration rate into the residual waste or into the vadose zone is taken to be the recharge rate. For the cases of leaks (either past leaks or potential retrieval leaks), all the contamination is assumed to be immediately available for transport. For the case of residual waste, explicit release calculations have been performed.

For residual wastes, release rate calculations are of two types as described in Section 3.4.4.2. In the first set of cases, the temporal shape of the release is assumed. The cases in this first set bracket the expected release times. In the second set of release cases, release rates are calculated based on physical/chemical principles (diffusion, advection, and solubility). For these cases, the transport through the vadose zone is performed during the same computer simulations as the release rate calculations.

Calculations of moisture flow and contaminant transport through the vadose zone and through groundwater to the WMA fence line are accomplished by two-dimensional flow and transport calculations. Two methods for extrapolating the results to the third dimension are described in Section 4.2.3.

For contaminant transport in the groundwater beyond the WMA fence line, independent steady-state streamline calculations are used. Calculations independent of the vadose calculations are adequate as the travel times in the groundwater (tens to hundreds of years) are much less than travel time in the vadose zone (thousands of years). Streamline calculations are used rather than the Hanford Site-wide Groundwater Model (Cole 2001) because the main focus of the analysis is the WMA fence line, which is calculated by the vadose zone model. Thus, the calculation of relative impacts further from the fence line does not justify the complexity of the Hanford Site-wide Groundwater Model. Previous work (Knepp 2002a and 2002b) shows good agreement between the streamtube calculations and the results of the Hanford Site-wide Groundwater Model.

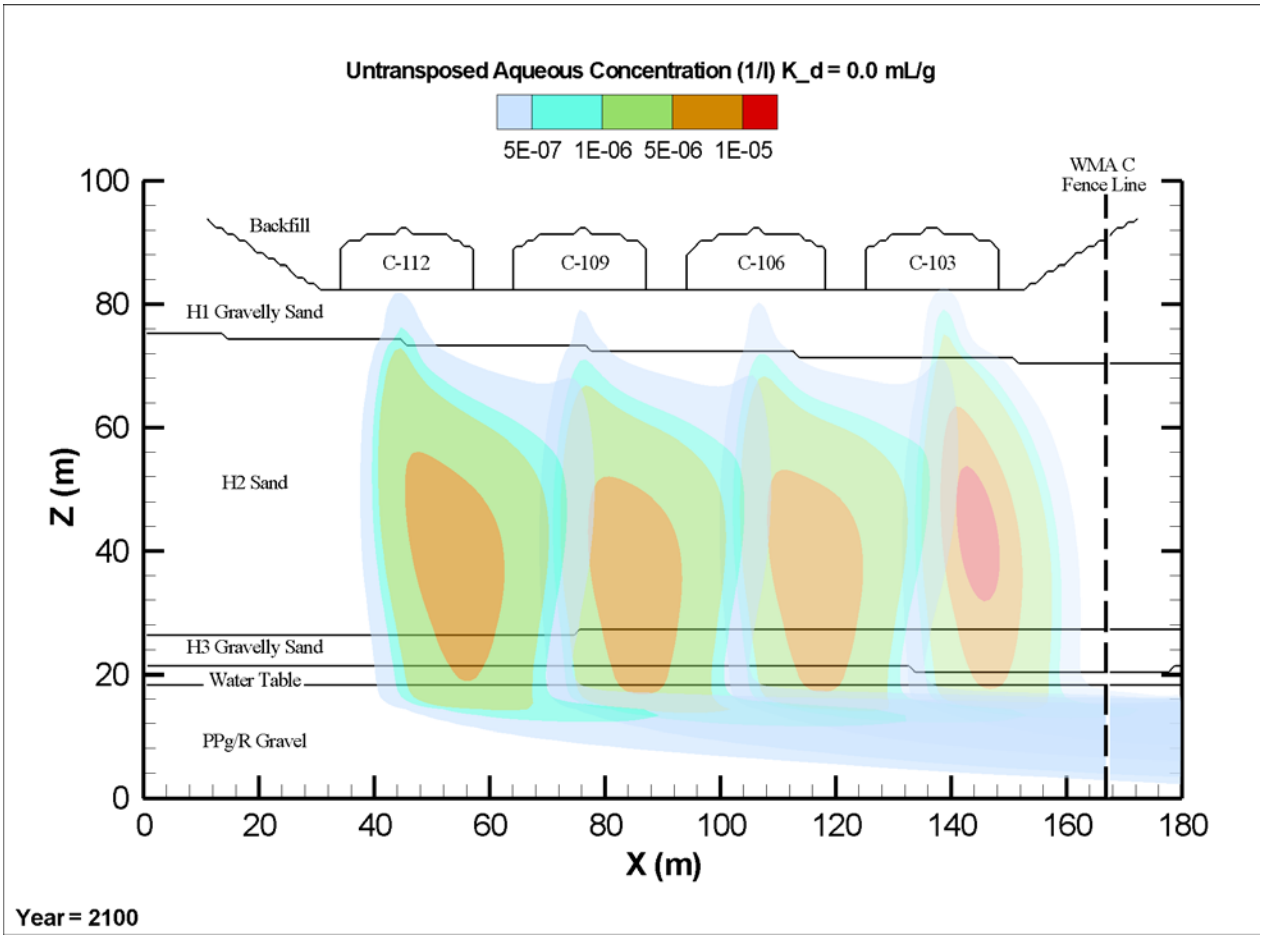
The integration of calculations includes the addition of inventory and dosimetry information. This section attempts to allow the reader to follow the moisture flow and contaminant transport from the beginning to the location of the potential impacts.

4.2.2 Calculational Accuracy and Superposition

All of the vadose zone calculations (as documented in *2003 Initial Assessments of Closure for the C Tank Farm: Numerical Simulations* [Zhang 2003]) were very stable and did not suffer significant mass loss.

A major assumption of this analysis is that simulations can be performed for one tank and the results can be linearly superimposed. Explicit calculations were also performed (Zhang 2003). These calculations show that no significant difference exists between overlapping the peak contaminant concentration results of the one-tank approach and the peak contaminant-concentration results of the multi-tank approach. Figure 4-1 shows the results for one case (Case 1v) of 8,000 gal potential retrieval leak in each of the four tanks in a groundwater flow line. The relatively small overlap of plumes provides an explanation why superposition works so well. An additional verification case (Case 5v) was run assuming a release of 10^{-3} Ci/yr for the first 500 years and then 0.1 Ci/yr for the next 5 years. (The different rates reflect the change in recharge due to a failing surface barrier.) Again, differences between the superimposed and verification run are small.

Figure 4-1. Untransposed Model Contaminant Transport Results for an 8,000 gal Retrieval Leak for a mobile (K_d = 0 mL/g) contaminant.



4.2.3 Extrapolation of Results to the Third Dimension

As noted in Section 4.2.1, the release/vadose zone/groundwater calculations are done in two dimensions. To obtain contaminant concentrations, the results must be extrapolated to the third dimension. Since both of the modeled dimensions are "long" compared to the transverse dimension, the use of an infinite source in the third dimension is inappropriate. Rather, two extrapolation methods were used.

The two-dimensional cross-sectional simulations yield the contaminant mass flux and BTCs at the tank farm fence line along the tank centerlines for the selected cross-section. To account for three-dimensional aspects, the tank centerline mass flux and BTCs are transformed to average values across the tank farm fence line using two translations. In the first translation, the centerline quantities are converted to average quantities on the tank farm fence line boundary as the cross-sectional projections. The length of the cross-sectional projection equals the mean inventory diameter, where the mean inventory diameter is computed for each source inventory. The inventory diameter is not necessarily the tank diameter. In the second translation, the cross-sectional average mass flux or BTCs for various cross-sections are translated to a single average mass flux or BTC across the entire tank farm fence line length using a length-weighted averaging scheme (White et al. 2001). Unless otherwise stated, results are presented using the second method.

4.2.4 Structure of Groundwater Pathway Discussion

The groundwater scenario is covered in many sections, so various key points can be emphasized in context. The following sections explain the analyses:

- Section 4.3 Residual Waste Releases
- Section 4.4 Vadose Zone Moisture Flow And Contaminant Transport
- Section 4.5 Groundwater Contaminant Transport to Fence Line
- Section 4.6 Groundwater Contaminant Transport Away From Fence Line
- Section 4.7 Superposition of Results
- Section 4.8 Translation into Impacts
- Section 4.9 Sensitivity Cases.

Section 4.10 describes the effect of other Hanford Site activities on the groundwater affected by this disposal action. Section 4.11 summarizes the information given in Sections 4.3 through 4.10.

4.3 RESIDUAL WASTE RELEASES

4.3.1 Introduction

As noted in Section 4.2.1, contaminants for past leak and potential retrieval leak sources are assumed to be available for transport immediately after the leak has occurred. However, contaminants from the residual waste (whether from tanks or ancillary equipment) are released more slowly. The following sections describe three physical/chemical approaches for such releases:

- Diffusion-Dominated Release
- Advection-Dominated Release
- Solubility-Controlled Dominated Release.

4.3.2 Diffusion-Dominated Release

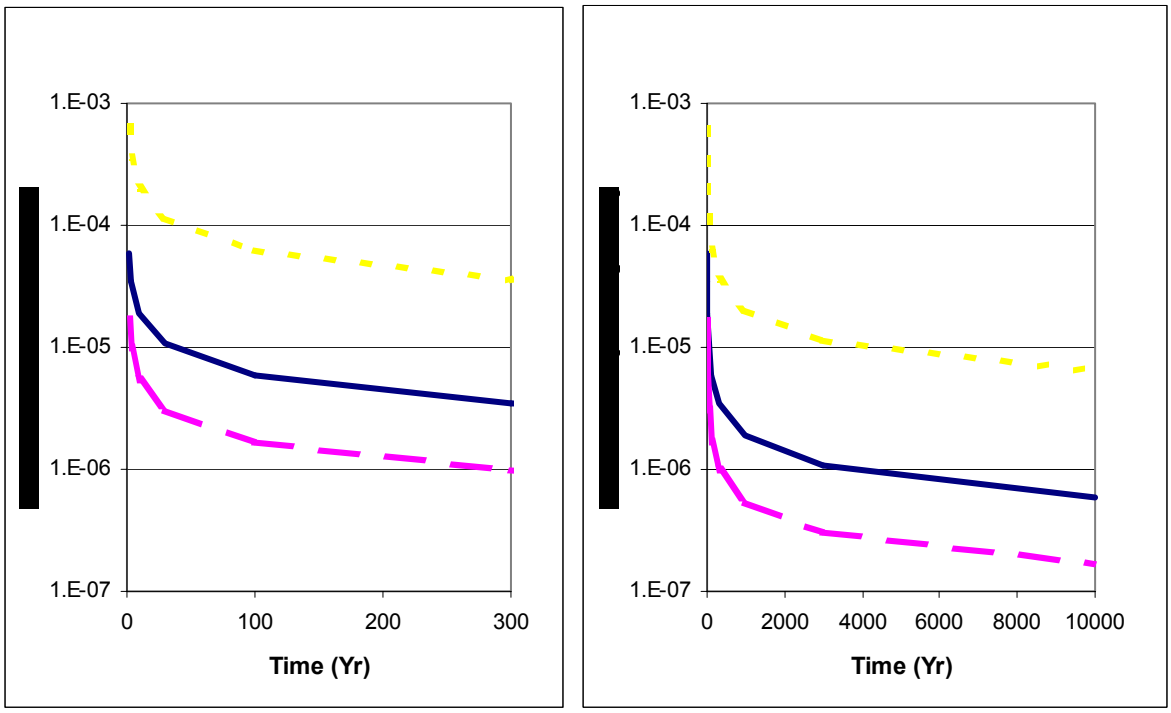
The diffusion-dominated release model is used to simulate the release of contaminants from stabilized (e.g., grouted tank or ancillary) wastes. Releases are assumed to begin on the first day in the year 2050, the date that tank integrity is lost. For releases from tanks, the release occurs over the bottom width of tank C-112 (75 ft [22.9 m]) with a source thickness of 32.5 in. (0.825 m). A source thickness of 1 in (2.5 cm) yields instantaneous release, which is not considered realistic for diffusion-dominated release from essentially a grouted waste form. To keep the release duration to a reasonable value, a larger source thickness was used. For these tank releases, two diffusion coefficients were used: 6×10^{-7} cm^2/s (Case 11) and 5×10^{-8} cm^2/s) (Case 14). For releases from ancillary equipment, the release occurs over a diameter of (22.9 ft (7 m) with a source thickness of 32.5 in. (0.825 m) and a diffusion coefficient of 6×10^{-7} cm^2/s (Case 13).

Results from the simulations for the flux out of the facility and into the vadose zone were not explicitly calculated and saved. Such fluxes will be presented in the next version of this document. Rather Figure 4-2 shows the releases for the three cases mentioned using equation 3-5, which is used as the source equation.

4.3.3 Advection-Dominated Release

The advection-dominated release model (Case 10), also known as the mixing-cell cascade model, is a second model to simulate the release of contaminants from stabilized (e.g., grouted tank or ancillary) wastes. Releases are assumed to begin on the first day in the year 2050, the date that tank integrity is lost. For releases from tanks, the release occurs over the bottom width of tank C-112 (75 ft [22.9 m]) with a source thickness of 32.5 in. (0.825 m). The number of mixing cells used was 10.

Figure 4-2. Release Rates into the Vadose Zone Calculated from the Diffusion-Dominated Release Model[a].



[a]The solid curve (Case 11) has an effective diffusion coefficient of 6×10^{-7} cm^2s for tank releases. The long-dash curve (Case 14) has an effective diffusion coefficient of 5 × 10-8 cm^2s. The short-dash line (Case 13) has an effective diffusion coefficient of 6×10^{-7} cm^2s for ancillary equipment releases.

Results from the simulations for the flux out of the facility and into the vadose zone were not saved and hence are not available. Such curves will be presented in the next version of this document. However, the release is quite fast. After approximately 20 years, 99% of contaminants have entered the vadose zone.

4.3.4 Solubility-Controlled Dominated Release

The solubility-controlled release model (Case 12) assumes that a dissolving solid controls the solution concentration in the aqueous phase of the constituents being released. Solubility models are thermodynamic equilibrium models and do not consider kinetics. Although no empirical solubility models exists for modeling contaminants from residual tank wastes, a solubility-controlled release model (i.e., “saltcake” model) has been postulated. When applied to residual tank wastes, the term “saltcake” applies to the sludge and hard-heel residual in the tanks that comprise the structure matrix. Again, the releases are assumed to begin on the first day in the year 2050, the date that tank integrity is lost. For releases from tanks, the release occurs over the bottom width of tank C-112 (75 ft [22.9 m]) with a source thickness of 32.5 in. (0.825 m).

Results from the simulations for the flux out of the facility and into the vadose zone were not saved and hence are not available. Such fluxes will be presented in the next version of this document. This release is extremely slow. Only 0.782% of the initial amount enters the vadose zone in the first 10,000 years.

4.4 MOISTURE FLOW AND CONTAMINANT TRANSPORT IN THE VADOSE ZONE

4.4.1 Introduction

The rate at which contaminants enter the groundwater (called break-through curves or BTCs) was calculated for each of the 14 cases described in Section 3.5.3. Because the simulations coupled, the BTCs combine release rate and vadose zone transport effects. Thus, this presentation starts with the simplest releases and ends with the temporally most complex, as follows:

4.4.2 Past and Potential Retrieval Leak Cases

4.4.3 Residual Waste – Fast Release Cases

4.4.4 Residual Waste – Slow Release Cases.

The final section compares the BTCs for all the cases.

4.4.2 Leak Cases (Past and Potential Retrieval)

The leak cases all share the characteristic of having contaminants immediately available for transport, that is, available on the first day of year 2000. They differ in the depth at which the source occurs (Case 4 = 30 ft [9.15 m], Cases 1 and 2 = 37 ft [11.28 m], and Case 3 = 80 ft [24.4 m]) and the additional volume of moisture added to the system (Cases 3 and 4 = no additional moisture, Case 1 = 8,000 gal over 14 days, and Case 2 = 20,000 gal over 14 days).

Initially, the addition of moisture (in the potential retrieval leak cases) completely saturates the soil near the leak (see Figure 4-3). However, by 2050, the aqueous saturations in the four cases are essentially the same (Figure 4-4). Because of the lower recharge rates after 2050 (for 500 years due to the surface barrier, and then for the remaining time due to natural conditions), the vadose zone dries out as shown by comparing Figures 4-3, 4-4, and 4-5. At early times, the vadose zone moisture saturation lies between 0.5 and 0.6, whereas at 12,000 years, the moisture saturation is between 0.3 and 0.4.

Figure 4-3. Estimated Aqueous Saturation at the End of a 14 Day Retrieval Leak of 8,000 gal. (Figure A.1b from Zhang 2003.)

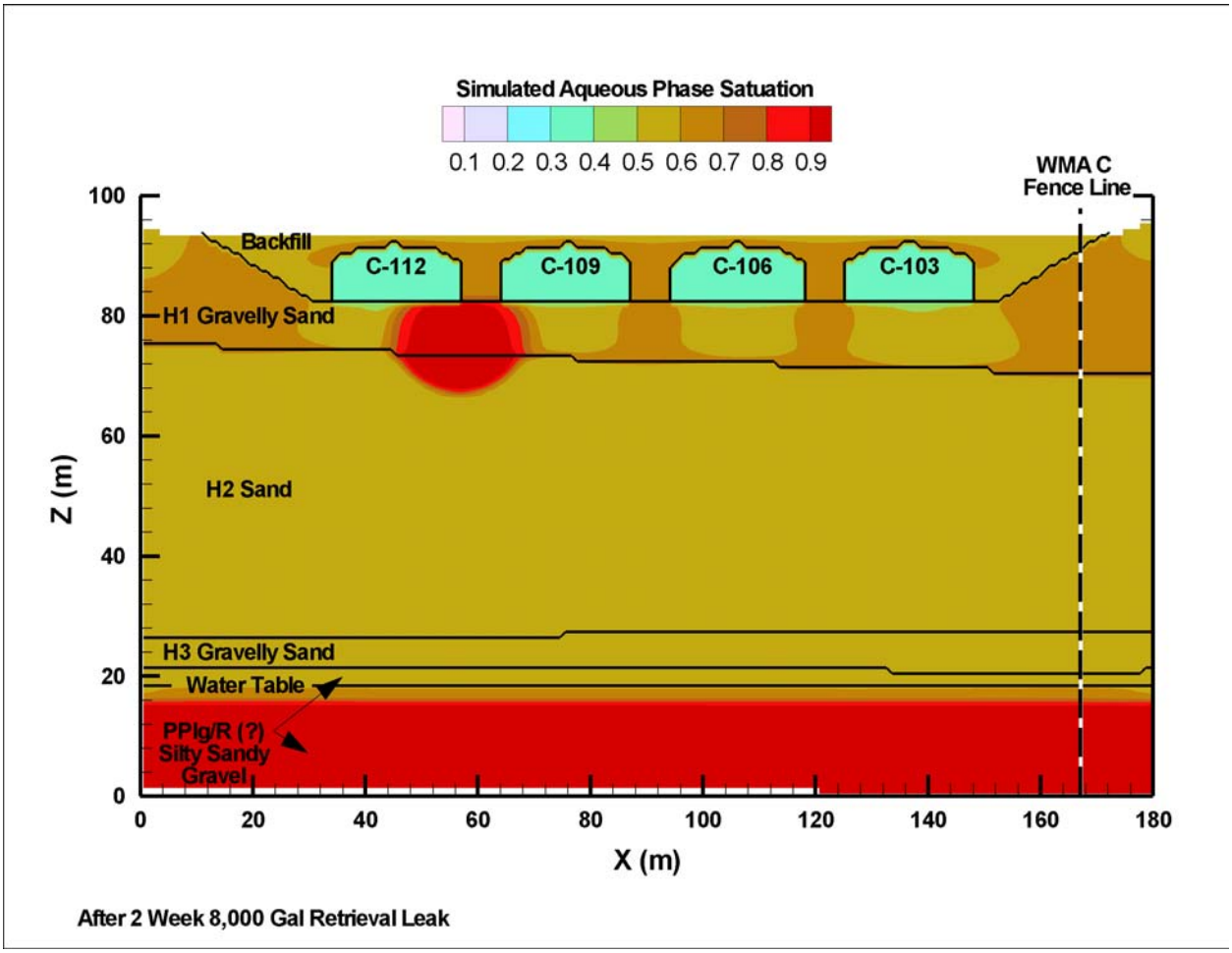


Figure 4-4. Estimated Aqueous Saturation in Year 2050 for No Added Moisture and for a 14 Day Leak of 8,000 gal. (Figures A.21a and A.2a from Zhang 2003.)

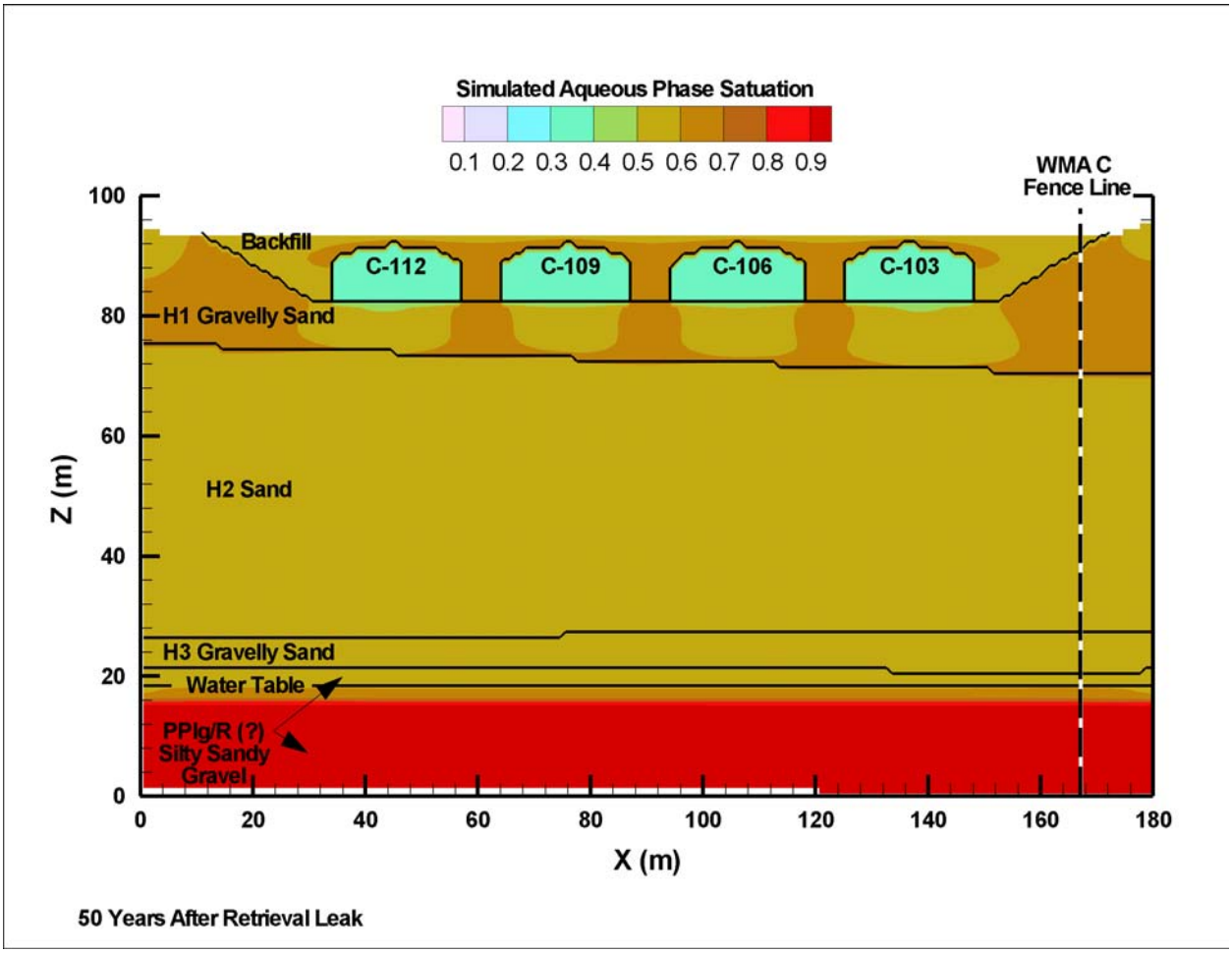
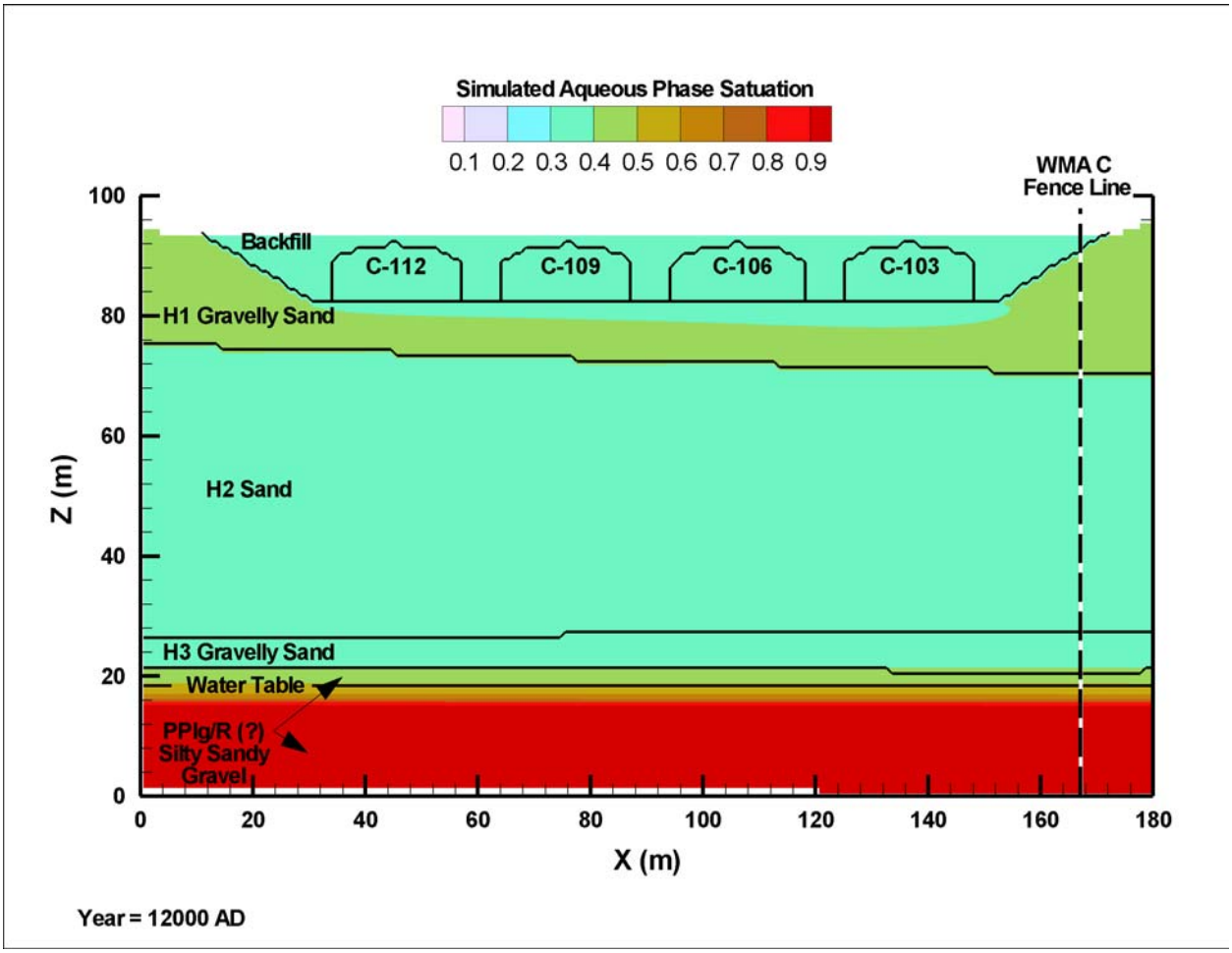


Figure 4-5. Estimated Aqueous Saturation in Year 12000. (Figure A.2b from Zhang 2003.)



The temporal shapes of the BTCs at the water table are very similar (see Figures 4-6 through 4-9). Each BTC has two peaks. The first peak corresponds to the pulse driven by the high moisture recharge prior to closure installation. Once the surface cover is installed, recharge greatly reduces (by a factor of 200) and contaminant transport lessens. Once the surface cover is assumed to instantly degrade (instantly increasing recharge by a factor of 7), contaminant transport increases, creating a second peak. In reality, the surface barrier will not instantly degrade, and the second peak will be more spread out in time.

Table 4-1 presents the key parameters (peak contaminant flux entering the groundwater and vadose travel time) for the BTCs for mobile contaminants for the leak cases. Impacts are expected in roughly the next 100 years. As expected, if the contaminant source is closer to the water table, the contamination will reach the groundwater sooner. In addition, because of the shorter travel time, there will be less dispersion and hence the peak contaminant flux will be higher. Similarly, higher fluxes and shorter travel times occur when leak water is added.

These insights are confirmed by simulations (White 2001, Freedman 2002) performed for the RCRA Corrective Action Program, the *Field Investigation Reports for the WMA S-SX* (Knepp 2001), and *Field Investigation Reports for the WMA B-BX-BY* (Knepp 2002). Those calculations

showed that water from water leaks could accelerate contaminant transport. Other calculations in those documents show that vadose zone travel times will increase and peak contaminant fluxes entering the groundwater will decrease if interim surface barriers are installed. For sources near the bottom of the tanks, interim barriers placed by 2010 could decrease peak fluxes by at least a factor of 2. However, for sources very near the water table (as in WMA B-BX-BY), there is little effect.

Figure 4-6. Estimated Break-through Curve for Mobile Contaminants (Tc-99) for Case 4 (Past Leak at 30 ft [9.2 m]). (Figure B.41a from Zhang 2003.)

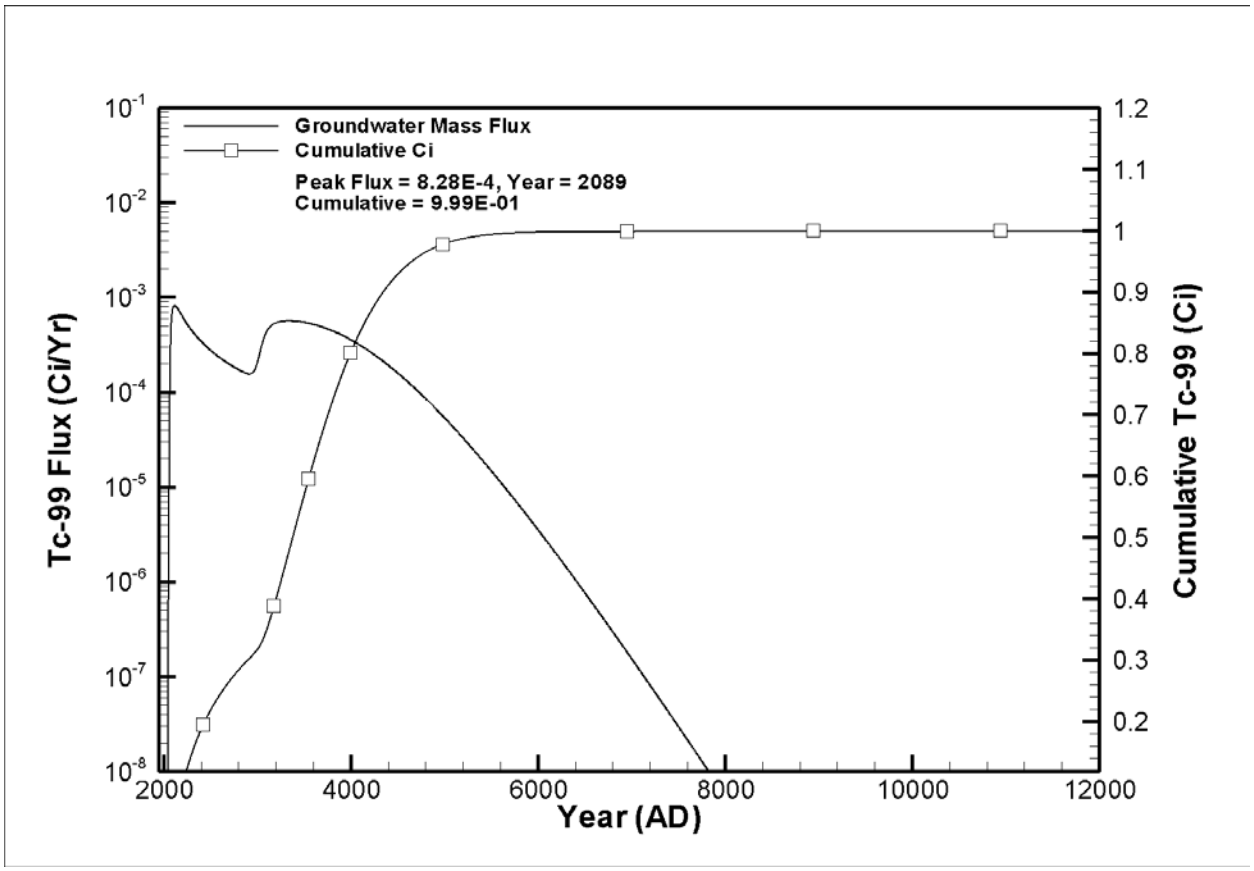


Figure 4-7. Estimated Break-through Curve for Mobile Contaminants (e.g., Tc-99) for Case 3 (Past Leak at 80 ft [24.4]). (Figure B.33a from Zhang 2003.)

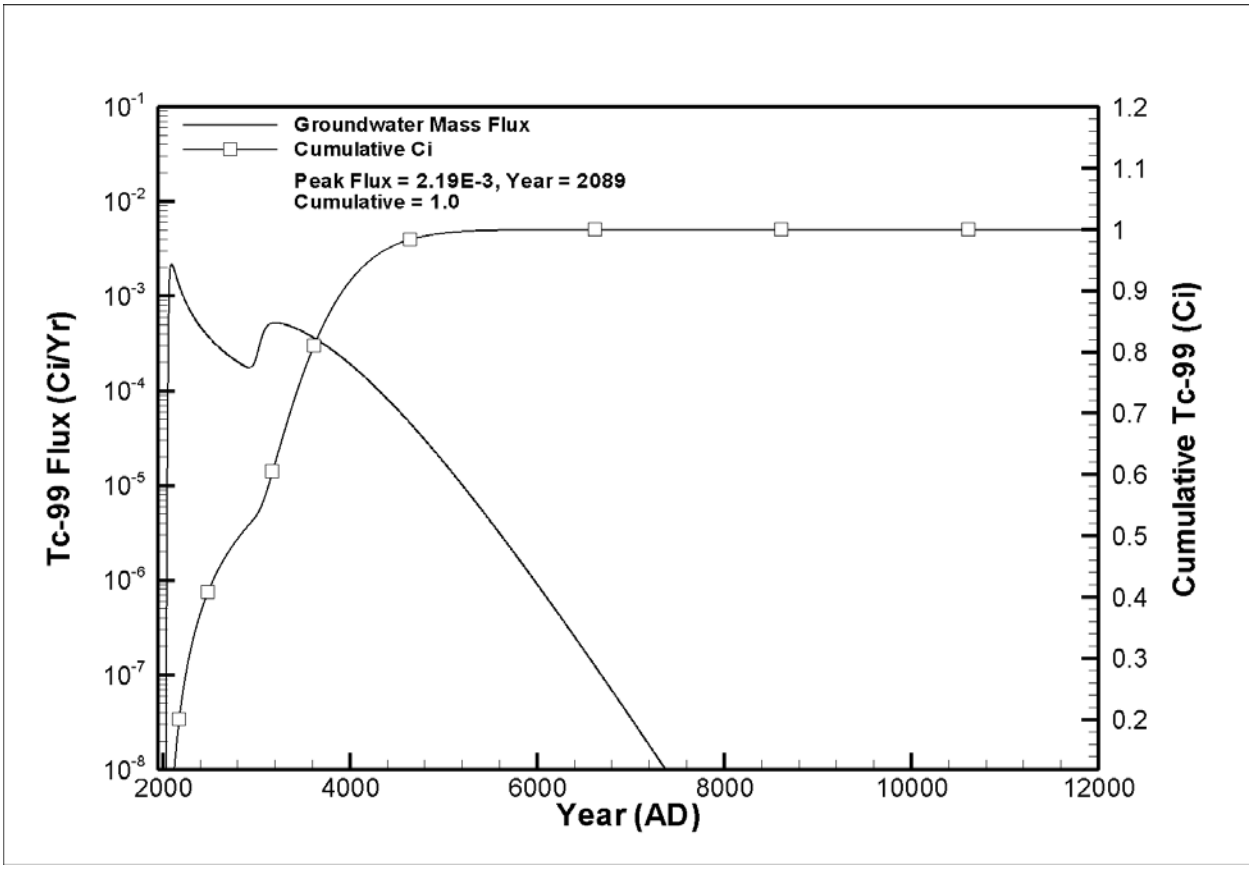


Figure 4-8. Estimated Break-through Curve for Mobile Contaminants (e.g., Tc-99) for Case 1 (Potential Retrieval leak of 8,000 gal at 37 ft [11 m]). (Figure B.1a from Zhang 2003.)

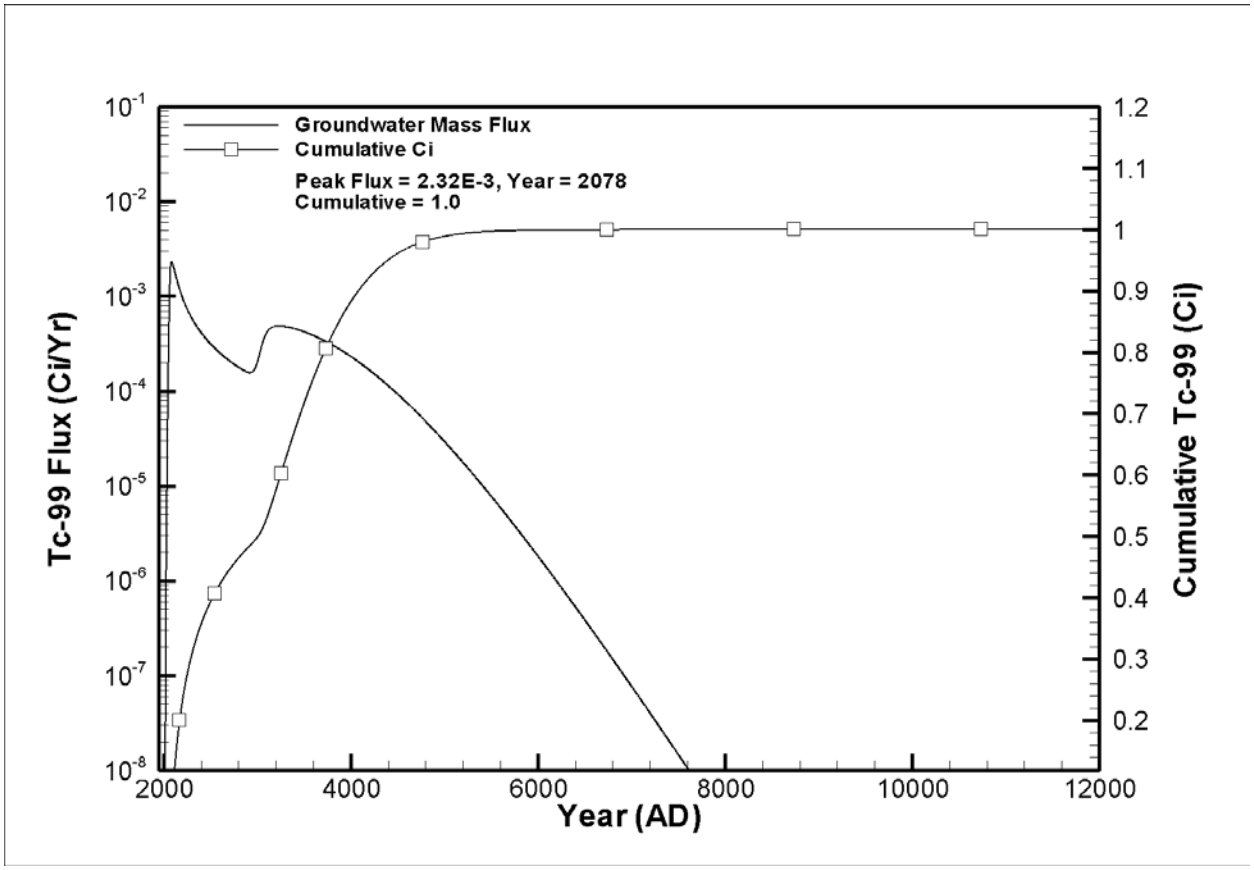


Figure 4-9. Estimated Break-through Curve for Mobile Contaminants (e.g., Tc-99) for Case 2 (Potential Retrieval Leak of 20,000 gal at 37 ft [11 m]). Assumes 1 Curie of Initial Inventory. (Figure B.25 from Zhang 2003.)

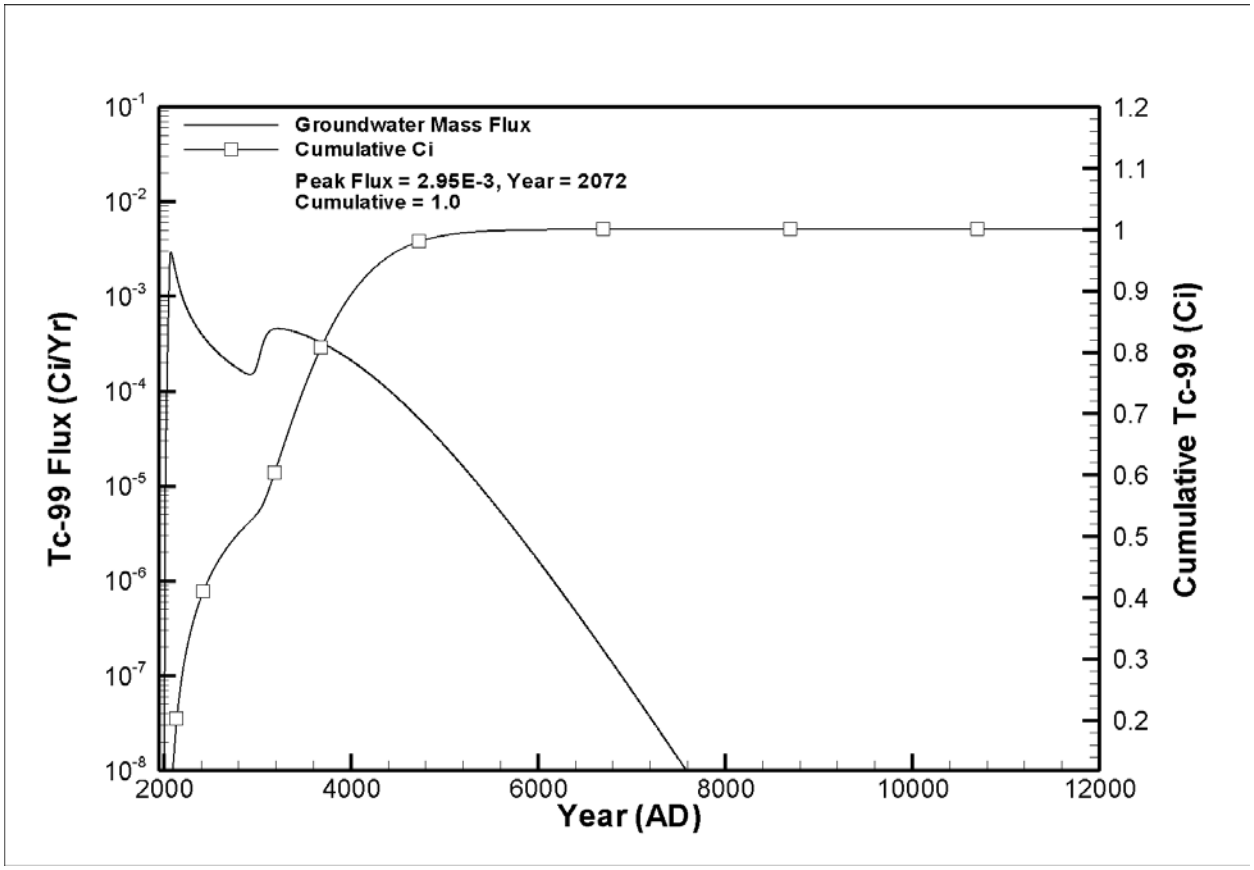


Table 4-1. Key Parameters for Groundwater Break-through Curves for Mobile Contaminants for Leak Cases

Case	Source Depth (ft [m])	Added Water (gal)	Peak Flux (Ci/Ci-yr)[a]	Time of Peak Flux (yr)
4	30 [9.2]	0	8.71×10^{-4}	2113
3	80 [24.4]	0	2.28×10^{-3}	2089
1	37 [11.3]	8,000	2.41×10^{-3}	2078
2	37 [11.3]	20,000	2.95×10^{-3}	2072

[a]Ci/yr flux per unit Ci of inventory.

4.4.3 Residual Waste Cases – Fast Release Cases

Since the release mechanism from residual waste is not yet established, a series of parametric cases were run. These assumed that releases would increase after the surface barrier degraded, and each case has an order of magnitude lower release rate than the previous case. Because only the release rate has been changed from the cases above, the aqueous saturation is the same as Case 3 or 4, see Figures 4-4 and 4-5.

The shapes of the BTCs for the cases where the main release is short (i.e. less than 1,000 years) are very similar, as seen in Figure 4-10. There is only one peak that is delayed by slightly more than 5,000 years. This shape is not unexpected as these cases assume tank integrity during the first 50 years (the time of highest recharge) and relatively low release rate during the time that the surface barrier is effective. Because the release time is short relative to the travel time, the main effect on the shape of the BTC to groundwater is the dispersion through vadose zone travel. These calculations show that for releases that have durations shorter than 1,000 years, the details of the release are not important.

In the advection-dominated release simulation (Case 10), 99% of the mobile contaminants have entered the vadose zone in 20 years. Thus, the BTC at groundwater resembles the fast release cases.

By comparing these results to Cases 1 and 2 (past leak at 30 ft and 80 ft [9.2 m and 24.4 m]), the value of the surface barrier can be determined. These releases are at 37 ft (11.3 m), implying that without a surface barrier, only one peak would occur and the peak contaminant flux at the groundwater would be about 1.02×10^{-3} Ci/(Ci-yr) at 2109. Thus, the main effect is to delay the flux by slightly less than the lifetime of the surface barrier with a small (25%) decrease in the peak contaminant flux.

Figure 4-10. Estimated Break-through Curve for Mobile Contaminants (e.g., Tc-99) for the Fast Residual Waste Release Cases (Case 5, 6, 7, 9, and 10). Assumes 1 Curie of Initial Inventory. (Figures B.49a, B.73a, B.81a, B97a, and B.105a from Zhang 2003.)

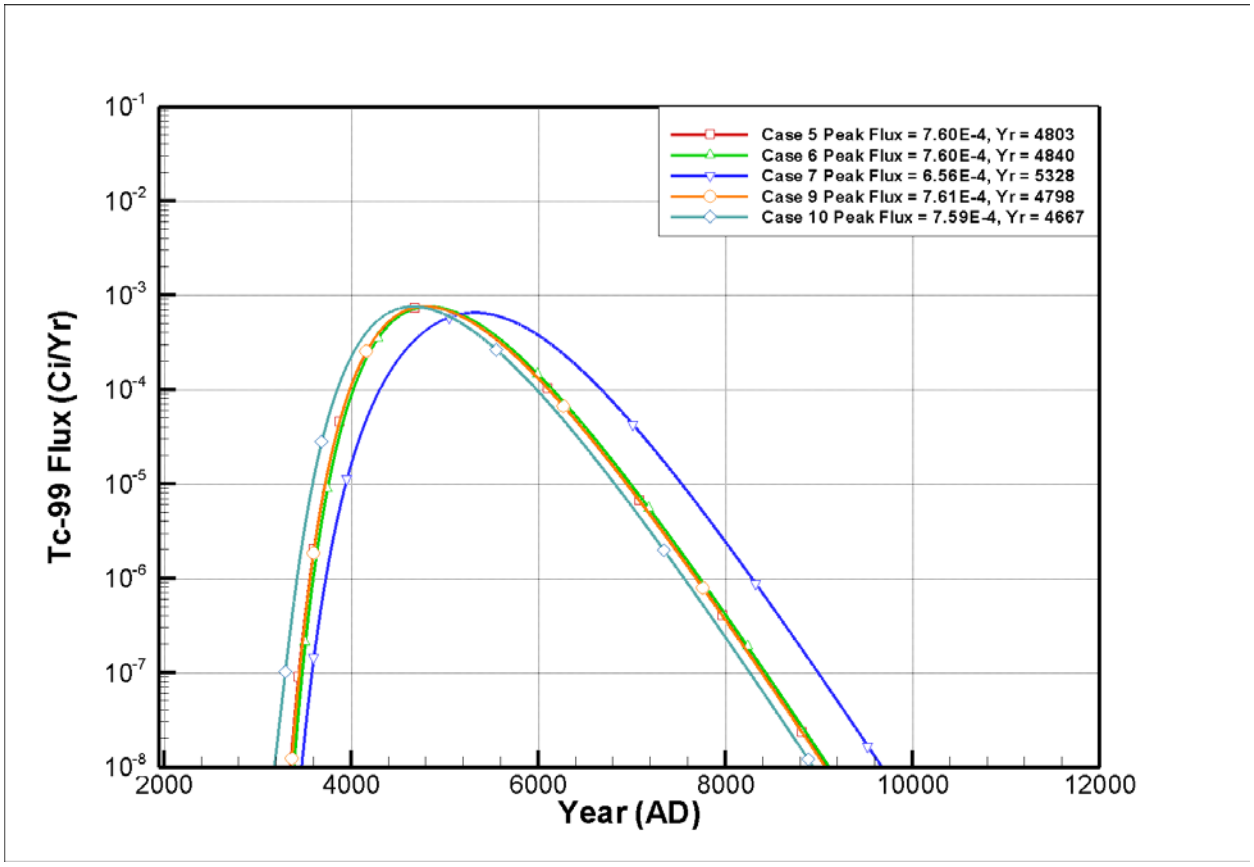


Table 4-2. Key Parameters for Groundwater Break-through Curves for Mobile Contaminants for Fast Release Residual Waste Cases.

Case	Release Rate (Ci/Ci-yr)		Peak Flux (Ci/Ci-yr)[a]	Time of Peak Flux (yr)	Fraction of Flux Reaching Groundwater in 10,000 Years
	First 500 Years	Thereafter			
9	10^{-1} for 10 years	0	7.6×10^{-4}	4798	1.0
5	10^{-3}	10^{-1} for 5 years	7.60×10^{-4}	4803	1.0
6	10^{-4}	10^{-2} for 95 years	7.61×10^{-4}	4840	1.0
7	10^{-5}	10^{-3} for 995 years	6.56×10^{-6}	5328	1.0
Case	**Release Mechanism**	**Depth (ft [m])**	**Peak Flux (Ci/Ci-yr)[a]**	**Time of Peak Flux (yr)**	**Fraction of Flux Reaching Groundwater in 10,000 Years**
10	Advection	37 [11.3]	7.64×10^{-4}	4649	0.999

[a]Ci/yr flux per unit Ci of inventory.

4.4.4 Residual Wastes – Slow Release Cases

The other release cases simulated residual waste having releases over a very long time. Again, the aqueous saturation is the same as Case 3 or 4 (see Figures 4-4 and 4-5). For these cases, the shape of the BTC at groundwater is not sharply peaked, but rather has a plateau shape, with some evidence of a peak at times around 5,000 years depending on the case. Such shapes are similar to those found in the *Hanford Immobilized Low-Activity Waste Performance Assessment: 2001 Version* (Mann 2001) that uses glass as the waste form. For such slow releases, the release time is much longer than the vadose zone travel time, so the temporal shape becomes more plateau-like as the release duration increases.

The different response for diffusion-dominated release from tanks (Case 11) and ancillary equipment (Case 13) for the same diffusion coefficient may result from the higher aqueous saturation between the tanks than underneath tanks as seen in Figures 4-4 and 4-5. These higher saturations result in higher hydraulic conductivities that increase migration rates and decrease dispersion effects, causing faster travel times and higher peak fluxes for ancillary equipment releases.

Figure 4-11. Estimated Break-through Curve for Mobile Contaminants (e.g., Tc-99) for the Slow Residual Waste Release Cases (Cases 8, 11, 12, 13, and 14). An initial Inventory of 1 Curie is Assumed.

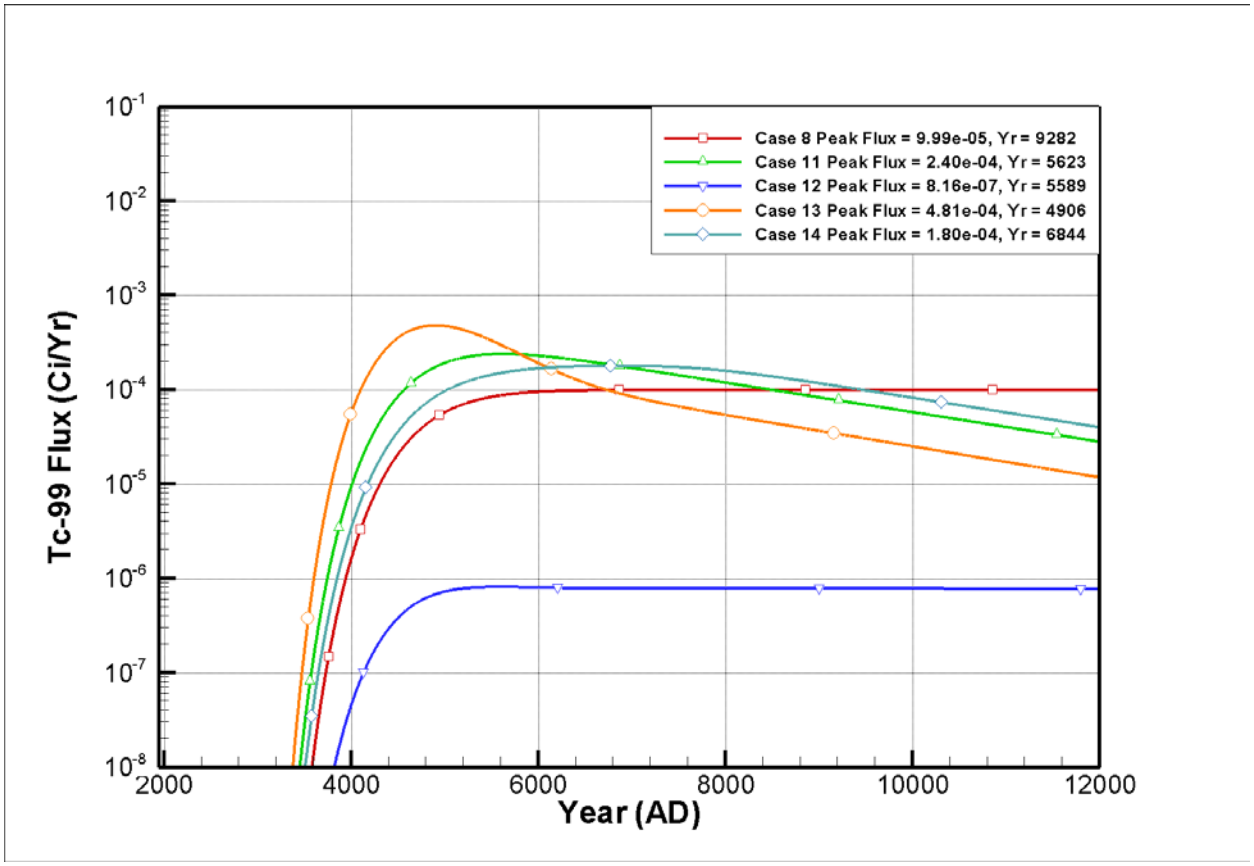


Table 4-3. Key Parameters for Groundwater Break-through Curves for Mobile Contaminants for Slow Release Residual Waste Cases.

Case	Release Rate (Ci/Ci-yr)		Peak Flux (Ci/Ci-yr)[a]	Time of Peak Flux (yr)	Fraction of Flux Reaching Groundwater in 10,000 Years
	First 500 Years	Thereafter			
8	10^{-6}	10^{-4} for 9,995 years	9.99×10^{-5}	9282	0.70
Case	**Release Mechanism**	**Depth (ft [m])**	**Peak Flux (Ci/Ci-yr)[a]**	**Time of Peak Flux (yr)**	**Fraction of Flux Reaching Groundwater in 10,000 Years**
11	Diffusion $D = 6x10^{-7}$ cm^2/s	37 [11.3]	2.41×10^{-4}	5607	0.92
14	Diffusion $D = 5x10^{-8}$ cm^2/s	37 [11.3]	1.80×10^{-4}	6844	0.89
13	Diffusion $D = 6x10^{-7}$ cm^2/s	20 [6.1] (between tanks)	4.81×10^{-4}	4906	0.97
12	Solubility	11 [37]	8.16×10^{-7}	5589	0.01

[a]Ci/yr flux per unit Ci of inventory.

4.4.5 Effect of Retardation in Contaminant Transport

So far, the discussion has concerned mobile contaminants, that is, contaminants that move with water. However, most contaminants have retarded transport; they interact with soil, effectively moving more slowly than moisture flows. The simulations provide for this analysis stressed low retardation (R_d). The distribution coefficients (K_d) used were 0.0, 0.01, 0.03, 0.10, 0.30, 0.60, and 1.0 mL/g. The relationship between R_d and K_d is

$$R_d = 1 + \rho/(\theta K_d),$$

where ρ is the bulk density and θ is the volumetric moisture content (which is a function of location and time). For models with constant ρ and θ, travel time is proportional to R_d, while the peak concentration is proportionally to $1/R_d$. In general as K_d exceeds 0.1 mL/g, the BTC to groundwater slowly rise. Table 4-4 presents effective retardation values for K_d = 0.6 mL/g for each case, while Table 4-5 displays retardation values for the various K_ds calculated. The "effective retardation" is defined as the ratio of the peak flux to groundwater for K_d = 0 to the peak flux value for the K_d simulated or to the value at 10,000 years, if no peak occurs in the groundwater BTC for that simulation. The latter occurs if the peak is beyond 10,000 years.

Table 4-4. Effective Retardation Values for K_d = 0.6 mL/g for Cases Simulated

Case	Description of Case	Effective Retardation
1	Retrieval Leak of 8,000 gal (source at 37 ft [11.3] bgs)	1,289
2	Retrieval Leak of 20,000 gal (source at 37 ft [11.3 m] bgs)	1,603
3	Past Leak at 80 ft (24.4)	197
4	Past Leak at 30 ft (9.1)	1,260
5	Tank Residual Waste: 10^{-3}/yr for 500 years, 10^{-1}/year for 5 years	11,801
6	Tank Residual Waste: 10^{-4}/yr for 500 years, 10^{-2}/year for 95 years	12,709
7	Tank Residual Waste: 10^{-5}/yr for 500 years, 10^{-3}/year for 995 years	22,162
8	Tank Residual Waste: 10^{-6}/yr for 500 years, 10^{-4}/year for 9,995 years	30,181
9	Tank Residual Waste: 10^{-1}/yr for 10 years	11,817
10	Tank Residual Waste: Advection-Dominated Release	14,568
11	Tank Residual Waste: Diffusion-Dominated Release; $D = 6 \times 10^{-7}$ cm^2/s	8,191
12	Tank Residual Waste: Solubility-Controlled Dominated Release	27,661
13	Ancillary Equipment: Diffusion-Dominated Release; $D = 6 \times 10^{-7}$ cm^2/s	63,456
14	Tank Residual Waste: Diffusion-Dominated Release; $D = 5 \times 10^{-8}$ cm^2/s	125,000

Note: The effective retardation is defined as the ratio of the peak flux to groundwater for Kd = 0 to the peak flux value for the Kd simulated or to the value at 10,000 years, if no peak occurs in the groundwater BTC for that simulation.

Table 4-5. Effective Retardation Values for Various Cases Simulated.

K_d (mL/g)	Case 3 Past Leak at 80 ft (24 m)	Case 1 Retrieval Leak of 8,000 gal	Case 11 Tank Residual Waste: Diffusion-Dominated Release; $D = 6 \times 10^{-7}$ cm^2/s	Case 13 Tank Residual Waste: Diffusion-Dominated Release; $D = 5 \times 10^{-8}$ cm^2/s
0.01	1.80	1.83	1.05	1.01
0.03	4.66	5.51	1.17	1.01
0.1	7.04	8.23	1.58	1.29
0.3	14.6	16.9	18.2	22.5
0.6	197	1,289	8,191	125,000
1.0	95,217	5,873,418	NV	NV

Note: The effective retardation is defined as the ratio of the peak flux to groundwater for $K_d = 0$ to the peak flux value for the K_d simulated or to the value at 10,000 years, if no peak occurs in the groundwater BTC for that simulation.

NV = No value available.

The effective retardation values can be understood by noting that the moisture content of the vadose zone is very high before 2050, dries out from the year 2050 to the time that the effect of the surface barrier becomes insignificant (~2500), and then becomes slightly more moist than under surface barrier conditions. Thus, Case 3 has the highest effective moisture content. The residual waste cases have higher retardation values because release is assume to start at the time the surface barrier becomes effective.

Although simulations were not performed for larger K_d values, the expected retardation values are much higher than shown in Tables 4-4 and 4-5. In fact, no flux to the water table was found for $K_d = 1.0$ mL/g for the slow release cases.

4.4.6 Comparison of Vadose Transport Cases

Some general conclusions can be derived from the results of the simulations described above:

- Leaks that occur before a surface barrier is installed have peaks in the relatively near future (before 2150).
- If the duration of the release is less than ~1,000 years, then a peak occurs at the time the surface barrier degrades. The height of the peak is independent of the release rate.
- For slowly releasing waste forms, the BTC has a plateau-like shape and the temporal shape of the release rate is important.
- Contamination retardation in the vadose can reduce impacts during the first 10,000 years to negligible values for $K_d > 1.0$ mL/g.

4.5 GROUNDWATER CONTAMINANT TRANSPORT TO FENCE LINE

As the contaminants move in the groundwater from their entrance under tank C-112 to the WMA C fence line, two effects occur:

- The contaminants are diluted in the greater volume of groundwater.
- The contaminants disperse as they travel.

The calculations simulated the vadose zone and groundwater transport to the fence line as an integrated package. For most cases, the calculations show a "well intercept factor" (defined as the peak flux value to the peak concentration value) of 8.5×10^{-5}/(liter-year). For the leak cases, the well intercept factors were about 4% lower (~8.2×10^{-5}/[liter-year]). There were no significant differences between the contaminant concentrations in groundwater directly underneath tank C-112 and the fence line for any of the cases. The calculated travel time from underneath tank C-112 to the fence line is very short (~3 years) compared to the vadose zone travel time.

The concentration values reported at the fence line are "fence-line averaged values"; that is, the plume is assumed to cover the entire WMA C fence line length. This is a good approximation for the residual waste left in tanks as the tanks cover the bulk of the WMA. However, it is a poor assumption for spatially confined leaks, such as pipeline leaks. The fence-line averaged values were calculated by dividing the peak concentrations by 233. (The peak calculations are based on 1 meter slices and the fence line is 233 m [760 ft] long.) Future work will model plumes in three dimensions to estimate actual peak values at the fence line.

4.6 GROUNDWATER CONTAMINANT TRANSPORT AWAY FROM FENCE LINE

Groundwater transport away from the fence line was calculated separately from the vadose zone travel. A stream tube model was used. According to the Hanford Site groundwater model, groundwater flows both east and north from this location; two calculations are presented with the results displayed in Table 4-6. The dilution factors going in either direction are about the same (1.7×10^{-2} to the exclusion boundary and 6×10^{-3} to the Columbia River). The biggest difference is the time to travel to the Columbia River, which is significantly longer when groundwater flow is to the north (230 years compared to 600 years). However, except in the cases of leaked waste, groundwater travel time is still small compared to vadose zone travel time.

The groundwater calculations from the fence line to the Columbia River assumed no retardation. With retarded species, retardation also occurs in the groundwater, reducing small concentrations even further.

Table 4-6. Dilution Effects Relative to Fence Line Concentrations and Travel Times (Yr) from WMA C Fence Line

Case	Description	Eastward Movement				Northward Movement			
		Exclusion Boundary		Columbia River		Exclusion Boundary		Columbia River	
		Conc.	Time	Conc.	Time	Conc.	Time	Conc.	Time
1	8,000 gal retrieval leak	$1.59x10^{-1}$	25	$5.31x10^{-2}$	242	$1.48x10^{-1}$	41	$5.15x10^{-2}$	603
2	20,000 gal retrieval leak	$1.79x10^{-2}$	21	$6.03x10^{-3}$	236	$1.68x10^{-2}$	37	$5.77x10^{-3}$	596
3	Past Leak at 80 ft (24.4 m)	$1.59x10^{-1}$	25	$5.48x10^{-2}$	241	$1.48x10^{-1}$	41	$5.43x10^{-2}$	604
4	Past Leak at 30 ft (9.1 m)	$1.58x10^{-1}$	24	$5.67x10^{-2}$	238	$1.49x10^{-1}$	39	$6.05x10^{-2}$	602
5	Residual Waste: 10^{-3}/yr for 500 years, 10^{-1}/year for 5 years	$1.55x10^{-2}$	22	$5.71x10^{-3}$	234	$1.46x10^{-2}$	41	$6.57x10^{-3}$	583
6	Residual Waste: 10^{-4}/yr for 500 years, 10^{-2}/year for 95 years	$1.55x10^{-2}$	22	$5.71x10^{-3}$	232	$1.46x10^{-2}$	41	$6.57x10^{-3}$	582
7	Residual Waste: 10^{-5}/yr for 500 years, 10^{-3}/year for 995 years	$1.54x10^{-2}$	27	$5.69x10^{-3}$	234	$1.45x10^{-2}$	41	$6.57x10^{-3}$	582
8[a]	Residual Waste: 10^{-6}/yr for 500 years, 10^{-4}/year for 9,995 years	$1.54x10^{-2}$	-1092	$5.71x10^{-3}$	-460	$1.45x10^{-2}$	-1082	$6.58x10^{-3}$	-103
9	Residual Waste: 10^{-1}/yr for 10 years	$1.55x10^{-2}$	22	$5.70x10^{-3}$	232	$1.46x10^{-2}$	40	$6.57x10^{-3}$	582
10	Residual Waste - Advection	$1.56x10^{-1}$	25	$5.76x10^{-2}$	232	$1.47x10^{-1}$	41	$6.64x10^{-2}$	582
11	Residual Waste –Diffusion1	$1.56x10^{-1}$	32	$5.78x10^{-2}$	234	$1.47x10^{-1}$	43	$6.67x10^{-2}$	578
12	Residual Waste – Solubility	$1.55x10^{-2}$	16	$5.70x10^{-3}$	229	$1.46x10^{-2}$	32	$6.59x10^{-3}$	579
13	Residual Waste –Diffusion2	$1.55x10^{-2}$	27	$5.70x10^{-3}$	233	$1.46x10^{-2}$	41	$6.58x10^{-3}$	583
14	Residual Waste – Diffusion3	$1.55x10^{-2}$	25	$5.70x10^{-3}$	239	$1.45x10^{-2}$	38	$6.56x10^{-3}$	578

[a]Negative travel times reflect slight change in temporal shape, which impacts when peak values occur.

4.7 SUPERPOSITION OF RESULTS

Superposition involves three aspects:

- Correcting the unit inventory results to results corresponding to the estimated inventory values for each contaminant
- Adding the four sources (past leaks, potential retrieval leaks, residual waste in tanks, and residual waste in ancillary equipment) for each area (such as the area around a given tank) in the WMA, and

- Combining the impacts from each source/component in the WMA into an integrated whole.

The following sections follow the above sequence. First, using the inventory of the key example of each source, inventory-adjusted values are presented in Section 4.7.1. In Section 4.7.2, the area around tank C-105 will be used as an example of superposition of a past leak, a potential 8,000-gal retrieval leak, and residual waste assuming 360 ft^3 of waste are left as residual. Section 4.7.3 looks at rows of tanks and other facilities parallel to groundwater flow to estimate the concentrations at the WMA fence line. Finally, Section 4.7.4 looks at points farther away from the fence line (the exclusion boundary and the Columbia River), points at which all the sources from all the facilities have dispersed enough to be completely intermixed.

4.7.1 Inventory-Corrected Concentrations

The calculations presented above have been for unit inventory sources. This section puts into context the importance of the various contaminants. This section will focus on the results for key examples for each of the four types of sources:

- Past Leaks (UPR-200-E-86)
- Potential Retrieval Leak (8,000 gal)
- Tank Residual (360 ft^3 of C-112 residual waste)
- Infrastructure Residual.

4.7.2 Past Leaks

The past leak with the largest mobile contaminant inventory is the UPR-200-E-86, a pipeline leak near the southern part of the WMA. Table 4-7a displays the peak contaminant groundwater concentration at the WMA fence line (fence-line averaged), the exclusion boundary, and the Columbia River for each of the major contaminants. Table 4-7b displays the data for all past leaks.

Table 4-7a. UPR-200-E-86 Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Example of Past Leak).

Contaminant	WMA Fence Line (fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	193.81	30.70	11.00
I-129	0.37	0.06	0.02
U	1.16	0.18	0.06
Cr	1.83	0.29	0.10
NO2	45.18	7.15	2.56
NO3	37.70	5.97	2.13

Table 4-7b. Groundwater Concentrations (pCi/L or µg/L) from All Past Leaks at Key Locations.

Contaminant	WMA Fence Line (fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	413.23	65.46	23.45
I-129	0.80	0.13	0.05
U	6.00	0.95	0.34
Cr	3.61	0.57	0.20
NO2	132.01	20.91	7.49
NO3	253.41	40.14	14.38

4.7.3 Potential Retrieval Leaks

In this analysis, potential retrieval leaks are assumed for two tanks (C-106 and C-107), and each is treated in the same manner. The main difference is that the leaked inventory depends on the current waste inventory of each tank. Table 4-8a displays the peak contaminant groundwater concentration from an 8,000 gal leak (based on C-106) at the WMA fence line (fence-line averaged), the exclusion boundary, and the Columbia River for each of the major contaminants. Data for tank C-107 are given in Table 8b, while the total from both potential leaks is given in Table 4.8c. Results for the 20,000 gal leak case are shown in Appendix C.

Table 4-8a. 8,000 Gallon Potential Retrieval Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Based on Tank C-106).

Contaminant	WMA Fence Line (fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	8.41	1.34	0.45
I-129	0.45	0.07	0.02
U	0.35	0.06	0.02
Cr	0.17	0.03	0.01
NO2	4.12	0.66	0.22
NO3	0.21	0.03	0.01

Table 4-8b. 8,000 Gallon Potential Retrieval Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Based on Tank C-107).

Contaminant	WMA Fence Line (fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	7.27	1.16	0.39
I-129	0.01	0.00	0.00
U	11.44	1.82	0.61
Cr	0.23	0.04	0.01
NO2	25.55	4.07	1.36
NO3	46.57	7.41	2.47

Table 4-8c. 8,000 Gallon Potential Retrieval Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Based on Both Tank C-106 and C-107 Leaking).

Contaminant	WMA Fence Line (fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	15.68	2.50	0.83
I-129	0.46	0.07	0.02
U	11.79	1.88	0.63
Cr	0.40	0.06	0.02
NO2	29.67	4.72	1.57
NO3	46.78	7.45	2.48

4.7.4 Tank Residual

Tank C-112 is used as an example because it is the tank modeled in the simulations. Other tanks, because of their different properties, will have different inventories and, therefore, different concentrations. Complete results are presented in Appendix C. Table 4-9a displays the peak contaminant groundwater concentration from the C-112 residual waste at the WMA fence line (fence-line averaged), the exclusion boundary, and the Columbia River for each of the major contaminants. Table 4-9b shows the sum over all 100- and 200-series tanks.

Table 4-9a. C-112 Tank Residual Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Diffusion-Dominated Release: $D = 6 \times 10^{-7}$ cm^2/s).

Contaminant	WMA Fence Line (fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	1.74	0.27	0.10
I-129	0.01	0.00	0.00
U	0.00	0.00	0.00
Cr	0.03	0.01	0.00
NO2	0.84	0.13	0.05
NO3	0.04	0.01	0.00

Table 4-9b. WMA C Tank Residual Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Diffusion-Dominated Release: $D = 6 \times 10^{-7}$ cm^2/s).

Contaminant	WMA Fence Line (fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	61.09	9.55	3.53
I-129	0.11	0.02	0.01
U	18.10	2.83	1.05
Cr	0.79	0.12	0.05
NO2	31.73	4.96	1.84
NO3	69.95	10.94	4.05

4.7.5 Infrastructure Residual

At present, the inventory estimate for the residuals left in WMA C infrastructure is only on a WMA basis. Table 4-10 displays the peak contaminant groundwater concentration from the infrastructure residual waste at the WMA fence line (peak fence-line averaged), the exclusion boundary, and the Columbia River for each of the major contaminants.

Table 4-10. Infrastructure Residual Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Diffusion-Dominated Release: $D = 6 \times 10^{-7}$ cm^2/s).

Contaminant	WMA Fence Line (Fence-line Average)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	10.24	0.16	0.06
I-129	0.02	0.00	0.00
U	2.95	0.04	0.01
Cr	0.16	0.00	0.00
NO2	5.22	0.08	0.02
NO3	11.32	0.17	0.06

4.7.6 All Sources

Because the various sources have different time signatures, the peak groundwater concentrations from each source cannot be simply added. Rather, the impacts for the different sources at each time step must be added to create a composite curve. From the composite curve, the peak concentration from the WMA can be determined. Figures 4-12 shows the fence-line averaged groundwater concentrations for Tc-99 at the WMA C fence line. The shapes for the other contaminants (except U) are very similar as the contaminants are mobile. The uranium groundwater concentrations, because of retardation, are very small and are increasing slowly at 10,000 years. As expected from earlier results on the individual sources, past leaks provide the most important contribution. This is not unexpected as past leaks have the highest source inventory and are transported during times having the highest recharge.

Table 4-11 provides peak groundwater concentrations at the WMA fence line (peak fence-line averaged), the exclusion boundary, and the Columbia River for Tc-99, I-129, U, Cr, NO_2, and NO_3 respectively.

Figure 4-12. Tc-99 Groundwater Concentrations from All WMA C Sources.

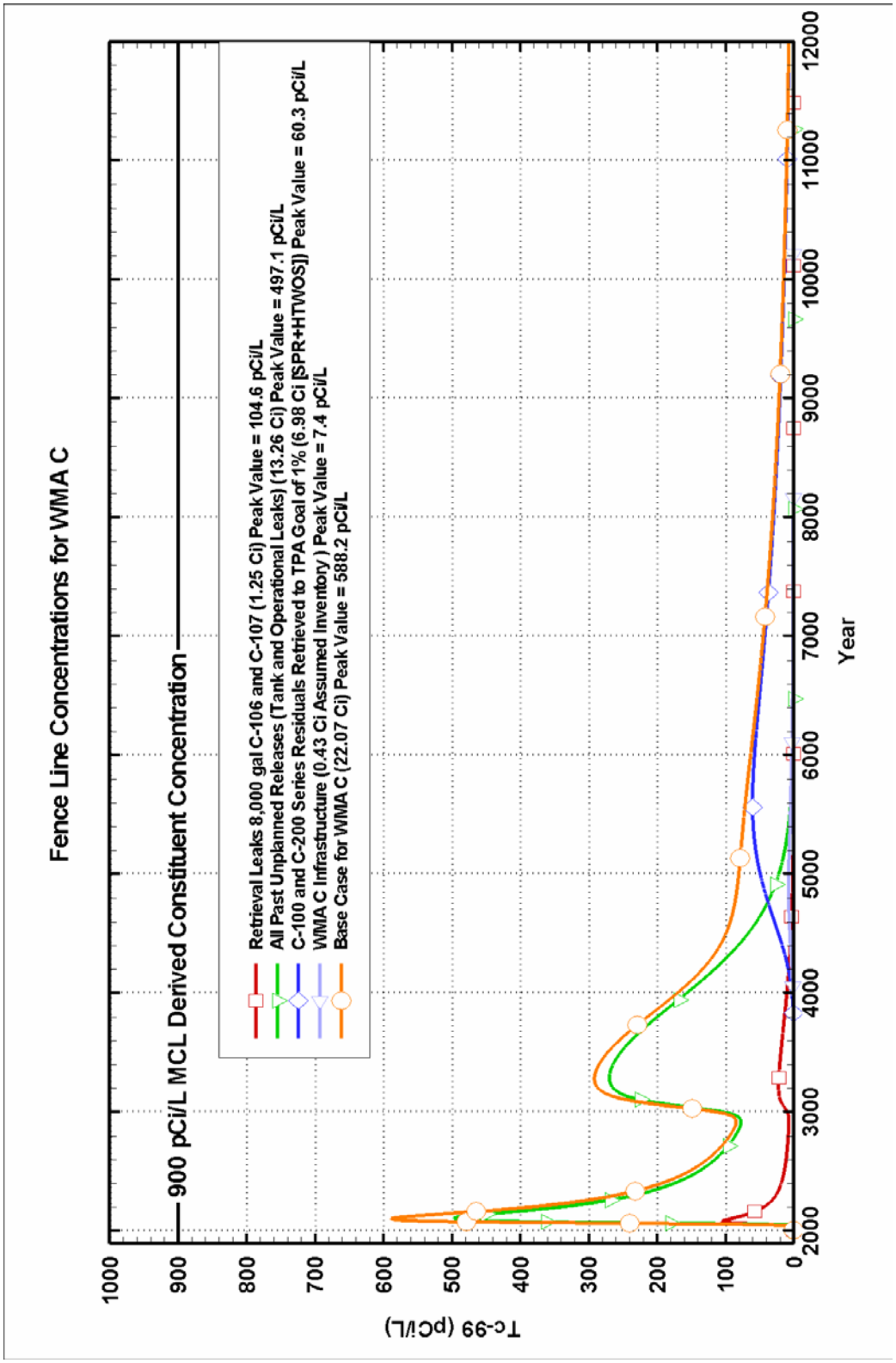


Table 4-11. Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations From All WMA C Sources.

Contaminant	WMA Fence Line (Fence-line Average)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	582.20	9.00	0.05
I-129	1.09	0.02	0.00
U	0.02	0.00	0.00
Cr	6.00	0.09	0.00
NO_2	227.00	3.51	0.02
NO_3	376.00	5.81	0.03

4.8 IMPACT ASSESSMENT

The values given so far have been for contaminant concentrations. However, for many cases the performance objectives are defined in terms of sums over contaminants using various weightings. Table 4-12 displays the peak contaminant groundwater concentration from the area around tank C-105 at the WMA fence line, the exclusion boundary, and the Columbia River for each of the major contaminants. The temporal shape for the impacts (except for alpha emitters) is the same as displayed in Figure 4-12 (Tc-99 groundwater concentration).

Table 4-12. Peak Groundwater Pathway Impacts from the WMA C at Key Locations

Impact	WMA Fence Line (Fence-line Average)	Eastward Flow	
		Exclusion Boundary	Columbia River
All-Pathways - Farmer (mrem in a year)	0.172	0.027	0.010
ILCR[a] (Industrial) (Cr only)	2.43×10^{-8}	3.41×10^{-9}	1.26×10^{-9}
Hazard Index (Industrial)	0.0075	0.0011	0.0004
Alpha-Emitters (pCi/L)	0[b]	0[b]	0[b]
Beta/gamma Emitters (mrem in a year)	0.172	0.027	0.010

[a]ILCR is the incremental lifetime cancer risk.

[b]The only alpha emitter explicitly calculated is uranium, which is not governed by standard. However, based on strong retardation of other alpha-emitters in Hanford soils (K_d > 1 ml/g), concentrations of regulated alpha emitters should not be present during the 10,000 years of analysis.

The calculations indicate that Tc-99 is slightly more important than I-129 for radiological impacts. For the all-pathways impact, Tc-99 contributes ~63% of the dose, with I-129 providing ~37%. For the drinking water dose, Tc-99 contributes ~75% of the dose.

Only one of the chemicals simulated (Cr) contributes to the chemical ILCR. The peak fence-line averaged radiological ILCR at the WMA C fence is 9.32×10^{-7}, ~90% of which comes from Tc-99.

The chemicals contribute to the hazard index. Chromium is the important contributor (~52%), with nitrite providing slightly less (~42%). Nitrate is third with ~6% contribution. Uranium hardly contributes at all with ~0.06%.

4.9 UNCERTAINITIES

4.9.1 Summary

Because this preliminary performance assessment is being performed early in the life of the closure project, there are significant uncertainties in the data used and even, in some cases, in the methods used. The following sections discuss the major areas of uncertainties:

- 4.9.2 Inventory
- 4.9.3 Release Rates
- 4.9.4 Recharge and Water Flow
- 4.9.5 Contaminant Transport

The areas having the largest impact are the uncertainties in inventory and release rates. A large body of data already exists for the Hanford vadose zone and groundwater. Inventory and release rates not only depend on decisions yet to be made, and the data bases for these areas are weak.

4.9.2 Inventory

Because there are four categories of sources (past leaks, potential retrieval leaks, residual waste in tanks, and residual waste in infrastructure) and each of the categories have very different properties, the uncertainties in the cases are discussed separately.

4.9.2.1 Past Leaks The impacts from past leaks are the largest of the four categories. They probably have the lowest uncertainties. The volumes and waste types of the major past leaks are fairly well known. There are plans (RPP-16608) to perform field characterization in the region around UPR-200-E-82 (both shallow direct penetration and deep [~150 to 200 ft (46 to 61 m)] borehole) and around the suspected tank C-105 retrieval leak (deep borehole) to validate the information.

Although it is possible that there are other examples of past leaks in this WMA that have not been found, the inventories used in this analysis are thought to be representative of the total past inventories. Historical records have been thoroughly searched (Wood 2003). Analyses (Wood

2003) of both internal tank waste levels and gamma ray measurements external to the large tanks also indicate no further large tank leaks other than that from tank C-105.

4.9.2.2 Potential Retrieval Leaks. The retrieval of the wastes from the tanks is just beginning. Tank C-106 has had most of its liquids removed, and efforts are continuing to reach a residual volume no larger than required by the HFFACO. There have been significant efforts to retrieve liquids from the SST system. This project, known as interim stabilization, is nearly finished. To date, there have been no known tank leaks from this effort.

However, leaks may occur during the retrieval of the solids. Previous leaks that have been plugged may become unplugged. Tank structures may weaken and fail. During retrieval, only two tanks (C-106 and C-107) are currently planned to undergo a process called modified sluicing, during which large volumes of water are added to the tanks. The other tanks will undergo dry retrieval, during which only very limited amounts of water will be added or a vacuum will be used to remove dry flaky material.

An estimate of 8,000 gal is used in this analysis as the volume of fluid leaked out of a total volume of 250,000 gal of fluid in the tank; that is, 3.2% of the initial inventory is lost to the soil). The estimated leak volume or source volume is likely to be incorrect. Therefore a second set of calculations for C-106 and C-107 were performed assuming 20,000 gal were lost, out of a volume of 250,000 gal; that is, 8% of the initial inventory is lost to the soil. This second case increases the amount leaked by a factor of 2.5. As seen from Table C-5, such an increase still results in groundwater concentrations below drinking water goals of 900 pCi/L for ^{99}Tc and 1 pCi/L for ^{129}I.

It is possible that the retrieval methods presently planned may change. Assuming an 8,000 gal loss during retrieval from tank C-104, then the ^{129}I groundwater concentrations would exceed 1 pCi/L. Considered individually, 8,000-gal retrieval leaks from other tanks would not be a concern. However, if all the tanks each leaked 8,000 gallons, then the ^{99}Tc would barely exceed 900 pCi/L.

4.9.2.3 Residual Waste in Tanks. Currently, all of the tanks in the WMA C exceed the HFFACO requirement for the volume of remaining residual waste. Prior to actual retrieval, it is not possible to accurately predict the volume of residual waste to be left in each of the tanks. Moreover, current inventory estimates are uncertain and because different retrieval methods will retrieve different contaminants with different (and presently unknown) efficiencies, the amount of important contaminants left in the tanks is not known. A series of sensitivity cases were performed to evaluate volumetric uncertainties assuming current inventory estimates are correct.

The effect of uncertainty of the residual volume translates directly into the uncertainty in the groundwater concentrations and hence risks impacts. Thus, if half of the HFFACO commitment residual volume limit were left in the tank, the estimated concentrations and impacts due to residual waste in tanks would be reduced by a factor of 2.

Table 4-13 displays the effect of the different inventories associated with the various retrieval technologies considered in this analysis (base case: C-106 and C-107 retrieved using modified sluicing with the remaining tanks being dry retrieved, all tanks being sluiced, all tanks being dry

retrieved, and present inventory reduced by the ratio to meet TPA commitments). Sluicing is projected to remove most of the soluble contaminants. The soluble contaminants cause groundwater impacts. Dry retrieval, on the other hand, redistributes the contaminant far less. The main change in relative concentrations for dry retrieval is due to the liquid component (containing the soluble and mobile contaminants) being removed. Straight volume reduction assumes no change in relative inventory amounts from current conditions. The base case assumes the present plans, but these plans may change.

Table 4-13. Fence line Averages of Groundwater Concentrations (pCi/L or µg/L) for the Various Residual Waste Cases at the WMA C Fenceline Assuming Different Inventories because of Different Planned Retrieval Scenarios for Each Tank

Tank	Tc-99	I-129	U	Cr	NO_2	NO_3
Base Case (C-106 and C-107 are sluiced, with the remaining tanks dry retrieved)	18.69	0.03	5.76	0.25	10.09	22.25
All tanks sluiced (i.e., use HTWOS values)	0.00	0.01	0.00	0.06	2.32	5.66
All tanks dry retrieved (i.e., use phase separation values)	21.10	0.04	6.09	0.33	10.78	23.37
Present inventories reduced by ratio of volume needed to attain HFFACO commitments	20.12	0.04	6.00	0.26	10.91	23.34

4.9.2.4 Residual Waste in Infrastructure. The amount of residual waste in the farm infrastructure is presently just an estimate. How this waste varies as a function of its position within the farm is unknown. What is known is the functional dependence of this uncertainty to the groundwater concentration and uncertainty. Again, the effect of uncertainty of the residual volume translates directly into the uncertainty in the groundwater concentrations and, hence, risk impacts. Thus, if half of the HFFACO residual volume limit commitment were left in the tank, the estimated concentrations and impacts due to residual waste in infrastructure would be reduced by a factor of 2.

4.9.2.5 Inventory Uncertainty Summation.

Because past leaks drive the peak groundwater concentrations, the uncertainty in the past leak inventory is most important. Fortunately, this inventory is relatively the best known and will be verified with planned field investigations.

Another important uncertainty is the tank residual inventory, which is affected by current inventory estimate uncertainties and future retrieval methods. If modified sluicing is used on more tanks, the estimated inventory resulting from potential leaks would increase over the base case, but the amount of soluble (and mobile) contaminants left in the tanks would decline. The exact relationship depends on the amount of leak volume assumed for each tank (an additional unknown). Until more experience is gained concerning retrieval efficiencies and potential leak volumes, only estimates can be made.

Uncertainties in residual waste in infrastructure is relatively unimportant given the unknowns in retrieval methods and efficiencies for waste currently in the tanks.

4.9.3 Release Rates

The base case assumes that the waste will be entrapped in a cementitious waste form that hinders moisture flow. Hence, the release mechanism is assumed to be diffusion-dominated. Table 4-14 displays fence line averages of groundwater concentrations for the various cases at the WMA C fence line assuming the planned retrieval scenarios for each tank.

As seen from Table 4-14, peak groundwater concentrations are sensitive to the assumed contaminant release rate. For fast release rates (i.e., for releases that occurring for times less than 1,000 years), the peak groundwater concentration is fairly insensitive to the release rate. However, for longer release times, the peak concentration values can vary by a factor of 3.

The present assumption (diffusion-dominated release) is in the middle of this range. Reducing the effective diffusion coefficient by an order of magnitude (6×10^{-7} cm^2/s to 5×10^{-8} cm^2/s) reduces the peak concentrations and the impacts by only about a factor of 2 and moves the peak out in time.

Choosing other release models (for example, advection-dominated release where water flow is the important process or solubility-controlled release where chemical dissolution is key) results in smaller values. More research on actual waste and closure methods is needed to resolve the assumptions.

Table 4-14. Fence line Averages of Groundwater Concentrations (pCi/L or µg/L) for the Various Residual Waste Cases at the WMA C Fence Line Assuming Various Contaminant Release Rate Scenarios.

Tank	Tc-99	I-129	U	Cr	NO2	NO3
Base Case (Diffusion Dominated Release Rate ($D_{eff} = 6 \times 10^{-7}$ cm^2/s)	61.36	0.11	32.24	1.37	59.38	106.52
Release Rate (10^{-3}/yr for 500 years and 0.1/yr for 5 years)	212.33	0.43	61.27	3.34	108.44	235.10
Release Rate (0.1/yr for 10 years)	195.80	0.35	58.02	2.52	101.70	224.17
Release Rate (10^{-4}/yr for 500 years and 0.01/yr for 95 years)	195.50	0.35	57.93	2.52	101.55	223.83
Release Rate (10^{-5}/yr for 500 years and 0.001/yr for 995 years)	169.03	0.30	50.08	2.18	83.74	190.74
Diffusion Dominated Release Rate ($D_{eff} = 5 \times 10^{-8}$ cm^2/s)	46.32	0.08	13.72	0.60	24.06	53.03
Release Rate (10^{-6}/yr for 500 years and 0.001/yr for 9,995 years)	25.72	0.05	7.62	0.33	13.36	29.44
Advection-Dominated Release Rate	18.69	0.03	5.76	0.25	10.09	22.25
Solubility-Controlled Release Rate	209.9	0.40	62.2	2.7	109.0	240.4

4.9.4 Recharge and Water Flow

Recharge and hydraulic conductivities were not explicitly investigated by the computer simulations made in this analysis. However, earlier analyses (such as the FIRS [Kneep 2002a and 2002b] and the ILAW PAs [Mann 2001] and the IDF risk assessment [Mann 2003]) show that recharge is a key parameter, while unsaturated hydraulic conductivities in the vadose zone soil play less of a role. However, the saturated hydraulic conductivity of the aquifer is important.

The base case assumes that permanent surface barriers are emplaced at year 2050 and last 500 years, instantly degrading to natural conditions (3.5 mm/yr). Until the permanent barriers are installed, enhanced recharges of 100 mm/yr occur. Because of this enhanced recharge, past leaks and potential retrieval leaks move relatively quickly to groundwater. The S/SX FIR (Knepp 2002a) shows that recharges of lower than 100 mm/yr reduce moisture flow and contaminant transport and result in lower impacts and slightly longer travel times. Recharge values of 50 mm/yr result in groundwater concentrations and impacts that are about a factor of 2 lower than the results of 100 mm/yr. The amount of recharge through tank farm surfaces is now being studied. Recharge values of 100 mm/yr seems to be on the high side with 50 mm/yr being on the low. The S/SX FIR also shows that placing a temporary surface cover in 2010 over past leaks could reduce their groundwater concentrations and impacts by about a factor of 2.

The degradation of the surface barrier has less impact as long as the surface barrier degrades in the few thousand-year time frame. Whether the barrier degrades instantly or over a thousand years has little effect on groundwater concentrations or impacts because the low natural recharge rates result in travel times very much longer than the barrier degradation times. Although explicit calculations for different long-term recharge rates have not been done for residual wastes, it is expected that the impacts from residual wastes will depend on the natural recharge rate assumed. The value used (3.5 mm/yr) is larger than expected for the soil type found around the C tank farm area (0.9 mm/yr) (Fayer 1999). Moreover, the impacts from residual waste are much smaller than from past leaks or potential retrieval leaks, which will occur before the barrier is installed.

Because of the long timeframes involved in these analyses, the soil moisture content adjusts to variable conditions relatively quickly. Thus, a unit gradient condition quickly occurs. In this condition, the unsaturated hydraulic conductivity adjusts (based on moisture content) to allow a constant flow of water though the vadose zone system equal to that of the applied recharge rate. Thus, uncertainties in hydraulic conductivity are reflected in uncertainties in moisture contents rather than in moisture and mobile contaminant transport.

Uncertainties in groundwater flow, in contrast, are important. Because the groundwater flow is so much larger than the vadose zone moisture flow, there is a large dilution in contaminant concentration when the contaminant enters the groundwater. Because this dilution changes linearly with the inverse of the groundwater flow (a product of hydraulic conductivity and hydraulic gradient, the difference in water pressures between the two points of moisture flow), hydraulic conductivity is important. However, the contaminant concentration is not inversely proportional to hydraulic conductivity as pressure differences lessen as hydraulic conductivity increases. For example, an increase in saturated hydraulic conductivity for the unconfined aquifer by an order of magnitude for Case 1 (8,000 gal retrieval leak) decreased the fenceline

concentration by a factor of 8.2, while for Case 11 (diffusion dominated release) decreased the concentration by a factor of 10. No additional water was released with Case 11. Again, field measures in the summer of 2003 should allow better estimations of groundwater flow rates near WMA C. Future assessments will look explicitly at the dependence of impacts on various assumed recharge rates and the new groundwater flow rate data.

4.9.5 Contaminant Transport

In general, the contaminants chosen for this study (Tc, I, Cr, NO_2, and NO_3) are mobile (i.e., they move with the moisture flow and do not experience retardation due to soil interactions). Uranium is conservatively assumed to have a distribution coefficient of 0.6 mL/g. In reality, much of the Cr will not be in the mobile form of Cr^{6+}. Thus, the values presented here for Cr and U should be conservative. However, the uncertainty in values for Tc, I, NO_2, and NO_3 (the contaminants that drive the analysis) due to chemical effects in transport should be small as numerous experiments have shown that these contaminants are not retarded in Hanford soils.

4.9.6 Summary

The natural system underneath the tanks is fairly well understood and thus provides relatively little uncertainty to the results. However, the man-made system is very uncertain. There are a large number of decisions to be made in the future (e.g., type of retrieval, degree of retrieval, efficiency of retrieval, type of closure) that will have a very large and significant impact on the accuracy of the results presented here. The largest uncertainties deal with inventory (the amount/composition of residual waste and the amount/composition of potential retrieval leaks). Closure methods will affect the next largest area of uncertainty (infiltration rates and residual release rates).

4.10 CUMULATIVE IMPACTS FROM HANFORD SITE ACTIVITIES

The Defense Nuclear Facilities Safety Board recommended (DNFSB 1994) that, when evaluating the impact of the disposal of radioactive waste, DOE consider not just the impact from the disposal action under consideration but all other government actions that might affect those impacts. This recommendation has been inserted into DOE O 435.1 (DOE 1999b). The Richland Operations Office has submitted a composite analysis (Kincaid 1998) that addressed all the Hanford Site's disposal and closure actions on the Hanford Site's Central Plateau for which inventories had been established. The DOE has conditionally approved this composite analysis (DOE 1999d).

A composite analysis (Kincaid 1998) was submitted to DOE-Headquarters supporting the active and planned low-level waste disposal on the 200 Area Plateau and was conditionally approved (DOE 1999d). It is a companion analysis to the performance assessments for active and planned disposal and remedial investigations and feasibility studies for remediation sites. With some limitations, primarily based on available inventory data, this was a first iteration analysis to discover the potential long-term impacts to an offsite individual from all waste forms residing at

the Hanford Site at the time of Site closure. For the composite analysis, the offsite individual resided outside the exclusive WMA and buffer zone as defined by the HFSUWG (1992). The analysis considered a 1,000-year regulatory period following Site closure and reached the following conclusions:

- Significant releases from the liquid discharge sites, tank leaks, losses from tanks during tank waste recovery operations, and pre-1988 solid waste burial grounds in-place before Site closure were separated in time significantly from any discharges from the active or planned disposal.

- Peak all-pathways dose to the maximally exposed individual outside the buffer zone after Site closure (assumed in 2050) was less than 6 mrem in a year. This was the result of the agricultural scenario. Lower doses resulted from the residential, industrial, and recreational scenarios. Despite high uncertainty in the inventories of past liquid discharges, tank leaks, tank losses, and pre-1988 burial grounds, these analyses indicated the dose outside the buffer zone would not exceed the dose constraint of 30 mrem in a year.

- Maximum contaminant concentrations are highest now and will decline with time. Releases from liquid discharge sites, tank leaks, future tank losses, and pre-1988 burial grounds continue to enter the aquifer over the next few decades, but, in general, the rate of nuclide mass releasing to the aquifer will decline from now until Site closure and then continue to decline.

- No releases from the TWRS ILAW disposal facilities, the ERDF trench, and the graphite cores of the production reactors are seen during the regulatory period of 1,000 years or the full 1,500 years analyzed.

The Hanford Site composite analysis is being maintained. The last annual summary was issued in 2002 (Bergeron 2002). The next version of the Hanford Site composite analysis is expected to be published in 2004.

4.11 SUMMARY OF GROUNDWATER PATHWAY CASES

Of the four sources (past leaks, potential leaks, residual waste in tanks, and residual waste in infrastructure), the highest impacts from the groundwater pathway are expected to be from past leaks. This source is also the best known and has the fewest uncertainties, especially from future decisions. However, depending on future decisions and actions (decisions on retrieval method and residual waste volume, and accidental tank ruptures leading to retrieval leaks), other sources could become more important.

Using current planning (as implemented in the base case), the estimated groundwater impacts are below performance standards as seen by the comparison in Table 4-15.

Table 4-15. Peak Groundwater Pathway Impacts from the WMA C Compared Against Performance Objectives.

Impact	WMA Fence Line (Fence-line Average)	Performance Objectives
All-Pathways - Farmer (mrem in a year)	0.172	25.
ILCR[a] (Industrial) (Cr only)	2.43×10^{-8}	1.0×10^{-5}
Hazard Index (Industrial)	0.0075	1
Alpha-Emitters (pCi/L)	0[\b]	15 pCi/L
Beta/gamma Emitters (mrem in a year)	0.172	4.0

[a] ILCR is the incremental lifetime cancer risk.

[b] The only alpha emitter explicitly calculated is uranium, which is not governed by standard. However, based on strong retardation of other alpha-emitters in Hanford soils (K_d > 1 ml/g), concentrations of regulated alpha emitters should not be present during the 10,000 years of analysis.

4.12 TRANSURANIC WASTE DISCUSSION

Some of the tanks may contain more than 100 nCi/g of TRU after retrieval is complete. To show that this residual waste is not hazardous requires an additional set of analyses. These analyses assume that:

1) The presently assumed retrieval methods are used (modified sluicing for tanks C-106 and C-107 and dry retrieval for the remaining tanks).

2) The residual volume will met HFFACO commitments of 360 ft^3 for 100-series tanks and 30 ft^3 for 200-series tanks.

3) The amount of TRU source material used as a comparison is the amount used to produced the waste (conservatively assumed to be 100 times the residual amount of TRU left in the tanks).

4) The release rate is given by diffusion-dominated release (i.e. 92% of the mobile contaminants reach the groundwater during 10,000 years).

5) Sr, Tc, Sn, I, and Cs experience no retardation (which is very conservative for Sr, Sn, and Cs).

6) The retardation experienced by Ra, Th, and Np is the same as experienced by U (which is very conservative).

7) The retardation experienced by Pu and Am is governed by a K_d of 1. mL/g (very conservative).

Table 4-16 presents the TRU cumulative release to groundwater during the first 10,000 years.

Table 4-16. TRU-Weighted Cumulative Release to Groundwater During the First 10,000 Years Assuming 1,000,000 Units of Source Material (per 40 CFR 191). (2 Pages)

Radionuclide	Performance Objective	HTWOS Inventory	Phase Separated Inventory	Base Case
^{90}Sr	1,000	6.04	5.25	2.79
^{99}Tc	10,000	222.35	183.78	65.76
^{126}Sn	1,000	42.27	26.07	35.01
^{129}I	100	33.16	21.14	9.92
^{134}Cs	1,000	0.24	0.19	0.21
^{137}Cs	1,000	0.69	0.22	0.24
^{226}Ra	100	$4.2x10^{-5}$	$3.7x10^{-5}$	$2.2x10^{-5}$
^{232}Th	10	$3.8x10^{-3}$	$3.7x10^{-3}$	$4.9x10^{-3}$
^{233}U	100	0.28	0.26	0.37
^{234}U	100	0.07	0.05	0.07
^{235}U	100	0.00	0.00	0.00
^{236}U	100	0.00	0.00	0.00
^{237}Np	100	0.01	0.01	0.01
^{238}Pu	100	0.00	0.00	0.00
^{238}U	100	0.06	0.04	0.06
^{239}Pu	100	0.04	0.04	0.05
^{240}Pu	100	0.01	0.01	0.01
^{241}Am	100	0.05	0.05	0.04
^{242}Pu	100	$4.3x10^{-7}$	4.0X10-7	$4.1x10^{-7}$
^{243}Am	100	$1.2x10^{-6}$	1.3X10-6	$1.0x10^{-6}$

Iodine-129 is the radionuclide closest to the limit (a little over a factor of 10) for the base case inventory. Other radioisotopes have larger margins for the base case inventory (Sr-90: 300, Tc-99: 160, Sn-126:30, and Cs isotopes: 4000). The higher mass radioisotopes have margins of 300 (U-233) to well over 1,000. These numbers are relatively insensitive to inventory methodology assumed. Also, since practically all of the inventory reaches groundwater (92%), the results are insensitive to the release rate model.

However, the results are sensitive to the amount of waste left in the tanks. Thus, it is not possible to place a strict probabilistic uncertainty on the results. However, given the low results in Table 4-16 and that these results are based on quite conservative assumptions, if the HFFACO commitments are met, it is very likely that there is less than 1 chance in 10 that performance

objectives in Table 4-16 would not be met and that there is less than 1 chance in 1,000 that values would exceed 10 times the performance objectives.

4.13 EFFECTS OF RELEASES TO AIR

Earlier performance assessment analyses (Wood et al. 1995a and 1996, Mann et al. 2001) have shown that the effects of contaminant releases to the air are negligible for both ILAW and solid waste buried in trenches with more than 16 ft (5 m) of cover above the waste. The estimated inventories for ^{3}H, ^{14}C, and transuranic nuclei contributing to the ^{222}Rn inventory are small for WMA C. For this risk assessment, we will use a simpler approach to bound the estimated air doses associated with ^{3}H and ^{14}C from the WMA C. The method developed for the 2001 ILAW PA (Mann et al. 2001) has been used to estimate the ^{222}Rn flux at the surface.

4.13.1 Calculational Approach

The principal mechanism by which nuclides migrate from the waste to the ground surface is gaseous diffusion. The analyses in the previous performance assessments have shown that other mechanisms such as capillary action, upward moisture diffusion, atmospheric pressure and temperature variations, wind, and rainfall have negligible secondary effects on the release of contaminants to the air (Mann et al. 2001). The diffusion of radioactive gases such as tritium (as water vapor), ^{14}C (as carbon dioxide), and ^{222}Rn (an inert gas) can be represented using Fick's Law of diffusion with a loss term for radioactive decay (Jury 1991). The amount available for diffusion, i.e, the source concentration is changing with time due to the release mechanism for the contaminants from the waste form and radioactive decay. Two cases (one for tritium and ^{14}C and the other for ^{222}Rn) must be considered because a decay chain that includes ^{238}U, ^{234}U, ^{230}Th, and ^{226}Ra is producing the ^{222}Rn, whereas tritium and ^{14}C are the original source material.

Because the estimated WMA C closure inventories for ^{3}H and ^{14}C are small, a bounding calculational approach has been used to estimate the air release doses for this risk assessment. Specifically, as annual fluxes are regulated, ^{3}H and ^{14}C inventories are released over a 1-year period for the different inventory source terms associated with WMA C. Air release doses are estimated for the combined past leaks and the retrieval leaks, and for the combined residual tank wastes in the tanks and the ancillary equipment. These air pathway doses are estimated by multiplying the initial inventories for ^{3}H and ^{14}C by their corresponding dose factors (Rittmann 1999) and summing the estimated dose from these two contaminants.

The approach developed for the 2001 ILAW PA (Mann et al. 2001) has been used to estimate the ^{222}Rn flux for the leaks (past and retrieval) and residual tank waste (tank and ancillary equipment). The source concentration of ^{222}Rn is based on the amount of ^{226}Ra that has been released from the waste form. The ^{226}Ra produces ^{222}Rn by radioactive decay. The amount of ^{226}Ra slowly increases for two reasons. First, an increasing fraction of the inventory is released from the waste form as time increases. Second, ^{226}Ra is being produced by the radioactive decay of ^{238}U and ^{234}U. If we ignore the transport of the uranium from its initial location within the waste, the peak ^{222}Rn flux occurs after all the contaminants are released from the waste form and

the ^{226}Ra has reached radioactive equilibrium with the ^{238}U. This equilibrium occurs on time frames greater than 1×10^6 years after closure.

For calculating the ^{222}Rn diffusion rate in the presence of radioactive decay, the source concentration is assumed to be constant. This assumption tends to exaggerate the diffusion flux at the surface. The steady-state diffusion equation is shown below. It also assumes the diffusion characteristics of the waste cover are uniform with depth.

$$D\frac{\partial^2 C}{\partial z^2} = \lambda C$$

The solution to the above equation has an exponential dependence in elevation as shown below. The boundary conditions that the soil concentration is C_0 at the waste (z=0) and zero at the surface ($z=z_0$) have been included. The solution is only valid from z=0 to $z=z_0$.

$$C = C_0\left[\frac{e^{-z\sqrt{\lambda/D}} - e^{-(2z_0 - z)\sqrt{\lambda/D}}}{1 - e^{-2z_0\sqrt{\lambda/D}}}\right]$$

$$J(z) = -D\frac{\partial C}{\partial z} \quad \text{thus} \quad J(z_0) = \frac{2\sqrt{\lambda D}\, C_0\, e^{-z_0\sqrt{\lambda/D}}}{1 - e^{-2z_0\sqrt{\lambda/D}}}$$

where

- C = gas concentration at elevation z in the soil, Ci/m^3. At the bottom of the soil cover, the soil concentration matches the gas concentration in the waste, i.e., $C=C_0$. At the top of the cover the gas concentration is zero.
- D = diffusion coefficient for low atomic number gases moving through media above waste (soil diffusion coefficient = 0.01 cm^2/s = 31.56 m^2/yr
- J = upward diffusion flux, $Ci/m^2/yr$
- z = vertical position in the soil, m. The bottom of the soil column is z=0, while the ground surface is $z=z_o$
- λ = radioactive decay constant for the nuclide, per year.

4.13.2 Air Releases from Leaks.

Air releases from leaks are associated with both past leaks and anticipated retrieval leaks. From Table 3-7 the estimated inventories associated with the anticipated retrieval leaks (8,000 gal) are

approximately a factor of 10 lower than the estimated past leak inventories for the contaminants on concern listed in the table. We have assumed the ^{3}H, ^{14}C, and ^{238}U inventories associated with the retrieval leaks are in the same ratio as the COCs listed in Table 3-7. Therefore, the inventory associated with both the past leaks and estimated retrieval leaks is 1.1 times the inventories for ^{3}H, ^{14}C, and ^{238}U provided in Table 3-2. The estimated inventories (decayed to January 2001) are 3.2 Ci ^{3}H, 2.1 Ci ^{14}C, and 0.071 Ci ^{238}U.

To bound the estimated air releases and corresponding doses for ^{3}H and ^{14}C, the entire leak inventory is assumed to be released over a 1-year period. The unit release dose factors from *Exposure Scenarios and Unit Dose Factors for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (Rittmann 1999) are 2.37×10^{-2} mrem/Ci for ^{3}H and 1.32 mrem/Ci for ^{14}C. Therefore the bounding air pathway dose is estimated to be 2.8 mrem/yr (= $3.2*2.37 \times 10^{-2}+2.1*1.32$ mrem/yr). The estimated air pathway dose from leaks is 2.8 mrem/yr and is predominately due to the estimated ^{14}C inventory. This estimated air pathway dose is smaller than the performance objective of 10 mrem/yr. This estimate is extremely conservative because it assumes that ^{3}H and ^{14}C are released in a single year and because it ignores the chemical interactions of the released ^{3}H and ^{14}C with the other waste constituents and the soil.

The ^{222}Rn flux depends on the relative inventory of ^{222}Rn in the waste, the effective surface area over which the^{222}Rn gas is emitted, and the transit time for the ^{222}Rn through the soil above the waste. The ^{230}Th, ^{226}Ra, and ^{222}Rn are all in radioactive equilibrium with the ^{238}U after approximately 1,000,000 years. If we assume no migration of the ^{238}U from the original leak site, then the ^{222}Rn inventory equals the ^{238}U inventory (0.071 Ci). To conservatively estimate the ^{222}Rn surface flux from leaks, we have assumed that the entire leaked inventory was at a depth of 30 ft (9.14 m) and uniformly distributed in a circular areal distribution 25 ft (7.62 m) in diameter. The leaked liquid would fill all the available pore space (assumed the sand H2 saturated porosity = 0.3819 from Table D-5, RPP-13310). The estimated leaked liquid is 57,000 gal from past leaks (Table 3-2) and 8,000 gal from retrieval leaks (total = 65,000 gal). Therefore, the estimated soil volume containing all leaked inventories is estimated to be 22,753 ft^3 = 65,000*0.13368/0.3819 ft^3 (645 m^3). This volume estimate ignores the fact that these leaks occurred at different times and in different places.

The calculation of the diffusion flux for ^{222}Rn is carried out using the formula given in equation 4.3. Assuming a depth of z_o= 30 ft (9.1 m), the diffusion flux at the ground surface is 1.79×10^{-8} Ci/m^2 per year, or 5.67×10^{-4} pCi/m^2 per second. This estimated ^{222}Rn flux is significantly lower than the performance objective of 20 pCi/(m^2 per s).

The estimated dose calculations and flux calculations for air releases from leak sources are conservative for the following reasons:

- The past leaks occurred at different times greater than 40 years prior to the anticipated closure of the WMA C and most of the ^{3}H and ^{14}C gases should have already diffused to the air prior to closure.

- The past tank leak for tank C-105 and the anticipated retrieval leaks occurred at a depth greater than30 ft (9.1 m).

- No credit was taken for any chemical reactions that would limit the ^{3}H and ^{14}C release as a gas (i.e., all the ^{14}C was assumed to be released as a gas).
- The estimated ^{222}Rn flux ignores any movement of the ^{238}U and its daughters from the leak site over the time period that the ^{222}Rn inventory builds up (over 1,000,000 years).
- The estimated ^{222}Rn flux grossly overestimates the available ^{222}Rn inventory produced as a daughter product for times up to 10,000 years after facility closure.

4.13.2 Air Releases from Residual Tank Waste

Air releases from the residual tank waste are associated with the residual waste in the tanks and the residual waste in the ancillary equipment. From Table 3-7, the estimated inventories associated with the residuals in the ancillary equipment are approximately a factor of 10 less than the estimated inventories associated with the residuals in the tanks for the contaminants of concern listed in the table. We have assumed the ^{3}H, ^{14}C, and ^{238}U inventories associated with the residuals in the ancillary equipment are in the same ratio as the COCs listed in Table 3-7. Therefore, the inventory associated with the all the tank residuals is estimated to be 1.1 times the tank residual inventories given in Table 3-5a. Therefore, the estimated tank waste residual inventory is 1.46 Ci ^{3}H, 0.305 Ci ^{14}C, and 0.802 Ci ^{238}U.

To bound the estimated air releases and corresponding doses for ^{3}H and ^{14}C, the entire leak inventory is assumed to be released over a one year period. The unit release dose factors are 2.37×10^{-2} mrem/Ci for ^{3}H and 1.32 mrem/Ci for ^{14}C (Rittmann 1999). Therefore, the bounding air pathway dose is estimated to be 0.44 mrem/yr (= $1.46*2.37 \times 10^{-2}+0.305*1.32$ mrem/yr). The estimated air pathway dose from leaks is 0.44 mrem/yr and is predominantly due to the estimated ^{14}C inventory. This estimated air pathway dose is smaller than the performance objective of 10 mrem/yr. This estimate is extremely conservative because it assumes that ^{3}H and ^{14}C are released in a single year and because it ignores the chemical interactions of the released ^{3}H and ^{14}C with the other waste constituents and the soil.

The estimated inventory for ^{238}U from the residual tank waste (both in tanks and ancillary equipment) is 0.801 Ci. After approximately 1,000,000 years, the ^{230}Th, ^{226}Ra, and ^{222}Rn are all in radioactive equilibrium with the ^{238}U. If we assume no migration of the ^{238}U from the original leak site, then the ^{222}Rn inventory equals the ^{238}U inventory (0.801 Ci). The estimated tank residual waste volume is 360 ft^3 (10.2 m^3) for each 100-series tank and 30 ft^3 (0.85 m^3) for each 200-series tank. The total residual tank waste volume from all tanks is 125.8 m^3 (= 12*10.2 + 4*0.85 m^3) (4,440 ft^3). Therefore, the ^{222}Rn concentration is bounded by 6.37×10^{-3} Ci/m^3 (neglects ignores volume of residual tank waste in ancillary equipment).

The calculation of the diffusion flux for ^{222}Rn is carried out using the formula given in equation 4.4. Assuming a depth of z_o=50 ft (15.2 m), the diffusion flux at the ground surface is 1.51×10^{-10} Ci/m^2 per year, or 4.78×10^{-6} pCi/m^2 per second. This estimated ^{222}Rn flux is significantly lower than the performance objective of 20 pCi/m^2 per second.

The bounding estimates are significantly lower than the performance objectives. These estimated impacts are truly bounding for the following reasons:

- Estimated release rates from the residual tank waste were chosen to maximize the release of the ^{3}H and ^{14}C contaminants.
- No credit was taken for any chemical reactions that would limit the ^{3}H and ^{14}C release as a gas (i.e., all the ^{14}C was assumed to be released as a gas).
- The estimated ^{222}Rn flux ignores any movement of the ^{238}U and its daughters from the disposal facility over the time period that the ^{222}Rn inventory builds up (over 1,000,000 years).
- The estimated ^{222}Rn flux grossly overestimates the available ^{222}Rn inventory produced as a daughter product for times up to 10,000 years after facility closure.

4.14 EFFECTS FROM BIOTIC PATHWAYS

Because of the depth of placement of the waste placement (more than 49.2 ft [15 m]) and the presence of the steel-reinforced concrete dome and walls, biotic pathways are not credible. That is, the ability for plant and animal life to transport the contaminants is extremely unlikely. Neither plants nor animals have a direct means of access to waste over the time of compliance (1,000 years). Moreover, given the low moisture content inside the closed facility, plant roots would not survive.

4.15 EFFECTS OF CATASTROPHIC EVENTS

Based on the discussion presented in Section 3.3.2.4, the only scenario considered is that of an ice-age flood that scrapes away all material down to 65.6 ft (20 m) (the depth of the tanks), then redeposits the material over the area of the Hanford Site. As noted in Section 2.2.5.4, the next such event might be expected in about 50,000 years.

The ILAW PA (Mann 2001) showed that this scenario yields extremely low doses, because of the resulting distributed nature of the waste. Explicit calculations for tank residuals will be performed in future performance assessments.

4.16 ALARA ANALYSIS

To keep exposures as low as reasonably achievable (ALARA), design, operations, and analysis projects must cooperate closely. The RPP Retrieval/Closure Program is committed to such integration. The design for closing the tank farms are expected to be optimized using the results of these studies.

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5.0 RESULTS FOR AN INADVERTENT INTRUDER SCENARIO

5.1 OVERVIEW

The DOE intends to control the closed sites for as long as the waste may be dangerous to an intruder. However, DOE recognizes that an inadvertent intruder may happen onto the site and not be discovered until after exposure has occurred.

Because of the construction of Hanford's SSTs, it is very unlikely that an inadvertent intruder would reach the waste. The most credible scenario, a driller seeking to install a groundwater well, is not truly credible because drilling techniques normally used in the area would not penetrate the top of the tank. The top of the Hanford's large underground tanks consists of steel re-enforced concrete. The drilling techniques used in the mid-Columbia basin for installing groundwater wells would not penetrate steel re-enforced concrete for many hundreds, if not thousands, of years. However, to determine the impact of such an improbable intrusion, standard DOE performance assessment scenarios are carried out.

As noted in Section 1.6, the time of compliance is 500 years after closure. However, results will be presented for the period of 100 to 1,000 years after closure. The performance objective for the driller scenario is 500 mrem (EDE) for a one-time exposure, while the performance objective for the residential scenario is 100 mrem (EDE) per year for a continuous exposure. The time of closure is taken to be year 2050. All the analyses presented in this section assume that the surface barrier is in place (Section 2.4.1). All calculations were performed using a spreadsheet to calculate decay and to convert inventory concentrations into doses.

5.2 INADVERTENT INTRUDER SCENARIOS

The pathways described here assume that no memory of the closed facility remains. The following principal cases of intruders were considered:

- An inadvertent intruder digs or drills into the closed site and brings some of the waste to the surface, receiving an acute dose.
- Another intruder (the homesteader) tills the waste into the soil and grows vegetables, receiving a continuous dose while engaged in various activities.

The following three intruder scenarios that involve bringing waste from the closed facility to the surface usually are considered in a performance assessment.

- Excavating for a basement or building foundation
- Drilling for groundwater or minerals
- Living where waste has been exhumed and scattered over the surface. For this scenario, the following three residential scenarios were evaluated:

a) Suburban resident with a garden

b) Rural farmer with a dairy cow

c) Commercial farmer

Scenario 1 (basement scenario) is not considered credible because the top of the waste is 5 m (16.4 ft) or more below the surface. Neither basements for home residences nor foundations for commercial structures are likely to extend this far below the surface. This scenario was not evaluated in these analyses.

For all other scenarios, waste is brought to the surface by drilling through a SST. For these scenarios, not all of the waste material taken from the borehole is available for inhalation or ingestion due to its particle size distribution and chemical form. Waste that is imbedded in a grout matrix, for example, is largely unavailable for inhalation or ingestion due to the chemical inertness of grout and the large particles that arrive at the surface. The large particles are consequences of drilling practices that minimize wear on the drill bit. The chemical inertness of grout means that any fine particles inhaled will be physically removed from the lungs before dissolving. An estimate of the fraction of the exhumed inventory available for internal routes is 10%.

Scenario 2, the construction of small water wells, is possible. The driller scenario begins with the assumption that some time after closure has been completed, a well is drilled through the waste. Drilling at the closed site is unintentional, and the waste is not recognized as a potential hazard, even though it is assumed to be in the form of cementious chunks. The waste, along with uncontaminated soil taken from the well, is spread over a work area near the well. The dose to the worker is the sum of the contributions from inhalation of resuspended dust, ingestion of trace amounts of soil, and external exposure at the center of a slab of contaminated soil.

Scenario 3(a) considers a family planting a garden using the material taken from the well. Each individual of concern receives dose by direct exposure to the radiation field in the garden, by inhaling resuspended dust, by ingesting trace amounts of soil, and by consuming garden produce. Given than a well is constructed (scenario 2), it is possible, if not probable, that someone will live near the borehole.

Scenario 3(b) assumes the 200 Area Plateau remains largely rural in the future. A well is drilled through the waste to obtain water for domestic needs. After the drillers leave, the borehole cuttings are spread over an area that is planted with grass and hay to feed a milk cow. The cow supplies 50% of the family's dairy needs. In addition, there is soil ingestion and inhalation, and external exposure while present in the pasture/hay field.

Scenario 3(c) assumes the 200 Area Plateau becomes a commercial farming operation in the future. A well is drilled through the waste to obtain water for domestic needs. After the drillers leave, the borehole cuttings are spread over an area that is planted with dry-land wheat, hay, or some other crop that is harvested and sold for profit. The owner of the farm does not consume any of the crops himself. His only exposures to the exhumed waste occur during the production of the crop. There is soil ingestion and inhalation, and external exposure while present in the field.

5.3 FACILITY DESCRIPTION AND ASSUMPTIONS FOR THE INADVERTENT INTRUDER ANALYSIS

Selecting values for parameters important in inadvertent intruder scenarios is difficult. Because such intrusion is postulated to be in the future, the nature of the intrusion is ill defined. Moreover, uncertainty abounds about the proper values to be used in a given scenario. DOE O 435.1 provides no specific guidance on the intruder scenario analysis. For this report the specific exposure scenario is defined in Rittmann (2003) and is based on intruder scenarios analyzed in earlier Hanford Site performance assessments (Wood 1995a and 1996, Mann 1998a and 2001).

For the inadvertent intruder scenarios, the most important variables are the amount of waste exhumed, the size of the area over which the waste is spread, and the physical integrity of the waste. Additional parameters, such as exposure time and inhalation rates, also are important but are not typically treated as variables.

The amount of waste material taken from the closed site is assumed to be the maximum average waste distribution times the area of the borehole for the well. The maximum average waste distribution is calculated for each tank assuming homogeneous concentrations in the tank. For this performance assessment, the diameter of the well is assumed to be 10 in. (25.4 cm). This value is consistent with the range of well diameters commonly found in local communities (4 to 10 in. [10.2 cm to 25.4] cm).

The area over which the driller spreads the waste is assumed to be 100 m^2 (about 1,100 ft^2). This value has been historically used in the Hanford ILAW performance assessments. For each intruder scenario, the following parameters were used:

Driller: The worker at the well drilling site is assumed to be exposed 8 hours a day for 5 days. The dose to the worker is the sum of the contributions from inhaling resuspended dust (0.12 mg/hour), ingesting trace amounts of soil (100 mg/day), and external exposure at the center of a slab of contaminated soil for 40 hours. The dose factors for this scenario can be found in Rittmann (2003) and are summarized in Appendix B, Table B-3. The homesteader is assumed to be exposed for 1 year. The soil inhalation rate for the homesteader is 573 mg/year. The incidental ingestion rate is the same as for the driller, 100 mg/day. The resulting dose factors are given in Rittmann (2003) and summarized in Appendix B, Table B-4.

Suburban Resident with a Garden: The smallest garden that will provide a family of four with 25% of their vegetable needs through the year is 1076.4 ft^2 (100 m^2). If the 231.6 ft^3 (6.56 m^3) of borehole cuttings are spread over an area of 1076.4 ft^2 (100 m^2) then the average depth is 2.64 in. (6.7 cm). The maximum depth is assumed to be 5.9 in. (15 cm) based on the average root depth of garden plants. With an average depth of 5.9 in. (15 cm), the spreading area is (484.4 ft^2 (45 m^2). Gardening activities include tilling the soil, which mixes the waste from the well into the top 5.9 in. (15 cm) of soil. In earlier Hanford Site performance assessments, the garden area has been as large as 0.62 ac (2,500 m^2). The 1076.4 ft^2 (100 m^2) garden was chosen for this performance assessment because the size represents an area large enough to supply a significant portion of a person's vegetable and fruit diet and because the smaller size produces a higher dose, making it the conservative scenario. Household gardens in the vicinity of the Hanford Site range in size from 107 ft^2 to 0.25 ac (10 m^2 to 1,000 m^2) (Napier 1984). In both scenarios the soil

mixing depth is assumed to be 5.9 in. (15 cm). This value has been used in other onsite performance assessments and is the typical rooting depth for garden vegetables.

Rural Farmer with a Dairy Cow: The cow's diet is a mixture of fresh fodder and stored feed. The fresh fodder comes from a pasture that covers about 0.62 ac (2,400 m^2), while the stored feed comes from hay and grain fields with a total area of about 0.69 ac (2,800 m^2). These areas are based on the milk cow model used in Revisions 1 and 3 of HNF-SD-WM-TI-707. For pasture, it is assumed that 40% of the grass is trampled by the cow and cannot be eaten. In addition, the cow eats only half of the standing biomass of pasture grass and hay. The cow's diet is a mixture of three types of plants (grass, hay, and grain) to simplify the model and to include all likely sources. The assumed area that will be used for averaging the exhumed waste is 1.24 ac (5,000 m^2). The actual area of contamination is probably less than 2,152.8 ft^2 (200 m^2) because the average depth is likely to be greater than 1 in. (2.54 cm). However, the actual area does not matter because the effects are averaged over the 1.24 ac (5,000 m^2) of the pasture/hay field.

Commercial Farmer: The farm field is assumed to be a section of land, 160 ac (64.7 ha). This is a typical land unit. It is judged to be the smallest that might be undertaken as a profit-making activity. The actual area of contamination is probably less than 2,152.8 ft^2 (200 m^2) because the average depth of tailings after they have been spread is likely to be greater than 1 in. (2.54 cm). However, the actual area does not matter because the effects are averaged over the 160 ac (64.7 ha) of the field.

5.4 INADVERTENT INTRUDER ANALYSIS RESULTS

The values given for all intruder scenarios assume the base case residual inventory. These values assume the base case residual inventory (Selected Phase Removal residual inventory for all tanks but C-106 and C-107, and HTWOS projected residual inventory for tanks C-106 and C-107 [Section 3.2.3]). The base case residual inventory is dependent on the retrieval technology (Section 2.3.5). The results shown in all intruder scenarios assume the retrieval goals are achieved. It must be emphasized that the results for all intruder scenarios are based on residual waste inventories that are not currently known, since no tanks have been retrieved to the HFFACO goal of 1%. The projected residual inventories have been based on the retrieval technologies and are based on the current BBI, which has been estimated from process records and limited sampling.

5.4.1 Driller Scenario

The results for the all constituents and tanks for the driller scenarios are given in Appendix C. Table 5-1 provides the total doses for WMA C for the years 2000 to 2500. Figure 5-1 presents the results for the five tanks with the highest impact (C-103, C-108, C-109, C-112, and C-201), as well as tank C-204, the tank with the lowest impact. C-201 has the highest impact at 500 years after closure. Of these tanks, only tank C-109 is above the performance of objective of 500

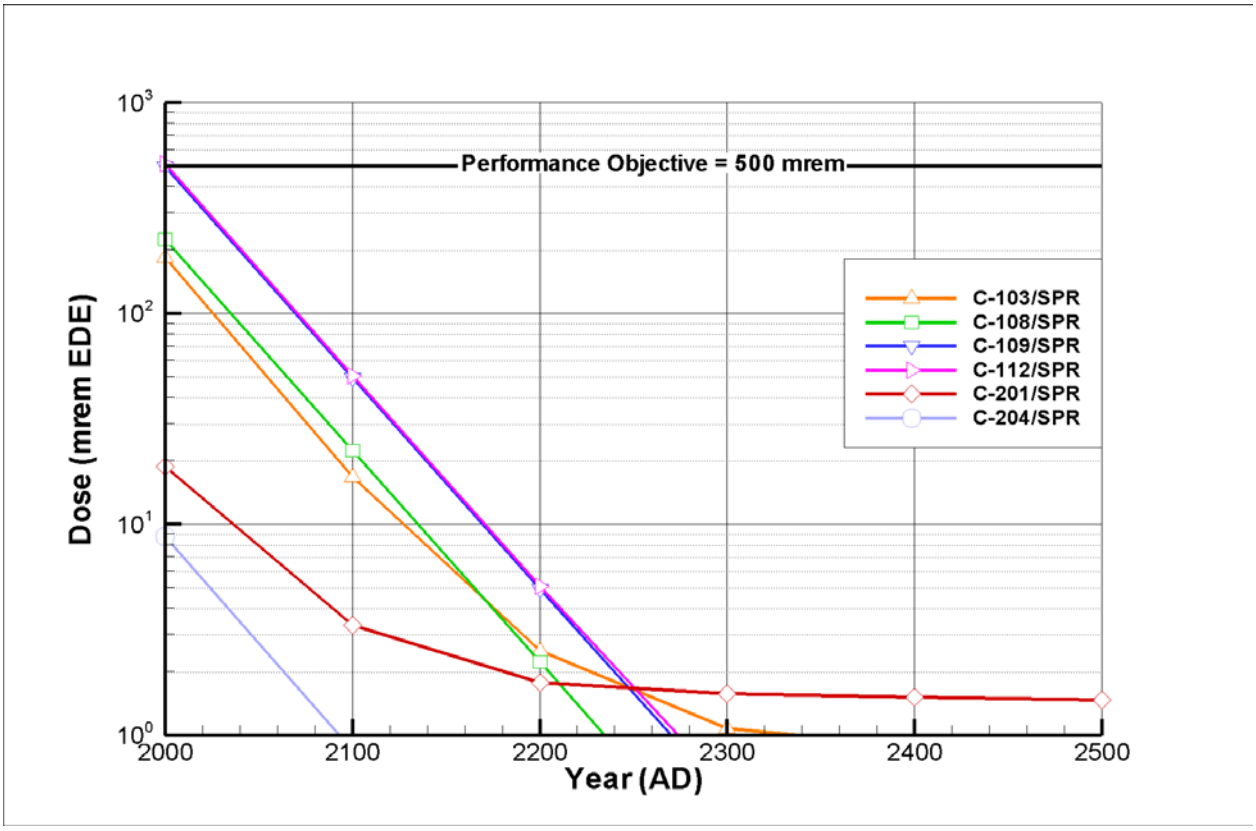
mrem EDE[9] for acute exposure. This dose occurs at the time of tank closure (nominally set to the year 2000). At 100 years after closure, the acute dose from this tank has decreased by a factor of 10 from 509 mrem to 50.5 mrem.

Table 5-1. Driller Inadvertent Intruder Dose for Each WMA C Tank from Year 2000 to 2500. The performance objective is 500 mrem. (2 Pages)

Tank Name/Inventory	Driller --> Dose at Year (mrem EDE)					
	2000	2100	2200	2300	2400	2500
C-101/SPR	80.444	8.038	0.892	0.186	0.116	0.108
C-102/SPR	20.990	2.247	0.441	0.257	0.232	0.225
C103/SPR	184.844	16.746	2.505	1.072	0.893	0.842
C-104/SPR	73.793	7.767	1.456	0.787	0.682	0.639
C-105/SPR	119.653	12.141	1.551	0.487	0.367	0.343
C-106/HTWOS	84.804	8.204	0.927	0.203	0.124	0.109
C-107/HTWOS	9.157	0.916	0.176	0.100	0.088	0.084
C-108/SPR	224.687	22.292	2.213	0.221	0.024	0.004
C-109/SPR	496.157	49.198	4.901	0.509	0.073	0.028
C-110/SPR	14.811	1.478	0.155	0.023	0.010	0.008
C-111/SPR	88.452	8.659	0.920	0.162	0.082	0.070
C-112/SPR	509.700	50.477	5.068	0.562	0.108	0.058
C-201/SPR	18.817	3.322	1.773	1.569	1.506	1.464
C-202/SPR	18.773	2.600	1.013	0.830	0.789	0.766
C-203/SPR	13.750	1.487	0.300	0.178	0.161	0.156
C-204/SPR	8.755	0.850	0.089	0.014	0.006	0.005

[9] All doses are given as effective dose equivalent (EDE)

Figure 5-1. Driller Inadvertent Intruder Doses for the Most Significant Tanks from Year 2000 to 2500.



At short times, ^{137}Cs and ^{90}Sr dominate, whereas at later times ^{239}Pu and ^{241}Am dominate; however, each tank is different, as can be seen from Tables 5-2(a) and 5-2(b), which show the contributions from tanks C-112 and C-201. The estimated acute exposure dose at 100 years after facility closure is 50.5 mrem for tank C-112. The major contributor to the acute dose is ^{137}Cs, which contributes approximately 97% of the exposure dose, while ^{90}Sr contributes 2%. While for tank C-201, which contains more transuranics than C-112, the estimated acute dose at 100 years after closure is again dominated by ^{137}Cs and ^{90}Sr, contributing 85 and 5% of the total acute dose (18.8 mrem), respectively. However, at 500 years, acute dose is dominated by ^{239}Pu, ^{240}Pu, and ^{241}Am, which contribute 74, 12, and 14% of the total dose (1.46 mrem).

As can be seen by this analysis, doses to an inadvertent driller fall will below the performance objectives for all tanks. These estimates are sensitive to parameters assumed for each exposure scenario. A number of sensitivity studies were performed to quantify the dependence on these parameters. The results of these studies are discussed in Section 5.5.3. However, none of the sensitivity cases changes the conclusion that the driller scenario meets the performance objective.

Table 5-2a. Driller Inadvertent Intruder Doses for Tank C-112 from Year 2000 to Year 2500, Showing Contribution from Major Radionuclides.

C-112	Inventory	Driller --> Dose at Year (mrem)					
	(Ci)	2000	2100	2200	2300	2400	2500
^{60}Co	1.12E-01	0.034	0.000	0.000	0.000	0.000	0.000
^{90}Sr	1.68E+04	10.571	0.968	0.089	0.008	0.001	0.000
^{137}Cs	7.39E+03	498.132	49.421	4.903	0.486	0.048	0.005
^{154}Eu	5.73E+00	0.843	0.000	0.000	0.000	0.000	0.000
^{155}Eu	3.97E+00	0.016	0.000	0.000	0.000	0.000	0.000
^{239}Pu	2.12E+00	0.012	0.012	0.012	0.012	0.012	0.012
^{241}Am	1.23E+01	0.084	0.071	0.061	0.052	0.044	0.038
Other Radionuclides		0.008	0.004	0.004	0.004	0.004	0.003
Total		**509.700**	**50.477**	**5.068**	**0.562**	**0.108**	**0.058**

Table 5-2b. Driller Inadvertent Intruder Doses for Tank C-201 from Year 2000 to Year 2500, Showing Contribution from Major Radionuclides.

C-201	Inventory	Driller --> Dose at Year (mrem)					
	(Ci)	0	100	200	300	400	500
^{90}Sr	87.7	0.776	0.071	0.007	0.001	0.000	0.000
^{126}Sn	1.19E-03	0.004	0.004	0.004	0.004	0.004	0.004
^{137}Cs	16.7	15.830	1.571	0.156	0.015	0.002	0.000
^{152}Eu	0.086	0.162	0.001	0.000	0.000	0.000	0.000
^{154}Eu	0.041	0.084	0.000	0.000	0.000	0.000	0.000
^{155}Eu	3.02	0.173	0.000	0.000	0.000	0.000	0.000
^{238}Pu	0.308	0.022	0.010	0.005	0.002	0.001	0.000
^{239}Pu	13.8	1.097	1.094	1.091	1.087	1.084	1.081
^{240}Pu	2.27	0.180	0.178	0.177	0.175	0.173	0.171
^{241}Pu	16.8	0.026	0.000	0.000	0.000	0.000	0.000
^{241}Am	4.82	0.461	0.393	0.335	0.285	0.243	0.207
Other Radionuclides		1.40E-03	1.75E-04	1.29E-04	1.10E-04	9.92E-05	9.33E-05
Total		**18.817**	**3.322**	**1.773**	**1.569**	**1.506**	**1.464**

5.4.2 Post-Intrusion Resident

The results given in this section are for the rural farmer with a dairy cow exposure scenario. This scenario is more conservative than the commercial farmer, but less conservative than the suburban resident with a garden. However, given the present day land use for the area surrounding the Hanford Site, the rural resident with a dairy cow is a more appropriate scenario than the suburban resident with a vegetable garden. Comparison of the various exposure scenarios is given in Section 5.5. Complete results for all post-intruder resident scenarios are given in Appendix C.

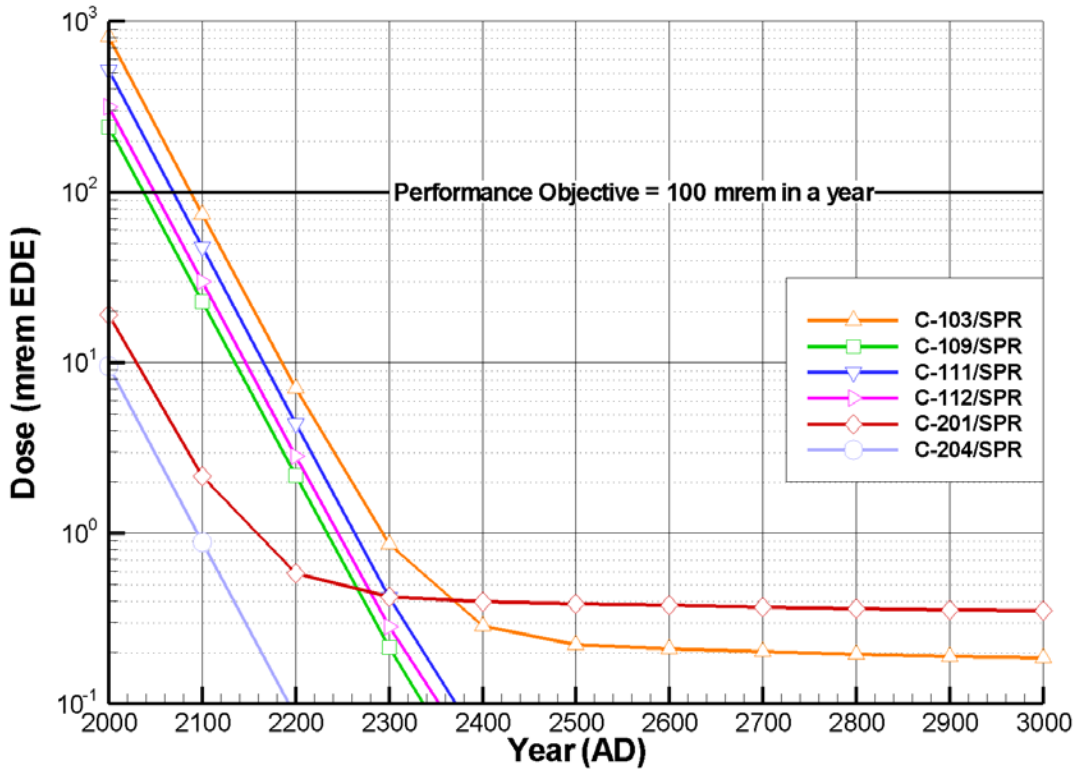
5.4.2.1 Rural Farmer with a Dairy Cow

Table 5-3 provides the total doses for each C farm tank for next 1,000 years following closure. Figure 5-2 presents the results for the five tanks (C-103, C-109, C-111, C-112, and C-201) with the highest impact, as well as tank C-204, the tank with the lowest impact. C-201 has the highest impact at 500 years after closure. At the time of closure (nominally set at the year 2000), tanks C-101, C-103, C-105, C-106, C-109, C-111, and C-112 are above the performance objective of 100 mrem. At 100 years after closure, no tanks are above the performance objective.

Table 5-3. Residential Inadvertent Intruder (Rural Farmer with a Dairy Cow) Doses for each WMA C SST from the Year 2000 to 3000.

Tank/ Inventory	Rural Farmer with a Dairy Cow --> Dose at Year (mrem)										
	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
C-101/SPR	122.18	11.350	1.079	0.126	0.038	0.029	0.028	0.028	0.028	0.028	0.028
C-102/SPR	64.84	6.024	0.613	0.113	0.065	0.060	0.058	0.057	0.056	0.055	0.054
C-103/SPR	809.46	74.216	7.048	0.863	0.285	0.223	0.210	0.202	0.196	0.190	0.186
C-104/SPR	76.55	7.277	0.860	0.250	0.183	0.168	0.160	0.153	0.147	0.142	0.137
C-105/SPR	142.37	13.327	1.333	0.213	0.105	0.092	0.088	0.085	0.082	0.080	0.079
C-106/SPR	231.72	21.339	1.997	0.212	0.045	0.028	0.025	0.023	0.022	0.021	0.020
C-107/HTWOS	56.20	5.169	0.495	0.065	0.024	0.020	0.018	0.018	0.017	0.016	0.016
C-108/HTWOS	55.17	5.443	0.538	0.054	0.006	0.001	0.001	0.000	0.000	0.000	0.000
C-109/SPR	239.86	22.828	2.182	0.215	0.027	0.008	0.007	0.006	0.006	0.006	0.006
C-110/SPR	4.04	0.398	0.041	0.006	0.003	0.002	0.002	0.002	0.002	0.002	0.002
C-111/SPR	516.40	47.439	4.377	0.421	0.056	0.021	0.017	0.016	0.015	0.014	0.014
C-112/SPR	315.34	29.755	2.830	0.284	0.041	0.017	0.013	0.011	0.010	0.010	0.009
C-201/SPR	18.97	2.158	0.584	0.424	0.398	0.386	0.377	0.369	0.362	0.356	0.350
C-202/SPR	19.56	2.023	0.389	0.230	0.209	0.202	0.197	0.193	0.189	0.186	0.183
C-203/SPR	14.79	1.414	0.173	0.055	0.043	0.041	0.040	0.039	0.038	0.038	0.037
C-204/SPR	9.53	0.885	0.084	0.009	0.002	0.001	0.001	0.001	0.001	0.001	0.001

Figure 5-2. Residential Inadvertent Intruder (Rural Farmer with a Dairy Cow) (Rural Farmer with a Dairy Cow) Doses for the Most Significant Tanks from Year 2000 to 2500.



The estimated maximum chronic exposure dose at 100 years after facility closure is 74.2 mrem in a year for tank C-103. The dose drops to below the 100 mrem per year in approximately 80 years. The major contributors to the chronic dose is ^{90}Sr, which contributes approximately 96% of the dose, and ^{137}Cs contributing 3% of the dose at 100 years. The estimated chronic exposure dose for tank C-103 at 500 years after tank closure (time of compliance) is 0.223 mrem in year with ^{239}Pu and ^{241}Am contributing most of the dose. Figure 5-3 shows the contribution of the major radionuclides for tank C-103. Tables 5-4(a) and 5-4(b) have been prepared to show the dose contribution for radionuclides for tanks C-103 (most impact at 100 years) and C-201 (most impact at 500 years). All WMA C tanks show the same trend, with ^{90}Sr and ^{137}Cs making the largest contribution to dose for the first 300 years, and ^{239}Pu and ^{241}Am contributing most of the dose after 350 years.

Figure 5-3. Inadvertent Intruder (Rural Farmer with a Dairy Cow) Doses for Tank C-103 from Year 2000 to 2500, showing Contribution of Major Radionuclides.

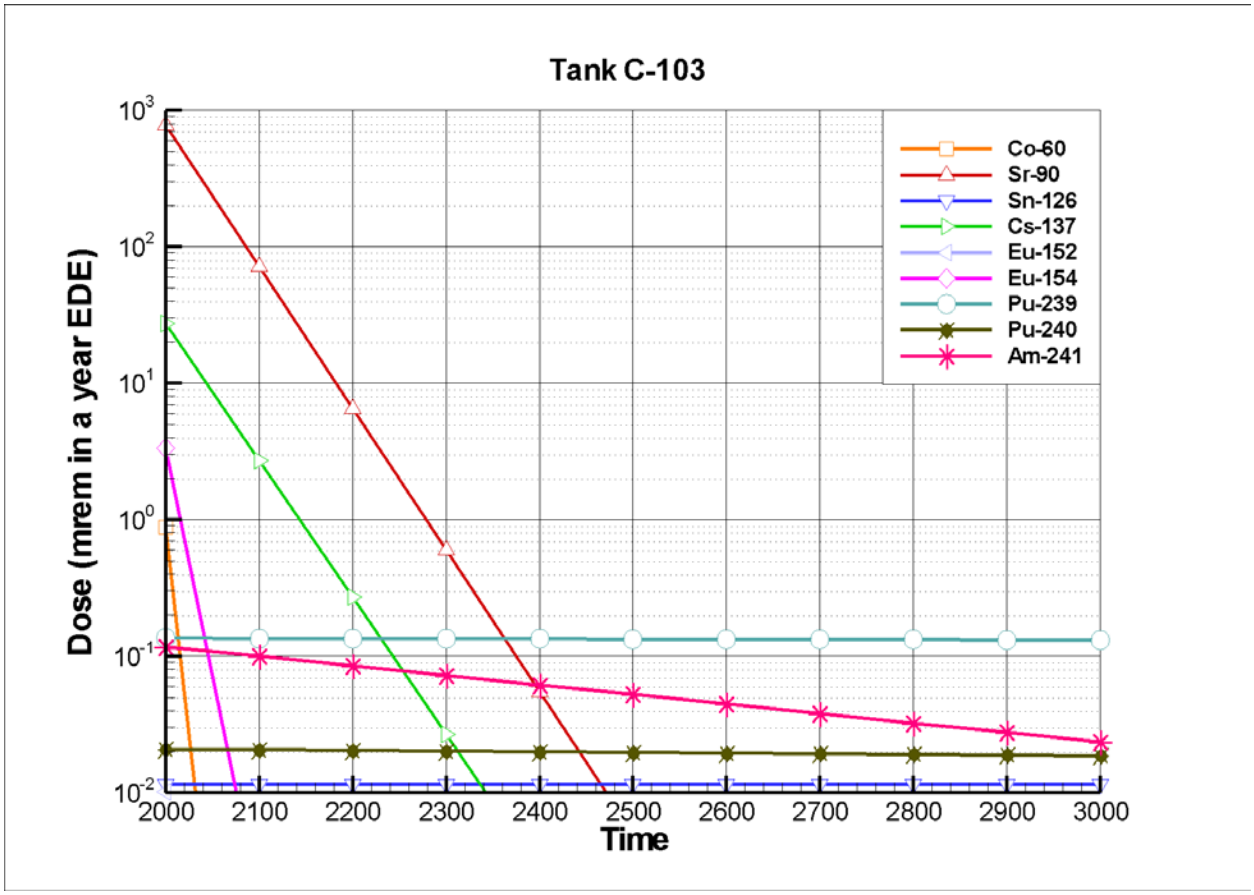


Table 5-4a. Inadvertent Intruder (Rural Farmer with a Dairy Cow) Doses for Tank C-103 from Year 2000 to Year 2500, Showing Contribution from Major Radionuclides.

Radionuclide	Inventory (Ci)	Rural Farmer with a Cow --> Dose at Year (mrem in year)							
		2000	2100	2200	2300	2400	2500	2700	3000
^{60}Co	15.4	0.879	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{90}Sr	64,700	777.430	71.224	6.525	0.598	0.055	0.005	0.000	0.000
^{126}Sn	0.243	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
^{137}Cs	1,790	27.437	2.722	0.270	0.027	0.003	0.000	0.000	0.000
^{152}Eu	0.384	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{154}Eu	118	3.365	0.002	0.000	0.000	0.000	0.000	0.000	0.000
^{155}Eu	70.5	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{239}Pu	90.3	0.135	0.135	0.135	0.134	0.134	0.133	0.133	0.131
^{240}Pu	13.9	0.021	0.021	0.020	0.020	0.020	0.020	0.019	0.019
^{241}Am	67.3	0.117	0.100	0.085	0.072	0.062	0.053	0.038	0.024
Other Radionuclides		6.8E-03	1.7E-03	9.1E-04	5.6E-04	4.1E-04	3.3E-04	2.8E-04	2.6E-04
Total		**809.467**	**74.216**	**7.048**	**0.863**	**0.285**	**0.223**	**0.202**	**0.186**

Table 5-4b. Inadvertent Intruder (Rural Farmer with a Dairy Cow) Doses for Tank C-201 from Year 2000 to Year 2500, Showing Contribution from Major Radionuclides.

Radionuclide	Inventory (Ci)	Rural Farmer with a Cow --> Dose at Year (mrem in year)							
		2000	2100	2200	2300	2400	2500	2700	3000
^{90}Sr	87.70	14.819	1.358	0.124	0.011	0.001	0.000	0.000	0.000
^{137}Cs	16.70	3.600	0.357	0.035	0.004	0.000	0.000	0.000	0.000
^{152}Eu	0.09	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{154}Eu	0.04	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{155}Eu	3.02	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{239}Pu	13.80	0.291	0.290	0.289	0.288	0.287	0.287	0.285	0.283
^{240}Pu	2.27	0.048	0.047	0.047	0.046	0.046	0.045	0.044	0.043
^{241}Am	4.82	0.118	0.101	0.086	0.073	0.062	0.053	0.038	0.024
Other Radionuclides		0.0164	0.0047	0.0026	0.0017	0.0012	0.0010	0.0009	0.0008
Total		18.972	2.158	0.584	0.424	0.398	0.386	0.369	0.350

5.5 UNCERTAINTIES

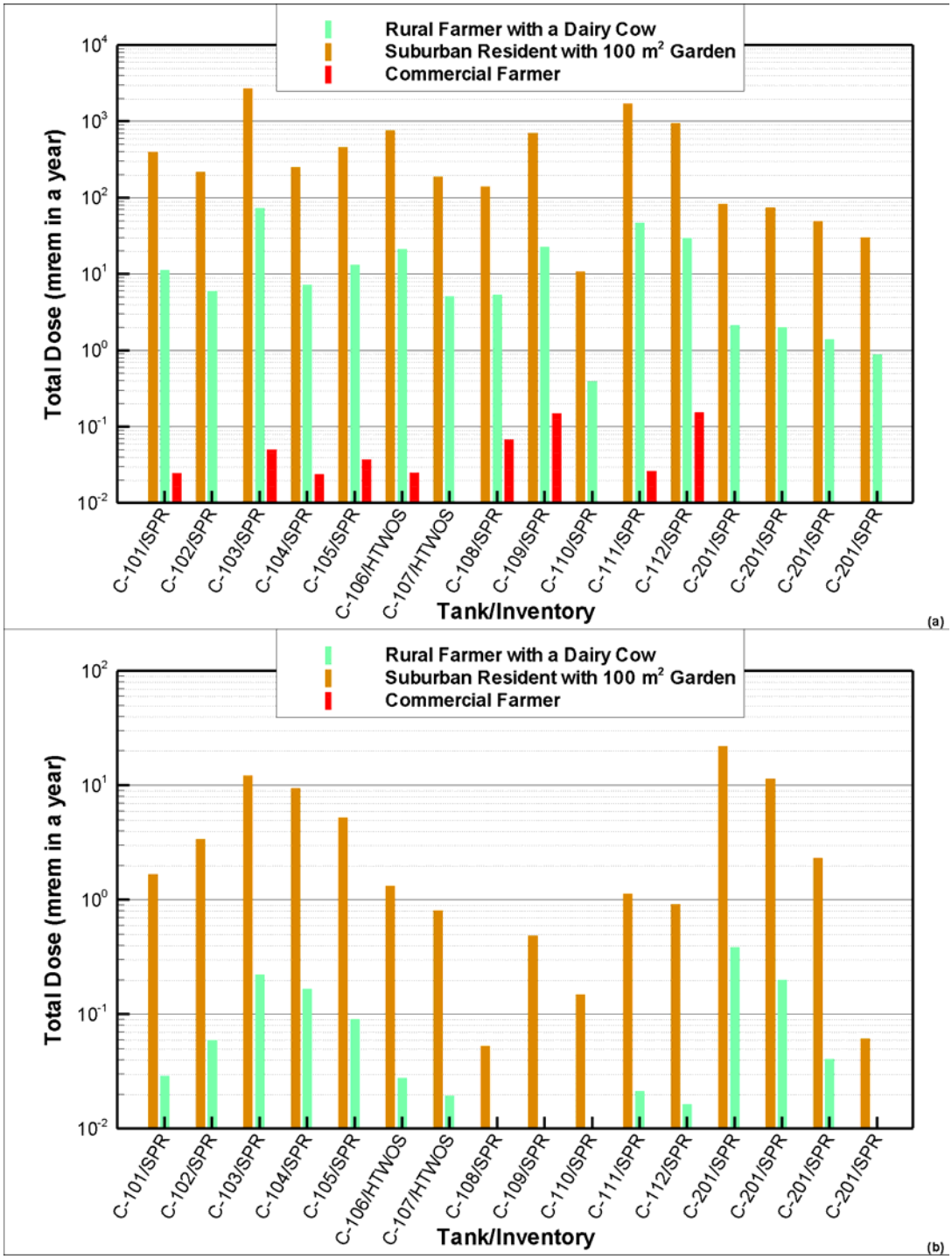
The numbers presented in the preceding sections are quite uncertain. Not only do the analyses attempt to estimate what people may do in the future as inadvertent intruders, but also the inventories of what will be left in the tanks is poorly known at best. This section describes these uncertainties and their impacts.

5.5.1 Post-Intruder Resident Scenarios

Three post-intruder resident scenarios were examined: suburban resident with a 1076.4 ft^2 (100 m^2) vegetable garden, a rural farmer with a dairy cow, and a commercial farmer. These scenarios are described in greater detail in Section 5.3. The results given in the previous section are for the rural farmer with a cow. Figure 5-4(a) gives the total dose estimate for each scenario of the WMA C tanks at 100 years, while Figure 5-4(b) provides this estimate at 500 years. At 100 years, the maximum dose (2,713 mrem) occurs at tank C-103 for the suburban resident. This is a factor of 40 over the maximum dose for rural farmer. The residential gardener receives dose from external radiation when working in the garden or dose from internal exposure when eating produce from the garden, while the rural farmer receives dose from ingestion of cows milk and working the pasture. The dose received by the commercial farmer is factor of 50 below that of rural farmer with a dairy cow. The commercial farmer is considered the most likely exposure scenario given the present day land use. At 500 years, the maximum dose (22.1) occurs at tank C-201, the shorter-lived radionuclides (such as ^{90}Sr and ^{137}Cs) have decayed away leaving the longer-lived radionuclides (such as ^{239}Pu and ^{241}Am). At this time (the time of compliance), all scenarios are below the 100 mrem in a year performance objective.

A note for the suburban resident, the garden size used in this scenario is1076.4 ft^2 (100 m^2). This garden size is much smaller than previous Hanford Site performance assessments (up to 0.62 ac (2,500 m^2). The change in garden size causes the internal dose estimates to increase by a factor that is the inverse of the ratio of the garden sizes (up to 25). However, the external doses from the larger garden are only 10 to 25% lower than the external dose from the smaller garden because of the shorter time spent in the smaller garden. Therefore, where direct doses dominate, the smaller garden area produces only a moderate increase in total dose. For radionuclides where ingestion is the main exposure pathway (^{90}Sr, plutonium isotopes, ^{241}Am), the ratio of the predicted dose is inversely proportional to the ratio of the garden areas.

Figure 5-4. Comparison between Inadvertent Intruder Scenarios for C Tank Farm at 100 Years (a) and 500 Years (b) after Closure.



5.5.2 Size of the Hole Drilled

The predicted dose is proportional to the amount of waste brought to the surface from the closed facility. For the base intruder case, the hole was conservatively estimated as 10 in. (0.254 m).

However, a more likely maximum diameter is 8 in (0.20 m). Such a smaller diameter hole would bring up only 64% of the waste that would come from the 10-in. (0.254-m) hole. This reduces the predicted dose by a factor of 0.36. The size of the borehole drilled is dependent on its use. Typically, most water wells within the Hanford surrounding environs usually are completed with a diameter ranging from 4 in. (0.1 m) to 8 in. (0.2 m). The drilling diameter is 2 in. (0.05 m) larger than the completed well.

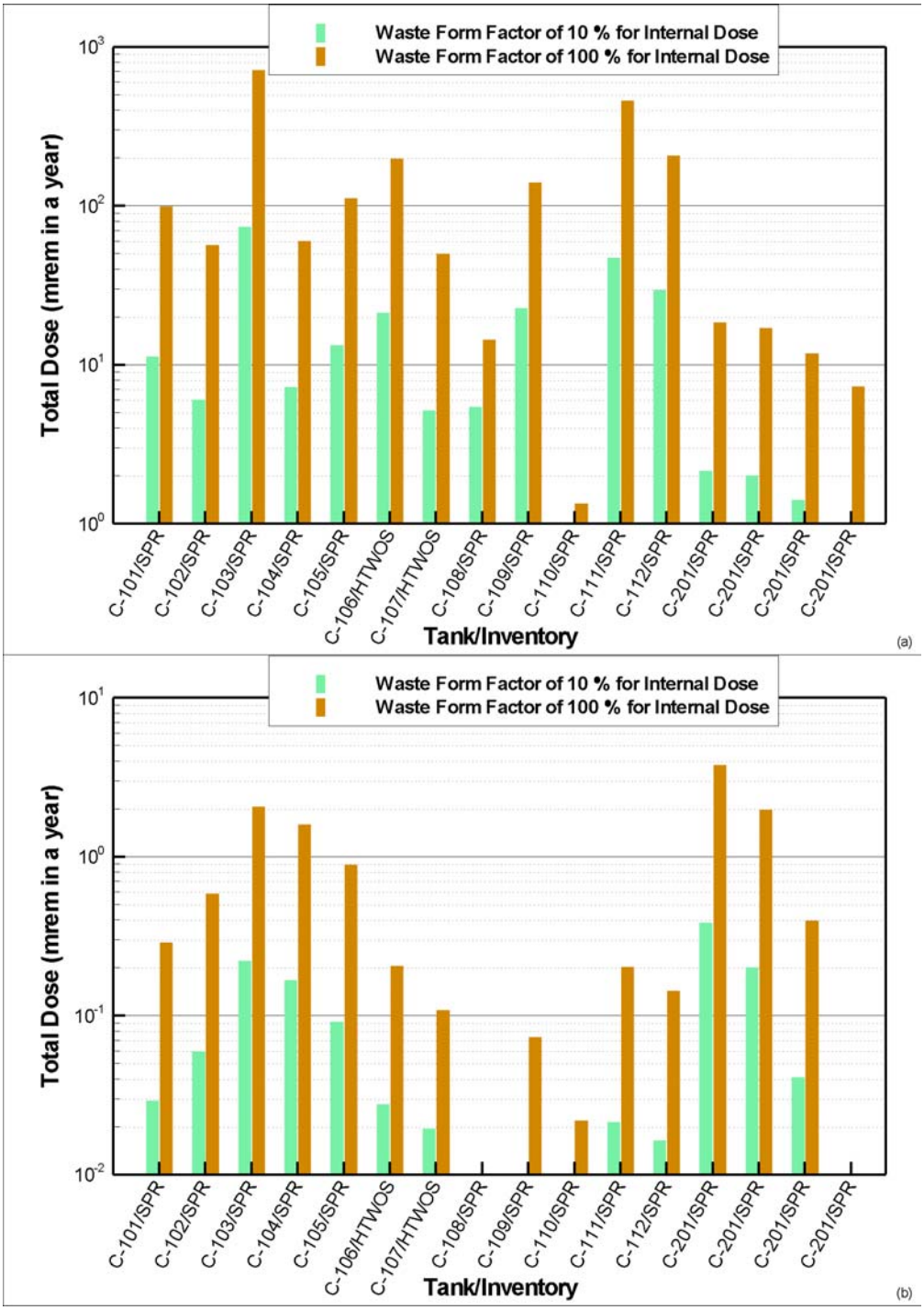
5.5.3 Waste Form Factor

The amount of material contributing to internal dose is dependent on particle size. Small sized particles are easily ingested or inhaled, and plants can uptake the waste more readily with a smaller particle size. It is assumed that the tanks will be filled with grout and that only 10% of the grout material will be fine enough to contribute to internal dose ("Licensing Requirements for Land Disposal of Radioactive Waste [NUREG-0782] and "Intruder Scenarios for Site-Specific Low-Level Radioactive Waste Classification" (DOE, 1988). Figure 5-5 has been prepared to show the difference between 100% of the waste form being available for uptake and 10% for the rural farmer with a dairy cow scenario. Figure 5.5(a) shows the comparison at 100 years after closure, while Figure 5.5 (b) shows the comparison at 500 years after closure. At 100 years, changing to 100% of the waste being available for internal dose increases the dose from a factor of 2.7 increase at tank C-108 to 9.7 increase at C-111. While at 500 years after closure, the dose increases from a factor 5.7 at tank C-107 to 9.9 at Tank C-101. Even though there is almost a 10-fold increase; the maximum dose with 100% of the waste form being available is still only 3.8 mrem, well below the performance objective of 100 mrem in a year.

5.5.4 Inventory

In this analysis, the base case inventory was used. The base case inventory assumes dry retrieval for all tanks but C-106 and C-107, which are presently scheduled to be sluiced. If sluiced, the inventory would be the projected HTWOS inventory, which typically projects smaller inventories in the tank than dry retrieval, by a factor of 5 to 7. If dry retrieval takes place in these tanks, the expected dose would increase by the same factor. If wet retrieval were to take place in the other tanks, then the dose would go down by the same factor (5 to 6). Additionally, an altogether different retrieval (acid washing) technology will be used on tank C-106. To date, no estimates have been published on how acid washing will affect the residual waste and what the subsequent residual radionuclide inventory will be.

Figure 5-5. Comparison between Waste Form Factors of 10% for C Tank Farm at 100 Years (a) and 500 Years (b) after Closure for the Rural Farmer.



5.6 SUMMARY OF THE INADVERTENT INTRUDER SCENARIO

The estimated dose for the driller scenario is 44 mrem at 100 years and 0.8 mrem at 500 years. This meets the performance objective by more than two orders of magnitude. At the time of compliance the dose originates primarily from ^{239}Pu.

The estimated dose for the residential scenario (rural farmer with dairy cow) is 74 mrem at 100 years and 0.4 mrem at 500 years. This easily meets the performance objective of 100 mrem at 500 years. At the time of compliance the dose originates primarily from ^{239}Pu.

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6.0 INTERPRETATION OF RESULTS

6.1 OVERVIEW

This section integrates the results presented in Sections 4 and 5. The many different results presented in those sections are reviewed and consolidated to provide a reasoned basis for evaluating the performance of the WMA C. This interpretation provides a preliminary assessment of the long-term environmental and human health effects of a closed WMA C.

6.2 INTEGRATION OF RESULTS

Section 7.1 compares the results to the performance objectives in detail. However, based on the results from Sections 4 and 5, a few general principles stand out:

- All performance objectives associated with release and migration of radionuclides to the point of compliance are met for the base case. The performance goals associated with release and migration of hazardous chemicals to the point of compliance is met with an even wider margin than met by radionuclides. Groundwater impacts are driven by past leaks, with impacts from potential retrieval leaks and residual waste being much less important. These conclusions depend heavily on the retrieval methods chosen and the amount of waste left in the tanks.

- Based on local drilling methods, it is very unlikely that an intruder drilling for water could penetrate a tank. However, if an intruder could penetrate the tanks, the impacts vary, depending on the assumed exposure scenario.

- A few key radionuclides are important (^{99}Tc, ^{129}I, and uranium isotopes for the groundwater pathway and ^{239}Pu and ^{241}Am for the inadvertent intruder scenario).

- Infiltration rates are important because they affect travel times and for certain residual waste scenarios they affect release rates.

As in all previous Hanford Site assessments, the mobile, long-lived radionuclides are most important for the groundwater pathway. Although the relative importance depends on the performance measure being used (beta-photon dose from drinking water, alpha concentration in drinking water, all-pathways), it is clear that ^{99}Tc and ^{129}I are the most important isotopes. Table 6-1 provides the information from all sources to the groundwater pathway. Section 4.8 provides more information.

For the inadvertent intruder scenario, a different set of radioisotopes is important. As shown in Table 6-2 for tank C-201 (the tank with the highest estimated impacts), the isotopes that are important vary with time (also see Figure 5-3). At short times, the important radioisotopes are ^{90}Sr and ^{137}Cs, which have half-lives of around 30 years. However, by the time of compliance (500 years), these two isotopes have decayed and the long-lived isotopes, ^{239}Pu, ^{240}Pu, and

^{241}Am, are important with ^{239}Pu contributing over two-thirds of the total dose. A more detailed discussion is given in Section 5.4.

Table 6-1. Peak Groundwater Pathway Impacts from WMA C at Key Locations.

Impact	WMA Fence Line (Fence-line Average)	Eastward Flow	
		Exclusion Boundary	Columbia River
All-Pathways - Farmer (mrem in a year)	0.172	0.027	0.010
ILCR[a] (Industrial) (Cr only)	2.43×10^{-8}	3.41×10^{-9}	1.26×10^{-9}
Hazard Index (Industrial)	0.0075	0.0011	0.0004
Alpha-Emitters (pCi/L)	0[b]	0[b]	0[b]
Beta/Gamma Emitters (mrem in a year)	0.172	0.027	0.010

[a]ILCR is the incremental lifetime cancer risk.

[b]The only alpha emitter explicitly calculated is uranium, which is not governed by standard. However, based on strong retardation of other alpha-emitters in Hanford soils ($K_d > 1$ ml/g), concentrations of regulated alpha emitters should not be present during the 10,000 years of analysis.

Table 6-2. Important Radioisotopes in Rural Farmer Inadvertent Intruder Scenario for Tank C-201 Using the Inventory Corresponding to Dry Retrieval (Separated Phase Retrieval).

Radionuclide	Inventory (Ci)	Rural Farmer with a Cow --> Dose at Year (mrem in year)							
		2000	2100	2200	2300	2400	2500	2700	3000
^{90}Sr	87.70	14.819	1.358	0.124	0.011	0.001	0.000	0.000	0.000
^{137}Cs	16.70	3.600	0.357	0.035	0.004	0.000	0.000	0.000	0.000
^{152}Eu	0.09	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{154}Eu	0.04	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{155}Eu	3.02	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000
^{239}Pu	13.80	0.291	0.290	0.289	0.288	0.287	0.287	0.285	0.283
^{240}Pu	2.27	0.048	0.047	0.047	0.046	0.046	0.045	0.044	0.043
^{241}Am	4.82	0.118	0.101	0.086	0.073	0.062	0.053	0.038	0.024
Other Radionuclides		0.0164	0.0047	0.0026	0.0017	0.0012	0.0010	0.0009	0.0008
Total		**18.972**	**2.158**	**0.584**	**0.424**	**0.398**	**0.386**	**0.369**	**0.350**

Because this is a preliminary performance assessment, the goal of this assessment is to identify the important drivers and processes that could affect long-term human health and the environment. The most important drivers for both the groundwater pathway and the inadvertent intruder are the choice and efficiency of retrieval method for each tank.

Even though the present analysis shows that past leaks are the greatest source for the groundwater pathway for the base case, different retrieval choices and implementations could lead to different conclusions. Such choices and implementations would affect the amount of key contaminants left in the tanks and the potential for leaked contaminants during retrieval. Sluicing retrieval methods are predicted to remove more of the mobile contaminants, but have a higher likelihood for causing potential leaks. The amount of retrieval (using any method) obviously also effects the amount of contaminants that affect the groundwater pathway or inadvertent intruder.

For the groundwater pathway, there are some other important drivers. The most important one being recharge, the amount of water passing through the near-surface region. For past leaks and potential retrieval leaks, the driver is recharge in the near-term, the time before a surface barrier is installed. This analysis assumed a conservative approach (high values of recharge [100 mm/yr] (0.14 in/yr)) for an extended duration [time of facility closure]). An improved analysis depends on tank farm recharge measurements (already started in the nearly B tank farm) and, more importantly, on future decisions on the placement of any temporary barriers and on the placement of the final permanent surface barrier.

For residual wastes (and the second peak on the BTC due to the degradation of the barrier from past leak and potential retrieval leak sources), the important drivers are the recharge rate through the degraded barrier and the amount of retardation for the non-mobile contaminants (such as uranium). This analysis assumed that the barrier performance would revert to natural conditions. However, because of the type of soil used in the barrier, it is likely to perform much better in its degraded state than local soils. A conservative retardation was assumed for uranium, so these results for uranium (other conditions being the same) should be bounding.

For the groundwater pathway, only six contaminants (^{99}Tc, ^{129}I, Cr, NO_2, NO_3, and U) were investigated. Based on previous Hanford Site assessments (including ones for tank farms), these are likely to be the most important contaminants. Future assessments will investigate more contaminants.

For the inadvertent intruder, by far the most important parameters are the inventories of residual material. As noted above, these depend on retrieval decisions yet to be made and implemented. Another important driver is the choice of exposure scenario. The most likely scenario (commercial farming) yields lower impacts than the one (rural farmer) used as the base case. Other parameters are best estimates, but are, of course, uncertain since they pertain to actions very far into the future.

6.3 VERIFICATION OF PERFORMANCE ASSESSMENT RESULTS

This section discusses the basis for concluding that the performance of the WMA C closure action has been completely addressed, the analysis is logically interpreted, the results are representative of the facility performance, and the results are sufficiently rigorous.

The completeness of a performance assessment activity can be judged on the effort to determine not only the best estimate case but also other cases that might affect the impacts of waste disposal. An important comment (see Section 1.6.4) is that the public not only wants to know what is expected to happen, but also how bad the consequences could be if these expectations are wrong. Because this is a preliminary performance assessment, alternate consequences have not been addressed in detail. This analysis has revealed that previous assumptions (that tank residual waste would be the most important source for the groundwater pathway, that retrieval methods might be important for potential retrieval leaks but not for tank residual inventory) were incomplete, if not faulty. Based on this analysis and other Hanford Site analyses (Knepp 2002a and 2002b and Mann 2001), future analyses should provide a more comprehensive treatment of:

1) Best estimate cases (groundwater, air, inadvertent intruder)

2) Sensitivity/uncertainty cases investigating

    a) Retrieval method

    b) Retrieval efficiency (amount left, potential retrieval leaks)

    c) Amount and placement of contaminants from past leaks

    d) Infiltration rates

    e) Release rates from residual waste

    f) Geochemical effects

    g) Exposure scenarios, particularly for inadvertent intrusion.

That this analysis is logically interpreted can be judged by reviewing the simple overall approach presented in Section 3.3. Calculations involving the air pathway and the inadvertent intruder scenarios are straightforward. In concept, the groundwater pathway is straightforward (water enters the disposal facility, waste degrades because of water contact, the water carries the released contaminants to groundwater, which carries the contaminants to the point of compliance). Despite the straightforwardness of the concept, the models used in each step are fairly complicated. However, for each step, simple models are provided to show that the complicated models provide appropriate results.

These results are not exact representations of closure performance because the wastes have not been retrieved and the facility closure plans have not been developed. However, through the use of conservative and best estimate cases, this analysis shows how likely candidate retrieval methods and various closure options will perform.

This preliminary performance assessment uses the best available data, methods, and codes. The results are strongly dependent on decisions that are expected to change as this and other studies provide information. This preliminary performance assessment is a beginning, not an end.

6.4 LIMITATIONS AND UNCERTAINTIES

Significant limitations and uncertainties exist in preliminary performance assessment, with the most uncertainty being associated with the inventories of various contaminant species, especially for the key long-lived mobile radionuclides. Other sources of limitation and uncertainty are related to the assumed conceptual model for vadose zone flow and transport, recharge (infiltration) at the tank farms, and assumptions regarding source-term release models for residual wastes in tank and tank ancillary equipment. Uncertainties also exist regarding the past leaks from tanks and tank ancillary equipment, as well as quantities lost during waste retrieval. However, the numerical simulation results demonstrated a significant separation in time between past leaks and potential future releases, on the basis of assumed timeline estimates of end states for closure. The closure barrier is assumed to be a RCRA Subtitle C barrier with a design life of 500 years, and a degraded barrier beyond 500 years.

The vadose zone conceptual model for flow and transport considered transient recharge rates. A conservatively high value (3.9 in./yr [100 mm/yr]) is used in this initial assessment for the present-day, gravel-covered tank farms, prior to placement of the RCRA subtitle C closure barrier. While the use of a lower value (e.g., 1.95 in./yr [50 mm/yr]) will lead to a lower near-term peak concentration, the predicted fence line concentrations will still violate MCL and EDE limits. Also, a recharge rate of 0.14 in./yr (3.5 mm/yr) was used for the degraded barrier. The barrier is assumed to degrade instantly. However, such an assumption results in conservatively higher peak concentrations, compared to the case where the degradation occurs gradually. The model used in this assessment did not consider the influence of preferential pathways, such as the potential presence of clastic dikes. Nor did the model use site-specific physical and hydraulic properties for the vadose zone soils in WMA C. However, these limitations are not expected to be significant compared to the uncertainties in the inventory estimates or release models for residual wastes in tank or tank ancillary equipment.

Diffusion-controlled release models are applied to porous solid waste forms (cemented or grouted wastes). The effective diffusion coefficient is based on leach test data and reflects a constituent's retardation in the matrix (i.e., by reaction with the cementitious matrix or adsorption onto matrix additives), as well as the physical hindrance in pores and the tortuosity of the matrix. No tank waste-based diffusion coefficient estimates are presently available for WMA C. Estimates used in this initial risk assessment are based on literature and are conservative. A smaller diffusion coefficient than the ones used in this initial assessment will lead to a lower peak concentration for contaminant breakthrough curves. Diffusion coefficients used in future closure assessments will be based on laboratory work.

The solubility-controlled release model assumed congruent release of various contaminants, with the major constituent in the waste (i.e., sodium nitrate) controlling the release of all constituents. As the major constituent dissolves, all other constituents within the tank are released in similar proportions. The solubility of sodium nitrate was assumed to be one-fifth of 360 g/L, based on

literature data, thus providing a conservative estimate. In addition to use of an equilibrium condition and a constant solubility value used in the absence of any characterization data, this particular release model has other significant limitations. WMA C tank wastes typically are not predominantly nitrate salts. Also, congruent dissolution of trace constituents with primary phases has not been demonstrated. This clearly suggests that additional characterization data are needed with respect to use of a solubility-controlled release model in future closure assessments. Also, there is no confidence that the selected solubility value will provide a conservatively high groundwater contamination estimate.

6.5 BASIS FOR WASTE ACCEPTANCE LIMITS

Because this is a preliminary performance assessment, closure requirements are not established. They will be established in future assessments by setting performance goals lower than the performance objectives and then based on the understanding gained in the performance assessment, establishing inventory limits and facility design requirements. This method was used in the establishing limits and requirements in the ILAW PA (Mann 2001).

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7.0 PERFORMANCE EVALUATION

7.1 OVERVIEW

This section compares the estimated impacts found in Sections 4 and 5 with the performance objectives established in Section 1 (Section 7.2) as well as the sensitivity of the results to key parameters (Section 7.3). Section 7.4 discusses the conservatisms and caveats associated with the analysis. The chapter concludes by describing the work planned to update the information contained in this performance assessment (Section 7.5).

7.2 COMPARISON OF ESTIMATED IMPACTS TO PERFORMANCE

This section compares the estimated impacts to the performance objectives for each area of protection cited in Section 1.3:

- Protection of the general public
- Protection of the inadvertent intruder
- Protection of groundwater resources
- Protection of surface water resources
- Protection of air resources.
- TRU requirements

The inadvertent intruder estimated impacts depend on inventory and facility design, and can be mitigated to some extent operationally. The estimated impacts for the other performance objectives (except for air resources) depend on inventory, waste form release rate, facility design, and groundwater flow rate.

7.2.1 Protection of General Public

Table 7-1 compares the performance objectives for protecting the general public with the results from the base analysis and best estimate cases. The estimated all-pathways doses are significantly lower than the performance objectives during the first 10,000 years. The DOE time of compliance is 1,000 years.

Table 7-1. Peak (during 10,000 Years) All-Pathway Exposure Scenarios for the Groundwater Pathway Impacts from WMA C at Key Locations.

Impact	Performance Objective	WMA Fence Line (Fence-line Average)	Eastward Flow	
			Exclusion Boundary	Columbia River
All-Pathways - Farmer (mrem in a year)	25	0.172	0.027	0.010
ILCR[a] (Industrial) (Cr only)	10^{-5}	2.43×10^{-8}	3.41×10^{-9}	1.26×10^{-9}
Hazard Index (Industrial)	1	0.0075	0.0011	0.0004

[a] ILCR is the incremental lifetime cancer risk.

7.2.2 Protection of Inadvertent Intruders

Table 7-2 compares the estimated impacts to the performance objectives for protecting the inadvertent intruder for tank C-201, which is the tank providing the largest intruder impact. The time of compliance starts at 500 years after closure. The acute exposure performance objective is met by a factor greater 300 The continuous exposure performance objective is met by a factor of approximately four for the base analysis case. ^{239}Pu, ^{240}Pu and ^{241}Am are the major contributors.

Table 7-2. Comparison of Estimated Impacts with Performance Objectives for Protecting the Inadvertent Intruder.

Performance Measure	Performance Objective	Estimated Impact at 500 years
Acute exposure (mrem)	500.0	1.46
Continuous exposure (mrem in a year)	100.0	0.39

Note: The time of compliance starts at 500 years. Results for tank C-201 are given, the tank with highest impacts

These results depend on the amount of contaminants left in the tanks. This amount depends on the volume of residual material and the concentration of contaminants, which, of course, depends on the retrieval method used.

7.2.3 Protection of Groundwater Resources

Table 7-3 compares the estimated impacts to the performance objectives for protecting the groundwater resources. At the DOE time of compliance (1,000 years) and the point of compliance (at the WMA fence line), the groundwater impacts are not significant. At 10,000 years the estimated impacts are much lower than the performance objectives for beta-photon emitters, the alpha-emitting radionuclides, and the analyzed chemicals for the base analysis case. The concentration of radium is insignificant. The most important radionuclide drivers

are the inventories of technetium and iodine, the infiltration rate, and the amount of mixing in the aquifer.

Table 7-3. Comparison of Estimated Peak Impacts with Performance Objectives for Protecting Groundwater Resources During First 10,000 Years[a].

Impact	Performance Objective	WMA Fence Line (Fence-line Average)	Eastward Flow	
			Exclusion Boundary	Columbia River
Alpha-Emitters (pCi/L)	15	0[b]	0[b]	0[b]
Beta/gamma Emitters (mrem in a year)	4	0.172	0.027	0.010
Cr (µg /L)	50.	0.16	0.00	0.00
NO_2 (µg /L)	1,000	5.22	0.08	0.02
NO_3 (µg /L)	10,000	11.32	0.17	0.06
U (µg /L)		2.95	0.04	0.01

[a]The point of compliance is a well at the CWA fence line.

[b]The only alpha emitter explicitly calculated is uranium, which is not governed by standard. However, based on strong retardation of other alpha-emitters in Hanford soils (K_d > 1 ml/g), concentrations of regulated alpha emitters should not be present during the 10,000 years of analysis.

7.2.4 Protection of Surface Water Resources

Table 7-3 also compares the estimated impacts to the performance objectives for protecting the surface water resources. The point of compliance is at a well intercepting the groundwater just before it mixes with the Columbia River. The estimated impacts are very low compared to the performance objectives for the base analysis case.

7.2.5 Protection of Air Resources

Table 7-4 compares the estimated impacts to the performance objectives for protecting air resources. The DOE time of compliance is 1,000 years and the point of compliance is just above the disposal facility. The estimated impacts from radon are over four orders of magnitude lower than the performance objectives. The estimate for other radionuclides assumes that the entire inventory is released in a year. Even with this assumption, the performance objective is met.

Table 7-4. Comparison of Estimated Impacts with Performance Objectives for Protecting Air Resources.

Performance Measure	Performance Objective	Estimated Impact at 1,000 years
Radon [pCi m^{-2} $second^{-1}$]	20.0	$<6x10^{-4}$
Other radionuclides (^{3}H and ^{14}C) [mrem in a year]	10.0	<2.8

Note: The DOE time of compliance is 1,000 years. The point of compliance is just above the disposal facility.

7.2.6 TRU Requirements

Table 7-5 presents the TRU cumulative release to groundwater during the first 10,000 years. The cumulative releases are below the performance objectives set by EPA. Iodine-129 is the radionuclide closest to the limit (a little over a factor of 10) for the base case inventory. Other radioisotopes have larger margins for the base case inventory. Because practically all of the mobile contaminants reach groundwater (92%), the results are insensitive to the release rate model.

Table 7-5. TRU-Weighted Cumulative Release to Groundwater During the first 10,000 years for 1,000,000 Units of Source Material

Radionuclide	Performance Objective	Base Case	Radionuclide	Performance Objective	Base Case
^{90}Sr	1,000	2.79	^{235}U	100	0.00
^{99}Tc	10,000	65.76	^{236}U	100	0.00
^{126}Sn	1,000	35.01	^{237}Np	100	0.01
^{129}I	100	9.92	^{238}Pu	100	0.00
^{134}Cs	1,000	0.21	^{238}U	100	0.06
^{137}Cs	1,000	0.24	^{239}Pu	100	0.05
^{226}Ra	100	2.2E-05	^{240}Pu	100	0.01
^{232}Th	10	4.9E-03	^{241}Am	100	0.04
^{233}U	100	0.37	^{242}Pu	100	4.1E-07
^{234}U	100	0.07	^{243}Am	100	1.0E-06

However, the results are sensitive to the amount of waste left in the tanks. Thus, it is not possible to place a strict probabisltic uncertainty on the results. However, given the low results in Table 7-5 and that these results are based on quite conservative assumptions, if the HFFACO commitments are met, it is very likely that there is less than 1 chance in 10 that performance objectives in Table 7-5 would not be met and that there is less than 1 change in 1,000 that values would exceed 10 times the performance objectives.

7.2.7 Summary

All of the estimated impacts meet the performance objectives set out in Section 1.3 for the base case. However, this conclusion rests on decisions and implementations that have not been made.

7.3 PERFORMANCE SENSITIVITY TO KEY PARAMETER UNCERTAINTIES

As repeatedly noted, these results are extremely sensitive to the retrieval methods chosen and the efficiency of their implementation. The events have not yet occurred.

If retrievals occur similar to that analyzed in this preliminary performance assessment, then past leaks in the WMA will be the largest source of contamination to the groundwater.

Since this is a preliminary assessment, the number of sensitivity studies presented is small. The inventory for past leaks is relatively well known since they are dominated by two large pipeline leaks. This inventory should be confirmed by field work and laboratory analyses planned for fiscal years 2004 and 2005. In addition, the water infiltration can be reasonably bounded based on other Hanford Site data. Since mobile contaminants are the primary drivers, soil geochemistry is relatively unimportant (and is again well known from other Hanford Site programs). The other major driver, groundwater flow, will also be confirmed by planned fiscal year 2004 activities.

For the intruder analysis, impacts are also expected to be small if present retrieval plans are properly implemented. The main uncertainties are inventory of tank residuals and the exposure scenario chosen. All under exposure scenarios, exposures would be below performance objectives.

7.4 CONSERVATISMS AND CAVEATS

Although this analysis was designed to be reasonably conservative (through choice of moisture infiltration values, geochemical effects, diffusion parameters), there are large unknowns because of the effect of future events. Only preliminary plans exist for the retrieval method to be used for each tank. There is very little experience for solid retrievals from tank on which to base retrieval efficiency. Closure planning is just getting starting. Once these activities mature (partially, at least, based on performance assessments like this one), then more accurate predictions can be made.

However, this analysis does show that if retrieval and closure plans can be implemented somewhat similar to those assumed here, WMA C can be closed while still meeting environmental performance requirements.

7.5 FURTHER WORK

Performance assessments are iterative in nature and improve as data gaps are filled. Assessments are updated as data gaps are filled to reflect a greater understanding of the system. This process begins with using existing data and supplementing known data gaps with assumptions. For this assessment, although current site-specific data needed for this risk assessment are incomplete, enough relevant data from other sources were available that specific assumptions were made to satisfy the data gaps.

When made, these assumptions tended to be on the conservative side. For example, this analysis used the most conservative values expected for residual inventory (Selected Phase Retention). Selected phase retention is associated with dry retrieval. As the risk assessment process continues, the conservative assumptions are replaced with site-specific data. In this case, sampling of residual waste following retrieval would provide the best residual waste inventory estimates.

The data gaps identified during the course of this analysis are given in Table 7-6, included in this table are the following:

- **Information type** can be either data (measurable quantity) or analysis (derived)
- **Impacts** identifies what item in the analysis would change with additional information
- **Knowledge Level** is based on professional judgment after reviewing available literature
- **Data Collection Feasibility** is based on professional judgment on the ease of collecting the data
- **Ranking** is based on professional judgment on how important this data is to the analysis
- **Path Forward** describes how the identified data gap should be addressed
- **Limitations** describe how the data gap is being addressed in this analysis.

Table 7-6. Data Gaps and Priorities.

Title	Information Type	Impacts	Knowledge Level	Data Collection Feasibility	Ranking	Path Forward	Limitations
Inventory estimates	Data and analysis	Peak concentrations and arrival times for breakthrough curves from various sources	Medium	Medium	1	Evaluate and update BBI and vadose zone inventory estimates, as appropriate.	Limited availability and uncertain quality for ancillary equipment and piping systems' inventory estimates
Residual waste release models	Data and analysis	Peak concentrations and arrival times for breakthrough curves due to residual wastes	Low	High	1	Characterize residual tank wastes; obtain empirical data on their release behavior especially for stabilized (grouted) and for solubility-driven waste forms.	In the absence of characterization data for release models, conservative values are being used for diffusion coefficients for stabilized (grouted) tank wastes. Considerable uncertainty exists also with the solubility-dominated release model used in this assessment.
Retrieval leak volumes	Data	Peak concentrations and arrival times for retrieval leaks	Low	Not known	1	Evaluate current leak detection monitoring methods during retrieval operations.	Leak volumes used in this assessment are data used in past analyses
Composition of leaked retrieval tank wastes	Data and analysis	Peak concentrations and arrival times for retrieval leaks	Low	Medium	1	Evaluate data collected during retrieval operations.	No data on composition available at this time and values used in this assessment are assumptions

Table 7-6. Data Gaps and Priorities.

Title	Information Type	Impacts	Knowledge Level	Data Collection Feasibility	Ranking	Path Forward	Limitations
Two-dimensional versus three-dimensional modeling	Analysis	Peak concentrations and arrival times for breakthrough curves from various sources	Medium	High	1	Perform STOMP simulations for both two- and three-dimensional setup of the tank farm flow domain and evaluate the approach being used to account for the third dimension.	An untested approach is presently being used to account for the third dimension.
Short Term Risk Assessment Closure Accident Scenarios	Analysis	Changes short-term risk for accident scenarios	Medium	High	1	Perform Safety Analysis for Closure Activities	Uses retrieval accident scenarios as a bounding case
Pre-closure (current) recharge estimates	Data	Peak concentrations and arrival times for breakthrough curves due to past and retrieval leaks	Medium	Medium	2	Review recently collected infiltration data for BX tank farm, and evaluate applicability for C tank farm conditions.	Data are derived from other sources and not a site-specific measurement.
Hydraulic and transport parameters for unconfined aquifer	Data	Breakthrough curves from various sources at the Exclusion Boundary and Columbia River	Medium	Medium	2	Evaluate applicability of Site-wide hydraulic and transport parameters that are being used in the initial assessment	Parameters being used in the initial assessment are believed to be conservative.

Table 7-6. Data Gaps and Priorities.

Title	Information Type	Impacts	Knowledge Level	Data Collection Feasibility	Ranking	Path Forward	Limitations
Post-closure (barrier) recharge estimates	Data	Peak concentrations and arrival times for breakthrough curves due to residual wastes	High	Medium	2	Review multi-year infiltration data collected for 200-BP-1 prototype barrier, and evaluate applicability for C tank farm RCRA barrier.	Use available data after review
Hydrologic properties of vadose zone units	Data	Peak concentrations and arrival times for breakthrough curves from various sources	Medium	Medium	3	Measure properties of site-specific soils.	Must extrapolate small scale (i.e., laboratory measurements) to large scale estimates
Existing vadose zone contamination	Data and analysis	Peak concentrations and arrival times for past leaks and unplanned releases	Low	Medium	2	Continue evaluating spectral gamma logging data as part of a FIR for WMA C.	Extrapolating local measurements to the entire vadose zone introduces uncertainty. Spectral data do not include long-lived mobile contaminants. Data are mostly from vertical point sources.

7.5.1 Future Performance Assessments

This preliminary performance assessment for WMA C closure is the first of a series of performance assessments. It will be followed by an initial full performance assessment for WMA C (expected in mid fiscal year 2004) and then maintenance performance assessments as tanks and other facilities in WMA C are retrieved, remediated, and closed. Discussions with Ecology have lead to the establishment of a series of risk assessments under the RCRA as documented in *Contents of Risk Assessments to Support the Retrieval and Closure of Tanks for the Washington State Department of Ecology* (Connelly 2003b). The RCRA risk assessments and the performance assessments will be merged as quickly as possible to provide a unified set of assessments to address long-term impacts.

Beside assessments of WMA C, there will be assessments of other SST farm WMAs. The first set of such preliminary performance assessments is likely to be performed for WMA S-SX in early to mid fiscal 2004. These will be followed by preliminary performance assessments for other WMAs (A/AX, B/BX/BY, T, TX/TY, and U) as well as full assessments.

7.5.2 Interactions with Retrieval/Closure Projects

This performance assessment activity will closely interact with other parts of the Retrieval and Closure Projects. It is these groups that will plan and implement retrieval and closure activities. It is these projects that will obtain the data on how efficiently they have achieved their goals. They will have the experience on which to estimate future retrievals and closures. It is expected that the Retrieval and Closure Projects will use the information generated in this report in the planning of their future activities.

7.5.3 Interactions with Tank Farm Vadose Zone Project

The Tank Farm Vadose Zone Project is the group responsible for detecting and remediating past leaks associated with SST farms. The information that this group has generated has been the bedrock for the data used in this assessment. As the Tank Farm Vadose Zone Project obtains further data and information on the single-shell tank system, particularly the WMA C, the data and information will be used in future assessments. Already the plans of the Tank Farm Vadose Zone Project have been altered by the generation of this analysis, particularly in the areas of the WMA C field investigation.

7.5.4 Interactions with Integrated Disposal Facility Project

The performance assessment activity associated with the Integrated Disposal Facility (formerly known as the ILAW Performance Assessment activity) has a significant data gathering effort on contaminated soils in the 200 East Area. The closure performance assessments will rely on such data and information for recharge, moisture movement, and contamination transport. These

closure activities will also built on the expertise developed for understanding how materials release contaminants that has been established for the ILAW activity.

7.5.5 Data Collection

As noted above, this activity will rely on other Hanford Site activities to generate new data and information. However, this activity will actively peruse the issues of amount and concentration of contaminants of tank residual material as well as the contaminant release rate of such materials. It will also fill in data gaps missed by other programs.

7.5.6 New Analyses

Because of the preliminary nature of this analysis, there are recognized limitations in the analysis itself: use of fence-line averages, number of contaminants, and number of sensitivity cases.

A limitation of the present analysis is the lack of information on distribution of contaminants at the source and then the subsequent spread of contaminants to the points of calculation. This assessment used a fence-line average to overcome this limitation. Future assessments will perform three-dimensional analyses to determine the actual spread and how point-wise values deviant from the fence-line average.

This analysis analyzed six contaminants (^{99}Tc, ^{129}I, Cr, NO_2, NO_3, and U). Past experience would indicate that these are the key contaminants. Future work will perform a screening analysis to determine the actual key contaminants for closure.

This assessment did not include the number of sensitivity and uncertainty cases usually associated with a performance assessment. The emphasis in this document was to determine key processes rather than to extensively define all the details. Future full closure performance assessments will include more sensitivity studies, particularly in the area of recharge, inventory, and retrieval/closure planning.

7.6 CONCLUSION

This performance assessment analyzed the long-term environmental and human health impact of closing WMA C. Four sources of contamination (past leaks, potential retrieval leaks, tank residual waste, and infrastructure residual waste) were considered. Six contaminants (^{99}Tc, ^{129}I, Cr, NO_2, NO_3, and U) were analyzed, based on past Hanford Site assessments. This analysis shows that if present retrieval and closure plans are carried out as currently tentatively planned, then long-term impacts to the environment will be below performance objectives. Moreover, this report provides some information to perform sensitivity studies if other retrieval and closure options are chosen. The reports also shows that, even though some of the tanks may contain waste having greater than 100 nCi/g of transuranic wastes, these tanks will still protect the environment and the inadvertent intruder.

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Mr. Anderson has over 31 years of experience as a geological engineer, environmental consultant, government manager and professor involving environmental characterization, compliance and remediation, mining, geology, water resources development, and program and project management. He has worked as a consultant at five DOE sites during the past decade: Hanford and Oak Ridge reservations, Portsmouth and Paducah Gaseous Diffusion Plants, and INEEL. He has also been a manager for the U.S. Geological Survey and the U.S. Office of surface Mining, and an assistant professor of geology. Mr. Anderson was responsible for FY 2001 Interim Measures engineering design and construction activities for the Tank Farm Vadose Zone Project. He managed this activity.

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Mr. Knepp managed the Tank Farm Vadose Zone Project for most of its existence and produced the Field Investigation Reports for the B/BX/BY and S/SX single-shell tank farms. For this document, he reviewed the document and provided strategic advice.

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Mr. Miller has managed and implemented groundwater characterization and remediation at many locations throughout the United States. His experience includes groundwater actions taken under RCRA, CERCLA, and other regulatory frameworks, both for governmental agencies and for private industrial clients. For this project, Mr. Miller directed the creation and testing of the Decision Management Tool software used to integrate the fate and transport calculations with unit risk factors for various receptors to calculate the estimated cancer risk, hazard index, and radiological dose over time due to the potential release of tank waste constituents.

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Dr. White is the principal author of the U.S. Department of Energy developed multiphase subsurface flow and transport simulators STOMP and STOMP90. Since his employment at the Laboratory in 1986, he has contributed to a diverse collection of projects. His research activities have been directed at developing mathematical descriptions of experimentally observed multiphase subsurface flow and transport processes and applying these descriptions to the effective remediation of contaminated subsurface environments through field-scale technology design, development or improvement. His most recent research has been focused on the theoretical development and numerical application of nonwetting fluid entrapment, mobilization and dissolution in porous media. For this project, he served as the technical lead on the vadose zone modeling and groundwater pathway effort.

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APPENDIX A

Dosimetry Data

All dosimetry data is from

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Table A-1. Radionuclides to be Considered and Their Half Lives. (2 pages)

Nuclide	Half life (years)	Short-lived progeny in equilibrium with parent
H-3	12.33	
Be-10	1.60E+06	
C-14	5,730	
Na-22	2.6019	
Si-32+D	329.56	P-32
Cl-36	300,992	
K-40	1.28E+09	
Ti-44+D	47.3	Sc-44
V-49	0.92539 (338 d)	
Mn-54	0.85454 (312.12 d)	
Fe-55	2.7299	
Co-60	5.2713	
Ni-59	74,999	
Ni-63	100.1	
Se-79	805,000	
Rb-87	4.80E+10	
Sr-90+D	28.149	Y-90
Zr-93	1.53E+06	
Nb-91	680	
Nb-93m	16.13	
Nb-94	20,300	
Mo-93	3,500	
Tc-99	11,097	
Ru-106+D	1.01736 (371.59 d)	Rh-106
Pd-107	6.50E+06	
Ag-108m+ D	127	Ag-108 (0.087)
Cd-109	1.26653 (462.6 d)	
Cd-113m	14.1	
In-115	4.41E+14	
Sn-121m+D	54.998	Sn-121 (0.776)
Sn-126+D	246,000	Sb-126m, Sb-126 (0.14)
Sb-125	2.7299	
Te-125m	0.15880 (58 d)	
I-129	1.57E+07	
Cs-134	2.0619	
Cs-135	2.30E+06	
Cs-137+D	29.999	Ba-137m (0.9443)
Ba-133	10.52	
Pm-147	2.6233	
Sm-147	1.06E+11	
Sm-151	89.997	
Eu-150	35.798	
Eu-152	13.33	
Eu-154	8.5919	
Eu-155	4.68	
Gd-152	1.08E+14	

Table A-1. Radionuclides to be Considered and Their Half Lives. (2 pages)

Nuclide	Half life (years)	Short-lived progeny in equilibrium with parent
Ho-166m	1,200	
Re-187	5.00E+10	
Tl-204	3.7801	
Pb-205	1.52E+07	
Pb-210+D	22.3	Bi-210
Bi-207	32.198	
Po-209	102	
Po-210	0.37886 (138.38 d)	
Ra-226+D	1,600	Rn-222, Po-218, Pb-214, Bi-214, Po-214(0.9998)
Ra-228+D	5.7498	Ac-228 Ac-227+D 21.769 Th-227 (0.9862), Fr-223 (0.0138), Ra-223, Rn-219, Po-215, Pb-211, Bi-211, Tl-207 (.99725), Po-211 (.00275)
Th-228+D	1.9129	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Po-212 (0.6406), Tl-208 (0.3594)
Th-229+D	7,340	Ra-225, Ac-225, Fr-221, At-217, Bi213, Po-21 3(0.9784), Tl-209 (0.0216)
Th-230	75,380	
Th-232	1.41E+10	
Pa-231	32,759	
U-232	69.799	
U-233	159,198	
U-234	245,694	
U-235+D	7.04E+08	Th-231
U-236	2.34E+07	
U-238+D	4.47E+09	Th-234, Pa-234m, Pa-234 (0.0013)
Np-237+D	2.14E+06	Pa-233
Pu-236	2.8999	
Pu-238	87.697	
Pu-239	24,110	
Pu-240	6,563	
Pu-241+D	14.35	U-237 (2.39E-05)
Pu-242	373,507	
Pu-244+D	8.00E+07	U-240 (0.9988), Np-240m, Np-240 (0.0012)
Am-241	432.7	
Am-242m+D	141	Am-242(0.9955), Np-238(0.0045)
Am-243+D	7,370	Np-239
Cm-242	0.44611 (162.94 d)	
Cm-243	28.499	
Cm-244	18.1	
Cm-245	8,500	
Cm-246	4,730	
Cm-247+D	1.600E+07	Pu-243
Cm-248	339,981	
Cm-250+D	11,300	Pu-246 (0.25), Am-246(0.25), Bk-250(0.14)
Bk-247	1,394	
Cf-248	0.91294 (333.45 d)	
Cf-249	350.6	
Cf-250	13.08	
Cf-251	897.98	
Cf-252	2.6449	

Note: Parentheses show (1) half-lives that are normally given in days, and (2) branching ratios that differ from 1.00.

Table A-2. Decay Chains Actually Computed

Zr-93	→	Nb-93m				
Mo-93	→	Nb-93m				
Sb-125	→ 0.23	Te-125m				
Pm-147	→	Sm-147				
Eu-152	→ 0.2792	Gd-152				
Pb-210	→	Po-210				
Po-209	→ 0.9974	Pb-205				
Ra-226	→	Pb-210	→	Po-210		
Ra-228	→	Th-228				
Th-230	→	Ra-226	→	Pb-210	→	Po-210
Th-232	→	Ra-228	→	Th-228		
Pa-231	→	Ac-227				
U-232	→	Th-228				
U-233	→	Th-229				
U-234	→	Th-230	→	Ra-226	→	Pb-210
U-235	→	Pa-231	→	Ac-227		
Pu-236	→	U-232	→	Th-228		
Pu-238	→	U-234				
Pu-241	→	Am-241	→	Np-237		
Pu-244	→	Pu-240				
Am-241	→	Np-237				
Am-242m	→ 0.827 → 0.173	Cm-242 Pu-242	→	Pu-238	→	U-234
Am-243	→	Pu-239				
Cm-242	→	Pu-238	→	U-234		
Cm-243	→ 0.0024 →	Pu-239 Am-243				
Cm-244	→	Pu-240				
Cm-245	→	Pu-241	→	Am-241	→	Np-237
Cm-247	→	Am-243				
Cm-250	→ 0.14 → 0.25	Cf-250 Cm-246				
Bk-247	→	Am-243				
Cf-248	→	Cm-244	→	Pu-240		
Cf-249	→	Cm-245	→	Pu-241	→	Am-241
Cf-250	→	Cm-246				
Cf-251	→	Cm-247				
Cf-252	→	Cm-248				

Notes:

1) Decay times are assumed to be less than 1000 years so that the ingrowth of progeny with long half-lives can be ignored.
2) There is a slight increase in the Pu-238 and U-234 for the Am-242m decay chain that is not shown. This is a result of the low-probability alpha decay of Am-242m. The complete chain is, Am-242m (0.00455)--->Np-238--->Pu-238--->U-234.

Table A-3. Exposure Pathway Summary for Standard Performace Assessment Scenarios.

		A.1.1.1.1 Standard Performance Assessment Exposure Scenarios								
	Exposure Scenarios ➡	Waste Intruders				All Pathways Farmer		Native American		Columbia River Population
	Exposure Pathways	Driller	Sub. Res.	Rural Res.	Com. Farm	GW	River	GW	River	
Water	Ingestion					●	●	●	●	●
	Vapor Inhalation					●	●	●	●	●
	Shower, dermal					●	●	●	●	●
	Swimming, dermal								●	●
	Sweat Lodge, inhalation							●	●	
Shore Sediments	Ingestion						●		●	●
	Inhalation									
	Dermal Contact						●		●	●
	External Radiation Dose						●		●	●
Soil	Ingestion	●	●	●	●	●	●	●	●	●
	Inhalation	●	●	●	●	●	●	●	●	●
	Dermal Contact					●	●	●	●	●
	External Radiation Dose	●	●	●	●	●	●	●	●	●
	Tritium Vapor Inhalation		●			●	●	●	●	●
Food Chain	Garden Produce		●			●	●	●	●	●
	Grains									
	Beef & Milk			Dairy only		●	●	●	●	●
	Poultry & Egg					●	●	●	●	●
	Fish						●		●	●
	Wild Game								●	

The annual dose equivalent (in mrem) is calculated for all of the exposure scenarios shown on this table. This is the only risk quantifier for the waste intruders. The other exposure scenarios also have incremental cancer risk from a lifetime exposure for both radionuclides and chemicals, and hazard index for chemicals.

Table A-4. Exposure Pathway Summary for HSRAM and MTCA Scenarios.

		Hanford Site Risk Assessment Methodology (HSRAM)							WAC 173-340	
	Exposure Scenarios ➡	Indus-trial	Recreational		Residential		Agricultural		MTCA B & C	
	Exposure Pathways		GW	River	GW	River	GW	River	GW	River
Water	Ingestion	●	●	●	●	●	●	●	●	●
	Vapor Inhalation	●	●	●	●	●	●	●		
	Shower, dermal	●	●	●	●	●	●	●		
	Swimming, dermal			●		●		●		
	Sweat Lodge, inhalation									
Shore Sediments	Ingestion			●		●		●		
	Inhalation									
	Dermal Contact			●		●		●		
	External Radiation Dose			●		●		●		
Soil	Ingestion	●	●	●	●	●	●	●		
	Inhalation	●	●	●	●	●	●	●		
	Dermal Contact	●	●	●	●	●	●	●		
	External Radiation Dose	●	●	●	●	●	●	●		
	Tritium Vapor Inhalation	●	●	●	●	●	●	●		
Food Chain	Garden Produce				●	●	●	●		
	Grains									
	Beef & Milk						●	●		
	Poultry & Egg									
	Fish			●		●		●		●
	Wild Game			●				●		

The annual dose equivalent (in mrem) is not calculated for the exposure scenarios shown on this table. The risk quantifiers for these scenarios are incremental cancer risk from a lifetime exposure for radionuclides

For the dose and risk factors in the ensuing tables, please note the following:

- The nuclides with "+D" have short half life progeny in secular equilibrium.
- All doses (mrem or person-rem) are the 50 year committed EDE from the first year of intake. All risks are the lifetime averages.
- Well Driller dose factor is mrem per Ci/kg. The Ci/kg is the total Ci exhumed divided by the total mass of soil & waste removed from the well.
- Post-Intrusion Resident dose factor is in mrem per Ci exhumed.
- Population numbers are the total for 5 million persons. All other dose/risk factors are per pCi/L in the water used.
- Major individual pathways are shown for intruder scenarios, only the total dose/risk are given for other pathways, please see Rittman (2003) for individual pathway contributions.

Table A-5. Scenario Dose Factors for the Well Driller, mrem per Ci/kg in borehole cuttings

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion
H-3	3.25E+01	0.00E+00	3.25E+01	4.65E-01	3.20E+01
Be-10	5.65E+03	1.61E+03	4.04E+03	1.71E+03	2.33E+03
C-14	1.08E+03	2.05E+01	1.06E+03	1.01E+01	1.05E+03
Na-22	1.79E+07	1.79E+07	5.79E+03	3.71E+01	5.75E+03
Al-26	2.20E+07	2.20E+07	7.36E+03	7.06E+01	7.29E+03
Si-32+D	2.76E+04	1.71E+04	1.05E+04	4.99E+03	5.50E+03
Cl-36	5.10E+03	3.48E+03	1.62E+03	1.06E+02	1.52E+03
K-40	1.31E+06	1.30E+06	9.36E+03	6.00E+01	9.30E+03
Ca-41	6.43E+02	0.00E+00	6.43E+02	6.16E+00	6.36E+02
Ti-44+D	1.80E+07	1.80E+07	1.45E+04	2.19E+03	1.23E+04
V-49	3.24E+01	0.00E+00	3.24E+01	1.67E+00	3.07E+01
Mn-54	6.81E+06	6.81E+06	1.42E+03	3.24E+01	1.39E+03
Fe-55	3.10E+02	0.00E+00	3.10E+02	6.49E+00	3.04E+02
Fe-60+D	7.75E+04	1.71E+01	7.75E+04	1.31E+03	7.62E+04
Co-60	2.06E+07	2.06E+07	1.36E+04	1.60E+02	1.35E+04
Ni-59	1.09E+02	0.00E+00	1.09E+02	4.44E+00	1.05E+02
Ni-63	3.00E+02	0.00E+00	3.00E+02	1.11E+01	2.89E+02
Se-79	4.41E+03	2.83E+01	4.38E+03	3.17E+01	4.35E+03
Rb-87	2.69E+03	2.14E+02	2.48E+03	1.56E+01	2.46E+03
Sr-90+D	1.13E+05	3.51E+04	7.77E+04	1.20E+03	7.65E+04
Zr-93	1.23E+03	0.00E+00	1.23E+03	4.03E+02	8.30E+02
Nb-91	1.75E+04	1.72E+04	2.77E+02	1.55E+01	2.61E+02
Nb-93m	4.35E+02	1.58E+02	2.77E+02	1.55E+01	2.61E+02
Nb-94	1.29E+07	1.29E+07	3.74E+03	1.75E+02	3.57E+03
Mo-93	1.71E+03	8.97E+02	8.12E+02	1.37E+02	6.75E+02
Tc-99	9.61E+02	1.91E+02	7.70E+02	4.03E+01	7.30E+02
Ru-106+D	1.76E+06	1.75E+06	1.43E+04	5.71E+02	1.37E+04
Pd-107	1.36E+02	0.00E+00	1.36E+02	6.20E+01	7.45E+01
Ag-108m+D	1.31E+07	1.31E+07	3.93E+03	1.22E+02	3.81E+03
Cd-109	2.95E+04	2.24E+04	7.10E+03	5.52E+02	6.55E+03
Cd-113m	8.89E+04	9.72E+02	8.79E+04	7.41E+03	8.05E+04
In-115	9.77E+04	6.03E+02	9.71E+04	1.81E+04	7.90E+04
Sn-121m+D	4.39E+03	3.21E+03	1.18E+03	5.76E+01	1.13E+03
Sn-126+D	1.61E+07	1.61E+07	1.10E+04	4.89E+02	1.05E+04
Sb-125	3.36E+06	3.36E+06	1.46E+03	5.90E+01	1.41E+03
Te-125m	2.49E+04	2.30E+04	1.87E+03	3.53E+01	1.84E+03
I-129	1.59E+05	1.97E+04	1.39E+05	8.42E+02	1.38E+05
Cs-134	1.28E+07	1.27E+07	3.69E+04	2.24E+02	3.67E+04
Cs-135	3.62E+03	5.82E+01	3.56E+03	2.20E+01	3.54E+03
Cs-137+D	4.62E+06	4.59E+06	2.52E+04	1.54E+02	2.50E+04
Ba-133	2.81E+06	2.81E+06	1.74E+03	3.78E+01	1.70E+03
Pm-147	7.91E+02	7.59E+01	7.15E+02	1.90E+02	5.25E+02
Sm-147	4.54E+05	0.00E+00	4.54E+05	3.62E+05	9.25E+04
Sm-151	3.41E+02	1.50E+00	3.40E+02	1.45E+02	1.95E+02
Eu-150	1.19E+07	1.19E+07	4.48E+03	1.30E+03	3.18E+03
Eu-152	9.15E+06	9.15E+06	4.31E+03	1.07E+03	3.24E+03
Eu-154	1.00E+07	1.00E+07	6.16E+03	1.38E+03	4.78E+03
Eu-155	2.78E+05	2.77E+05	9.65E+02	2.00E+02	7.65E+02
Gd-152	1.26E+06	0.00E+00	1.26E+06	1.18E+06	8.05E+04
Ho-166m	1.39E+07	1.39E+07	7.78E+03	3.74E+03	4.04E+03
Re-187	5.02E+00	0.00E+00	5.02E+00	2.63E-01	4.76E+00

Table A-5. Scenario Dose Factors for the Well Driller, mrem per Ci/kg in borehole cuttings

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion
Tl-204	7.81E+03	6.12E+03	1.69E+03	1.17E+01	1.68E+03
Pb-205	8.45E+02	1.07E+01	8.34E+02	1.90E+01	8.15E+02
Pb-210+D	2.76E+06	9.00E+03	2.75E+06	6.58E+04	2.69E+06
Bi-207	1.23E+07	1.23E+07	2.84E+03	9.68E+01	2.74E+03
Po-209	1.26E+06	2.69E+04	1.24E+06	5.18E+04	1.19E+06
Po-210	9.92E+05	6.96E+01	9.92E+05	4.15E+04	9.50E+05
Ra-226+D	1.50E+07	1.43E+07	7.07E+05	4.16E+04	6.65E+05
Ra-228+D	8.60E+06	7.86E+06	7.44E+05	2.35E+04	7.20E+05
Ac-227+D	1.87E+07	2.88E+06	1.58E+07	8.42E+06	7.40E+06
Th-228+D	1.47E+07	1.26E+07	2.06E+06	1.66E+06	4.06E+05
Th-229+D	1.27E+07	2.24E+06	1.04E+07	8.42E+06	2.02E+06
Th-230	1.54E+06	1.82E+03	1.54E+06	1.27E+06	2.74E+05
Th-232	6.93E+06	7.89E+02	6.93E+06	5.57E+06	1.37E+06
Pa-231	1.18E+07	2.73E+05	1.15E+07	6.20E+06	5.30E+06
U-232	7.28E+05	1.36E+03	7.27E+05	7.21E+04	6.55E+05
U-233	1.85E+05	2.06E+03	1.83E+05	3.87E+04	1.45E+05
U-234	1.80E+05	6.09E+02	1.80E+05	3.81E+04	1.42E+05
U-235+D	1.29E+06	1.12E+06	1.69E+05	3.53E+04	1.34E+05
U-236	1.71E+05	3.24E+02	1.71E+05	3.60E+04	1.35E+05
U-238+D	3.44E+05	1.76E+05	1.68E+05	3.42E+04	1.34E+05
Np-237+D	6.42E+06	1.58E+06	4.83E+06	2.61E+06	2.22E+06
Pu-236	1.29E+06	3.42E+02	1.29E+06	7.02E+05	5.85E+05
Pu-238	3.50E+06	2.30E+02	3.50E+06	1.90E+06	1.60E+06
Pu-239	3.85E+06	4.32E+02	3.85E+06	2.08E+06	1.77E+06
Pu-240	3.85E+06	2.23E+02	3.85E+06	2.08E+06	1.77E+06
Pu-241+D	7.42E+04	2.79E+01	7.42E+04	3.99E+04	3.43E+04
Pu-242	3.67E+06	1.95E+02	3.67E+06	1.99E+06	1.68E+06
Pu-244+D	6.32E+06	2.71E+06	3.61E+06	1.95E+06	1.66E+06
Am-241	4.04E+06	6.66E+04	3.97E+06	2.15E+06	1.82E+06
Am-242m+D	3.92E+06	9.84E+04	3.82E+06	2.06E+06	1.76E+06
Am-243+D	5.27E+06	1.33E+06	3.94E+06	2.13E+06	1.82E+06
Cm-242	1.41E+05	2.58E+02	1.41E+05	8.37E+04	5.75E+04
Cm-243	3.60E+06	8.58E+05	2.74E+06	1.49E+06	1.26E+06
Cm-244	2.21E+06	1.92E+02	2.21E+06	1.20E+06	1.01E+06
Cm-245	4.59E+06	5.13E+05	4.07E+06	2.20E+06	1.87E+06
Cm-246	4.03E+06	1.77E+02	4.03E+06	2.18E+06	1.85E+06
Cm-247+D	6.34E+06	2.62E+06	3.71E+06	2.00E+06	1.71E+06
Cm-248	1.48E+07	1.34E+02	1.48E+07	7.99E+06	6.80E+06
Cm-250+D	8.69E+07	2.57E+06	8.43E+07	4.55E+07	3.89E+07
Bk-247	5.77E+06	6.42E+05	5.13E+06	2.78E+06	2.35E+06
Cf-248	3.82E+05	1.90E+02	3.82E+05	2.15E+05	1.67E+05
Cf-249	7.78E+06	2.61E+06	5.16E+06	2.79E+06	2.37E+06
Cf-250	2.33E+06	1.80E+02	2.33E+06	1.27E+06	1.07E+06
Cf-251	6.06E+06	7.86E+05	5.27E+06	2.85E+06	2.43E+06
Cf-252	1.20E+06	2.67E+02	1.20E+06	6.63E+05	5.40E+05

Table A-6. Scenario Dose Factors for the Post Intruder Resident (Suburban resident with 100 m^2 garden), mrem per Ci exhumed. (2 pages)

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion	Vegetables
H-3	3.19E+00	0.00E+00	3.19E+00	3.04E-01	8.71E-04	2.89E+00
Be-10	1.24E+01	9.66E-01	1.14E+01	1.37E+00	3.73E+00	6.31E+00
C-14	6.22E+02	1.21E-02	6.22E+02	7.89E-03	1.63E+00	6.20E+02
Na-22	1.14E+04	1.01E+04	1.36E+03	2.60E-02	8.06E+00	1.35E+03
Al-26	1.32E+04	1.32E+04	2.48E+01	5.64E-02	1.17E+01	1.31E+01
Si-32+D	4.13E+02	1.02E+01	4.03E+02	3.96E+00	8.75E+00	3.90E+02
Cl-36	8.26E+04	1.90E+00	8.26E+04	7.32E-02	2.10E+00	8.26E+04
K-40	5.29E+03	7.71E+02	4.52E+03	4.72E-02	1.46E+01	4.51E+03
Ca-41	2.61E+02	0.00E+00	2.61E+02	4.83E-03	1.00E+00	2.60E+02
Ti-44+D	1.08E+04	1.08E+04	6.76E+01	1.73E+00	1.95E+01	4.63E+01
V-49	1.25E-01	0.00E+00	1.25E-01	9.39E-04	3.46E-02	8.93E-02
Mn-54	3.59E+03	3.36E+03	2.35E+02	1.77E-02	1.52E+00	2.34E+02
Fe-55	1.70E+00	0.00E+00	1.70E+00	4.58E-03	4.29E-01	1.26E+00
Fe-60+D	9.13E+02	4.15E+02	4.98E+02	1.05E+00	1.23E+02	3.74E+02
Co-60	1.25E+04	1.19E+04	5.85E+02	1.20E-01	2.01E+01	5.65E+02
Ni-59	5.70E+00	0.00E+00	5.70E+00	3.55E-03	1.68E-01	5.53E+00
Ni-63	1.56E+01	0.00E+00	1.56E+01	8.86E-03	4.60E-01	1.52E+01
Se-79	9.98E+01	1.61E-02	9.98E+01	2.34E-02	6.44E+00	9.33E+01
Rb-87	1.91E+03	1.28E-01	1.91E+03	1.25E-02	3.92E+00	1.90E+03
Sr-90+D	3.57E+04	2.09E+01	3.57E+04	9.43E-01	1.21E+02	3.56E+04
Zr-93	3.36E+00	1.01E-03	3.36E+00	3.22E-01	1.34E+00	1.70E+00
Nb-91	1.49E+01	1.03E+01	4.53E+00	1.24E-02	4.17E-01	4.10E+00
Nb-93m	4.55E+00	9.40E-02	4.46E+00	1.21E-02	4.08E-01	4.04E+00
Nb-94	7.78E+03	7.72E+03	6.19E+01	1.39E-01	5.71E+00	5.61E+01
Mo-93	4.60E+02	5.31E-01	4.59E+02	1.08E-01	1.07E+00	4.58E+02
Tc-99	5.06E+03	1.09E-01	5.06E+03	2.98E-02	1.08E+00	5.06E+03
Ru-106+D	1.35E+03	8.89E+02	4.62E+02	3.31E-01	1.59E+01	4.45E+02
Pd-107	3.10E+00	0.00E+00	3.10E+00	4.93E-02	1.19E-01	2.93E+00
Ag-108m+D	7.86E+03	7.85E+03	1.39E+01	9.74E-02	6.07E+00	7.70E+00
Cd-109	7.98E+02	1.17E+01	7.86E+02	3.39E-01	8.05E+00	7.77E+02
Cd-113m	1.15E+04	5.75E-01	1.15E+04	5.76E+00	1.25E+02	1.14E+04
In-115	2.67E+02	3.62E-01	2.66E+02	1.45E+01	1.26E+02	1.26E+02
Sn-121m+D	1.17E+01	1.92E+00	9.82E+00	4.57E-02	1.79E+00	7.98E+00
Sn-126+D	9.74E+03	9.65E+03	9.20E+01	3.90E-01	1.68E+01	7.48E+01
Sb-125	1.92E+03	1.90E+03	2.84E+01	4.62E-02	2.46E+00	2.59E+01
Te-125m	8.75E+00	5.61E+00	3.14E+00	6.37E-03	6.64E-01	2.47E+00
I-129	2.88E+03	1.17E+01	2.87E+03	6.65E-01	2.18E+02	2.65E+03
Cs-134	1.21E+04	7.02E+03	5.10E+03	1.52E-01	4.98E+01	5.05E+03
Cs-135	5.55E+02	3.49E-02	5.55E+02	1.76E-02	5.66E+00	5.50E+02
Cs-137+D	6.63E+03	2.74E+03	3.89E+03	1.22E-01	3.95E+01	3.85E+03
Ba-133	1.71E+03	1.65E+03	5.43E+01	2.91E-02	2.63E+00	5.17E+01
Pm-147	3.19E+00	4.27E-02	3.15E+00	1.33E-01	7.38E-01	2.28E+00
Sm-147	8.77E+02	0.00E+00	8.77E+02	2.89E+02	1.48E+02	4.41E+02
Sm-151	1.35E+00	8.96E-04	1.35E+00	1.15E-01	3.10E-01	9.24E-01
Eu-150	7.11E+03	7.09E+03	2.11E+01	1.03E+00	5.04E+00	1.51E+01
Eu-152	5.44E+03	5.42E+03	2.10E+01	8.32E-01	5.05E+00	1.52E+01
Eu-154	5.92E+03	5.89E+03	3.05E+01	1.06E+00	7.34E+00	2.21E+01
Eu-155	1.65E+02	1.60E+02	4.75E+00	1.49E-01	1.14E+00	3.46E+00
Gd-152	1.45E+03	0.00E+00	1.45E+03	9.39E+02	1.29E+02	3.84E+02
Ho-166m	8.38E+03	8.35E+03	2.87E+01	2.99E+00	6.45E+00	1.92E+01
Re-187	1.64E+00	0.00E+00	1.64E+00	2.10E-04	7.59E-03	1.63E+00

Table A-6. Scenario Dose Factors for the Post Intruder Resident (Suburban resident with 100 m^2 garden), mrem per Ci exhumed. (2 pages)

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion	Vegetables
Tl-204	8.49E+00	3.51E+00	4.98E+00	8.51E-03	2.46E+00	2.51E+00
Pb-205	7.47E+00	6.44E-03	7.47E+00	1.52E-02	1.30E+00	6.15E+00
Pb-210+D	2.72E+04	5.37E+00	2.72E+04	6.95E+01	5.04E+03	2.21E+04
Bi-207	7.38E+03	7.36E+03	2.20E+01	7.65E-02	4.34E+00	1.76E+01
Po-209	7.46E+03	1.61E+01	7.44E+03	4.12E+01	1.89E+03	5.51E+03
Po-210	3.03E+03	2.74E-02	3.03E+03	1.52E+01	6.97E+02	2.32E+03
Ra-226+D	1.41E+04	8.60E+03	5.51E+03	3.43E+01	1.14E+03	4.33E+03
Ra-228+D	1.09E+04	5.21E+03	5.73E+03	2.22E+02	1.19E+03	4.32E+03
Ac-227+D	3.12E+04	1.72E+03	2.95E+04	6.62E+03	1.17E+04	1.12E+04
Th-228+D	9.05E+03	6.91E+03	2.13E+03	1.11E+03	5.44E+02	4.79E+02
Th-229+D	1.40E+04	1.34E+03	1.26E+04	6.73E+03	3.22E+03	2.68E+03
Th-230	1.82E+03	2.02E+00	1.82E+03	1.01E+03	4.39E+02	3.65E+02
Th-232	8.85E+03	1.53E+02	8.70E+03	4.46E+03	2.25E+03	1.99E+03
Pa-231	2.15E+04	1.78E+02	2.13E+04	5.06E+03	8.67E+03	7.60E+03
U-232	7.58E+03	6.38E+02	6.94E+03	2.64E+02	1.12E+03	5.56E+03
U-233	1.47E+03	1.25E+00	1.47E+03	3.05E+01	2.26E+02	1.22E+03
U-234	1.44E+03	3.60E-01	1.44E+03	2.98E+01	2.21E+02	1.19E+03
U-235+D	2.02E+03	6.63E+02	1.36E+03	2.76E+01	2.09E+02	1.12E+03
U-236	1.37E+03	1.91E-01	1.37E+03	2.81E+01	2.10E+02	1.13E+03
U-238+D	1.47E+03	1.04E+02	1.36E+03	2.67E+01	2.09E+02	1.13E+03
Np-237+D	3.44E+04	9.46E+02	3.34E+04	2.07E+03	3.53E+03	2.78E+04
Pu-236	2.13E+03	1.24E+00	2.13E+03	5.00E+02	8.38E+02	7.90E+02
Pu-238	6.34E+03	1.37E-01	6.34E+03	1.51E+03	2.55E+03	2.28E+03
Pu-239	7.02E+03	2.59E-01	7.02E+03	1.66E+03	2.83E+03	2.53E+03
Pu-240	7.02E+03	1.34E-01	7.02E+03	1.66E+03	2.83E+03	2.53E+03
Pu-241+D	1.38E+02	3.24E-02	1.38E+02	3.25E+01	5.58E+01	4.95E+01
Pu-242	6.68E+03	1.17E-01	6.68E+03	1.59E+03	2.69E+03	2.40E+03
Pu-244+D	8.21E+03	1.63E+03	6.59E+03	1.56E+03	2.66E+03	2.37E+03
Am-241	7.24E+03	3.99E+01	7.20E+03	1.72E+03	2.91E+03	2.57E+03
Am-242m+D	7.10E+03	5.90E+01	7.04E+03	1.67E+03	2.85E+03	2.52E+03
Am-243+D	7.97E+03	7.96E+02	7.17E+03	1.70E+03	2.90E+03	2.57E+03
Cm-242	1.43E+02	1.08E-01	1.43E+02	3.77E+01	5.31E+01	5.22E+01
Cm-243	5.37E+03	5.12E+02	4.86E+03	1.17E+03	1.98E+03	1.71E+03
Cm-244	3.89E+03	1.14E-01	3.89E+03	9.41E+02	1.59E+03	1.37E+03
Cm-245	7.62E+03	3.08E+02	7.32E+03	1.76E+03	2.99E+03	2.56E+03
Cm-246	7.24E+03	1.06E-01	7.24E+03	1.74E+03	2.96E+03	2.54E+03
Cm-247+D	8.25E+03	1.57E+03	6.68E+03	1.60E+03	2.74E+03	2.34E+03
Cm-248	2.66E+04	8.01E-02	2.66E+04	6.38E+03	1.09E+04	9.32E+03
Cm-250+D	1.53E+05	1.54E+03	1.52E+05	3.63E+04	6.22E+04	5.33E+04
Bk-247	9.69E+03	3.85E+02	9.30E+03	2.22E+03	3.76E+03	3.33E+03
Cf-248	1.59E+03	9.56E-02	1.59E+03	1.35E+02	2.11E+02	1.25E+03
Cf-249	3.06E+04	1.57E+03	2.90E+04	2.23E+03	3.79E+03	2.30E+04
Cf-250	1.28E+04	1.07E-01	1.28E+04	9.86E+02	1.66E+03	1.01E+04
Cf-251	3.02E+04	4.71E+02	2.97E+04	2.27E+03	3.88E+03	2.35E+04
Cf-252	5.99E+03	1.50E-01	5.99E+03	4.66E+02	7.60E+02	4.77E+03

Table A-7. Scenario Dose Factors for the Post Intruder Resident (Rural Resident with Dairy Cow), mrem per Ci exhumed. (2 pages)

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion	Milk
H-3	1.08E-01	0.00E+00	1.08E-01	1.08E-01	1.74E-05	5.37E-06
Be-10	1.67E-01	3.86E-02	1.28E-01	5.31E-02	7.45E-02	2.32E-04
C-14	1.36E+01	4.80E-04	1.36E+01	3.07E-04	3.27E-02	1.35E+01
Na-22	4.25E+02	3.77E+02	4.74E+01	1.01E-03	1.61E-01	4.72E+01
Al-26	5.28E+02	5.27E+02	3.84E-01	2.19E-03	2.33E-01	1.48E-01
Si-32+D	8.05E-01	4.08E-01	3.97E-01	1.54E-01	1.75E-01	6.84E-02
Cl-36	2.66E+03	7.22E-02	2.66E+03	2.85E-03	4.19E-02	2.66E+03
K-40	1.41E+02	3.07E+01	1.11E+02	1.83E-03	2.93E-01	1.11E+02
Ca-41	1.00E+01	0.00E+00	1.00E+01	1.88E-04	2.00E-02	1.00E+01
Ti-44+D	4.42E+02	4.29E+02	1.32E+01	6.74E-02	3.91E-01	1.28E+01
V-49	7.72E-04	0.00E+00	7.72E-04	3.65E-05	6.91E-04	4.46E-05
Mn-54	1.12E+02	1.12E+02	6.26E-02	6.89E-04	3.04E-02	3.16E-02
Fe-55	9.58E-03	0.00E+00	9.58E-03	1.78E-04	8.58E-03	8.21E-04
Fe-60+D	3.46E+01	3.18E+01	2.86E+00	4.08E-02	2.47E+00	3.50E-01
Co-60	4.64E+02	4.62E+02	1.99E+00	4.65E-03	4.02E-01	1.58E+00
Ni-59	3.23E-01	0.00E+00	3.23E-01	1.38E-04	3.36E-03	3.19E-01
Ni-63	8.83E-01	0.00E+00	8.83E-01	3.44E-04	9.20E-03	8.73E-01
Se-79	2.35E+00	6.29E-04	2.35E+00	9.11E-04	1.29E-01	2.22E+00
Rb-87	4.70E+01	5.12E-03	4.69E+01	4.84E-04	7.85E-02	4.69E+01
Sr-90+D	9.66E+02	8.31E-01	9.65E+02	3.66E-02	2.42E+00	9.63E+02
Zr-93	3.94E-02	8.05E-05	3.93E-02	1.25E-02	2.67E-02	4.48E-05
Nb-91	4.21E-01	4.13E-01	8.83E-03	4.81E-04	8.34E-03	1.33E-05
Nb-93m	1.24E-02	3.72E-03	8.65E-03	4.72E-04	8.17E-03	1.30E-05
Nb-94	3.09E+02	3.09E+02	1.20E-01	5.42E-03	1.14E-01	1.81E-04
Mo-93	1.65E+00	2.11E-02	1.63E+00	4.18E-03	2.13E-02	1.61E+00
Tc-99	2.54E+01	4.23E-03	2.54E+01	1.16E-03	2.16E-02	2.54E+01
Ru-106+D	3.08E+01	3.04E+01	3.43E-01	1.29E-02	3.18E-01	1.24E-02
Pd-107	2.45E-01	0.00E+00	2.45E-01	1.92E-03	2.38E-03	2.41E-01
Ag-108m+D	3.13E+02	3.13E+02	1.49E-01	3.78E-03	1.21E-01	2.36E-02
Cd-109	5.15E+00	4.13E-01	4.73E+00	1.32E-02	1.61E-01	4.56E+00
Cd-113m	7.59E+01	2.27E-02	7.58E+01	2.24E-01	2.51E+00	7.31E+01
In-115	3.91E+00	1.45E-02	3.89E+00	5.62E-01	2.53E+00	8.04E-01
Sn-121m+D	2.72E-01	7.65E-02	1.95E-01	1.78E-03	3.58E-02	1.58E-01
Sn-126+D	3.88E+02	3.86E+02	1.83E+00	1.52E-02	3.36E-01	1.48E+00
Sb-125	7.14E+01	7.13E+01	8.14E-02	1.79E-03	4.91E-02	3.04E-02
Te-125m	1.60E-01	1.25E-01	3.53E-02	2.48E-04	1.33E-02	2.18E-02
I-129	2.89E+02	4.68E-01	2.89E+02	2.59E-02	4.37E+00	2.84E+02
Cs-134	4.48E+02	2.59E+02	1.89E+02	5.91E-03	9.96E-01	1.88E+02
Cs-135	2.19E+01	1.40E-03	2.19E+01	6.83E-04	1.13E-01	2.18E+01
Cs-137+D	2.62E+02	1.09E+02	1.53E+02	4.74E-03	7.91E-01	1.52E+02
Ba-133	6.53E+01	6.50E+01	3.07E-01	1.13E-03	5.25E-02	2.53E-01
Pm-147	2.26E-02	1.60E-03	2.10E-02	5.17E-03	1.48E-02	1.02E-03
Sm-147	1.44E+01	0.00E+00	1.44E+01	1.12E+01	2.96E+00	2.06E-01
Sm-151	1.11E-02	3.58E-05	1.11E-02	4.49E-03	6.20E-03	4.31E-04
Eu-150	2.82E+02	2.82E+02	1.48E-01	3.99E-02	1.01E-01	7.01E-03
Eu-152	2.14E+02	2.14E+02	1.40E-01	3.23E-02	1.01E-01	7.02E-03
Eu-154	2.31E+02	2.31E+02	1.98E-01	4.13E-02	1.47E-01	1.02E-02
Eu-155	6.21E+00	6.18E+00	3.01E-02	5.78E-03	2.27E-02	1.58E-03
Gd-152	3.92E+01	0.00E+00	3.92E+01	3.65E+01	2.58E+00	1.79E-01
Ho-166m	3.34E+02	3.34E+02	2.54E-01	1.16E-01	1.29E-01	8.98E-03
Re-187	1.71E-02	0.00E+00	1.71E-02	8.16E-06	1.52E-04	1.69E-02

Table A-7. Scenario Dose Factors for the Post Intruder Resident (Rural Resident with Dairy Cow), mrem per Ci exhumed. (2 pages)

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion	Milk
Tl-204	4.95E-01	1.34E-01	3.61E-01	3.31E-04	4.91E-02	3.12E-01
Pb-205	4.96E-02	2.58E-04	4.94E-02	5.89E-04	2.61E-02	2.27E-02
Pb-210+D	1.95E+02	2.14E-01	1.94E+02	2.70E+00	1.01E+02	9.09E+01
Bi-207	2.93E+02	2.93E+02	2.91E-01	2.97E-03	8.67E-02	2.01E-01
Po-209	7.94E+01	6.42E-01	7.87E+01	1.60E+00	3.78E+01	3.94E+01
Po-210	2.87E+01	7.66E-04	2.87E+01	5.91E-01	1.39E+01	1.42E+01
Ra-226+D	5.15E+02	3.44E+02	1.71E+02	1.33E+00	2.28E+01	1.47E+02
Ra-228+D	4.05E+02	2.24E+02	1.80E+02	8.63E+00	2.37E+01	1.48E+02
Ac-227+D	5.73E+02	6.81E+01	5.05E+02	2.57E+02	2.33E+02	1.47E+01
Th-228+D	3.08E+02	2.54E+02	5.41E+01	4.31E+01	1.09E+01	1.67E-01
Th-229+D	3.80E+02	5.36E+01	3.27E+02	2.61E+02	6.45E+01	9.92E-01
Th-230	4.84E+01	1.18E-01	4.83E+01	3.94E+01	8.77E+00	1.68E-01
Th-232	2.41E+02	1.29E+01	2.29E+02	1.73E+02	4.51E+01	1.03E+01
Pa-231	3.80E+02	7.65E+00	3.73E+02	1.96E+02	1.73E+02	2.88E+00
U-232	1.08E+02	4.77E+01	6.03E+01	1.03E+01	2.24E+01	2.76E+01
U-233	1.19E+01	5.07E-02	1.18E+01	1.18E+00	4.52E+00	6.12E+00
U-234	1.16E+01	1.43E-02	1.16E+01	1.16E+00	4.42E+00	5.99E+00
U-235+D	3.72E+01	2.63E+01	1.09E+01	1.07E+00	4.18E+00	5.66E+00
U-236	1.10E+01	7.60E-03	1.10E+01	1.09E+00	4.20E+00	5.70E+00
U-238+D	1.50E+01	4.13E+00	1.09E+01	1.04E+00	4.19E+00	5.68E+00
Np-237+D	1.91E+02	3.78E+01	1.53E+02	8.06E+01	7.06E+01	1.66E+00
Pu-236	3.65E+01	1.62E-01	3.63E+01	1.94E+01	1.68E+01	1.87E-01
Pu-238	1.10E+02	5.49E-03	1.10E+02	5.87E+01	5.10E+01	1.68E-01
Pu-239	1.21E+02	1.04E-02	1.21E+02	6.44E+01	5.66E+01	1.87E-01
Pu-240	1.21E+02	5.35E-03	1.21E+02	6.44E+01	5.66E+01	1.87E-01
Pu-241+D	2.38E+00	1.91E-03	2.38E+00	1.26E+00	1.12E+00	3.74E-03
Pu-242	1.16E+02	4.67E-03	1.16E+02	6.17E+01	5.38E+01	1.77E-01
Pu-244+D	1.79E+02	6.51E+01	1.14E+02	6.05E+01	5.31E+01	1.75E-01
Am-241	1.27E+02	1.60E+00	1.25E+02	6.66E+01	5.82E+01	2.63E-01
Am-242m+D	1.25E+02	2.36E+00	1.22E+02	6.50E+01	5.70E+01	3.42E-01
Am-243+D	1.56E+02	3.18E+01	1.24E+02	6.61E+01	5.81E+01	2.63E-01
Cm-242	2.59E+00	3.15E-03	2.58E+00	1.47E+00	1.06E+00	5.60E-02
Cm-243	1.08E+02	2.03E+01	8.76E+01	4.56E+01	3.97E+01	2.40E+00
Cm-244	7.02E+01	4.51E-03	7.02E+01	3.66E+01	3.17E+01	1.92E+00
Cm-245	1.44E+02	1.23E+01	1.32E+02	6.84E+01	5.99E+01	3.63E+00
Cm-246	1.31E+02	4.24E-03	1.31E+02	6.77E+01	5.92E+01	3.59E+00
Cm-247+D	1.83E+02	6.29E+01	1.20E+02	6.22E+01	5.47E+01	3.32E+00
Cm-248	4.79E+02	3.20E-03	4.79E+02	2.48E+02	2.18E+02	1.32E+01
Cm-250+D	2.79E+03	6.16E+01	2.73E+03	1.41E+03	1.24E+03	7.53E+01
Bk-247	1.77E+02	1.54E+01	1.62E+02	8.62E+01	7.52E+01	3.40E-01
Cf-248	9.49E+00	3.26E-03	9.49E+00	5.23E+00	4.22E+00	3.95E-02
Cf-249	2.25E+02	6.26E+01	1.63E+02	8.66E+01	7.57E+01	2.00E-01
Cf-250	7.16E+01	4.21E-03	7.16E+01	3.83E+01	3.32E+01	8.76E-02
Cf-251	1.85E+02	1.89E+01	1.66E+02	8.83E+01	7.75E+01	2.04E-01
Cf-252	3.33E+01	5.64E-03	3.33E+01	1.81E+01	1.52E+01	3.99E-02

Table A-8. Scenario Dose Factors for the Post Intruder Resident (Commercial Farmer), mrem per Ci exhumed. (2 pages)

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion
H-3	9.46E-03	0.00E+00	9.46E-03	9.46E-03	1.35E-07
Be-10	1.95E-03	5.97E-04	1.36E-03	7.80E-04	5.76E-04
C-14	2.64E-04	7.41E-06	2.57E-04	4.50E-06	2.52E-04
Na-22	5.83E+00	5.83E+00	1.26E-03	1.48E-05	1.25E-03
Al-26	8.15E+00	8.15E+00	1.83E-03	3.21E-05	1.80E-03
Si-32+D	9.91E-03	6.30E-03	3.61E-03	2.26E-03	1.35E-03
Cl-36	1.48E-03	1.12E-03	3.66E-04	4.18E-05	3.24E-04
K-40	4.76E-01	4.74E-01	2.29E-03	2.69E-05	2.26E-03
Ca-41	1.57E-04	0.00E+00	1.57E-04	2.76E-06	1.55E-04
Ti-44+D	6.63E+00	6.63E+00	4.01E-03	9.89E-04	3.02E-03
V-49	5.88E-06	0.00E+00	5.88E-06	5.35E-07	5.34E-06
Mn-54	1.73E+00	1.73E+00	2.45E-04	1.01E-05	2.35E-04
Fe-55	6.89E-05	0.00E+00	6.89E-05	2.61E-06	6.63E-05
Fe-60+D	5.11E-01	4.91E-01	1.97E-02	5.99E-04	1.91E-02
Co-60	7.15E+00	7.14E+00	3.18E-03	6.82E-05	3.11E-03
Ni-59	2.80E-05	0.00E+00	2.80E-05	2.02E-06	2.60E-05
Ni-63	7.61E-05	0.00E+00	7.61E-05	5.05E-06	7.11E-05
Se-79	1.02E-03	9.72E-06	1.01E-03	1.34E-05	9.95E-04
Rb-87	6.93E-04	7.91E-05	6.14E-04	7.10E-06	6.07E-04
Sr-90+D	3.21E-02	1.28E-02	1.92E-02	5.37E-04	1.87E-02
Zr-93	3.92E-04	1.24E-06	3.90E-04	1.84E-04	2.07E-04
Nb-91	6.45E-03	6.38E-03	7.15E-05	7.07E-06	6.44E-05
Nb-93m	1.27E-04	5.75E-05	7.00E-05	6.92E-06	6.31E-05
Nb-94	4.77E+00	4.77E+00	9.61E-04	7.95E-05	8.82E-04
Mo-93	5.53E-04	3.27E-04	2.26E-04	6.14E-05	1.65E-04
Tc-99	2.49E-04	6.54E-05	1.84E-04	1.70E-05	1.67E-04
Ru-106+D	4.73E-01	4.70E-01	2.64E-03	1.89E-04	2.46E-03
Pd-107	4.65E-05	0.00E+00	4.65E-05	2.81E-05	1.84E-05
Ag-108m+D	4.84E+00	4.84E+00	9.93E-04	5.55E-05	9.38E-04
Cd-109	7.83E-03	6.39E-03	1.44E-03	1.93E-04	1.24E-03
Cd-113m	2.30E-02	3.51E-04	2.27E-02	3.28E-03	1.94E-02
In-115	2.80E-02	2.24E-04	2.78E-02	8.25E-03	1.95E-02
Sn-121m+D	1.49E-03	1.18E-03	3.02E-04	2.61E-05	2.76E-04
Sn-126+D	5.97E+00	5.96E+00	2.82E-03	2.23E-04	2.60E-03
Sb-125	1.10E+00	1.10E+00	4.06E-04	2.63E-05	3.80E-04
Te-125m	2.04E-03	1.93E-03	1.06E-04	3.63E-06	1.03E-04
I-129	4.14E-02	7.23E-03	3.41E-02	3.79E-04	3.38E-02
Cs-134	4.01E+00	4.01E+00	7.78E-03	8.67E-05	7.70E-03
Cs-135	9.06E-04	2.16E-05	8.84E-04	1.00E-05	8.74E-04
Cs-137+D	1.69E+00	1.68E+00	6.18E-03	6.95E-05	6.11E-03
Ba-133	1.01E+00	1.01E+00	4.22E-04	1.66E-05	4.06E-04
Pm-147	2.15E-04	2.47E-05	1.90E-04	7.59E-05	1.14E-04
Sm-147	1.87E-01	0.00E+00	1.87E-01	1.65E-01	2.29E-02
Sm-151	1.14E-04	5.53E-07	1.14E-04	6.59E-05	4.79E-05
Eu-150	4.36E+00	4.36E+00	1.36E-03	5.85E-04	7.79E-04
Eu-152	3.31E+00	3.31E+00	1.26E-03	4.75E-04	7.81E-04
Eu-154	3.57E+00	3.57E+00	1.74E-03	6.06E-04	1.13E-03
Eu-155	9.58E-02	9.55E-02	2.61E-04	8.48E-05	1.76E-04
Gd-152	5.56E-01	0.00E+00	5.56E-01	5.36E-01	1.99E-02
Ho-166m	5.16E+00	5.16E+00	2.70E-03	1.70E-03	9.97E-04
Re-187	1.29E-06	0.00E+00	1.29E-06	1.20E-07	1.17E-06

Table A-8. Scenario Dose Factors for the Post Intruder Resident (Commercial Farmer), mrem per Ci exhumed. (2 pages)

Nuclide	Total	External	Internal	Soil Inhalation	Soil Ingestion
Tl-204	2.46E-03	2.07E-03	3.84E-04	4.85E-06	3.80E-04
Pb-205	2.14E-04	3.98E-06	2.10E-04	8.64E-06	2.02E-04
Pb-210+D	8.22E-01	3.30E-03	8.19E-01	3.96E-02	7.79E-01
Bi-207	4.52E+00	4.52E+00	7.14E-04	4.36E-05	6.70E-04
Po-209	3.25E-01	9.92E-03	3.16E-01	2.35E-02	2.92E-01
Po-210	1.16E-01	1.18E-05	1.16E-01	8.68E-03	1.08E-01
Ra-226+D	5.51E+00	5.32E+00	1.96E-01	1.95E-02	1.76E-01
Ra-228+D	3.78E+00	3.47E+00	3.10E-01	1.27E-01	1.83E-01
Ac-227+D	6.63E+00	1.05E+00	5.58E+00	3.78E+00	1.80E+00
Th-228+D	4.64E+00	3.92E+00	7.17E-01	6.33E-01	8.41E-02
Th-229+D	5.16E+00	8.29E-01	4.33E+00	3.84E+00	4.98E-01
Th-230	6.47E-01	1.83E-03	6.46E-01	5.78E-01	6.78E-02
Th-232	3.09E+00	1.99E-01	2.89E+00	2.54E+00	3.49E-01
Pa-231	4.34E+00	1.18E-01	4.22E+00	2.88E+00	1.34E+00
U-232	1.06E+00	7.37E-01	3.24E-01	1.51E-01	1.73E-01
U-233	5.31E-02	7.84E-04	5.23E-02	1.74E-02	3.49E-02
U-234	5.14E-02	2.21E-04	5.12E-02	1.70E-02	3.42E-02
U-235+D	4.55E-01	4.07E-01	4.80E-02	1.57E-02	3.23E-02
U-236	4.86E-02	1.17E-04	4.85E-02	1.60E-02	3.25E-02
U-238+D	1.11E-01	6.38E-02	4.76E-02	1.52E-02	3.24E-02
Np-237+D	2.31E+00	5.84E-01	1.73E+00	1.18E+00	5.45E-01
Pu-236	4.17E-01	2.50E-03	4.14E-01	2.85E-01	1.29E-01
Pu-238	1.26E+00	8.48E-05	1.26E+00	8.61E-01	3.94E-01
Pu-239	1.38E+00	1.60E-04	1.38E+00	9.46E-01	4.38E-01
Pu-240	1.38E+00	8.27E-05	1.38E+00	9.46E-01	4.38E-01
Pu-241+D	2.72E-02	2.96E-05	2.72E-02	1.85E-02	8.62E-03
Pu-242	1.32E+00	7.22E-05	1.32E+00	9.06E-01	4.15E-01
Pu-244+D	2.31E+00	1.01E+00	1.30E+00	8.89E-01	4.11E-01
Am-241	1.45E+00	2.47E-02	1.43E+00	9.78E-01	4.50E-01
Am-242m+D	1.43E+00	3.64E-02	1.39E+00	9.53E-01	4.40E-01
Am-243+D	1.91E+00	4.92E-01	1.42E+00	9.70E-01	4.49E-01
Cm-242	2.98E-02	4.87E-05	2.97E-02	2.15E-02	8.20E-03
Cm-243	1.29E+00	3.14E-01	9.75E-01	6.69E-01	3.07E-01
Cm-244	7.82E-01	6.98E-05	7.82E-01	5.37E-01	2.45E-01
Cm-245	1.66E+00	1.90E-01	1.47E+00	1.00E+00	4.63E-01
Cm-246	1.45E+00	6.55E-05	1.45E+00	9.94E-01	4.57E-01
Cm-247+D	2.31E+00	9.73E-01	1.34E+00	9.13E-01	4.23E-01
Cm-248	5.32E+00	4.95E-05	5.32E+00	3.64E+00	1.68E+00
Cm-250+D	3.13E+01	9.51E-01	3.03E+01	2.07E+01	9.61E+00
Bk-247	2.08E+00	2.38E-01	1.85E+00	1.27E+00	5.81E-01
Cf-248	1.09E-01	5.03E-05	1.09E-01	7.67E-02	3.26E-02
Cf-249	2.82E+00	9.68E-01	1.86E+00	1.27E+00	5.85E-01
Cf-250	8.19E-01	6.51E-05	8.19E-01	5.63E-01	2.56E-01
Cf-251	2.19E+00	2.91E-01	1.89E+00	1.30E+00	5.99E-01
Cf-252	3.83E-01	8.72E-05	3.83E-01	2.66E-01	1.17E-01

Table A-9. Dose and Risk Factors for the All-Pathways Farmer Scencario. (2 pages)

Nuclide	Groundwater		Surface Water (Columbia River)	
	mrem per pCi/L	Risk per pCi/L	mrem per pCi/L	Risk per pCi/L
H-3	4.75E-05	2.66E-09	4.77E-05	2.67E-09
Be-10	3.09E-03	1.54E-07	4.63E-03	2.57E-07
C-14	4.85E-03	1.91E-07	3.49E-01	1.01E-05
Na-22	4.73E-02	2.86E-06	5.37E-02	3.03E-06
Si-32+D	7.23E-03	2.93E-07	8.00E-03	3.30E-07
Cl-36	2.49E-02	4.71E-06	2.54E-02	4.73E-06
K-40	2.88E-02	2.65E-06	9.16E-02	6.10E-06
Ti-44+D	5.81E-02	8.87E-06	1.69E-01	1.39E-05
V-49	4.16E-05	2.71E-09	8.20E-05	6.25E-09
Mn-54	6.07E-03	2.87E-07	1.05E-02	4.30E-07
Fe-55	5.94E-04	2.95E-08	9.94E-04	5.24E-08
Co-60	3.99E-02	4.12E-06	7.94E-02	5.15E-06
Ni-59	3.61E-04	1.99E-08	4.30E-04	2.38E-08
Ni-63	9.90E-04	4.83E-08	1.18E-03	5.78E-08
Se-79	1.29E-02	4.16E-07	1.78E-02	5.79E-07
Rb-87	8.40E-03	5.77E-07	4.08E-02	1.97E-06
Sr-90+D	1.53E-01	4.68E-06	1.83E-01	5.25E-06
Zr-93	1.05E-03	2.21E-08	2.69E-03	6.49E-08
Nb-91	3.44E-04	2.06E-08	8.92E-04	5.61E-08
Nb-93m	3.30E-04	1.65E-08	8.46E-04	5.13E-08
Nb-94	1.54E-02	5.82E-06	4.63E-02	7.17E-06
Mo-93	1.12E-03	1.40E-07	1.16E-03	1.44E-07
Tc-99	1.75E-03	6.98E-07	1.85E-03	7.06E-07
Ru-106+D	3.76E-02	2.22E-06	3.87E-02	2.29E-06
Pd-107	1.98E-04	1.42E-08	2.03E-04	1.46E-08
Ag-108m+D	1.67E-02	5.44E-06	3.93E-02	6.33E-06
Cd-109	9.44E-03	1.20E-07	1.81E-02	2.52E-07
Cd-113m	1.18E-01	7.65E-07	2.24E-01	1.49E-06
In-115	1.25E-01	8.96E-07	5.21E+01	4.28E-04
Sn-121m+D	4.56E-03	3.04E-07	2.68E-02	1.82E-06
Sn-126+D	5.62E-02	9.29E-06	2.94E-01	2.22E-05
Sb-125	4.37E-03	4.11E-07	6.52E-03	5.02E-07
Te-125m	2.77E-03	8.39E-08	7.60E-03	2.69E-07
I-129	5.74E-01	1.53E-05	6.11E-01	1.61E-05
Cs-134	1.51E-01	3.96E-06	6.37E-01	1.42E-05
Cs-135	1.44E-02	4.58E-07	6.10E-02	1.62E-06
Cs-137+D	1.06E-01	4.36E-06	4.42E-01	1.20E-05
Ba-133	4.62E-03	7.81E-07	7.43E-03	8.61E-07
Pm-147	7.45E-04	4.00E-08	8.49E-04	4.74E-08
Sm-147	1.36E-01	8.92E-07	1.52E-01	1.02E-06
Sm-151	2.80E-04	1.35E-08	3.12E-04	1.56E-08
Eu-150	1.46E-02	4.33E-06	3.41E-02	5.04E-06
Eu-152	1.22E-02	2.77E-06	2.39E-02	3.17E-06
Eu-154	1.51E-02	2.60E-06	2.59E-02	2.95E-06
Eu-155	1.31E-03	7.92E-08	1.73E-03	9.64E-08
Gd-152	1.25E-01	6.90E-07	1.38E-01	7.91E-07
Ho-166m	1.75E-02	6.15E-06	4.40E-02	7.27E-06
Re-187	8.48E-06	9.15E-10	1.22E-05	1.22E-09
Tl-204	4.69E-03	3.11E-07	1.15E-01	8.45E-06
Pb-205	1.09E-03	1.38E-08	2.70E-03	3.83E-08

Table A-9. Dose and Risk Factors for the All-Pathways Farmer Scencario. (2 pages)

Nuclide	Groundwater		Surface Water (Columbia River)	
	mrem per pCi/L	Risk per pCi/L	mrem per pCi/L	Risk per pCi/L
Pb-210+D	3.59E+00	1.94E-05	8.90E+00	5.47E-05
Bi-207	1.41E-02	4.66E-06	3.32E-02	5.38E-06
Po-209	2.01E+00	3.71E-05	2.40E+00	5.11E-05
Po-210	1.53E+00	2.36E-05	1.84E+00	3.47E-05
Ra-226+D	9.81E-01	1.61E-05	1.23E+00	1.99E-05
Ra-228+D	1.05E+00	2.87E-05	1.30E+00	3.62E-05
Ac-227+D	9.46E+00	1.09E-05	1.07E+01	1.27E-05
Th-228+D	5.39E-01	7.28E-06	8.09E-01	1.16E-05
Th-229+D	2.64E+00	1.21E-05	3.98E+00	1.94E-05
Th-230	3.61E-01	1.92E-06	5.42E-01	3.12E-06
Th-232	1.79E+00	7.27E-06	2.71E+00	9.92E-06
Pa-231	6.76E+00	4.00E-06	7.13E+00	4.36E-06
U-232	9.20E-01	1.05E-05	9.76E-01	1.13E-05
U-233	2.03E-01	1.71E-06	2.13E-01	1.81E-06
U-234	1.99E-01	1.68E-06	2.08E-01	1.78E-06
U-235+D	1.89E-01	2.03E-06	1.99E-01	2.16E-06
U-236	1.89E-01	1.59E-06	1.98E-01	1.69E-06
U-238+D	1.88E-01	2.14E-06	1.98E-01	2.27E-06
Np-237+D	2.91E+00	2.04E-06	3.22E+00	2.32E-06
Pu-236	7.45E-01	1.64E-06	8.27E-01	1.86E-06
Pu-238	2.04E+00	2.69E-06	2.27E+00	3.06E-06
Pu-239	2.26E+00	2.77E-06	2.51E+00	3.15E-06
Pu-240	2.26E+00	2.77E-06	2.51E+00	3.15E-06
Pu-241+D	4.37E-02	3.62E-08	4.85E-02	4.11E-08
Pu-242	2.14E+00	2.63E-06	2.38E+00	2.99E-06
Pu-244+D	2.12E+00	4.15E-06	2.36E+00	4.79E-06
Am-241	2.32E+00	2.16E-06	2.58E+00	2.46E-06
Am-242m+D	2.25E+00	1.52E-06	2.50E+00	1.73E-06
Am-243+D	2.32E+00	2.73E-06	2.58E+00	3.14E-06
Cm-242	7.28E-02	7.87E-07	8.08E-02	9.00E-07
Cm-243	1.60E+00	2.21E-06	1.78E+00	2.52E-06
Cm-244	1.29E+00	1.72E-06	1.43E+00	1.95E-06
Cm-245	2.39E+00	2.33E-06	2.66E+00	2.67E-06
Cm-246	2.36E+00	2.10E-06	2.63E+00	2.39E-06
Cm-247+D	2.19E+00	3.14E-06	2.43E+00	3.63E-06
Cm-248	8.69E+00	7.71E-06	9.65E+00	8.76E-06
Cm-250+D	4.97E+01	4.52E-05	5.52E+01	5.15E-05
Bk-247	3.00E+00	2.80E-06	3.40E+00	3.26E-06
Cf-248	2.35E-01	1.04E-06	2.62E-01	1.19E-06
Cf-249	3.42E+00	4.12E-06	3.82E+00	4.73E-06
Cf-250	1.53E+00	2.06E-06	1.71E+00	2.35E-06
Cf-251	3.49E+00	3.48E-06	3.90E+00	3.98E-06
Cf-252	7.71E-01	1.13E-06	8.60E-01	1.29E-06

Table A-10. Dose and Risk Factors for the Native American Scenario. (2 pages)

Nuclide	Groundwater		Surface Water (Columbia River)	
	mrem per pCi/L	Risk per pCi/L	mrem per pCi/L	Risk per pCi/L
H-3	1.05E-04	1.39E-08	1.19E-04	1.62E-08
Be-10	2.29E-02	1.13E-06	1.15E-01	1.57E-05
C-14	1.15E-02	1.38E-06	2.06E+01	1.38E-03
Na-22	1.04E-01	1.38E-05	1.73E-01	1.83E-05
Si-32+D	6.28E-02	2.82E-06	1.08E-01	8.11E-06
Cl-36	8.11E-02	4.02E-05	1.11E-01	4.33E-05
K-40	7.30E-02	2.21E-05	3.75E+00	4.97E-04
Ti-44+D	1.57E-01	6.65E-05	5.25E+00	6.31E-04
V-49	1.05E-04	1.44E-08	2.53E-03	5.08E-07
Mn-54	1.16E-02	1.24E-06	2.36E-01	1.88E-05
Fe-55	1.20E-03	1.33E-07	2.51E-02	3.34E-06
Co-60	7.73E-02	1.94E-05	1.78E+00	1.19E-04
Ni-59	1.18E-03	1.75E-07	5.34E-03	7.28E-07
Ni-63	3.23E-03	4.16E-07	1.47E-02	1.76E-06
Se-79	2.81E-02	2.12E-06	3.21E-01	2.50E-05
Rb-87	2.43E-02	6.55E-06	1.96E+00	2.02E-04
Sr-90+D	3.84E-01	4.21E-05	2.21E+00	1.23E-04
Zr-93	6.13E-03	1.43E-07	1.04E-01	6.15E-06
Nb-91	9.04E-04	1.36E-07	3.21E-02	5.04E-06
Nb-93m	8.79E-04	9.69E-08	3.18E-02	4.96E-06
Nb-94	3.02E-02	5.20E-05	6.50E-01	1.28E-04
Mo-93	4.00E-03	1.22E-06	6.79E-03	1.83E-06
Tc-99	4.34E-03	4.87E-06	1.02E-02	5.99E-06
Ru-106+D	7.15E-02	9.27E-06	1.28E-01	1.79E-05
Pd-107	1.17E-03	1.26E-07	1.48E-03	1.90E-07
Ag-108m+D	3.19E-02	4.46E-05	2.26E-01	6.97E-05
Cd-109	2.71E-02	7.22E-07	5.44E-01	1.92E-05
Cd-113m	3.45E-01	5.25E-06	6.70E+00	1.06E-04
In-115	4.28E-01	5.77E-06	3.11E+03	5.97E-02
Sn-121m+D	8.29E-03	1.31E-06	1.34E+00	2.13E-04
Sn-126+D	1.00E-01	7.37E-05	1.28E+01	1.74E-03
Sb-125	8.91E-03	1.91E-06	7.45E-02	1.10E-05
Te-125m	6.11E-03	4.50E-07	2.95E-01	2.64E-05
I-129	1.46E+00	1.09E-04	3.67E+00	2.19E-04
Cs-134	3.38E-01	2.01E-05	2.93E+01	1.44E-03
Cs-135	3.27E-02	3.36E-06	2.82E+00	1.66E-04
Cs-137+D	2.37E-01	2.90E-05	2.00E+01	1.07E-03
Ba-133	9.53E-03	4.30E-06	3.53E-02	6.43E-06
Pm-147	3.37E-03	2.54E-07	9.60E-03	1.29E-06
Sm-147	3.69E+00	2.66E-05	4.62E+00	4.47E-05
Sm-151	1.96E-03	8.56E-08	3.92E-03	3.92E-07
Eu-150	3.89E-02	3.19E-05	2.55E-01	5.32E-05
Eu-152	3.28E-02	1.63E-05	1.85E-01	2.99E-05
Eu-154	4.15E-02	1.38E-05	2.13E-01	2.99E-05
Eu-155	4.58E-03	4.31E-07	2.11E-02	2.42E-06
Gd-152	1.13E+01	3.27E-05	1.21E+01	4.74E-05
Ho-166m	6.75E-02	5.56E-05	3.22E-01	9.21E-05
Re-187	2.18E-05	8.61E-09	2.48E-04	5.19E-08
Tl-204	9.32E-03	1.43E-06	6.63E+00	1.14E-03
Pb-205	2.61E-03	7.90E-08	9.92E-02	3.52E-06

Table A-10. Dose and Risk Factors for the Native American Scenario. (2 pages)

Nuclide	Groundwater		Surface Water (Columbia River)	
	mrem per pCi/L	Risk per pCi/L	mrem per pCi/L	Risk per pCi/L
Pb-210+D	8.63E+00	1.15E-04	3.27E+02	5.06E-03
Bi-207	2.70E-02	3.34E-05	1.94E-01	5.24E-05
Po-209	4.63E+00	2.40E-04	2.84E+01	2.20E-03
Po-210	3.54E+00	1.52E-04	2.23E+01	1.71E-03
Ra-226+D	2.73E+00	1.55E-04	1.62E+01	5.63E-04
Ra-228+D	2.73E+00	1.81E-04	1.71E+01	1.18E-03
Ac-227+D	1.00E+02	5.06E-04	1.75E+02	7.47E-04
Th-228+D	1.68E+01	4.93E-04	3.28E+01	1.08E-03
Th-229+D	8.51E+01	7.74E-04	1.65E+02	1.80E-03
Th-230	1.27E+01	1.02E-04	2.36E+01	2.71E-04
Th-232	5.63E+01	2.17E-04	1.11E+02	4.51E-04
Pa-231	7.33E+01	1.56E-04	9.55E+01	2.00E-04
U-232	2.73E+00	1.24E-04	5.51E+00	1.89E-04
U-233	8.16E-01	4.63E-05	1.41E+00	6.08E-05
U-234	8.01E-01	4.55E-05	1.38E+00	5.98E-05
U-235+D	7.51E-01	4.36E-05	1.31E+00	5.89E-05
U-236	7.59E-01	4.21E-05	1.31E+00	5.56E-05
U-238+D	7.41E-01	4.15E-05	1.29E+00	5.98E-05
Np-237+D	3.10E+01	6.92E-05	4.98E+01	1.00E-04
Pu-236	8.25E+00	8.17E-05	1.31E+01	1.11E-04
Pu-238	2.24E+01	1.22E-04	3.60E+01	1.76E-04
Pu-239	2.45E+01	1.21E-04	3.96E+01	1.78E-04
Pu-240	2.45E+01	1.21E-04	3.96E+01	1.78E-04
Pu-241+D	4.72E-01	1.26E-06	7.61E-01	1.95E-06
Pu-242	2.35E+01	1.14E-04	3.78E+01	1.68E-04
Pu-244+D	2.31E+01	1.20E-04	3.72E+01	1.90E-04
Am-241	2.54E+01	1.01E-04	4.09E+01	1.45E-04
Am-242m+D	2.44E+01	5.84E-05	3.94E+01	8.74E-05
Am-243+D	2.52E+01	1.03E-04	4.07E+01	1.52E-04
Cm-242	9.48E-01	5.23E-05	1.42E+00	6.82E-05
Cm-243	1.75E+01	9.80E-05	2.82E+01	1.37E-04
Cm-244	1.42E+01	8.98E-05	2.27E+01	1.23E-04
Cm-245	2.60E+01	1.02E-04	4.20E+01	1.47E-04
Cm-246	2.58E+01	9.97E-05	4.16E+01	1.43E-04
Cm-247+D	2.37E+01	1.01E-04	3.83E+01	1.50E-04
Cm-248	9.44E+01	3.57E-04	1.52E+02	5.14E-04
Cm-250+D	5.38E+02	2.02E-03	8.69E+02	2.92E-03
Bk-247	3.28E+01	1.20E-04	5.65E+01	1.82E-04
Cf-248	2.52E+00	6.29E-05	4.17E+00	8.44E-05
Cf-249	3.35E+01	1.34E-04	5.75E+01	2.01E-04
Cf-250	1.52E+01	9.52E-05	2.58E+01	1.35E-04
Cf-251	3.42E+01	1.28E-04	5.87E+01	1.94E-04
Cf-252	7.87E+00	5.54E-05	1.32E+01	7.73E-05

Table A-11. Risk Factors for the HSRAM Industrial and Residential Scenarios. (2 pages)

Nuclide	HSRAM Industrial	HSRAM Residential	
	Groundwater Risk per pCi/L	Groundwater Risk per pCi/L	Surface Water (Columbia River) Risk per pCi/L
H-3	6.75E-10	2.81E-09	2.85E-09
Be-10	3.54E-08	1.85E-07	5.83E-07
C-14	7.77E-09	5.62E-08	2.98E-05
Na-22	2.96E-07	3.23E-06	3.41E-06
Si-32+D	6.31E-08	3.54E-07	5.77E-07
Cl-36	1.66E-08	1.55E-06	1.62E-06
K-40	1.79E-07	1.76E-06	1.21E-05
Ti-44+D	8.76E-07	1.25E-05	2.53E-05
V-49	6.10E-10	3.14E-09	1.38E-08
Mn-54	4.70E-08	4.66E-07	8.54E-07
Fe-55	4.31E-09	2.20E-08	9.22E-08
Co-60	5.55E-07	6.58E-06	8.92E-06
Ni-59	1.37E-09	7.49E-09	2.26E-08
Ni-63	3.36E-09	1.82E-08	5.42E-08
Se-79	3.65E-08	1.88E-07	6.89E-07
Rb-87	2.62E-08	2.31E-07	4.48E-06
Sr-90+D	3.72E-07	2.62E-06	4.77E-06
Zr-93	5.57E-09	2.85E-08	1.67E-07
Nb-91	4.43E-09	2.79E-08	1.43E-07
Nb-93m	4.03E-09	2.11E-08	1.31E-07
Nb-94	6.16E-07	9.83E-06	1.18E-05
Mo-93	1.68E-08	1.26E-07	1.49E-07
Tc-99	1.38E-08	3.36E-07	3.65E-07
Ru-106+D	2.22E-07	1.21E-06	1.42E-06
Pd-107	1.26E-09	6.78E-09	1.09E-08
Ag-108m+D	5.86E-07	9.11E-06	9.94E-06
Cd-109	2.51E-08	1.31E-07	5.32E-07
Cd-113m	1.44E-07	7.92E-07	3.07E-06
In-115	1.70E-07	8.65E-07	1.29E-03
Sn-121m+D	1.76E-08	9.30E-08	4.69E-06
Sn-126+D	8.41E-07	1.25E-05	4.89E-05
Sb-125	6.73E-08	6.62E-07	8.76E-07
Te-125m	1.67E-08	8.36E-08	6.42E-07
I-129	7.42E-07	3.85E-06	6.97E-06
Cs-134	3.53E-07	2.77E-06	3.34E-05
Cs-135	2.37E-08	1.36E-07	3.66E-06
Cs-137+D	3.27E-07	3.58E-06	2.61E-05
Ba-133	1.10E-07	1.25E-06	1.34E-06
Pm-147	8.47E-09	4.38E-08	6.86E-08
Sm-147	1.92E-07	9.70E-07	1.68E-06
Sm-151	2.79E-09	1.45E-08	2.71E-08
Eu-150	4.78E-07	7.30E-06	8.00E-06
Eu-152	3.37E-07	4.62E-06	5.08E-06
Eu-154	3.41E-07	4.26E-06	4.76E-06
Eu-155	1.40E-08	1.07E-07	1.56E-07
Gd-152	1.55E-07	7.78E-07	1.37E-06
Ho-166m	6.49E-07	1.04E-05	1.14E-05
Re-187	8.98E-11	6.24E-10	1.75E-09
Tl-204	2.94E-08	1.52E-07	2.47E-05

Table A-11. Risk Factors for the HSRAM Industrial and Residential Scenarios. (2 pages)

Nuclide	HSRAM Industrial	HSRAM Residential	
	Groundwater Risk per pCi/L	Groundwater Risk per pCi/L	Surface Water (Columbia River) Risk per pCi/L
Pb-205	3.17E-09	1.63E-08	9.60E-08
Pb-210+D	4.46E-06	2.29E-05	1.35E-04
Bi-207	5.20E-07	7.85E-06	8.52E-06
Po-209	2.37E-06	1.83E-05	6.43E-05
Po-210	1.89E-06	1.38E-05	4.73E-05
Ra-226+D	2.62E-06	2.13E-05	3.34E-05
Ra-228+D	5.67E-06	3.29E-05	5.72E-05
Ac-227+D	2.63E-06	1.42E-05	2.26E-05
Th-228+D	1.73E-06	9.63E-06	2.26E-05
Th-229+D	2.90E-06	1.55E-05	4.32E-05
Th-230	4.78E-07	2.43E-06	6.96E-06
Th-232	9.40E-07	1.13E-05	1.75E-05
Pa-231	9.33E-07	5.22E-06	7.80E-06
U-232	1.87E-06	1.38E-05	1.63E-05
U-233	3.68E-07	1.88E-06	2.49E-06
U-234	3.62E-07	1.85E-06	2.45E-06
U-235+D	4.02E-07	2.42E-06	3.06E-06
U-236	3.43E-07	1.75E-06	2.32E-06
U-238+D	4.49E-07	2.37E-06	3.16E-06
Np-237+D	4.10E-07	2.76E-06	3.99E-06
Pu-236	3.98E-07	2.13E-06	2.87E-06
Pu-238	6.80E-07	3.41E-06	5.62E-06
Pu-239	7.00E-07	3.51E-06	5.94E-06
Pu-240	7.00E-07	3.51E-06	5.94E-06
Pu-241+D	9.10E-09	4.60E-08	6.81E-08
Pu-242	6.64E-07	3.33E-06	5.64E-06
Pu-244+D	8.64E-07	5.78E-06	8.68E-06
Am-241	5.43E-07	2.74E-06	4.61E-06
Am-242m+D	3.80E-07	1.94E-06	3.10E-06
Am-243+D	6.11E-07	3.67E-06	5.75E-06
Cm-242	2.01E-07	9.97E-07	1.35E-06
Cm-243	5.21E-07	2.91E-06	4.38E-06
Cm-244	4.36E-07	2.17E-06	3.33E-06
Cm-245	5.60E-07	3.03E-06	4.96E-06
Cm-246	5.31E-07	2.66E-06	4.50E-06
Cm-247+D	6.28E-07	4.44E-06	6.45E-06
Cm-248	1.94E-06	9.73E-06	1.65E-05
Cm-250+D	1.12E-05	5.76E-05	9.65E-05
Bk-247	6.69E-07	3.64E-06	6.06E-06
Cf-248	2.32E-07	1.16E-06	1.64E-06
Cf-249	7.68E-07	5.12E-06	7.67E-06
Cf-250	4.49E-07	2.25E-06	3.49E-06
Cf-251	7.15E-07	3.96E-06	6.53E-06
Cf-252	2.52E-07	1.25E-06	1.78E-06

Table A-12. Risk Factors for the HSRAM Agricultural and Recreational Scenarios. (2 pages)

Nuclide	HSRAM Agricultural		HSRAM Recreational	
	Groundwater Risk per pCi/L	Surface Water (Columbia River) Risk per pCi/L	Groundwater Risk per pCi/L	Surface Water (Columbia River) Risk per pCi/L
H-3	3.31E-09	3.35E-09	4.73E-11	9.22E-11
Be-10	1.91E-07	5.89E-07	2.99E-09	3.08E-07
C-14	2.40E-07	2.99E-05	6.54E-10	2.97E-05
Na-22	4.50E-06	4.67E-06	2.32E-08	1.87E-07
Si-32+D	3.56E-07	5.79E-07	5.33E-09	1.11E-07
Cl-36	6.72E-06	6.79E-06	1.39E-09	6.74E-08
K-40	3.83E-06	1.42E-05	1.60E-08	1.03E-05
Ti-44+D	1.46E-05	2.74E-05	8.74E-08	1.25E-05
V-49	3.35E-09	1.41E-08	5.13E-11	1.07E-08
Mn-54	4.67E-07	8.55E-07	3.57E-09	3.90E-07
Fe-55	3.40E-08	1.04E-07	3.63E-10	6.93E-08
Co-60	6.73E-06	9.07E-06	4.62E-08	2.34E-06
Ni-59	3.31E-08	4.82E-08	1.16E-10	1.17E-08
Ni-63	8.02E-08	1.16E-07	2.83E-10	2.87E-08
Se-79	4.12E-07	9.12E-07	3.07E-09	4.93E-07
Rb-87	8.10E-07	5.06E-06	2.21E-09	4.20E-06
Sr-90+D	6.45E-06	8.61E-06	3.14E-08	1.74E-06
Zr-93	2.85E-08	1.67E-07	4.69E-10	1.29E-07
Nb-91	2.79E-08	1.43E-07	3.83E-10	1.05E-07
Nb-93m	2.11E-08	1.31E-07	3.39E-10	1.05E-07
Nb-94	9.83E-06	1.18E-05	6.51E-08	1.91E-06
Mo-93	1.67E-07	1.90E-07	1.41E-09	1.41E-08
Tc-99	4.72E-07	5.01E-07	1.16E-09	2.50E-08
Ru-106+D	2.61E-06	2.83E-06	1.85E-08	2.07E-07
Pd-107	2.29E-08	2.71E-08	1.06E-10	1.26E-09
Ag-108m+D	9.13E-06	9.96E-06	6.06E-08	8.11E-07
Cd-109	1.55E-07	5.56E-07	2.11E-09	4.00E-07
Cd-113m	9.68E-07	3.24E-06	1.21E-08	2.18E-06
In-115	1.08E-06	1.29E-03	1.43E-08	1.29E-03
Sn-121m+D	3.50E-07	4.95E-06	1.49E-09	4.56E-06
Sn-126+D	1.45E-05	5.09E-05	8.72E-08	3.61E-05
Sb-125	6.63E-07	8.76E-07	5.37E-09	2.13E-07
Te-125m	9.45E-08	6.53E-07	1.40E-09	5.60E-07
I-129	2.33E-05	2.64E-05	6.25E-08	2.38E-06
Cs-134	5.59E-06	3.62E-05	2.86E-08	3.06E-05
Cs-135	5.94E-07	4.12E-06	2.00E-09	3.50E-06
Cs-137+D	6.31E-06	2.89E-05	3.03E-08	2.25E-05
Ba-133	1.26E-06	1.36E-06	9.72E-09	8.38E-08
Pm-147	5.02E-08	7.51E-08	7.12E-10	2.29E-08
Sm-147	1.11E-06	1.82E-06	1.60E-08	3.77E-07
Sm-151	1.69E-08	2.95E-08	2.35E-10	6.36E-09
Eu-150	7.32E-06	8.01E-06	4.80E-08	7.02E-07
Eu-152	4.65E-06	5.10E-06	3.12E-08	4.52E-07
Eu-154	4.30E-06	4.81E-06	3.00E-08	4.85E-07
Eu-155	1.14E-07	1.64E-07	1.17E-09	4.53E-08
Gd-152	8.59E-07	1.45E-06	1.28E-08	3.05E-07
Ho-166m	1.04E-05	1.15E-05	6.85E-08	1.06E-06
Re-187	1.16E-09	2.29E-09	7.58E-12	9.24E-10

Table A-12. Risk Factors for the HSRAM Agricultural and Recreational Scenarios. (2 pages)

Nuclide	HSRAM Agricultural		HSRAM Recreational	
	Groundwater Risk per pCi/L	Surface Water (Columbia River) Risk per pCi/L	Groundwater Risk per pCi/L	Surface Water (Columbia River) Risk per pCi/L
Tl-204	3.81E-07	2.49E-05	2.47E-09	2.45E-05
Pb-205	1.73E-08	9.69E-08	2.67E-10	7.39E-08
Pb-210+D	2.43E-05	1.36E-04	3.76E-07	1.07E-04
Bi-207	7.86E-06	8.53E-06	5.18E-08	6.73E-07
Po-209	2.99E-05	7.59E-05	1.99E-07	4.20E-05
Po-210	1.96E-05	5.31E-05	1.59E-07	3.36E-05
Ra-226+D	2.41E-05	3.63E-05	2.36E-07	8.97E-06
Ra-228+D	4.03E-05	6.46E-05	4.78E-07	2.21E-05
Ac-227+D	1.42E-05	2.26E-05	2.18E-07	5.25E-06
Th-228+D	9.63E-06	2.26E-05	1.40E-07	1.28E-05
Th-229+D	1.56E-05	4.32E-05	2.39E-07	2.18E-05
Th-230	2.44E-06	6.96E-06	3.96E-08	3.60E-06
Th-232	1.13E-05	1.75E-05	1.00E-07	5.16E-06
Pa-231	5.22E-06	7.80E-06	7.91E-08	8.75E-07
U-232	1.44E-05	1.69E-05	1.64E-07	1.66E-06
U-233	2.04E-06	2.65E-06	3.06E-08	3.25E-07
U-234	2.00E-06	2.61E-06	3.01E-08	3.20E-07
U-235+D	2.58E-06	3.23E-06	3.40E-08	3.57E-07
U-236	1.90E-06	2.47E-06	2.85E-08	3.03E-07
U-238+D	2.57E-06	3.36E-06	3.76E-08	4.10E-07
Np-237+D	2.82E-06	4.04E-06	3.52E-08	6.86E-07
Pu-236	2.13E-06	2.87E-06	3.32E-08	6.67E-07
Pu-238	3.41E-06	5.62E-06	5.62E-08	1.13E-06
Pu-239	3.51E-06	5.94E-06	5.79E-08	1.17E-06
Pu-240	3.51E-06	5.94E-06	5.79E-08	1.17E-06
Pu-241+D	4.60E-08	6.81E-08	7.56E-10	1.52E-08
Pu-242	3.33E-06	5.64E-06	5.49E-08	1.11E-06
Pu-244+D	5.78E-06	8.68E-06	7.47E-08	1.48E-06
Am-241	2.75E-06	4.61E-06	4.49E-08	9.04E-07
Am-242m+D	1.94E-06	3.11E-06	3.16E-08	6.12E-07
Am-243+D	3.67E-06	5.76E-06	5.18E-08	1.04E-06
Cm-242	1.00E-06	1.35E-06	1.64E-08	3.58E-07
Cm-243	2.92E-06	4.39E-06	4.35E-08	8.57E-07
Cm-244	2.18E-06	3.34E-06	3.59E-08	7.19E-07
Cm-245	3.04E-06	4.97E-06	4.67E-08	9.38E-07
Cm-246	2.67E-06	4.51E-06	4.39E-08	8.81E-07
Cm-247+D	4.45E-06	6.46E-06	5.47E-08	1.06E-06
Cm-248	9.77E-06	1.65E-05	1.61E-07	3.23E-06
Cm-250+D	5.78E-05	9.67E-05	9.32E-07	1.87E-05
Bk-247	3.64E-06	6.07E-06	5.59E-08	1.30E-06
Cf-248	1.29E-06	1.78E-06	1.90E-08	4.81E-07
Cf-249	5.59E-06	8.14E-06	6.61E-08	1.46E-06
Cf-250	2.56E-06	3.80E-06	3.70E-08	8.77E-07
Cf-251	4.45E-06	7.02E-06	5.99E-08	1.39E-06
Cf-252	1.41E-06	1.94E-06	2.07E-08	4.90E-07

Table A-13. Dose and Risk Factors for the Columbia River Population. (2 pages)

Nuclide	Dose	Risk
	mrem per pCi/L	Risk per pCi/L
H-3	2.36E-01	3.08E-02
Be-10	1.49E+01	1.77E+00
C-14	2.19E+01	2.30E+00
Na-22	2.09E+02	2.95E+01
Si-32+D	3.49E+01	3.56E+00
Cl-36	9.82E+01	4.69E+01
K-40	1.28E+02	3.58E+01
Ti-44+D	3.13E+02	1.57E+02
V-49	1.99E-01	2.99E-02
Mn-54	2.80E+01	2.97E+00
Fe-55	2.69E+00	3.07E-01
Co-60	2.05E+02	4.79E+01
Ni-59	1.54E+00	2.15E-01
Ni-63	4.22E+00	5.12E-01
Se-79	5.63E+01	4.19E+00
Rb-87	3.60E+01	8.27E+00
Sr-90+D	6.90E+02	6.12E+01
Zr-93	5.11E+00	2.54E-01
Nb-91	1.73E+00	2.83E-01
Nb-93m	1.60E+00	1.87E-01
Nb-94	1.21E+02	1.33E+02
Mo-93	5.17E+00	1.75E+00
Tc-99	7.68E+00	7.76E+00
Ru-106+D	1.65E+02	2.22E+01
Pd-107	8.65E-01	1.58E-01
Ag-108m+D	1.23E+02	1.14E+02
Cd-109	4.48E+01	1.30E+00
Cd-113m	5.56E+02	8.61E+00
In-115	8.19E+02	1.45E+01
Sn-121m+D	1.94E+01	3.14E+00
Sn-126+D	3.06E+02	1.89E+02
Sb-125	2.20E+01	4.49E+00
Te-125m	1.31E+01	9.10E-01
I-129	2.42E+03	1.56E+02
Cs-134	6.49E+02	3.97E+01
Cs-135	6.12E+01	5.84E+00
Cs-137+D	4.63E+02	6.02E+01
Ba-133	2.68E+01	1.03E+01
Pm-147	3.54E+00	4.35E-01
Sm-147	6.43E+02	1.00E+01
Sm-151	1.33E+00	1.51E-01
Eu-150	1.05E+02	8.07E+01
Eu-152	7.73E+01	4.05E+01
Eu-154	8.72E+01	3.37E+01
Eu-155	6.46E+00	8.86E-01
Gd-152	5.79E+02	7.80E+00
Ho-166m	1.34E+02	1.40E+02
Re-187	3.89E-02	1.33E-02
Tl-204	2.09E+01	3.19E+00
Pb-205	5.25E+00	1.59E-01
Pb-210+D	1.73E+04	2.18E+02

Table A-13. Dose and Risk Factors for the Columbia River Population. (2 pages)

Nuclide	Dose	Risk
	mrem per pCi/L	Risk per pCi/L
Bi-207	1.03E+02	8.49E+01
Po-209	9.31E+03	4.03E+02
Po-210	7.12E+03	2.33E+02
Ra-226+D	4.69E+03	2.61E+02
Ra-228+D	5.00E+03	3.18E+02
Ac-227+D	4.58E+04	1.28E+02
Th-228+D	2.59E+03	8.02E+01
Th-229+D	1.27E+04	1.49E+02
Th-230	1.73E+03	2.32E+01
Th-232	8.65E+03	1.99E+02
Pa-231	3.27E+04	5.69E+01
U-232	4.41E+03	1.39E+02
U-233	9.67E+02	1.90E+01
U-234	9.47E+02	1.87E+01
U-235+D	9.00E+02	2.43E+01
U-236	9.00E+02	1.77E+01
U-238+D	8.97E+02	2.41E+01
Np-237+D	1.40E+04	2.86E+01
Pu-236	3.60E+03	1.93E+01
Pu-238	9.88E+03	3.05E+01
Pu-239	1.09E+04	3.16E+01
Pu-240	1.09E+04	3.16E+01
Pu-241+D	2.11E+02	4.17E-01
Pu-242	1.04E+04	3.00E+01
Pu-244+D	1.03E+04	6.20E+01
Am-241	1.12E+04	2.49E+01
Am-242m+D	1.09E+04	1.78E+01
Am-243+D	1.12E+04	3.72E+01
Cm-242	3.52E+02	8.75E+00
Cm-243	7.76E+03	2.67E+01
Cm-244	6.24E+03	1.93E+01
Cm-245	1.16E+04	2.89E+01
Cm-246	1.14E+04	2.40E+01
Cm-247+D	1.06E+04	4.90E+01
Cm-248	4.21E+04	8.80E+01
Cm-250+D	2.40E+05	5.30E+02
Bk-247	1.45E+04	3.48E+01
Cf-248	1.11E+03	1.13E+01
Cf-249	1.62E+04	5.87E+01
Cf-250	7.25E+03	2.26E+01
Cf-251	1.66E+04	4.28E+01
Cf-252	3.65E+03	1.23E+01

Appendix B

Equations Used in Major Codes

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B. GOVERNING EQUATIONS USED IN MAJOR CODES

B.1 INTRODUCTION

This section briefly summarizes the equations used in the major computer codes. More information can be found in the user's manual for each of the codes:

- STOMP White and Oostrom 1999.

B.2 FLOW AND TRANSPORT

B.2.1 Overview

This section discusses the equations important in calculating moisture flow and contaminant transport. All three major codes use the same basic equations. The first section presents the equations on which the water flow calculations are based. The next section discusses contaminant transport associated with moisture flow. The final section describes moisture movement under diffusive conditions.

B.2.2 Moisture Flow

Two distinct moisture content regimes are present during contaminant transport: the unconfined aquifer and the disposal facility/vadose zone. In the unconfined aquifer all the pore spaces are filled with water; that is, the medium is saturated with water. In the disposal facility/ vadose zone the pore spaces between the soil particles are only partially filled with water. These zones are unsaturated.

Water flow through a saturated porous medium, such as the unconfined aquifer, is governed by the empirical relationship known as Darcy's Law (Freeze 1979) and by the conservation of mass. Darcy's law can be expressed as

$$\vec{v} = -\vec{K}\,\vec{\nabla} h \qquad \text{(C.1)}$$

where v is the velocity vector (m/year)
K is the hydraulic conductivity tensor (m/year)
h is the hydraulic head vector (m).

By using the conservation of water entering and leaving a volume and by using Darcy's law to relate the hydraulic gradient to the rate at which water enters and leaves the same volume, transient water flow in a saturated porous media can be expressed as

$$\nabla\left[\overset{\Leftrightarrow}{K}\nabla h\right] = \frac{Sh}{t} + Q \tag{C.2}$$

where S is the specific storage (m^{-1})

Q is the source or sink of moisture (y^{-1}).

Darcy's law defines the discharge of water through a cross section of porous media. However, in contamination transport, the average velocity of water flowing through the medium is important. This is because contaminants that are not geochemically retarded move with the water. The average velocity of the pore water is determined by dividing the velocity of the water by the porosity of the medium. Porosity is defined as the ratio of void space to total volume.

In an unsaturated medium, the pores are not completely filled with water. Capillary forces and the dependence of hydraulic conductivity on moisture content also must be considered. Richards equation (Richards 1931) becomes the governing equation:

$$\nabla[K(\psi)\nabla\psi\,] + \partial K_{zz}(\psi)/\partial z = (d\theta/d\psi)\,(\partial\psi/\partial t) + Q \tag{C.3}$$

where K is again the hydraulic conductivity tensor (m/year), but now depends on the pressure head

ψ is the pressure head (m), which depends on the moisture content

θ is the moisture content (dimensionless)

z is the vertical column of moisture (m).

The relationship between the pressure head and the hydraulic head is simply

$$h = \psi + z. \tag{C.4}$$

For the performance assessment calculations, the hydraulic conductivity tensor is reduced to a single function, with

$$K_{ij} = K, \text{ for } i = j \text{ and} \tag{C.5}$$

$$K_{ij} = 0, \text{ for } i \neq j.$$

The functional dependence of the pressure head on moisture content and of the hydraulic conductivity on pressure head and ultimately on moisture content is discussed in Section 3.4.3.2.

For extremely dry conditions, vapor diffusion may be important. In such conditions, water does not move as a collective body, but rather as single molecules. Such diffusion can be described by Fick's equation,

$$\frac{dm}{dt} = -\,Dv\,A\,\frac{dC}{dx} \tag{C.6}$$

where dm/dt is the mass rate of water vapor diffusion (g/year)

D_v is the effective vapor diffusion coefficient (m^2/year)

A is the cross section area (m^2)

C is the water vapor mass concentration in the gas phase (g/m^3)

dC/dx is the water vapor mass concentration gradient (g/m^4).

B.2.3 Advective and Diffusive Transport

The equation for the advective and diffusive transport of contaminants can be viewed as a mass balance on a differential volume. The advective-dispersive equation for solute movement through a porous medium with a constant, steady-state flow velocity was developed (Codell 1982) for the limiting case of unidirectional advective transport with three-dimensional dispersion in a homogeneous, saturated aquifer,

$$n_e \frac{\partial C}{\partial t} + (n - ne)\frac{\partial G}{\partial t} + (1 - n)\frac{\partial P}{\partial t} + n_e u \frac{\partial C}{\partial x} =$$

$$n_e \left[E_x \frac{\partial^2 C}{\partial x^2} + E_y \frac{\partial^2 C}{\partial y^2} + E_z \frac{\partial^2 C}{\partial z^2} \right] +$$

$$(n - n_e)\left[E_x^1 \frac{\partial^2 G}{\partial x^2} + E_y^1 \frac{\partial^2 G}{\partial y^2} + E_z^1 \frac{\partial^2 G}{\partial z^2} \right] -$$

$$n_e \lambda C - (1 - n)\lambda P - (n - n_e)\lambda G \qquad \text{(C.7)}$$

where C is the dissolved concentration in the liquid phase in voids that are interconnected and allow flow [flowing voids] (g/m^3 or Ci/m^3)

G is the dissolved concentration in the liquid phase in voids that are not interconnected and do not allow flow [non-flowing voids] (g/m^3 or Ci/m^3)

P is the particulate concentrations on the solid phase (g/g or Ci/g)

n is the total porosity (dimensionless)

n_e is the effective porosity (dimensionless)

t is the time (year)

u is the x-component of groundwater or pore water velocity (m/year)

E_i is the dispersion coefficient in the flowing voids in the i-th (where i = x, y, or z) direction (m^2/year)

$E_i^{'}$ is the diffusion coefficient in the non-flowing voids in the i-th direction (m^2/year)

λ is the decay constant [= (ln 2)/half life] (y^{-1}).

Each term in the equation represents some aspect of the solute movement through the porous medium. The first term on the left of the equal sign is the accumulation (storage) of the

solute in the liquid phase in the flowing void. The second term is the accumulation in the liquid phase in the nonflowing void. The third term is the accumulation in the solid phase; and the term to the left of the equal sign is x-direction advective transport in the flowing voids in the liquid phase. The first term to the right of the equal sign represents the dispersive transport in the flowing voids in the liquid phase in each direction. The second term represents the diffusive transport in the nonflowing voids in the liquid phase in each direction. The last terms are the chemical degradation or radioactive decay in the liquid phase in the flowing void, in the solid phase, and in the liquid phase in the nonflowing void respectively.

Using the following assumptions:

- The dissolved concentration in the nonflowing voids (G) equals the dissolved concentration in the flowing voids (C) for each time and position
- The contaminant absorption process can be described by a constant, ($K = \rho^* K_d/(1 - n)$), representing the ratio between the contaminant absorbed to the soil matrix (P) and the contaminant dissolved in solution (C)
- The diffusion in the nonflowing void (E'_i) is comparable with the dispersion in the flowing void (E_i),the equation (D.7) can be simplified to

$$\frac{\partial C}{\partial t} + \frac{u}{R_f}\frac{\partial C}{\partial x} = \frac{D_x}{R_f}\frac{\partial^2 C}{\partial x^2} + \frac{D_y}{R_f}\frac{\partial^2 C}{\partial y^2} + \frac{D_z}{R_f}\frac{\partial^2 C}{\partial z^2} - \lambda C \qquad \text{(C.8)}$$

in which $$D_i = n\, E_i / n_e \qquad \text{(C.9)}$$

and $$R_f = n / n_e + (\rho^* K_d) / n_e \qquad \text{(C.10)}$$

and where

D_i is the pseudodispersion coefficient (m^2/year)

R_f is the retardation factor (dimensionless)

ρ is the bulk density (g/m^3)

K_d is the equilibrium (partition or distribution) coefficient (m^3/g).

The retardation factor (R_f) is used as a measure of the mobility of constituents in a porous medium.

By making the following substitutions,

$$u^* = u / R_f \qquad \text{(C.11)}$$

and $$D_i^* = D_i / R_f ,$$

the contaminant transport equation can be written as

$$\frac{\partial C}{\partial t} + u^* \frac{\partial C}{\partial x} = D_x^* \frac{\partial^2 C}{\partial x^2} + D_y^* \frac{\partial^2 C}{\partial y^2} + D_z^* \frac{\partial^2 C}{\partial z^2} - \lambda C \tag{C.12}$$

The first equation of this section [equation (D.1)] specifically addresses the general conditions for saturated flow and solute movement. However, with the following minor modifications, it also can be applied to the unsaturated zone:

- The porosities (n and n_e) are assumed to be equal to the soil matrix moisture content
- The one-dimensional flow is in the vertical direction.
- For this case, the retardation factor is defined by

$$R_f = 1 + (\rho^* K_d) / \theta \tag{C.13}$$

where θ is the moisture content of the partially saturated zone and dispersion is considered only in the flow direction.

B.2.4 Vapor Transport

Some contaminants may move upward from the disposal facility to the surface because they are in the vapor phase. Such movement is governed by Fick's second law,

$$D \frac{\partial^2 C}{\partial z^2} = \frac{\partial C}{\partial t} \tag{C.14}$$

where

C	is the concentration (g/m^3 or Ci/m^3)
z	is the distance (m)
t	is time (year)
D	is the diffusion coefficient (m^2/year).

The solution for concentration C in the z direction over time t is given by:

$$\frac{C}{C_0} = erfc\left(\frac{z}{2\sqrt{Dt}}\right) \tag{C.15}$$

where erfc is the complimentary error function and C/C_o is the relative concentration. The mass transport across the surface becomes

$$\frac{\partial C}{\partial t} = \frac{C_0}{2\sqrt{\pi DT}} \frac{z}{t} \exp\left(\frac{-z^2}{4Dt}\right) \tag{C.16}$$

B.3 WASTE FORM

ADVECTION-, DIFFUSION-, AND SOLUBILITY-DOMINATED Release Models for Residual Wastes

As discussed in the main text, the source terms for the risk assessment consist of four separate sources that include (a) past leaks and spills, (b) leakage during retrieval, (c) residual waste leachate from the tanks following closure, and (d) residual waste leachate from the tank ancillary following closure. The past leaks represent tank waste that has leaked into the vadose zone and has been migrating through vadose zone for a number of years. Retrieval leakage to the vadose zone refers to waste leakage that could occur during waste retrieval operations using water-based sluicing.

Releases from the residual wastes (both from tank and tank ancillary equipment) in most cases would occur over a long time period following closure of the tank farm when infiltrating water would enter the tank, dissolve contaminants, and migrate contaminants into the vadose zone and to the groundwater. In addition to the scenarios where the release duration is fixed and are defined in the main text as R_0 through R_4 release scenarios (see Appendix A), three additional models –advection-dominated, diffusion-dominated, and solubility-controlled – will be considered. Unlike the R_0 through R_4 release scenarios, release durations for these three models are not fixed a priori. Detailed descriptions on the three models are presented later. First, the conceptual basis and assumptions for the source term release are presented.

B.3.1 Conceptual Model of Source Term Release.

The actual process of contaminant (radionuclides and hazardous chemicals) release for residual wastes from a tank cannot be modeled precisely because of the variability of chemical and physical reactions that occur between the waste material and the infiltrating water. In the real system, contaminants are distributed in a heterogeneous manner within the tank. These contaminants are released into solution at different rates because of the variability in waste material. Finally, variable types and quantities of contaminants are dissolved into the infiltrating water over time, depending on which waste material contacts a particular fluid volume. Therefore, averaging concepts are used in modeling to simplify the mathematical representation of the real system. These concepts must be justified, however, as being a conservative representation of the real system.

The following assumptions are made for the source-term release estimates.

- The release of contaminants from tank residuals is evaluated assuming that the structural integrity of the tanks degrades, allowing recharge (infiltrating) water to enter the tank, and dissolve contaminants from the residuals. The release of contaminants occurs by dissolution of the waste material contaminants into the infiltrating water migrating into and out of tanks through cracks.

- For both stabilized (grouted) and unstabilized (not grouted) residual wastes in tank and tank ancillary equipment, it is assumed that the contaminant inventory will be available for release into the infiltrating solution via an advection-dominated or a diffusion-dominated or a solubility-controlled release model

- Unit quantities are assumed for various modeling runs. Because risk estimates are directly proportional to total inventory, the modeling runs with unit quantities can be scaled to calculate risk for any initial inventory.

- Three radionuclides (i.e., Tc-99, I-129 and U-238) are considered for the three release models (i.e., advection-, diffusion-dominated, and solubility-controlled) described below.

- For those stabilized waste materials that are incorporated into a waste form that controls radionuclide release by diffusion (i.e., grout), it is assumed that the diffusion coefficient remains constant over time for the diffusion-dominated release model.

- Contaminant inventories are assumed to be homogeneously distributed among the wastes. For the stabilized, grouted wastes, it is assumed that the contaminants are uniformly distributed in the residual wastes only in the bottom of the tank.

B.3.2 Mathematical Models of Release Mechanisms for the Advection-, Diffusion-, and Solubility-Dominated Models

As indicated earlier, in addition to the R_0 through R_4 release scenarios (Appendix A), the source terms will be estimated by an alternate advection-, diffusion-, or solubility-dominated release model. The mathematical description and conditions under which the different mechanisms occur are provided in the following sections. The area under each release model equals to unit inventory.

Advection-Dominated Release Model. The advection-dominated release model (mixing-cell cascade model) is used to simulate the processes of releases from stabilized (grouted tank or tank ancillary) wastes. For stabilized wastes, the radionuclides exit the facility at a rate determined by the flow of water and the amount of dispersion (mixing) within the tank. The mixing-cell cascade model (Kozak et al. 1990; Wood et al. 1995) is based on the dispersion analysis of chemical reactors and allows the analysis to incorporate the effects of dispersion in the tank in a simplified manner. In this model, the tank inside is considered to be composed of a cascade of N equal-sized, well-stirred cells in series. The total volume of the N cells is equal to the volume of the tank residual waste.

$$Q(t) = q\,A\,C_o\,e^{-\alpha Nt} \sum_{n=1}^{N} \frac{(\alpha Nt)^{n-1}}{(n-1)!}$$

The mixing-cell cascade model for N equal-sized cells is described by the following equation:

where:

Q = release rate (Ci/yr)

q = vertical Darcy flux (m/yr)

A = horizontal (planar) area of the tank inside

$\alpha = q/(\theta dR)$

θ = volumetric moisture content in the residual waste

d = vertical depth of the residual waste material (m)

R = retardation factor in the waste material (assumed R=1).

The initial concentration of contaminant in the interstitial water can be determined from the following equation:

$$C_0 = \frac{m}{\theta VR}$$

where m equals total facility inventory (assumed unity) of the radionuclides in the tank and V equals total volume of the residual waste (i.e., 360 ft^3 or 1% residual following TPA goal). The spatially variable velocities, V, and moisture contents, θ, which are obtained via flow modeling within the tank, will be used to determine C_o. Note that all simulation runs except for Cases 11 and 12 use backfill as the tank fill material. Cases 11 and 12 use grout as the tank fill material.

The mixing-cell cascade model provides results equivalent to the one-dimensional, convective-dispersion equation with varying values of the dispersion coefficient (Kozak et al. 1990). In the limit, as N approaches infinity, the model represents flow through a system with zero dispersion, whereas for N equal to one, the model represents flow with an infinite dispersion coefficient. A value of N = 10 will be used reflecting moderate dispersion.

Diffusion-Dominated Release Model. The diffusion-dominated release model is used to simulate the release of contaminants from stabilized (e.g., grouted tank or tank ancillary) wastes. In the absence of little or no advection through the waste container, the release can be modeled as a diffusion-limited process. The diffusion from cylindrical containers leads to an expression for flux that contains infinite series (Kozak et al. 1990). The series converges slowly for small diffusion coefficients for short times, and even for relatively long times. As a result, a one-dimensional diffusion solution can be adopted (Crank 1975). The solution, for a semi-infinite medium with the concentration C_0 throughout, initially, and with zero surface concentration, is given by

$$C = C_0 \, erf \frac{x}{2\sqrt{(D_e t)}}$$

where:

erf = standard error function,

D_e = effective diffusion coefficient of the radionuclides in the waste form, and

t = time.

The rate of loss of diffusing substance per unit area from the semi-infinite medium when the surface concentration is zero, is given by:

$$\left(D_e \frac{\partial C}{\partial x} \right)_{x=0} = C_0 \sqrt{\frac{D_e}{\pi t}}$$

The above equation has the form of diffusion mass transfer based on leaching theory. This simplified release model leads to the following form:

$$q = A \, C_0 \sqrt{\frac{D_e}{\pi t}}$$

where:

q = release rate from a single waste cell (Ci/yr),

A = effective surface area of a single cell, and

C_0 = concentration in a cell.

Because the residual waste is likely contained in various cells with differing sizes and shapes, the diffusive release rate, Q, from all residual waste in the tank can be determined by the following equation:

$$Q = C_0 \sqrt{\frac{D_e}{\pi t}} \sum_{i=1}^{n} A_i$$

$$= C_0 A_t \sqrt{\frac{D_e}{\pi t}}$$

where n is the number of cells, A_i is the surface area of individual cells and A_t is total surface area of a tank.

By assuming that the cells are constant, i.e.,

$$I = C_0 \sum_{i=1}^{n} V_i = C_0 V_t$$

where I is the total inventory, V_i is the volume of i-th cell and V_t is the total volume of all cells.

Combining preceding equations, we obtain:

$$Q = I \frac{A_t}{V_t} \sqrt{\frac{D_e}{\pi t}}$$

The ratio A_t/V_t can be replaced by a ratio of a surface area over volume of a tank (only the portion of the tank containing waste will be used to obtain the ratio).

The model calculation is conservative in two aspects. First, the surface area of a tank might not be completely exposed to a moving stream of water. Second, the radionuclides reaching the tank surface area are assumed to be released into the water stream and instantaneously reach the bottom of the tank for release. Two different diffusion coefficient values will be used: 6 x10^{-7} cm^2/sec based on Kincaid et al. (1995) and 5 x 10^{-8} cm^2/sec based on *Hanford Waste-Form Release and Sediment Interaction* (Serne and Wood 1990).

Solubility-Controlled Release Model. Solubility-controlled release models assume that a known solid is present or rapidly forms, and controls the solution concentration in the aqueous phase of the constituents being released. Solubility models are thermodynamic equilibrium models and do not consider kinetics (time required to dissolve or completely precipitate) (Serne and Wood 1990). When identification of the likely controlling solid is difficult, empirical solubility experiments are performed to gather data that can be used to generate an empirical solubility release model. Such empirical models assume a controlling solid and fix the chemistry of all constituents to derive a fixed value for the concentration of specific contaminants. No solubility empirical models presently exist for modeling contaminants from residual tank wastes. However, a solubility-controlled release model (i.e., "cake" model) has often been postulated in previous risk assessments.

The cake model consists of a very simple mathematical formulation containing a recharge rate term, a term for waste solid solubility, and a term for the cross-sectional area of the waste source (i.e., single-shell tank footprint).

The contaminant release mechanism of the cake model is the dissolution of the "structural matrix." As the matrix dissolves, all the contaminants are assumed to leach congruently at the same rate. When applied to the residual tank wastes, the term "cake" applies to the sludge and hard heel residual in the tanks, which compose the "structural matrix." The release rate for a given contaminant (Tc-99, I-129 and U-238) is given by:

$$dM / dt = -M_o \, A \, Q_w \, C_{wo}^{sol} / M_{wo}$$

where M_{wo} = the original mass of cake (kg). M_{wo} can be derived by the product of tank waste volume (TPA goal of 99% removal) and waste density (1.7 g/cm^3),

M_o = the original quantity of the contaminant in Ci embedded in the cake,

M = M(t) is the current quantity of the contaminant contained in the cake (Ci or kg) at time t,

A = the surface area of the cake exposed to the release mechanism,

C_{wo}^{sol} = the aqueous solubility of the cake simulated as a nitrate salt; the concentration most commonly used is 360 g/L. Based on expected waste characteristics, a value of 72 g/L will be used.

Q_w = the recharge rate in cm/yr, also termed "infiltration rate," and

dM/dt = the rate of loss of contaminant from the cake waste form per unit time t (the rate at which the contaminant enters the vadose zone).

Recharge rates for the cake model are listed in Table l in the main text. Cross-sectional footprint for the cake model consists of the individual tank area.

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Appendix C

DETAILED RESULTS OF THE ANALYSIS

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Table C-1a. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Tank C-105 Leak) – Leak at Bottom of Tank

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	155.73	24.68	8.53
I-129	0.30	0.05	0.02
U	0.00	0.00	0.00
Cr	0.79	0.13	0.04
NO2	21.70	3.44	1.19
NO3	25.42	4.03	1.39

Table C-1b. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (UPR-200-E-81) – Leak at Level of Bottom of the Tanks

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	8.23	1.30	0.45
I-129	0.02	0.00	0.00
U	10.49	1.66	0.57
Cr	1.76	0.28	0.10
NO2	146.85	23.28	8.05
NO3	467.18	74.05	25.60

Table C-1c. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (UPR-200-E-82) – Leak at Level of Bottom of the Tanks

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	404.24	64.08	22.15
I-129	0.78	0.12	0.04
U	1.48	0.23	0.08
Cr	2.06	0.33	0.11
NO2	56.32	8.93	3.09
NO3	66.00	10.46	3.62

Table C-1d. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (UPR-200-E-86) – Leak at Level of Bottom of the Tanks

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	501.87	79.55	27.50
I-129	0.97	0.15	0.05
U	3.01	0.48	0.16
Cr	4.74	0.75	0.26
NO2	117.00	18.55	6.41
NO3	97.63	15.48	5.35

Table C-1e. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Total) – Leak at Level of Bottom of the Tanks

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	787.20	309.07	250.13
I-129	220.10	219.17	219.06
U	230.97	220.90	219.66
Cr	223.61	219.73	219.25
NO2	443.87	254.64	231.32
NO3	777.59	307.54	249.60

Table C-2a. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Tank C-105 Leak) – Leak at Pipeline Level

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	60.14	9.53	3.41
I-129	0.12	0.02	0.01
U	0.00	0.00	0.00
Cr	0.31	0.05	0.02
NO2	8.38	1.33	0.48
NO3	9.82	1.55	0.56

Table C-2b. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (UPR-200-E-81) – Leak at Pipeline Level

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	3.18	0.50	0.18
I-129	0.01	0.00	0.00
U	4.05	0.64	0.23
Cr	0.68	0.11	0.04
NO2	56.71	8.98	3.22
NO3	180.41	28.58	10.24

Table C-2c. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (UPR-200-E-82) – Leak at Pipeline Level

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	156.11	24.73	8.86
I-129	0.30	0.05	0.02
U	0.57	0.09	0.03
Cr	0.79	0.13	0.05
NO2	21.75	3.45	1.23
NO3	25.49	4.04	1.45

Table C-2d. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (UPR-200-E-86) – Leak at Pipeline Level

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	193.81	30.70	11.00
I-129	0.37	0.06	0.02
U	1.16	0.18	0.07
Cr	1.83	0.29	0.10
NO2	45.18	7.16	2.56
NO3	37.70	5.97	2.14

Table C-2e. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Total) – Leak at Pipeline Level

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	438.42	253.76	231.45
I-129	219.42	219.07	219.02
U	223.62	219.73	219.26
Cr	220.78	219.28	219.10
NO2	305.84	232.76	223.93
NO3	434.71	253.17	231.24

Table C-3. Past Leak Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Total) – Best Estimate of Leak Location

Contaminant	WMA Fence Line (Fence-line averaged)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	508.82	80.61	28.57
I-129	0.98	0.16	0.06
U	5.78	0.92	0.33
Cr	4.10	0.65	0.23
NO2	145.34	23.02	8.21
NO3	269.02	42.62	15.22

Tank C-105 Leak location is at bottom of tank
UPR leak locations are at pipeline level.

Table C-4a. 8,000 Gallon Potential Retrieval Leaks Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	1.88	0.00	25.98	0.81	24.82	165.99
C-102	3.57	0.01	22.03	1.99	45.69	197.89
C-103	92.46	0.18	16.11	1.87	44.07	3.73
C-104	156.80	2.04	95.43	3.95	98.68	52.99
C-105	220.06	0.25	26.60	1.12	22.76	22.01
C-106	8.49	0.05	0.36	0.17	4.14	0.21
C-107	102.46	0.13	25.12	2.51	95.43	129.22
C-108	16.73	0.00	0.41	0.63	23.63	42.44
C-109	87.32	0.01	10.98	0.32	32.98	48.66
C-110	85.97	0.00	5.33	1.14	17.65	264.94
C-111	7.30	0.01	11.49	0.23	25.66	46.77
C-112	165.18	0.01	65.15	0.38	75.16	100.57
C-201	0.04	0.00	0.00	0.01	0.11	0.61
C-202	0.04	0.00	0.00	0.01	0.58	1.73
C-203	0.08	0.00	0.01	0.01	0.66	2.27
C-204	0.05	0.00	0.00	0.01	0.43	1.46

Table C-4b. 20,000 Gallon Potential Retrieval Leaks Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	4.71	0.01	64.95	2.02	62.04	414.98
C-102	8.92	0.02	55.08	4.97	114.22	494.73
C-103	231.14	0.45	40.28	4.66	110.17	9.33
C-104	392.00	5.10	238.58	9.87	246.69	132.47
C-105	550.15	0.63	66.50	2.79	56.91	55.02
C-106	21.22	0.11	0.89	0.42	10.34	0.52
C-107	256.15	0.33	62.79	6.29	238.58	323.06
C-108	41.84	0.01	1.03	1.57	59.07	106.11
C-109	218.30	0.01	27.44	0.80	82.46	121.66
C-110	214.92	0.01	13.31	2.84	44.13	662.34
C-111	18.25	0.01	28.72	0.58	64.14	116.92
C-112	412.95	0.03	162.88	0.94	187.89	251.42
C-201	0.10	0.00	0.01	0.02	0.28	1.53
C-202	0.10	0.00	0.01	0.02	1.45	4.32
C-203	0.19	0.00	0.02	0.03	1.66	5.66
C-204	0.12	0.00	0.01	0.02	1.07	3.66

Table C-5. Potential Retrieval Leaks Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average). Only Tanks C-106 and C-107 assumed to Leak

Leak	Tc-99	I-129	U	Cr	NO2	NO3
8,000 gallons each	111	0.18	25	3	100	129
20,000 gallons each	277	0.44	64	7	249	324

Table C-6a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory and R0 Release Rate (10^{-3}/yr for 500 years and 0.1/yr for 5 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.24	0.26	7.87	52.67
C-102	0.32	0.00	1.95	0.18	4.03	17.48
C-103	12.78	0.02	2.23	0.26	6.11	0.52
C-104	16.89	0.22	10.28	0.43	10.65	5.72
C-105	46.51	0.05	5.63	0.24	4.82	4.65
C-106	6.50	0.04	0.27	0.13	3.17	0.16
C-107	11.52	0.01	2.83	0.28	10.73	14.51
C-108	7.06	0.00	0.17	0.27	9.97	17.93
C-109	38.38	0.00	4.82	0.14	14.51	21.43
C-110	13.48	0.00	0.83	0.18	2.77	41.47
C-111	3.56	0.00	5.60	0.11	12.50	22.78
C-112	44.55	0.00	17.51	0.10	20.20	27.04
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.27	3.81
C-203	0.07	0.00	0.01	0.01	0.58	1.99
C-204	0.04	0.00	0.00	0.01	0.38	1.29

Table C-6b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory and R0 Release Rate (10^{-3}/yr for 500 years and 0.1/yr for 5 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.24	0.26	7.87	52.67
C-102	0.32	0.00	1.95	0.18	4.06	17.45
C-103	16.33	0.03	2.80	0.41	6.84	0.66
C-104	16.87	0.22	10.31	0.43	10.65	5.72
C-105	46.51	0.05	5.63	0.24	4.82	4.65
C-106	12.80	0.10	0.51	0.71	1.00	0.15
C-107	11.52	0.01	2.83	0.28	10.76	14.51
C-108	7.06	0.00	0.17	0.27	9.97	17.96
C-109	38.38	0.00	4.82	0.14	14.54	21.43
C-110	13.56	0.00	0.84	0.18	2.78	41.75
C-111	3.56	0.00	5.60	0.11	12.50	22.72
C-112	44.55	0.00	17.54	0.10	20.17	26.98
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.27	3.81
C-203	0.07	0.00	0.01	0.01	0.58	1.99
C-204	0.04	0.00	0.00	0.01	0.38	1.29

Table C-6c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory and R0 Release Rate (10^{-3}/yr for 500 years and 0.1/yr for 5 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.08	0.00	0.00	0.03	0.99	6.67
C-102	0.09	0.00	0.00	0.05	1.12	4.79
C-103	1.20	0.00	0.00	0.04	0.57	0.06
C-104	2.22	0.03	0.00	0.06	1.40	0.75
C-105	3.50	0.00	0.00	0.02	0.36	0.35
C-106	5.58	0.03	0.00	0.11	2.72	0.14
C-107	1.91	0.00	0.00	0.06	2.15	3.25
C-108	1.76	0.00	0.00	0.07	2.48	4.48
C-109	7.17	0.00	0.00	0.03	2.71	4.01
C-110	6.81	0.00	0.00	0.09	1.40	20.93
C-111	0.55	0.00	0.00	0.02	1.94	3.53
C-112	11.43	0.00	0.00	0.03	5.21	6.95
C-201	0.01	0.00	0.00	0.00	0.03	0.14
C-202	0.01	0.00	0.00	0.00	0.13	0.40
C-203	0.01	0.00	0.00	0.00	0.08	0.27
C-204	0.01	0.00	0.00	0.00	0.08	0.27

Table C-6d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and R0 Release Rate (10^{-3}/yr for 500 years and 0.1/yr for 5 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.24	0.26	7.87	52.67
C-102	0.32	0.00	1.95	0.18	4.06	17.45
C-103	16.33	0.03	2.80	0.41	6.84	0.66
C-104	16.87	0.22	10.31	0.43	10.65	5.72
C-105	46.51	0.05	5.63	0.24	4.82	4.65
C-106	12.80	0.10	0.51	0.71	1.00	0.15
C-107	11.52	0.01	2.83	0.28	10.76	14.51
C-108	7.06	0.00	0.17	0.27	9.97	17.96
C-109	38.38	0.00	4.82	0.14	14.54	21.43
C-110	13.56	0.00	0.84	0.18	2.78	41.75
C-111	3.56	0.00	5.60	0.11	12.50	22.72
C-112	44.55	0.00	17.54	0.10	20.17	26.98
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.27	3.81
C-203	0.07	0.00	0.01	0.01	0.58	1.99
C-204	0.04	0.00	0.00	0.01	0.38	1.29
Total	212.33	0.43	61.27	3.34	108.44	235.10

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-7a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory for Tank Residual Case, and R1 Release Rate (10^{-4}/yr for 500 years and 0.01/yr for 95 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.24	0.26	7.87	52.67
C-102	0.32	0.00	1.95	0.18	4.03	17.48
C-103	12.78	0.02	2.23	0.26	6.11	0.52
C-104	16.89	0.22	10.28	0.43	10.65	5.72
C-105	46.51	0.05	5.63	0.24	4.82	4.65
C-106	6.50	0.04	0.27	0.13	3.17	0.16
C-107	11.52	0.01	2.83	0.28	10.73	14.51
C-108	7.06	0.00	0.17	0.27	9.97	17.93
C-109	38.38	0.00	4.82	0.14	14.51	21.43
C-110	13.48	0.00	0.83	0.18	2.77	41.47
C-111	3.56	0.00	5.60	0.11	12.50	22.78
C-112	44.55	0.00	17.51	0.10	20.20	27.04
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.27	3.81
C-203	0.07	0.00	0.01	0.01	0.58	1.99
C-204	0.04	0.00	0.00	0.01	0.38	1.29

Table C-7b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory and R1 Release Rate (10^{-4}/yr for 500 years and 0.01/yr for 95 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.24	0.26	7.87	52.67
C-102	0.32	0.00	1.95	0.18	4.06	17.45
C-103	16.33	0.03	2.80	0.41	6.84	0.66
C-104	16.87	0.22	10.31	0.43	10.65	5.72
C-105	46.51	0.05	5.63	0.24	4.82	4.65
C-106	12.80	0.10	0.51	0.71	1.00	0.15
C-107	11.52	0.01	2.83	0.28	10.76	14.51
C-108	7.06	0.00	0.17	0.27	9.97	17.96
C-109	38.38	0.00	4.82	0.14	14.54	21.43
C-110	13.56	0.00	0.84	0.18	2.78	41.75
C-111	3.56	0.00	5.60	0.11	12.50	22.72
C-112	44.55	0.00	17.54	0.10	20.17	26.98
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.27	3.81
C-203	0.07	0.00	0.01	0.01	0.58	1.99
C-204	0.04	0.00	0.00	0.01	0.38	1.29

Table C-7c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory and R1 Release Rate (10^{-4}/yr for 500 years and 0.01/yr for 95 years))

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.08	0.00	0.00	0.03	0.99	6.67
C-102	0.09	0.00	0.00	0.05	1.12	4.79
C-103	1.20	0.00	0.00	0.04	0.57	0.06
C-104	2.22	0.03	0.00	0.06	1.40	0.75
C-105	3.50	0.00	0.00	0.02	0.36	0.35
C-106	5.58	0.03	0.00	0.11	2.72	0.14
C-107	1.91	0.00	0.00	0.06	2.15	3.25
C-108	1.76	0.00	0.00	0.07	2.48	4.48
C-109	7.17	0.00	0.00	0.03	2.71	4.01
C-110	6.81	0.00	0.00	0.09	1.40	20.93
C-111	0.55	0.00	0.00	0.02	1.94	3.53
C-112	11.43	0.00	0.00	0.03	5.21	6.95
C-201	0.01	0.00	0.00	0.00	0.03	0.14
C-202	0.01	0.00	0.00	0.00	0.13	0.40
C-203	0.01	0.00	0.00	0.00	0.08	0.27
C-204	0.01	0.00	0.00	0.00	0.08	0.27

Table C-7d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and R1 Release Rate (10^{-4}/yr for 500 years and 0.01/yr for 95 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.24	0.26	7.87	52.67
C-102	0.32	0.00	1.95	0.18	4.06	17.45
C-103	16.33	0.03	2.80	0.41	6.84	0.66
C-104	16.87	0.22	10.31	0.43	10.65	5.72
C-105	46.51	0.05	5.63	0.24	4.82	4.65
C-106	5.58	0.03	0.00	0.11	2.72	0.14
C-107	1.91	0.00	0.00	0.06	2.15	3.25
C-108	7.06	0.00	0.17	0.27	9.97	17.96
C-109	38.38	0.00	4.82	0.14	14.54	21.43
C-110	13.56	0.00	0.84	0.18	2.78	41.75
C-111	3.56	0.00	5.60	0.11	12.50	22.72
C-112	44.55	0.00	17.54	0.10	20.17	26.98
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.27	3.81
C-203	0.07	0.00	0.01	0.01	0.58	1.99
C-204	0.04	0.00	0.00	0.01	0.38	1.29
Total	195.50	0.35	57.93	2.52	101.55	223.83

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-8a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory for Tank Residual Case, and R2 Release Rate (10^{-5}/yr for 500 years and 0.001/yr for 995 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.52	0.00	7.12	0.22	6.81	45.54
C-102	0.27	0.00	1.68	0.15	3.49	15.12
C-103	11.05	0.02	1.93	0.22	5.28	0.45
C-104	14.61	0.19	8.89	0.37	9.21	4.94
C-105	40.21	0.05	4.87	0.20	4.17	4.02
C-106	5.62	0.03	0.24	0.11	2.74	0.14
C-107	9.96	0.01	2.45	0.24	9.28	12.55
C-108	6.10	0.00	0.15	0.23	8.62	15.50
C-109	33.19	0.00	4.17	0.12	12.55	18.53
C-110	11.65	0.00	0.72	0.15	2.39	35.85
C-111	3.08	0.00	4.84	0.10	10.80	19.69
C-112	38.52	0.00	15.14	0.09	17.47	23.38
C-201	0.07	0.00	0.01	0.01	0.22	1.17
C-202	0.08	0.00	0.01	0.01	1.10	3.29
C-203	0.06	0.00	0.00	0.01	0.50	1.72
C-204	0.04	0.00	0.00	0.01	0.32	1.11

Table C-8b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory (10^{-5}/yr for 500 years and 0.001/yr for 995 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.52	0.00	7.12	0.22	6.81	45.54
C-102	0.27	0.00	1.68	0.15	3.51	15.09
C-103	14.12	0.03	2.42	0.36	5.91	0.57
C-104	14.58	0.19	8.91	0.37	9.21	4.94
C-105	40.21	0.05	4.87	0.20	4.17	4.02
C-106	11.07	0.09	0.44	0.61	0.87	0.13
C-107	9.96	0.01	2.45	0.24	9.30	12.55
C-108	6.10	0.00	0.15	0.23	8.62	15.53
C-109	33.19	0.00	4.17	0.12	12.57	18.53
C-110	11.72	0.00	0.73	0.15	2.40	36.09
C-111	3.08	0.00	4.84	0.10	10.80	19.65
C-112	38.52	0.00	15.16	0.09	17.44	23.33
C-201	0.07	0.00	0.01	0.01	0.22	1.17
C-202	0.08	0.00	0.01	0.01	1.10	3.29
C-203	0.06	0.00	0.00	0.01	0.50	1.72
C-204	0.04	0.00	0.00	0.01	0.32	1.11

Table C-8c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory for Tank Residual Case, and R2 Release Rate (10^{-5}/yr for 500 years and 0.001/yr for 995 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.07	0.00	0.00	0.03	0.86	5.77
C-102	0.08	0.00	0.00	0.04	0.04	0.04
C-103	1.04	0.00	0.00	0.03	0.03	0.03
C-104	1.92	0.02	0.00	0.05	0.05	0.05
C-105	3.03	0.00	0.00	0.02	0.02	0.02
C-106	4.82	0.03	0.00	0.09	0.09	0.09
C-107	1.65	0.00	0.00	0.05	0.05	0.05
C-108	1.52	0.00	0.00	0.06	0.06	0.06
C-109	6.20	0.00	0.00	0.02	0.02	0.02
C-110	5.89	0.00	0.00	0.08	0.08	0.08
C-111	0.48	0.00	0.00	0.02	0.02	0.02
C-112	9.88	0.00	0.00	0.02	0.02	0.02
C-201	0.01	0.00	0.00	0.00	0.00	0.00
C-202	0.01	0.00	0.00	0.00	0.00	0.00
C-203	0.01	0.00	0.00	0.00	0.00	0.00
C-204	0.01	0.00	0.00	0.00	0.00	0.00

Table C-8d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and R2 Release Rate (10^{-5}/yr for 500 years and 0.001/yr for 995 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.52	0.00	7.12	0.22	6.81	45.54
C-102	0.27	0.00	1.68	0.15	3.51	15.09
C-103	14.12	0.03	2.42	0.36	5.91	0.57
C-104	14.58	0.19	8.91	0.37	9.21	4.94
C-105	40.21	0.05	4.87	0.20	4.17	4.02
C-106	4.82	0.03	0.00	0.09	0.09	0.09
C-107	1.65	0.00	0.00	0.05	0.05	0.05
C-108	6.10	0.00	0.15	0.23	8.62	15.53
C-109	33.19	0.00	4.17	0.12	12.57	18.53
C-110	11.72	0.00	0.73	0.15	2.40	36.09
C-111	3.08	0.00	4.84	0.10	10.80	19.65
C-112	38.52	0.00	15.16	0.09	17.44	23.33
C-201	0.07	0.00	0.01	0.01	0.22	1.17
C-202	0.08	0.00	0.01	0.01	1.10	3.29
C-203	0.06	0.00	0.00	0.01	0.50	1.72
C-204	0.04	0.00	0.00	0.01	0.32	1.11
Total	169.03	0.30	50.08	2.18	83.74	190.74

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-9a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory for Tank Residual Case, and R4 Release Rate (0.1/yr for 10 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.25	0.26	7.88	52.75
C-102	0.32	0.00	1.95	0.18	4.04	17.51
C-103	12.80	0.02	2.23	0.26	6.12	0.52
C-104	16.92	0.22	10.30	0.43	10.66	5.72
C-105	46.58	0.05	5.64	0.24	4.83	4.66
C-106	6.51	0.04	0.27	0.13	3.17	0.16
C-107	11.53	0.01	2.83	0.28	10.75	14.54
C-108	7.07	0.00	0.18	0.27	9.99	17.96
C-109	38.44	0.00	4.83	0.14	14.54	21.47
C-110	13.50	0.00	0.84	0.18	2.77	41.53
C-111	3.56	0.00	5.61	0.11	12.51	22.81
C-112	44.62	0.00	17.54	0.10	20.23	27.08
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.28	3.82
C-203	0.07	0.00	0.01	0.01	0.58	2.00
C-204	0.04	0.00	0.00	0.01	0.38	1.29

Table C-9b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory for Tank Residual Case, and R4 Release Rate (0.1/yr for 10 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.25	0.26	7.88	52.75
C-102	0.32	0.00	1.95	0.18	4.07	17.48
C-103	16.36	0.03	2.81	0.41	6.85	0.67
C-104	16.89	0.22	10.33	0.43	10.66	5.72
C-105	46.58	0.05	5.64	0.24	4.83	4.66
C-106	12.82	0.10	0.51	0.71	1.00	0.15
C-107	11.53	0.01	2.83	0.28	10.78	14.54
C-108	7.07	0.00	0.17	0.27	9.99	17.99
C-109	38.44	0.00	4.83	0.14	14.56	21.47
C-110	13.58	0.00	0.84	0.18	2.78	41.81
C-111	3.56	0.00	5.61	0.11	12.51	22.76
C-112	44.62	0.00	17.57	0.10	20.20	27.02
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.28	3.82
C-203	0.07	0.00	0.01	0.01	0.58	2.00
C-204	0.04	0.00	0.00	0.01	0.38	1.29

Table C-9c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory for Tank Residual Case, and R4 Release Rate (0.1/yr for 10 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.08	0.00	0.00	0.03	1.00	6.68
C-102	0.09	0.00	0.00	0.05	1.12	4.80
C-103	1.20	0.00	0.00	0.04	0.57	0.06
C-104	2.22	0.03	0.00	0.06	1.40	0.75
C-105	3.51	0.00	0.00	0.02	0.36	0.35
C-106	5.58	0.03	0.00	0.11	2.72	0.14
C-107	1.91	0.00	0.00	0.06	2.15	3.26
C-108	1.76	0.00	0.00	0.07	2.49	4.49
C-109	7.18	0.00	0.00	0.03	2.72	4.01
C-110	6.82	0.00	0.00	0.09	1.40	20.96
C-111	0.55	0.00	0.00	0.02	1.94	3.54
C-112	11.45	0.00	0.00	0.03	5.22	6.96
C-201	0.01	0.00	0.00	0.00	0.03	0.14
C-202	0.01	0.00	0.00	0.00	0.13	0.40
C-203	0.01	0.00	0.00	0.00	0.08	0.27
C-204	0.01	0.00	0.00	0.00	0.08	0.27

Table C-9d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and R4 Release Rate (0.1/yr for 10 years)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.60	0.00	8.25	0.26	7.88	52.75
C-102	0.32	0.00	1.95	0.18	4.07	17.48
C-103	16.36	0.03	2.81	0.41	6.85	0.67
C-104	16.89	0.22	10.33	0.43	10.66	5.72
C-105	46.58	0.05	5.64	0.24	4.83	4.66
C-106	5.58	0.03	0.00	0.11	2.72	0.14
C-107	1.91	0.00	0.00	0.06	2.15	3.26
C-108	7.07	0.00	0.17	0.27	9.99	17.99
C-109	38.44	0.00	4.83	0.14	14.56	21.47
C-110	13.58	0.00	0.84	0.18	2.78	41.81
C-111	3.56	0.00	5.61	0.11	12.51	22.76
C-112	44.62	0.00	17.57	0.10	20.20	27.02
C-201	0.08	0.00	0.01	0.01	0.25	1.35
C-202	0.09	0.00	0.01	0.01	1.28	3.82
C-203	0.07	0.00	0.01	0.01	0.58	2.00
C-204	0.04	0.00	0.00	0.01	0.38	1.29
Total	195.80	0.35	58.02	2.52	101.70	224.17

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-10a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory for Tank Residual Case, and Advection Dominated Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.06	0.00	0.82	0.03	0.78	5.23
C-102	0.03	0.00	0.19	0.02	0.40	1.74
C-103	1.27	0.00	0.22	0.03	0.61	0.05
C-104	1.68	0.02	1.02	0.04	1.06	0.57
C-105	4.62	0.01	0.56	0.02	0.48	0.46
C-106	0.65	0.00	0.03	0.01	0.31	0.02
C-107	1.14	0.00	0.28	0.03	1.07	1.44
C-108	0.70	0.00	0.02	0.03	0.99	1.78
C-109	3.81	0.00	0.48	0.01	1.44	2.13
C-110	1.34	0.00	0.08	0.02	0.28	4.12
C-111	0.35	0.00	0.56	0.01	1.24	2.26
C-112	4.43	0.00	1.74	0.01	2.01	2.69
C-201	0.01	0.00	0.00	0.00	0.02	0.13
C-202	0.01	0.00	0.00	0.00	0.13	0.38
C-203	0.01	0.00	0.00	0.00	0.06	0.20
C-204	0.00	0.00	0.00	0.00	0.04	0.13

Table C-10b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory for Tank Residual Case, and Advection Dominated Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.06	0.00	0.82	0.03	0.78	5.23
C-102	0.03	0.00	0.19	0.02	0.40	1.73
C-103	1.62	0.00	0.28	0.04	0.68	0.07
C-104	1.68	0.02	1.02	0.04	1.06	0.57
C-105	4.62	0.01	0.56	0.02	0.48	0.46
C-106	1.27	0.01	0.05	0.07	0.10	0.01
C-107	1.14	0.00	0.28	0.03	1.07	1.44
C-108	0.70	0.00	0.02	0.03	0.99	1.78
C-109	3.81	0.00	0.48	0.01	1.45	2.13
C-110	1.35	0.00	0.08	0.02	0.28	4.15
C-111	0.35	0.00	0.56	0.01	1.24	2.26
C-112	4.43	0.00	1.74	0.01	2.00	2.68
C-201	0.01	0.00	0.00	0.00	0.02	0.13
C-202	0.01	0.00	0.00	0.00	0.13	0.38
C-203	0.01	0.00	0.00	0.00	0.06	0.20
C-204	0.00	0.00	0.00	0.00	0.04	0.13

Table C-10c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory for Tank Residual Case, and Advection Dominated Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.00	0.00	0.00	0.00	0.10	0.66
C-102	0.00	0.00	0.00	0.00	0.11	0.48
C-103	0.00	0.00	0.00	0.00	0.06	0.01
C-104	0.00	0.00	0.00	0.01	0.14	0.07
C-105	0.00	0.00	0.00	0.00	0.04	0.03
C-106	0.00	0.00	0.00	0.01	0.27	0.01
C-107	0.00	0.00	0.00	0.01	0.21	0.32
C-108	0.00	0.00	0.00	0.01	0.25	0.45
C-109	0.00	0.00	0.00	0.00	0.27	0.40
C-110	0.00	0.00	0.00	0.01	0.14	2.08
C-111	0.00	0.00	0.00	0.00	0.19	0.35
C-112	0.00	0.00	0.00	0.00	0.52	0.69
C-201	0.00	0.00	0.00	0.00	0.00	0.01
C-202	0.00	0.00	0.00	0.00	0.01	0.04
C-203	0.00	0.00	0.00	0.00	0.01	0.03
C-204	0.00	0.00	0.00	0.00	0.01	0.03

Table C-10d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and Advection Dominated Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.06	0.00	0.82	0.03	0.78	5.23
C-102	0.03	0.00	0.19	0.02	0.40	1.73
C-103	1.62	0.00	0.28	0.04	0.68	0.07
C-104	1.68	0.02	1.02	0.04	1.06	0.57
C-105	4.62	0.01	0.56	0.02	0.48	0.46
C-106	0.00	0.00	0.00	0.01	0.27	0.01
C-107	0.00	0.00	0.00	0.01	0.21	0.32
C-108	0.70	0.00	0.02	0.03	0.99	1.78
C-109	3.81	0.00	0.48	0.01	1.45	2.13
C-110	1.35	0.00	0.08	0.02	0.28	4.15
C-111	0.35	0.00	0.56	0.01	1.24	2.26
C-112	4.43	0.00	1.74	0.01	2.00	2.68
C-201	0.01	0.00	0.00	0.00	0.02	0.13
C-202	0.01	0.00	0.00	0.00	0.13	0.38
C-203	0.01	0.00	0.00	0.00	0.06	0.20
C-204	0.00	0.00	0.00	0.00	0.04	0.13
Total	18.69	0.03	5.76	0.25	10.09	22.25

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-11a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory for Tank Residual Case, and Diffusion Dominated Release Rate (D_{eff} = 6 x10^{-7} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.19	0.00	2.59	0.08	2.47	16.53
C-102	0.10	0.00	0.61	0.06	1.27	5.49
C-103	4.01	0.01	0.70	0.08	1.92	0.16
C-104	5.30	0.07	3.23	0.13	3.34	1.79
C-105	14.60	0.02	1.77	0.07	1.51	1.46
C-106	2.04	0.01	0.09	0.04	0.99	0.05
C-107	3.61	0.00	0.89	0.09	3.37	4.55
C-108	2.22	0.00	0.05	0.08	3.13	5.63
C-109	12.05	0.00	1.51	0.04	4.55	6.73
C-110	4.23	0.00	0.26	0.06	0.87	13.01
C-111	1.12	0.00	1.76	0.04	3.92	7.15
C-112	13.98	0.00	5.50	0.03	6.34	8.49
C-201	0.03	0.00	0.00	0.00	0.08	0.42
C-202	0.03	0.00	0.00	0.00	0.40	1.20
C-203	0.02	0.00	0.00	0.00	0.18	0.63
C-204	0.01	0.00	0.00	0.00	0.12	0.40

Table C-11b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory for Tank Residual Case, and Diffusion Dominated Release Rate (D_{eff} = 6 x10^{-7} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.19	0.00	3.23	0.13	3.34	1.79
C-102	0.10	0.00	1.77	0.07	1.51	1.46
C-103	5.13	0.01	0.09	0.04	0.99	0.05
C-104	5.29	0.07	0.89	0.09	3.37	4.55
C-105	14.60	0.02	0.05	0.08	3.13	5.63
C-106	4.02	0.03	1.51	0.04	4.55	6.73
C-107	3.61	0.00	0.26	0.06	0.87	13.01
C-108	2.22	0.00	1.76	0.04	3.92	7.15
C-109	12.05	0.00	5.50	0.03	6.34	8.49
C-110	4.26	0.00	0.00	0.00	0.08	0.42
C-111	1.12	0.00	0.00	0.00	0.40	1.20
C-112	13.98	0.00	0.00	0.00	0.18	0.63
C-201	0.03	0.00	0.00	0.00	0.12	0.40
C-202	0.03	0.00	18.95	0.82	34.46	73.69
C-203	0.02	0.00	0.00	0.00	0.00	0.00
C-204	0.01	0.00	0.00	0.00	0.00	0.00

Table C-11c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory for Tank Residual Case, and Diffusion Dominated Release Rate (D_{eff} = 6 x10^{-7} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.00	0.00	0.00	0.00	0.10	0.66
C-102	0.00	0.00	0.00	0.00	0.11	0.48
C-103	0.00	0.00	0.00	0.00	0.06	0.01
C-104	0.00	0.00	0.00	0.01	0.14	0.07
C-105	0.00	0.00	0.00	0.00	0.04	0.03
C-106	0.00	0.00	0.00	0.01	0.27	0.01
C-107	0.00	0.00	0.00	0.01	0.21	0.32
C-108	0.00	0.00	0.00	0.01	0.25	0.45
C-109	0.00	0.00	0.00	0.00	0.27	0.40
C-110	0.00	0.00	0.00	0.01	0.14	2.08
C-111	0.00	0.00	0.00	0.00	0.19	0.35
C-112	0.00	0.00	0.00	0.00	0.52	0.69
C-201	0.00	0.00	0.00	0.00	0.00	0.01
C-202	0.00	0.00	0.00	0.00	0.01	0.04
C-203	0.00	0.00	0.00	0.00	0.01	0.03
C-204	0.00	0.00	0.00	0.00	0.01	0.03

Table C-11d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and Diffusion Dominated Release Rate (D_{eff} = 6 x10^{-7} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.19	0.00	3.23	0.13	3.34	1.79
C-102	0.10	0.00	1.77	0.07	1.51	1.46
C-103	5.13	0.01	0.09	0.04	0.99	0.05
C-104	5.29	0.07	0.89	0.09	3.37	4.55
C-105	14.60	0.02	0.05	0.08	3.13	5.63
C-106	1.75	0.01	0.00	0.03	0.85	0.04
C-107	0.60	0.00	0.00	0.02	0.67	1.02
C-108	2.22	0.00	1.76	0.04	3.92	7.15
C-109	12.05	0.00	5.50	0.03	6.34	8.49
C-110	4.26	0.00	0.00	0.00	0.08	0.42
C-111	1.12	0.00	0.00	0.00	0.40	1.20
C-112	13.98	0.00	0.00	0.00	0.18	0.63
C-201	0.03	0.00	0.00	0.00	0.12	0.40
C-202	0.03	0.00	18.95	0.82	34.46	73.69
C-203	0.02	0.00	0.00	0.00	0.00	0.00
C-204	0.01	0.00	0.00	0.00	0.00	0.00
Total	61.36	0.11	32.24	1.37	59.38	106.52

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-12a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory for Tank Residual Case, and Solubility-Controlled Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.0006	0.0000	0.0088	0.0003	0.0085	0.0566
C-102	0.0003	0.0000	0.0021	0.0002	0.0043	0.0188
C-103	0.0137	0.0000	0.0024	0.0003	0.0066	0.0006
C-104	0.0181	0.0002	0.0110	0.0005	0.0114	0.0061
C-105	0.0499	0.0001	0.0060	0.0003	0.0052	0.0050
C-106	0.0070	0.0000	0.0003	0.0001	0.0034	0.0002
C-107	0.0124	0.0000	0.0030	0.0003	0.0115	0.0156
C-108	0.0076	0.0000	0.0002	0.0003	0.0107	0.0193
C-109	0.0412	0.0000	0.0052	0.0002	0.0156	0.0230
C-110	0.0145	0.0000	0.0009	0.0002	0.0030	0.0445
C-111	0.0038	0.0000	0.0060	0.0001	0.0134	0.0245
C-112	0.0478	0.0000	0.0188	0.0001	0.0217	0.0290
C-201	0.0001	0.0000	0.0000	0.0000	0.0003	0.0015
C-202	0.0001	0.0000	0.0000	0.0000	0.0014	0.0041
C-203	0.0001	0.0000	0.0000	0.0000	0.0006	0.0021
C-204	0.0000	0.0000	0.0000	0.0000	0.0004	0.0014

Table C-12b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory for Tank Residual Case, and Solubility-Controlled Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.0006	0.0000	0.0088	0.0003	0.0085	0.0566
C-102	0.0003	0.0000	0.0021	0.0002	0.0044	0.0187
C-103	0.0175	0.0000	0.0030	0.0004	0.0073	0.0007
C-104	0.0181	0.0002	0.0111	0.0005	0.0114	0.0061
C-105	0.0499	0.0001	0.0060	0.0003	0.0052	0.0050
C-106	0.0137	0.0001	0.0005	0.0008	0.0011	0.0002
C-107	0.0124	0.0000	0.0030	0.0003	0.0116	0.0156
C-108	0.0076	0.0000	0.0002	0.0003	0.0107	0.0193
C-109	0.0412	0.0000	0.0052	0.0002	0.0156	0.0230
C-110	0.0146	0.0000	0.0009	0.0002	0.0030	0.0448
C-111	0.0038	0.0000	0.0060	0.0001	0.0134	0.0244
C-112	0.0478	0.0000	0.0188	0.0001	0.0217	0.0290
C-201	0.0001	0.0000	0.0000	0.0000	0.0003	0.0015
C-202	0.0001	0.0000	0.0000	0.0000	0.0014	0.0041
C-203	0.0001	0.0000	0.0000	0.0000	0.0006	0.0021
C-204	0.0000	0.0000	0.0000	0.0000	0.0004	0.0014

Table C-12c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory for Tank Residual Case, and Solubility-Controlled Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.0001	0.0000	0.0000	0.0000	0.0011	0.0072
C-102	0.0001	0.0000	0.0000	0.0001	0.0012	0.0051
C-103	0.0013	0.0000	0.0000	0.0000	0.0006	0.0001
C-104	0.0024	0.0000	0.0000	0.0001	0.0015	0.0008
C-105	0.0038	0.0000	0.0000	0.0000	0.0004	0.0004
C-106	0.0060	0.0000	0.0000	0.0001	0.0029	0.0001
C-107	0.0020	0.0000	0.0000	0.0001	0.0023	0.0035
C-108	0.0019	0.0000	0.0000	0.0001	0.0027	0.0048
C-109	0.0077	0.0000	0.0000	0.0000	0.0029	0.0043
C-110	0.0073	0.0000	0.0000	0.0001	0.0015	0.0225
C-111	0.0006	0.0000	0.0000	0.0000	0.0021	0.0038
C-112	0.0123	0.0000	0.0000	0.0000	0.0056	0.0075
C-201	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
C-202	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004
C-203	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003
C-204	0.0000	0.0000	0.0000	0.0000	0.0001	0.0003

Table C-12d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and Solubility-Controlled Release Rate

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.0006	0.0000	0.0088	0.0003	0.0085	0.0566
C-102	0.0003	0.0000	0.0021	0.0002	0.0044	0.0187
C-103	0.0175	0.0000	0.0030	0.0004	0.0073	0.0007
C-104	0.0181	0.0002	0.0111	0.0005	0.0114	0.0061
C-105	0.0499	0.0001	0.0060	0.0003	0.0052	0.0050
C-106	0.0060	0.0000	0.0000	0.0001	0.0029	0.0001
C-107	0.0020	0.0000	0.0000	0.0001	0.0023	0.0035
C-108	0.0076	0.0000	0.0002	0.0003	0.0107	0.0193
C-109	0.0412	0.0000	0.0052	0.0002	0.0156	0.0230
C-110	0.0146	0.0000	0.0009	0.0002	0.0030	0.0448
C-111	0.0038	0.0000	0.0060	0.0001	0.0134	0.0244
C-112	0.0478	0.0000	0.0188	0.0001	0.0217	0.0290
C-201	0.0001	0.0000	0.0000	0.0000	0.0003	0.0015
C-202	0.0001	0.0000	0.0000	0.0000	0.0014	0.0041
C-203	0.0001	0.0000	0.0000	0.0000	0.0006	0.0021
C-204	0.0000	0.0000	0.0000	0.0000	0.0004	0.0014
Total	0.2099	0.0004	0.0622	0.0027	0.1090	0.2404

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-13a. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Ratioed BBI Inventory for Tank Residual Case, and Diffusion Dominated Release Rate (D_{eff} = 5 x10^{-8} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.14	0.00	1.95	0.06	1.87	12.48
C-102	0.08	0.00	0.46	0.04	0.96	4.14
C-103	3.03	0.01	0.53	0.06	1.45	0.12
C-104	4.00	0.05	2.44	0.10	2.52	1.35
C-105	11.02	0.01	1.33	0.06	1.14	1.10
C-106	1.54	0.01	0.06	0.03	0.75	0.04
C-107	2.73	0.00	0.67	0.07	2.54	3.44
C-108	1.67	0.00	0.04	0.06	2.36	4.25
C-109	9.09	0.00	1.14	0.03	3.44	5.08
C-110	3.19	0.00	0.20	0.04	0.66	9.82
C-111	0.84	0.00	1.33	0.03	2.96	5.40
C-112	10.55	0.00	4.15	0.02	4.79	6.41
C-201	0.02	0.00	0.00	0.00	0.06	0.32
C-202	0.02	0.00	0.00	0.00	0.30	0.90
C-203	0.02	0.00	0.00	0.00	0.14	0.47
C-204	0.01	0.00	0.00	0.00	0.09	0.31

Table C-13b. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Phase Separated Inventory for Tank Residual Case, and Diffusion Dominated Release Rate (D_{eff} = 5 x10^{-8} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.14	0.00	1.95	0.06	1.87	12.48
C-102	0.08	0.00	0.46	0.04	0.96	4.14
C-103	3.87	0.01	0.66	0.10	1.62	0.16
C-104	4.00	0.05	2.44	0.10	2.52	1.35
C-105	11.02	0.01	1.33	0.06	1.14	1.10
C-106	3.03	0.02	0.12	0.17	0.24	0.03
C-107	2.73	0.00	0.67	0.07	2.55	3.44
C-108	1.67	0.00	0.04	0.06	2.36	4.25
C-109	9.09	0.00	1.14	0.03	3.45	5.08
C-110	3.21	0.00	0.20	0.04	0.66	9.89
C-111	0.84	0.00	1.33	0.03	2.96	5.38
C-112	10.55	0.00	4.16	0.02	4.78	6.39
C-201	0.02	0.00	0.00	0.00	0.06	0.32
C-202	0.02	0.00	0.00	0.00	0.30	0.90
C-203	0.02	0.00	0.00	0.00	0.14	0.47
C-204	0.01	0.00	0.00	0.00	0.09	0.31

Table C-13c. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on HTWOS Inventory for Tank Residual Case, and Diffusion Dominated Release Rate (D_{eff} = 5 x10^{-8} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.02	0.00	0.00	0.01	0.24	1.58
C-102	0.02	0.00	0.00	0.01	0.26	1.14
C-103	0.28	0.00	0.00	0.01	0.13	0.01
C-104	0.53	0.01	0.00	0.01	0.33	0.18
C-105	0.83	0.00	0.00	0.00	0.09	0.08
C-106	1.32	0.01	0.00	0.03	0.64	0.03
C-107	0.45	0.00	0.00	0.01	0.51	0.77
C-108	0.42	0.00	0.00	0.02	0.59	1.06
C-109	1.70	0.00	0.00	0.01	0.64	0.95
C-110	1.61	0.00	0.00	0.02	0.33	4.96
C-111	0.13	0.00	0.00	0.00	0.46	0.84
C-112	2.71	0.00	0.00	0.01	1.23	1.65
C-201	0.00	0.00	0.00	0.00	0.01	0.03
C-202	0.00	0.00	0.00	0.00	0.03	0.09
C-203	0.00	0.00	0.00	0.00	0.02	0.06
C-204	0.00	0.00	0.00	0.00	0.02	0.06

Table C-13d. Tank Residual Waste Groundwater Concentrations (pCi/L or µg/L) at C WMA Fence Line (Fence-Line Average) Based on Expected Retrieval Scenarios and Diffusion Dominated Release Rate (D_{eff} = 5 x10^{-8} cm^2/s)

Tank	Tc-99	I-129	U	Cr	NO2	NO3
C-101	0.14	0.00	1.95	0.06	1.87	12.48
C-102	0.08	0.00	0.46	0.04	0.96	4.14
C-103	3.87	0.01	0.66	0.10	1.62	0.16
C-104	4.00	0.05	2.44	0.10	2.52	1.35
C-105	11.02	0.01	1.33	0.06	1.14	1.10
C-106	1.32	0.01	0.00	0.03	0.64	0.03
C-107	0.45	0.00	0.00	0.01	0.51	0.77
C-108	1.67	0.00	0.04	0.06	2.36	4.25
C-109	9.09	0.00	1.14	0.03	3.45	5.08
C-110	3.21	0.00	0.20	0.04	0.66	9.89
C-111	0.84	0.00	1.33	0.03	2.96	5.38
C-112	10.55	0.00	4.16	0.02	4.78	6.39
C-201	0.02	0.00	0.00	0.00	0.06	0.32
C-202	0.02	0.00	0.00	0.00	0.30	0.90
C-203	0.02	0.00	0.00	0.00	0.14	0.47
C-204	0.01	0.00	0.00	0.00	0.09	0.31
Total	46.32	0.08	13.72	0.60	24.06	53.03

Tanks C-106 and C-107 inventories based on modified sluicing; other tanks are based on dry retrieval.

Table C-14. Infrastructure Residual Peak Groundwater Concentrations (pCi/L or µg/L) at Key Locations (Diffusion-Dominated Release: D = $6x10^{-7}$ cm^2/s)

Contaminant	WMA Fence Line (Fence-line Average)	Eastward Flow	
		Exclusion Boundary	Columbia River
Tc-99	10.24	0.16	0.06
I-129	0.02	0.00	0.00
U	2.95	0.04	0.01
Cr	0.16	0.00	0.00
NO2	5.22	0.08	0.02
NO3	11.32	0.17	0.06

Table C-15a. Inadvertent Driller Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	5.506	0.504	0.046	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	74.821	7.423	0.736	0.073	0.007	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15a. Inadvertent Driller Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.093	0.092	0.092	0.092	0.092	0.091	0.091	0.091	0.091	0.090	0.090
240Pu	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.014	0.014	0.014
241Pu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**80.444**	**8.038**	**0.892**	**0.186**	**0.116**	**0.108**	**0.107**	**0.106**	**0.106**	**0.105**	**0.105**

Table C-15b. Inadvertent Driller Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.354	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	3.184	0.292	0.027	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	17.121	1.699	0.169	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15b. Inadvertent Driller Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.163	0.162	0.162	0.161	0.161	0.160	0.160	0.160	0.159	0.159	0.158
240Pu	0.030	0.030	0.029	0.029	0.029	0.028	0.028	0.028	0.027	0.027	0.027
241Pu	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.067	0.057	0.049	0.041	0.035	0.030	0.026	0.022	0.019	0.016	0.013
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**20.990**	**2.247**	**0.441**	**0.257**	**0.232**	**0.225**	**0.219**	**0.215**	**0.210**	**0.207**	**0.204**

Table C-15c. Inadvertent Driller Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	4.659	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	40.710	3.730	0.342	0.031	0.003	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	120.657	11.971	1.188	0.118	0.012	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	17.355	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.287	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15c. Inadvertent Driller Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.007	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.510	0.509	0.507	0.506	0.505	0.503	0.502	0.500	0.499	0.497	0.496
240Pu	0.079	0.078	0.077	0.076	0.075	0.074	0.074	0.073	0.072	0.071	0.071
241Pu	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.458	0.390	0.332	0.283	0.241	0.205	0.175	0.149	0.127	0.108	0.092
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**184.844**	**16.746**	**2.505**	**1.072**	**0.893**	**0.842**	**0.808**	**0.779**	**0.755**	**0.734**	**0.716**

Table C-15d. Inadvertent Driller Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.856	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	3.171	0.291	0.027	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.091	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	66.934	6.641	0.659	0.065	0.006	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	1.677	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.074	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15d. Inadvertent Driller Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
231Pa	0.052	0.052	0.052	0.052	0.052	0.051	0.051	0.051	0.051	0.051	0.051
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
238Pu	0.012	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.322	0.321	0.320	0.319	0.318	0.317	0.316	0.315	0.314	0.313	0.312
240Pu	0.063	0.063	0.062	0.061	0.061	0.060	0.059	0.059	0.058	0.058	0.057
241Pu	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.449	0.382	0.326	0.277	0.236	0.201	0.171	0.146	0.124	0.106	0.090
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**73.793**	**7.767**	**1.456**	**0.787**	**0.682**	**0.639**	**0.607**	**0.580**	**0.556**	**0.536**	**0.519**

Table C-15e. Inadvertent Driller Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.532	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	6.103	0.559	0.051	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	112.568	11.168	1.108	0.110	0.011	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15e. Inadvertent Driller Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.237	0.236	0.235	0.235	0.234	0.233	0.233	0.232	0.231	0.231	0.230
240Pu	0.036	0.036	0.035	0.035	0.035	0.034	0.034	0.034	0.033	0.033	0.033
241Pu	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.165	0.140	0.119	0.102	0.087	0.074	0.063	0.054	0.046	0.039	0.033
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**119.653**	**12.141**	**1.551**	**0.487**	**0.367**	**0.343**	**0.330**	**0.320**	**0.311**	**0.303**	**0.296**

Table C-15f. Inadvertent Driller Dose for Tank C-106 Using the HTWOS Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	11.263	1.032	0.095	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	70.777	7.022	0.697	0.069	0.007	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	2.486	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15f. Inadvertent Driller Dose for Tank C-106 Using the HTWOS Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
238Pu	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.026	0.026
240Pu	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
241Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.097	0.083	0.071	0.060	0.051	0.044	0.037	0.032	0.027	0.023	0.020
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**84.804**	**8.204**	**0.927**	**0.203**	**0.124**	**0.109**	**0.102**	**0.096**	**0.091**	**0.087**	**0.083**

Table C-15g. Inadvertent Driller Dose for Tank C-106 Using the HTWOS Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.149	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	2.869	0.263	0.024	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	5.521	0.548	0.054	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.469	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15g. Inadvertent Driller Dose for Tank C-106 Using the HTWOS Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
240Pu	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.051	0.043	0.037	0.031	0.027	0.023	0.019	0.017	0.014	0.012	0.010
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**9.157**	**0.916**	**0.176**	**0.100**	**0.088**	**0.084**	**0.080**	**0.077**	**0.074**	**0.072**	**0.070**

Table C-15h. Inadvertent Driller Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.216	0.020	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	224.463	22.270	2.209	0.219	0.022	0.002	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15h. Inadvertent Driller Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**224.687**	**22.292**	**2.213**	**0.221**	**0.024**	**0.004**	**0.002**	**0.002**	**0.001**	**0.001**	**0.001**

Table C-15i. Inadvertent Driller Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	6.733	0.617	0.057	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	489.369	48.552	4.817	0.478	0.047	0.005	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15i. Inadvertent Driller Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
240Pu	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.013	0.011	0.010	0.008	0.007	0.006	0.005	0.004	0.004	0.003	0.003
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**496.157**	**49.198**	**4.901**	**0.509**	**0.073**	**0.028**	**0.023**	**0.022**	**0.021**	**0.020**	**0.020**

Table C-15j. Inadvertent Driller Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.036	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	14.762	1.465	0.145	0.014	0.001	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15j. Inadvertent Driller Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.004	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**14.811**	**1.478**	**0.155**	**0.023**	**0.010**	**0.008**	**0.008**	**0.007**	**0.007**	**0.007**	**0.007**

Table C-15k. Inadvertent Driller Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	26.301	2.410	0.221	0.020	0.002	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	62.014	6.153	0.610	0.061	0.006	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15k. Inadvertent Driller Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.035	0.035	0.035	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
240Pu	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.068	0.058	0.049	0.042	0.036	0.030	0.026	0.022	0.019	0.016	0.014
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**88.452**	**8.659**	**0.920**	**0.162**	**0.082**	**0.070**	**0.064**	**0.060**	**0.057**	**0.054**	**0.052**

Table C-15l. Inadvertent Driller Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	10.571	0.968	0.089	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	498.132	49.421	4.903	0.486	0.048	0.005	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.843	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15l. Inadvertent Driller Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
237Np	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
238Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
240Pu	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.084	0.071	0.061	0.052	0.044	0.038	0.032	0.027	0.023	0.020	0.017
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**509.700**	**50.477**	**5.068**	**0.562**	**0.108**	**0.058**	**0.048**	**0.042**	**0.038**	**0.035**	**0.032**

Table C-15m. Inadvertent Driller Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.776	0.071	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	15.830	1.571	0.156	0.015	0.002	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.162	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.084	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.173	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15m. Inadvertent Driller Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.022	0.010	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	1.097	1.094	1.091	1.087	1.084	1.081	1.078	1.075	1.072	1.069	1.066
240Pu	0.180	0.178	0.177	0.175	0.173	0.171	0.169	0.167	0.166	0.164	0.162
241Pu	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.461	0.393	0.335	0.285	0.243	0.207	0.176	0.150	0.128	0.109	0.093
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**18.817**	**3.322**	**1.773**	**1.569**	**1.506**	**1.464**	**1.428**	**1.397**	**1.369**	**1.346**	**1.325**

Table C-15n. Inadvertent Driller Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.810	0.074	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	16.588	1.646	0.163	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.169	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.087	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15n. Inadvertent Driller Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.012	0.005	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.572	0.571	0.569	0.567	0.566	0.564	0.562	0.561	0.559	0.558	0.556
240Pu	0.094	0.093	0.092	0.091	0.090	0.089	0.088	0.087	0.086	0.085	0.084
241Pu	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.242	0.206	0.176	0.150	0.127	0.109	0.092	0.079	0.067	0.057	0.049
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**18.773**	**2.600**	**1.013**	**0.830**	**0.789**	**0.766**	**0.747**	**0.731**	**0.717**	**0.704**	**0.693**

Table C-15o. Inadvertent Driller Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.618	0.057	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	12.607	1.251	0.124	0.012	0.001	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.130	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.137	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15o. Inadvertent Driller Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.114	0.114	0.114	0.113	0.113	0.113	0.112	0.112	0.112	0.112	0.111
240Pu	0.019	0.019	0.018	0.018	0.018	0.018	0.018	0.017	0.017	0.017	0.017
241Pu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.048	0.041	0.035	0.030	0.025	0.022	0.018	0.016	0.013	0.011	0.010
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**13.750**	**1.487**	**0.300**	**0.178**	**0.161**	**0.156**	**0.152**	**0.149**	**0.146**	**0.143**	**0.141**

Table C-15p. Inadvertent Driller Dose for Tank C-204 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.400	0.037	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	8.133	0.807	0.080	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.083	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.089	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-15p. Inadvertent Driller Dose for Tank C-204 Using the Separated Phase Retrieval Inventory

Radionuclide	Driller --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**8.755**	**0.850**	**0.089**	**0.014**	**0.006**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**	**0.005**

Table C-16a. Inadvertent Rural Farmer Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	105.139	9.632	0.882	0.081	0.007	0.001	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	17.014	1.688	0.167	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16a. Inadvertent Rural Farmer Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.025	0.025	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
240Pu	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
241Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**122.184**	**11.350**	**1.079**	**0.126**	**0.038**	**0.029**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**

Table C-16b. Inadvertent Rural Farmer Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.067	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	60.801	5.570	0.510	0.047	0.004	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	3.893	0.386	0.038	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16b. Inadvertent Rural Farmer Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.043	0.043	0.043	0.043	0.043	0.043	0.042	0.042	0.042	0.042	0.042
240Pu	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007
241Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.017	0.015	0.012	0.011	0.009	0.008	0.007	0.006	0.005	0.004	0.003
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**64.844**	**6.024**	**0.613**	**0.113**	**0.065**	**0.060**	**0.058**	**0.057**	**0.056**	**0.055**	**0.054**

Table C-16c. Inadvertent Rural Farmer Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.879	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	777.430	71.224	6.525	0.598	0.055	0.005	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	27.437	2.722	0.270	0.027	0.003	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	3.365	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16c. Inadvertent Rural Farmer Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.135	0.135	0.135	0.134	0.134	0.133	0.133	0.133	0.132	0.132	0.131
240Pu	0.021	0.021	0.020	0.020	0.020	0.020	0.020	0.019	0.019	0.019	0.019
241Pu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.117	0.100	0.085	0.072	0.062	0.053	0.045	0.038	0.032	0.028	0.024
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**809.467**	**74.216**	**7.048**	**0.863**	**0.285**	**0.223**	**0.210**	**0.202**	**0.196**	**0.190**	**0.186**

Table C-16d. Inadvertent Rural Farmer Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.162	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	60.560	5.548	0.508	0.047	0.004	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	15.221	1.510	0.150	0.015	0.001	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.325	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.017	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16d. Inadvertent Rural Farmer Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
232U	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.085	0.085	0.085	0.085	0.084	0.084	0.084	0.084	0.083	0.083	0.083
240Pu	0.017	0.017	0.016	0.016	0.016	0.016	0.016	0.016	0.015	0.015	0.015
241Pu	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.115	0.098	0.083	0.071	0.060	0.052	0.044	0.037	0.032	0.027	0.023
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**76.557**	**7.277**	**0.860**	**0.250**	**0.183**	**0.168**	**0.160**	**0.153**	**0.147**	**0.142**	**0.137**

Table C-16e. Inadvertent Rural Farmer Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	116.554	10.678	0.978	0.090	0.008	0.001	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	25.598	2.540	0.252	0.025	0.002	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16e. Inadvertent Rural Farmer Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.063	0.063	0.062	0.062	0.062	0.062	0.062	0.062	0.061	0.061	0.061
240Pu	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
241Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.042	0.036	0.031	0.026	0.022	0.019	0.016	0.014	0.012	0.010	0.008
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**142.371**	**13.327**	**1.333**	**0.213**	**0.105**	**0.092**	**0.088**	**0.085**	**0.082**	**0.080**	**0.079**

Table C-16f. Inadvertent Rural Farmer Dose for Tank C-106 Using the HTWOS Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	215.085	19.705	1.805	0.165	0.015	0.001	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	16.095	1.597	0.158	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.482	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16f. Inadvertent Rural Farmer Dose for Tank C-106 Using the HTWOS Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
240Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.025	0.021	0.018	0.015	0.013	0.011	0.010	0.008	0.007	0.006	0.005
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**231.725**	**21.339**	**1.997**	**0.212**	**0.045**	**0.028**	**0.025**	**0.023**	**0.022**	**0.021**	**0.020**

Table C-16g. Inadvertent Rural Farmer Dose for Tank C-107 Using the HTWOS Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	54.793	5.020	0.460	0.042	0.004	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	1.255	0.125	0.012	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.091	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16g. Inadvertent Rural Farmer Dose for Tank C-107 Using the HTWOS Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
240Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.013	0.011	0.009	0.008	0.007	0.006	0.005	0.004	0.004	0.003	0.003
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**56.203**	**5.169**	**0.495**	**0.065**	**0.024**	**0.020**	**0.018**	**0.018**	**0.017**	**0.016**	**0.016**

Table C-16h. Inadvertent Rural Farmer Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	4.133	0.379	0.035	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	51.043	5.064	0.502	0.050	0.005	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16h. Inadvertent Rural Farmer Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**55.178**	**5.443**	**0.538**	**0.054**	**0.006**	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-16i. Inadvertent Rural Farmer Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	128.570	11.779	1.079	0.099	0.009	0.001	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	111.282	11.041	1.095	0.109	0.011	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16i. Inadvertent Rural Farmer Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
240Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.003	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**239.866**	**22.828**	**2.182**	**0.215**	**0.027**	**0.008**	**0.007**	**0.006**	**0.006**	**0.006**	**0.006**

Table C-16j. Inadvertent Rural Farmer Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.680	0.062	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	3.357	0.333	0.033	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16j. Inadvertent Rural Farmer Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**4.040**	**0.398**	**0.041**	**0.006**	**0.003**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**

Table C-16k. Inadvertent Rural Farmer Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	502.265	46.015	4.216	0.386	0.035	0.003	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	14.102	1.399	0.139	0.014	0.001	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16k. Inadvertent Rural Farmer Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
240Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.017	0.015	0.013	0.011	0.009	0.008	0.007	0.006	0.005	0.004	0.004
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**516.401**	**47.439**	**4.377**	**0.421**	**0.056**	**0.021**	**0.017**	**0.016**	**0.015**	**0.014**	**0.014**

Table C-16l. Inadvertent Rural Farmer Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	201.867	18.494	1.694	0.155	0.014	0.001	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	113.275	11.238	1.115	0.111	0.011	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.163	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16l. Inadvertent Rural Farmer Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
240Pu	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.021	0.018	0.016	0.013	0.011	0.010	0.008	0.007	0.006	0.005	0.004
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**315.342**	**29.755**	**2.830**	**0.284**	**0.041**	**0.017**	**0.013**	**0.011**	**0.010**	**0.010**	**0.009**

Table C-16m. Inadvertent Rural Farmer Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	14.819	1.358	0.124	0.011	0.001	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	3.600	0.357	0.035	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16m. Inadvertent Rural Farmer Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.291	0.290	0.289	0.288	0.287	0.287	0.286	0.285	0.284	0.283	0.283
240Pu	0.048	0.047	0.047	0.046	0.046	0.045	0.045	0.044	0.044	0.043	0.043
241Pu	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.118	0.101	0.086	0.073	0.062	0.053	0.045	0.038	0.033	0.028	0.024
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**18.972**	**2.158**	**0.584**	**0.424**	**0.398**	**0.386**	**0.377**	**0.369**	**0.362**	**0.356**	**0.350**

Table C-16n. Inadvertent Rural Farmer Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	15.461	1.416	0.130	0.012	0.001	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	3.772	0.374	0.037	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16n. Inadvertent Rural Farmer Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.152	0.151	0.151	0.150	0.150	0.150	0.149	0.149	0.148	0.148	0.147
240Pu	0.025	0.025	0.024	0.024	0.024	0.024	0.023	0.023	0.023	0.023	0.022
241Pu	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.062	0.053	0.045	0.038	0.033	0.028	0.024	0.020	0.017	0.015	0.012
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**19.566**	**2.023**	**0.389**	**0.230**	**0.209**	**0.202**	**0.197**	**0.193**	**0.189**	**0.186**	**0.183**

Table C-16o. Inadvertent Rural Farmer Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	11.811	1.082	0.099	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	2.867	0.284	0.028	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16o. Inadvertent Rural Farmer Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.029
240Pu	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004
241Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.012	0.011	0.009	0.008	0.007	0.006	0.005	0.004	0.003	0.003	0.002
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**14.794**	**1.414**	**0.173**	**0.055**	**0.043**	**0.041**	**0.040**	**0.039**	**0.038**	**0.038**	**0.037**

Table C-16p. Inadvertent Rural Farmer Dose for Tank C-204 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	7.638	0.700	0.064	0.006	0.001	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	1.849	0.183	0.018	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-16p. Inadvertent Rural Farmer Dose for Tank C-204 Using the Separated Phase Retrieval Inventory

Radionuclide	Rural Farmer with a Cow --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**9.531**	**0.885**	**0.084**	**0.009**	**0.002**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**

Table C-17a. Inadvertent Commercial Farmer Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.016	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.231	0.023	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17a. Inadvertent Commercial Farmer Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.247**	**0.025**	**0.003**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17b. Inadvertent Commercial Farmer Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.053	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17b. Inadvertent Commercial Farmer Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.064**	**0.007**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**

Table C-17c. Inadvertent Commercial Farmer Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.118	0.011	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.372	0.037	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17c. Inadvertent Commercial Farmer Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.560**	**0.051**	**0.008**	**0.003**	**0.003**	**0.003**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**

Table C-17d. Inadvertent Commercial Farmer Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.206	0.020	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17d. Inadvertent Commercial Farmer Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.227**	**0.024**	**0.004**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**

Table C-17e. Inadvertent Commercial Farmer Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.018	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.347	0.034	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17e. Inadvertent Commercial Farmer Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.368**	**0.037**	**0.005**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**

Table C-17f. Inadvertent Commercial Farmer Dose for Tank C-101 Using the HTWOS Inventory

Radionuclide	Commercial Farmer → Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.033	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.218	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229^{Th}	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17f. Inadvertent Commercial Farmer Dose for Tank C-101 Using the HTWOS Inventory

Radionuclide	Commercial Farmer → Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.259**	**0.025**	**0.003**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17g. Inadvertent Commercial Farmer Dose for Tank C-107 Using the HTWOS Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17g. Inadvertent Commercial Farmer Dose for Tank C-107 Using the HTWOS Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.028**	**0.003**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17h. Inadvertent Commercial Farmer Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer → Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.692	0.069	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17h. Inadvertent Commercial Farmer Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer → Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.693**	**0.069**	**0.007**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17i. Inadvertent Commercial Farmer Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.020	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	1.509	0.150	0.015	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17i. Inadvertent Commercial Farmer Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**1.529**	**0.152**	**0.015**	**0.002**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17j. Inadvertent Commercial Farmer Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.046	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17j. Inadvertent Commercial Farmer Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.046**	**0.005**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17k. Inadvertent Commercial Farmer Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.076	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.191	0.019	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17k. Inadvertent Commercial Farmer Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.268**	**0.026**	**0.003**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17l. Inadvertent Commercial Farmer Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.031	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	1.536	0.152	0.015	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17l. Inadvertent Commercial Farmer Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**1.570**	**0.155**	**0.016**	**0.002**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17m. Inadvertent Commercial Farmer Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.049	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17m. Inadvertent Commercial Farmer Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
240Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.058**	**0.010**	**0.005**	**0.005**	**0.005**	**0.004**	**0.004**	**0.004**	**0.004**	**0.004**	**0.004**

Table C-17n. Inadvertent Commercial Farmer Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.051	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17n. Inadvertent Commercial Farmer Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.058**	**0.008**	**0.003**	**0.003**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.002**

Table C-17o. Inadvertent Commercial Farmer Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.039	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17o. Inadvertent Commercial Farmer Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.042**	**0.005**	**0.001**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-17p. Inadvertent Commercial Farmer Dose for Tank C-204 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	0.025	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-17p. Inadvertent Commercial Farmer Dose for Tank C-204 Using the Separated Phase Retrieval Inventory

Radionuclide	Commercial Farmer --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.027**	**0.003**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Table C-18a. Inadvertent Commercial Farmer Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	3882.056	355.654	32.583	2.985	0.273	0.025	0.002	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	428.570	42.520	4.218	0.419	0.042	0.004	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18a. Inadvertent Commercial Farmer Dose for Tank C-101 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.025	0.011	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	1.422	1.418	1.414	1.410	1.406	1.402	1.398	1.394	1.390	1.386	1.382
240Pu	0.238	0.235	0.233	0.230	0.228	0.225	0.223	0.221	0.218	0.216	0.214
241Pu	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.024	0.020	0.017	0.015	0.013	0.011	0.009	0.008	0.007	0.006	0.005
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**4312.393**	**399.865**	**38.477**	**5.067**	**1.969**	**1.674**	**1.639**	**1.629**	**1.621**	**1.614**	**1.607**

Table C-18b. Inadvertent Commercial Farmer Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	1.734	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	2244.937	205.669	18.842	1.726	0.158	0.014	0.001	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	98.069	9.730	0.965	0.096	0.010	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.098	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18b. Inadvertent Commercial Farmer Dose for Tank C-102 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.072	0.072	0.072	0.072	0.072	0.071	0.071	0.071	0.071	0.071	0.071
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.061	0.028	0.013	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000
239Pu	2.497	2.490	2.483	2.475	2.468	2.461	2.454	2.447	2.440	2.433	2.426
240Pu	0.458	0.453	0.448	0.443	0.439	0.434	0.430	0.425	0.421	0.416	0.412
241Pu	0.078	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.926	0.789	0.672	0.572	0.487	0.415	0.354	0.301	0.257	0.218	0.186
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**2349.166**	**219.238**	**23.498**	**5.393**	**3.639**	**3.401**	**3.313**	**3.248**	**3.191**	**3.141**	**3.098**

Table C-18c. Inadvertent Commercial Farmer Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
60Co	22.824	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.015	0.007	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	28705.031	2629.805	240.929	22.073	2.022	0.185	0.017	0.002	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.112	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.290	0.289	0.289	0.289	0.289	0.289	0.288	0.288	0.288	0.288	0.288
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	691.117	68.567	6.803	0.675	0.067	0.007	0.001	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.023	0.011	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.257	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	85.869	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	1.399	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18c. Inadvertent Commercial Farmer Dose for Tank C-103 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
237Np	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
238Pu	0.111	0.051	0.023	0.010	0.005	0.002	0.001	0.000	0.000	0.000	0.000
239Pu	7.829	7.806	7.784	7.762	7.739	7.717	7.695	7.673	7.651	7.629	7.607
240Pu	1.205	1.192	1.180	1.167	1.155	1.143	1.131	1.119	1.107	1.096	1.084
241Pu	0.132	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	6.313	5.377	4.580	3.901	3.323	2.830	2.411	2.053	1.749	1.490	1.269
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**29522.584**	**2713.189**	**261.637**	**35.922**	**14.642**	**12.214**	**11.584**	**11.176**	**10.836**	**10.542**	**10.288**

Table C-18d. Inadvertent Commercial Farmer Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	4.194	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	2236.064	204.857	18.768	1.719	0.158	0.014	0.001	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.037	0.037	0.037
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.431	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	383.396	38.038	3.774	0.374	0.037	0.004	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	8.296	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.168	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.651	0.027	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Table C-18d. Inadvertent Commercial Farmer Dose for Tank C-104 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
231Pa	0.710	0.709	0.707	0.706	0.704	0.703	0.701	0.700	0.698	0.697	0.695
232U	0.033	0.012	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079	0.079
234U	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
235U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
237Np	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
238Pu	0.186	0.084	0.038	0.017	0.008	0.004	0.002	0.001	0.000	0.000	0.000
239Pu	4.933	4.919	4.905	4.891	4.877	4.863	4.849	4.835	4.821	4.807	4.793
240Pu	0.971	0.961	0.951	0.941	0.931	0.921	0.911	0.902	0.892	0.883	0.874
241Pu	0.263	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	6.191	5.274	4.492	3.826	3.259	2.776	2.364	2.014	1.715	1.461	1.244
243Am	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**2646.891**	**255.069**	**33.822**	**12.658**	**10.155**	**9.465**	**9.010**	**8.632**	**8.308**	**8.029**	**7.788**

Table C-18e. Inadvertent Commercial Farmer Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	2.608	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	4303.536	394.268	36.121	3.309	0.303	0.028	0.003	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.104	0.104	0.104	0.104	0.104	0.103	0.103	0.103	0.103	0.103	0.103
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	644.785	63.971	6.347	0.630	0.062	0.006	0.001	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18e. Inadvertent Commercial Farmer Dose for Tank C-105 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.049	0.022	0.010	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000
239Pu	3.633	3.622	3.612	3.601	3.591	3.581	3.571	3.560	3.550	3.540	3.530
240Pu	0.556	0.550	0.544	0.538	0.533	0.527	0.522	0.516	0.511	0.505	0.500
241Pu	0.058	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	2.270	1.934	1.647	1.403	1.195	1.018	0.867	0.738	0.629	0.536	0.456
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**4957.621**	**464.474**	**48.388**	**9.594**	**5.794**	**5.268**	**5.070**	**4.923**	**4.797**	**4.688**	**4.593**

Table C-18f. Inadvertent Commercial Farmer Dose for Tank C-106 Using the TWOS Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.132	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.007	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	7941.577	727.566	66.656	6.107	0.559	0.051	0.005	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.159	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.162	0.162	0.162	0.162	0.162	0.162	0.161	0.161	0.161	0.161	0.161
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	405.404	40.221	3.990	0.396	0.039	0.004	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.013	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.139	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	12.298	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.238	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18f. Inadvertent Commercial Farmer Dose for Tank C-106 Using the TWOS Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
238Pu	0.017	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.416	0.415	0.414	0.413	0.411	0.410	0.409	0.408	0.407	0.406	0.404
240Pu	0.085	0.084	0.083	0.082	0.082	0.081	0.080	0.079	0.078	0.077	0.077
241Pu	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	1.341	1.143	0.973	0.829	0.706	0.601	0.512	0.436	0.372	0.317	0.270
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**8362.080**	**769.638**	**72.308**	**8.014**	**1.983**	**1.332**	**1.190**	**1.107**	**1.040**	**0.982**	**0.933**

Table C-18g. Inadvertent Commercial Farmer Dose for Tank C-107 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.732	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.009	0.005	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	2023.106	185.346	16.980	1.556	0.143	0.013	0.001	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.276	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.224	0.224	0.224	0.224	0.223	0.223	0.223	0.223	0.223	0.223	0.223
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	31.621	3.137	0.311	0.031	0.003	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.017	0.008	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.128	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	2.321	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18g. Inadvertent Commercial Farmer Dose for Tank C-107 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.221	0.220	0.220	0.219	0.219	0.218	0.217	0.217	0.216	0.215	0.215
240Pu	0.035	0.035	0.034	0.034	0.033	0.033	0.033	0.032	0.032	0.032	0.031
241Pu	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.703	0.598	0.510	0.434	0.370	0.315	0.268	0.229	0.195	0.166	0.141
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**2059.457**	**189.585**	**18.291**	**2.506**	**0.997**	**0.808**	**0.748**	**0.706**	**0.671**	**0.641**	**0.615**

Table C-18h. Inadvertent Commercial Farmer Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	152.620	13.982	1.281	0.117	0.011	0.001	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	1285.709	127.559	12.655	1.256	0.125	0.012	0.001	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18h. Inadvertent Commercial Farmer Dose for Tank C-108 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
240Pu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.025	0.021	0.018	0.016	0.013	0.011	0.010	0.008	0.007	0.006	0.005
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**1438.409**	**141.591**	**13.983**	**1.417**	**0.177**	**0.053**	**0.039**	**0.037**	**0.035**	**0.034**	**0.033**

Table C-18i. Inadvertent Commercial Farmer Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	4747.200	434.914	39.845	3.650	0.334	0.031	0.003	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.086	0.086	0.086	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	2803.078	278.101	27.591	2.737	0.272	0.027	0.003	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.057	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18i. Inadvertent Commercial Farmer Dose for Tank C-109 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
237Np	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
238Pu	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.224	0.223	0.222	0.222	0.221	0.220	0.220	0.219	0.219	0.218	0.217
240Pu	0.038	0.038	0.037	0.037	0.036	0.036	0.036	0.035	0.035	0.035	0.034
241Pu	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.186	0.158	0.135	0.115	0.098	0.083	0.071	0.060	0.051	0.044	0.037
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**7550.951**	**713.531**	**67.925**	**6.855**	**1.055**	**0.490**	**0.425**	**0.408**	**0.398**	**0.389**	**0.382**

Table C-18j. Inadvertent Commercial Farmer Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	25.111	2.301	0.211	0.019	0.002	0.000	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	84.556	8.389	0.832	0.083	0.008	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18j. Inadvertent Commercial Farmer Dose for Tank C-110 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.089	0.089	0.089	0.089	0.088	0.088	0.088	0.088	0.087	0.087	0.087
240Pu	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
241Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.056	0.048	0.041	0.035	0.029	0.025	0.021	0.018	0.015	0.013	0.011
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**109.866**	**10.863**	**1.209**	**0.261**	**0.164**	**0.150**	**0.145**	**0.142**	**0.139**	**0.136**	**0.134**

Table C-18k. Inadvertent Commercial Farmer Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	18545.136	1699.008	155.654	14.260	1.306	0.120	0.011	0.001	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	355.211	35.241	3.496	0.347	0.034	0.003	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18k. Inadvertent Commercial Farmer Dose for Tank C-111 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.532	0.531	0.529	0.528	0.526	0.525	0.523	0.522	0.520	0.519	0.517
240Pu	0.059	0.058	0.057	0.057	0.056	0.056	0.055	0.054	0.054	0.053	0.053
241Pu	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.938	0.799	0.681	0.580	0.494	0.421	0.358	0.305	0.260	0.221	0.189
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**18902.053**	**1735.656**	**160.434**	**15.786**	**2.431**	**1.138**	**0.962**	**0.896**	**0.848**	**0.807**	**0.772**

Table C-18l. Inadvertent Commercial Farmer Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
60Co	0.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	7453.547	682.855	62.560	5.731	0.525	0.048	0.004	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099	0.099
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	2853.271	283.080	28.085	2.786	0.276	0.027	0.003	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	4.170	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18l. Inadvertent Commercial Farmer Dose for Tank C-112 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
235U	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
237Np	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
238Pu	0.016	0.007	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.184	0.183	0.183	0.182	0.182	0.181	0.181	0.180	0.180	0.179	0.179
240Pu	0.029	0.029	0.029	0.028	0.028	0.028	0.027	0.027	0.027	0.027	0.026
241Pu	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	1.154	0.983	0.837	0.713	0.607	0.517	0.441	0.375	0.320	0.272	0.232
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**10312.767**	**967.265**	**91.820**	**9.566**	**1.742**	**0.925**	**0.779**	**0.706**	**0.649**	**0.601**	**0.559**

Table C-18m. Inadvertent Commercial Farmer Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.040	0.020	0.010	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	547.162	50.128	4.592	0.421	0.039	0.004	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	90.673	8.996	0.893	0.089	0.009	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.809	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.415	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.843	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18m. Inadvertent Commercial Farmer Dose for Tank C-201 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.339	0.154	0.070	0.032	0.015	0.007	0.003	0.001	0.001	0.000	0.000
239Pu	16.825	16.776	16.728	16.680	16.632	16.585	16.537	16.490	16.442	16.395	16.348
240Pu	2.767	2.738	2.709	2.681	2.653	2.625	2.597	2.570	2.543	2.516	2.490
241Pu	0.403	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	6.358	5.416	4.613	3.929	3.347	2.851	2.428	2.068	1.762	1.500	1.278
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**666.697**	**84.262**	**29.640**	**23.860**	**22.720**	**22.096**	**21.590**	**21.153**	**20.771**	**20.435**	**20.139**

Table C-18n. Inadvertent Commercial Farmer Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.042	0.021	0.011	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	570.870	52.300	4.791	0.439	0.040	0.004	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	95.017	9.427	0.935	0.093	0.009	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.843	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.433	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.876	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18n. Inadvertent Commercial Farmer Dose for Tank C-202 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.178	0.081	0.037	0.017	0.008	0.003	0.002	0.001	0.000	0.000	0.000
239Pu	8.778	8.753	8.728	8.703	8.678	8.653	8.628	8.603	8.579	8.554	8.529
240Pu	1.438	1.423	1.408	1.393	1.379	1.364	1.350	1.336	1.322	1.308	1.294
241Pu	0.211	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	3.338	2.843	2.421	2.062	1.757	1.496	1.274	1.086	0.925	0.788	0.671
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**682.088**	**74.881**	**18.356**	**12.737**	**11.897**	**11.547**	**11.279**	**11.050**	**10.850**	**10.674**	**10.519**

Table C-18o. Inadvertent Commercial Farmer Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.032	0.016	0.008	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	436.107	39.954	3.660	0.335	0.031	0.003	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	72.213	7.164	0.711	0.071	0.007	0.001	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.646	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.331	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.670	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18o. Inadvertent Commercial Farmer Dose for Tank C-203 Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.036	0.016	0.007	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000
239Pu	1.756	1.751	1.746	1.741	1.736	1.731	1.726	1.721	1.716	1.711	1.706
240Pu	0.289	0.286	0.283	0.280	0.277	0.274	0.271	0.268	0.265	0.263	0.260
241Pu	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.668	0.569	0.484	0.412	0.351	0.299	0.255	0.217	0.185	0.158	0.134
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**512.837**	**49.780**	**6.918**	**2.865**	**2.424**	**2.328**	**2.271**	**2.225**	**2.185**	**2.149**	**2.118**

Table C-18p. Inadvertent Commercial Farmer Dose for Tank C-204Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
3H	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14C	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60Co	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63Ni	0.021	0.010	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000
79Se	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90Sr	282.004	25.836	2.367	0.217	0.020	0.002	0.000	0.000	0.000	0.000	0.000
90Y	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93mNb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
93Zr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
99Tc	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
106Ru	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113mCd	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
125Sb	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
126Sn	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
129I	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
134Cs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137Cs	46.585	4.622	0.459	0.045	0.005	0.000	0.000	0.000	0.000	0.000	0.000
137mBa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
151Sm	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
152Eu	0.416	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
154Eu	0.213	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155Eu	0.433	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
226Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
228Ra	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227Ac	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
229Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C-18p. Inadvertent Commercial Farmer Dose for Tank C-204Using the Separated Phase Retrieval Inventory

Radionuclide	Suburban Resident with Vegetable Garden --> Dose at Year (mrem)										
	0	100	200	300	400	500	600	700	800	900	1000
232Th	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
231Pa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
233U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
234U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
235U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
236U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238U	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
237Np	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
239Pu	0.036	0.036	0.036	0.036	0.036	0.035	0.035	0.035	0.035	0.035	0.035
240Pu	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.005
241Pu	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Pu	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
241Am	0.014	0.012	0.010	0.008	0.007	0.006	0.005	0.004	0.004	0.003	0.003
243Am	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
242Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
243Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
244Cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**329.759**	**30.537**	**2.894**	**0.327**	**0.086**	**0.062**	**0.058**	**0.057**	**0.056**	**0.055**	**0.055**

Appendix D

Quality Assurance

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D QUALITY ASSURANCE

D.1 OVERVIEW

This section describes the quality assurance activities associated with the performance assessment activity. The quality assurance activities involve reviewing the Performance Assessment by recognized subject matter experts and knowledgeable stakeholders. Three separate areas are covered: experimental data collection, computer code use, and analyses. The following sections are arranged according to which organization performs the activity being discussed.

D.2 CH2M HILL HANFORD GROUP, INC.

The River Protection Project (RPP) Immobilized Waste Program quality assurance activities are covered by the RPP Quality Assurance Program Description (CHG 2000) and associated implementing procedures. This program addresses the requirements of the *Quality Assurance Program Description* of the Tank Farms Contractor, which is based on Title 10 *Code of Federal Regulations* (CFR) Part 830.120 and U.S. Department of Energy (DOE) Order 5700.6C (DOE 1991).

CH2M HILL Hanford Group, Inc. (CHG) is responsible for the quality aspects of all work discussed in this performance assessment.

D.3 PACIFIC NORTHWEST NATIONAL LABORATORY

Pacific Northwest National Laboratory personnel conducted their work for the performance assessment according to the appropriate portions of the laboratory's quality assurance (QA) program. This program conforms to 10 CFR 830.120, "Quality Assurance" through implementation of its Subject Based Management System (SBMS). The SBMS (http://sbms.pnl.gov) includes a set of administrative procedures that define how the requirements of 10 CFR 830.120 are implemented. The administrative procedures define controls, policies, and established methods for managing and conducting all aspects of work that affect quality.

A key aspect of the QA program involves technical and peer reviews of procedures, test plans, data, calculations, and test results. The reviews range from verifying that calculations or data reduction have been performed correctly to evaluating the test methodology described in a proposed test plan.

Records generated from all activities are indexed and managed according to QA program requirements. Record-holding facilities are used for long-term records retention and storage.

D.4 OTHER CONTRACTORS

Other organizations, Fluor Federal Services, CH2MHill Corporate, Flour Hanford Services, Columbia Energy, worked on this activity. Their work was performed under either the quality assurance plans of CHG or the Pacific Northwest National Laboratory.

D.5 TECHNICAL REVIEWS OF SUPPORTING DOCUMENTS

External technical reviews by outside experts will be held on specialized topics because of the large amount of technical data used in performance assessments. These reviews will be done to ensure that the proper methods, techniques, and resources are used in obtaining the data.

Hanford Site experts reviewed each data package. In addition, experts from outside the Hanford Site will reviewed the waste form and geotechnical data packages. The list of external reviewers will be supplied at a later date.