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Rev. 0

DATA PACKAGES FOR THE HANFORD IMMOBILIZED LOW-ACTIVITY TANK WASTE PERFORMANCE ASSESSMENT: 2001 VERSION

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Executive Summary

This document defines the contents, format, and methods to be used for the *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (ILAW PA). This document also provides the data to be used for the supporting calculations. The data are summarized in the main body of the report while the 16 appendices contain the documents used as primary references.

The *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* provides an analysis of the long-term environmental and health impacts of the onsite disposal of Hanford immobilized low-activity tank waste packages. The purpose of the 1998 version[1] was to provide an assessment that would bound the impacts given the limited site-specific and waste-specific data available[2]. The assessment was based on the requirements of DOE Order 5820.2a with the acknowledgment that the order was undergoing revision. This document was conditionally accepted by the Department of Energy and formed part of the basis for the issuance of a Disposal Authorization Statement for the Hanford Site, including the disposal of ILAW.[3]

The next version (known as the 2001 ILAW PA) will use the site-specific and waste form-specific data that have been collected in the past few years. The emphasis of the 2001 ILAW PA will be on how these new data affect the conclusions of the 1998 ILAW PA. These new data and analyses will fulfill the conditions of the DOE headquarters acceptance. The 2001 ILAW PA will also follow the guidance of the new DOE order on radioactive waste management (DOE O 435.1[4]), particularly in the areas of document content and format.

The methods to be used in the performance assessment include the standards (known as performance objectives) against which the impact of the disposal action will be judged, the various scenarios and pathways that will be analyzed, and the tools with which the analyses will be done.

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[1] F.M. Mann, R.J. Puigh II, P.D. Rittmann, N.W. Kline, J.. Voogd, Y. Chen, C.R. Eiholzer, C.T. Kincaid, B.P. McGrail, A.H. Lu, G.F. Williamson, N.R. Brown, and P.E. LaMont, *Hanford Immobilized Low-Activity Tank Waste Performance Assessment*, DOE/RL-97-69, U.S. Department of Energy, Richland, Washington, March 1998.

[2] F.M. Mann, *Data Packages for the Hanford Low-level Tank Waste Interim Performance Assessment*, WHC-SD-WM-RPT-166, Rev. 0, Westinghouse Hanford Company, Richland, Washington, July 1995.

[3] C.L. Huntoon (Assistant Secretary for Environmental Management), letter to John T. Conway (Chairman, Defense Nuclear Facilities Safety Board) U.S. Department of Energy, Washington, D.C., October 25, 1999.

[4] *Radioactive Waste Management*, DOE O 435.1, U.S. Department of Energy, Washington, D.C., September 1999.

The major data areas covered include:

- Location/geology
- Inventory
- Disposal facility design
- Recharge
- Release rate from the waste form package
- Hydrology
- Geochemistry
- Dosimetry
- Agriculture Use

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Acronyms

BBI	best basis inventory
CA	Composite Analysis
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFEST	Coupled Fluid, Energy, and Solute Transport (computer code)
CFR	Code of Federal Regulations
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
ILAW	Immobilized Low-Activity Waste
ILAW PA	Immobilized Low-Activity Waste Performance Assessment
LFRG	Low-Level Waste Disposal Facility Federal Review Group
NRC	Nuclear Regulatory Commission
PA	Performance Assessment
RCRA	Resource Conservation and Recovery Act
RH	remotely handled (refers to trench disposal facility design)
STORM	Subsurface Transport Over Reactive Multiphases (computer code)
TWRS EIS	Tank Waste Remediation System Environmental Impact Statement
TWRSO&UP	Tank Waste Remediation System Operation and Utilization Plan (Kirkbride 1999)
WAC	Washington Administrative Code

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

This document defines the contents, format, and methods to be used for the *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (ILAW PA) to be issued in 2001. This document also provides the data to be used for the supporting calculations. The data are summarized in the main body of the report while the 16 appendices contain the documents used as primary references.

1.2 BACKGROUND

The Hanford Site, in south-central Washington State has been used extensively for producing defense materials by the Department of Energy (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. In the late 1980s, the Site's original mission ended. This mission left a large inventory of radioactive and mixed waste stored in buried single- and double-shell tanks in the Hanford Site 200 Areas.

Today, the 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 the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology 1998-1) 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 Hanford Site's single- and double-shell tanks, then treated to separate the low-level fraction (now called the low-activity fraction) from the high-level and transuranic fractions. Both fractions will then be immobilized.

The two products (the small volume of high-level immobilized waste and the much larger volume of low-activity waste) will be disposed of in different locations. The high-level waste will be stored on the Hanford Site until sent to a federal geologic repository. The low-activity immobilized waste will be placed in a near-surface disposal system in the 200 East Area of the Hanford Site. On the order of 160,000 m^3 (5,6000,000 ft^3) of low-activity immobilized waste will be disposed of under this plan. This is among the largest amounts of waste in the DOE Complex (DOE 1995) and has one of the largest inventories of long-lived radionuclides at a low-level waste disposal facility.

The DOE is proceeding (DOE-RL 1996a) to procure privatized services for treating and immobilizing the tank waste. In August 1998, DOE placed a contract with BNFL, Inc. (DOE/BNFL 1998) to produce the ILAW with the first delivery currently scheduled in 2008.

The first phase of the effort would extend for about a decade. The contract for the second phase, in which most of the waste will be processed, will be awarded in the second half of the decade.

1.3 PREVIOUS ASSESSMENTS

In 1998, the first version of the *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (Mann 1998a) was issued and submitted to the Federal Low-Level Waste Review Group (LFRG) for review and action. The Federal Low-Level Waste Review Group has completed their review. Based on this review the DOE has conditionally accepted the ILAW Performance Assessment (DOE 1999f). This acceptance is contingent upon the following actions: providing the LFRG with documentation of the near-term glass activities to provide confidence that the glass performance assumed in the performance assessment can actually be achieved, and addressing the secondary issues identified by the review team in future revisions to the performance assessment.

Most of the data in the 1998 ILAW PA came from the *Data Packages for the Hanford Low-level Tank Waste Interim Performance Assessment (Mann 1995)*, although some data were updated to reflect more current values.

A number of other impact assessments have also been done at the Hanford Site:

- The *Long-Term Performance Assessment of Grouted Phosphate/Sulfate Waste from N Reactor Operations* (Stewart 1987) forms the basis of the environmental assessment (DOE 1986) for the disposal of low-level radioactive waste generated by decontamination operations and other activities associated with N Reactor operations. Because this performance assessment predates the DOE order on radioactive waste management, the DOE review was conducted by reviewing the environmental assessment.

- The *Performance Assessment of Grouted Double-Shell Tank Waste Disposal at Hanford* (Kincaid 1995) dealt with disposing of low-level liquid waste from the double-shell tanks. The waste was to be combined with cement, flyash, and clay to form a grout that would be poured into large subsurface vaults located to the east of the 200 East Area. The Peer Review Panel (Wilhite 1994) approved the grout performance assessment in principle. DOE (Lytle 1995) found that the analysis performed in Kincaid (1995) was "technically adequate and provides reasonable assurance that the selected performance objectives would be met." Noting, however, 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.

- The *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds* (Wood 1994) dealt with the solid waste from operations at the Hanford Site and other sites. This waste is placed into trenches in the western part of the 200 West Area and then covered with a *Resource Conservation and Recovery Act of 1976* (RCRA)-compliant 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 were related to added documentation.

- 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 has also been conditionally approved by DOE-Headquarters (Frei 1997).

- The *Environmental Remediation Disposal Facility Performance Assessment* (Wood 1995) 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 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 (DOE-RL 1993) was written.

- The *Composite Assessment for Hanford Site* (CA) (Kincaid 1998) was prepared in response to Recommendation 94-2 of the Defense Nuclear Facilities Safety Board to the Secretary of the Department 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 CA has undergone headquarters review by the Federal Low-Level Waste Review Group. Based on this review the DOE has conditionally accepted the CA (DOE 1999f). This acceptance is contingent upon the following actions: providing the LFRG by September 30, 2001 with an addendum to the composite analysis that addresses bounding analyses in the 200 Area that include the PUREX tunnels, the chemical separations plants and the CERCLA sites, and resolve the path forward for the Gable Mountain Pond; and address the secondary issues identified in the LFRG review.

- The *Environmental Impact Statement for the Tank Waste Remediation System* (TWRS EIS) (DOE 1996b) analyzed various options to manage the Hanford Site’s tank waste with the record of decision issued in 1997 (DOE 1997). Because of the scope of the TWRS EIS, the analyses relied on data less complete and less project-specific than this performance assessment. The record of decision includes the disposal of ILAW in the Hanford Site 200 Areas.

1.4 OTHER RELEVANT HANFORD DATA COLLECTION EFFORTS

Besides the data collection efforts associated with the ILAW PA activity, there are a number of data collection efforts at the Hanford Site that can provide useful data to the ILAW PA activity. Close cooperation with these activities is maintained.

As part of the maintenance program for the Solid Waste Burial Ground Performance Assessments, work on retardation through near-field materials (especially concrete) is being performed.

The maintenance of the Composite Analysis is being undertaken by the Hanford Groundwater / Vadose Zone Integration Project. The Characterization of Systems activity, the Science and Technology activity, and the System Assessment Capability activity will provide (respectively) a centralized data source for Hanford inventory and geotechnical data, improved methods and data, and updated analyses. For the most part, new data will come from other sources.

The Tank Farm Vadose Zone Program has an active program characterizing the vadose zone in and near tank farms. A number of boreholes are planned which will not only provide contaminant concentrations, but also important geologic, geochemical, and hydraulic data in various parts of the 200 Areas.

The 200 Areas Remediation Project will have an active characterization effort in the 200 Areas as it starts planning remediation efforts.

The Hanford Groundwater Project has an active program to monitor groundwater quality at the Hanford Site. This program will be drilling boreholes (in order to replace monitoring wells going dry) from which geotechnical data will be obtained.

1.5 GUIDANCE

Guidance for the performance assessment mainly derives from *Format and Content Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments and Composite Analyses* (DOE 1999a) and *Maintenance Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments and Composite Analyses* (DOE 1999b).

1.6 CONTENTS OF THIS REPORT

Section 2.0 briefly describes the contents and formats of the 2001 ILAW PA. Section 3.0 describes the methods to be used in the PA, including the performance objectives, the scenarios, and the computer codes. Chapter 4.0 summarizes the data to be used, including data on

- Location/geology
- Inventory
- Disposal facility design
- Recharge
- Release rate from the waste form package
- Hydrology
- Geochemistry

- Dosimetry

The appendices contain the documents used as primary references.

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2.0 CONTENTS AND FORMAT

The contents and format for the 2001 ILAW PA is based on the guidance in Format and Content Guide for U.S. Department of Energy Low-Level Waste Disposal Facility Performance Assessments and Composite Analyses (DOE 1999a). The structure to be used is displayed in Table 2.1.

Table 2.1 Contents of the 2001 ILAW PA

1.0 EXECUTIVE SUMMARY

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3.0 METHODS

3.1 OVERVIEW

This section covers the methods to be used in the 2001 ILAW PA. The methods include the standards (known as performance objectives) against which the effect of the disposal action will be judged, the various scenarios and pathways which will be analyzed, and the tools with which the analyses will be done.

3.2 PERFORMANCE OBJECTIVES

> The performance objectives are similar to those used in the 1998 ILAW PA. The major differences are the inclusion of chemicals to support RCRA analyses and explicit comparisons to be done at 1,000 years to support the requirements of the DOE order on radioactive waste management.

Performance objectives are the standards against which the effect of the disposal action will be done. The manual (DOE 1999d –1) for the new DOE order on radioactive waste management, DOE O 435.1 (DOE 1999c) provides performance objectives for a performance assessment as:

- (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"

This performance assessment will also be the technical supporting document for the Resource Conservation and Recovery Act (RCRA) Part B permit and for discussions with the U.S. Nuclear Regulatory Commission (NRC) on the waste classification of ILAW. Therefore, additional items were considered in the establishment of the performance objectives used in the 2001 ILAW PA. Specifically, the RCRA concerns bring in the impacts of hazardous chemicals. The NRC concerns bring in the requirements of 10 CFR 61, which mainly add the requirements for an analysis to 10,000 years after closure.

Therefore, as documented in Appendix A, the various requirements noted above have been merged into an unified set of performance objectives for the 2001 ILAW PA (Mann 1999a). Table 3.1 presents the performance objectives for radionuclides, while Table 3.2 presents the performances objectives for chemicals.

Table 3.1 Radiological Performance Objectives

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	
^{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 maximal exposure, but no closer than 100 meters (328 feet) from the disposal facility.
[e] Evaluated at the 200 East Area fence.
[f] Evaluated at the disposal facility.
[g] Evaluated at the Columbia River, no mixing with the river is assumed.
[h] Main driver is DOE Orders on *Radioactive Waste Management* (DOE 1988 and DOE 1999c)
[i] Main driver is DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE 1993).
[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 3.2 Performance Goals for Hazardous Materials

Inorganic Compounds/Elements			
Chemical		Groundwater	Surface Waters
Ammonia			4.0 mg/l
Antimony		0.006 mg/l	0.006 mg/l
Arsenic		0.00005 mg/l	0.05 mg/l
Barium		1.0 mg/l	2.0 mg/l
Beryllium		0.004 mg/l	0.004 mg/l
Cadmium		0.005 mg/l	0.00077 mg/l
Chlorine		250. mg/l	230. mg/l
Chromium		0.05 mg/l	0.011 mg/l
Copper		1.0 mg/l	0.0078 mg/l
Cyanide		0.2 mg/l	0.0052 mg/l
Fluoride		4.0 mg/l	4.0 mg/l
Iron		0.3 mg/l	
Lead		0.05 mg/l	0.0015 mg/l
Manganese		0.05 mg/l	
Mercury		0.002 mg/l	0.000012 mg/l
Nickel			0.115 mg/l
Nitrate as N		10. mg/l	10. mg/l
Nitrite as N		1.0 mg/l	1.0 mg/l
Nitrite plus Nitrate		10. mg/l	10. mg/l
Selenium		0.01 mg/l	0.005 mg/l
Silver		0.05 mg/l	
Sulfate		250. mg/l	
Thallium		0.002 mg/l	
Zinc		5.0 mg/l	0.072 mg/l
Organic Compounds			
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	
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
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

No entry in a cell indicates that no limit was found.

3.3 SCENARIOS AND PATHWAYS

3.3.1 Introduction

The scenarios and pathways are basically unchanged from the 1998 ILAW PA.

The selection of scenarios and pathways for the 2001 ILAW PA is more fully described in Appendix B (Mann 1999b). Possible scenarios were suggested by analyzing the performance objectives given in Section 3.2 and determining which parameters could lead to exposure which is given by the performance objective. The pathways to be analyzed are groundwater, air, and inadvertent intruder. Finally, probable natural events are identified in Section 3.3.5.

In 1992, the Hanford Future Site Uses Working Group (consisting of local, state, and federal officials, representatives of tribal nations, people from agriculture and labor, as well as members of environmental and special interest groups) was charged to determine potential future uses of the various parts of the Hanford Site. Their summary report (HFSUWG 1992-1) 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 disposal areas."*

The DOE along with the U.S. Department of Interior, local governments, and affected tribal nations have recently issued a comprehensive land use plan for the Hanford Site for at least the next 50 years (DOE 1999e). The plan outlines that the 200 Areas (or Central Plateau) would be used exclusively as a waste management area.

Except for the inadvertent intruder scenario, the scenarios described here assume that some controls remain in place to prevent public intrusion into the disposal site. That is, the barriers and markers that have been left are effective in preventing open use of the land directly over the disposal site.

3.3.2 Groundwater Pathway

Past Hanford Site performance assessments (see Section 1.3) have shown that the groundwater pathway to be the most restrictive for the vast majority of radionuclides. Previous assessments have not analyzed the effect of chemicals. Figure 3-1 shows the details of the groundwater pathway. The eight steps are

1) Precipitation (rain or snow) enters the soil. Much of this water returns to the atmosphere by evaporation from the soil surface or transpiration through plant leaves. The remaining water moves down below the surface evapotranspiration zone at a very low rate.

2) The deep water continues to move downward, but some of the water is diverted by any intact sand-gravel capillary barrier.

3) The water that is not diverted away from the waste may be chemically modified by the local environment, interacts with the waste form, and accumulates contaminants.

4) The water (possibly a reduced amount because waste form dissolution and mineral formation consume water) leaves the disposal facility carrying contaminants with it. Some contaminants may interact with the material in the disposal facility, slowing the release of contaminants to the surrounding natural environment.

5) Contaminated water moves through the undisturbed, unsaturated zone (vadose zone) below the disposal facility down to the unconfined aquifer. The contaminants may interact with soil sediments causing further retardation. Changes to the properties of the natural system are considered, but are not major.

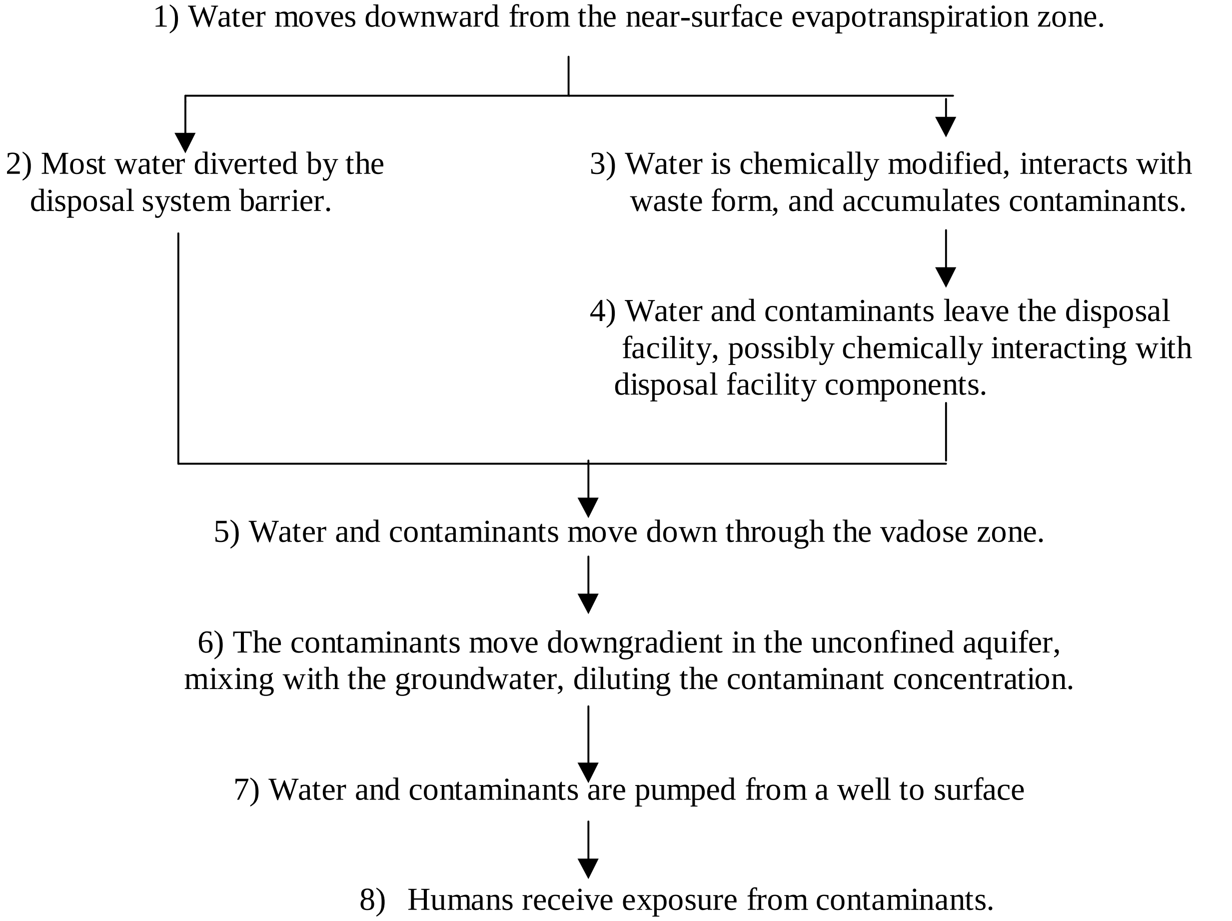
6) The water and contaminants move and mix with the water in the unconfined aquifer until they are extracted from the aquifer and brought to the surface or until they reach the Columbia River.

7) Contaminants are extracted by being carried to the surface with groundwater being pumped through a well.

8) The contaminants result in human exposure through a variety of exposure pathways (ingestion, inhalation, dermal contact, and external radiation).

The 1998 ILAW PA (Mann 1998a) showed that the second most mobile radionuclides (such as uranium and its daughters) peaked at about 50,000 years, a time at which the most mobile radionuclides (technetium, selenium, and many chemicals) were still significant. Explicit numerical simulations will be performed from the present to 100,000 years in the future (i.e., twice the time for the peak all-pathways dose) using best-estimate values for all parameters. Comparisons to the performance objectives will be made at 1,000 years and at 10,000 years after closure of the ILAW disposal facility (which is assumed to be in 2030).

Figure 3-1. Eight Sequential Steps for the Groundwater Pathway



3.3.3 Air Pathway

The previous performance assessment (Mann 1998a) showed that using conservative assumptions that releases to the atmosphere are many orders of magnitude (four in the case of radon releases and nine for other gases) less than performance objectives. As in the 1998 ILAW PA, diffusion of gaseous species will be treated.

3.3.4 Inadvertent Intruder Scenarios

Following the practice of the Nuclear Regulatory Commission (NRC 1988, NRC 1997), three scenarios were considered:

- A basement is excavated which extends into the waste and hence contaminants are brought to the surface,
- A well is drilled through the waste, bringing contaminants to the surface,

- Contaminants that have been brought to the surface are mixed with the surrounding soil as a residential farmer works the soil.

Because the waste will be below (> 5 meters) the levels that basement excavations are dug in the Columbia Basin region, the first scenario (basement excavation) is not treated. The other two scenarios are treated.

3.3.5 Natural Event Scenarios

The main natural events to be expected are 1) erosion of the surface above this disposal units due to wind, 2) subsidence of the engineered barriers or facilities, 3) earthquakes, and 4) flooding due to post-glacial events. As in the 1998 ILAW PA, the first three events will be treated as part of the degradation of the disposal facility, while a simple calculation will estimate the effect of post-glacial flooding.

3.4 COMPUTER CODES

3.4.1 Introduction

Selection processes resulted in newer codes than used in the 1998 ILAW PA.

Computer codes will be used for four purposes:

- calculate contaminant release rates from the waste packages and from the disposal facility,
- calculate moisture flow and contaminant transport in the vadose zone,
- calculate moisture flow and contaminant transport in groundwater, and
- merge the results of the other codes.

For the first three codes, the code selection criteria, code selection, and verification packages have been published and are described below. The code that merges the results will be discussed in the 2001 ILAW PA itself.

3.4.2 Waste Form Release and Near-Field Contaminant Transport Code

The 1998 ILAW PA showed that a key intermediate result is the waste form release rate, which is calculated over thousands of years. The code selection criteria and selection process is documented in *Selection Of A Computer Code For Hanford Low-Level Waste Engineered-System Performance Assessment* (McGrail 1998a), which is included as Appendix C of this document. The needed capabilities were identified from an analysis of the important physical and chemical processes expected to affect LAW glass corrosion and the mobility of radionuclides. The available computer codes with suitable capabilities were ranked in terms of the feature sets implemented in the code that match a set a physical, chemical, numerical, and functional capabilities needed to assess release rates from the engineered system. The highest ranked computer code was found to be the STORM code developed at PNNL for the U.S.

Department of Energy for evaluation of arid land disposal sites. The verification studies for STORM are documented in *Subsurface Transport Over Reactive Multiphases (STORM): A General, Coupled, Nonisothermal Multiphase Flow, Reactive Transport, and Porous Medium Alteration Simulator, Version 1.09, User's Guide* (Bacon et. al. 2000), which is included as Appendix D.

3.4.3 Vadose Zone Moisture Flow and Contaminant Transport Code

The selection process for the vadose zone code was more formal. The code selection criteria were determined (Mann 1998b) and vendors formally submitted proposals which were formally evaluated (Voogd 1999). These latter documented which includes the code selection criteria is attached as Appendix E. The code selection criteria were heavily based on those used in the code selection for the earlier ILAW PAs (Mann 1996) which themselves were based on DOE and NRC criteria. The VAM3DF code, an earlier version of which has been approved by the DOE, EPA, and Washington State Department of Ecology for vadose zone calculations (TPA Milestone 29-2) was selected. Documentation on verification of VAM3DF (Finfrock 2000) can be found in Appendix F.

3.4.4 Groundwater Flow and Contaminant Transport Code

The Richland Operations Office (DOE-RL 1996b) has directed the Hanford Groundwater Program to establish a single groundwater model for the Hanford Site. As a followup to this directive, RL initiated a project in FY 1997 to consolidate multiple groundwater models at the Hanford Site into a single consolidated site-wide groundwater model. The overall recommendations made by RL to select the site-wide groundwater model in the initial phase of the consolidation process are documented in DOE-RL (2000). In this effort, RL initiated an evaluation of computer codes for implementation with the consolidated site-wide groundwater model. Only two computer codes were reviewed in this initial phase of the model-consolidation process: 1) the VAM3D-CG code developed by Hydrogeologic, Inc., in Herndon, Virginia, and 2) the CFEST-96 code developed by the CFEST Co. in Irvine, California. The GWRS model is implemented based on the VAM3D-CG code. The HGWP model is based on the CFEST-96 code. In a qualitative comparison of the two computer codes, both VAM3D-CG and CFEST-96 were found to be technically acceptable because they

- were included in the list of accepted groundwater flow and transport codes identified in Milestone M-29-01 (DOE/RL 1991)
- met the technical capabilities and administrative requirements outlined in the original Milestone M-29-01 document and generally met the technical capabilities and administrative requirement in this report.

In the interest of minimizing initial cost and potential schedule impacts, RL selected the CFEST-96 code as an interim code for implementing the consolidated site-wide groundwater model since it was already implemented with the selected conceptual and numerical model. Documentation of the specific application of the CFEST code to the selected site-wide groundwater flow and transport model at Hanford is provided in Wurstner et al. (1995), Cole et al. (1997), and Kincaid et al. (1998).

RL deferred decisions on final selection of the code until the external peer review of the consolidated site-wide groundwater model and the resulting final refinements and modifications have been completed. When this first phase of the model-consolidation process is completed, RL may consider more in-depth testing and benchmarking of the CFEST-96, VAM3D-0CG, and other applicable codes using the refined and modified site-wide groundwater model before reaching a final decision on selection of a code.

3.5 CALCULATIONAL STRATEGY

The calculational strategy adopted for this performance assessment has been to provide the best estimate for the performance of this disposal action against the performance assessment objectives outlined in section 3.2 of this report. This best estimate calculation is based on the best estimates for the data used in the computer codes to calculate the transport of contaminants from the waste site to the receptors for the various scenarios calculated within this performance assessment.

The authors recognize that there are uncertainties associated with these calculations and the calculational approach. In a broad sense these uncertainties are associated with our understanding of the physical system performance, uncertainty in the models used to approximate the physical system, uncertainty in the codes used to model the transport, and uncertainty in the data input into these codes. An estimate for uncertainty in the data input to the code calculations is provided within the data reports summarized in section 4.0. The other uncertainties are explored through a set of sensitivity calculations where bounding values are used in the calculations for different physical system assumptions. This approach is undertaken in an attempt to convince both the regulators and the public that the proposed disposal action is "acceptable."

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4.0 DATA

4.1 INTRODUCTION

The data to be used in the calculations of the 2001 ILAW PA are described in this section. For most of the topics, the ILAW PA activity has maintained an energetic data gathering and interpretation activity. For other activities (for example, disposal facility design and dosimetry) closely coupled interfaces were developed with those responsible for the information either at the ILAW project level or at the Hanford Site level.

In each subsection, the methods used to generate the values are described and the values for the most important parameters are given. Full details are given in appendices G through N which contain the reports on which this chapter is based. These reports have all undergone Hanford review and several reports (Appendices J, L, M, and N) have undergone external review.

4.2 LOCATION/GEOLOGY

The current plan (Burbank 1999, Taylor 1999a) is to construct new facilities in the south central part of the 200 East Area (Rutherford 1997). Although the existing disposal vaults at the central eastern edge of the 200 East Area are not planned to be used, they will be analyzed as they may be used in the future.

> The current plan is to use new facilities in the south-central part of Hanford's 200 East Area. The geology of this area is based on a new borehole as well as reexamining samples from previous holes. The resulting geologic data are more detailed and believed to be more accurate.

The geology of the two disposal sites is given in *Geologic Data Package for the 2001 ILAW PA* (Reidel 1999) which is attached as Appendix G. The Hanford Site lies in the Pasco Basin of the Columbia Plateau. The Columbia Plateau consists of a sequence of thick basalt flows that occurred 5 to 7 million years ago. Overlying the basalt flows are sediments of the late Miocene, Pliocene, and Pleistocene ages, known as the Ringold Formation and (nearer the surface) the Hanford formation. The Hanford formation arises from deposits from post-glacier flooding (between 780,000 years ago and 13,000 years ago) and consists mainly of unconsolidated sand and sandy gravel layers. The unconfined aquifer is near the interface between the Hanford formation and Ringold Formation throughout the Hanford Site and at the disposal sites is about 80-95 meters (262-312 feet) below the surface. Clastic dikes have been observed at the existing disposal site are assumed to exist at the new ILAW site as well.

Data used in the (Reidel 1999) report compilation was obtained from surface geologic studies and from borehole data. The surface geology and geomorphology of the Hanford Site has been mapped and published by Reidel and Fecht (1994a, 1994b). Borehole data consisting of drilling logs, archived samples and geophysical logs are the principal data sets used to interpret the subsurface at the existing disposal site and the new ILAW disposal site. In addition, numerous reports describing the geology of the area and vicinity are available and are a valuable source of information (e.g., Tallman et al. 1979; DOE 1988; Connelly et al. 1992; Lindberg et al. 1993, Lindsey et al. 1992, 1994b). During the course of this study, archived natural gamma geophysical logs from boreholes at the new ILAW site and surrounding area were located and the logs were incorporated into the interpretations. Geophysical logs include boreholes from surrounding waste disposal sites obtained prior to discharge of effluent and provide a valuable source of information for stratigraphic correlations.

Elevation information were obtained from well completion reports or as-built diagrams if available, or from Chamness and Merz (1993). Because the boreholes are from so many vintages and because several different surveys have been used at the Hanford Site over the years, no attempt was made to assure consistency in the elevation survey data. However, differences among surveys are generally small (<3 feet; 1 m) with respect to other uncertainties associated with the data and, except for water levels in areas with a relatively flat water table, will not affect significantly the information presented in this database.

The methodology used in the process of building the data package followed a series of steps that were designed to insure the data were used properly. First, the main stratigraphic units and contacts were identified in boreholes with geologist's logs and geophysical data. Gross gamma-ray logs were examined with respect to the geologist's logs for geophysical signatures of the stratigraphy. For many boreholes from both sites, chip samples from the Hanford Geotechnical Sample Library were examined to help control the location of contacts and lithologies of stratigraphic units and lateral changes in the percentage of silt, sand, and gravel. Next, boreholes with driller’s logs and gross gamma-ray logs were examined and compared to nearby wells and boreholes. At the new ILAW site, the stratigraphy was built out from borehole 299-E17-21 using boreholes with geologist's logs and geophysical logs. Boreholes for which only driller’s logs were available were given the least priority for constructing the geologic models.

The stratigraphy at the existing disposal vaults site has the top of the Columbia River Basalt Group at an elevation (above sea level) of approximately 91 m (300 ft). The top of the Ringold Formation ranges between 113-128 m (370-420 ft). The average thickness of the Unit A sequence within the Ringold Formation is 23.7 m (78 ft). The average thickness of the Ringold Formation fine-grain sequence above the Unit A sequence is 5.5 m (18 ft). In some areas beneath the existing disposal site this formation is not present. The Hanford Formation gravel sequence is approximately 31m (102 ft) thick; and the Hanford Formation sand sequence varies from 41 to 67 m (134-220 ft). Finally, recent surface deposits range in thickness between 1.5-4.5 m (5-15 ft). The current water table is in the Ringold Formation fine-grain sequence or in the Hanford Formation gravel sequence.

The stratigraphy at the new ILAW disposal site has the top of the Columbia River Basalt Group at an elevation (above sea level) of approximately 84 m (275 ft). The top of the Ringold Formation ranges between 91-122 m (300-400 ft). The Hanford Formation gravel sequence thickness is approximately 27-46m (88-150 ft) thick; and the Hanford Formation sand sequence varies from 64 to 76 m (210-250 ft). Within the sandy sequence three paleosols were identified. Finally, Eolian deposits cover the southern part of the new ILAW disposal site and range in thickness between 3 to 15 m (10-50 ft). The current water table is in the Hanford Formation gravel sequence below the new disposal site.

4.3 INVENTORY

> Both radionuclide and chemical inventory are given. The radionuclide and inorganic material inventory is based on the current best basis estimates of what is the tank waste inventory corrected for the separation that will occur during the treatment phase as well as contract limits. The organic material inventory is based on RCRA disposal limits.
>
> The ^{99}Tc inventory (5,790 Ci) is lower than in the 1998 ILAW PA because 80% of the Tc will be removed according to the current contract with BNFL.

The environmental or health impact of each radionuclide or chemical is proportional to the amount of the material at the point of impact. However, normally it is the sum of these impacts over materials at the point of impact that is important. Thus, as shown by the previous Hanford Site performance assessments (see Section 1.3), particularly the last version of the ILAW PA, the significant materials are the most mobile due to the long travel times of the other materials. This section summarizes the data in the *Immobilized Low-Activity Tank Waste Inventory Data Package* report (Wootan 1999) that is included as Appendix H in this document.

Both radionuclides and chemicals are considered in this performance assessment. Although DOE O 435.1 only requires performance assessments for radionuclides, the Office of River Protection of DOE along with the Washington State Department of Ecology have determined that the technical analyses should support the Resource Conservation and Recovery Act (RCRA) permitting requirements as well. Thus, one technical analysis will serve as the basis for protection of the public under the requirements of the Atomic Energy Act and RCRA.

Forty-six radionuclides and twenty-five chemicals are explicitly treated in the best basis tank inventories. These materials were selected by the TWRS Characterization Program (Kupfer 1999) as those important for safety, disposal, and processing requirements. This set includes all the radionuclides identified as significant in the 1998 ILAW PA (Mann 1998a) as well as those identified in the screening studies for the ILAW PAs (Schmittroth 1995). The chemicals identified in the 2001 ILAW PA performance objectives (Mann 1999a) that are not listed in the tank inventories should not survive the vitrification process. Therefore, their upper bound concentrations in the waste form were set equal to the concentration limits for land disposal (40 CFR 268).

The nominal ILAW inventories for all the materials explicitly included are based on the *Tank Waste Remediation System Operation and Utilization Plan* (Kirkbride 1999), also known as the TWRSO&UP. The best basis tank by tank inventories (BBI) as of October 1, 1998 were adjusted for waste transfers not accounted for in the BBI, and for non-BBI analytes that are in the waste treatment contract. The BBI inventories were adjusted to a common date (October 1, 1998). The BBI values are based on a tank by tank evaluation of measurements from tank samples as well as modeling results of transfers to and from the tank. The retrieval and feed delivery process was modeled by estimating liquid and solid partitioning (Hendrickson 1998) and by following the April 1, 1999 DOE guidance (Taylor 1999b) on schedules and contract requirements. Vitrification losses were explicitly included in the model and are described in Kirkbride 1999).

As noted in the 1998 ILAW PA, the previously accepted half-lives of ^{79}Se and ^{126}Sn are now thought to be underestimates. This underestimate for ^{126}Sn has been confirmed (Brodzinski 1999). Thus, inventories for ^{79}Se and ^{126}Sn in the TWRSO&UP have been multiplied by 0.08 and 0.40, respectively.

Table 4.1 provides the total inventory in the tanks and in the ILAW packages as well as the expected average and maximum concentration in the ILAW packages for each radionuclide and chemical considered. The following provide short descriptions of key materials:

- ^{3}H: No tritium is expected to survive the vitrification process to end up in ILAW packages (Kirkbride 1999).
- ^{14}C: No ^{14}C is expected to survive the vitrification process and end up in the ILAW packages (Kirkbride 1999).
- ^{79}Se: Results are based on models, but are considered conservative, since the model neglects previous removals such as disposals to cribs.
- ^{90}Sr: Values are constrained by the current contract (DOE/BNFL 1998) and assumption that this constraint applies to all ILAW waste.
- ^{99}Tc The values are felt to be conservative because the shipments to off-site are neglected. Values are also constrained by the current contract (DOE/BNFL 1998) and assumption that this constraint applies to al ILAW waste.
- ^{126}Sn Results are based on models that overestimate the distribution in tanks 241-AZ-101 and 241-AZ-102.
- ^{129}I The values are felt to be conservative since no credit was taken for losses of iodine to the atmosphere during processing.
- ^{137}Cs Values are constrained by the treatment contract (DOE/BNFL 1998).
- U Many of the values are based on total uranium analysis of samples.
- ^{237}Np The BBI inventory is 30% higher than the global estimate. Two tanks (241-An-103 and 241-AN-105) are thought to have the bulk of the Np, but only “bounding value estimates” are available for those two tanks.
- Pu Values are primarily based on accountability records and samples.

Table 4.1 ILAW Package Inventories (Ci for radionuclide and kg for chemical) and Concentrations (Ci/m^3 for radionuclide and kg/m^3 for chemical)

Material	Tank Inventory	ILAW Inventory	Average Package Concentration	Maximum Upper Bound Package Concentration
3-H	2.46E+04	0.00E+00	0.00E+00	4.66E-01
14-C	4.38E+03	0.00E+00	0.00E+00	8.00E+00
59-Ni	8.58E+02	1.67E+02	1.06E-03	6.20E-02

Material	Tank Inventory	ILAW Inventory	Average Package Concentration	Maximum Upper Bound Package Concentration
60-Co	1.99E+04	4.18E+03	2.64E-02	4.39E+00
63-Ni	8.45E+04	1.62E+04	1.02E-01	7.00E+02
79-Se	5.74E+01	4.80E+01	3.03E-04	2.55E-02
90-Sr	5.99E+07	4.50E+06	2.85E+01	7.00E+03
93-Zr	4.12E+03	1.25E+03	7.94E-03	3.32E-01
93m-Nb	2.53E+03	8.36E+02	5.29E-03	4.05E-01
99-Tc	2.89E+04	5.79E+03	3.66E-02	3.00E+00
106-Ru	1.27E+05	8.94E+02	5.65E-03	1.10E+02
113m-Cd	1.67E+04	7.97E+03	5.04E-02	1.34E+00
125-Sb	2.47E+05	5.20E+04	3.29E-01	9.23E+01
126-Sn	4.64E+02	1.69E+02	1.07E-03	3.41E-02
129-I	1.01E+02	2.20E+01	1.39E-04	8.00E-02
134-Cs	8.71E+04	3.76E+02	3.73E-01	3.36E-01
137-Cs	6.37E+07	9.11E+05	5.76E+00	4.60E+03
151-Sm	2.61E+06	7.80E+05	4.93E+00	2.43E+02
152-Eu	1.45E+03	3.07E+02	1.94E-03	5.96E-01
154-Eu	1.83E+05	3.77E+04	2.38E-01	8.92E+01
155-Eu	1.76E+05	3.15E+04	1.99E-01	1.23E+02
226-Ra	1.14E+03	1.03E+03	6.53E-03	9.36E-01
227-Ac	8.75E+01	6.05E-02	3.83E-07	7.63E-03
228-Ra	7.75E+01	3.32E+01	2.10E-04	7.49E-03
229-Th	1.81E+00	3.40E-01	2.15E-06	1.82E-04
231-Pa	1.53E+02	3.37E-01	2.13E-06	1.40E-02
232-Th	4.40E+00	1.28E+00	8.09E-06	6.17E-04
232-U	1.49E+02	3.46E+01	2.19E-04	2.11E-02
233-U	5.72E+02	1.31E+02	8.26E-04	8.18E-02
234-U	3.42E+02	4.41E+01	2.79E-04	4.54E-02
235-U	1.46E+01	1.79E+00	1.13E-05	1.96E-03
236-U	1.24E+01	1.43E+00	9.03E-06	9.60E-04
237-Np	1.85E+02	8.10E+01	5.13E-04	1.46E-03
238-Pu	2.70E+03	1.06E+02	6.72E-04	1.91E-03
238-U	3.28E+02	4.83E+01	3.06E-04	4.12E-02
239-Pu	5.55E+04	3.05E+03	1.93E-02	5.49E-02
240-Pu	1.13E+04	5.25E+02	3.32E-03	9.47E-03
241-Am	1.07E+05	1.08E+04	6.85E-02	1.95E-01
241-Pu	1.66E+05	7.17E+03	4.53E-02	9.28E+00
242-Cm	1.72E+02	5.76E+01	3.64E-04	5.30E+01
242-Pu	1.07E+00	4.49E-02	2.84E-07	8.09E-07
243-Am	1.76E+01	6.89E-01	4.36E-06	1.24E-05
243-Cm	3.47E+01	6.73E+00	4.26E-05	1.21E-04
244-Cm	7.84E+02	1.01E+02	6.36E-04	1.81E-03

Material	Tank Inventory	ILAW Inventory	Average Package Concentration	Maximum Upper Bound Package Concentration
Ag+	1.51E+03	1.08E+02	6.83E-04	1.59E+00
Al(OH)4-	0.00E+00	5.31E+06	3.36E+01	1.53E+03
Al+3	8.27E+06	4.05E+06	2.56E+01	5.29E+02
As+5	2.08E+01	1.76E+01	1.12E-04	1.75E-01
B+3	6.53E+03	6.54E+02	4.14E-03	1.04E+01
Ba+2	1.70E+03	1.86E+01	1.17E-04	1.32E+01
Be+2	1.09E+02	6.14E-01	3.89E-06	1.94E+00
Bi+3	6.31E+05	9.96E+03	6.30E-02	3.27E+02
Ca+2	3.19E+05	4.78E+04	3.03E-01	6.54E+01
Cd+2	4.18E+02	6.30E+01	3.98E-04	6.81E-01
Ce+3	2.38E+05	2.33E+03	1.47E-02	7.93E+02
Cl-	9.37E+05	9.31E+05	5.89E+00	4.67E+01
CN-	1.09E+05	0.00E+00	0.00E+00	2.06E+00
CO3-2	9.46E+06	0.00E+00	0.00E+00	1.79E+02
Cr(OH)4-	0.00E+00	4.05E+05	2.56E+00	2.31E+02
Cr (TOTAL)	6.72E+05	2.74E+05	1.73E+00	9.37E+01
Cs+	1.18E+05	1.12E+03	7.13E-01	5.67E+01
Cu+2	3.15E+02	7.33E-01	4.63E-06	2.19E-01
F-	1.20E+06	9.94E+05	6.28E+00	9.97E+01
Fe+3	1.40E+06	4.48E+04	2.83E-01	2.68E+02
H2O	8.70E+07	0.00E+00	0.00E+00	1.65E+03
Hg+2	2.10E+03	1.92E+02	1.22E-03	1.11E+00
K+	8.75E+05	8.33E+05	5.27E+00	6.57E+01
La+3	5.13E+04	5.06E+02	3.20E-03	9.10E+00
Li+	3.04E+01	3.02E+01	1.91E-04	4.98E-03
Mg+2	3.38E+03	2.84E+02	1.80E-03	1.53E+01
Mn+4	1.96E+05	1.38E+04	8.71E-02	1.79E+01
Mo+6	1.31E+03	6.21E+02	3.93E-03	5.58E-01
Na+	4.90E+07	5.69E+07	3.60E+02	1.01E+03
NH3	5.01E+05	0.00E+00	2.53E+00	9.51E+00
Ni+2	1.80E+05	3.05E+04	1.93E-01	5.25E+01
NO2-	1.26E+07	0.00E+00	0.00E+00	2.40E+02
NO3-	5.25E+07	0.00E+00	0.00E+00	9.96E+02
OH (BOUND)	2.11E+07	0.00E+00	0.00E+00	4.01E+02
OH-	3.66E+06	0.00E+00	0.00E+00	6.95E+01
Pb+2	8.40E+04	7.83E+03	4.95E-02	8.77E+00
PO4-3	5.56E+06	5.16E+06	3.26E+01	7.36E+02
Rh+3	5.19E+01	NA	0.00E+00	6.56E-03
Ru+3	1.21E+00	NA	0.00E+00	1.53E-04
Se+6	6.11E-01	5.33E-01	3.37E-06	6.80E-04
Si+4	9.41E+05	4.20E+05	2.66E+00	1.54E+02

Material	Tank Inventory	ILAW Inventory	Average Package Concentration	Maximum Upper Bound Package Concentration
SO4-2	3.91E+06	3.39E+06	2.15E+01	3.16E+02
Sr+2	4.55E+04	2.20E+03	1.39E-02	8.01E+00
Te+6	3.04E+02	NA	0.00E+00	3.84E-02
Th+4	NA	NA	0.00E+00	4.86E-01
Ti+4	2.60E+02	1.49E+01	9.42E-05	4.00E-01
Tl+3	2.54E+04	NA	0.00E+00	3.21E+00
TOC	2.00E+06	0.00E+00	0.00E+00	3.79E+01
U(TOTAL)	7.61E+04	1.73E+04	1.10E-01	2.85E+01
V+5	1.68E+01	NA	0.00E+00	2.13E-03
W+6	NA	NA	0.00E+00	2.01E+00
Zn+2	2.89E+03	1.98E+03	1.25E-02	3.48E+00
Zr+4	4.65E+05	1.23E+04	7.76E-02	2.07E+01
1,1,1-trichlorethane	NA	0.00E+00	0.00E+00	2.07E-02
1,1,2-trichloro-1,2,2-trifluoroethane	NA	0.00E+00	0.00E+00	1.03E-01
1,1,2-trichloroethane	NA	0.00E+00	0.00E+00	2.07E-02
1,1-dichloroethylene	NA	0.00E+00	0.00E+00	2.07E-02
1,2-dichloroethane	NA	0.00E+00	0.00E+00	2.07E-02
acetone	NA	0.00E+00	0.00E+00	5.51E-01
benzene	NA	0.00E+00	0.00E+00	3.45E-02
carbon tetrachloride	NA	0.00E+00	0.00E+00	2.07E-02
chlorobenzene	NA	0.00E+00	0.00E+00	2.07E-02
chloroform	NA	0.00E+00	0.00E+00	2.07E-02
ethyl acetate	NA	0.00E+00	0.00E+00	1.14E-01
ethyl benzene	NA	0.00E+00	0.00E+00	3.45E-02
hexachorobutadiene	NA	0.00E+00	0.00E+00	1.93E-02
methyl ethyl ketone	NA	0.00E+00	0.00E+00	1.24E-01
methyl isobutyl ketone	NA	0.00E+00	0.00E+00	1.14E-01
methylene chloride	NA	0.00E+00	0.00E+00	1.03E-01
n-butyl alcohol	NA	0.00E+00	0.00E+00	8.96E-03
nitrobenzene	NA	0.00E+00	0.00E+00	4.82E-02
o-dichlorobenzene	NA	0.00E+00	0.00E+00	2.07E-02
pyridine	NA	0.00E+00	0.00E+00	5.51E-02
tetrachloroethylene	NA	0.00E+00	0.00E+00	2.07E-02
toluene	NA	0.00E+00	0.00E+00	3.45E-02
trichloroethylene	NA	0.00E+00	0.00E+00	2.07E-02
trichloromonofluoromethane	NA	0.00E+00	0.00E+00	1.03E-01
vinyl chloride	NA	0.00E+00	0.00E+00	2.07E-02
xylenes-mixed isomers	NA	0.00E+00	0.00E+00	1.03E-01
1,1,2,2-tetrachloroethane	NA	0.00E+00	0.00E+00	2.07E-02
1,1-dichloroethane	NA	0.00E+00	0.00E+00	2.07E-02

Material	Tank Inventory	ILAW Inventory	Average Package Concentration	Maximum Upper Bound Package Concentration
1,2,4-trichlorobenzene	NA	0.00E+00	0.00E+00	6.55E-02
1,2-dichloropropane	NA	0.00E+00	0.00E+00	6.20E-02
1,3-dichlorobenzene	NA	0.00E+00	0.00E+00	2.07E-02
1,4-dichlorobenzene	NA	0.00E+00	0.00E+00	2.07E-02
1,4-dioxane	NA	0.00E+00	0.00E+00	5.86E-01
2-sec-butyl-4,6-dinitrophenol	NA	0.00E+00	0.00E+00	8.61E-03
3-chloropropene	NA	0.00E+00	0.00E+00	1.03E-01
acetonitrile	NA	0.00E+00	0.00E+00	1.31E-01
acetophenone	NA	0.00E+00	0.00E+00	3.34E-02
acrylonitrile	NA	0.00E+00	0.00E+00	2.89E-01
aldrin	NA	0.00E+00	0.00E+00	2.27E-04
benzo(a)pyrene	NA	0.00E+00	0.00E+00	1.17E-02
chloroethane	NA	0.00E+00	0.00E+00	2.07E-02
cis-1,3-dichoropropene	NA	0.00E+00	0.00E+00	6.20E-02
cyanide	NA	0.00E+00	0.00E+00	2.03E+00
dibenzo(a,h)anthracene	NA	0.00E+00	0.00E+00	2.82E-02
dichlorodifluoromethane	NA	0.00E+00	0.00E+00	2.48E-02
dieldrin	NA	0.00E+00	0.00E+00	4.48E-04
dimethylnitrosamine	NA	0.00E+00	0.00E+00	7.92E-03
diphenylamine	NA	0.00E+00	0.00E+00	4.48E-02
endrin	NA	0.00E+00	0.00E+00	4.48E-04
ethylene dibromide	NA	0.00E+00	0.00E+00	5.17E-02
heptachlor	NA	0.00E+00	0.00E+00	2.27E-04
hexachlorobenzene	NA	0.00E+00	0.00E+00	3.45E-02
hexachlorocyclohexane alpha bhc	NA	0.00E+00	0.00E+00	2.27E-04
hexachlorocyclohexane beta bhc	NA	0.00E+00	0.00E+00	2.27E-04
isodrin	NA	0.00E+00	0.00E+00	2.27E-04
lindane (all isomers)	NA	0.00E+00	0.00E+00	2.27E-04
methacrylonitrile	NA	0.00E+00	0.00E+00	2.89E-01
methyl bromide	NA	0.00E+00	0.00E+00	5.17E-02
methyl chloride	NA	0.00E+00	0.00E+00	1.03E-01
p-dinitrobenzene	NA	0.00E+00	0.00E+00	7.92E-03
pentachloronitrobenzene	NA	0.00E+00	0.00E+00	1.65E-02
pentachlorophenol	NA	0.00E+00	0.00E+00	2.55E-02
phenol	NA	0.00E+00	0.00E+00	2.14E-02
polychlorinated biphenyls (PCB)	NA	0.00E+00	0.00E+00	3.45E-02
propionitrile	NA	0.00E+00	0.00E+00	1.24E+00
toxaphene	NA	0.00E+00	0.00E+00	8.96E-03
trans-1,3-dichloropropene	NA	0.00E+00	0.00E+00	6.20E-02
triethylamine	NA	0.00E+00	0.00E+00	2.79E-04

Footnotes:

Inventories for radionuclides are as of 10/1/98.

NA entries refer to components where inventory information is not available.

The ^{90}Sr will have ^{90}Y daughter in equilibrium. The ^{137}Cs will have ^{137m}Ba daughter in equilibrium.

Tank inventories of specific organics are not available. Organics are not expected to survive the vitrification process.

4.4 DISPOSAL FACILITY DESIGN

> The design for the ILAW disposal facility (trenches with surface barrier) is based on the mixed waste disposal facility at the Hanford Site. This is a major change from the 1998 ILAW PA which is based on a pre-conceptual design using concrete vaults. Also, conceptual designs have been published for the use of concrete vaults for ILAW.

This section summarizes the data given in *Disposal Facility Data for the Hanford Immobilized Low-Activity Tank Waste* (Puigh 1999), which is included as Appendix I of this document.

The Immobilized Low-Activity Waste (ILAW) disposal planning was to utilize the existing disposal vaults from the grout program suitably modified to receive ILAW packages and new disposal facilities currently in their early design phase. In December 1999 the Department of Energy identified the remote handled trench as the baseline concept for ILAW disposal at Hanford (Taylor 1999a). The 2001 ILAW PA will consider both concepts in assessing long term environmental impacts from the proposed disposal action.

The existing disposal vaults were originally constructed in the late 1980's and early 1990's. These vaults were designed to contain a liquid low-level waste (LLW) grout mixture during the curing and solidification period, and to serve as a disposal structure for the resulting grouted waste monolith. Five vaults were constructed. One vault was filled before termination of the program leaving four empty vaults available for use.

Each vault is 37.6 m (123.5 ft) long and 15.4 m (50.5 ft) wide, with a roof clearance of 10.4 m (34.0 ft), providing 579 m^2 (6,236 ft^2) of floor space. The vaults are constructed of reinforced concrete, and were designed and constructed in compliance with RCRA requirements for both hazardous waste surface impoundments and land disposal units. Each vault is built above a RCRA-compliant leak detection and collection system. The leak detection system consists of a sealed concrete slab sloped to a collection sump fitted with a riser pipe to the surface. The system is capable of collecting, detecting, sampling, and removing any leachate that might escape from the primary vault structure.

A conceptual design activity has been performed to modify the existing disposal vaults to accept and ultimately serve as a disposal facility for the ILAW from the Hanford waste tanks (Pickett 1998a). The existing asphalt layer and concrete "topping" layer above the precast concrete roof slabs will be removed from the four available vaults. For each vault, side wall and end wall extensions 1.8 m (6.0 ft) high will be added to the original top of the side and end walls, respectively. To support the unloading of ILAW packages from the transportation vehicles, rails for a gantry crane are to be placed on top of the side wall extensions and will run the full length of the vaults.

A conceptual design for the new ILAW disposal facilities (Pickett 1998b) utilizes a long concrete vault concept divided into cells. Each vault will be an underground, open-topped, concrete vault approximately 23 m (76 ft) wide, 207.8 m (686 ft) long, and 8.1 m (26.7 ft) deep below grade. The top of the vault walls will extend 1 m (3.3 ft) above grade. Each vault will be divided into 11 cells, separated by concrete partition walls.

Each vault is built above a RCRA-compliant leak detection and collection system. It consists of a cast-in-place reinforced concrete basin approximately 209.5 m (687.0 ft) long, 24.7 m (81 ft) wide with walls 1.07 m (3.5 ft) high. The basin floor is 0.6 m (2 ft) thick and contains steel reinforcing bars within. The catch basin is lined with two flexible membrane liners, and on top of these lie a layer of gravel with perforated collection pipe routed to sumps, one at each end of a vault. Liquids entering the sump can be removed by use of a portable pump lowered down a riser pipe.

Interim closure for each filled cell in the new disposal facility will consist of using inert backfill material followed by a "controlled density fill," unreinforced concrete. A waterproof membrane will be placed above the "controlled density fill." After all cells in the vault have been filled and interim closed, a closure cap consisting of a capillary break followed by a modified RCRA Subtitle C cap will be placed over the entire vault. A similar closure is assumed for the existing disposal vaults. Each vault will be interim closed using the process used for the cell closure for the new disposal facility. After all vaults have been filled and interim closed, a similar closure cap will be placed over all four vaults.

One trench concept that is receiving additional consideration is the Remote Handled (RH) trench concept. Under the ILAW disposal alternative described below, the disposal facility is a Resource Conservation and Recovery Act (RCRA) compliant landfill (i.e., double lined trench with leachate collection system). Many operational aspects and ancillary activities of the landfill (e.g., leachate collection and disposition, storm water control, installation of surface barrier at closure, etc.) would be similar to that incorporated into the Radioactive Mixed Waste Burial Trench, which was designed and constructed under the Solid Waste Program. However, operational activities related to ILAW package receipt and emplacement in the trench would be modified to accommodate the potentially higher radiation dose rate from remote-handled ILAW.

The RH trench complex would be constructed in the same location as the new ILAW disposal facility. The RH trench internal dimensions 260 m long by 80 m wide by 10 m deep. The trench sides have a 3:1 slope.

The current waste package design consists of a cubic, stainless steel package having outer dimensions of 1.4 m on each side. The package is filled to within 85% capacity with the remaining volume filled with silicate sand. The void volume will be less than 5% (by volume). Current plans for waste loading into each disposal facility design is as follows. Each existing disposal vault would contain seven layers of waste packages with 25 x 10 packages on each layer. Each cell within the new ILAW disposal facility vault would contain six layers of waste packages with 12 x 14 packages on each layer. Finally, each remote handled trench would have the packing characteristics outlined in Table 4.2.

Table 4.2 Trench Packing Characteristics

Layer	Cells per layer	Matrix size per cell	Packages per layer
1	2	6 x 132	1,584
2	3	6 x 140	2,520
3	4	7 x 150	4,200
4	6	6 x 160	5,760
		Total packages per trench	14,064

The design for the ILAW disposal facilities has not yet been finalized. Facility uncertainty cases have been identified that may impact disposal performance. For example, the following sensitivity cases have been identified: waste form geometry and waste loading into the glass, new facility vault layout with respect to geometry and groundwater flow, different options for closure, inclusion of a capillary break or side wall diverter into the design, and early failure of the system.

4.5 RECHARGE

Recharge rates are based on lysimetry and tracer measurements as well as computer simulations. The recharge rate for the surface barrier (0.1 mm/year) is reduced from the 0.5 mm/year value in the 1998 ILAW PA. Two natural rates (0.9 and 4.2 mm/year) are given based on the type of surface soil. These rates straddle the value used in the 1998 ILAW PA (3.0 mm/year).

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. Recommendations for recharge rates are taken from *Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment* (Fayer 1999), that is reproduced in Appendix J of this document. Long-term estimates of moisture flux through the ground surface are needed for a fully functional surface cover, the cover sideslope, the immediate surrounding terrain (Pre-Hanford), as well as for degraded cover conditions. The estimates were derived from lysimeter and tracer measurements collected by the ILAW PA activity and by other projects combined with a modeling analysis.

Values for the recharge are given in Table 4.3. Values are given for two separate surface soils, Rupert sands and Burbank loamy sands. The Rupert sands are located at the site of the existing grout vaults and at the southernmost 60% of the new ILAW disposal site. The Burbank loamy sand is located at the northernmost 40% of the new ILAW disposal site. Impacts from degradation of the barrier, vegetation change, climate change, and irrigation were considered in establishing the best estimate and bounding values.

Table 4.3 Recharge Rate Estimates (mm/year) [a]

Surface feature	Pre-Hanford	Construction	Cover design Life	Post Cover Design Life
Surface cover	na	na	0.1 (0.01, 4.0)	0.1 (0.01,4.0)
Cover sideslope	na	na	50 (4.2, 86.4)	50 (4.2, 86.4)
Rupert sand	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)	0.9 (0.16, 4.0)
Burbank Loamy sand	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)	4.2 (2.8, 5.5)
Construction	na	55.4 (50, 86.4)	na	na
na = not applicable				

a best estimate case given, with values for reasonable bounding cases given in parentheses.

4.6 RELEASE RATE FROM THE WASTE FORM PACKAGE

4.6.1 Introduction

The 1998 ILAW PA showed that the release rate from the waste form was one of the key parameters in the performance assessment. This rate is a major determinant of the impact of disposal as well as setting the temporal structure of that impact. The data for determining the waste form release rate are given in *Waste Form Release Data Package for the 2001 Immobilized Low-Activity Waste Performance Assessment* (McGrail 2001), which is also included as Appendix K to this document.

> Key parameters needed to calculate waste form release rates are based on an extensive series of measurements of glasses thought to be in the compositional space of the ILAW product. Data for other needed reaction rates are taken from standard chemical databases. In contrast, the release rate assumed in the base case of the 98 ILAW PA was based on a release rate of 4.4 ppm/year.

The net radionuclide release rate is a function of the intrinsic release rate from the glass attenuated by chemical sinks associated with the formation of secondary phases. Because these rates depend on a variety of parameters (amount of moisture, amount of silicic acid [the main by-product of dissolved glass] in solution, pH, amount and type of secondary phases), which will vary with time, the release rate must be calculated. However, in order for the calculations to be credible they must be based on an accepted paradigm and an extensive database.

4.6.2 Paradigm for Waste Release

The paradigm for the calculations is given in A Strategy to Conduct an Analysis of the Long-Term Performance of Low-Activity Glass in a Shallow Subsurface Disposal System at Hanford (McGrail 2000b). This document has been favorably reviewed (Wicks 1999) by an internationally known set of experts (Dr. Bernd Grambow, Dr. Etienne Vernaz, Prof. Werner Lutze, Dr. Elmer Wilhite, and Dr. George Wicks) who were selected independently of this project by the DOE-EM 50, Tanks Focus Area.

The main thrust of the paradigm is that only a few elementary reactions define the rate-determining step in waste form release. Over the last few decades, a general rate equation has been derived from this simple idea to describe the dissolution of glass (and more ordered materials) into aqueous solution:

$$k = k_o a_{H^+}^{-\eta} \exp\left(\frac{-E_a}{RT}\right)\left[1-\left(\frac{Q}{K_g}\right)^{\sigma}\right]\prod_j a_j^{\eta_j} \qquad (1)$$

where:
- k = dissolution rate, g/m²/d
- k_o = intrinsic rate constant, g/m²/d
- a_{H^+} = hydrogen ion activity
- a_j = activity of the j^th aqueous species that acts as an inhibitor or as a catalyst of dissolution
- E_a = activation energy, kJ/mol
- R = gas constant, kJ/mol·K
- T = temperature, K
- Q = ion activity product
- K_g = pseudoequilibrium constant
- η = power law coefficient
- σ = Temkin coefficient.

As glass is metastable, the reaction proceeds one way (i.e. glass dissolves). Another simple but important reaction is alkali ion exchange. The waste form will contain high concentrations of sodium (up to 25 weight percent). At the temperatures of interest, the exchange of sodium in the glass with hydrogen in the water is important as the reaction effectively increases the pH of the solution.

Both the glass dissolution and ion exchange reactions release glass components to water. However, as the concentration of dissolved glass components increases, solubility limits are often reached and secondary phases can precipitate. Secondary phase formation is important because it can strip chemicals from the aqueous solution, affecting the glass corrosion rate or trap important contaminants.

4.6.3 Waste Form Experiments

The parameters in these equations are established by a set of various experiments, performed at various temperatures and pHs:

- single-pass flow-through test
- product consistency test
- vapor hydration test
- pressurized unsaturated flow-through test.

4.6.3.1 Single-Pass Flow-Through Test

The single-pass flow-through test has solutions of known chemistry flow (at various rates) through a container with glass samples at various temperatures. Such tests determine the intrinsic rate constant (k) of the glass as a function of the various conditions. Many experiments have shown that this rate (also known as the forward rate) is the maximum rate at which glass can dissolve for the given conditions. A limitation of this test is that only very short-term behavior can be determined.

4.6.3.2 Product Consistency Test

The product consistency test was established to compare glasses produced over periods of time (i.e., the consistency of the glass making process). The test, which involves placing a crushed glass in a solution at a fixed temperature, allows long-term testing of glasses to determine how they will behave as the environment surrounding them changes (although in an uncontrolled manner). The major limitations of this test are that the environment changes in an uncontrolled manner and (for ILAW disposal) the test is conducted under saturated conditions.

4.6.3.3 Vapor Hydration Test

The vapor hydration test involves moisture attack at high temperatures (i.e. vapors), which accelerates the dissolution of glasses and the formation of secondary phases. The major limitation of this test is that being performed at much higher temperatures (> 100 ^{o}C) than those of interest (14 ^{o}C). This test could be emphasizing processes important at higher temperatures and missing processes important at the lower temperatures.

4.6.3.4 Pressurized Unsaturated Flow-Through Test

The pressurized unsaturated flow-through test involves flowing unsaturated water with known chemistry through glass samples (which may be crushed, fractured, or in some other form). This test can be used to investigate a variety of conditions as the chemical environment can be monitored and controlled. The major limitations of this test are its newness and its complexity. However, this test comes closest to what will happen in the disposal facility.

4.6.4 Other Data Sources

Data (equilibrium constants) for the formation of secondary phases come mainly from the literature. However, the test conditions described above were used to establish reaction rate constants for the kinetic rate law and for the ion exchange reaction.

4.6.5 Data Values for Glasses

The exact glass composition that the Waste Treatment Plant (WTP) operator will used for ILAW has not been determined. The ILAW PA activity has worked with the WTP contractor, the DOE Environmental Science program, and the Tanks Focus Area to investigate a set of glasses in the likely processing space. For the 2001 ILAW PA, the base analysis case uses LAWABP1 as the reference glass. This glass has the most extensive database of any glass in its compositional space. The composition of LAWABP1 is based on the composition of preliminary BNFL, Inc. glasses. The WTP contractor has indicated that the composition of LAWABP1 remains in their design space. As a sensitivity case, a higher waste loading glass (23 wt% Na_2O), has also been tested. Table 4.4 provides a summary of the best-estimate values for the kinetic rate law parameters important in calculating contaminant release from the LAWABP1 and HLP-31 glass waste forms. Table 4.5 provides the list of secondary phases, chemical reaction, and equilibrium constants that were considered in the waste form release calculations.

Table 4.4. Summary of Best Estimate Rate Law Parameters for LAWABP1 and HLP-31 Glass[a]

Parameter	Meaning	LAWABP1	HLP-31	Comments
k_o	forward rate constant (g m^{-2} d^{-1})	3.4×10^{6}	1.0×10^{7}	HLP-31 based on 26°C data only
K_g	apparent equilibrium constant for glass based on activity product a[SiO_2(aq)]	4.9×10^{-4}	ND	Not Defined. The HLP-31 glass dissolution rate did not change as function of a[SiO_2(aq)]
η	pH power law coefficent	0.35	0.35	HLP-31 value assumed same as LAWABP1
E_a	activation energy of glass dissolution reaction (kJ/mol)	68	68	HLP-31 value assumed same as LAWABP1
σ	Temkin coefficient	1	1	Assigned constant
r_x	Na ion-exchange rate (mol m^{-2} s^{-1})	3.4×10^{-11}	0	No detectable ion exchange rate for HLP-31

Table 4.5. Secondary Phase Reaction Network for LAWABP1 Glass. log K is calculated at 15°C

Phase	Reaction	log K

Aluminum Hydroxide $Al(OH)_3(am)$	$Al(OH)_3(am) = AlO_2^- + H^+ + H_2O$	-13.10
Analcime $Na_{0.96}Al_{0.96}Si_{2.04}O_6 \cdot H_2O$	Analcime = $0.96AlO_2^- + 0.96Na^+ + 2.04SiO_2(aq)$	-9.86
Anatase TiO_2	Anatase + $2H_2O = Ti(OH)_4(aq)$	-6.64
Baddeleyite ZrO_2	Baddeleyite + $2H_2O = Zr(OH)_4(aq)$	-9.29
Catapleite $Na_2ZrSi_3O_9 \cdot 2H_2O$	Catapleite + $2H^+ = 2Na^+ + Zr(OH)_4(aq) + 3SiO_2(aq) + H_2O$	Unknown
Goethite $Fe(OH)_3$	Goethite + $H_2O = Fe(OH)_3(aq)$	-11.09
Herschelite $Na_{1.62}K_{0.50}Al_{2.26}Si_{4.00}O_{12.45} \cdot 6H_2O$	Herschelite = $1.62Na^+ (aq) + 0.50K^+ (aq) + 2.26AlO_2^- + 4SiO_2(aq) + 0.14H^+ + 5.93H_2O$	-40.94
Lanthanum Hydroxide $La(OH)_3(am)$	$La(OH)_3(am) + 3H^+ = 3H_2O + La^{3+}$	22.55
Nontronite-K $K_{0.33}Fe_2Al_{0.33}Si_{3.67}O_{11} \cdot H_2O$	Nontronite-K + $2H_2O = 0.330AlO_2^- + 2Fe(OH)_3(aq) + 0.330K^+ + 3.67SiO_2(aq)$	-43.70
Nontronite-Mg $Mg_{0.165}Fe_2Al_{0.33}Si_{3.67}O_{11} \cdot H_2O$	Nontronite-Mg + $2H_2O = 0.330AlO_2^- + 2Fe(OH)_3(aq) + 0.165Mg^{2+} + 3.67SiO_2(aq)$	-43.36
Nontronite-Na $Na_{0.33}Fe_2Al_{0.33}Si_{3.67}O_{11} \cdot H_2O$	Nontronite-Na + $2H_2O = 0.330AlO_2^- + 2Fe(OH)_3(aq) + 0.330Na^+ + 3.67SiO_2(aq)$	-43.33
Phillipsite $Na_{0.5}K_{0.5}AlSi_3O_8 \cdot H_2O$	Phillipsite = $0.5Na^+ + 0.5K^+ + AlO_2^- + 3SiO_2(aq) + H_2O$	-19.87
Plutonium Oxide PuO_2	$PuO_2 + H^+ + 0.25O_2(g) = PuO_2^+ + 0.5H_2O$	-5.18
Sepiolite $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$	Sepiolite + $8H^+ = 4Mg^{2+} + 6SiO_2(aq) + 11H_2O$	31.29
Sauconite $Na_{0.3}Zn_3(Si,Al)_4O_{10}(OH)_2 \cdot 4H_2O$	Sauconite + $5H^+ = 0.3Na^+ + 3Zn^{2+} + 2.95SiO_2(aq) + 1.3AlO_2^- + 7.5H_2O$	Unknown
Amorphous Silica $SiO_2(am)$	$SiO_2(am) = SiO_2(aq)$	-2.85
Soddyite $(UO_2)_2SiO_4 \cdot 2H_2O$	Soddyite = $2UO_2^{2+} + SiO_2(aq)$	0.39
Weeksite $K_2(UO_2)_2Si_6O_{15} \cdot 4H_2O$	Weeksite + $6H^+ = 2K^+ + 2UO_2^{2+} + 6SiO_2(aq) + 7H_2O$	15.38
Zinc Hydroxide $Zn(OH)_2$	$Zn(OH)_2(am) + 2H^+ = 2H_2O + Zn^{2+}$	14.44

4.7 HYDROLOGY

4.7.1 Overview

Hydrologic processes describe how moisture moves through the subsurface. Because there are distinct regions associated with subsurface flow and transport at the ILAW disposal facilities, the system has been divided into three parts: near-field, far-field, and groundwater.

4.7.2 Near-Field Hydrology Data

The best-estimate and bounding values for the near-field hydrologic parameters were based on literature values as well as measurements done especially for this activity. The values are similar to those of the 1998 ILAW PA.

The processes and data important for moisture flow in the near-field, that is, the zone between the surface and the bottom of the engineered disposal facility is described in *Near-Field Hydrology Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment* (Meyer 1999), which is reproduced as Appendix L. Physical and hydraulic properties (particle size distribution, particle density, bulk density, porosity, water retention, and hydraulic conductivity as a function of moisture content) and associated transport parameters (dispersivity and effective diffusion coefficient) are given for materials of the surface cover, the vault structure, diversion layers, the water conditioning layer, and the backfill materials. Table 4.6 presents best-estimate parameter values for near-field materials. Best estimate values for transport parameters can be found in chapter 5 of *Near-Field Hydrology Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment* and are not repeated here because of their length.

Table 4.6 Best-Estimate Hydraulic Parameter Values For Near-Field Materials

Material	ρ_p (g/cm^3)	ρ_b (g/cm^3)	θ_s	θ_r	α (cm^{-1})	n	K_s (cm/s)
Silt Loam-Gravel admixture	2.72	1.48	0.456	0.0045	0.0163	1.37	$8.4\text{x}10^{-5}$
Compacted Silt Loam	2.72	1.76	0.353	0.0035	0.0121	1.37	$1.8\text{x}10^{-6}$
Sand Filter	2.755	1.88	0.318	0.030	0.538	1.68	$8.58\text{x}10^{-5}$
Gravel Filter	2.725	1.935	0.290	0.026	8.1	1.78	$1.39\text{x}10^{-2}$
Gravel Drainage	2.725	1.935	0.290	0.006	17.8	4.84	2.0
Asphaltic Concrete	2.63	2.52	0.04	0.000	$1.0\text{x}10^{-7}$	2.0	$1\text{x}10^{-11}$
Vault Concrete	2.63	2.46	0.067	0.00	$3.87\text{ x}10^{-5}$	1.29	$1.33\text{x}10^{-9}$
Vault Filler Material	2.63	1.59	0.397	0.005	0.106	4.26	$3.79\text{x}10^{-2}$
Glass Waste	2.68	2.63	0.02	0.00	0.2	3	0.01
Diversion Layer Sand	2.8	1.65	0.371	0.045	0.0683	2.08	$3.00\text{x}10^{-2}$
Diversion Layer Gravel	2.8	1.38	0.518	0.014	3.54	2.66	1.85
Backfill	2.76	1.89	0.316	0.049	0.035	1.72	$1.91\text{x}10^{-3}$

Conditioning layer	2.73	1.59	0.397	0.005	0.106	4.26	3.79×10^{-2}

ρ_p = particle density ρ_b = dry bulk density θ_s = saturated water content
θ_r = residual water content α,n = van Genutchen fitting parameters
K_s = saturated hydraulic conductivity

A discussion of uncertainty in the estimated parameter values and reasonable bounds for parameter values are also presented in the document.

4.7.3 Far-Field Hydrology

The best-estimate and bounding values for the far-field hydrologic parameters were based on samples from the ILAW boreholes as well as other boreholes in the 100 Area. Laboratory measured data were upscaled using stocastic theory. The values are similar to those of the 1998 ILAW PA.

The processes and data important for moisture flow and contaminant transport in the far-field, that is, the region between the bottom of the engineered disposal facility and the water table are described in *Far-Field Hydrology Data Package for the Immobilized Low-Activity Waste Performance Assessment* (Khaleel 1999), which is reproduced as Appendix M. This document summarizes the hydraulic parameter estimates based on data from the ILAW borehole and data on gravelly samples from the 100 Area boreholes. The document also describes the processes for upscaling such small-scale laboratory measurements to field-scale applications, and provides recommendation for parameter estimates to be used at that scale. Table 4.7 provides the best estimate values for parameters impacting moisture flow. Best estimate values for transport parameters (bulk density, diffusivity, and dispersivity) are also described in *Far-Field Hydrology Data Package for the Immobilized Low-Activity Waste Performance Assessment*. The document also presents an overall approach for sensitivity and uncertainty analysis for far-field flow and transport predictions.

Table 4.7 Best-Estimate Hydraulic Parameter Values For Far-Field Layers

Formation	Number of samples	θ_s	θ_r	α (1/cm)	n	ℓ	K_s (cm/s)
Sandy	20	0.375	0.041	0.057	1.768	0.5	2.88E-03
Gravelly	15	0.138	0.010	0.021	1.374	0.5	5.60E-04

θ_s = saturated water content θ_r = residual water content
α,n = van Genutchen fitting parameters ℓ = pore size distribution factor
K_s = saturated hydraulic conductivity

4.7.4 Groundwater

Groundwater hydrology is an integral part of the Hanford Sitewide model. As was noted in Section 3.4.4, this model is mandated for Hanford Site use. Information on the hydrology used can be found in Cole 1997.

4.8 GEOCHEMISTRY

Geochemical values (solubilities and K_ds) are based on site-specific samples for the most part, but in a few cases depend on literature values or chemical similarity. Values are given for 5 zones (having different soil properties and impacts from released waste). These values are similar to the values used in the 1998 ILAW PA.

Geochemical effects are based on the discussion and values presented in *Geochemical Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (Kaplan 1999), provided in Appendix N of this document. The geochemistry is described using two parameters, the distribution coefficient (K_d value) and the solubility product of a specified solid. The distribution coefficient is a thermodynamic construct. It is the ratio of the concentration of a species reversibly adsorbed/exchanged to a geomedia's surface site divided by the concentration of the species in solution. Parameters are given for five zones:

1) Near-Field: inside the disposal facility (K_d and solubility values)
2) Degraded Concrete Vault (K_d and solubility values)
3) Chemically Impacted Far-Field in Sand Sequence (K_d values only)
4) Chemically Impacted Far-Field in Gravelly Sequence (K_d values only)
5) Far Field in Gravel Sequence (K_d values only).

Values are based on site-specific samples for the most part, but in a few cases depend on literature values or chemical similarity. The document describes corrections due to the amount of gravel or moisture present. Since the tables are quite extensive, the only full table displayed is the one for K_d values in the gravel sequence of the far-field zone (see Table 4.8). Other important geochemical data (e.g., near-field field values for important radionuclides) are displayed in Table 4.9. Other information is provided in *Geochemical Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment.*

Table 4.8 Best-Estimate K_d Values For Far-Field Gravel Sequence (a)

Radionuclide	Reasonable Conservative Kd_{gc} (mL/g)	"Probable" Kd_{gc} (mL/g)	Kd_{gc} Range (mL/g)
Ac	6.	30.	6. to 130.
Am	6.	30.	6. to 130.
C	0.05	0.5	0.05 to 100.
Ce	6.	30.	6. to 130.

Radionuclide	Reasonable Conservative Kd_{gc} (mL/g)	"Probable" Kd_{gc} (mL/g)	Kd_{gc} Range (mL/g)
Cl	0.	0.	0. to 0.06
Cm	6.	30.	6. to 130.
Co	100.	200.	100. to 1250.
Cs	50.	200.	50. to 400.
Eu	6.	30.	6. to 130.
^{3}H	0.	0.	0. to 0.06
I	0.	0.01	0.0 to 1.5
Nb	5.	30.	5. to 250.
Ni	5.	30.	5. to 250.
Np	0.2	1.5	0.2 to 2.5
Pa	0.2	1.5	0.2 to 2.5
Pb	800.	600.	800. to 8000.
Pu	5.	15.	5. to 200.
Ra	0.5	1.4	0.5 to 20.
Ru	1.	2.	1. to 100.
Se	0.3	0.7	0.3 to 1.5
Sn	5.	30.	5. to 250.
Sr	0.5	1.4	0.5 to 20.
Tc	0.	0.	0. to 0.06
Th	4.	100.	4. to 250.
U	0.05	0.06	0.01 to 8.
Zr	4.	100.	4. to 250.

[a] The aqueous phase is untainted Hanford groundwater except for trace levels of radionuclides; the solid phase is composed of the unaltered gravel-dominated sequence material. Kd_{gc} is the gravel-corrected K_d value.

Table 4.9 Other Important Geochemical Values

Element	Reasonable Conservative	"Best" Value	Range	Zone
Tc	0.1	1	0.1 to 1.2	Zone 1: Near-Field K_d (mL/g)
U	5	20	10 to 800	Zone 1: Near-Field K_d (mL/g)
U	1×10^{-6}	1×10^{-7}		Zone 1: Near Field Solubility (M)
I	1	2	1 to 5	Zone 2: Degraded Aged Concrete K_d (mL/g)
U	70	100	70 to 250	Zone 2: Degraded Aged Concrete K_d (mL/g)
U	1×10^{-6}	1×10^{-7}		Zone 2: Degraded Aged Concrete Solubility (M)

4.9 DOSIMETRY

Dosimetry values are based on Hanford Site standards and have been approved by the Hanford Environmental Dose Oversight Panel.

Dosimetry scenarios and parameter values are based on the discussion and values presented in

Dosimetry Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment (Rittmann 1999), also Appendix O of this document. The scenarios for human exposure to the hazardous materials associated with the ILAW glass are defined in Appendix B (Mann 1999b). Table 4.10 provides the unit dose factors for the intrusion scenario where a post-intrusion resident lives near the exhumed waste associated with a well drilled through the disposal site. Internal and external contributions are separated because the glass matrix will prevent a portion of the exhumed waste from contributing to the internal dose. All of the exhumed activity contributes to the external dose.

Table 4.11 provides unit dose factors for exposure scenarios that use contaminated groundwater. The first four columns of unit dose factors are based on a well near the disposal facility. The last column is based on groundwater entering the Columbia River.

The first column of unit dose factors," HSRAM Industrial," are for employees of a business that uses well water for drinking and showering. The second column of numbers," HSRAM Residential," are for people in a suburban setting who obtain a portion of their diet from a garden that is irrigated with well water. The third column of numbers, "All Pathways Farmer," adds animal products, such as milk and meat to the exposure scenario. The fourth column of numbers, "Native American Subsistence Resident," can be considered a bounding case in that all intake parameters are maximized. The last column of numbers, "Columbia River Population," give the collective dose to 5 million people living near the Columbia River between the Hanford Site and the Pacific Ocean.

Table 4.10 Unit Dose Factors for Post-Intrusion Resident (mrem per Ci exhumed)

Nuclide	External	Internal
H-3	0	1.46E+02
Se-79	4.24E-02	1.24E+02
Sr-90+D	5.15E+01	2.00E+04
Tc-99	1.69E-01	7.93E+02
Sn-126+D	2.41E+04	1.05E+02
I-129	2.58E+01	6.70E+03
Cs-137+D	6.80E+03	1.23E+03
Pa-231	4.78E+02	3.81E+04
U-233	3.21E+00	2.74E+03
U-234	9.04E-01	2.68E+03
U-235+D	1.66E+03	2.51E+03
U-236	4.81E-01	2.54E+03
U-238+D	2.61E+02	2.45E+03
Np-237+D	2.30E+03	2.39E+04
Pu-239	6.48E-01	1.18E+04
Pu-240	3.34E-01	1.18E+04
Am-241	9.98E+01	1.23E+04

Table 4.11 Total Unit Dose Factors for Low-Water Infiltration Cases

Nuclide	HSRAM Industrial*	HSRAM Residential*	All Pathways Farmer*	Native American Sustenance Resident*	Columbia River Population**
H-3	1.62E-5	4.92E-5	4.58E-5	1.03E-4	2.29E-1
Se-79	2.18E-03	7.26E-03	1.15E-02	3.10E-02	5.03E+01
Sr-90+D	3.83E-02	1.30E-01	1.19E-01	3.38E-01	5.53E+02
Tc-99	3.65E-04	1.31E-03	3.54E-03	1.23E-02	1.46E+01
Sn-126+D	5.28E-03	4.07E-02	5.63E-02	1.20E-01	2.36E+02
I-129	6.90E-02	2.31E-01	3.77E-01	1.21E+00	1.64E+03
Cs-137+D	1.25E-02	4.84E-02	7.53E-02	2.14E-01	3.25E+02
Pa-231	2.68E+00	8.87E+00	7.08E+00	1.84E+01	3.40E+04
U-233	7.51E-02	2.45E-01	2.19E-01	5.77E-01	1.04E+03
U-234	7.35E-02	2.40E-01	2.14E-01	5.65E-01	1.02E+03
U-235+D	6.93E-02	2.28E-01	2.03E-01	5.34E-01	9.62E+02
U-236	6.99E-02	2.28E-01	2.04E-01	5.37E-01	9.65E+02
U-238+D	6.95E-02	2.27E-01	2.03E-01	5.34E-01	9.60E+02
Np-237+D	1.12E+00	3.72E+00	2.97E+00	7.73E+00	1.42E+04
Pu-239	8.94E-01	2.96E+00	2.36E+00	6.14E+00	1.13E+04
Pu-240	8.94E-01	2.96E+00	2.36E+00	6.14E+00	1.13E+04
Am-241	9.19E-01	3.05E+00	2.43E+00	6.32E+00	1.17E+04

* Annual dose in mrem for a groundwater concentration of 1 pCi/l
** Annual dose in person-rem per Columbia River concentration of 1 pCi/l

4.10 AGRICULTURE USE

The future application of Hanford land for potential agriculture use is presented and described in *Determining Reasonable Future Agriculture Land Use on the Hanford Site* (Evans 2000), also Appendix P of this document.

Potential land use and economic scenarios on the Hanford Site favor intensive, large-scale agricultural development growing high-value orchard, vineyard, and vegetable crops. Such large enterprises would be able to afford to import clean water and use high-level water management to minimize deep drainage. It is highly probable that any future irrigation development on the Hanford Site would be pressurized irrigation systems because of the site's very sandy soils and undulating topography. Water would be supplied to the fields by pressurized pipelines rather than canals or ditches. Because of the light soils and widely variable topography of the Hanford Site, new advances in micro-irrigation and self-propelled irrigation (i.e., linear move and center pivot systems) will probably have the most promise for future irrigation.

A reasonable estimate of deep percolation in 50 years would be the current best achievable levels of the best technology: from 2% to 15% of the applied water, not including water applied for frost protection or other non-irrigation uses. Recharge from irrigation would probably range from 50 to 500 mm/yr compared to historical estimated natural recharge rates, even with the expected improved technologies and systems. Wine grapes would have the least recharge, while field crops would potentially have the greatest deep percolation losses. Small acreage, irrigated ranchette development would probably contribute about twice the recharge to the unconfined aquifer systems as large scale irrigation.

Washington State Department of Ecology well data records were reviewed for the area surrounding the Hanford Site. Average screened lengths for the wells in the region ranged from 4.6 to 9.7 m.

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Appendix A

Performance Objectives For The Hanford Immobilized Low-Activity Waste (ILAW) Performance Assessment

ref. HNF-EP-0826, Rev. 3
August 1999

Appendix B

Scenarios For The Hanford Immobilized Low-Activity Waste (ILAW) Performance Assessment

ref. HNF-EP-0828, Rev. 3
August 1999

Appendix C

Selection Of A Computer Code For Hanford Low-Level Waste Engineered-System Performance

ref. PNNL-10830 Rev. 1
March 1998

Appendix D

Subsurface Transport Over Reactive Multiphases (STORM): A General, Coupled Nonisothermal Multiphase Flow, Reactive Transport, and Porous Medium Alteration Simulator, Version 2.0, User's Guide

ref. PNNL-13108
February 2000

Appendix E

Recommendations for Computer Code Selection of a Flow and Transport Code to be Used in Undisturbed Vadose Zone calculations for TWRS Immobilized Wastes

ref. HNF-4356 Rev. 0
April 1999

Appendix F

Verification and Validation for VAM3DF, Version 1.00 (FFS version 1.00)

ref. HNF-5769, Rev. 0
January 2000

Appendix G

Geologic Data Packages for the 2001 Immobilized Low-Activity Tank Waste Performance Assessment

ref. PNNL-12257, Rev. 1
December 1999

Appendix H

Immobilized Low-Activity Tank Waste Inventory Data Package

ref. HNF-4921, Rev. 0
September 1999

Appendix I

Disposal Facility Data for the Hanford Immobilized Low-Activity Tank Waste

ref. HNF-4950, Rev. 1
December 1999

Appendix J

Recharge Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment

ref. PNNL-13033
December 1999

Appendix K

Waste Form Release Data Package for the 2001 Immobilized Low-Activity Waste Performance Assessment

ref. PNNL-13043, Rev. 2
February 2001

Appendix L

Near-Field Hydrology Data Package for the Immobilized Low-Activity Waste 2001 Performance Assessment

ref. PNNL-13035
December 1999

Appendix M

Far-Field Hydrology Data Package for the Immobilized Low-Activity Waste Performance Assessment

ref. HNF-4769, Rev. 1
December 1999

Appendix N

Geochemical Data Package for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment

ref. PNNL-13037
December 1999

Appendix O

Exposure Scenarios and Unit Dose Factors for the Hanford Immobilized Low-Activity Tank Waste Performance Assessment

ref. HNF-SD-WM-TI-707 Rev. 1
December 1999

Appendix P

Prosser Agricultural Report

ref. PNNL-13125
January 2000