PERFORMANCE OBJECTIVES

FOR THE

HANFORD IMMOBILIZED LOW-ACTIVITY WASTE (ILAW) PERFORMANCE ASSESSMENT

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List of Acronyms

ALARA	as low as reasonably achievable
ARAR	applicable or relevant and appropriate requirement
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
EDE	effective dose equivalent
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ILAW	immobilized low-activity waste
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Agency
PA	performance assessment
RCRA	Resource Conservation and Recovery Act
TWRS	Tank Waste Remediation System
TWINS	TWRS Information System
WAC	Washington Administrative Code

1.0 OVERVIEW

The purpose of the next version of the *Hanford Immobilized Low-Activity Tank Waste* (ILAW) *Performance Assessment* (ILAW PA) is to provide an updated estimate of the long-term human health and environmental impact of the disposal of ILAW and to compare these estimates against performance objectives. Since the previous performance assessment (Mann 1998) was issued, considerable additional data on waste form behavior and soil geotechnical properties have been collected. Such a radiological performance assessment is required by U.S. Department of Energy (DOE) Orders on radioactive waste management (DOE 1988a and DOE 1999a).

The ILAW PA will also support other activities necessary for the disposal of ILAW. The Nuclear Regulatory Commission (NRC) has required (Paperiello 1997) that the original ILAW PA (Mann 1998) and updates be supplied in order to support DOE's request that ILAW be classified as incidentalwaste, that is, wastethat is produced in association with reprocessing and meets three criteria (Paperiello 1997):

1) the "wastes have been processed (or will be further processed) to remove key radionuclides to the maximum extent that is technically and economically practical,"

2) the "waste will be incorporated in a solid physical form at a concentration that does not exceed the applicable concentration for Class C [low-level waste] as set out in 10 CFR 61," and

3) the "wastes are managed, pursuant to the Atomic Energy Act, so that safety requirements comparable to the performance objectives set out in 10 CFR Part 61, Subpart C are satisfied."

The NRC expects that the analyses in the ILAW PAs show that the disposal system will meet performance requirements at least as protective as those required by the NRC. In their review of the *Hanford Low-Level Tank Wastes Interim Performance Assessment* (Mann 1997a), the staff of the NRC (Paperiello 1997) indicated that meeting the performance objectives in the interim performance assessment (which are the same as the ones in this document) would indeed meet the performance objectives of the NRC regulations (10 CFR 61).

DOE will also use the 2001 ILAW PA as part of the technical basis for permits required by the State of Washington in its regulation of the disposal of mixed waste. Mixed waste is waste that is both radioactive and dangerous (or radioactive and hazardous if federal terminology is used). The previous version of the ILAW PA only estimated long-term impacts from radionuclides. It must be emphasized that this document provides the performance objectives for the 2001 ILAW PA and that the standards to be used in the permits issued by the State of Washington may have a different basis.

The initial step in performing an assessment of the long-term impact of disposing of low-level waste from Hanford tanks is the determination of criteria by which success or failure will be judged. These criteria, known as performance objectives, are based on

- DOE requirements (primary source),
- NRC requirements,
- EPA land disposal restrictions,
- State of Washington requirements,
- Programmatic requirements, and
- Public involvement

The DOE requirements not only include the regulation directing the creation of the PA, but also regulations that are directly and indirectly cited in that regulation. In addition, other PAs produced in the DOE Complex and "case law" offer precedents that indicate what may constitute a successful performance assessment.

This document updates the performance objectives (Mann 1995) created for the *Hanford Low-Level Tank Wastes Interim Performance Assessment* (Mann 1997) and the *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (Mann 1998). These performance objectives will be used in the next revision of the performance assessment which is scheduled for 2001.

These performance objectives are only for the long-term assessment of the public health and environmental impacts from the disposal of immobilized low-activity tank waste. The TWRS Immobilized Waste Program, of which the ILAW performance assessment activity is a part, has additional objectives that relate to other parts of the Immobilized Waste Program. Thus, for example, worker and public safety during construction and active facility operation are not considered here. Although reviewed by others performing Hanford Site assessments, it must be emphasized that these performance objectives deal only with the ILAW disposal effort and not with the performance objectives of other Hanford Site disposal actions.

As described in the following sections,

2. Introduction
3. Regulations and Other Performance Assessments
4. Programmatic Requirements
5. Public Involvement,

performance objectives have been determined for both radioactive and chemical species. The radiological objectives are shown in Table 1.0 and are unchanged from those radiological performance objectives (Mann 1995) defined for the earlier ILAW PAs. Because the DOE orders on radioactive waste management specify only radiological performance objectives, the chemical goals are displayed in the appendix, Appendix A.

TABLE 1.0 RADIOLOGICAL PERFORMANCE OBJECTIVES

(These are Unchanged from Mann 1995)

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 [j]
All others (total)	15 pCi/ℓ [j]
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 1988a and DOE 1999a)

[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).

2.0 INTRODUCTION

2.1 General Requirements

Before low-level waste may be disposed of, a performance assessment must be written and then approved by the DOE (DOE 1988a, DOE 1999a). The performance assessment is to determine whether "reasonable assurance" exists that the performance objectives of the disposal facility will be met. The DOE requirements for waste disposal (DOE 1988a, DOE 1999a) require (see Appendix B)

- The protection of public health and safety; and
- The protection of the environment.

Although quantitative limits are sometimes stated (for example, the all-pathways exposure limit is 25 mrem/year), usually the requirements are stated in a general nature. Quantitative limits were established by:

- investigating all potentially applicable regulations as well as interpretations of the review panels which DOE has established to review performance assessments,
- interacting with program management to establish the additional requirements of the program, and
- interacting with the public (i.e., the Hanford Advisory Board members; as well as affected Tribal Governments) to understand the values of residents in the Pacific Northwest.

Because of space considerations, not all radionuclides and dangerous chemicals are listed in this document. The radionuclides listed here are those which were explicitly treated in the ILAW PA (Mann 1998). The dangerous chemicals listed here are those most often detected in Hanford tank waste as documented in the *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project* (Wiemers 1998).

2.2 1998 ILAW PA

Presently, there are about 54 million gallons of high-level waste stored in underground tanks located in the central plateau area of the Hanford Site. The present plans are to retrieve these wastes, separate the wastes into streams, and then vitrify each stream. The high-level waste stream would contain relatively little volume, but it would contain the bulk of the radionuclides. The vitrified high-level waste will be stored onsite until it is shipped to a federally approved geological repository. The low-activity waste stream will contain most of the material, but relatively few radionuclides. The vitrified (or immobilized) low-activity waste is planned to be disposed of in near-surface underground vaults in the 200 East Area (which is part of Hanford's central plateau).

The 1998 ILAW PA (Mann 1998) only analyzed the impacts of radionuclides. The most restrictive performance objective was for beta and gamma emitters in groundwater (estimated impact = 2.0 mrem/yr compared to a performance objective of 4.0 mrem/yr). The main radionuclides contributing to this result was ^{99}Tc and ^{79}Se. The next most restrictive performance objective was the all-pathways scenario (estimated impact = 6.4 mrem/yr compared to a performance objective of 25 mrem/yr). The performance objective for alpha emitters in ground water (15 pCi/liter) was more easily met (estimated impact = 1.7 pCi/liter). Performance objectives for surface water protection, air emissions, and protection of inadvertent intrusion were all met by at least a factor of ten.

2.3 Programmatic Uses of the ILAW PA

The TWRS Immobilized Waste Program will use the ILAW PA in a variety of ways. The design of the disposal facilities is in the conceptual model stage. The results of the PA (particularly the sensitivity cases) will be used to optimize the design using subsequent design stages in order to keep doses as low as reasonable achievable. Similarly, the selection of the waste form formulation and processing are in the early stages. The ILAW PA data collection activities as well as the analyses for the document are aiding DOE and BNFL, Inc. in optimizing waste form performance. As the total cost of the retrieval, separation, vitrification, and disposal activities is many 10's of billions of dollars, optimization can have large financial impacts.

3.0 REGULATIONS AND OTHER PERFORMANCE ASSESSMENTS

3.1 Introduction

A number of federal and state regulations are potentially applicable to the determination of how well the public health, safety and the environment must be protected. Table C.1 in Appendix C lists the regulations that were reviewed and that were judged potentially relevant to this proposed disposal action. Quantitative limits from such regulations are contained in the remaining tables of Appendix C.

Other regulations and general environmental acts were not included in Table C.1 because:

- Requirements fall under other parts of the TWRS Immobilized Waste Program (i.e., the National Environmental Policy Act – NEPA);

- Requirements are for different environmental actions (for example, the Comprehensive Environmental Response, Compensation, and Liability Act – CERCLA);

- Requirements deal with general environmental concerns (e.g., Endangered Species Act) and such concerns are thought to be adequately addressed for the long-term by regulations presented here; or

- The regulations are only at a preliminary stage and are likely to change. Examples are the Radiation Site Cleanup Regulation (proposed 40 CFR 196) and Environmental Radiation Standards for Management and Disposal of Low-Level Waste (proposed 40 CFR 193) from the U.S. Environmental Protection Agency. The development of these proposals will be closely followed.

This is not the first performance assessment concerning the disposal of low-level waste in the DOE complex. In fact, it is not the first one concerning Hanford wastes. Such prior assessments provide “case law” interpretations. Table D.1 in Appendix D lists the performance objectives of the other performance assessments in the DOE complex.

3.2 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. This value is used consistently in the regulations (DOE 1988a, DOE 1999a, and 10 CFR 61) and was used in the past performance assessments. However, the EnvironmentalProtection Agency has issued a guidance for CERCLA cleanup actions (EPA 1997) that 15 mrem/yr should be used. Although other methods are available for determining body dose (Mann 1995), the effective dose equivalent method was selected because regulations normally use this method.

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 1996a) 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 (DOE 1993-1). This order sets a limit of 100 mrem in a year from all sources. In addition, the order requires that if the dose is above 30 mrem in a year, then an additional analysis is required. For the Hanford Site, this is considered to be a fence surrounding the present Hanford Site 200 Areas. The *Composite Analysis for the Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* (Kincaid 1998) shows compliance with this requirement.

Little guidance is provided on the interpretation of ALARA (as low as reasonably achievable). The philosophy of the new DOE Order on Radioactive Waste Management is that results from the performance assessment are to be used to minimize potential impacts by better disposal facility designs and better disposal operational practices. The Immobilized Waste Program is integrating design and safety (including environmental considerations) into a single program so that the exposure effects can be minimized. The iterative approach uses environmental and safety analyses of preconceptual designs (see Mann 1996), followed by preliminary and detailed designs using the results of those analyses, followed by more complete environmental and safety analysis (for example, successors to this document). Disposal facility components will be incorporated whenever their inclusion significantly adds protection to human health or to the environment.

The compliance time for this performance assessment is 10,000 years. (The compliance time is the time starting 100 years from the time of closure over which the predicted dose must remain below the performance objectives.) However, the calculation will be carried out to the time of maximum impact if that time is longer than 10,000 years. This compliance time is significantly longer than that included in the guidance for draft DOE Order 435.1 (1,000 years).

The compliance time used is, however, consistent with the compliance time used by the NRC [see, for example, the *Branch Technical Position on a Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities* (NRC 1997)]. Because the waste being disposed of is derived from high-level waste, the NRC has indicated that DOE must protect the public and the environment consistent with NRC standards (Paperiello 1997). Thus, the more conservative time of compliance is used in this performance assessment. The time of compliance used here is consistent with that used in the other Hanford Site performance assessments: the Grout Performance Assessment (Kincaid 1995), the 200 West Area Solid Waste Performance Assessment (Wood 1995), and the 200 East Area Solid Waste Performance Assessment (Wood 1996). Results at 1,000 years will also be presented to compare the impacts to the performance objectives at the DOE time of compliance.

The point of compliance will be the point of maximum exposure at least 100 meters down gradient from the disposal facilities. This follows the requirements of the new DOE manual on radioactive waste management (DOE 1999b). Under the Resource Conservation and Recovery Act (RCRA), the point of compliance for a disposal facility is at the fenceline for the facility. However, no fenceline has yet been established. Moreover, as shown in the previous ILAW PA (Mann 1998), because of the physical extent of the disposal facilities, doses at closer locations are not significantly higher than at a point of compliance at 100 meters.

3.3 Protection for Workers

For this performance assessment, as for others performed under DOE orders on radioactive waste management, worker health is not explicitly addressed. Rather , the more restrictive requirements for the general public are used. Protection for workers during construction and operations will be addressed in the safety analysis report that will be prepared for the Immobilized Waste Program.

3.4 Protection of the Inadvertent Intruder

The exposure limits for protecting a hypothetical inadvertent intruder are consistent with the regulations (DOE 1988a, DOE 1999a, and 10 CFR 61) and with earlier performance assessments. As shown in Table D.1. These limits are 500 mrem (EDE) for a one-time (acute) exposure and 100 mrem (EDE)/year for a continuous exposure.

The compliance time for protecting an inadvertent intruder is defined differently from the time of compliance for protecting the general public or the environment. The inadvertent intrusion time of compliance 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 (DOE 1996b). 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 1995 and Wood 1996) also have used a compliance time of 500 years. This is consistent with the NRC requirement for Class C waste (10 CFR 61) that inadvertent intruders be protected for 500 years.

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 disposal action. Therefore, protection of an inadvertent intruder shall be considered met if the exposure limits are met at 500 years after closure. Calculations will be run from 100 years to 1,000 years after the time of disposal to obtain the doses as a function of time.

3.5 Protection of Ground Water Resources

The protection of ground water resources is the most complicated requirement to determine. The level of protection for groundwater is usually based on its intended use. However, predicting future groundwater use is highly subjective given the long time frames involved in a performance assessment. The quantities being limited (decay rate and dose) differ in the various regulations. Moreover, different regulatory agencies approach the protection of groundwater resources using a variety of methods. In addition, earlier DOE performance assessments have taken different approaches. The guidance under the new DOE order on radioactive waste management (see Appendix B) is to use the site's groundwater protection management plan. However, the Hanford Site's plan (DOE-RL 1995) focuses only on shortterm activities and does not address the metrics to apply for the long-term protection of groundwater.

Previous performance assessments have generalized the requirements from the "National Primary Drinking Water Regulations" (40 CFR 141) for determining if the disposal action meets the groundwater protection requirement. The scenario used is based on a public drinking water system serving at least 25 people and located at the point of compliance of the disposal facility. The previous performance assessments set a limit for the total exposure from all radionuclides for an individual drinking the water at less than 4 mrem (EDE) in a year. The "National Primary Drinking Water Regulations," however, use the limit of 4 mrem in a year not for all radionuclides, but for just beta and gamma emitters. The distance of 100 meters from the disposal facility is given in the manual for the new DOE order on radioactive waste management (DOE 1999b). Four mrem (EDE) in a year was chosen for two reasons. First, the value corresponds to the risk-based limit found in the "National Primary Drinking Water Regulations." Second, for most of the radionuclides, the value is more restrictive (see Table C.9) than decay rate concentration limits specified in the Washington State regulations (WAC 173-200).

The requirements for alpha emitters are the same in both the Washington State (WAC 173-200) and Federal (10 CFR 141) regulations. 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 (^{226}Ra, total radium, and other) and set the same quantitative limits. These decay rate concentration limits (Table 1.0) are used for this performance assessment.

Washington State's requirements for beta emitters are based on a screening level previously used 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 conservative by a factor of about 100. This high degree of conservatism exists for radionuclides, such as ^{99}Tc, that are important in this performance assessment.

For this 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 “Maximum Contaminant Level Goals” subpart of 40 CFR 141 (40 CFR 141, Subpart F) and 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 *Tank Waste Remediation System Environmental Impact Statement* (TWRS EIS) (DOE 1996c), a joint publication of the Washington State Department of Ecology and DOE. Thus, the performance objective is an EDE of 4 mrem in a year for beta/photon emitters and a concentration of 15 pCi per liter for alpha emitters. Although uranium is not restricted by the regulations, for this analysis it is included under other alpha emitters. The values are displayed in Table 1.0. A dose of 4 mrem (EDE) in a year for 70 years corresponds to an incremental health risk of 0.0001 (EPA 1989b).

To ensure compliance with the intent of Federal and State groundwater regulations, the limits shown in Table 1.0 are applied to a well 100 meters downgradient from the disposal facility for a time period of 10,000 years after closure (the same time of compliance as for protection of the general public). Calculations will also be done for a location at the future Hanford Site boundary (DOE 1996b) and for 1,000 years after closure to compare the results at the DOE time of compliance. The hypothetical well from which the water is drawn is sized to provide the minimum public drinking water system that serves 25 people (40 CFR 141).

Performance goals for chemicals were chosen by selecting the most restrictive of the Federal and State groundwater regulations. All inorganic chemicals found in the regulations are included in Table A.1. However, for organic chemicals only those organic chemicals that have been detected frequently in tank waste (Wiemers 1998) are included in Table A.2.

3.6 Protection of Surface Water Resources

Federal (40 CFR 141) and State requirements (WAC 173-201A) for surface water protection are similar in scope and objectives. Both are directed at preventing degradation of surface water quality and preservation of highest priority water uses. The point of compliance for performance assessment purposes is where the groundwater is predicted to reach the Columbia River. The concentration of radionuclides in the groundwater at the point where it enters the Columbia River should meet all the standards listed in Table 1.0.

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

The compliance time for protecting surface water resources is selected as 10,000 years, the same compliance time as for protecting groundwater resources. Calculations will also be done for 1,000 years after closure to compare the results at the DOE time of compliance.

Performance goals for chemicals were chosen by selecting the more restrictive of the Federal and State groundwater regulations. All inorganic chemicals found in the regulations are included in Table A.1. However, for organic chemicals only those organic chemicals that have been detected frequently in tank waste are included in Table A.2.

3.7 Protection of Air Resources

Air emissions limits were taken from the draft DOE manual on radioactive waste management (DOE 1999b) which are the same limits found in Parts H and Q of the "National Emissions Standards for Hazardous Air Pollutants" (40 CFR 61H and 40 CFR 61Q). 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.

4.0 PROGRAMMATIC REQUIREMENTS

The TWRS Immobilized Waste Program has mandated that all wastes to be disposed of and/or stored in the facility shall meet NRC Class C concentration limits (10 CFR 61). In addition, the immobilized waste form will meet Resource Conservation and Recovery Act [RCRA] (40 CFR 261, 40 CFR 264, and 40 CFR 268) concentration limits as well as the requirements of the ILAW treatment contract (BNFL 1998). Table C.8 lists these limits in the immobilized waste form.

Although the ILAW performance assessment is being created to meet the DOE Order (DOE 1988a, DOE 1999a) requirement to prepare a radiological performance assessment, the TWRS Immobilized Waste Program will also use the ILAW PA to support permits required by the Washington State Department of Ecology and the Washington State Department of Health. Therefore, performance goals for concentrations of chemicals have also been established (using the same procedures as for the radionuclides). These performance goals are shown in Appendix A.

5.0 PUBLIC INVOLVEMENT

It is important that Hanford stakeholders have the opportunity to affect the scenarios analyzed in the ILAW performance assessment. Public comments were requested on the original version of this document (Mann 1994) as well as revision 2 (Mann 1999).

A summary of the initial version of the scenarios 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. Their comments and corresponding responses to the previous version of this document are available for review (Murkowski 1995).

Revision 2 of this document was made available for public review following the public involvement procedures established by the Hanford Groundwater / Vadose Zone Integration Project (that is, announcements were made at biweekly meetings, the review period was noted on the published list of Integration Project activities, and the documents were available on the Integration Project's web site). Only the Oregon Office of Energy submitted comments (Blazek 1999) and these mainly dealt with waste classification, the extent of public announcement, and other general program activities. Because of the nature of the comments, no changes were made to revision 2 based on these comments. The comments from the Oregon Office of Energy as well as the responses (Taylor 1999) to them by the Department of Energy's Office of River Protection are available on request.

Comments on this version of the document should be sent to:

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Since calculations for the performance assessment will begin in October 1999, to be effective the comments should be sent as soon as possible.

6.0 REFERENCES

10 CFR 20, “Standards for Protection Against Radiation,”, 10 CFR 20, U.S. Nuclear Regulatory Commission, Washington, D.C., November 24, 1992.

- Subpart C, “Occupational Dose Limits,” Sections 1201 through 1208.
- Subpart D, “Radiation Dose Limits for Individual Members of the Public.”
- Subpart K, “Waste Disposal,” Sections 2001 through 2007.

10 CFR 61, “Licensing Requirements for the Land disposal of Radioactive Waste,” 10 CFR 61, U.S. Nuclear Regulatory Commission, Washington, D.C., May 25, 1989.

- Subpart C, “Performance Objectives,” Sections 40 through 44.
- Subpart D, “Technical Requirements for Land Disposal Facilities,” Sections 50 through 59.

10 CFR 835, “Occupational Radiation Protection,” 10 CFR 835, U.S. Department of Energy, Washington, D.C., November 4, 1998.

- Subpart C, “Standards for Internal and External Exposure,” Sections 202 through 209.

10 CFR 1021, “National Environmental Policy Act Implementing Procedures.”

40 CFR 61, “National Emission Standards for Hazardous Air Pollutants 40 CFR 61, Section 92, U.S. Environmental Protection Agency, Washington, D.C. December 15, 1989.

- Subpart H, “National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities, Section 92.
- Subpart Q, “National Emission Standards for Radon Emissions from Department of Energy Facilities,” Section 192.

40 CFR 141, “National Primary Drinking Water Regulations,” 40 CFR 141, U.S. Environmental Protection Agency, Washington, D.C. December 24, 1975.

- Subpart B, “Maximum Contaminant Levels,,” Sections 11 through 16.
- Subpart F, “Maximum Contaminant Level Goals,” Sections 50 to 51.
- Subpart G, “National Revised Primary Drinking Water Regulations: Maximum Contaminant Levels,” Part 60 to 63.

40 CFR 143, "National Secondary Drinking Water Standards", 40 CFR 143, U.S. Environmental Protection Agency, Washington, D.C., December 15, 1994.

40 CFR 192, “Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, ” 40 CFR 192, U.S. Environmental Protection Agency, Washington, D.C., January 11, 1995.

- Subpart D, “Standards for Management of Uranium Byproduct Materials Pursuant to Section 84 of the Atomic Energy Act of 1954, as Amended,” Sections 30 to 34.

40 CFR 261, "Identification and Listing of Hazardous Waste, "U. S. Environmental Protection Agency, Washington, D.C., August 31, 1993.

- Subpart B, "Criteria for Identifying the Characteristics of Hazardous Waste and for Listing Hazardous Waste," Sections 10 and 11.
- Subpart C, "Characteristics of Hazardous Waste," Sections 20 through 24.

40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," U.S. Environmental Protection Agency, Washington, D.C., February 16, 1993.

- Subpart F, "Release from Solid Waste Management Units," Sections 90 to 101."

40 CFR 268, "Land Disposal Restrictions," U.S. Environmental Protection Agency, Washington, D.C., May 26, 1998.

- Subpart D, "Treatment Standards", Section 40 through 48.

Alm 1997, "Critical Assumptions for Department of Energy Low-Level Disposal Facility Assessments,", letter from A.L. Alm (Assistant Secretary for Environmental Management, U.S. Department of Energy, Washington, D.C.) to John T. Conway (Chairman, Defense Nuclear Facility Safety Board) dated March 7, 1997.

Blazek 1999, M.L. Blazek (Oregon Office of Energy), letter to Fred Mann dated June 9, 1999, Salem, Oregon.

BNFL/DOE 1998, contract between BNFL, Inc. and the U.S. Department of Energy regarding TWRS Privatization, Contract number DE-AC06-96RL13308, Modification No. A005, July 25, 1998.

- Part 1, Section C, Item 2.2.2 contains the Immobilized Low-Activity Waste product requirements.

Code of Federal Regulations. See reference under XX CFR YYY.

DOE Orders

DOE O 420.1, "Facility Safety."
DOE O 430.1, "Life Cycle Asset Management."
DOE O 435.1 (Draft), "Radioactive Waste Management," see DOE 1999a.
DOE O 440.1, "Worker Protection Management for DOE Federal and Contractor Employees."
DOE O 451.1A, "National Environmental Policy Act Compliance Program."
DOE Order 5820.2A, "Radioactive Waste Management," see DOE 1988a.
DOE Order 5400.1, "General Environmental Protection Program," see DOE 1990.
DOE Order 5400.5, "Radiation Protection of the Public and the Environmental," see DOE 1993.

DOE 1988a, DOE Order 5820.2A, "Radioactive Waste Management," U.S. Department of Energy, Washington, D.C., September 26, 1988.

- Chapter III, Section 3a deals with the radiological performance assessment requirements.

DOE 1988b, *Consultation Draft Site Characterization Plan*, DOE/RW-0164, Volume 2, Page 3.4-16, U.S. Department of Energy, Washington, D.C., January 1988.

DOE 1990, "General Environmental Protection Program", DOE Order 5400.1, U.S. Department of Energy, Washington, D.C., June 29, 1990.

DOE 1993, "Radiation Protection of the Public and the Environment," DOE Order 5400.5, U.S. Department of Energy, Washington, D.C., January 7, 1993.

DOE 1996a, "Department of Energy Radiological Health and Safety Policy," DOE P 441.1, U.S. Department of Energy, Washington, D.C. April 26, 1996.

DOE 1996b, *Draft Hanford Remediation Action Environmental Impact Statement sand Comprehensive Land Use Plan*, DOE/EIS-0222D, U.S. Department of Energy, Washington, D.C., August 1996.

DOE 1996c, *Environmental Impact Statement for the Tank Waste Remediation System*, DOE/EIS-1089, U.S. Department of Energy (Washington, D.C.) and the Washington State Department of Ecology (Olympia, Washington), August 1996.

DOE 1996d, *Comparison of Low-Level Waste Disposal Programs of DOE and Selected International Countries*, DOE/LLW-236, U.S. Department of Energy, Washington, D.C., June 1996.

DOE 1996e, "Draft Recommendations on Prospective Assessments for Long-Term Management of Low-Level Radioactive Waste," memorandum from R. Beube, U.S. Department of Energy, Washington, D.C., September 5, 1996.

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

DOE 1999b, *Radioactive Waste Management Manual*, DOE M 435.1, U.S. Department of Energy, Washington, D.C., July 9, 1999.

DOE 1999c, *Implementation Guide for DOE M 435.1*, DOE G 435.1, U.S. Department of Energy, Washington, D.C., July 9, 1999.

DOE 1999d, *Format and Content Guide for U.S. Department of Energy Low-Level Disposal Facility Performance Assessments and Composite Analyses,* DOE G 435.1-1, U.S. Department of Energy, Washington, D.C., September 1999.

DOE 1999e, DOE O 435.1, *Radioactive Waste Management, Technical Basis for DOE M 435.1*, U.S. Department of Energy, Washington, D.C., September 1999.

DOE /RL 1995 *Hanford Site Ground Water Protection Management Plan*, DOE-RL-89-12, Rev. 2, U.S. Department of Energy, Washington, July 1995.

EPA 1988, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversation Factors for Inhalation, Submersion, and Ingestion*, EPA-520/1-88-020, U.S. Environmental Protection Agency, Federal Guidance Report Number 11, U.S. Government Printing Office.

EPA 1989, *Risk Assessment Methodology: Environmental Impact Statement for NESHAPS Radionuclides. Volume 1: Background Information Document*, EPA/520/1-89/005, U.S. Environmental Protection Agency, Washington, D.C., January 1989.

EPA 1997, "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination," OSWER No. 9200.4-18, Environmental Protection Agency, Washington, D.C., 1997.

Hollis 1997, D. Hollis, E. Vold, R. Shuman, K. Birdsell, K. Bower, W. Hansen, D. Krier, P. Longmire, B. Newman, D. Rogers, and E. Springer, *Performance Assessment and Composite Analysis for Los Alamos National Laboratory Material Disposal Area G*, LA-UR-97-85, Los Alamos National Laboratory, Los Alamos, New Mexico, March 1997.

Kincaid 1995, C. T. Kincaid, J.A. Voogd, J.W. Shade, J. H. Westsik, Jr, G. A. Whyatt, M.D. Freshley, M.G. Piepho, K.A. Blanchard, K. Rhoads, and B. G. Lauzon, Performance Assessment of Grouted Double Shell Tank Waste Disposal at Hanford, WHC-DS-WM-EE-004, Rev. 1, Westinghouse Hanford Company, Richland, Washington, May 1995.

Kincaid 1998, C.T. Kincaid, M.P. Bergeron, C.R. Cole, M.D. Freshley, D.L. Strenge, P.D. Thorne, L.W. Vail, and S.K. Wurstner, *Composite Analysis for the Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, PNNL-11800, Pacific Northwest National Laboratory, Richland, Washington, March 1998.

Maheras 1994, S.J. Maheras, A.S. Rood, S.O. Magnuson, M.E. Sussman, and R.N. Bhatt, *Radioactive Waste Management Complex Low-Level Waste Radiological Performance Assessment*, EGG-WM-8773, Idaho National Engineering Laboratory, EG&G Idaho Inc., Idaho Falls, Idaho, May 1994.

Mann 1994, *Overview of the Performance Objectives and Scenarios of the TWRS Low-Level Waste Disposal Program*, WHC-EP-0827, Rev. 0, Westinghouse Hanford Company, Richland, Washington, October 1994.

Mann 1995, F.M. Mann, *Performance Objectives of the Tank Waste Remediation Systems Low-Level Waste Disposal Program*, WHC-EP-0826, Rev. 1, Westinghouse Hanford Company, January 1995.

Mann 1997, F.M. Mann, C.R. Eiholzer, A.H. Lu, P.D. Rittmann, N.W. Kline, Y. Chen, B.P. McGrail, G.F. Williamson, N.R. Brown, and L.A. LaMont, *Hanford Low-Level Tank Waste Interim Performance Assessment*, WHC-EP-0884, Rev. 1, Westinghouse Hanford Company, Richland, Washington, September 1997.

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

Mann 1999, *Overview of the Performance Objectives and Scenarios of the TWRS Low-Level Waste Disposal Program*, WHC-EP-0827, Rev. 2, Westinghouse Hanford Company, Richland, Washington, March 1999.

MMES 1994, *Performance Assessment for Continuing and Future Operations of the Solid Waste Storage Area 6*, ORNL-6783, Oak Ridge National Laboratory, Martin Marietta Energy Systems, Inc. Oak Ridge, Tennessee, February 1994.

Murkowski 1995, "Performance Objectives and Scenarios for the Glass Low-Level Waste Interim Performance Assessment," letter from R.J. Murkowski (Manager, Storage and Disposal Program, Westinghouse Hanford Company) to L. Erickson (U.S. Department of Energy, Richland Operations) dated January 27, 1995.

NRC 1988, *Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility*, NUREG-1200, Rev. 1, U.S. Nuclear Regulatory Commission, Washington, D.C. January 1988.

NRC 1997, Branch Technical Position on Performance Assessment Methodology for Low-Level Disposal Facilities (draft for public comment). NUREG-1573. Low-Level Waste Management Branch, U.S. Nuclear Regulatory Commission, Washington, D.C., May 1997.

Owendoff 1999, Letter from James M. Owendoff (acting Assistant Secretary for Environmental Management, U.S. Department of Energy) to John T. Conway (Chairman, Defense Nuclear Facilities Safety Board), containing the progress report on the implementation of DNFSB Recommendation 94-2, dated April 28, 1999.

Paperiello 1997,"Classification of Hanford Low-Activity Tank Waste Fraction," letter from C.J. Paperiello (Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission) to Jackson Kinzer, dated June 1997.

Schott 1997, G.J. Schott, V. Yuecl, M.J. Sully, L.E. Barker, S.E. Rawlinson, and B.A. Moore, *Performance Assessment / Composite Analysis for the Area 3 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada*, DOE/NV-491, Rev. 2, U.S. Department of Energy, Nevada Operations Office, Lass Vegas, Nevada, September 1997.

Schott 1998, *Performance Assessment for the Area 5 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada*, DOE/NV/11718-176, Rev. 2.1, U.S. Department of Energy, Nevada Operations Office, Lass Vegas, Nevada, January 1998.

Taylor 1999, W.J. Taylor, letter to M.L. Blazek (Oregon Office of Energy) dated July 8, 1999, U.S. Department of Energy, Office of River Protection, Richland, Washington.

WAC 173-200, "Water Quality Standards for Groundwaters of the State of Washington," WAC 173-200, Washington State Department of Ecology, Olympia, Washington, October 31, 1990.

- "Criteria," Section 040.
- "Enforcement limit," Section 050.
- "Point of Compliance," Section 060.

WAC 173-201A, "Water quality Standards for Surface Waters of the State of Washington," WAC 173-201A, Washington State Department of Ecology, Olympia, Washington, December 18, 1997.

- "Toxic Substances," Section 040.
- "Radioactive Substances," Section 050.

WAC 173-303, "Dangerous Waste Regulations," Washington State Department of Ecology, Olympia, Washington, January 12, 1998.

- "Dangerous Waste Characteristics," Section 090.
- "Dangerous Waste Criteria," Section 100.
- "Releases from Regulated Units," Section 645.

WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides," Washington State Department of Ecology, Olympia, Washington, May 7, 1986.

- "Ambient Standard,", Section 040.
- "General Standards for Maximum Permissible Emissions," Section 050.
- "Emission Standards for New and Modified Emission Units," Section 60.

WAC 246-221, "Radiation Protection Standards," Washington State Department of Health, Olympia, Washington, January 31, 1991.

- Occupational Dose Limits for Adults,", Section 010.
- "Dose Limits for Individual Members of the Public," Section 060.
- "Appendix A – Concentrations in Air and Water Above Natural Background," Section 290.

WAC 246-247, "Radiation Protection – Air Emissions," Washington State Department of Health, Olympia, Washington, March 4, 1994.

- "Standards," Section 040.

WAC 246-250, "Radioactive Waste – Licensing Land Disposal," WAC 246-250, Washington State Department of Health, Olympia, Washington, December 20, 1996.

- "General Requirement," Section 160.
- "Protection of the General Population from Releases of Radioactivity," Section 170.
- "Protection of Individuals from Inadvertent Intrusion," Section 180.
- "Protection of Individuals During Operations,", Section 190.

Washington Administrative Code, see WAC XX-YYY.

Wiemers 1998, K.D. Wiemers, M.E. Lerchen, M. Miller, and K. Meier, *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project*, PNNL-12040, Rev. 0, Pacific Northwest National Laboratory, October 1998.

WSRC 1992, *Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility*, WSRC-RP-92-1360, Westinghouse Savannah River Company, Aiken, South Carolina, December 1992.

WSRC 1994, *Radiological Performance Assessment for the E-Area Vaults Disposal Facility*, WSRC-RP-94-218, Westinghouse Savannah River Company, Aiken, South Carolina, April 1994.

Wood 1994, D.E. Wood (chairman), R.U. Curl (technical Secretary), D.R. Armstrong, J.R. Cook, M.R. Dolenc, D.C. Kockner, K.W. Owens, E.P. Regnier, G.W. Roles, R.R. Seitz, and M.I. Wood, *Performance Assessment Test Team Progress Report*, DOE/LLW-157, Rev. 1, Idaho National Engineering Laboratory, Idaho Falls, Idaho, May 1994.

Wood 1995, M.I. Wood, R. Khaleel, P.D. Rittmann, A.H. Lu, S.H. Finfrock, R.J. Serne, and K.J. Cantrell, *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Area Burial Grounds*, WHC-EP-0645, Westinghouse Hanford Company, Richland, Washington, February 1995.

Wood 1996, M.I. Wood, R. Khaleel, P.D. Rittmann, A.H. Lu, S.H. Finfrock, T.H. DeLorenzo, and D.Y. Garbrick, *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Area Burial Grounds,* WHC-EP-0875, Westinghouse Hanford Company, Richland, Washington, September 1996.

Appendix A Dangerous Materials Performance Goals

Chemical concentration limits for groundwater protection and surface water protection are determined by identifying the Federal and State regulations dealing with chemicals in the environments and applying the most restrictive limit. Although organic compounds are not expected to be measurably present in the immobilized product resulting from a vitrification process, organic compounds are listed here.

Table A.1 Performance Goals for Inorganic Materials

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

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

Table A.2 Performance Goals for Organic Compounds [a]

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

(a) Greater than 100 analytical detects in tank waste or greater than 20 analytical detects in TWINS Solid/Liquid Hits. Taken from Wiemers 1998.

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

Appendix B. DOE Orders on Low-Level Waste Disposal

B.1 DOE Order 5820.2A (DOE 1988a) (effective 09/26/88)

This is the DOE Order currently governing the disposal of low-level waste (5820.2A). A new order (435.1 [see section B.2 below]) will replace this order. Chapter III, Section 3a states that the objectives are to

1) "Protect public health and safety in accordance with standards specified in applicable EH orders and other DOE orders.
2) Assure that external exposure to the waste and concentrations of radioactive material which may be released into surface water, ground water, soil, plants, and animals results in effective dose equivalent that does not exceed 25 mrem/yr to any member of the public. Releases to the atmosphere shall meet the requirements of 40 CFR 61. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.
3) Assure that the committed effective dose equivalents received by individuals who inadvertently may intrude into the facility after the loss of active institutional control (100 years) will not exceed 100 mrem/year for continuous exposure or 500 mrem for a single acute exposure.
4) Protect ground water resources, consistent with Federal, State, and local requirements."

B.2 DOE Order 435.1 (DOE 1999a)

B.2.1 DOE Order 435.1 (*Radioactive Waste Management*)

DOE Order 435.1 is the DOE order on radioactive waste management which should be effective when the next version of the *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* is prepared and submitted.

DOE Order 435.1 requires

(4a) "DOE radioactive waste management activities shall be systematically planned, documented, executed, and evaluated."

(4b). "Radioactive waste shall be managed to

(1) Protect the public from exposure to radiation from radioactive materials. Requirements for public protection are in DOE O 5400.5, *Radiation Protection of the Public and the Environment.*

(2) Protect the environment. Requirements for environmental protection are in DOE O 5400.1, *General Environmental Protection Program,* and DOE O 5400.5, *Radiation Protection of the Public and the Environment.*

(3) Protect the work force. Requirements for radiation protection of workers are in 10 CFR 835; requirements for industry safety are in DOE O 440.1, *Worker Protection Management for DOE Federal and Contractor Employees.*

(4) Comply with applicable Federal, state, and local laws and regulations. These activities shall also comply with applicable Executive Orders and other DOE directives."

(4c) "All radioactive waste shall be managed in accordance with the requirements in DOE M 435.1, *Radioactive Waste Management Manual*." [DOE 1999b]

B.2.2 *Radioactive Waste Management Manual* (DOE M 435.1)

The document that implements DOE Order 435.1 is DOE M 435.1, *Radioactive Waste Management Manual* (DOE 1999b). This manual requires (Chapter I, 1D) the following regulations and DOE directives for all DOE radioactive waste management facilities, operations, and activities.

(1D) "**Analysis of Environmental Impacts**. Radioactive waste management facilities, operations, and activities shall meet the requirements of 10 CFR 1021, *National Environmental Policy Act Implementing Procedures*; and DOE O 451.1A, National Environmental Policy Act Compliance Program."

(1E10) "**Mixed Waste**. Radioactive waste that contains a hazardous waste component is also subject to the *Resource Conservation and Recovery Act* (RCRA) as amended." Note hazardous waste is termed "dangerous waste" in Washington State requirements.

(1E13) **"Radiation Protection.** Radioactive waste management facilities, operations, and activities shall meet the requirements of 10 CFR 835, *Occupational Radiation Protection,* and DOE O 5400.5, *Radiation Protection of the Public and the Environment.*"

(1E18) **"Site Evaluation And Facility Design.** New radioactive waste management facilities, operations, and activities shall be sited and designed in accordance with DOE O 420.1, *Facility Safety,* and DOE O 430.1, *Life Cycle Asset Management*."

(1E21) **"Worker Protection.** Radioactive waste management facilities, operations, and activities shall meet the requirements of DOE O 440.1, *Worker Protection Management for DOE Federal and Contractor Employees*."

Section P of Chapter IV of the DOE *Radioactive Waste Management Manual* has additional requirements for low-level waste disposal facilities.

(1) **"Performance Objectives**. Low-level waste disposal facilities shall be sited, designed, operated, maintained, and closed so that reasonable assurance exists that the following performance objectives will be met for waste disposed of after September 26, 1988:

(a) Dose to representative members of the public shall not exceed 25 mrem (0.25 mSv) in a year total effective dose equivalent from all exposure pathways, excluding the dose from radon and its progeny in air.
(b) Dose to representative members of the public via the air pathway shall not exceed 10 mrem (0.10 mSv) in a year total effective dose equivalent, excluding the dose from radon and its progeny.
(c) Release of radon shall be less than an average flux of 20 $pCi/m^2/s$ (0.74 $Bq/m^2/s$) at the surface of the disposal facility. Alternatively, a limit of 0.5 pCi/l (0.185 Bq/l) of air may be applied.

(2) **Performance Assessment**. A site-specific radiological performance assessment shall be prepared and maintained for DOE low-level waste disposal facilities which received waste after September 26, 1988. The performance assessment shall include calculations of potential dose to representative future members of the public and potential releases from the facility to provide reasonable expectation that the performance objectives identified in this Chapter will not be exceeded over a period of 1,000 years after facility closure.

(a) Analyses performed to demonstrate compliance with the performance objectives in this chapter, and to establish limits on performance measures for inadvertent intruders in this chapter shall be based on reasonable activities in the critical group of exposed individuals. Unless otherwise specified, the assumption of average living habits and exposure conditions in representative critical groups of individuals projected to receive the highest dose is appropriate. ...
(b) The point of compliance shall correspond to the point of highest projected dose or concentration beyond a 100 meter buffer zone surrounding the disposed waste. A larger or smaller buffer zone may be used provided adequate justification is provided.
(c) Performance assessments shall address reasonably foreseeable natural processes that might disrupt barriers against release and transport of radioactive materials.
(d) Performance assessments shall use DOE-approved dose coefficients (dose conversion factors) for internal and external exposure of reference adults.
(e) The performance assessment shall include an estimate of the maximum projected dose, flux, or concentration and the time of the maximum, in the sensitivity/uncertainty analysis.
(f) Performance assessments shall include a demonstration that projected releases of the radionuclides to the environment shall be maintained as low as reasonably achievable (ALARA).

(g) For the purpose of establishing limits on radionuclides that may be disposed near-surface, the performance assessment shall include an assessment of impacts to water resources.

(h) For purposes of establishing limits on concentration of radionuclides that may be disposed of near-surface, the performance assessment shall include an assessment of impacts calculated for a hypothetical person assumed to inadvertently intrude into the low-level waste disposal facility. For intruder analyses, institutional controls shall be assumed to be effective in deterring intrusion for at least 100 years following closure. The intruder analyses shall use performance measures of 100 mrem (1 mSv) in a year total effective dose equivalent for chronic exposure and 500 mrem (5 mSv) total effective dose equivalent for acute exposure."

B.2.3 *Implementation Guide for DOE M 435.1* (DOE G 435.1)

The Department of Energy has also issued an implementation guide (DOE 1999c) on how the *Radioactive Waste Management Manual* is to be used.

Section IV.P(1) provides guidance on the performance objectives.

(1) The use of the phrase 'representative members of the public' is "to indicate that overly conservative assumptions such as age, sex, or assumed activities of persons, are not made."

(2) The air-pathway objective (10 mrem in a year) "is for all sources on the DOE site, not just the disposal facility."

(3) Sources of radon include the "constituent of waste at the time of disposal or produced by radioactive decay following disposal."

- "In most cases, the ground surface emanation limit for radon of 20 $pCi/m^2/s$ should be used. However, in cases where the disposed waste radiologically resembles uranium or thorium mill tailings, the limit on air concentration may be warranted. The radon dose can also be calculated as part of the total air dose, in which case, radon does not need to be addressed separately."

Section IV.P.(2) provides guidance on the performance assessment. "Detailed guidance on conducting performance assessments has been developed and is contained in *Format and Content Guide for U.S. Department of Energy Low-Level Disposal Facility Performance Assessments and Composite Analyses*" (DOE 1999d). Guidance explicitly in the implementation guide includes

(1) The compliance time period is 1,000 years after the disposal facility has been closed. "This time was selected to encompass rates of processes likely to govern migration of radiochemical species most likely to contribute to calculated dose. Longer times of assessments are not to be used to assess compliance because of the inherent large uncertainties in extrapolating calculations over long time frames."

(2) "Performance assessment analyses should be based on reasonable activities of the portion of the exposed population likely to receive the highest dose (i.e., the

critical group). The performance assessment analyses should not be based on "worst case" assumptions. Rather, the analyses should be based on scenarios that represent reasonable actions of a typical group of individuals performing activities that are consistent with regional social customs, work, and housing practices, and expected regional environmental conditions at the time of the exposure scenario."

(3) "The concept of a buffer zone is inherent in defining a low-level waste disposal facility. The disposal facility is comprised of a number of disposal units." "Setting the extent of the buffer zone at 100 meters is somewhat arbitary, but 100 meters is considered to be sufficient, but not unreasonably large, for the stated purposes." "In certain cases, e.g. if the disposal facility is located adjacent to the current DOE site boundary, it may be more appropriate to use a smaller buffer zone. In other cases, e.g., where the disposal facility is located far from the DOE site boundary, and the site's land use planning does not envision relinquishing control of the site, a larger buffer zone could be considered."

(4) Natural processes "might disrupt the intended performance of the disposal facility, but such consideration should be limited to those processes which are foreseeable." Examples of such natural processes are corrosion which "will, in time, breach most containers; environmental conditions, will, in time, consume the capacity of chemical buffers, and burrowing animals and root intrusion will eventually breach disposal facility caps." "Other processes or events, although not regularly occurring, are, nonetheless, reasonably foreseeable. Such events would include severe weather such as flooding (e.g., 100 year flood, probable maximum flood), and seismic events. Other processes, such as climate change, are considered to be too speculative for consideration in the performance assessment."

(5) Dose calculations are "for adults (i.e., Reference Man). The actual dose to a particular individual from a given exposure to radioactive material is dependent on a number of characteristics, including age and sex. However, doses are not to be predicted for specific individuals or classes of persons. Rather, the calculations are to represent potential exposures to hypothetical future members of the public."

(6) "Performance assessments should include ALARA assessment that focus on alternatives for low-level waste disposal. The alternatives considered might consider the use of different disposal unit covers, waste forms, containers, or other alternatives (e.g. concrete vaults versus earthen trenches) consistent with the situation being addressed. The rigor of the ALARA assessment and its analysis of alternatives should be commensurate with the magnitude of the risk and decisions to be made."

(7) "The hierarchy for establishing water resource protection performance measures is:

- First, the DOE LLW disposal facility must comply with any applicable State or local law, regulation, or legally applicable requirements for water resource protection.

- Second, the DOE LLW disposal facility should comply with any formal agreement applicable to water resource protection that is made with appropriate State or local officials.
- Third, if neither the above conditions apply, the site should select assumptions for use in the performance assessment based on criteria established in the site groundwater protection management program and any formal land-use plans.
- If none of the above conditions apply, the site should identify a performance measure for protection of water resources that is consistent with the use of water as a drinking water source. Examples of this type of performance measure would be the assumption of the concentration limits in 40 CFR 141 or a dose limit of 4 mrem per year above background from the ingestion of water."

(8) "Although DOE is committed to retaining control of land containing residual radioactive material, such as disposed low-level waste, it is nonetheless appropriate to consider the impacts of potential inadvertent intrusion. Intrusion can be considered either as an accident scenario which could occur during lapses of institutional control or as a hypothetical situation assumed simply to provide a basis for establishing control over the concentration of radioactive material acceptable in a near-surface disposal facility."

"Institutional control should be assumed to be effective in preventing intrusion for 100 years following disposal facility closure. Longer periods may be assumed with justification (e.g. land-use planning, passive controls)."

"Development of intruder scenarios should be based on the following assumptions

- Intruders could carry out activities for no more than about a year before discovery.
- An intruder performs reasonable activities consistent with regional social customs and well drilling, excavation, and construction practices, and the regional environmental conditions projected for the time that intrusion is assumed to occur.
- Intrusion events involve random contact with waste.
- An intruder will take reasonable, investigative actions upon discovery of unusual materials.
- Intrusion events that contact waste should normally be assumed to be limited to drilling or simple extraction scenarios involving use of relatively unsophisticated tools and commonplace machinery.
- Doses calculated for an intruder will depend on waste disposal facility design and operating practices, and may be reduced by practices such as disposal below depths normally associated with common construction activities, use of intruder barriers or durable waste forms or containers, or distributed disposal of higher activity waste."

"The inadvertent intruder assessment should, at a minimum, include consideration of an acute construction scenario, an acute well drilling scenario, and a chronic agricultural scenario."

B.2.4 *Technical Basis for DOE M 435.1*

Further information is given in the *Technical Basis for DOE M 435.1* (DOE 1999e). In particular, the sections on the performance objectives and performance assessment given justification for the approach taken and the values used.

1) The requirement of an all-pathways effective dose equivalent "is consistent with established radiation protection practice that allocates a fraction of the 100 mrem/yr public dose to a particular practice or activity. It is also consistent with the regulatory practice of the NRC to require all-pathways assessments, and this is consistent with the NRC low-level waste disposal facility licensing regulations at 10 CFR 61."

2) The requirement on groundwater protection "provides defense in depth to the all pathways performance objective." "Guidance developed for this requirement describes a tiered structure for its application. The guidance is based on a recognition that at the current time, there are no applicable Federal regulations. Therefore, the emphasis is to be consistent with the site's groundwater protection management program. Also, the role of future use commitments between DOE and other authorities in the management of water resources may provide a sound basis for making decisions."

3) The time period for compliance (1,000 years after closure) "was selected after consideration of the times used in other regulations (e.g. 10 CFR 191, 40 CFR 192), and recognition of the uncertainties and hypothetical nature of long-term projections." "based on the study, *Comparison of Low-Level Waste Disposal Programs of DOE and Selected International Countries* (DOE/LLW-236) [DOE 1996d] two countries (Canada and Sweden) have established a time of compliance of 10,000 years. The other two countries (France and the United Kingdom) have not specified a time of compliance. Similarly, to date, DOE, NRC, and EPA have not specified a time of compliance for low-level waste disposal facility performance assessments. A team composed of primarily of DOE contractor performance assessment staff evaluated the options for a time of compliance. In its progress report, *Performance Assessment Task Team Progress Report* (DOE/LLW-157, Rev. 1) [Wood 1994], the team recommended a time of compliance of 10,000 years. This time was consistent with the time specified on 10 CFR 191 for high-level and transuranic waste disposal, and was considered to be conservative in that no longer times had been seriously proposed. This time or longer times had been used in DOE disposal facility performance assessments conducted up to that time. Subsequently, EPA asked agency reviewers for their opinions on the use of 10,000, 1,000, or some other time frame as the time of compliance for low-level waste disposal facility performance assessments. DOE responded that its position was that 1000 years was an appropriate time."

4) The “point of compliance is consistent with regulatory positions included in 40 CFR 192.32 and 40 CFR 264.95. The NRC regulation at 10 CFR 61.52(a)(8) states that a ‘buffer zone of land must be maintained between any buried waste and the disposal site boundary …’ In NUREG-1200, section 4.3.6 [NRC 1988] it is recommended that this buffer be at least 30 m wide. The Performance Assessment Task Team recommended a point of compliance of 100 meters in the *Performance Assessments Task Team Progress Report* (DOE/LLW-157, Rev. 1). [Wood 1994] In the *Draft Recommendations on Prospective Assessments for Long-Term Management of Low-Level Radioactive Waste* (memorandum, R. Beube, dated September 5, 1996) [DOE 1996e], the DOE Office of Environment recommended that the point of compliance should be at the point of public access. Therefore the point of compliance would be the site boundary. The Office of Environment recommendations further acknowledged that it may be prudent to use a closer point of assessment if there is uncertainty about the future location of the site boundary. 40 CFR 192.32 permits the establishment of alternative concentration limits that are as low as reasonable and meet the standards of 40 CFR 264.94(a) at all points at a greater distance than 500 meters from the edge of the disposal area and/or outside the site boundary.”

5) “The rationale for using standard adult dose conversion factors comes from the fact that in a performance assessment one is calculating a postulated dose to a hypothetical future person assumed to be engaged in a set of ‘normal’ activities over a period of years. Consequently, performing calculations as if real people of known age were being impacted by releases from the facility is not reasonable.”

6) “in addition to calculations over the time of compliance (1000 years), performance assessments also are to present calculations of maxima relative to each of the performance objectives. The results of these calculations are part of the sensitivity and uncertainty analysis which would support a conclusion that the model is providing a reasonable projection. These longer calculations address the need to ensure that there are no unexpected significant increases shortly after the time of compliance and provide a mechanism for understanding the model performance and significance of modelling parameters. The calculation of maxima does present the possibility that there may be results that exceed the performance objectives. The significance of these results must be handled with caution and judgement. The further out in time that the maxima occurs, the less significant is the relationship to the performance objective.”

   “This requirement represents a DOE policy decision; it derives in part from IAEA Fundamental Principles of Radioactive Waste Management.”

7) “The use of the ALARA concept in long-term assessments is a best management practice that contributes defense-in-depth to the possible exposures from a disposal facility. Application of the ALARA principle for managing current operational exposures has practical and measurable merit in that real doses are being avoided or reduced. This concept is extended here by addressing projected releases of materials well into the future which <u>may</u> result in doses.”

8) “The concept of protection of inadvertent intrusion is consistent with national and international practice (NRCP, ICRP, IAEA). The NRC included the protection of inadvertent intruders as one of the performance objectives in 10 CFR 61. Other international and national organizations have and continue to include the protection of inadvertent intruders as one of the elements of radiation protection.”

“Since the intent of the Department is to control the use of the land where low-level waste is disposed until the land can be released, inadvertent intruder calculations provide defense-in-depth by limiting the concentration of waste that can be disposed of in the near surface. With each performance assessment evaluating and developing limits for near-surface disposal, DOE is more cost-effective in managing waste and is consistent with the philosophy of using performance based requirements.”

Appendix C   Supporting Tables

Table C.1 List of Relevant Regulations

REGULATION	COMMENT
Radioactive Waste Management (DOE Order 5820.2A) [DOE 1988a]	Current DOE order covering disposal of low-level waste.
Radioactive Waste Management (DOE Order 435.1) [DOE 1999a]	New DOE order covering disposal of low-level waste, released July 9, 1999.
Licensing Requirements for Land Disposal of Radioactive Wastes (10 CFR 61)	Requirements of the Nuclear Regulatory Commission for the land disposal of low-level radioactive waste
Radioactive Waste – Licensing and Disposal (WAC 246-250)	Sets requirements for disposal of low-level radioactive wastes in the State of Washington
General Environmental Protection Program (DOE Order 5400.1) (DOE 1990)	Lists executive orders, laws, and regulations which DOE actions must meet
Radiation Protection of the Public and the Environment (DOE Order 5400.5) (DOE 1993)	Provides exposure limits for general activities
Department of Energy Radiological Health and Safety Policy (DOE 1996a)	Establishes basis of DOE's radiological control programs
Occupational Radiation Protection (10 CFR 835)	Establishes radiation protection standards, limits, and programs for protecting individuals from ionizing radiation from the conduct of DOE activities
Standards for Protection Against Radiation (10 CFR 20)	Establishes standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the NRC.
Radiation Protection Standards (WAC 246-221)	Sets radiation protection standards for the state of Washington
National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities (40 CFR 61.192)	Establishes maximum exposure to public via air pathway for non-radon radionuclides
National Emission Standards for Radon Emissions from Department of Energy Facilities (40 CFR 61.192)	Establishes maximum exposure to public of Ra-222 via air pathway
Ambient Air Quality Standards and Emission Limits for Radionuclides (WAC 173-480)	Sets emission standards into air for radionuclides in the state of Washington
Radiation Protection – Air emissions (WAC 246-247)	Sets radioactive air emissions standard
National Primary Drinking Water Regulations (40 CFR 141)	Sets drinking water standards
Water Quality Standards for Ground Waters of the State of Washington (WAC 173-200)	Sets standards for ground waters in the State of Washington

REGULATION	**COMMENT**
Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A)	Sets standards for surface waters in the State of Washington
Identification and Listing of Hazardous Waste (40 CFR 261)	Establishes which wastes are subject to RCRA
Land Disposal Restrictions (40 CFR 268)	Limits disposal options for hazardous wastes
Dangerous Waste Regulations (WAC 173-303)	Implements RCRA in the State of Washington

Table C.2 Requirements Of Relevant General Radioactive Waste Regulations

DOE Order 5820.2a: (DOE 1988a)	
All pathways	25 mrem/year
ALARA	See footnote
Intruder (100 years)	100 mrem/year (continuous)
Intruder (100 years)	500 mrem (single event)

DOE M 435.1 (DOE 1999b)	
All pathways (<1,000 years)	25 mrem/year
ALARA	See footnote
Intruder (> 100 years or larger)	100 mrem/year (continuous)
Intruder (> 100 years or larger)	500 mrem (single event)

DOE Order 5400.5 (DOE 1993)	
All pathways (from all DOE facilities at the site)	100 mrem/year (analysis performed by a separate document)

WAC 246-221-060	
All pathways	2 mrem/hour
All pathways	100 mrem/year

10 CFR 61. 41	
All pathways (whole body)	25 mrem/year
All pathways (thyroid)	75 mrem/year
All pathways (other organs)	25 mrem/year
Only Class C disposal	See Table C.8

WAC 246-250-170	
All pathways (whole body)	25 mrem/year
All pathways (thyroid)	75 mrem/year
All pathways (other organs)	25 mrem/year

Following DOE Order 435.1 guidance, ALARA restrictions are taken to require sensitivity studies showing the significance of various design options.

Table C.3 Requirements of Relevant Worker Protection Regulations

10 CFR 835	
All pathways (effective dose equivalent)	5,000 mrem/year
Sum of deep dose equivalent for external exposures and the committed dose equivalent to any organ or tissue other than the lens of the eye	50,000 mrem
Lens of the eye (dose equivalent)	15,000 mrem
Shallow dose equivalent to the skin or any extremity	50,000 mrem
WAC 246-221-010	
All-Pathways	5,000 mrem/year
Sum of deep dose equivalent for external exposures and the committed dose equivalent to any organ or tissue other than the lens of the eye	50,000 mrem
Lens of the eye (annual limit)	15,000 mrem
Shallow dose equivalent to the skin or any extremity (annual limit)	50,000 mrem

Table C.4 Requirements of Relevant Air Regulations

DOE O 435.1	
Air emissions (except radon)	10 mrem/year
Air emissions (radon)	20 pCi/m^2s

DOE Order 5400.5 (DOE 1993)	
Air emissions (except radon)	10 mrem/year

40 CFR 61.92	
Air emission (except radon)	10 mrem/year

40 CFR 61.192	
Air emissions (radon)	20 pCi/m^2s

WAC 173-480-040	
Air emissions (except radon) (whole body)	25 mrem/year
Air emissions (except radon) (critical organ)	75 mrem/year

WAC 173-480-060
Best available radionuclide control technology

WAC 246-247-040
References WAC 173-480 and 40 CFR 61

Table C.5 Requirements of Relevant Drinking Water Regulations

DOE Order 5400.5 (DOE 1993)	
Radionuclides	4 mrem/year
Ra-226 plus Radium-228	$5x10^{-9}$ µCi/ml (= 5 pCi/l)
Alpha emitters (but not Rn nor U)	$1.5x10^{-8}$ µCi/ml (=15 pCi/l)

40 CFR 141.11	
Arsenic	0.05 mg/l

40 CFR 141.12	
Trihalomethanes	0.10 mg/l

40 CFR 141.15	
Ra-226+Ra-228	5 pCi/l
Alpha activity (except Ra and U)	15 pCi/l

40 CFR 141.16	
Beta and photon activity (2 L/d)	4 mrem/year
H-3	20,000 pCi/l
Sr-90	8 pCi/l

40 CFR 141.61		
CAS #	Constituent (a)	Limit
56-23-5	Carbon tetrachloride	0.005 mg/l
71-43-2	Benzene	0.005 mg/l
71-55-6	1,1,1-Trichloroethane	0.2 mg/l
75-09-2	Dichloromethane (Methylene Chloride)	0.005 mg/l
79-00-5	1,1,2-Trichloroethane	0.005 mg/l
79-01-6	1,1,2-Trichloroethylene	0.005 mg/l
95-47-6	o-Xylene	0.7 mg/l
100-41-4	Ethyl benzene	0.1 mg/l
106-46-7	1,4-Dichlorobenzene	0.075 mg/l
108-88-3	Toluene	1.0 mg/l
127-18-4	1,1,2,2-Tetrachloroethene	0.005 mg/l

40 CFR 141.62			
Antimony	0.006 mg/l	Barium	2.0 mg/l
Beryllium	0.004 mg/l	Cadmium	0.005 mg/l
Chromium	0.1 mg/l	Cyanide	0.2 mg/l
Fluorine	4.0 mg/l	Mercury	0.002 mg/l
Nitrate (as N)	10. mg/l	Nitrite (as N)	1. mg/l
Nitrate + Nitrite (as N)	10. mg/l	Selenium	0.05 mg/l
Thallium	0.002 mg/l		

a Greater than 100 analytical detects in tank waste or greater than 20 analytical detects in TWINS Solid/Liquid Hits. Taken from Wiemers 1998.

Table C.6 Requirements of Relevant Groundwater Regulations

40 CFR 264.94			
Arsenic	0.005 mg/l	Barium	1.0 mg/l
Cadmium	0.01 mg/l	Chromium	0.05 mg/l
Lead	0.05 mg/l	Mercury	0.002 mg/l
Selenium	0.01 mg/l	Silver	0.05 mg/l

WAC 173-200-040	
Alpha emitters	15 pCi/l
Beta emitters	50 pCi/l
H-3	20,000 pCi/l
Sr-90	8 pCi/l
Ra 226 plus Ra-228	5 pCi/l
Ra 226	3 pCi/l

Chemical	**WAC 173-200-040**	**WAC 173-303-645**
Arsenic	0.00005 mg/l	0.05 mg/l
Barium	1 mg/l	1 mg/l
Cadmium	0.01 mg/l	0.01 mg/l
Chlorine	250. mg/l	
Chromium	0.05 mg/l	0.05 mg/l
Copper	1. mg/l	
Fluorine	4. mg/l	
Iron	0.30 mg/l	
Lead	0.05 mg/l	0.05 mg/l
Manganese	0.05 mg/l	
Mercury	0.002 mg/l	0.002 mg/l
Selenium	0.01 mg/l	0.01 mg/l
Silver	0.05 mg/l	0.05 mg/l
Zinc	5. mg/l	
Sulfate (SO_4)	250. mg/l	
Nitrate (as N)	10. mg/l	
CAS #	Constituent (a)	**WAC 173-200-040**
56-23-5	Carbon tetrachloride	0.0003 mg/l
67-66-3	Chloroform	0.007 mg/l
71-43-2	Benzene	0.001 mg/l
71-55-6	1,1,1-Trichloroethane	0.003 mg/l
75-09-2	Dichloromethane (Methylene Chloride)	0.005 mg/l
106-46-7	1,4-Dichlorobenzene	0.004 mg/l
117-81-7	Bis(2-ethylhexyl)phthalate	0.006 mg/l

a Greater than 100 analytical detects in tank waste or greater than 20 analytical detects in TWINS Solid/Liquid Hits. Taken from Wiemers 1998.

Table C.7 Requirements Of Relevant Surface Water Regulations

WAC 173-201A-040			
Ammonia	4.0 mg/l	Arsenic	0.19 mg/l
Cadmium (a)	0.00077 mg/l	Chlorine	230. mg/l
Copper (a)	0.0078 mg/l	Chromium	0.011 mg/
Cyanide	0.0052 mg/l	Lead (a)	0.00146 mg/l
Mercury	0.000012 mg/l	Nickel (a)	0.115 mg/l
Selenium	0.005 mg/l	Zinc (a)	0.072 mg/l

a based on Columbia River at Pasco having a mean hardness of 73 mg/l (DOE 1988b)

WAC 173-201A-050	
Radionuclides	0.01 of WAC 246-221-290 Or EPA drinking water standards (40 CFR 141, see Table C.5 above)
Radionuclide (a)	0.01 of WAC 246-221-290
H - 3	200. pCi/l
Se- 79	3. pCi/l
Sr- 90	8. pCi/l
Zr- 93	3. pCi/l
Nb- 93m	8. pCi/l
Tc- 99	20. pCi/l
Sn-126	0.2 pCi/l
I -129	0.04 pCi/l
Cs-137	0.6 pCi/l
Ra-226	0.003 pCi/l
Ra-228	0.005 pCi/l
Th-232	0.000005 pCi/l
Pa-231	0.000006 pCi/l
U –233	0.005 pCi/l
U –234	0.005 pCi/l
U –235	0.006 pCi/l
U –236	0.005 pCi/l
U –238	0.006 pCi/l
Np-237	0.00002 pCi/l
Pu-239	0.00003 pCi/l
Pu-240	0.00003 pCi/l
Am-241	0.00003 pCi/l
Am-243	0.00003 pCi/l

Table C.8 Requirements of Relevant Regulations for Concentrations in Waste

BNFL Contract (BNFL/DOE 1998)			
Sr 90	3 Ci/m^3	Tc 99 (a)	0.1 Ci/m^3
Cs 133	3 Ci/m^3		
On average, 80% of Tc99 delivered from vendor shall be removed			

10CFR61.55 (limits given are for isotope in activated metal)			
C - 14	8. Ci/m^3	Ni- 59	220. Ci/m^3
Ni - 63	700. Ci/m^3	Nb-94	0.2 Ci/m^3
Sr - 90	7000. Ci/m^3	I-129	0.08 Ci/m^3
Cs - 137	4600. Ci/m^3		
Alpha emitters (with half-lives greater than 5 years)			100 nCi/g
Pu – 241	3500 nCi/g	Cm-242	20000 nCi/g

40 CFR 261.24 (a)			
Arsenic	5 mg/l	Barium	100 mg/l
Cadmium	1 mg/l	Chromium	5 mg/l
Lead	5 mg/l	Mercury	0.2 mg/l
Selenium	1mg/l	Silver	5 mg/l
`CAS #	Constituent (b)		
56-23-5	Carbon tetrachloride		0.5 mg/kg
67-66-3	Chloroform		6.0 mg/kg
78-93-3	2-Butanone (Methyl ethyl ketone)		200. mg/kg
79-00-5	1,1,2-Trichloroethane		0.5 mg/kg
106-46-7	1,4-Dichlorobenzene		7.5 mg/kg
110-86-1	Pyridine		5. mg/kg
127-18-4	1,1,2,2-Tetrachloroethene		0.7 mg/kg

40 CFR 268.40 (a)			
Arsenic	5.0 mg/l	Barium	100 mg/l
Cadmium	1.0 mg/l	Chromium (total)	5.0 mg/l
Cyanide	590 mg/kg	Lead	5.0 mg/l
Mercury	0.02 mg/l	Selenium	5.7 mg/l
Silver	5.0 mg/l		
CAS #	Constituent (b)		Waste limit
56-23-5	Carbon tetrachloride		6.0 mg/kg
67-56-1	Methyl alcohol		0.75 mg/l
67-64-1	2-Propanone (Acetone)		160. mg/kg
67-66-3	Chloroform		6.0 mg/kg
71-36-3	n-Butyl alcohol		2.6 mg/kg
71-43-2	Benzene		10. mg/kg
71-55-6	1,1,1-Trichloroethane		6. mg/kg
74-87-3	Chloromethane (Methyl Chloride)		30. mg/kg

75-05-8	Acetonitrile	38. mg/kg
75-09-2	Dichloromethane (Methylene Chloride)	30. mg/kg
75-69-4	Trichlorofluoromethane	30. mg/kg
75-71-8	Dichlorodifluoromethane	7.2 mg/kg
76-13-1	1,2,2-Trichlorotrifluoroethane	30. mg/kg
78-93-3	2-Butanone (Methyl ethyl ketone)	36. mg/kg
79-00-5	1,1,2-Trichloroethane	6. mg/kg
79-01-6	1,1,2-Trichloroethylene	6. mg/kg
95-47-6	o-Xylene	30. mg/kg
100-41-4	Ethyl benzene	10. mg/kg
106-46-7	1,4-Dichlorobenzene	6.0 mg/kg
107-12-0	Propionitrile (Ethyl Cyanide)	360. mg/kg
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	33. mg/kg
108-88-3	Toluene	10. mg/kg
108-94-1	Cyclohexane	0.75 mg/l
110-86-1	Pyridine	16. mg/kg
117-81-7	Bis(2-ethylhexyl)phthalate	28. mg/kg
127-18-4	1,1,2,2-Tetrachloroethene	6. mg/kg

40 CFR 268.48 (Universal Treatment Standards)(a)			
Antimony	1.15 mg/l	Arsenic	5.0 mg/l
Barium	21. mg/l	Beryllium	0.014 mg/l
Cadmium	0.11 mg/l	Chromium (total)	0.60 mg/l
Cyanide (total)	590. mg/kg	Lead	0.75 mg/l
Mercury	0.025 mg/l	Nickel	11.0 mg/l
Selenium	5.7 mg/l	Silver	0.14 mg/l
Thallium	0.078 mg/l	Vanadium	0.23 mg/l
Zinc	5.3 mg/l		

CAS #	Constituent (b)	
56-23-5	Carbon tetrachloride	6.0 mg/kg
67-56-1	Methyl alcohol	0.75 mg/l
67-64-1	2-Propanone (Acetone)	160. mg/kg
67-66-3	Chloroform	6.0 mg/kg
71-36-3	n-Butyl alcohol	2.6 mg/kg
71-43-2	Benzene	10. mg/kg
71-55-6	1,1,1-Trichloroethane	6. mg/kg
74-87-3	Chloromethane (Methyl Chloride)	30. mg/kg
75-05-8	Acetonitrile	38. mg/kg
75-09-2	Dichloromethane (Methylene Chloride)	30. mg/kg
75-69-4	Trichlorofluoromethane	30. mg/kg
75-71-8	Dichlorodifluoromethane	7.2 mg/kg
76-13-1	1,2,2-Trichlorotrifluoroethane	30. mg/kg
78-93-3	2-Butanone (Methyl ethyl ketone)	36. mg/kg
79-00-5	1,1,2-Trichloroethane	6. mg/kg
79-01-6	1,1,2-Trichloroethylene	6. mg/kg
95-47-6	o-Xylene	30. mg/kg

100-41-4	Ethyl benzene	10. mg/kg
106-46-7	1,4-Dichlorobenzene	6.0 mg/kg
107-12-0	Propionitrile (Ethyl Cyanide)	360. mg/kg
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	33. mg/kg
108-88-3	Toluene	10. mg/kg
108-94-1	Cyclohexane	0.75 mg/l
110-86-1	Pyridine	16. mg/kg
117-81-7	Bis(2-ethylhexyl)phthalate	28. mg/kg
127-18-4	1,1,2,2-Tetrachloroethene	6. mg/kg

WAC 173-303-090 (a)			
Arsenic	5 mg/l	Barium	100 mg/l
Cadmium	1 mg/l	Chromium	5 mg/l
Lead	5 mg/l	Mercury	0.2 mg/l
Selenium	1 mg/l	Silver	5 mg/l
CAS #	Constituent (b)		
56-23-5	Carbon tetrachloride		0.5 mg/kg
67-66-3	Chloroform		6.0 mg/kg
78-93-3	2-Butanone (Methyl ethyl ketone)		200. mg/kg
79-00-5	1,1,2-Trichloroethane		0.5 mg/kg
106-46-7	1,4-Dichlorobenzene		7.5 mg/kg
110-86-1	Pyridine		5. mg/kg
127-18-4	1,1,2,2-Tetrachloroethene		0.7 mg/kg

a where unit is “mg/l”, then concentration is established by a TCLP test.

b Greater than 100 analytical detects in tank waste or greater than 20 analytical detects in TWINS Solid/Liquid Hits. Taken from Wiemers 1998.

Table C.9 Conversion between Water Concentration and Dose [(*)]

Nuclide (Taken from ILAW PA [Mann 1998])	Concentration (pCi/l)	Dose (mrem/year)
H-3	20,000. [a,b,g,s]	0.92 [g,s]
C-14	50 [a] 3 [c]	0.076 [g] 4. [b] 0.015 [s]
Se-79	50. [a] 3. [c]	0.3 [g] 4. [b] 0.2 [s]
Sr-90	8. [a,b,g] 3. [c,s]	0.82 [g] 0.31 [s]
Zr-93	50. [a] 3. [c]	0.06 [g] 4. [b] 0.012 [s]
Nb-93m	50. [a] 8. [c]	0.02 [g] 4. [b] 0.004 [s]
Tc-99	50. [a,g] 20. [c]	0.05 [g] 4. [b] 0.02 [s]
Sn-126	50. [a] 0.2 [c]	0.8 [g] 4. [b] 0.003 [s]
I-129	50. [a] 19.6 [g] 2,000. [c,s]	10. 4. [b,g] 400. [s]
Cs-137	50. [a,g] 110. [s] 200. [c]	1.8 [g] 4. [b,s] 7.3
Sm-151	50. [a] 10. [c]	0.014 [g] 4. [b] 0.003 [s]
Ra-226	3. [a,g] 5. [b] 0.3 [c,s]	2.4 [g] 4. 0.24 [s]
Ra-226+Ra-228	5. [a,b,g] 0.3 [c,s]	4.1 [g] 0.24 s
Th-232	15. [a,b,g,s] 20. [c]	31. [g,s] 7.8
U-232	15. [a,b,g,s] 300. [c]	14. [g,s] 71.
U-233	15. [a,b,g,s] 300. [c]	3.0 [g,s] 59.

Nuclide (Taken from ILAW PA [Mann 1998])	Concentration (pCi/l)	Dose (mrem/year)
U-234	15. [a,b,g,s] 300. [c]	2.8 [g,s] 57.
U-235	15. [a,b,g,s] 300. [c]	2.7 [g,s] 55.
U-236	15. [a,b,g,s] 300. [c]	2.7 [g,s] 55.
U-238	15. [a,b,g,s] 400. [c]	2.7 [g,s] 71.
Np-237	15. [a,b,g,s] 30. [c]	43.[g,s] 140.
Pu-239	15. [a,b,g,s] 50. [c]	47.[g,s] 160.
Pu-240	15. [a,b,g,s] 50. [c]	47.[g,s] 160.
Am-241	15. [a,b,g,s] 40. [c]	49.g,s 131.
Am-243	15. [a,b,g,s] 40. [c]	49.g,s 130.

* Conversion performed by assuming 2/d per day water consumption and EPA internal dose conversion coefficients (EPA 1988)
a Washington State ground water standard (WAC 173-200)
b National drinking water standard (40 CFR 141)
c Washington State surface water standard from WAC 246-221-290 Table (using 0.01 of value found in table)
g Ground water standard, minimum of state and national standards
s Surface water standard, minimum of state and national standards

Appendix D. Performance Objectives of Previous DOE Performance

Table D.1 Performance Objectives of Previous DOE Performance

(Status Given in Owendoff 1999)

Hanford Site: *Performance Assessment of Grouted Double Shell Tank Waste Disposal at Hanford* (Kincaid 1993)		
All-Pathways	<10,000 yr	25 mrem/yr
Drinking Water	<10,000 yr 100 m downgradient	4 mrem/yr
Air emissions (radon)		20 pCi/m^{2}s
Inadvertent Intruder	>500 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
ALARA	<10,000 yr	500 persons-rem/yr
Status	Found "technically acceptable" by Peer Review Panel, but new mission (ILAW) has made PA moot.	

Hanford Site: *Performance Assessment for the Disposal of Low-Level Waste in the 200 West Burial Grounds* (Wood 1995)		
All-Pathways	<10,000 yr	25 mrem/yr
Drinking Water	<10,000 yr 100 m downgradient	4 mrem/yr
Air emissions (radon)		20 pCi/m^{2}s
Inadvertent Intruder	>100 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Approved by DOE	

Hanford Site: *Performance Assessment for the Disposal of Low-Level Waste in the 200 East Burial Grounds* (Wood 1996)		
All-Pathways	<10,000 yr	25 mrem/yr
Drinking Water	<10,000 yr 100 m downgradient	4 mrem/yr
Air emissions (radon)		20 pCi/m^{2}s
Inadvertent Intruder	>100 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Approved by DOE	

Hanford Site: *Hanford Immobilized Low-Activity Tank Waste Performance Assessment* (Mann 1998)		
All-Pathways	<10,000 yr	25 mrem/yr
Drinking Water Beta emitters	<10,000 yr 100 m downgradient	 4 mrem/yr 15 pCi/l
Air emissions all but radon radon	<10,000 yr	 10 mrem/yr 20 pCi/m^2s
Inadvertent Intruder	>500 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Submitted to DOE	

Idaho National Engineering And Environmental Laboratory: *Radioactive Waste Management Complex Low-Level Waste Radiological Performance Assessment* (Maheras 1994)		
All-Pathways (but air)		25 mrem/yr
Drinking Water all alpha emitters (other than U and Rn)	100 m downgradient	 4 mrem/yr 15 pCi/l
Air emissions		10 mrem/yr
Inadvertent Intruder	>100 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Approved by DOE	

Los Alamos National Laboratory: *Performance Assessment and Composite Analysis for Los Alamos National Laboratory Material Disposal Area G* (Hollis 1997)		
All-Pathways	<10,000 yr	25 mrem/yr
Drinking Water	<10,000 yr 100 m downgradient	4 mrem/yr
Air emissions (all LANL facilities) all but radon radon		 10 mrem/yr 20 pCi/m^2s
Inadvertent Intruder	>100 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Submitted	

Nevada Test Site: *Performance Assessment / Composite Analysis for the Area 3 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada* (Schott 1997)		
All-Pathways	<1,000 year 100 m downgradient	25 mrem/yr
Drinking Water Beta/gamma emitters Gross alpha Ra-226 + Ra-228	<1,000 year 100 m downgradient	 4 mrem/yr 15 pCi/l 5 pCi/l
Air emissions All but radon radon	 100 m down gradient waste cap	 10 mrem/yr 20 pCi/m^2s
Inadvertent Intruder	> 100 year < 1,000 year	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Submitted	

Nevada Test Site: *Performance Assessment for the Area 5 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada* (Schott 1998)		
All-Pathways	<1,000 year	25 mrem/yr
Drinking Water Beta/gamma emitters Gross alpha Ra-226 + Ra-228	<1,000 year 42,000 m downgradient	 4 mrem/yr 15 pCi/l 5 pCi/l
Air emissions All but radon radon	<1,000 year 100 m down gradient waste cap	 10 mrem/yr 20 pCi/m^2s
Inadvertent Intruder	> 100 year <1,000 year	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Submitted	

Oak Ridge National Laboratory: *Performance Assessment for Continuing and Future Operations Solid Waste Storage Area 6* (MMES 1994)		
All-Pathways		25 mrem/yr
Drinking Water	100 m downgradient	4 mrem/yr
Inadvertent Intruder	>100 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Approved by DOE	

Savannah River Site: *Radiological Performance Assessment for the Z-Area Saltsone Disposal Facility* (WSRC 1992)		
All-Pathways		25 mrem/yr
Drinking Water		4 mrem/yr
Inadvertent Intruder	>100 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Approved by DOE	

Savannah River Site: *Radiological Performance Assessment for the E-Area Vaults Disposal Facility* (WSRC 1994)		
All-Pathways		25 mrem/yr
Drinking Water	100 m downgradient	EPA Standards U: 20 g/l
Air emissions (radon)		20 pCi/m^2s
Inadvertent Intruder	>100 yr	Continuous: 100 mrem/yr Acute: 500 mrem/yr
Status	Approved by DOE	

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