YMP/94-05

YMP/94-05

U.S. DEPARTMENT OF ENERGY

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YUCCA MOUNTAIN

YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT

MINED GEOLOGIC DISPOSAL SYSTEM LICENSE APPLICATION ANNOTATED OUTLINE

Volume 3 of 3

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MGDS License Application Annotated Outline

Chapter 6.0 Overall System Performance Assessment

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6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT

The purpose of this chapter is to demonstrate compliance with the overall performance objective for the geologic repository after permanent closure defined in 10 CFR 60, *Disposal of High-Level Radioactive Wastes in Geologic Repositories*, Section 112. The information in this chapter is intended to satisfy the requirements of 10 CFR 60.21(c)(1)(ii)(C) regarding the evaluation of the postclosure performance of the proposed geologic repository for anticipated processes (undisturbed conditions) and events and for unanticipated processes and events (disturbed conditions). The information developed in this evaluation is also used in the evaluation of the siting criteria of 10 CFR 60.122 in accordance with the requirements of 10 CFR 60.21(c)(1)(ii)(B). This chapter will also cover 10 CFR 60.113(c) as necessary and will include other requirements allocated per any subsequent revision of DG-3003 Appendix A.

Information is presented in this chapter to explain the measures to support the models used in the evaluation as required in 10 CFR 60.21(c)(1)(ii)(F). This information includes a description of the conceptual models and computational models used in Total System Performance Assessment (TSPA), the processes and events addressed by those models, and the scenarios evaluated using those models. Justification for exclusion of processes or events from the evaluation is provided. Non-quantitative information is referenced, as needed, to support the quantitative analysis. Verification and validation of the codes and models used is discussed.

[This chapter focuses only on the overall postclosure system performance. The evaluation of the subsystem performance of the engineered and natural barriers is presented elsewhere in this License Application (LA). The assessment of compliance with the pre-waste emplacement groundwater travel time criterion of 10 CFR 60.113(b) is discussed in Chapter 3 [see Subsection 3.3.5]. Preclosure performance with respect to compliance with the criteria of 10 CFR 60.111 is discussed in Chapter 4 [see Section 4.5]. Compliance with the performance criteria of 10 CFR 60.113 for the engineered barrier system (EBS) is discussed in Chapter 5 [see Section 5.2]]

Waste Isolation and Containment Strategy. The U.S. Department of Energy is committed to a strategy that demonstrates, with reasonable assurance, the ability of the Yucca Mountain site and any associated engineered barriers to safely contain the radioactive wastes and isolate them from the accessible environment. The overall waste isolation and containment strategy is fundamentally based on a defense-in-depth philosophy that serves to mitigate the uncertainties associated with the performance of the individual elements of the engineered and natural components of the total system of containment and isolation barriers (i.e., the multiple barriers that make up the engineered and natural systems). The uncertainties in overall system performance caused by the inherent uncertainties in the natural and engineered systems, processes, models, and properties are explicitly addressed in the performance assessment analyses in order to identify the significance of the uncertainties on our ability to demonstrate compliance with reasonable assurance. In some instances, conservative performance assessments are conducted using bounding assumptions for models or properties. These assessments tend to over predict the expected release of radionuclides. However, illustrating the potential consequences associated with such conservative assessments assists in illustrating the robustness of the overall waste isolation and containment argument and therefore enhances our ability to make the argument that this natural system and the associated engineered system provide adequate safety with reasonable assurance. In order to accomplish this, the conservative assumptions must be clearly documented and demonstrated to be conservative.

As will be presented in this chapter, the overall waste isolation and containment strategy embodied in this LA is essentially the same as that contained in the Department's 1988 Site Characterization Plan and the 1994 Five Year Plan. The strategy consists of a natural system that provides a relatively stable geologic environment isolated from the biosphere, with only a very unlikely possibility of direct or indirect anthropogenic or natural intrusion events that could cause releases of radionuclides. The strategy also relies on a favorable near field environment characterized by low liquid saturations in the host rock and the engineered materials placed in the emplacement drifts. This near field environment is a key element in controlling the rate of degradation of the waste packages, the rate of mobilization of the radionuclides by dissolution of the waste form, and the rate of radionuclide release from the waste package and the EBS by advective and diffusive transport processes. In addition, the strategy identifies the need to design long-lived waste packages to limit the release of gaseous radionuclides. The strategy also emphasizes the slow migration through the natural barrier system of any radionuclides released from the EBS. Finally, the strategy acknowledges the [potential] role the saturated zone [will] plays given the individual dose-based environmental standard [INN 6.0-1].

The individual elements of the waste isolation and containment strategy are illustrated in Figure 6.0-1. All of the components of the waste disposal system work in concert to meet the objectives of limiting the exposure of potentially affected populations and individuals to radiation associated with the wastes to be contained. The roles of each of the individual elements is briefly discussed below. Detailed discussion of the technical basis supporting the description of the individual elements is incorporated by reference to other sections of the LA.

External Features, Events, and Processes. The expected behavior of the waste disposal system over time is potentially impacted by externally initiated anthropogenic or natural features, events, and processes. The principal features, events, and processes that are considered to potentially affect the overall system performance are:

- Future climate changes,
- Future tectonic events including basaltic igneous activity and volcanism, and
- Future human interference.

The characteristics of these features, events, and processes are presented in Chapter 3 [see Subsection 3.2.2]. The identification and evaluation of the probability and consequences of the anticipated and unanticipated features, events, and processes is presented in Section 6.3. In evaluating the overall system response to these features, events, and processes, care is taken to ensure that the scenarios which contain them are complete and mutually exclusive.

Thermal Effects. The radioactive wastes to be disposed at Yucca Mountain produce heat due to the natural decay of the fissionable materials. The heat produced potentially impacts essentially every element of the overall disposal system as illustrated in Figure 6.0-1. In particular, the thermal regime (which is dependent on the repository-scale thermal load as presented in Chapter 4 [see Subsection 4.1.3] and evaluated in Chapter 3 [see Subsection 3.1.5] and the waste package-scale thermal load as presented in Chapter 5 [see Subsections 5.1.3 and 5.1.4]) affects the near field environment which in turn impacts the rock mass stability, the near field humidity and liquid saturations and fluxes, the waste package degradation, and radionuclide mobilization. In addition, the thermal regime affects the liquid saturation and flux in the unsaturated zone and may impact the radionuclide transport characteristics of both the unsaturated and saturated zones. Evaluation of the significance of alternative thermal management strategies on overall system performance is presented in Section 6.3.

Near-Field Environments. The near-field environment defines the expected thermal, hydrologic, geochemical, and geomechanical conditions in which the waste packages reside and the uncertainties in these conditions. These conditions are impacted by the construction and operation of the underground facility and the emplacement of the heat-generating wastes. The technical basis for defining the expected near-field environment has been determined with models of the expected processes and relevant process interactions that have been substantiated by observations and testing carried out in the Exploratory Studies Facility [see Subsections 3.1.2, 3.1.3, 3.1.5, 5.1.3, and 5.1.4]. Evaluation of the significance of the uncertain and spatially variable near-field environments on the overall system performance are presented in Section 6.3.

Waste Package Degradation. The modes and rates of waste package degradation affect the time after emplacement of the wastes at which the waste form is exposed to the near field environments. Models of waste package degradation and their substantiation and uncertainty are presented in Chapter 5 [see Subsection 5.2.1]. The justification for these models and the corresponding properties will be [has been] based on a combination of direct laboratory testing and comparison to analog material behavior in similar environments [see Subsection 5.2.1]. The significance of uncertainties in the waste package degradation models and properties on the overall system performance is presented in Section 6.3.

Radionuclide Mobilization. Once the waste form is exposed to the near-field environment, alteration and dissolution of the waste form can be initiated resulting in the mobilization of the radionuclides into a transporting medium (either air or water). The expected rate at which the radionuclides are mobilized depends on many factors including the geochemistry of the fluids in contact with the waste form, the properties of the waste form, the existence and stability of colloids, the temperature, and the solubility of the relevant species of the different radionuclides. The available information with which to define these factors and the corresponding uncertainty are presented in Chapter 5 [see Subsections 5.1.2 and 5.2.1]. The significance of the uncertainty in these models and properties on the overall system performance are presented in Section 6.3.

Radionuclide Release from the EBS. Following the mobilization of the radionuclides, the dissolved radionuclides must be transported through the degraded waste package and the remainder of the engineered materials placed in the drifts before they are released to the advective gas or water flow in the geosphere. Both advective and diffusive release mechanisms through the engineered barrier are possible. [However, for the low saturations expected in the drifts, diffusive transport tends to dominate [see Subsection 5.2.1].] The technical rationale for the range of transport models and rates is presented in Chapter 5 [see Subsection 5.2.1]. An evaluation of the significance of the expected range in transport models and properties and their inherent uncertainty is presented in Section 6.3.

Unsaturated Zone Flow and Radionuclide Transport. With the primary exception of ^{14}C, the radionuclides released from the EBS are generally transported through the natural barrier system to the accessible environment in the aqueous phase. ^{14}C is considered to be transported primarily in the gaseous phase [see Subsection 5.1.2]. Expected models for ground-water flow and radionuclide transport in the unsaturated zone and the uncertainty and spatial variability associated with these models and the included properties are presented in Chapter 3 [see Subsection 3.1.2]. The significance of alternate unsaturated zone flow and transport models and the uncertain flow and transport properties on the overall system performance is presented in Section 6.3.

Saturated Zone Flow and Radionuclide Transport. The saturated zone performs two different roles in the overall system performance of the Yucca Mountain site. On one hand, the aqueous advective travel time in the saturated zone tends to delay the arrival of relevant radionuclides to the accessible environment. In addition, dilution in the saturated zone tends to lower the peak radionuclide concentrations at the accessible environment or points of ultimate use of the groundwater further down gradient. Expected models for ground-water flow and radionuclide transport in the saturated zone and the uncertainty and spatial variability associated with these models and the included properties are presented in Chapter 3 [see Subsection 3.1.2]. The significance of alternate saturated zone flow and transport models and the uncertain flow and transport properties on the overall system performance is presented in Section 6.3.

[Biosphere Transport. The ultimate consequence associated with the disposal of radioactive wastes is caused by the potential exposure of individuals to the radiation by either direct exposure, inhalation, or ingestion. Assessment of all possible exposure pathways and the resulting individual or population doses caused by potential releases to these pathways is presented in Section 6.3.] [INN 6.0-1]

Status of TSPA Work. The current status of documented TSPA analyses is presented throughout this chapter. A summary of all TSPA analyses conducted is presented in Table 6.0-1. [INN 6.0-2] [This information is not included at this time for the purpose of establishing compliance with the applicable standards. At this early stage, before the gathering of site data is complete, these analyses are included for the purpose of establishing the approach and methodology that will be used. Care is taken to clearly separate the sections that describe the current state of knowledge from those that will be used to demonstrate compliance at a future time.]

The TSPA analyses documented in this chapter are used for all aspects of the program that have a bearing on the evaluation of the geologic repository. The TSPA analyses are performed in an iterative fashion. [As new characterization data, designs, or test results become available, new assessments will be performed. Successive TSPA analyses identify issues that are addressed by design, analysis, test, or characterization activities. This allows for iterative refinement of the system, determination of characterization needs, and a robust demonstration of the adequacy of the repository system. TSPA analyses will be performed to provide support to the final site suitability evaluation, and, if the site is found to be suitable, will continue to be conducted to support the Environmental Impact Statement and each phase of the LA process.]

A number of TSPA-like analyses have been performed between 1983 and the present time. A summary discussion of the earlier total system performance analyses can be found in U.S. Department of Energy (1994). TSPA-1991 (Barnard et al., 1992; Eslinger et al., 1993) was the first in the series of total system assessments conducted by the Yucca Mountain Site Characterization Office, and in 1993, the Yucca Mountain Site Characterization Office completed the second iteration (TSPA-1993). The details of the individual analyses conducted in TSPA-1993 are presented in Wilson et al. (1994) and Andrews et al. (1994).

The TSPA analyses conducted in 1991 and 1993 advanced the methodology by showing that the tools are generally available [although improvements are still needed] to conduct complex, probabilistic TSPA analyses. Analyses that are used to evaluate compliance with the final Environmental Protection Agency (EPA) Standard [INN 6.0-1], and the Nuclear Regulatory Commission (NRC) regulation that implements it, must address the complete extent of uncertainty, and will be very complex. The 1991 and 1993 assessments were, in effect, practice calculations of this type that provided useful feedback to design and site characterization. [These complex calculational exercises will continue through preparation of the LA, and iteratively thereafter, to keep pace with the ongoing Performance Confirmation Program (Chapter 8) which extends through construction and operation to the license amendment for closure.]

Objectives of TSPA-1993. The TSPA that eventually demonstrates compliance with total system performance requirements must address all reasonable processes and events that could contribute to the release of radionuclides to the accessible environment. However, the objective of TSPA-1993 was not to establish compliance; the lack of sufficient qualified site data and the preliminary nature of the repository design precludes a demonstration of compliance at this time. The objectives of TSPA-1993 were to:

a. Enhance the realism/representativeness of the analyses through iterative refinements;

b. Incorporate new information and designs into the analyses;

c. Test the effects/importance (i.e., sensitivity) of certain assumptions on the behavior of the system; and

d. Evaluate alternative measures of performance or safety.

The assessments were performed to help focus site investigations and materials testing programs, not to establish compliance with regulations; therefore, the reader is cautioned that the processes and events which were selected for inclusion in TSPA-1993 were not intended to comprise a necessary and sufficient set for regulatory purposes.

The total system postclosure performance measure applicable to Yucca Mountain has been questioned by Section 801 of the National Energy Policy Act of 1992 (Public Law, 102-486). Section 801 calls for the National Academy of Science (NAS) to evaluate the reasonableness/appropriateness of alternate environmental standards to ensure the protection of the public if a nuclear waste repository is located at Yucca Mountain. In particular, the NAS is to evaluate the potential use of a dose-based standard to protect the public from future radiation exposure. Although it is impossible to prejudge the outcome, the NAS committee convened to address this issue (as well as how EPA may decide to implement the recommendations of the NAS committee), it does seem prudent to quantify the expected doses associated with a potential repository at Yucca Mountain. As a result, TSPA-1993 considers both the cumulative normalized radionuclide release at the accessible environment and the peak individual dose as relevant performance measures. The peak dose is the highest annual dose that the maximally exposed individual may receive over a specified period of time following repository closure. In addition, because the time period of regulatory concern is also uncertain, the analyses incorporate the most significant radionuclide peaks that occur several tens to hundreds of thousands of years after closure.

Organization of TSPA-1993. The TSPA-1993 was performed by two Yucca Mountain Site Characterization Office Performance Assessment participants. Sandia National Laboratories used its Total System Analyzer (TSA) code system in TSPA-1991 (Barnard et al., 1992) and TSPA-1993. (Wilson et. al., 1994). The Civilian Radioactive Waste Management System Management and Operating Contractor used the Repository Integration Program (RIP) code, developed by Golder Associates, Inc., (GAI, 1993; Miller et al., 1993; Kossik and Hachey, 1993; Miller et al., 1992) after first testing it by duplicating the TSPA-1991 results using the TSPA-1991 data set (INTERA, 1993).

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10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories

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ACRONYMS AND ABBREVIATIONS

BWR	Boiling Water Reactor
CCDF	Complementary Cumulative Distribution Function
cm	centimeter
EBS	Engineered Barrier System
EPA	Environmental Protection Agency
km	Kilometer
kW	Kilowatt
LA	License Application
m	meter
MGDS	Mined Geologic Disposal System
MTU	Metric Ton of Uranium
NAS	National Academy of Science
NRC	Nuclear Regulatory Commission
PWR	Pressurized Water Reactor
RIP	Repository Integration Program
TBD	To be determined
TSA	Total System Analyzer
TSPA	Total System Performance Assessment
YMIM	Yucca Mountain Integrating Model

Table 6.0-1 Summary and Documentation of Each Iteration of Performance Assessment

Iteration	Models Used	Scenarios	Documentation
1	Primarily based on systems models with input from subsystem models and limited input from process models.	Isothermal conditions Human Intrusion Seismicity Volcanism	SAND91-2795, 1992.
2	Primarily based on systems models with input from subsystem models and limited input from process models.	Repository Thermal Perturbation Human Intrusion Volcanism	SAND93-2675, 1994. CRWMS M&O B00000000-01717-2200-00099-Rev. 01, 1993. DOE XXX, 1994
. . . .			

[Note: This table will be completed using [INN 6.0-2].]

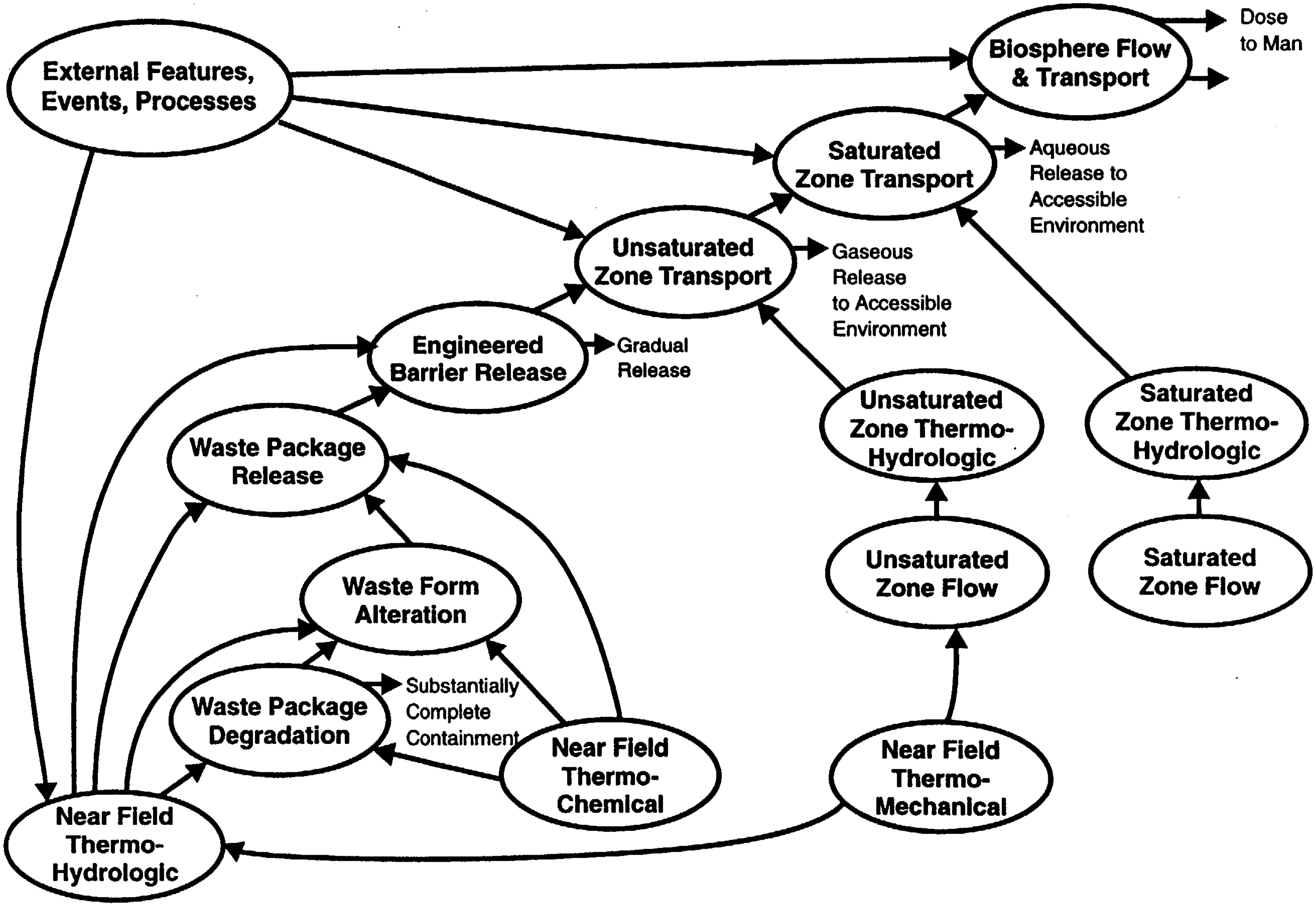

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Figure 6.0-1 Components of Overall System Performance Assessment

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.0-1
Section Number and Title:	6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT
Lead Author/Support Author and Phone:	J.O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.0-1
Explicit description of the needed information:	Regulatory standard for releases at Yucca Mountain. This standard will provide release/dose requirements for the high-level waste repository at Yucca Mountain. Currently 40 CFR 191 is being used until new standards are available.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	U.S. Environmental Protection Agency
Information Source Description:	"Repromulgation" of environmental standards for Yucca Mountain
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.0-2
Section Number and Title:	6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT
Lead Author/Support Author and Phone:	J.O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	TSPA reports. Reports on TSPA, iteration 1 through the one for the Safety Analysis Report.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	TBD
Information Source Description:	TBD
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS License Application Annotated Outline

Section 6.1 Basic Approach

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6.1-1	Documentation of data and results for each iteration of TSPA.
6.1-2	Listing of current issues where TSPA will be used in their resolution, listing of issues resolved, and topical report references for resolved issues.
6.1.2-1	Description of types of models used in each iteration of TSPA, description of how the CCDF was formed, and an interpretation of the uncertainty incorporated into the CCDF.

6.1 BASIC APPROACH

The purpose of this section is to describe the conceptual and mathematical approach used for the assessment of the overall system performance presented in this chapter. [The TSPA that will be conducted for this LA will consist of a sequence of assessments, each of which constitutes a nested collection of analyses integrated through a comprehensive top-level model. The TSPA analyses presented in this chapter are the culmination of a number of years of TSPA iterations that have been presented to the NRC for review and comment. These iterative assessments, each of which incorporates site characteristics, design data, and other relevant information available at the time of the analyses, demonstrate successive stages in the development of understanding of the system [INN 6.1-1]. The scope of each iteration of the TSPA is summarized and documented in Table 6.0-1.

The results of each iteration in the sequence of assessments will be presented to the NRC staff for comment. Comments from the NRC and other concerned parties will be considered in developing successive performance assessment iterations. [Each iteration focuses on resolution of selected issues in regulatory compliance as well as the incorporation of additional data and models. Table 6.1-1 shows a complete list of issues, the status of their resolution, and cites topical reports addressing those issues [INN 6.1-2]. With respect to compliance, the most prominent features of each performance assessment iteration are the products of computational models. However, reasonable assurance of compliance also depends substantially upon information from evaluation of natural analogues and confirmatory tests. Iterative performance assessment analyses and review enables resolution of issues at successive stages of development. The status of resolution of issues that will be tabulated in Table 6.1-1 will indicate the extent to which issues have been resolved prior to submission of the Safety Analysis Report and those which require resolution during the performance confirmation program [see Chapter 8].]

6.1.1 Conceptual Background for the Assessment of Overall System Performance

The overall system performance will be evaluated through modeling of the following processes and events:

- Radionuclide release from the EBS (including waste package degradation, waste form alteration, waste package release, and engineered barrier release);
- Near field thermomechanical processes;
- Near field thermo-chemical processes;
- Unsaturated zone flow;
- Unsaturated zone hydrothermal processes;

- Unsaturated zone radionuclide transport (including both gas and aqueous phase processes);
- Saturated zone flow;
- Saturated zone hydrothermal processes;
- Saturated zone radionuclide transport;
- Biosphere processes;
- Potentially disruptive external events; and
- Coupled processes (such as thermal, mechanical, hydrologic, and chemical) of this fully coupled system, or process models may not be necessary or even possible but are included here to show that they are being considered.

The relationship among the individual components of the overall system is shown in Figure 6.0-1. Each of the components is modeled at more than one level of detail. Models used to understand processes are generally not used to evaluate overall performance, because to do so, the total system performance model would have to incorporate so much detail as to become unwieldy. Given the complexity of the processes involved, process models and performance models are likely to remain separated. The performance assessment analyses consider the full range of models from the detailed process models which are designed to capture all the relevant details of individual processes, to the total system performance models which are designed to capture all the relevant processes in an abstracted form that assures inclusion of the major results, and the corresponding uncertainty in these results, of the underlying process models. (Abstraction in this case is the process of simplifying the description of more complex processes, retaining those aspects to which higher-level overall system performance is sensitive. For example, if the effects of thermomechanical processes are determined to be insignificant with respect to the total system performance, then they may not be included in the abstracted representation for performance assessment purposes (although these models may be important for preclosure safety and retrievability issues as discussed in Chapter 4 [see Subsections 4.5.1 and 4.5.2]).

The performance assessment models may be thought of as forming a hierarchy such as that depicted in Figure 6.1.1-1, with the process models forming the base and the most comprehensive models at the apex. Here "comprehensive" is used to indicate that the models at the apex contain all of the important processes in an abstracted form. Intermediate to the process and total system performance models are subsystem or domain models which integrate by abstraction all the processes relevant to the performance of some major segment of the system. An example of a subsystem model would be the EBS model, which is a subsystem as far as the total system is concerned because it does not consider radionuclide transport through the natural barrier (although it does consider the near field environments which are affected by the natural system in which the repository drifts are constructed). For the purposes of visualization, the hierarchy of models is divided into three levels. However, the boundaries between model levels (especially between process and subsystem models) are not necessarily distinct.

Process models are generally analyzed using deterministic numerical codes that incorporate coupled interactions (for example, the synergistic effects between water, water vapor, gas, and heat flow). The objective of these models is to reasonably represent the physical (chemical) processes that are expected to occur at the Yucca Mountain site and within the EBS. For a number of processes, alternate conceptual models may be [have been] postulated that can not be distinguished on the basis of available observations. In these cases, the TSPA analyses described in Section 6.3 are used to evaluate the significance of the uncertainty in the conceptual representation on the overall system performance objectives.

Subsystem models are either deterministic or probabilistic models that are used in analysis of individual scenarios, bounding analyses, or determinations of process uncertainty. [An example of a subsystem model is the waste package model that will incorporate chemical/geochemical, flow, stress, and thermal processes in an abstracted form.] Subsystem models are used to investigate process uncertainty through incorporation of the range of expected processes that could occur within the natural and EBSs.

TSPA models are probabilistic codes that combine all reasonably relevant scenarios. The total system models are the most abstract models that are used to evaluate the expected performance of the repository system given anticipated and unanticipated processes and events (i.e., the calculation of the Complementary Cumulative Distribution Function (CCDF) to demonstrate compliance with the EPA health and safety standard). The total system models are used for conducting bounding analyses of the effects of scenarios and combinations of scenarios on the total system performance. Because the models used in TSPA analyses are more abstract, these models are constructed with additional degrees of conservatism to assure that the calculated performance is not underpredicted.

The iterative performance assessment process can be envisioned as beginning at the base of the model hierarchy triangle (Figure 6.1.1-1) and conducting sensitivity analyses over a representative range of parameters. The transfer of information between hierarchy levels is accomplished by using the results of process models to formulate input for subsystem models, and using subsystem results as a basis for input for system models. The results of the system models are then compared with those of the subsystem and process models to ensure that the total system of results is consistent. This approach to exercising the entire hierarchy of models is a method towards gaining reasonable assurance in the results of the overall system performance. The process could also have been envisioned as beginning at the apex and then exercising the process models to confirm that the results of the TSPA models are reasonably consistent with the results of the more detailed analyses.

6.1.2 Mathematical Background for the Assessment of Overall System Performance

The conceptual representation of the overall system and individual components discussed in Subsection 6.1.1 must be implemented in scientific and engineering software before the analyses can be performed. Each software to be implemented has a life cycle plan and is under configuration management. For software which has been developed for application to the assessment of the overall performance of the Yucca Mountain site and associated engineered barriers, the software development life cycle consists of documentation describing the software requirements specifications, the mathematical representations embodied in the software, the software design specifications, a software users manual, and a software verification and validation plan. The software used in the assessment of the overall system performance are described in Section 6.3, with specific reference to the software verification and validation discussed in Subsection 6.3.6.

The overall system performance assessments require the use of stochastic modeling methods in order to incorporate the uncertainty in conceptual models and parameters and to address the possible effects associated with external processes and events. While the bulk of the TSPA analyses have used Monte Carlo-type techniques (as was done in TSPA-1991 and TSPA-1993), additional collaborative analyses are planned using alternative methods, including fault tree analyses (such as used by Electric Power Research Institute in the Risk Engineering software IMARC) and moment methods.

Two different approaches are used for the development of the complementary cumulative distribution coefficients using the Monte Carlo method. In the first method, which is termed the direct simulation approach, a single simulation is made in which all the important features, events and processes describing the individual scenario classes are included. A large number of realizations are performed, with each realization representing a possible future history of the repository system. For each realization, the appropriate probabilities of occurrence are applied to determine whether an event or process occurs over the time period of interest. Each realization represents the behavior of the overall system over the entire time of the calculation and a history of radionuclide releases over that time are produced. After all the realizations have been calculated, their associated normalized performance results are combined.

Although this method is conceptually straight-forward and has the advantage of ensuring mutually exclusive scenarios, separate analyses of each subsystem would allow for the determination of which features or events are most important. As a result a second method is used in which all possible future histories, or scenarios, are subdivided into subsets called scenario classes. The parameter space is subdivided in such a way that the scenario classes are mutually exclusive (i.e., no scenario is counted twice) and exhaustive (i.e., any scenario belongs to at least one of the classes). A conditional performance result (conditional upon the parameter values that define the scenario class) is calculated for each scenario class and then the combined result is a weighted sum of the conditional results.

Preliminary TSPAs have used both Monte Carlo formalisms. This is necessary because exhaustive, mutually exclusive lists of scenario classes have not been developed [see Section 6.3] and may not be comprehensive in screening scenario classes. The strategy is to approach exhaustiveness and evaluate many representative scenario classes conditionally. Those that are shown to affect system performance will be further evaluated to determine if a limited subset of scenarios within that class is responsible for the change in performance. A simplified scenario class will then be carried forward into the formal TSPAs.

[Note: This section will be completed using [INN 6.1.2-1].]

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Wilson, M. L., J. H. Gauthier, R. W. Barnard, G. E. Barr, H. A. Dockery, E. Dunn, R. R. Eaton, D. C. Guerin, N. Lu, M. J. Martinez, R. Nilson, C. A. Rautman, T. H. Robey, B. Ross, E. E. Ryder, A. R. Schenker, S. A. Shannon, L. H. Skinner, W. G. Halsey, J. Gansemer, L. C. Lewis, A. D. Lamont, I. R. Triay, A. Meijer, and D. E. Morris, 1994. Total-System PA for Yucca Mountain -- SNL Second Iteration (TSPA-1993), SAND93-2675, Sandia National Laboratories, Albuquerque, NM.

Table 6.1-1 Status of Issue Resolution Using TSPA

Issue	Status		Topical Report (Reference)
	Resolved	Open	
1. Erosion		x	YMP/92-41-TPR, DOE, 1993 (in revision).
2. Volcanism		x	
. . .			

[Note: This table will be completed using [INN 6.1-2].]

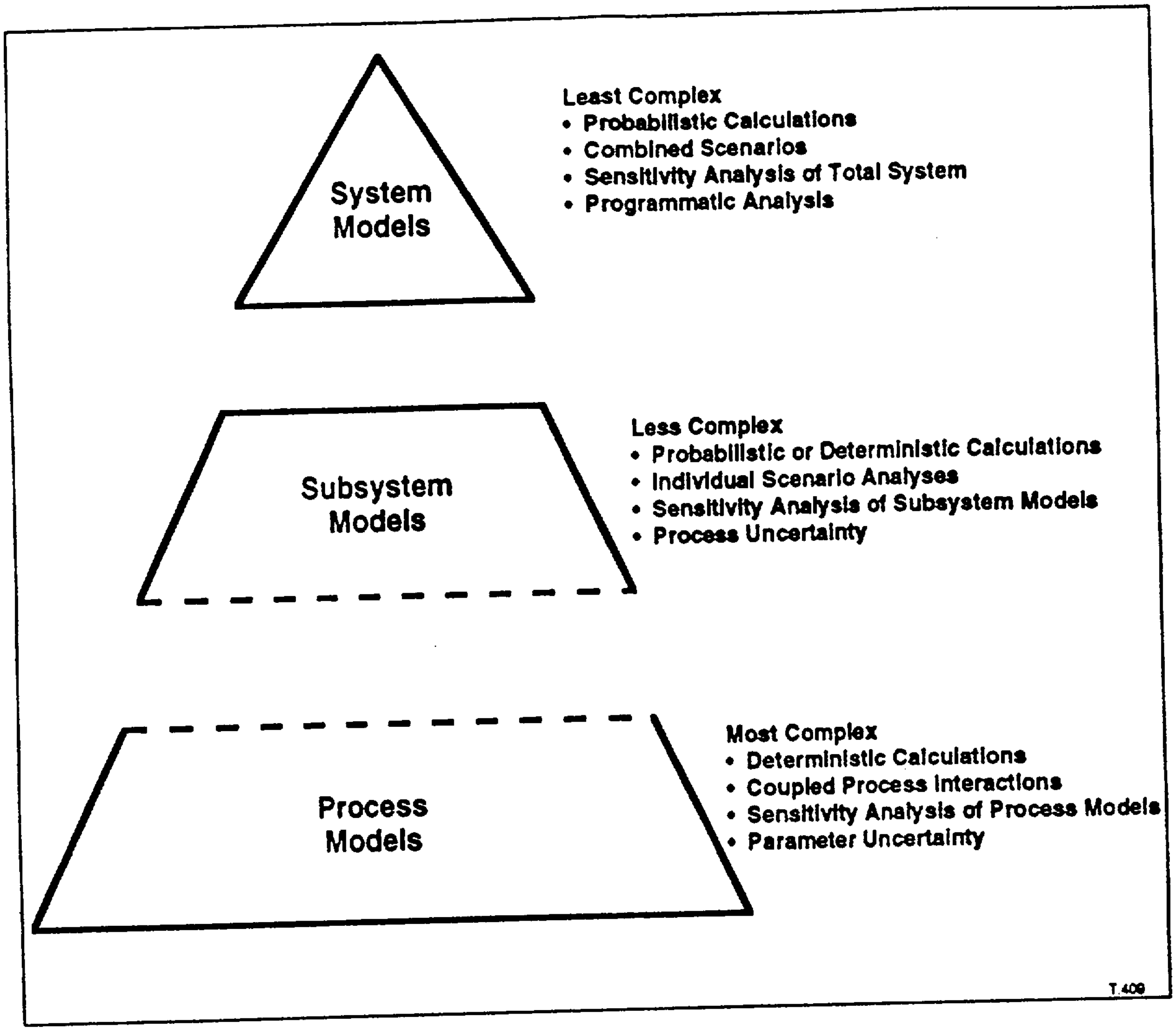

Figure 6.1.1-1. Hierarchy of Models Used in TSPA

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.1-1
Section Number and Title:	6.1 BASIC APPROACH
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Documentation of data and results for each iteration of TSPA. Iterations began with TSPA, TSPA-1991 and will continue through the iteration for the License Application.
Information will be used to support:	
The Information is needed by/for (date or event):	2000
Most likely source of the Information:	TBD
Information Source Description:	Iteration 1, TSPA SAND91-2795, 1992. Iteration 2, Total System Assessment SAND93-2675, 1994 and CRWMS M&O B00000000-01717-2200-00099-Rev. 1, 1994.
Does the supporting data need to be QA?	For iteration used in License Application

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.1-2
Section Number and Title:	6.1 BASIC APPROACH
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Figure 6.1.1-1 and Table 6.1-1
Explicit description of the needed information:	Listing of current issues where TSPA will be used in their resolution, listing of issues resolved, and topical report references for resolved issues.
Information will be used to support:	
The Information is needed by/for (date or event):	2000
Most likely source of the Information:	TBD
Information Source Description:	Currently DOE has a preliminary issue list. Site Characterization Plan.
Does the supporting data need to be QA?	Yes, for each issue discussed in the License Application

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.1.2-1
Section Number and Title:	6.1 BASIC APPROACH
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Description of types of models used in each iteration of TSPA, description of how the CCDF was formed, and an interpretation of the uncertainty incorporated into the CCDF.
Information will be used to support:	
The Information is needed by/for (date or event):	2000
Most likely source of the Information:	TBD
Information Source Description:	TSPA reports for iteration 1 through that for the Safety Analysis Report.
Does the supporting data need to be QA?	For iterations used in support of the License Application

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS License Application Annotated Outline

Section 6.2 System Description

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6.2 SYSTEM DESCRIPTION

This section describes the conceptual models, and processes and events that are analyzed to assess the overall repository system performance. The system, as used in this section, consists of the geologic units and the hydrogeologic units within the controlled area [INN 6.2-1] and the influence (on the system) of natural processes and events, thermal loading, and human-initiated processes and events during the next 10,000 years and beyond. The fluid flow within the controlled area is related to the regional flow system (described in Chapter 3) where necessary to define boundary conditions for analyses and is influenced by events and processes that occur both within the controlled area and the region.

6.2.1 Conceptual Models

[The potential conceptual model alternatives that could be used for evaluation of system performance are developed and documented [INN 6.2.1-1]. Conceptual models considered describe part or all of the following system elements: the EBS (including the waste package), the natural barrier system (e.g., the repository as influenced by thermal loading, liquid and gas flow in the unsaturated zone, liquid flow in the saturated zone, radionuclide transport in both the unsaturated and saturated zones), and the biosphere. [The potential conceptual models that are considered are screened and either rejected or incorporated into the calculational models that are used in the overall system performance assessment that is presented in this LA]. [INN 6.2.1-1]

[Tables 6.2.1-1 through 6.2.1-10 provide a summary of the conceptual and calculational models as shown in Figure 6.2.1-1 in the categories of engineered barrier (including waste package degradation, waste form alteration, waste package release, and engineered barrier release), repository thermomechanical, near field thermochemical, unsaturated zone flow, unsaturated zone thermohydrologic, unsaturated zone radionuclide transport (includes both gas-phase, and aqueous phase transport), saturated zone flow, saturated zone thermohydrologic, saturated zone radionuclide transport and biosphere, respectively. Table 6.2.1-11 provides the references for each category that justify elimination of the potential conceptual models that are not considered in the LA [INN 6.2.1-2]. A detailed discussion of the elimination of alternative conceptual models is contained in the sections that follow.]

Conceptual Models Used in TSPA-1993.

The portion of Subsection 6.2.1 that follows is not included as part of the LA, but is included to indicate the status of performance assessment at the current time. The assessment was not done under quality assurance, the models used are not under quality assurance, and qualified data were not available for the analyses. As the iterations of performance assessment continue they will be placed under the quality assurance program and the results will be incorporated in the LA. At that time the sections describing TSPA-1993 will be removed.

Engineered Barrier Models Used in TSPA-1993. Conceptually, a repository consisted of corrosion resistant waste packages emplaced either in vertical boreholes drilled into the floor of the emplacement drifts, or placed horizontally on the floor of the drifts [INN 6.2.1-3]. Current concepts are focused on in-drift emplacement. These waste packages contain either mild steel canisters with vitrified high-level waste, or unreprocessed spent nuclear fuel assemblies, complete with structural metal components [INN 6.2.1-4]. Figures 6.2.1-1, 6.2.1-2, and 6.2.1-3 illustrate these repository layout and waste package emplacement concepts. Waste packages also include a thick mild steel corrosion allowance barrier to further delay the failure of the package. Between the waste package and the rock, there may be nothing but air (on all sides but one, of course), or there may be an engineered backfill, such as crushed tuff (Chapter 5, Subsection 5.1.3).

Once degradation of the waste package allows access to the waste, the spent fuel may release gaseous radionuclides, and if liquid (water) is able to come into physical contact with the waste, it solubilizes the spent fuel's largely uranium dioxide matrix and the fission product and activation product radionuclides embedded within it. Some small fraction of these radionuclides coat the surfaces of spent fuel fragments, and contribute to an initial high rate of release. This high rate of release is then followed by releases at the slow rate dictated by the rate at which the matrix can dissolve for the alteration controlled radionuclides (radionuclides such as ^{14}C, ^{99}Tc, ^{129}I, and ^{135}Cs). Other radionuclides such as the actinides are considered to undergo solubility limited release from the waste form. Similar mechanisms control the rate at which radionuclides may be released from the high-level waste glass blocks and fragments. Once radionuclides are in solution, it becomes possible for them to migrate with moving fluid, or diffuse through fluid that is not moving. As the radionuclides migrate or diffuse through the backfill (if employed) surrounding the waste package they are released from the EBS to the natural barrier.

The engineered barrier processes included in TSPA-1993 broadly fall into four categories:

a. Waste package degradation [INN 6.2.1-5];

b. Waste form alteration [INN 6.2.1-6];

c. Waste package release [INN 6.2.1-7]; and

d. Engineered barrier release [INN 6.2.1-8].

Descriptions of the process models are outlined below.

Waste Package Degradation. The waste package degradation processes included in TSPA-1993 include dry oxidation of the container at elevated temperatures and aqueous corrosion of the container including general and pitting corrosion processes as a function of temperature. The processes for initiation of aqueous corrosion included a case with a threshold based on the rock residual liquid saturation and a case with a temperature based threshold. In addition to corrosion processes, a defective construction failure mode was included.

Waste Form Alteration. For those radionuclides that are bound in the fuel matrix, the fuel form itself is an effective barrier to release. The amount and type of radionuclides available for transport depends on their distribution within the spent fuel form. The alteration process defines an upper limit for the rate that certain high solubility radionuclides can be released. The waste form alteration processes that allow the release of the bound fraction of the inventory included temperature dependent oxidation and aqueous alteration as a function of pH, carbonate concentration, and temperature.

Waste Package Release. Waste package release processes included rate limits based on solubility (partitioned by isotopic abundance) and alteration limits (discussed above). The waste package was assumed to fail completely at the time of first penetration. Those gaseous radionuclides that reside in the gap between the fuel and cladding are assumed to be released instantaneously upon breach of the innermost barrier of the waste package. Alteration controlled radionuclides are assumed to be released at the alteration rate and solubility controlled radionuclides are released at a rate dependent on water flux and individual radionuclide solubilities.

Engineered Barrier Release. The TSPA-1993 did not take performance credit for backfill in terms of reducing the water flux impinging on the waste packages nor was credit taken for the retardation of radionuclide travel through the backfill material. One of the individual TSPAs did perform thermal calculations for a case with backfill surrounding the waste packages and the resulting temperature distributions were used in the waste package degradation model (Wilson et al., 1994).

Near Field Thermomechanical Models. No near field thermomechanical processes were included in TSPA-1993 [INN 6.2.1-9].

Near Field Thermochemical Models. The near field thermochemical processes considered include waste form alteration processes (discussed above), radionuclide solubility limits, and retardation of radionuclides by sorption on the host rock. Radionuclide solubilities were formulated as a function of temperature and groundwater pH where the data or theory exist to support these dependencies. The retardation factors used in the analyses did not have any dependency on environmental parameters, but did consider parameter variability as expressed by expert elicitation. The groundwater chemistry was assumed to be unaffected by the thermal perturbation [INN 6.2.1-10].

Unsaturated Zone Flow Models. The unsaturated zone flow processes are divided into two categories: gaseous flow and liquid flow. In addition, the liquid phase flow was modeled using two distinctly different conceptualizations, matrix-dominated flow regimes and fracture-dominated flow regimes [INN 6.2.1-11].

Unsaturated Zone Gas Flow - Gas flow in the unsaturated zone may be important for several reasons [INN 6.2.1-12]:

a. Transport of gaseous radionuclides (i.e., ^{14}C);

b. Water vapor flow may make an important contribution to the water balance; and

c. Gas convection may contribute somewhat to heat transfer from the repository.

Large scale flows of air through Yucca Mountain have been shown (Weeks, 1987) to be driven by the combination of topographic relief and temperature differences between the surface and subsurface. The effect on density of humidity differences also contributes to gas flow. Barometric pressure fluctuation, aerodynamic effects of wind blowing over the mountain, and diurnal temperature changes may also have an effect on gas flow. These rapidly oscillating flows are omitted from the model used in TSPA-1993 because their time scales are too short to allow the pressure changes to penetrate very far into the mountain (Montazer et al., 1985), and they do not cause net movement of gas at depth. Consequently, the omission of these effects should not significantly affect contaminant transport or heat transfer. The model used to develop gas velocity distributions is described in the section on thermohydrologic models.

Unsaturated Zone Liquid Flow - The current conceptual model for flow in the unsaturated zone includes both fracture and matrix flow, both in equilibrium and nonequilibrium; however, the computational models upon which TSPA-1993 is based do not yet represent the complexity considered to be present at the site with regard to the degree of equilibrium between fractures and matrix porosity. Therefore, two separate flow models were considered in order to gain some insight into the importance of fracture-matrix coupling; the composite porosity model and the "weeps" model. [Both of these conceptualizations are idealized, and reality is probably somewhere in between the two modes of fracture/matrix interaction, and may include matrix flow with episodes of rapid, localized fracture flow [INN 6.2.1-1].]

Conceptually, fluid flow is influenced by the thermal perturbation in the vicinity of the repository. Since the magnitude of this perturbation may (for some thermal loads or areal power densities) be the dominant force in driving flow, the thermohydrologic processes are seen to be very important in describing the behavior of the system during the thermal pulse. It is because of this importance that the thermohydrologic processes and models are described separately.

Unsaturated Zone Liquid Flow - Composite Porosity Model - The first flow model assumed the fractures and matrix to always be in equilibrium. Darcy's Law, with equivalent properties calculated to suitably average the rock matrix and fracture permeabilities was used to calculate the flow velocity in one-dimensional columns. Liquid water movement was thus constrained to move vertically downward with uniform flux across the column. In this representation, liquid water is constrained to flow through the matrix if saturation levels remain sufficiently low to allow capillary forces to control water movement. If moisture content reaches saturation water flows in fractures.

In the composite porosity model, groundwater flow and aqueous transport are modeled in one dimension as isothermal and single-phase. Matrix/fracture coupling is assumed to be strong for transport and for water flow. Flow is represented by Darcy's Law, and transport is represented by generalized advection/dispersion equations (see Dudley et al., 1988).

Percolation flux at the repository is applied as a boundary condition rather than by calculating infiltration and potential diversion through lateral flow in upper layers. Hydrogeologic properties within stratigraphic layers are modeled as homogeneous and isotropic.

In the Wilson et al. (1994) composite-porosity adaptation of the source term model, Lawrence Livermore National Laboratory's Yucca Mountain Integrating Model (YMIM, Barnard et al., 1992; Wilson et al., 1994), releases are represented by a limited number of distinct groups [INN 6.2.1-13]. The use of such groups allows the incorporation of variation of container environments within the repository. Each group's releases are calculated using a single representative container, so effectively each group is treated as a set of containers with identical conditions. However, from one group to the next, temperature and hydrologic conditions can vary.

All composite-porosity-model computer runs use ten container groups. (Note, however, that a 57-kW/acre simulation with eight unsaturated-zone columns has a total of 80 container groups---10 times 8.) The number of containers in each group is chosen so that seven of the groups have the same number of containers, one group has approximately one tenth as many, one group has approximately one hundredth as many, and the last group has approximately one thousandth as many. The small groups are included so as to have small numbers of containers to better resolve releases under conditions when only a small fraction of containers is wet. For example, suppose in a particular simulation that 1% of containers is calculated to be contacted by water. With ten equal container groups, 1% would have to be approximated by 0 or 10%, neither of which is satisfactory. With the scheme described above, 1% of the containers can be approximated much more closely.

Container and fuel temperatures are interpolated between "center" and "edge" temperature curves as follows. A fraction of containers equal to the "dryout" fraction is assumed to have the "center" temperature. A number of groups as close to that number of containers as possible is set to the "center" temperature. Temperatures for the other groups are interpolated linearly between the "center" and "edge" temperatures. The groups with small numbers of containers are always chosen to be at the "edge" end of the interpolation (because cooler containers are more likely to be wet).

The most important difference among the container groups is in assumptions about wetting. Using algorithms to be described below, three wetting states are defined: wet, moist, and dry. Wet containers are assumed to be contacted by flowing water, so they can be attacked by aqueous corrosion processes (if the temperature is low enough) and they can have advective aqueous releases and/or gaseous releases. Moist containers are assumed to have no flowing water, but they are contacted by rubble and so are moist because of contact with pore water. Aqueous-corrosion processes are assumed to take place on moist containers (if the temperature is below 100°C), and they can have gaseous releases if they fail, but no aqueous releases. In this model, if container temperature is defined to be over 100°C, aqueous corrosion does not occur. The boiling point at the repository horizon is actually somewhat less that 110°C. The rate of aqueous corrosion depends on the quantity of water present, as well as the temperature and the wetting state. Similarly, aqueous releases would depend on temperature as well as quantity of water and wetting state.

Dry containers have no contact with either flowing water or rubble, or are within the dryout fraction of the repository. Only dry oxidation can take place on dry containers, and they can have only gaseous releases if they fail.

The division of containers into the three wetting states is not fixed, but varies with time. At some times, in some of the simulations, all of the containers are dry because the dryout fraction is 1. During a wet-climate period, most of the containers may be wet, while during a dry-climate period they are mostly dry. Because the flow conditions switch between the same two steady states at climate changes, the same number of containers are wet during each wet period and the same (different) number are wet during each dry period (except during the thermal period, which is the first few thousand years). However, it is not assumed that the same containers are wet or dry during similar climate periods. During a single climate period (except for the thermal period), container groups remain wet, moist, or dry, but when climate changes, the groups are shuffled so that the wetting state of a group can change (actually, only the seven equal-size container groups are shuffled; the three small groups have the same wetting state during similar climate periods).

Container wetting is determined for those containers not in the dryout fraction. Containers within the dryout fraction are assumed to be protected from flowing water and are considered to be dry. Percolation flux that would have passed through the dryout zone is diverted around it instead, and passes through the parts of the repository outside the dryout zone, if any. This shedding flux is only accounted for in the source term calculation, and is not included in the calculation of flow and transport after the thermal pulse, when rewetting is assumed to occur and restore ambient flux conditions.

The fraction of the wet area that actually has flowing fractures (seepage flow) is calculated using an algorithm which assumes a log-normal distribution of groundwater flux, spatially. It is assumed that a fraction of that flux is carried by the porous matrix, so that the average flux available for seepage flow is given by the difference between the total flux and that determined to [illegible] in the matrix. This quantity is the amount of water flux that is used in calculating advective releases for those containers that have advective releases.

There is episodicity in the calculated fraction of time that water is flowing in fractures, and in the fraction of time that a container is moist. This periodicity is a function of the "dry" or "wet" climatic conditions assigned by the model for a given time.

One realization, out of a set created by a geostatistical simulation, was used for the composite-porosity aqueous-release calculations. Unsaturated zone aqueous-transport modeling was restricted to the region from the repository down to the water table, and the eight vertical columns are shown in Figure 6.2.1-4. The water-table elevations shown in Figure 6.2.1-4 are for present conditions. In the simulations, water-table elevation for dry-climate periods can vary from the elevation shown in the figure to 10 m higher, and water-table elevation for wet-climate periods varies from 50 m higher than in the figure to 120 m higher. During wet-climate periods, the water table may rise above the zeolitic unit in Columns 3, 4, 5, and 8.

The fraction of containers assumed to be contacted by rubble is different for vertical or in-drift containers because in-drift-emplaced containers are always contacted by backfill, whereas borehole-emplaced containers may be protected from contact with moist rock by the borehole air-gap. Borehole stability and the probability of rubble infilling have not been investigated, though the Electric Power Research Institute, in its performance assessments, has considered the subject (McGuire et al., 1990, 1992).

Water-collection area is another parameter that is different for vertical and in-drift containers, and is used to calculate the amount of water flowing to and later through a container by multiplying it by the flux. There are no data on which to base an estimate of the effective water collection area. Water could tend to avoid the excavated, backfilled tunnels or it could be focused by the stress-relief fractures. The subject has not been studied in detail, so assumptions are made.

For this TSPA, the value of the water collection area was made a function of the horizontal cross-sectional area of the waste containers. A log-uniform distribution was assumed with a one-order-of-magnitude range, centered on the physical container cross-sectional area. Values were 0.13 to 1.3 m^2 for vertical emplacement, and 2.7 to 27 m^2 for in-drift emplacement. The uncertainty in this parameter is probably greater than one order of magnitude, but its importance is masked by the overriding importance of variations in the percolation flux which it multiplies.

For each aqueous-release simulation, 300 realizations are computed for each of the unsaturated-zone columns. For each realization of a column, unsaturated-zone flow is calculated for both "dry" and "wet" climatic conditions; releases from the EBS and unsaturated-zone transport are calculated, switching between the dry and wet flows at climate-change times; and then saturated-zone transport is calculated for a flow tube corresponding to each unsaturated zone column.

Unsaturated Zone Flow - Weeps Model - The second flow model, flow in fractures, was investigated by Wilson et al. (1994). The weeps model was designed to investigate this alternative flow concept. Figure 6.2.1-5 illustrates the concept of the weeps model. A complete description of the weeps model can be found in Gauthier et al. (1992) and in TSPA-1991 (Barnard et al., 1992) [INN 6.2.1-14]. The Wilson et al. (1994) analysis of total system performance using the weeps model was essentially a separate TSPA within TSPA-1993. Every aspect of the composite-porosity analysis was repeated for the weeps analysis: thermal effects, engineered system integrity, and release gas and aqueous pathways flow and transport.

Yucca Mountain ground water might not percolate slowly and uniformly through the mountain; rather, it might flow in episodic pulses through the fractures. In this conceptual model of groundwater flow, Yucca Mountain offers some waste containers little or no protection from fast moving flows of water. Some evidence exists for this flow mechanism, but the evidence is inconclusive. Locally perched water has been observed at Yucca Mountain at wells USW UZ-1 (Whitfield et al., 1990), and at USW UZ-14 (Dyer, 1993), and approximately 20 km southeast of Yucca Mountain at Skull Mountain (Ingraham et al., 1991). At Rainier Mesa, some 50 km northeast of Yucca Mountain with a tuff stratigraphy similar to Yucca Mountain, but with increased precipitation and different geologic structure, substantial flow has been observed through faults and fractures in the unsaturated zone (Wang et al., 1993).

The weeps model is not a process model; rather it is a mathematical construct based on several postulates or axioms, upon which mathematical transformations are performed. Thus, if the postulates hold, and if the transformations are appropriate and properly parameterized, the results could describe the basic flow conditions at Yucca Mountain.

The most important postulate is that flow within Yucca Mountain occurs vertically downward in locally saturated zones. That is, flow is gravity driven, and capillary effects are assumed to be negligible. Flowing groundwater therefore does not interact with the bulk of the tuff matrix, and if it does, something similar to the composite-porosity model results.

Another important postulate is that the weeps only contact the repository at discrete points, and degradation of the container only occurs at those points of contact. If a weep passes through the repository without contacting a container, there is no effect. It is assumed that containers not contacted by weeps do not corrode. This assumption is not necessarily conservative, because the containers at least undergo dry oxidation, and could be subject to aqueous corrosion from non-flowing water held in the tuff matrix. In general, it is expected that corrosion would be minor in these cases. If containers fail, releases are most likely limited to gaseous radionuclides or diffusion of dissolved radionuclides unless the container is subsequently contacted by a weep. If the container fails, because of a manufacturing defect or because of corrosion from previous contact with a weep, but is not currently contacted by a weep, only release of gaseous radionuclides occurs.

The weeps model is parameterized based on descriptions of the weeps and the geometric layout of the repository. Figure 6.2.1-6 presents an overview of this parameterization. Weeps are described according to their size, the amount of water they carry, and their flow episodicity, which can occur on different time scales. For example, a weep might only flow during pluvial climates, and then only one month out of the year. The repository is parameterized by its overall cross-sectional area and the cross-sectional area of contacted containers, i.e., contact area, that the waste containers present to the weeps.

Describing weeps in the absence of reliable data on weeps at Yucca Mountain requires use of an analogue, Rainier Mesa, where flow is concentrated in several large fractures/faults that are typically most active several months after the spring thaw (Wang et al., 1993). Therefore, weep flow at Yucca Mountain is described as flow through fractures. This assumption appears appropriate, at least in the repository block where the highly fractured, low permeability matrix of the Topopah Spring unit could be conducive to fracture flow.

Weep size is parameterized by an aperture and a width (a horizontal length). Wilson (1993) showed that results of the weeps model are very sensitive to the aperture and hence to the size of the weeps. Gauthier et al. (1992) showed that a large number of small weeps are worse for repository performance than a small number of large weeps. Thus, it is conservative to underestimate weep size, and hence it was assumed that weeps at Yucca Mountain flow in fractures of any size, and that the distribution of weep sizes is the same as that of fracture sizes. It is further assumed that, during a flow episode, a given weep is flowing at the capacity of the fracture it occupies. Distributing all infiltrating water among fractures then allows computation of the number of flowing fractures.

Conductivity of the fracture is calculated using the parallel-plate approximation. Flow through the fracture is calculated using Darcy's Law, enhanced to take into account non-laminar flow. The enhancement is based on an empirical model defined by Ward (1964). The amount of water flowing through the fracture over a given time is dependent on flow episodity. In this TSPA, the episode factor is constant for all weeps of a given weep pattern. This episode factor is also carried through the calculation involving transient weeps formed during the repository thermal pulse. The number of flowing fractures in a particular flow pattern can then be calculated by continually producing weeps, and subtracting the amount of water flowing through the weeps from the total infiltrating water, until the infiltrating water is totally distributed.

The results of this weep-flow calculation are the amount of water flowing through each weep, the area contacted by each weep, and the total number of weeps. The weep area and the contact area of a container are used to calculate the probability of a weep hitting a container. Tracking each weep is prohibitive in terms of the needed computer memory, so all weeps are produced, but only weeps contacting containers are tracked. The amount of flowing water in a weep hitting a container is used by the source term model (YMIM) to determine container lifetime if the container is below 100°C, and waste dissolution after container failure.

The velocity of water flowing in weeps can also be calculated, and the travel time from the repository to the water table is typically on the order of days to years. These times are so short that travel time is neglected in the analysis; i.e., the groundwater travel time in the unsaturated zone is assumed to be zero.

For TSPA-1993, the weeps model was used to produce 1,000 realizations in a Monte Carlo simulation of repository performance for each of the repository designs being examined, as previously described. Each realization spans one million years. During this time, new weep patterns form, intersecting new sets of containers. These new flow patterns and container sets are calculated at each climate change and at each time step during the time period of the repository thermal pulse.

In the weeps model, no interaction is allowed between the tuff matrix and the flow in the fractures. In the composite-porosity model, flow is allowed in both the matrix and the fractures and the flow is completely coupled. Thus, the weeps model is a bound for matrix-fracture interaction (there is none), but the weeps model is not a bound for repository performance. The weeps model is a tool for investigating how a repository might perform if flow is limited to discrete, locally saturated zones through Yucca Mountain.

Allowing weeps of varied sizes in every weep-flow realization means that containers can be contacted by different amounts of water. Allowing weep pattern to change in response to thermal effects and climate change means that duration of contact can be different for different containers. To track these evolving conditions, the weeps model accounts for each container individually throughout its predicted lifetime.

Not all containers contacted by weeps are simulated by the source term model YMIM. A simplified corrosion calculation is performed on each container contacted by a weep to determine if it can eventually fail; only a container that can fail is considered for a YMIM calculation. The simplified corrosion calculation is similar to that used by YMIM, except it only considers localized aqueous corrosion and the corrosion is confined to only one pit for the corrosion resistant barrier. For the corrosion allowance barrier only aqueous general corrosion is considered, so localized corrosion rates are set to be higher than the aqueous general corrosion rates for the simplified calculation. The result is an overestimate of corrosion and an underestimate of failure time. An assumed juvenile failure distribution was also incorporated.

Thermal dryout was included in the modeling. As the dryout zone expands and contracts, changes are expected to occur in the flow pattern. As implemented in the weeps model, these changes take into account previously flowing weeps, thus providing some memory in the process. When the dryout zone is expanding, weeps that fall within the growing protected area of the repository are eliminated, and an effective flux over the new unprotected part of the repository is calculated from both the water displaced by the dryout zone and the diverted infiltrating water. The difference between the new flux and the old flux over the new unprotected area is used to calculate how much water should be added to the weep flow.

This amount of water, as modified by an episodity factor, is used to generate weeps in the new unprotected area until the water is depleted. This process is illustrated in Figure 6.2.1-7.

When the dryout zone is contracting, displacement of water ceases, and infiltrating water is spread over an ever increasing area of the repository. New weeps are formed in the formerly protected areas, and some weeps are eliminated in the unprotected areas. Figure 6.2.1-8 illustrates flow-pattern changes during dryout-zone contraction.

Since there is no groundwater travel time included for the unsaturated zone, only one column was needed to describe vertical transport to the saturated zone, and it was linked to one of the flow tubes selected from the composite-porosity flow and transport model for the saturated zone. Gas flow was also calculated using the same model as used in the composite porosity model calculations.

Unsaturated Zone Thermohydrologic Process Models. The TSPA-1993 incorporated functional relationships between the thermal load and temperature, aqueous flux, gaseous flux, liquid saturation and relative humidity by abstraction from detailed calculations of coupled heat and fluid flow in the geosphere. The processes involved with thermally driven gas flow will be discussed separately from thermally driven liquid flow.

<u>Thermally Driven Gas Flow.</u> A model (Ross et al., 1993, Wilson et al., 1994) of gas flow driven by temperature and humidity differences was used to develop gas velocity distributions for use in estimating ^{14}C releases for the TSPA-1993 [INN 6.2.1-15]. It was not used for water balance or heat transfer predictions. In this model, gas flow and gaseous transport are treated in two dimensions. Three two-dimensional cross-sections through Yucca Mountain were used. Gas flow was modeled using the assumption that relative humidity is always 100%, and gaseous transport is modeled as being purely advective, with no diffusion. The gas-flow calculations are transient and coupled with heat flow, however, barometric pressure fluctuations and temperature differences between day and night were neglected.

<u>Thermally Driven Liquid Flow</u>. The processes incorporated into thermally driven liquid flow took into account:

a. Fluid flow in both liquid and gas phases under pressure, viscous, and gravity forces;

b. Capillary and phase adsorption for the liquid phase;

c. Vapor pressure lowering due to capillary effects;

d. Binary diffusion in the gas phase; and

e. Heat transport due to conduction, convection, and binary diffusion.

The calculational model used was V-TOUGH (Nitao, 1989), a modified version of the TOUGH code (Pruess, 1987) which is capable of simulating coupled multidimensional transport of water, vapor, air, and heat in porous and fractured material [INN 6.2.1-16]. The paucity of data on geometric/hydraulic characteristics of fractures at Yucca Mountain, as well as the computational complexity associated with modeling hydrothermal behavior in a discrete fracture network necessitated the use of the equivalent continuum model. The equivalent continuum model forces liquid movement to occur primarily within the matrix and is controlled by the matrix permeability, whereas air/vapor movement takes place primarily in the fractures and is controlled by the fracture permeability. The repository models used in support of TSPA-1993 were of 2-D axisymmetric geometry.

Unsaturated Zone Radionuclide Transport Processes. The transport processes in the unsaturated zone included separate models for the gas phase and the aqueous phase. The gas phase transport assumed the flow velocities described in the section on thermohydrologic processes, with the transport of ^{14}C (the only gaseous radionuclide considered) retarded with respect to the gas/vapor owing to its tendency to dissolve in (and exsolve from) pore fluids.

Radionuclides were transported in the aqueous phase with the motion of the fluid carrying them according to the one-dimensional advection-dispersion equation with radioactive decay but were retarded in comparison to the fluid flow. Retardation was included as certain radionuclides tend to sorb onto (and desorb from) the host rock. The retardation factors were calculated with a simple model using distribution coefficients (K_d) that were assumed to be independent of environmental conditions, but with variability as expressed through expert elicitation.

Saturated Zone Flow Model. The saturated zone flow was assumed to occur in a single horizontal pathway between the repository and the accessible environment. Flow within that pathway assumed to be through equivalent porous media. Two independent three dimensional models were developed in an attempt to explain the large hydraulic gradient to the north of the site [INN 6.2.1-17].

The TSPA-1991 exercise used a two-dimensional representation of the saturated flow system built on models of Czarnecki (1985) and Czarnecki and Waddell (1984). New interpretations of the cause of the large hydraulic gradient in the saturated zone northwest of the site (Fridrich et al., 1991; Sinton, 1989; Czarnecki, 1989) suggest that the saturated flow system may only be adequately represented locally when modeled in three dimensions.

These new interpretations are based on two models, called the non-diversionary model and the diversionary model, that best fit the available information concerning the existence of the large hydraulic gradient region in that area. For the non-diversionary models, all fluid flowing within the tuffaceous units northwest of the large hydraulic gradient region continue flowing in the tuffs as the fluid moves to the southeast. In the diversionary model, some portion of the fluid flowing in the saturated tuffs flows abruptly downward, in the area coincident with the high gradient region, and then continues to flow to the southeast within the Paleozoic carbonate aquifer that underlies the tuffs.

Two models were created that represent two alternate conceptual models of the saturated flow system, consistent with current site data. Numerical experiments were used to determine the effects on the flow system induced by the introduction of four geologic features. [The exact values of the hydraulic properties associated with these four features are currently unknown, however, values thought to be appropriate are inserted for the purpose of the exercise. If, indeed, the introduction of the features produces a better fit to current data, subsequent guidance to site characterization will be to test the validity of the assumptions associated with these features [INN 6.2.1-18].]

The two conceptualizations for the saturated zone were quantified and calibrated against existing well hydraulic head data. Assumptions of properties for several geologic features were incorporated to provide an acceptable fit to the well head data. Numerous flow and transport realizations were produced using these models, and the results indicated the probable achievement of steady state flow conditions for most nodes by the end of a 4,700 year calculational period. This in turn allowed the resulting three-dimensional water velocities and hydrodynamic dispersivities to be abstracted for use in the one-dimensional flow tubes of the total system assessments conducted by both Andrews et al. (1994) and Wilson et al. (1994). Because longitudinal dispersivities were uncertain, Wilson et al. (1994) used the 50% solute breakthrough time, which is relatively independent of dispersivity values, divided into the distance to the accessible environment, as an effective transport velocity.

For calculations of cumulative releases to the accessible environment, calculations for the velocity of a unit concentration of conservative tracer coming from three potential source areas, for the two conceptual models, resulted in six probability distribution functions for effective velocity. To abstract this information for use in the probabilistic total system assessment, curves were fitted to these distributions from which representative effective velocity values were estimated. The curve fitting parameters were the calculated mean velocities and a subjective curve fitting parameter that has a relation to longitudinal dispersivity. Two of the source areas yielded similar values, for both the effective velocities and the dispersivity (tabulated below) so they were combined.

Effective Velocity and Dispersivity for the Six Saturated Zone Cases

Case	Velocity (m/yr)	Dispersivity (m)
Prow Pass source, no drain	5.9	130
Bullfrog source, no drain	8.7	170
Calico Hills source, no drain	6.0	110
Prow Pass source, drain	10.8	150
Bullfrog source, drain	12.5	100
Calico Hills source, drain	10.3	150

The conceptual model differences were significant, and because of the lack of certainty concerning which model is more likely, uniform distributions were assigned to the two source areas' effective velocities that spanned the values obtained for the two conceptual models (see table below). For the dispersivity, the minimum value and a rule-of-thumb value of 10% of the path length were assumed to bound a uniform distribution, shown as follows.

Velocity and Dispersivity Distributions for Total System Simulations

Model Parameter	Distribution
CH/PP* velocity (Cols. 3-5,7,8)	uniform from 5.5 to 11 m/yr
BF+ velocity (Cols. 1,2,6)	uniform from 8.5 to 12.5 m/yr
Dispersivity	uniform from 100 to 500 m

* Calico Hills/Prow Pass source
\+ Bullfrog source

Effective velocity and dispersivity are needed to calculate cumulative releases over a specified time, but to calculate dose, concentrations must be known. In order to calculate saturated zone concentrations, the vertical and horizontal mixing lengths must be estimated. The horizontal mixing length was taken to be the length of the repository perpendicular to the groundwater flow direction in the saturated zone, about 3,000 m, plus the transverse dispersivity, which was estimated to be between 200 and 700 m in both directions, yielding a range of 3,400 to 4,400 m. Determining the vertical mixing depth, on the other hand, was a more complicated matter requiring the interpretation of field data.

In the creation of the saturated zone three-dimensional model, the saturated zone was modeled as an approximately 8 km x 8 km x 200 m confined system. The modeled region extends far enough laterally to include the region of the high hydraulic gradient to the northwest and the

5-km distance to the accessible environment. The resulting three-dimensional block is divided into four layers, each 50 m thick. There are several technical arguments indicating that the mixing depth can be represented using a block thickness on the order of 200 to 300 m for this model. One of these arguments is that U. S. Geological Survey tracer injection tests (e.g., Lobmeyer et al., 1983) shows considerable inhomogeneity over the tested depths, i.e. in excess of 1,000 m. In each well, evidence of one or more zones with significant differences in hydraulic properties was encountered within the first 200 m below the water table. These zones might then be expected to divert flow at different levels in different locations, thus inducing mixing within that 200 m layer. In addition, data from one well (UE-25 P#1) shows an aquitard at about 1,100 m depth, sufficiently nontransmissive to support a 20-m head difference across the aquitard (Craig and Robison, 1984). This implies that, if the aquitard is continuous, the problem can be truncated vertically by a horizontal plane above the aquitard. This would argue that 400 m is a maximum thickness for the block. However, it should be noted that there are very few wells that sample to this depth, so the continuity of the aquitard is not known.

Given this uncertainty, a range of vertical mixing depths was assumed to span from 50 to 500 m. This range, when multiplied by the horizontal mixing length, yielded a range for mixing area values that were rounded off to $2*10^4$ to $2*10^6$ m^2, and was assigned a log-uniform distribution.

The treatment by Andrews et al. (1994) of the saturated zone was also based on the saturated zone modeling reported in Wilson et al. (1994). The Darcy flux distribution was obtained directly from the flow analysis by Barr. The flux values in each of the individual grid blocks within the entire model domain were averaged to obtain a mean value of 2 m/year, with minimum and maximum values of 4.7×10^{-6} m/year and 390 m/year, respectively. This was thought an unrealistically wide range for the purposes of this assessment, however, so the distribution was modified to narrow the range.

The saturated zone was assumed to be a single, horizontal pathway extending 5,000 m from beneath the repository to the accessible environment. The hydrologic parameters of the entire saturated zone were assumed to be equivalent to those of the Prow Pass welded tuff. The radionuclide releases from each of the nine unsaturated-zone columns used in the unsaturated flow and transport calculations were discharged into one location within the saturated zone, 5000 m up gradient from the accessible environment.

Dose calculations involve the division of mass release rate by the mixing volumetric flow rate (m^3/yr), which was assumed to be a function of the cross-sectional area of the saturated-zone (m^2) and the saturated-zone flux (m/yr). The cross-sectional area was held constant and set equal to the footprint of the repository, 2.0×10^5 m^2. A constant mixing depth of 50 m was assumed.

Given that the saturated zone mixing volume in the Andrews et al. (1994) calculation was held constant, the only property of the saturated zone that was varied was the groundwater flux.

Saturated Zone Thermohydrologic Process Model. No thermohydrologic processes were included in the saturated zone [INN 6.2.1-19].

Saturated Zone Radionuclide Transport Process Model. The radionuclide transport processes included in the saturated zone were the same as described under the section on unsaturated zone aqueous transport processes with the addition of including horizontal and vertical mixing in order to radionuclide concentrations and resulting doses [INN 6.2.1-20].

Biosphere Process Model. Andrews et al. (1994) used conversion factors appropriate for calculation of whole body dose for an individual that obtains all of his/her drinking water and crop irrigation water from the contaminated saturated zone. The biosphere processes addressed by this model include the uptake of radionuclides by plants, uptake, elimination, accumulation, distribution, and hazard of the radioactive emissions within the human body [INN 6.2.1-21].
The Wilson et al. (1994) contribution used conversion factors appropriate to only ingestion of contaminated ground water.

6.2.2 Potentially Disruptive Processes and Events

[The credible potentially disruptive processes and events that could reasonably affect the geologic repository over the next 10,000 years are presented in Table 6.2.2-1 [INN 6.2.2-1].] These processes and events are categorized by causes, which include tectonic, geomorphic, climatic, and anthropogenic. Anthropogenic effects are either repository related or related to human activities. [Table 6.2.2-1 also indicates the location [INN 6.2.2-1] in which each of the processes and events are a consideration (i.e., could potentially affect the long term behavior of the repository), and the general effects that could be expected from the process or event.] Each of the processes and events is discussed by the category of its root cause, its expected location, and its effect on the postclosure performance of the overall system.

Processes and events that are caused by tectonics are uplift/subsidence/tilting, folding, faulting, seismicity, and volcanism. Each of these could alter the groundwater flow pathways or hydraulic conductivity which could affect groundwater flow, gas flow, and radionuclide transport to the accessible environment. Volcanism could affect the repository through magmatic intrusion into the emplacement area, entrainment of waste, and ejection of radionuclides into the biosphere. Intrusion of magma into an aquifer could cause steam that could travel along faults, fracture zones, or zones of higher hydraulic conductivity to reach the repository. The steam could increase corrosion rates, leaching, and radionuclide transport. The tectonic processes and events, uplift/subsidence/tilting, folding, faulting, and seismicity within the region could alter flow paths from the repository through changes in the regional groundwater flow patterns or local changes in the water table elevation. Seismicity in the region and faulting within the controlled area could increase hydraulic conductivities and release perched ground water or decrease travel time from the repository to the accessible environment. Faulting could shear waste packages and initiate releases along fault planes. In addition to hydrologic and travel time considerations, regional seismicity can induce mass gravity movements (e.g., landslides).

The geomorphic processes and events considered are erosion and mass gravity movements such as landslides. Erosion could expose waste over long periods of time (millions of years) or cause oversteepening of slopes, making them more susceptible to mass gravity movements (YMP/92-41-TPR, *Evaluation of the Potentially Adverse Condition "Evidence of Extreme Erosion During the Quaternary Period" at Yucca Mountain, NV*). Mass gravity movements can create dams and ponds which would increase infiltration and water percolation through the repository. A reduction of depth of the repository caused by erosion or mass gravity movement could also alter flow paths in the unsaturated zone which could affect the repository. For erosion or mass gravity movements to affect the repository significantly, they would have to occur above or nearly above the emplacement area within the controlled zone. [Because of the potential for lateral flow associated with perched groundwater zones, erosion and mass gravity movements within the controlled zone are considered.]

Climate change could cause increased precipitation and increased infiltration which would increase the amount of water and water vapor moving through the repository. This increase could cause an increase in water-table elevation and changes in groundwater flow paths. As discussed previously, increased precipitation could result in increased erosion. Increased infiltration could decrease groundwater travel time, increase leaching, and cause water table rise, all of which are important within the controlled area. Increased infiltration in the region could alter regional groundwater flow patterns, which could affect flow paths.

Repository-caused processes and events include thermomechanical response of the rock mass surrounding the emplacement area, and thermally induced geochemical changes that could increase hydraulic conductivity. Increased hydraulic conductivity could increase groundwater flow, gas flow, and radionuclide transport. Geochemical alteration associated with the long-term thermal pulse could change fracture fillings and/or matrix minerals and potentially reduce sorption of radionuclides in the repository near field. Geochemical changes could potentially extend beyond the emplacement area and into the controlled area. [For this reason, geochemical changes are considered within the controlled area in order to examine the potential significance of these smaller effects beyond the emplacement area.]

The undisturbed repository behavior could be changed through future human actions. Human activities considered are intrusion, induced infiltration, groundwater withdrawal, and weapons testing. Intrusion could result from drilling (either vertical or lateral) into the emplacement area or from mining into contaminated rock within a contaminated groundwater plume which could extend from the emplacement area. To meet the requirements of the EPA Standard [INN 6.2.2-2], and because drilling and mining in search of natural resources could alter flow paths, intrusion is considered within the controlled area. Human activities could increase infiltration from water spreading, underground injection of water, or construction of dams and ponds within the controlled area. Groundwater withdrawal could alter the direction of flow and/or the rate of flow along flow paths. Weapons testing over the next 10,000 years in the vicinity of the repository could also potentially alter water and gas flow paths.

Potentially Disruptive Processes and Events Used in TSPA-1993.

Basaltic Volcanism Events. Calculations were performed that addressed the potential for indirect releases due to magma-waste interactions. Specifically, accelerated waste-package degradation due to the heat and aggressive volatiles emitted from a magmatic intrusion near a waste package was considered. This analysis considers only indirect effects where there is no waste-magma contact. Actual volcanic events would naturally be expected to have a range of interactions, from entrainment of waste, to encapsulation of waste, to attack by volatiles. This analysis was not intended to bound the effects of volcanism, rather to investigate a particular aspect of the potential interactions.

Human Intrusion Events. Human intrusion events were considered in TSPA-1993 (Wilson et al., 1993). It was assumed that there will be drilling that may intersect either a waste container or contaminated rock. Radionuclides would then be entrained in the drilling fluid and carried to the surface [INN 6.2.2-3].

6.2.3 Undisturbed Performance Processes and Events

The processes affecting performance of the repository in its undisturbed state are considered to be those naturally occurring processes at the Yucca Mountain site and its vicinity which can be influenced by the construction of the facility, the thermal pulse, and any release of radioactive materials over the next 10,000 years and beyond. The processes include physical and chemical processes such as underground flow of fluids and transport of contaminants. These processes are affected by thermal loading and geochemical/chemical behavior of waste and waste package materials interacting with rock, gas, and water over long periods of time. The natural processes are affected by repository-induced processes and are also influenced by events expected to occur over the next 10,000 years, such as seismicity and climatic change.

Processes and events affecting the undisturbed engineered barrier that are considered for performance are [presented in Table 6.2.3-1 [INN 6.2.3-1] To provide insight into the level of detail being considered for the engineered barrier processes, Table 6.2.3-2 [INN 6.2.3-1] presents the potential data requirements necessary for analysis of these processes and events. Each entry in Table 6.2.3-2 and in subsequent data Tables (in this section) may represent either a single value for each material or an entire data set (e.g., the number of data points represented for each line of the data Tables is not constant; the radionuclide inventory [represented by the first line of Table 6.2.3-2] contains the number of curies over time of each radionuclide in the repository for each waste form).

The repository and near-field undisturbed processes and events considered for performance are [presented in Table 6.2.3-3 [INN 6.2.3-1.] These include the mechanical, hydrologic, and geochemical responses of the repository and the near field host rock to the thermal and chemical effects of the waste. For insight into the level of detail of analyses of these processes and events, the potential sets of data required are [presented in Table 6.2.3-4 [INN 6.2.3-1.] Because of the similarity of these data sets for waste package gap filler and backfill to the data necessary for seals, the data sets necessary for evaluation of repository seals are also [presented in Table 6.2.3-2.]

The biosphere processes and events affecting the repository in its undisturbed state that are considered for performance are [presented in Table 6.2.3-5 [INN 6.2.3-1].] Potential data sets necessary for analysis of processes and events have been partially compiled (Table 6.2.3-6). The remaining data for Table 6.2.3-6 will be supplied through [INN 6.2.3-2.] Because of the importance of fluid flow and transport processes between the waste and the accessible environment, these processes and events are [presented in greater detail in Tables 6.2.3-7 and 6.2.3-8], respectively. The potential data sets required for analysis of fluid flow and transport are presented in Tables 6.2.3-9 and 6.2.3-10, respectively. For both fluid flow and transport, the data sets for unsaturated conditions are [presented in Tables 6.2.3-7 through 6.2.3-10,] and these data sets will be simplified for saturated conditions.

[The processes and events considered for undisturbed performance at the Yucca Mountain site are summarized in Table 6.2.3-11 [INN 6.2.3-1.] These are categorized by cause and expected location of consideration (i.e., within the emplacement area, repository disturbed zone, controlled area, etc.). The potential effects of the processes and events are also tabulated. [Table 6.2.3-11 and other Tables in this section will be completed or updated through [INN 6.2.3-1].]

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Table 6.2.1-4 Models Used for Analysis of Unsaturated Zone Flow

Conceptual Models	Calculational Models	Reference
Porous Media Dual Porosity Dual Permeability . .	TOUGH2	Pruess, 1987

Note: Tables 6.2.1-1 through 6.2.1-10 are similar in design and only 6.2.1-4 is shown here. These tables will be completed using INN 6.2.1-1.

6.2.1-1	Models Used for Analysis of the Engineered Barrier (includes: waste package degradation, waste form alteration, waste package release, and engineered barrier release).
6.2.1-2	Models Used for Analysis of Repository Thermomechanical Effects.
6.2.1-3	Models Used for Analysis of Near Field Thermochemical Processes.
6.2.1-4	Models Used for Analysis of Unsaturated Zone Flow.
6.2.1-5	Models Used for Analysis of Unsaturated Zone Thermohydrologic Processes.
6.2.1-6	Models Used for Analysis of Unsaturated Zone Radionuclide Transport (includes; aqueous phase and gaseous phase transport).
6.2.1-7	Models Used for Analysis of Saturated Zone Flow.
6.2.1-8	Models Used for Analysis of Saturated Zone Thermohydrologic Processes.
6.2.1-9	Models Used for Analysis of Saturated Zone Radionuclide Transport.
6.2.1-10	Models Used for Analysis of Biosphere Processes.

Table 6.2.1-11 Justification of Conceptual Models Not Included in the Performance Assessment

Area	Conceptual Models Eliminated	Documentation
Engineered Barrier	Examples	Reference for each area which justifies elimination
Repository Thermomechanical		
Near Field Thermochemical		
Unsaturated Zone Flow		
Unsaturated Zone Thermohydrologic		
Unsaturated Zone Radionuclide Transport		
Saturated Zone Flow		
Saturated Zone Thermohydrologic		
Saturated Zone Radionuclide Transport		
Biosphere		

Note: This table will be completed using INN 6.2.1-2.

Table 6.2.2-1 Location and General Effects of Potential Disruptive Processes and Events

Cause	Process/Event	Location	General Effects
Tectonic	• Uplift/Subsidence/Tilting	Region	Alteration of flow paths
	• Folding	Region	Alteration of flow paths
	• Faulting	Controlled area and region	Alteration of flow paths
	• Seismicity	Region	Alteration of flow paths
	• Volcanism		
	- magmatic intrusion	Emplacement area	Waste entrainment
	- hydrothermal intrusion	Controlled area	Corrosion/leaching/migration
	• Mass gravity movements	Region	Alteration of flow paths
Geomorphic	• Erosion	Controlled area	Reduced depth to waste, increased infiltration
	• Dissolutioning		
	• Mass Gravity Movements		Reduced travel time
	- Dams & Ponds		
Repository	• Thermomechanical	Disturbed zone	Alteration of flow paths
	• Geochemical	Disturbed zone and controlled area	Alteration of flow path and alteration of sorption
Climatic	• Infiltration	Controlled area and region	Decreased travel time, increased leaching, and water table rise
	• Flooding	Emplacement area	Increased infiltration
	• Erosion/Mass Gravity - Dams & Ponds	Controlled area	Increased infiltration
Human	• Intrusion		
	- Drilling	Controlled area	Waste exhumation, alteration of flow paths, and drinking water wells
	- Mining	Controlled area	Exhumation of contaminated rock
	• Groundwater Withdrawal	Region	Decreased travel time, alteration of flow paths
	• Infiltration		
	- Groundwater injection/water spreading	Controlled area	Increased infiltration, alteration of flow paths
	- Dams & Ponds	Controlled area	Increased infiltration
	• Weapons Testing	Controlled area	Alteration of flow paths

Note: This table will be completed based on analyses in INN 6.2.2-1.

Table 6.2.3-1 Engineered Barrier Processes and Events for Undisturbed Performance

Engineered Barrier Environment Processes
- Thermal
- Mechanical
- Radiation
- Geochemical
- Hydrodynamic

Waste Package Degradation Processes
- Uniform corrosion
- Pitting corrosion
- Stress crack corrosion
- Crevice corrosion
- Mechanical
- Hydrogen embrittlement
- Oxidation
- Microbiologically influenced corrosion

Waste Form Release Processes
- Gaseous release
  - Instantaneous
  - Gradual
- Aqueous release processes
  - Solubility controlled
  - Alteration controlled

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-2 Potential Engineered Barrier Data Requirements

Waste Form

- Radionuclide inventory
    - Percent in matrix
    - Percent in gap
    - Percent in grain and grain boundary
    - Percent in cladding
    - Fission history
- Chemical properties
    - Percent of fuel/waste wet
    - Radiolysis
    - Colloid formation
    - Solubility
    - Fuel and glass alteration rate
    - Fuel and glass composition
    - Radiation induced changes
    - Thermally induced changes
    - Corrosion induced changes
    - Oxidation induced changes
- Thermal properties
    - Density
    - Specific heat
    - Thermal conductivity
- Radiation properties
    - Densities
    - Attenuation cross sections

Table 6.2.3-2 Potential Engineered Barrier Data Requirements (Continued)

Waste Package Materials

- Thermal properties
  - Density
  - Specific heat
  - Thermal conductivity
- Radiation properties
  - Densities
  - Attenuation cross sections
- Mechanical properties
  - Moduli (elasticity, etc.)
  - Poisson's ratio
- Corrosion properties
  - Uniform corrosion parameters
  - Pitting parameters
  - Stress cracking parameters
  - Crevice corrosion parameters
  - Oxidation parameters
  - Chemical properties
  - Corrosion depth to failure
  - Microbiologically influenced corrosion parameters

Table 6.2.3-2 Potential Engineered Barrier Data Requirements (Continued)

Gap Filler, Backfill, and Seals[1]

- Hydrodynamic properties
  - Porosity
  - Tortuosity
  - Permeability
  - Saturation
  - Retardation
  - Diffusion coefficients
- Water chemistry
  - Radiolysis
  - Radiation induced changes
  - Temperature induced changes
  - Colloid formation
  - Corrosion induced changes
- Thermal properties
  - Density
  - Specific heat
  - Thermal conductivity
- Radiation properties
  - Density
  - Specific heat
  - Thermal conductivity

Geometry

- Waste package
- Gap, gap filler, and backfill
- Placement

---

[1] Technically, data sets for evaluation of repository seals should be presented in Table 6.2.3-4 but are presented here because of their similarity to filler and backfill.

Table 6.2.3-2 Potential Engineered Barrier Data Requirements (Continued)

Boundary and Initial Conditions

- Temperature
- Manufactured defects
- Mechanical failure
- Chemical composition
- In situ stress
- Water saturation
- Fluid flux
- Thermal flux
- Radiation flux

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-3 Repository and Near-Field Processes and Events for Undisturbed Performance

Heat Transfer

- Convection
- Radiation
- Conduction

Mechanical Response

- Rock mass deformation
- Joint deformation
- Rock failure
- Seal deformation[2] see Table 6.2.3-2.

Hydrologic Response

- Water and water vapor flow
- Gas flow
- Permeability change

Geochemical Response

- Precipitation/dissolution reactions
- Colloid formation
- Aqueous reactions
- Ion exchange
- Redox reactions
- Adsorption/desorption
- Rock/water interactions

Note: This table will be completed using INN 6.2.3-1.

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[2] For data sets needed for evaluation of repository seals, see Table 6.2.3-2 under Gap Filler, Backfill, and Seals.

Table 6.2.3-4 Potential Repository and Near-Field Data Requirements

Heat Transfer

- Heat transfer as a function of time
- Convective heat transfer as a function of temperature
- Radiative heat transfer
- Conduction

  - Rock mass bulk properties
  - Rock mass heat capacity as a function of saturation
  - Rock mass thermal conductivity
  - Air density
  - Air heat capacity
  - Air thermal conductivity
  - Water density
  - Water heat capacity
  - Water thermal conductivity

Mechanical Response

- Intact rock and rock mass properties

  - Density
  - Elastic constants (anisotropy)
  - Internal friction properties
  - Deformation modulus (time, temperature, stresses)
  - Compressive strength (time, temperature, stresses)
  - Tensile strength (time, temperature, stresses)

- Effects of damage function on rock mass properties
- Rock mass properties under dynamic loading

Table 6.2.3-4 Potential Repository and Near-Field Data Requirements (Continued)

Hydrologic Response

- Saturated water intrinsic permeability
- Permeability as a function of water saturation
- Capillary pressure as a function of water saturation
- Total porosity
- Liquid fracture matrix coupling function
- Thermal expansion
- Thermal conductivity
- Specific heat

Geochemical Response

- Dispersivity
- Minerals/petrologic description
- Diffusion coefficients
- Equilibrium distribution coefficients
- Chemical thermodynamic database
- Fluid chemistry

Boundary Conditions

- Pressure or hydraulic potential
- Water saturation
- Water and gas flux
- Overburden loading
- Temperature
- Thermal flux

Initial Conditions

- Ambient stresses
- Ambient temperature
- Fluid pore pressure
- Joint geometry

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-5 Biosphere Processes and Events for Undisturbed Performance

- Climate variation
    - Precipitation change
- Surface water
    - Rivers and streams
    - Lakes and ponds
- Dose to man and environment
    - Inhalation
    - Ingestion
    - Immersion
    - Direct radiation
    - Food chain transport
    - Population

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-6 Potential Biosphere Data Requirements

Fluid Flow
(See Table 6.2.3-8)

Radionuclide Transport
(See Table 6.2.3-10)

Note: This table will be completed using INN 6.2.3-2.

Table 6.2.3-7 Fluid Flow Processes and Events for Undisturbed Performance

Porous flow

- Gas, vapor, liquid

Fracture flow

- Gas, vapor, liquid

Fracture/matrix coupling

- Equilibrium and disequilibrium

Gas, vapor, liquid

Thermal effects

- Thermal expansion
- Block slip (hydraulic conductivity change)

Geochemical effects

- Precipitation/dissolution reactions

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-8 Potential Fluid Flow Data Requirements

Matrix and Fracture Material Properties

- Liquid fluid phases
    - Saturated water intrinsic permeability
    - Relative permeability as a function of water saturation
    - Capillary pressure as a function of water saturation
    - Total porosity
    - Liquid fracture - matrix coupling term
    - Fracture water saturation delay (model parameter)
- Gas fluid phases
    - Saturated gas intrinsic permeability
    - Relative permeability as a function of gas saturation
    - Capillary pressure as a function of gas saturation
    - Gas fracture - matrix coupling function
    - Fracture gas saturation delay
    - Dissolved gas in liquid as a function of temperature and pressure
    - Base vapor - gas diffusion coefficients
    - Temperature dependent diffusion exponent
    - Tortuosity and related factors
    - Mass fraction phase factor
- Thermal effects of porous medium for water and gas
    - Thermal expansion vs. saturation
    - Thermal conductivity vs. saturation
    - Specific heat vs. saturation
- Fracture properties (individual and sets)
    - Dimensions
    - Orientations
    - Connectivity

Table 6.2.3-8 Potential Fluid Flow Data Requirements (Continued)

Fluid Properties

- Liquid densities as a function of temperature, pressure, concentration
- Gas densities as a function of temperature, pressure, concentration
- Vapor densities as a function of temperature and pressure
- Dynamic liquid viscosities as a function of temperature, pressure, concentration
- Dynamic gas viscosities as a function of temperature, pressure, concentration
- Dynamic vapor viscosities as a function of temperature and pressure
- Thermal conductivity as a function of temperature and pressure
- Specific heat as a function of temperature, pressure, concentration
- Thermophysical water properties (steam tables)

Boundary Conditions

- Pressure or hydraulic potential conditions
- Temperature conditions
- Fluid saturations
- Flux of fluid and temperature

Initial Conditions

- (same as boundary conditions)

Geometry

- Hydrologic unit contacts
- Fault geometry
- Discrete fracture geometry

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-9 Transport Processes and Events for Undisturbed Performance

- Diffusion
- Dispersion
- Retardation
    - Ion exchange
    - Adsorption/desorption
    - Precipitation/dissolution
    - Matrix diffusion
    - Chelation
- Geochemical reactions
- Radioactive decay

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-10 Potential Transport Data Requirements

Material Characteristics (matrix and fracture)

- Dispersivities
- Total porosity
- Effective porosity
- Diffusivity
- Specific density
- Fracture configuration from flow model

Fluid Properties

- Liquid densities as a function of temperature, pressure, concentration
- Dynamic liquid viscosities as a function of temperature, pressure, concentration
- Thermal conductivity as a function of temperature, pressure, concentration
- Diffusion coefficient as a function of temperature, pressure, concentration

Geochemistry

- Minerals/petrologic description
- Sorption coefficients
- Matrix diffusion coefficients
- Equilibrium distribution coefficient
- Chemical thermodynamic database
- Sorption isotherms
- Natural colloids, organics
- Actinide polymerization
- Reaction rates

Liquid Phase

- Flow vector fields
- Saturation distribution
- Temperature distributions
- Condensed water vapor fields

Table 6.2.3-10 Potential Transport Data Requirements (Continued)

Gas Phase

- Water vapor flow fields
- Flow vector fields
- Saturation distributions
- Temperature distribution

Boundary Conditions

- Concentrations
- Contaminant fluxes

Initial Conditions

- Concentrations
- Contaminant fluxes
- Radionuclide inventory

Geometry

- From flow model

Note: This table will be completed using INN 6.2.3-1.

Table 6.2.3-11 Summary of Processes and Events for Undisturbed Performance

Cause	Process/Event	Where Considered	General Effects
Waste thermal output	• Heat transfer	Emplacement area and controlled area	Thermally induced fluid flow
	• Heat transfer	Disturbed zone	Stress/strain alterations, permeability alteration
	• Heat transfer	Disturbed zone	Geochemical changes
Waste radiation output	• Radiolysis	Emplacement area	Geochemical changes
Corrosion	• Waste package degradation	Emplacement area	Gaseous and/or aqueous releases
Underground Opening	• Creep	Disturbed zone	Spalling and/or structural collapse
Geochemical	• Waste leaching	Emplacement area	Mobilization of radionuclides
	• Sorption	Controlled area	Retardation of radionuclides
	• Colloid formation	Emplacement area	Mobilization of radionuclides
	• Precipitation/dissolution	Controlled area	Changes in fluid conductivity
Tectonic processes	• Seismicity	Controlled area	Alteration of flow paths
Precipitation/climatic change	• Infiltration	Controlled area	Increased fluid flow and water table rise
		Region	Alteration of flow paths
	• Flooding	Controlled area	Increased fluid flow
Fluid Flow	• Gaseous and/or liquid transport of radionuclides	Controlled area	Radionuclide migration Dilution of radionuclide concentrations
Diffusion	• Matrix diffusion	Controlled area	Radionuclide migration Dilution of radionuclide concentrations
Radionuclide Ingestion	• Dose-to-man	Accessible environment	Health effects
Radionuclide Inhalation	• Dose-to-man	Accessible environment	Health effects

Note: This table will be completed using the analyses in INN 6.2.3-1.

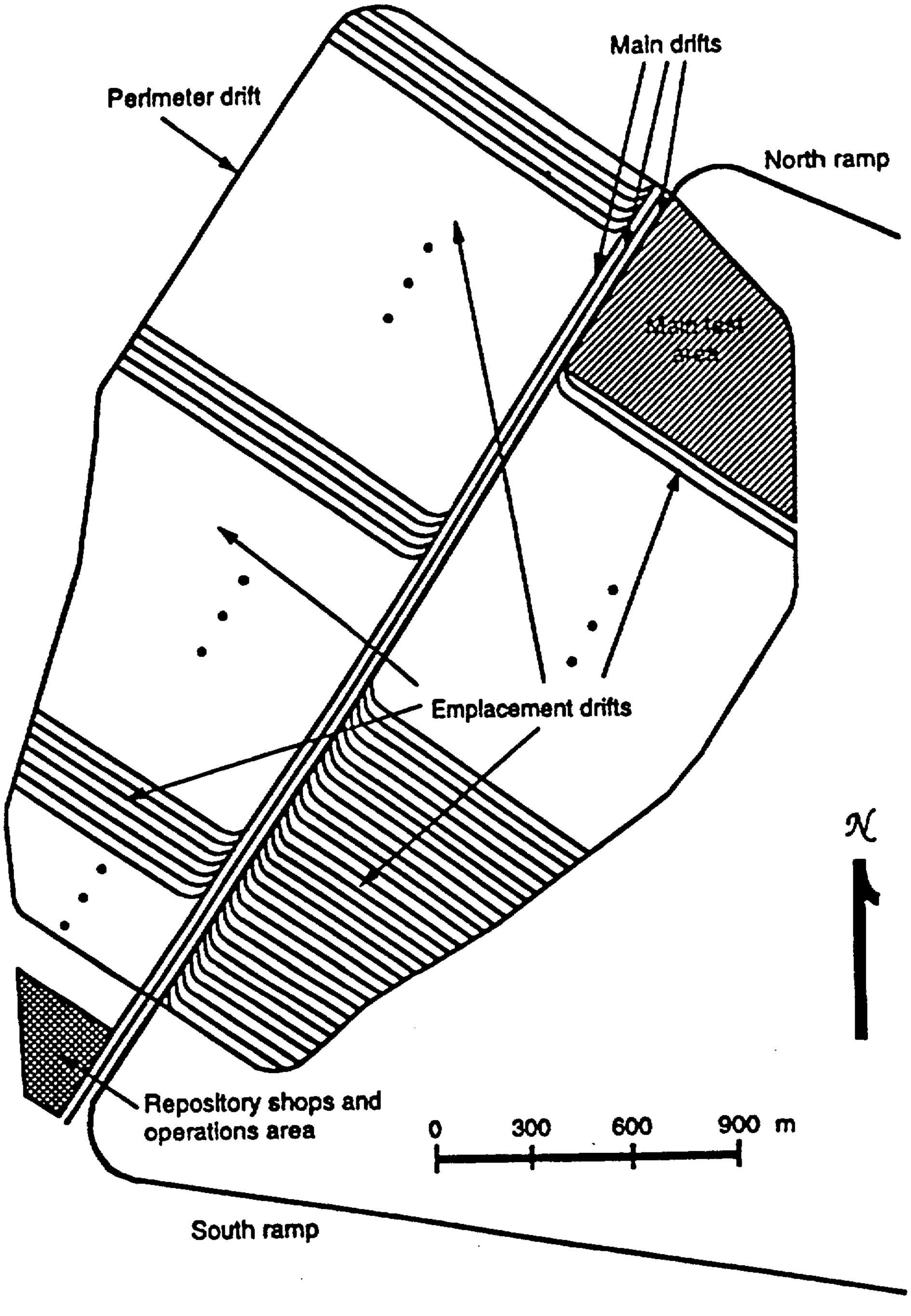


Figure 6.2.1-1 A Conceptual Repository Layout

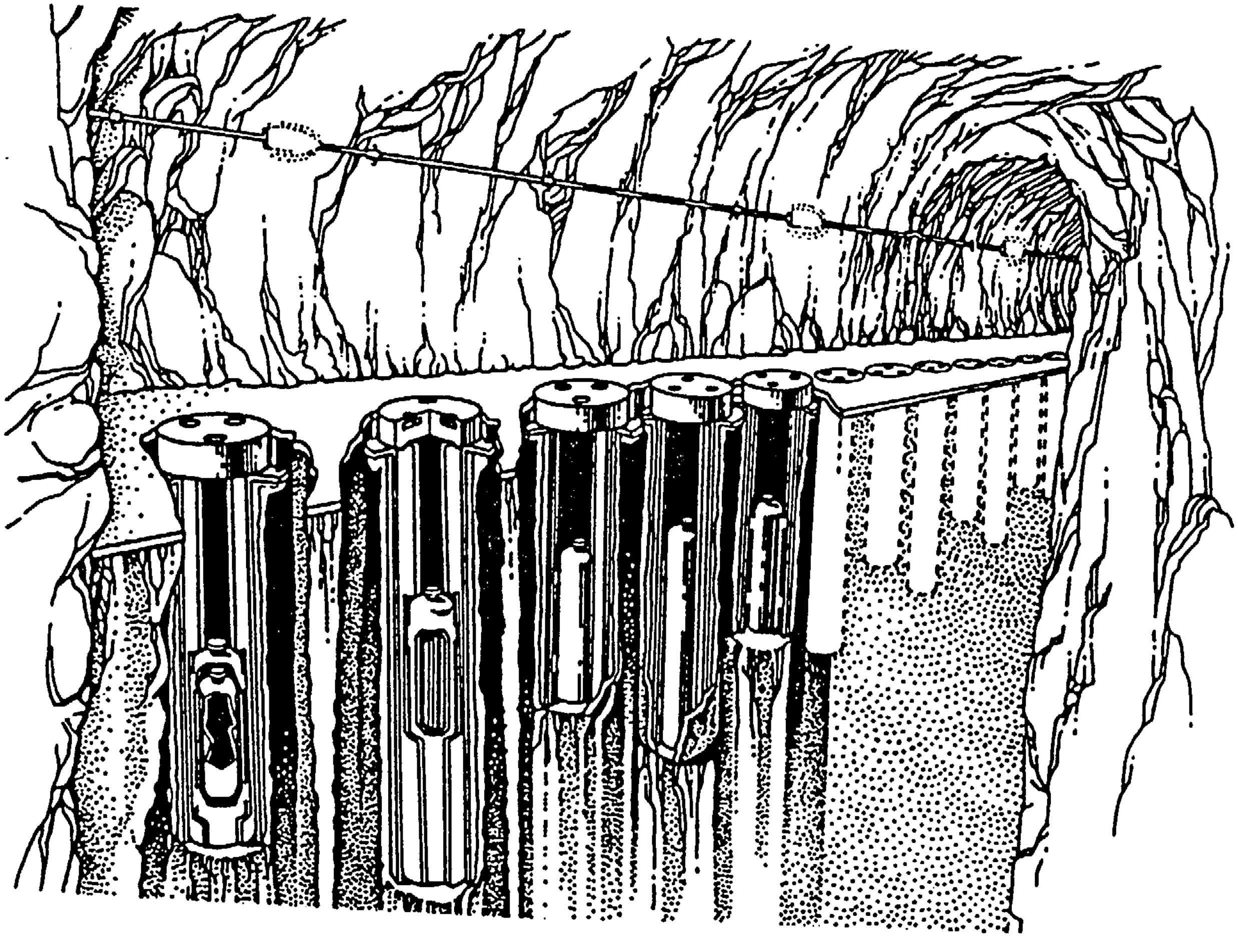


Figure 6.2.1-2 Artist's Rendition of Vertical Emplacement of High-Level Waste Glass (Short) and Spent Nuclear Fuel (Long) Waste Packages

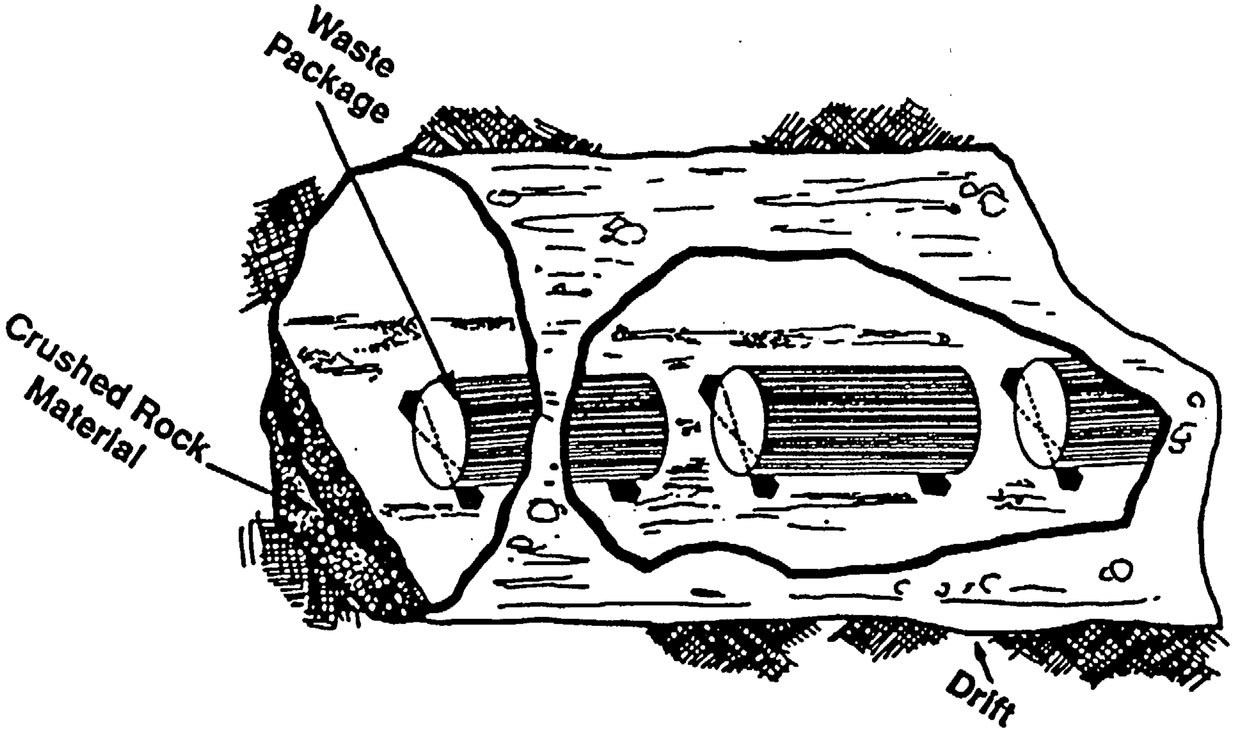


Figure 6.2.1-3 Schematic of In-Drift Emplacement Option (Current Baseline)

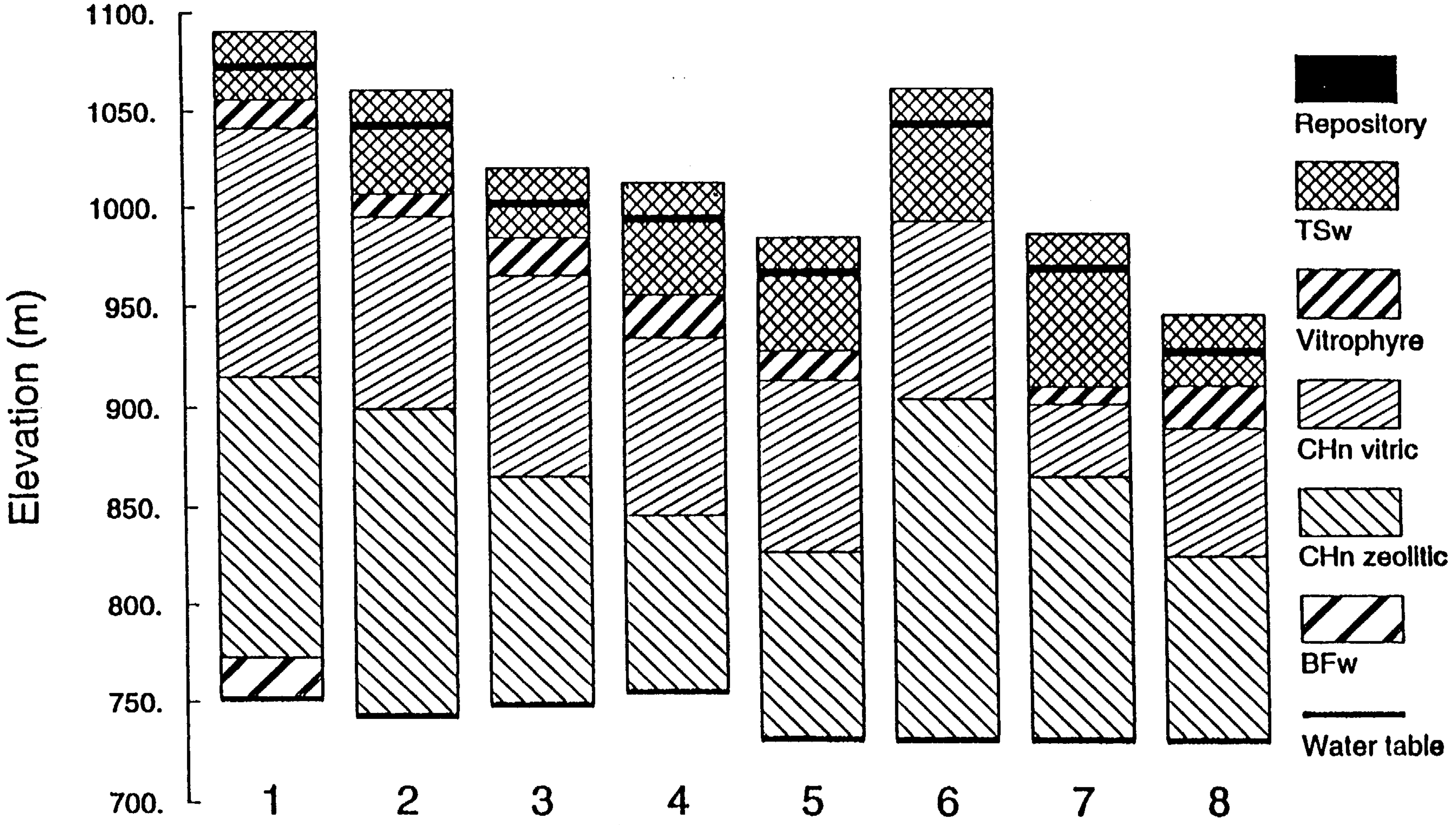


Figure 6.2.1-4 Column Stratigraphies for the Composite-Porosity Calculations

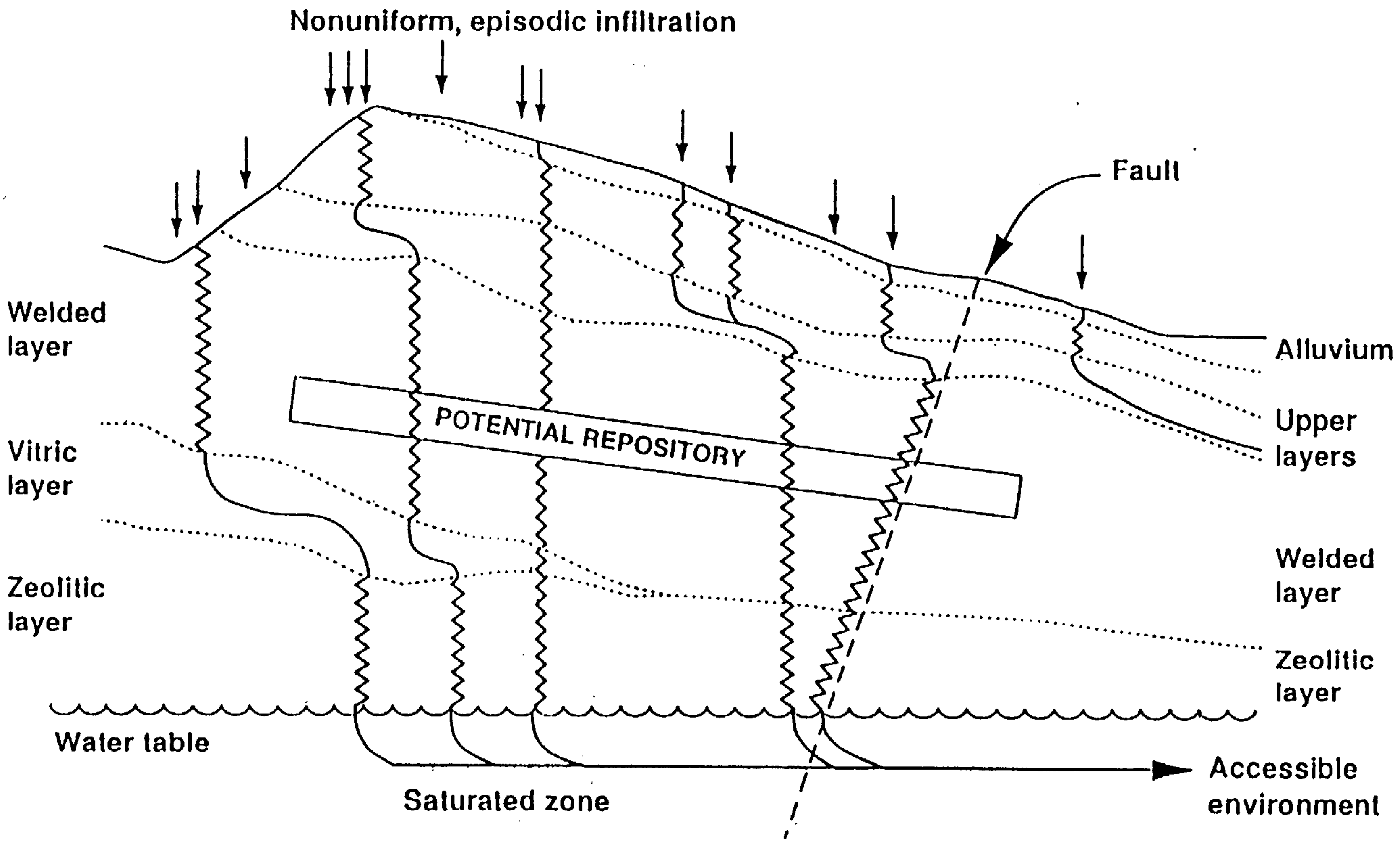


Figure 6.2.1-5 Schematic of Postulated Weep Flow at Yucca Mountain; Zig-Zag Lines - Saturated Fractures; Smooth Curves - Saturated Matrix Flow Through Nonwelded Units

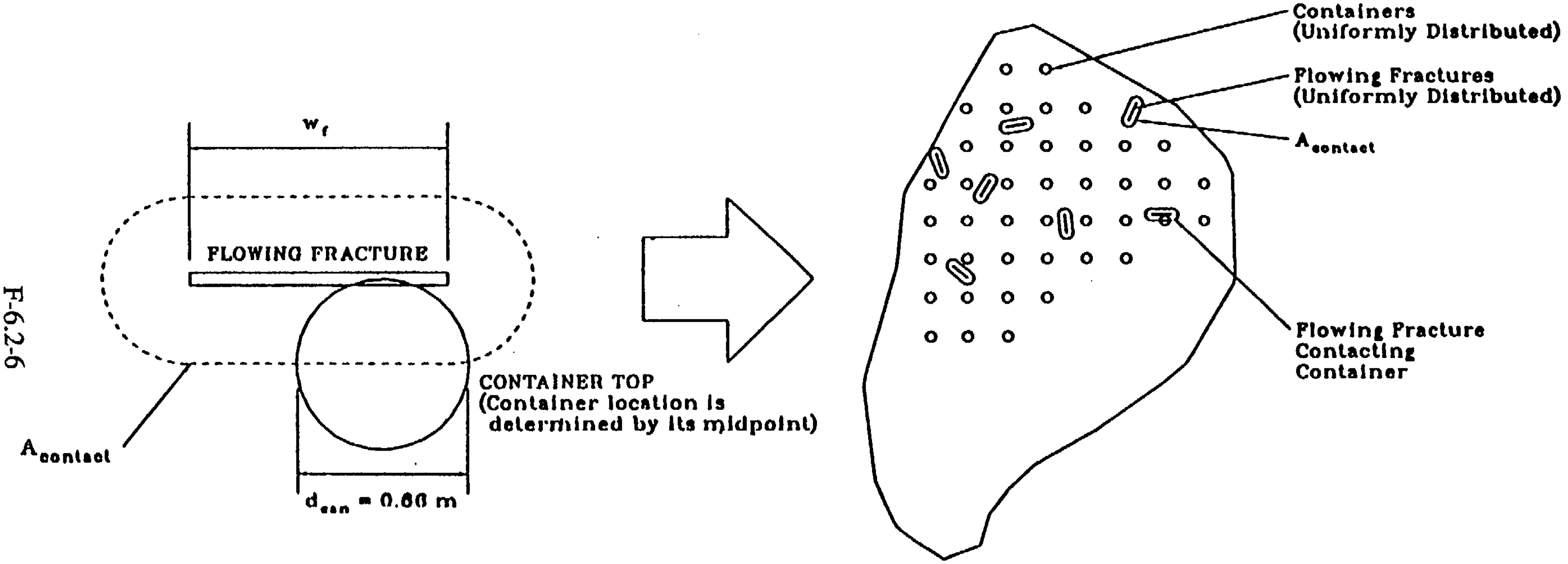


Figure 6.2.1-6 Schematic of Weeps Model Calculation of Probability of A Weep Contacting a Container: the Quotient of the Area of Contact ($A_{contact}$) and the Repository Area

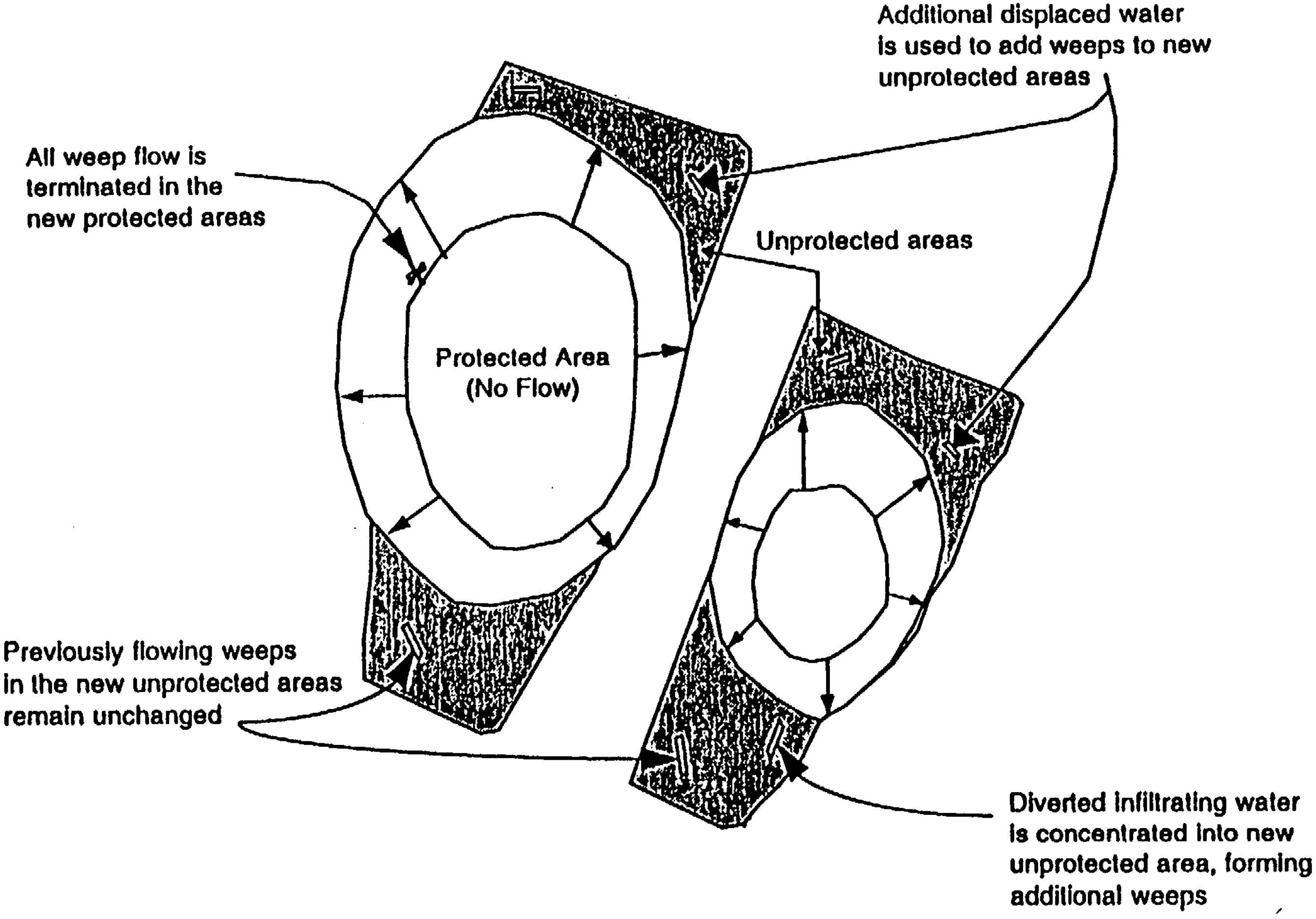
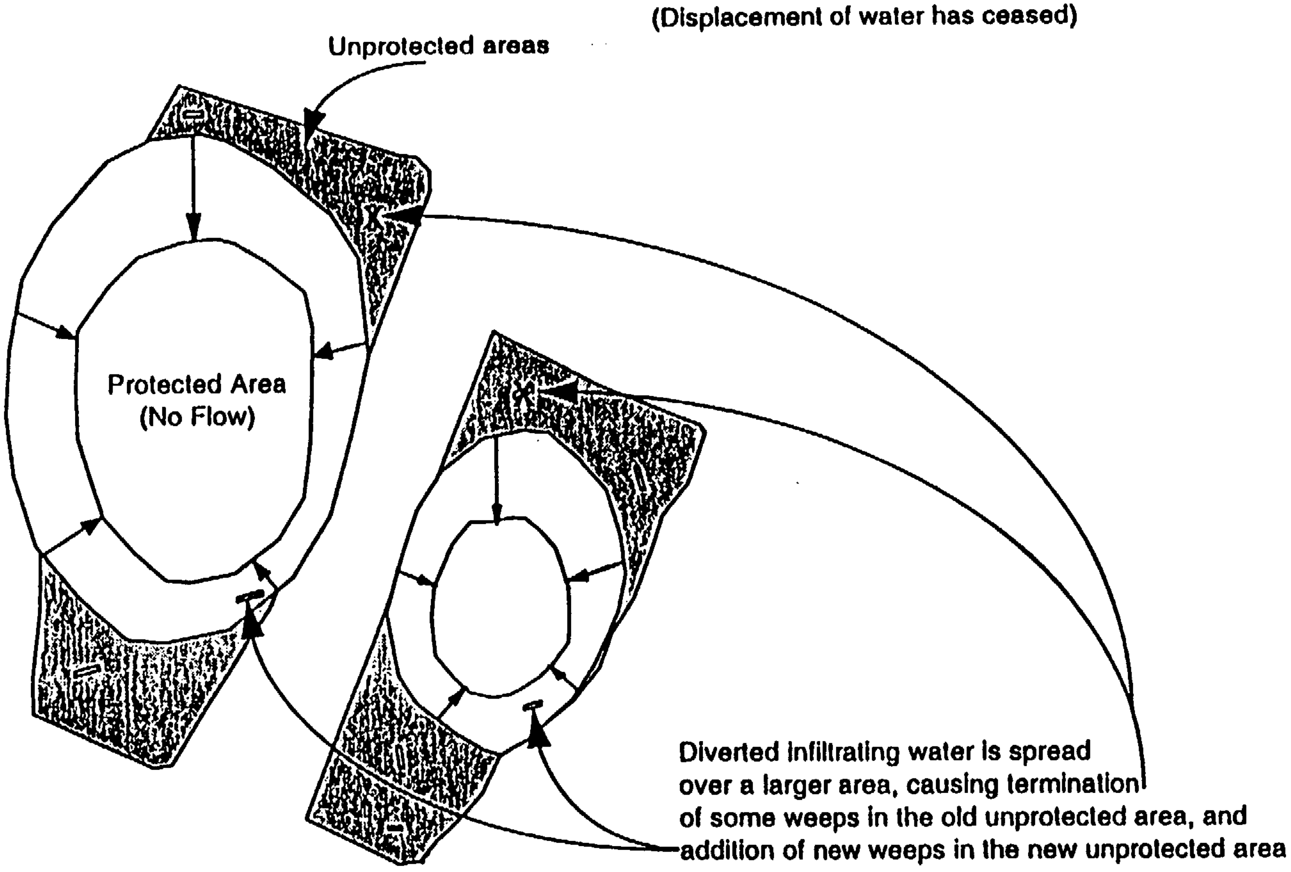


Figure 6.2.1-7 Flow Pattern Changes Calculated by the Weeps Model When the Dryout Zone is Expanding



Diverted infiltrating water is spread over a larger area, causing termination of some weeps in the old unprotected area, and addition of new weeps in the new unprotected area

Figure 6.2.1-8 Flow Pattern Changes Calculated by the Weeps Model When the Dryout Zone is Contracting

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2-1
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Stratigraphic and structural features. Description of the geologic and hydrogeologic units that will be used for performance assessment. This description should also include major faults.
Information will be used to support:	Completion of the text in Section 6.2.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-1
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Tables 6.2.1-1 through 6.2.1-10 and associated text
Explicit description of the needed information:	Documentation of potential conceptual models. Documentation of conceptual models should be provided for the following broad categories; the EBS, the natural barrier system, and the biosphere. The EBS includes all components of the system as well as models of their behavior under repository conditions. The natural barrier system includes geologic, hydrologic, and geochemical models associated with flow and transport through this system. The biosphere includes all of the pathway models and assumptions associated with radionuclides and their effects on man and the environment. As an example this documentation for flow models should include those hydrogeologic conceptual models that affect boundary conditions for the groundwater flow models (i.e., conceptual models of the steep hydraulic gradient northwest of the site) as well as conceptual flow models in both the unsaturated and saturated zones. Conceptual flow models should include porous media, dual porosity, dual permeability, discrete fracture. The documentation should also indicate how well the conceptual hydrogeologic flow models fit the site data, and whether any models can be eliminated on this basis.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-2
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Tables 6.2.1-11 and associated text
Explicit description of the needed information:	Listing of calculational models not included in performance analyses. This list should include all potentially acceptable conceptual models that have been eliminated in the categories of EBS, natural barrier system, and biosphere and a detailed justification for their rejection.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-3
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Repository design including waste package layout, backfill, and thermal loading.
Information will be used to support:	Completion of text in Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-4
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Engineered barrier design. Detailed design of the waste package and EBS for all waste forms.
Information will be used to support:	Completion of text in Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-5
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Waste package degradation models. The models include the conceptual waste package corrosion models for processes such as oxidation, pitting, and stress corrosion.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-6
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Waste form alteration models. Alteration rate of spent fuel and high-level waste glass, and solubilities of key radionuclides (i.e., those contributing to long-term release).
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-7
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Waste package release models. Description of the mechanisms of release from the waste package. This includes diffusion and advection for various package failure scenarios.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-8
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Engineered barrier release models. Detailed description of the processing of release of radionuclides from failed packages. These processes include diffusion through the backfill.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-9
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Near field thermomechanical models. Documentation of conceptual thermomechanical models and qualification (verification and validation) of software used that contains these models.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-10
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Near field thermomechanical models. Documentation of thermomechanical models and qualification of software used that contains these models.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-11
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Unsaturated zone flow models. Documentation of conceptual flow models and qualification of all software used that contains these models.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-12
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	[illegible] O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Unsaturated zone gas flow models. Documentation of conceptual flow models and qualification of all software used that contains these models.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-13
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Qualification of YMIM and AREST. Documentation of conceptual models used in this software and qualification (verification and validation) of the models.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-14
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Qualification of Weeps. Documentation of conceptual flow models used in Weeps and qualification of the Weeps model.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-15
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Qualification of gas flow model. Documentation of conceptual models and qualification (verification and validation) of the model by Ross et al. (1993)
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-16
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Qualification of TOUGH and V-TOUGH. Documentation of conceptual models contained in TOUGH and V-TOUGH and qualification of the models.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-17
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Qualification of saturated zone flow models. Documentation of conceptual flow models and qualification of the models such as MODFLOW and FEHM.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-18
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Documentation of conceptual hydrogeologic flow models. Documentation of hydrogeologic flow models (i.e., concepts causing steep hydraulic gradient).
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-19
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Saturated zone thermohydrologic processes. Documentation of conceptual thermohydrologic models, both natural and repository caused, and qualification of models used in their analysis.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-20
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Qualification of transport models. Documentation of conceptual transport models and qualification of software that contains these models for both the unsaturated and saturated zones.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.1-21
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Qualification of biosphere models. Documentation of conceptual models and qualification of software that contains these models.
Information will be used to support:	Completion of text for Subsection 6.2.1.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.2-1
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Tables 6.2.2-1, 6.2.3-1 through 6.2.3-5 and 6.2.3-7 through 6.2.3-10, and associated text
Explicit description of the needed information:	Analysis of potentially descriptive processes and events. This analysis should include the location and occurrence of potentially disruptive processes and events, an analysis of whether they could affect long-term repository behavior, justification for elimination of those deemed not to affect repository behavior, and for those having a long-term effect, the effects on the repository performance measure (i.e., either cumulative release or dose).
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.2-2
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Environmental Protection Agency standards for the Yucca Mountain site. To provide release/dose requirements for the high-level waste repository at Yucca Mountain. Currently 40 CFR 191 is being used until new standards are available. This standard will serve as the basis of whether processes and events can be eliminated from farther consideration (i.e., do they have a significant effect on the repository performance measure that is the basis for the standard).
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.2-3
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Human intrusion scenarios. Documentation of the human intrusion scenarios analyzed as disruptive events. These included, but were not limited to, drilling, mining, and use of contaminated water and soil for crop production.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.3-1
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Tables 6.2.3-1 through 6.2.3-5 and 6.2.3-7 through 6.2.3-11, and associated text
Explicit description of the needed information:	Processes and events considered for undisturbed performance in each iteration of performance assessment. Documentation of data and data distributions used in performance assessment and for completion of tables in Subsection 6.2.3.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.2.3-2
Section Number and Title:	6.2 SYSTEM DESCRIPTION
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.2.3-6 and associated text
Explicit description of the needed information:	Documentation of data and assumptions required for biosphere processes and events. Documentation should include all assumptions made for dose analyses for individuals as well as populations. For example, standard man drinking, eating, bathing habits, and mode of food production. Location of individual and/or population. Nature of the population and pathways of exposure for different segments of that population.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

Section 6.3 Assessment of Compliance: Cumulative Release of Radioactive Materials

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6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS

[The purpose of this section is to demonstrate that the overall performance of the repository system at Yucca Mountain complies with 10 CFR 60.112 which requires compliance with the EPA Standard for Yucca Mountain (to be determined). The EPA standard promulgated under 40 CFR 191 does not currently apply to Yucca Mountain as stated in Section 801 of the Comprehensive National Energy Policy Act of 1992 (Public Law 102-486). This Act directs the EPA to have the NAS perform a study to determine the reasonableness of different types of environmental standards to protect human health. Based on the NAS recommendations, the EPA is to promulgate a new standard explicitly for Yucca Mountain. Until the new EPA Standard for Yucca Mountain is promulgated 40 CFR 191 is being used. The performance of the overall repository system at the Yucca Mountain site is evaluated in terms of cumulative releases of radioactive materials to the accessible environment over a 10,000-year period after repository closure. In addition, assessments predict release performance for longer periods of time, 100,000 years or longer, and will provide estimates of what the dose to the maximally exposed individual would be for time periods of up to 1 million years. Although these longer-term analyses are highly uncertain, especially with respect to disturbed conditions, they provide some degree of assurance that rapid degradation of the overall repository system does not occur beyond the 10,000-year analysis period of 40 CFR 191. Screening of processes and events, development of scenarios, and screening of scenarios are summarized and references are provided to fully document selected processes and events, and the resulting scenarios that are analyzed. This entire section will be completed using [INN 6.3-1] and [INN 6.3-2].]

[Sensitivity analyses are presented to provide an understanding of parameters, conceptual models, and process uncertainty. Sensitivity analyses were performed to identify those elements of the overall system that affect the performance of the repository for each of the scenarios. Deterministic analyses combined with sensitivity analyses were conducted with process and subsystem models to demonstrate that the systems models, used to produce the CCDF yield conservative results. The approaches to developing the CCDFs are discussed to demonstrate compliance with the requirements of the EPA Standard [INN 6.3-3]. In addition, CCDFs are presented for both the disturbed and undisturbed scenarios of repository behavior. For the undisturbed case, conditions where concentrations of radionuclides reach the accessible environment by gaseous and groundwater pathways during the first 10,000 years are analyzed. Here undisturbed conditions are defined as the behavior of the repository under expected conditions and similarly disturbed conditions are defined as the behavior of the repository under unexpected conditions. Longer term analyses (100,000 years and beyond) are also included where they yield additional insight into the potential long-term repository performance. Analyses also are included that demonstrate compliance with the individual protection requirements (dose from all pathways) and the groundwater protection requirements (dose from drinking water) of the EPA Standard [INN 6.3-3]. The models used in the analyses are listed and their characteristics are summarized. The status of code verification and model validation is summarized and references are provided that describe verification and validation in detail. In addition, confirmatory testing (presented in Chapter 8) is cross-referenced where results are expected to provide data for further validation of models.]

6.3.1 Screening of Processes and Events

6.3.1.1 Screening Criteria

[Screening criteria are designed to eliminate those processes and events that do not contribute to the CCDF or significantly to dose [INN 6.3-3], because they are physically or logically unrealistic or are expected to have trivial consequences. Initially, processes and events are eliminated from those identified in Subsections 6.2.2 and 6.2.3 when site characterization results indicate that a particular process or event does not or cannot occur in the vicinity of the site. At this stage, processes and events that are known to occur in the region but have not been found at the site are retained. Processes and events that clearly have probabilities of occurrence lower than 10^{-8} in a given year or where they are physically or logically unrealistic and not credible are eliminated. Where uncertainties in the probability of occurrence are high, processes and events are retained. The criterion that processes or events must significantly alter the releases of radionuclides over 10,000 years is applied, and those processes and events showing no significant changes in release are eliminated. For example, climatic change could increase infiltration, which would increase flow through the repository and potentially increase radionuclide transport; therefore, climatic change is retained. Remaining events are combined into scenarios and appropriate process models are used, the resulting analyses are included in the CCDF and in dose calculations. Where no effect on the position of the CCDF is observed, additional processes and events are eliminated. The criteria used in screening processes and events are presented in Table 6.3.1.1-1 [INN 6.3-1]. This section will be rewritten based on [INN 6.3-1], [INN 6.3-2], and [INN 6.3-3].]

6.3.1.2 Selected Processes and Events

[The processes and events which passed the screening criteria in Subsection 6.3.1.1 are listed in Table 6.3.1.2-1 [INN 6.3.1.2-1] along with a summary of the effects of the processes and events on performance assessment results. These processes and events are used in the development of scenarios described in Subsection 6.3.2. The results of analyses using process models (models that incorporate the processes that remain after screening) and performance assessment models (models that incorporate abstractions of remaining processes) are presented (Table 6.3.1.2-1). The level of confidence related in the effects of the processes and events on the analyses is also included in Table 6.3.1.2-1. Those processes and events for which there is a low confidence in the probability of occurrence are also included.]

Processes and Events Selected for TSPA-1993.

The next several sections present a top-level overview of the processes included in TSPA-1993 for the purpose of conducting sensitivity analyses. This discussion of the processes and events is organized into conceptual models for key systems.

The TSPA-1993 analyses directly incorporate the expected dependency of several processes and parameters on the thermohydrologic regime. In particular, detailed thermohydrologic analyses were used to determine the temperature, aqueous flux, gaseous flux, and liquid saturation in the vicinity of the repository under a number of possible thermal loads. These primary results were then used to modify the radionuclide solubility, engineered barrier release, and geosphere transport properties that affect the radionuclide release to the accessible environment. In addition, TSPA-1993 directly incorporates the corrosion (both general and pitting) of the waste package's corrosion allowance outer barrier and corrosion resistant inner barrier in determining the expected time to "failure" of the waste package. The direct inclusion of thermally dependent processes and parameters, and the corrosion of the waste package is an advancement over TSPA-1991, and fulfills the one of the major objectives of the study.

The analyses of aqueous releases presented in TSPA-1991 utilized a radionuclide inventory that was limited to the radionuclides believed to contribute most significantly to the normalized cumulative release over 10,000 years (with the normalization being to the Table 1 values in 40 CFR 191 [EPA 1985]). The TSPA-1993 expands the inventory to include all radionuclides (and their parents) which may potentially contribute to the peak individual dose over a time period of up to one million years. In addition, TSPA-1993 considers the inventory associated with spent fuel from commercial nuclear reactors as well as defense high-level radioactive waste. A defense waste inventory component was considered in one, but not both, TSPA-1991 analyses.

Since the completion of TSPA-1991, significant new information had been collected and new designs have been proposed that change some of the fundamental premises of the earlier analyses. In particular, laboratory measurements of radionuclide solubility and retardation over a range of likely environmental conditions have been generated by scientists at Los Alamos National Laboratory [INN 6.3.1.2-2]. In addition, thermally dependent waste form alteration and glass dissolution rates are available from studies conducted at Lawrence Livermore National Laboratory and Pacific Northwest Laboratories. The design of the repository (with special emphasis on the thermal load), the mode of waste package emplacement (vertical in borehole vs. horizontal in drift), and the waste package design (varying thicknesses of an outer corrosion-allowance material such as mild steel surrounding varying thicknesses of an inner corrosion-resistant material such as Alloy 825) have all undergone changes since the completion of TSPA-1991. The earlier analyses concentrated on the Site Characterization Plan, DOE/RW-0199, thermal load (nominally 141 kW/ha or 57 kW/acre), waste emplacement mode (vertical in borehole) and waste package design (thin corrosion resistant material). Although the proposed designs are not fixed, an important role of performance assessment is to assess the advantages/disadvantages of the different proposed designs on long-term performance. As a result, TSPA-1993 incorporates alternative designs and investigates the sensitivity of releases and doses to those designs.

There were two organizations contributing to TSPA-1993. Due to limited resources and the desire to minimize duplication, only one of the TSPA-1993 analyses considered the possible effects of disruptive events such as human intrusion, volcanic intrusion (whether direct release effects or indirect effects), and tectonism. These processes and their potential affects on postclosure performance are discussed in TSPA-1991 (Barnard et al., 1992; Eslinger et al., 1993). The TSPA-1993 does incorporate these disruptive events (Wilson et al., 1994). A complete performance assessment must include all reasonable scenarios which could contribute to the release of radionuclides to the accessible environment. However, since there would be little significant difference in outcome of superimposing the same perturbations on two sets of calculations, the comparative value of having two different modeling teams was in evaluation of site- and design-related effects on the expected release rather than in evaluation of the externally initiated releases. Externally initiated releases are much more dependent on the assumptions regarding the probability of occurrence and the geometric descriptions of the event. The same assumptions and descriptions would have been used by both teams.

Engineered Barrier Processes.

The engineered barrier processes included in TSPA-1993 broadly fall into four categories:

a. waste package degradation;
b. waste form alteration;
c. waste package release; and
d. engineered barrier release.

These processes are described in 6.2.1 in the discussion on conceptual models used in TSPA-1993.

Near Field Thermomechanical Processes. No near field thermomechanical processes were included in TSPA-1993.

Near Field Thermochemical Processes. The near field thermochemical processes considered include waste form alteration processes, radionuclide solubilities, and retardation of radionuclides by sorption on the host rock. Radionuclide solubilities were formulated as a function of temperature and groundwater pH where data or theory exist to support the formulation. The retardation factors used in the analysis did not have any dependency on environmental parameters, but did consider parameter variability as expressed by expert elicitation. The groundwater chemistry was assumed to be unaffected by the thermal perturbation.

Unsaturated Zone Flow. The unsaturated zone flow processes are divided into two categories; (1) gaseous flow, and (2) liquid flow.

<u>Unsaturated Zone Gas Flow</u>

The gas flow predictions included topographic and thermal driving forces.

<u>Unsaturated Zone Liquid Flow</u>

The current conceptual model for flow in the unsaturated zone includes both fracture and matrix flow, both in equilibrium and non-equilibrium. However, the models available at the time of TSPA-1993 did not represent the complexity considered to be present at the site with regard to the degree of equilibrium between fractures and matrix porosity. Therefore, two separate flow models were considered in order to gain some insight into the importance of fracture-matrix coupling.

The first flow model assumed the fractures and matrix to always be in equilibrium. Liquid water movement was constrained to move vertically downward with uniform flux across the column. In this representation, liquid water is constrained to flow through the matrix if saturation levels remain sufficiently low to allow capillary forces to control water movement. If saturation increases above that point, water may flow in fractures. The second model, was designed to address the possibility of fracture flow by artificially constraining all water to move in fractures.

Unsaturated Zone Thermohydrologic Processes. TSPA-1993 incorporated functional relationships between the thermal load and temperature, aqueous flux, gaseous flux, liquid saturation, and relative humidity by abstraction from detailed calculations of coupled heat and fluid flow in the geosphere. The thermally driven gas flow processes will be discussed separately from thermally driven liquid flow.

Thermally Driven Gas Flow. The gas flow model used in the transport of ^{14}C to the accessible environment was based on three two-dimensional cross-sections through Yucca Mountain and was derived from coupled heat and fluid flow in porous material with time varying solutions. The assumption was made that the gas phase is in equilibrium with the liquid phase, in other words, the air is always at 100% relative humidity. The results presented by Ross (1993) formed the basis for the TSPA calculations.

Thermally Driven Liquid Flow. The processes incorporated into thermally driven liquid flow accounted for fluid flow in both liquid and gas phases under pressure, viscous and gravity forces, capillary and phase adsorption for the liquid phase, vapor pressure lowering due to capillary effects, binary diffusion in the gas phase, and heat transport due to conduction, convection, and binary diffusion.

Unsaturated Zone Radionuclide Transport Processes. The transport processes in the unsaturated zone were modeled separately for the gas phase and the aqueous phase.

The gas phase transport assumed the flow velocities described in the section on thermohydrologic processes, with the transport of ^{14}C (the only gaseous radionuclide considered) retarded with respect to the gas/vapor because of its tendency to dissolve in (and exsolve from) pore fluids.

Radionuclides were transported in the aqueous phase with the motion of the fluid carrying them according to the one dimensional advection-dispersion equation with radioactive decay and retardation. The retardation factors was calculated with a simple model using distribution coefficients (K_d) that were assumed to be independent of environmental conditions, but with variability as expressed through expert elicitation [INN 6.3.1.2-3].

Saturated Zone Flow. The saturated zone flow was assumed to occur in a single horizontal pathway between the repository and the accessible environment. Equivalent porous media was assumed to incorporate the fractures and the matrix. Two independent three-dimensional models were developed in an attempt to explain the large hydraulic gradient to the north of the site (Wilson et al., 1994). These models are described in Section 6.2. Water velocities and hydrodynamic dispersivities were abstracted from the three-dimensional models for use in the one-dimensional flow tubes.

Saturated Zone Thermohydrologic Processes. No thermohydrologic processes were included in the saturated zone.

Saturated Zone Radionuclide Transport Processes. The radionuclide transport processes included in the saturated zone were the same as described under the section on unsaturated zone aqueous transport processes with the addition of including horizontal and vertical mixing in order to calculate radionuclide concentrations and dose.

Biosphere Processes. The TSPA-1993 used conversion factors appropriate for calculation of whole body dose for an individual that obtains all of his/her drinking water and crop irrigation water from the contaminated saturated zone. The biosphere processes addressed in this model include the uptake of radionuclides by plants, uptake, elimination, accumulation, distribution, and hazard of the radioactive emissions within the human body (Andrews et al., 1994). The TSPA-1993 also used conversion factors appropriate to only ingestion of contaminated groundwater (Wilson et al., 1994).

Basaltic Volcanism Events. Calculations were performed that addressed the potential for indirect releases due to magma-waste interactions. Specifically, accelerated waste-package degradation due to the heat and aggressive volatiles emitted from a magmatic intrusion near a waste package was considered. This analysis considered only indirect effects where there was no waste-magma contact. Actual volcanic events would naturally be expected to have a range of interactions, from entrainment of waste, to encapsulation of waste, to attack by volatiles. This analysis was not intended to bound the effects of volcanism, rather to investigate a particular aspect of the potential interactions.

Human Intrusion Events. Human intrusion events were considered in TSPA-1993 (Wilson et al., 1994). Drilling was assumed to intersect either a waste container or contaminated rock. Radionuclides were assumed to be entrained in the drilling fluid and carried to the surface.

Climate Change. The climate change processes included in TSPA-1993 will be discussed in Subsection 6.3.2.1.

6.3.1.3 Justification for Elimination of Processes and Events

[Many processes and events have been eliminated from further consideration in the screening process described above. Those processes and events which are not present, have low probability of occurrence, or have no material effect on the performance of the repository, are summarized in Table 6.3.1.3-1 [INN 6.3-1.3-1]. These analyses demonstrate that those processes and events are not present, not credible, or have no significant effect on the repository. These analyses include detailed process model evaluations as well as TSPA evaluations. The level of confidence required for elimination of insignificant processes and events was determined, analyses were conducted, and the processes and events were eliminated [INN 6.3-1.3-1]. Those processes and events that were retained were used in the analyses of and in the development of scenarios, respectively.

Justification for Elimination of Processes and Events in TSPA-1993. TSPA-1993 was not intended to demonstrate a thorough screening of processes and events, rather it addresses specific issues of importance to the project at this point in the characterization schedule. No processes or events were eliminated by TSPA-1993, however, findings were made regarding the importance of the processes and events considered, and recommendations were made for additional investigations and analyses where better definition of processes and events is needed.

6.3.2 Scenario Development and Screening

Scenario development and screening are the next phase of analysis after the processes and events have been evaluated. The method for developing and screening scenarios for undisturbed conditions, as well as the selected scenarios, is presented below.

6.3.2.1 Scenario Development - Undisturbed Conditions

[The method of developing scenarios for anticipated (undisturbed) conditions involves combining the processes and events selected in Subsection 6.3.1. Reasonable scenarios are developed by combining processes and events using the approach that is presented in ______ [INN 6.3.2.1-1]. The method of constructing scenarios is presented in Figure 6.3.2.1-1.]

Undisturbed Scenarios Used in TSPA-1993. Since two analytical teams contributed analyses to TSPA-1993, and since these two teams used different calculational tools (RIP and TSA), some differences in analyses were unavoidable. The objective was not to benchmark RIP and TSA since this had essentially been done previously by an INTERA, Inc. (1993) application of RIP to the TSPA-1991 problem, in which RIP yielded results that were comparable to those that had been obtained using TSA. Purposeful differences between the RIP and TSA approaches were retained in the TSPA-1993 exercise to provide additional insight into conducting performance assessment analyses, and some purposeful differences in the cases analyzed were retained to ensure additional insight into the systems that were addressed. Steps were taken, however, to ensure that needless differences in the two analyses would be avoided. For example, to the extent practicable, Andrews et al. (1994) used the results of the extensive Wilson et al. (1994) data gathering activities. However, the structure of the RIP code used by Andrews et al. (1994) as compared with the TSA used by Wilson et al. (1994) dictated differences in the use and encoding of some of these data. The structure of the RIP code, as compared with TSA, also dictated some differences in analytical approach. Thus, there were slight differences in the undisturbed scenarios analyzed in TSPA-1993.

The two TSPA-1993 participants calculated an undisturbed performance case that included climate change, but two somewhat different approaches were used to incorporate the climate change effects. As in TSPA-1991 (Barnard et al., 1992), the Wilson et al. (1994) calculations for TSPA-1993 included the calculation of aqueous and gaseous releases using two different conceptual models for unsaturated-zone groundwater flow at Yucca Mountain: the composite-porosity model and the weeps model. The composite-porosity model assumes that flow is shared between the rock matrix and the fractures because of capillary forces (pressure equilibrium between matrix and fracture flows), whereas the weeps model assumes that water flows in locally saturated fractures with no matrix/fracture interaction. Both of these conceptualizations are idealized, and reality is probably somewhere between these two modes of fracture/matrix interaction, and may include matrix flow with episodes of rapid, localized fracture flow. [As was observed in TSPA-1991, and as will be shown below bases on TSPA-1993, releases to the accessible environment are significantly different for the two models, so it is important to look for field evidence that may determine which model (if either) is a better representation of reality [INN 6.3.2.1-2].]

For the undisturbed case, the composite-porosity model and its release results are summarized first. The weeps model and its results and implications will be discussed in terms of sensitivity studies. The focus on the composite-porosity results allows a closer comparison between the reference case results obtained by Andrews et al. (1994) and Wilson et al. (1994) in TSPA-1993. Aspects of calculations performed only by one of the participants will be presented in sections relating to sensitivity analyses.

In terms of the engineered system cases run, the two that were most comparable involved a corrosion-allowance barrier 10 cm thick, made of mild steel. This barrier surrounds a 0.95 cm corrosion resistant alloy container with either spent fuel assemblies or high-level waste pour-canisters, emplaced horizontally in the drifts with a spacing that creates an areal power density of 57 kW/acre in the repository. Waste inventories were quite closely comparable between the two participants' calculations, with 10% of the 70,000 MTU repository being vitrified high-level waste and the rest being spent fuel from boiling water reactors (~32% of the repository inventory) and pressurized water reactors (~58% of repository). The reference case waste package would be placed horizontally in a drift and would contain either 7 MTU of BWR spent fuel, 9 MTU of PWR spent fuel, or the equivalent of 0.5 MTU high-level waste.

The calculations by Andrews et al. (1994) included an inventory of 39 radionuclides, while the Wilson et al. (1994) calculations addressed eight radionuclides for the aqueous and gaseous pathway releases. These eight radionuclides were selected to be those most likely to contribute to release or dose. Direct release calculations performed by Wilson et al. (1994) included an inventory for 43 radionuclides, however. As may be seen in the individual TSPA-1993 reports, there was little difference between the calculational outcomes that was attributable to the differences in radionuclides considered. The 10,000 year reference case, for example, had basically only three radionuclides contributing to releases, and only one of the three contributed significantly. Thus, the practical differences in radionuclides considered in the two analyses were negligible.

Several metal barrier degradation rates were evaluated in sensitivity analyses. The Wilson et al. (1994) analysis used the YMIM code to determine the time of waste package failure. The analyses by Andrews et al. (1994) used two sets of waste package metal barrier failure rate equations, called the Stahl (Stahl, 1993) and the Lamont (Andrews et al., 1994 Appendix F) failure distributions after the individuals that contributed them. The Lamont equations are the same as used in YMIM. Hence, for the engineered system performance calculations, the Management and Operating Contractor Lamont cases are directly comparable with the Wilson et al. (1994) engineered system barrier failure calculations, and are used for the reference case comparisons below.

Finally, the Andrews et al. (1994) evaluated failure-time distribution sensitivity to the initiation of corrosion being controlled by either a temperature or a rock volumetric water content threshold. The temperature cutoff, meaning there was assumed to be no corrosion above 100°C, was identical to the temperature cutoff assumption of Wilson et al. (1994). Therefore, the temperature controlled initiation case was selected as part of the reference case.

6.3.2.2 Screening of Scenarios

[Criteria for screening the scenarios to select the significant ones or to eliminate insignificant scenarios are presented in this section along with the selected and eliminated scenarios. The scenarios were developed according to the methods shown in Figure 6.3.2.1-1 and screened using the methods described in [INN 6.3.2.1-1]. The screening was conducted using the screening criteria presented in Table 6.3.2.2-1 [INN 6.3.2.2-1]. The screening criteria include; that the scenario must be both logically and physically possible, have a probability of occurrence greater than 10^{-8}, have a significant effect on the CCDF, and have a significant effect on doses. Guidelines provided by the NRC were incorporated into the screening criteria as appropriate. The level of confidence required to eliminate a scenario is presented in Table 6.3.2.2-2 [INN 6.3.2.2.-2]. The listing of the scenarios that passed through the screening is provided in Table 6.3.2.2-3. These scenarios are used in the analyses of cumulative release and dose that are required to demonstrate compliance with 10 CFR 60 and the EPA Standard [INN 6.3-3].]

Disturbed Scenarios used in TSPA-1993. The selection of disturbed scenarios for TSPA-1993 did not result from an exhaustive screening. The disturbed scenarios were chosen to address specific issues of importance to the site characterization program at this point in time. Two disturbed scenarios were investigated; human intrusion and basaltic volcanism.

<u>Human Intrusion</u>. For the analysis of human intrusion, it was assumed that at randomly selected times after closure of the repository, there will be drilling that may intersect either a waste container or contaminated rock. Radionuclides are then entrained in the drilling fluid and carried to the surface. The drilling operation is assumed to be trying to reach the carbonate aquifer below the repository. The analysis assumes that present-day drilling technology is used (i.e., a rotary drill bit, liquid drilling fluid to lubricate the bit and carry away cuttings, and well-bore casing to stabilize the drillhole), as suggested in guidelines given in 40 CFR 191. Fragments of waste or contaminated rock cuttings are carried to the surface in the circulating drilling mud where they accumulate in the drilling-mud pit.

Basaltic Volcanism. The performance of the potential Yucca Mountain repository under certain magmatic-activity disruptive events was evaluated. This analysis is a continuation of that done for TSPA-1991 (Barnard et al., 1992). In the previous assessment, direct releases from the repository subjected to magma–waste interactions was investigated. The current analysis looks at indirect releases due to the magma–waste interactions. Specifically, this analysis treats the change to the aqueous-transport source term arising because of accelerated waste-package degradation due to the heat and aggressive volatiles emitted from a magmatic intrusion near a waste package. The analysis assumes the waste package lifetime is drastically shortened by the presence of the magmatic intrusion. Figure 6.3.2.2-1 illustrates the particular scenario selected for evaluation from the multiple magmatic-interaction scenarios discussed in detail in Barr et al. (1993).

The TSPA-1993 analysis was an attempt to bound the range of consequences of interactions between magma and repository waste. TSPA-1991 looked at direct surface releases due to volcanism, while this analysis considered only indirect effects where there is no waste-magma contact. Actual volcanic events would naturally be expected to have a range of interactions — from entrainment of waste, to encapsulation of waste, to attack by volatiles. It must be emphasized that this analysis is restricted to investigating the effects of heat and aggressive volatiles only (i.e., no direct waste–magma contact). This required several restrictive assumptions regarding the nature of the interactions. Because of the low probability of occurrence for volcanism, the consequences are calculated separately, and the probability of occurrence is then applied to produce the CCDF.

6.3.3 Consequence Analysis: Estimates of Cumulative Releases

6.3.3.1 Repository Performance Results

[The Yucca Mountain Repository consequence analysis results are presented in the _______ [INN 6.3.3.1-1]. The analyses indicating the suitability of the site for disposal of radioactive waste are provided in [INN 6.3.3.1-1], and will be used to complete this section. This section will also cross-reference the engineered barrier analyses contained in Chapter 5.]

6.3.3.2 Cumulative Releases

[The CCDFs which provide the estimate of cumulative releases to the accessible environment are presented in figures (there will be one figure for each of n scenarios, [INN 6.3.3.1-1]. The results necessary for completion of this section will be provided by [INN 6.3.3.1-1].]

Cumulative Release Estimates from TSPA-1993. This section will discuss the release estimates from both conceptual flow models; the composite porosity model, and the fracture flow model (weeps model). In addition, the results of several sensitivity studies will be presented. In this section, the undisturbed case estimates of system performance are compared with a selected set of performance measures. These results follow an explanation of the performance measures that were selected.

In this section, results of the composite-porosity-model and "weeps" model Monte Carlo simulations are presented in terms of the "EPA sum," or normalized cumulative release of radioactivity to the accessible environment. The accessible environment is defined as the maximum distance allowed in 40 CFR 191; for aqueous releases the accessible environment is 5 km away from the repository, and for gaseous releases the accessible environment is the ground surface above the repository. Cumulative release is normalized as specified by the EPA in 40 CFR 191.13. Even though 40 CFR 191 no longer applies to Yucca Mountain, the EPA sum is still a useful quantity to calculate, for three reasons:

a. A new regulation for the Yucca Mountain site has not yet been specified;

b. The EPA sums are a surrogate for total dose to the population, but are easier to calculate; and

c. The EPA sums can be compared with those from past calculations, past estimates of doses are less common (Doctor et al., 1992; Eslinger et al., 1993).

It is not possible to prejudge the outcome of the NAS committee work on recommending a basis for a Yucca Mountain standard. It is also not certain how the EPA may decide to implement the NAS recommendations. Therefore, TSPA-1993 (Andrews et al., 1994 and Wilson el al., 1994) considers three performance measures: first, the cumulative normalized radionuclide release at the accessible environment at 10,000 years specified in 40 CFR 191; second, the cumulative normalized radionuclide release at the accessible environment at 100,000 years; and third, the peak individual dose over a million year period. The maximum radiation-dose rate to an individual received by drinking contaminated water from the saturated zone at the accessible environment will be discussed in a later section (Section 6.4). For the sake of allowing a comparison with the other two cumulative release calculations, an additional calculation was done addressing cumulative normalized radionuclide release to the accessible environment at a million years. This comparison is discussed below along with the 100,000-year results.

These three performance measures address the possibility of an extended compliance period for cumulative releases in the new regulations, and the possibility of the new standard requiring a dose calculation rather than a cumulative release calculation.

Undisturbed Performance - Composite Porosity Model. This section presents results that incorporate the radionuclide releases from the engineered system, the transport of released radionuclides by gaseous or aqueous pathways through the unsaturated zone, and by aqueous pathways through the saturated zone. The flow through the unsaturated zone was determined using the composite porosity model described in Section 6.2.

Simulations comprising 100 realizations (Andrews et al., 1994) and 300 realizations for each of eight columns selected to cover the range of stratigraphy using the repository (Wilson et al., 1994) were generated which reflect the stochastic nature of the input parameters. Figures 6.3.3.2-1 and 6.3.3.2-2 show the CCDFs of the cumulative normalized releases to the accessible environment, as prepared by Andrews et al. (1994) and by Wilson et al. (1994), respectively.

In Figure 6.3.3.2-1, the total release to the accessible environment is dominated by ^{14}C with only a slight contribution from ^{99}Tc. Several realizations have releases of ^{237}Np to the accessible environment, but these are significantly lower than a cumulative normalized release of 10^{-6}. The magnitude of the early-time gaseous releases in this analysis is primarily a function of the frequency of the waste package failures. If the waste packages fail at early times, the transport velocities will be higher because the repository is hotter, and the amount of ^{14}C decay that has occurred will be smaller. Therefore, if a large number of waste packages fail at or during an early-time period, a large portion of the ^{14}C quick-release fraction will be released early, creating an initial early-time spike (Figure 6.3.3.2-3). The zig-zag at precisely every thousand-year interval in the plot of Figure 6.3.3.2-3 is a plotting artifact and has no physical significance. Because the 10,000-yr normalized gaseous releases are much greater than the normalized aqueous releases, the combined CCDFs (Figure 6.3.3.2-4) are nearly identical to the gaseous-release CCDFs. Therefore, the release of radionuclides to the accessible environment within the first 10,000 years after waste emplacement is dominated by ^{14}C.

Regarding the gaseous release results, each Wilson et al. (1994) gaseous-release simulation involved 1,000 computed realizations. The repository is not subdivided into columns for these calculations, but is treated as a whole. For each realization, releases from the EBS are calculated and then convolved with ^{14}C transport-time distributions. Cumulative releases to the accessible environment over 10,000 years are saved for each realization. Radiation doses are not calculated for gaseous releases. As in TSPA-1991, calculated ^{14}C releases exceed the limits specified by the EPA in the remanded criteria of 40 CFR 191.13. Also as in TSPA-1991, there is enough conservatism built into the calculations that this exceedence should not be cause for alarm. For example, as mentioned in Wilson et al. (1994), inclusion of fuel-rod cladding integrity in the source-release calculations could reduce releases by a factor of three to five.

In terms of the aqueous release results, 300 realizations were computed for each of eight unsaturated-zone columns selected to represent distinctive stratigraphic pathways. For each realization of a column, unsaturated-zone flow is calculated for both "dry'' and "wet'' climatic conditions; releases from the EBS and unsaturated-zone transport are calculated, switching between the "dry'' and "wet'' flows at climate-change times; and then saturated-zone transport is calculated for the saturated zone flow tube corresponding to each unsaturated zone column [INN 6.3.3.2-1 and INN 6.3.3.2-2]. Most model parameters are sampled independently for the columns contributing to a given simulation because the correlation lengths for hydrogeologic properties are expected to be much smaller than the distance between columns (for example, Rautman and Robey (1993), use 150 m for the major-axis porosity correlation length) [INN 6.3.3.2-3].

The only model parameters that are correlated among columns are the climate parameters (infiltration, water-table rise, and climate-change times), and they are chosen to be the same for all columns in a given simulation. Note that water-table elevation varies from column to column, but the change from nominal is taken to be the same for all columns. Also note that percolation flux varies from column to column because it depends on matrix saturated conductivity, and has a random aspect as well. Because of the climate parameters, the release calculations for the columns are not completely independent, allowing releases from all the columns for a given realization to be simply added together, since the realization represents the same climate scenario for each column.

Ten thousand years is a relatively short time compared to most of the unsaturated-zone transport times, which explains the large number of zero and near-zero 10,000-year aqueous releases reflected in the higher likelihood portion of the curve in Figure 6.3.3.2-1 or 6.3.3.2-2. Also, releases that do reach the accessible environment are on a very nonlinear part of the breakthrough curve, which explains the large range of 10,000-year releases.

For the reference case, a 10,000-year cumulative aqueous release standard similar to 40 CFR 191 could be met by a repository at Yucca Mountain, given current designs, data and assumptions. In this section, those assumptions include that no disruptive unanticipated events occur. Since gaseous release of ^{14}C presents a much lower level of risk from aqueous release of the same radionuclide, because of rapid dilution in the atmosphere, it should be treated differently by a standard that is based on health risks. The magnitude of potential doses from ^{14}C gaseous releases are discussed in Section 6.4. Demonstrating compliance with such a standard would still not be easy, however, because of the burden of proof required for every data set, and assumptions important to determining the value of the performance measure addressed by the calculations. This burden of proof must allow the regulatory authority to find, in the course of the formal licensing process, that there is reasonable assurance that the system will comply with the regulations.

The reference case probabilistic calculations described for the 10,000-year period were continued for the 100,000-year period. Andrews et al. (1994) again used a simulation of 100 realizations, and Wilson et al. (1994) used 300 simulations for each of the eight vertical columns used to describe the natural system. Figures 6.3.3.2-5 and 6.3.3.2-6 present the Andrews et al. (1994) CCDF for the total aqueous releases and the release of ^{99}Tc and ^{237}Np to the accessible environment, and the comparable Wilson et al. (1994) results, respectively. The curve representing total release to the accessible environment crosses over the cross-hatched EPA limit in both figures, however, the releases are normalized to a 10,000-year standard and not a 100,000-year standard. The total normalized cumulative aqueous releases to the accessible environment for the 100,000-year simulation are greater than the aqueous releases (based on ^{99}Tc) for the 10,000-year simulation by several orders of magnitude. It should be noted that the normalized cumulative releases to the accessible environment of ^{14}C at 10,000 years, yielded higher releases than the total aqueous releases at 100,000 years for over 90 percent of the realizations. If the normalized cumulative releases of ^{14}C at 100,000 years were simulated and included, the total curves in Figures 6.3.3.2-5 and 6.3.3.2-6 would be shifted farther to the right to incorporate the higher total releases. The case illustrated in Figure 6.3.3.2-6 is not exactly the reference case, but is based on a vertically emplaced, thin-walled container without a corrosion allowance barrier. The performance contribution of the 10 cm mild steel corrosion allowance barrier is negligible in these calculations, as will be discussed in Section 6.4.

At 100,000 years, ^{99}Tc has the highest calculated EPA cumulative release. The release of ^{237}Np begins prior to the end of the 100,000-year period, but is negligible compared with the

^{99}Tc contribution to cumulative release.

[If a regulation similar to the current 40 CFR 191 were promulgated for aqueous pathway releases, but for a 100,000 year compliance period rather than the current 10,000 years, it appears that the reference case design, data sets and assumptions would suggest that compliance may be expected. Such a standard, however, would be ten times more conservative than the current standard, which no longer applies at Yucca Mountain. The increased stringency results from the 100,000 year cumulative release being compared to the 10,000 year cumulative release value of the standard rather than 10 times the value (i.e., for a 100,000 year period the value in the standard should be increased by a factor of 10 for the same release rate). The investment needed to supply the burden of proof required to make a licensing compliance argument over such a long time with such stringency and so little flexibility may be unrealistically high. In addition, there are unknowns such as potentially disruptive events that cannot be quantified with certainty over very long times irrespective of the resources applied.

It is possible that a standard may be promulgated that is similar to the current 40 CFR 191, for aqueous pathway releases, except that it may contain an additional requirement for a qualitative evaluation of undisturbed system performance from 10,000 to 100,000 years to show that no precipitous decline in performance is expected. The type of calculational results illustrated here would be of the type needed to show compliance with such a standard. The tightening of key uncertainties through further site and materials testing would be necessary to provide a defensible basis for such compliance assessments.

Sensitivity Results. The results presented below were developed to determine the sensitivity of the system performance to design and characterization parameters that are either uncertain or yet to be developed. It must be emphasized that these sensitivity results are only indications of what may be important. The models and data sets are still very preliminary, so great confidence cannot be placed in the results. However, when viewed appropriately, the results can be useful. For example, a parameter that appears in the sensitivity analysis as possibly important is the fraction of containers contacted by rubble, or rubble fraction. The proper way to view this finding is not necessarily to conclude that rubble is important to repository performance. The rubble fraction is part of a simple model used to predict wetting of containers, a model that may need to be replaced as near-field environment studies progress.

Therefore, a more general conclusion is that container-wetting mechanisms and near-field water flow are important, and should be better understood. Part of the reason that container wetting is important to the results is that the model used for container corrosion is strongly temperature- and moisture-dependent, and the two are linked. If the temperature-dependence of the assumed pitting rate for Alloy 825 were reduced, for example, it could also reduce the importance of the container-wetting model [INN 6.3.3.2-4].]

Undisturbed Performance - Weeps Model. The Wilson et al. (1994) analyses using the weeps model was essentially a separate TSPA within TSPA-1993. Every aspect of the composite-porosity analysis was repeated for the weeps analysis: thermal effects, engineered system integrity and release, and gas and aqueous pathways flow and transport. The weeps model is described in detail in Subsection 6.3.3.3.

Weeps-model calculations are presented for the same performance measures as already shown for the composite porosity results. Thermal loading and engineered barrier sensitivities were similar between the composite porosity and weeps models, even though the higher thermal load shed more water over some regions containing waste packages, this effect appears to have been balanced by the lack of corrosion within the expanded dry-out zone.

Because the results of sensitivity studies of thermal load and container design were similar to those obtained using the composite-porosity model, the major differences between the results of the weeps and composite-porosity models are discussed for only one case, the 141 kW/ha (57-kW/acre) repository with vertically emplaced, thin-walled containers without a mild steel overpack. Each of the 1,000 realizations simulated 1,000,000 years of repository life, beginning with a thermal perturbation of the environment and including 21 climate changes that alternated between dry and wet periods. Different containers at different temperatures are contacted by weeps for varying durations.

The conditional CCDF for combined cumulative aqueous and gaseous releases at 10,000 years, as normalized to the EPA limits, is shown in Figure 6.3.3.2-7. Note that, contrary to results obtained with the composite-porosity model, the magnitude of the aqueous and gaseous releases are similar. For the most likely cases (above 0.9 on the probability scale of Figure 6.3.3.2-7) the gaseous releases are the major contributor to total releases, and are primarily a function of juvenile failures. For the lower probability cases (below 0.1) aqueous releases dominate. In general, for these extreme cases, corrosion-induced failures approach the number of juvenile failures and even outnumber juvenile failures.

By comparison, 10,000 year CCDFs for the composite porosity model show ^{14}C releases to the accessible environment that are three orders of magnitude greater than calculated by the weeps model. This difference in results is attributable to the larger number of containers that remain dry in the weeps calculations because water contact is restricted to discrete locations. By contrast, the 10,000 year CCDF for composite-porosity aqueous releases for the same case shows much lower releases to the accessible environment, up to four orders of magnitude in the higher probability region. This result, notwithstanding that fewer containers failed in the weeps model at comparable time, is attributable to the zero unsaturated zone travel time in the weeps model versus the very long unsaturated zone travel times typical for the composite porosity model calculations.

Sensitivity Studies - Thermal Loading and Repository Layout. The thermal load and repository layout options addressed in TSPA-1993 included three variations of thermal load and two emplacement modes. The Wilson et al. (1994) analyses considered both vertical borehole and horizontal in-drift emplacement (Figures 6.2.1-2 and 6.2.1-3). The Andrews et al. (1994) analyses only considered the in-drift option. The Wilson et al. (1994) analysis of the vertically emplaced packages is difficult to compare directly with the other emplacement option, however, because the vertically emplaced container consists of only one thin Alloy 825 barrier, while all in-drift waste packages were additionally overpacked with an outer barrier of mild steel. The thinner mild steel barriers, as will be seen in the next section, provided little additional performance, so the 10,000 year TSPA results for the borehole and in-drift emplaced waste packages are essentially the same (as may be seen on Figure 6.3.3.2-4). As discussed in a subsequent section, human intrusion results differed for the vertically emplaced and horizontally emplaced waste packages, with the horizontally emplaced packages providing a larger surface area to be contacted by random vertical drilling. In terms of effects from a vertical magmatic intrusion, however, the horizontally emplaced packages present less of a target area. Neither of these disruptive event scenario's consequences appeared to be meaningful, however, at least in terms of exceeding the TSPA requirements of the now inapplicable EPA Standard.

Figure 6.3.3.2-4 also shows little 10,000-year total system release difference for the 141 and 282 kW/ha (57 and 114 kW/acre) cases addressed in the Wilson et al. (1994) calculations. A figure (6.3.3.2-8) describing the same analysis by Andrews et al. (1994) shows a similar result: no significant difference (less than an order of magnitude) between the 10,000-year total system releases for the 141 and 282 kW/ha (57 and 114 kW/acre) cases. An additional case, 70.5 kW/ha (28.5 kW/acre) was analyzed in the Andrews et al. (1994) calculations, however, and its results are also shown in Figure 6.3.3.2-8. These results, when compared with the 141 kW/ha case, begin to approach an order of magnitude difference in 10,000 year total system releases to the accessible environment. This difference, however, is not long lived as shown in the 100,000-year total system release (Figure 6.3.3.2-9).

Sensitivity Studies - Waste Package Design. Various metal barrier thickness options were addressed in TSPA-1993. Only Wilson et al. (1994) analyzed the 0.95 cm Alloy 825 container that is vertically emplaced. Both the studies analyzed in-drift emplaced multi-barrier waste packages with an inner barrier of Alloy 825 and an outer barrier of mild steel. The thicknesses analyzed were: (1) 0.95 cm inner, 10 cm outer; (2) 3.5 cm inner, 10 cm outer; (3) 0.95 cm inner, 20 cm outer; and (4) 0.95 cm inner, 45 cm outer.

The waste package failure rates for these four design configurations is shown in Figure 6.3.3.2-10. A comparable figure is provided by Andrews et al. (1994) (Figure 6.3.3.2-11) for the three cases with a 0.95 cm inner wall, but using a slight variant of the corrosion rate equation. In terms of total failures, the calculation suggests that the 10 cm outer barrier cases were failed at a couple of thousand years, that the 20 cm outer barrier cases were failed after about 22,000 years, and that about 65% of the 45 cm outer barrier waste packages remained intact at 100,000 years. The Wilson et al. (1994) results suggest that there is little difference between how long the 10 and 20 cm outer barriers take to fail, which is at about 2,000 years, but about 20% of the 10 cm outer barriers remain intact over 100,000 years and about 40% of the 20 cm outer barriers also remain intact over that long time. About 60% of the 45 cm outer barriers have not failed at 100,000 years, but the bulk of the failures is completed at about 3,000 years. For the 45 cm outer barrier case, the fraction remaining intact at 100,000 years is comparable, but the implication of one analysis is that there is little additional failure after 100,000 years while the other suggests a steady continuation of the failure rate until all of the packages have failed.

Some of the differences between these results lie in the near-field environment and corrosion rate assumptions embodied in the two analyses. A fraction of the Wilson et al. (1994) waste packages remains "dry," essentially forever, and the Andrews et al. (1994) for these particular calculations, assumed a more rapid, universal corrosion rate. These variations in assumptions and codes mask some of the differences between the designs, but the more meaningful evaluation of these designs is in terms of total system releases to the accessible environment. The additional uncertainties introduced in modeling the migration of releases from the waste package to the accessible environment overshadow these nuances of the modeling schemes employed.

Figure 6.3.3.2-12 shows, as Figure 6.3.3.2-4 showed, the 10,000-year total system release results for the Andrews et al. (1994) and Wilson et al. (1994) analyses, respectively. It may readily be seen that differences were not significant (an order of magnitude difference in releases is assumed a convenient measure of significance) except for the 45 cm outer barrier case. These results are dominated by the ^{14}C release component, and differences are, therefore, direct function of waste package failure rates. To focus on the 45 cm outer barrier case, similar plots were provided for 100,000-year release and 1,000,000-year dose results. Figure 6.3.3.2-13 shows that at 100,000 years there is still a significant difference in releases from the 45 cm case.

Sensitivity Studies - Dry Climate Percolation Flux

A scatter plot of cumulative releases as a function of the Topopah Spring welded unit dry climate percolation flux, shown in Figure 6.3.3.2-14, suggests the variability in that performance measure is largely explained by the variability in the dry climate percolation flux parameter. Dry climate percolation flux, wet climate percolation flux, and the first climate-change time may all be important if the composite-porosity model is applicable, especially for shorter times like 10,000 years. But dry percolation flux is more important than wet percolation flux because dry-climate conditions usually prevail in the model as container temperatures fall below 100°C, at which time containers that are wet or moist will tend to fail. The Topopah Spring welded unit matrix saturated conductivity, and the potential for rubble to fall from the excavation and contact the waste packages are important to determining container wetting and near-field water flow and releases. The wetting, flow, and release processes are not well understood. The Topopah Spring welded unit bulk permeability and retardation factor are important for determining the EPA Standard's measure of cumulative release for ^{14}C (40 CFR 191.13, vacated), because they affect how much of the ^{14}C can be transported to the surface in 10,000 years. If the EPA promulgates a new regulation for Yucca Mountain, the importance of gaseous-transport parameters may change.

6.3.3.3 Methods Used for Cumulative Releases

[The methods used for cumulative release and dose analyses have been previously defined in general terms in discussion of the iterative Performance Assessment (Section 6.1). The results from the total system models are converted to CCDFs which are shown in figures (there will be one figure for each of n scenarios). A detailed discussion of the dose assessment methods can be found in [INN 6.3.3.1-1), and this material will be.used to complete this section and Table 6.3.3.3-1.]

Methods Used for Cumulative Releases in TSPA-1993. The combination of gaseous and aqueous releases to obtain the distribution of releases (Figures 6.3.3.2-1 and 6.3.3.2-2) for nominal conditions involved adding gaseous and aqueous partial EPA sums at the same probability level. This procedure was followed because the aqueous and gaseous releases were calculated independently. It would be preferable to calculate them in parallel, using the same values for shared variables (climate variables, source variables, and bulk conductivity), in which case the aqueous and gaseous releases for each realization would be additive. Because the dependencies between the two are not preserved, it is necessary to follow some ad hoc procedure to combine them, and the one used here appears to be the best choice.

6.3.4 Probability Estimates

[The determination of which processes and events require estimates of probability of occurrence are described in detail in [INN 6.3.3.1-1]. Different methods were used to develop estimates of probability of occurrence for the selected processes and events. These methods included expert judgment.] This section and the subsections that follow will be completed using [INN 6.3.3.1-1, INN 6.3.4-1 and INN 6.3.4-2].

6.3.4.1 Probability of Occurrence of Processes and Events

The processes and events selected in Subsection 6.3.1.2 have a probability of occurrence which can be determined with different levels of uncertainty depending on the approach used. [These probabilities are presented in Table 6.3.4.1-1 [INN 6.3.4-1].

Probability of Occurrence of Processes and Events Used in TSPA-1993.

Magmatic Events. The probability of occurrence used for the TSPA-1993 is calculated using the same formalism that was used in TSPA-1991 analysis; a discussion of the factors in the probability calculation is given in Section 7.3 of TSPA-1991 (Barnard et al., 1992). The overall probability of exceeding a given release value from a Yucca Mountain repository is given by

$$P[E_1E_2E_3]=P[E_1]\bullet P[E_2|E_1]\bullet P[E_3|E_1E_2]$$

where E_1 is the volcanic recurrence rate in the region of Yucca Mountain, E_2 is the probability of eruption in the repository itself, and E_3 is the probability that the releases (i.e., the consequences of the volcanism) exceed a given release value. In Crowe et al. (1992) several published estimates of the volcanic recurrence rate are listed and discussed. This information was not available when the TSPA-1991 work was being done. The values of E_1 range from 6.0×10^{-7} to 2.8×10^{-5}/yr, with the most geologically reasonable values clustered in the range 1×10^{-6} to 6×10^{-6}/yr. The mean value of this range is 4.0×10^{-6}/yr. Crowe et al. do not report new values for the probability of an event occurring in the repository. E_2 was originally calculated using the assumption that the repository area was 6 km^2. For these analyses, the repository areas are different (4.6 km^2 for the 57-kW/acre layouts and 2.3 km^2 for the 114-kW/acre cases). Scaling the previous value of E_2 by the two areas gives the probability of occurrence for a magmatic intrusion over 10,000 years as 1.8×10^{-4} for the 57-kW/acre case and 1.0×10^{-4} for the 114-kW/acre case. E_3 is given by the conditional CCDF produced by the analysis.

To extrapolate this probability to 1,000,000 years requires assumptions about whether the 10,000-year rate of volcanism will be constant, increasing, decreasing, or chaotic over the 1,000,000-year period. Crowe et al. (1992) argue that using a constant rate will likely not underestimate the recurrence rate. With the assumption of a constant million-year rate, the probabilities for the two cases become 1.8×10^{-2} and 1.0×10^{-2} for 57 kW/acre and 114 kW/acre, respectively, over this period. The table below lists the probabilities that 0, 1, or 2 magmatic events will occur over the 10,000- and 1,000,000-year periods using the 57 kW/acre probability of occurrence. From the table it can be seen that a magmatic event is quite unlikely over both periods—there is an almost 100% probability of having no events over 10,000 years; there is about a 98% chance of having no events over 1,000,000 years. The probabilities of having 1 event occur are in the range 10^{-4} to 10^{-2} for the two time periods, and multiple magmatic events are even more unlikely. Therefore, it was assumed that the releases for both 10,000 and 1,000,000 years are due to the occurrence of a single event.

Probabilities of Occurrence for Magmatic Events

Number of Events	10,000 Years	1,000,000 Years
0	9.998×10^{-1}	9.8×10^{-1}
1	2.4×10^{-4}	2.3×10^{-2}
2	2.9×10^{-8}	2.8×10^{-4}

Human Intrusion. Probabilities of a direct hit on a waste container, or a near miss, meaning contaminated rock is intersected, are proportional to the horizontal areas of the targets—the container, or the amount of contaminated rock. If a direct hit occurs, a random amount of waste (ranging from 0% to 100% of the content) is assumed to be brought to the surface. The amount of radioactivity released is dependent on the assumed frequency of drilling, the timing and location of drilling, and the activity and location of the radionuclides. The repository-related parameters used in the drilling analyses are shown below.

Repository-related Parameters for Drilling Analyses

Emplacement Configuration	Repository Area (km^2)	Maximum Number of Boreholes per 10,000 years
Borehole, 57 kW/acre	4.61	14
Borehole, 114 kW/acre	3.14	10
In-Drift, 57 kW/acre	4.63	14
In-Drift, 114 kW/acre	2.33	7

6.3.4.2 Probability of Occurrence of Scenarios

The probability of occurrence of the scenarios involves a combination of the probability of occurrence of each of the processes and events included in the scenario. [These will be identified in [INN 6.3.4-2] and used to complete Table 6.3.4.2-1.]

6.3.4.3 Method of Probability Estimation

[The methods used for probability estimation are shown in Table 6.3.4.3-1 [INN 6.3.4-2].

6.3.4.4 Probabilities of Transient Phenomena

[The methods used for determination of probabilities of transient phenomena are shown in Table 6.3.4.4-1 [INN 6.3.4-2].

6.3.4.5 Uncertainty in Probability Estimation

The probability estimates of processes and events and the scenarios that will be developed using them contain uncertainty. [The estimation of uncertainty will be defined in [INN 6.3.4-2] and the results will be used to complete this section.]

6.3.4.6 Additional Discussion on Probability Estimation

[This section contains a discussion of alternative methods of estimating probabilities and the justification of not using those methods [INN 6.3.4-2].]

6.3.5 Compliance Assessment for Cumulative Releases

[The compliance assessment for cumulative releases takes the iterative approach described in Section 6.0. A process of analysis and comparison of repository performance under selected scenarios to determine whether the repository complies with the appropriate release and dose standards has been adopted [INN 6.3-3]. The CCDFs were developed following the methods defined in ______ [INN 6.3.5-1]. The analyses for cumulative release indicate that the site satisfies the EPA Standards (to be determined) for the selected scenarios. The conditional CCDFs for each of the scenarios are presented in several figures (there will be one figure for each one of the n scenarios). Sensitivity analyses of the results indicate the effect of uncertainty on the CCDFs [INN 6.3.5-2].]

6.3.5.1 Demonstration of Compliance with 10 CFR 60.112

[The demonstration of compliance with 10 CFR 60.112, the overall system performance objective for cumulative release, is presented in ______ [INN 6.3.5.1-1].]

6.3.5.2 Method of CCDF Formulation

[The conditional CCDFs were formulated according to the method presented in Table 6.3.5.2-1 [INN 6.3.5.2-1]. This section will be completed using [INN 6.3.5.2-1] which will describe the method of composing the CCDF.]

6.3.5.3 Composite CCDF for Yucca Mountain

[The composite CCDF for Yucca Mountain is shown in Figure 6.3.5.3-1 [INN 6.3.5.2-1] and [INN 6.3.5-1], and material contained in these reports (TBD) will be used to complete this section.]

6.3.5.4 Uncertainties in Development of the CCDF

[The uncertainties in the Yucca Mountain CCDF are presented in Table 6.3.5.4-1 [INN 6.3.5.2-1], and information contained in this report (TBD) will be used to complete this section.]

6.3.5.5 Alternative Representations of the CCDF

[The alternative representations of the CCDF are presented in _______[INN 6.3.5.2-1]. This report (TBD) will be used to complete this section.]

6.3.6 Model and Code Verification and Validation

[The information in this section on code verification and model validation will be cross referenced with Chapter 8 because many of the tests described in that Chapter will provide the basis for model validation. The results of code verification and model validation will be incorporated primarily by reference. (A summary will be included here.)]

Verification of calculational models involves comparison of results with results from analytical solutions. It includes verifying that the software is properly coded. Validation provides reasonable assurance that the model embodied in a computer code is a correct representation of the process or system for which it is intended.

[The codes to be verified and models to be validated relative to cumulative release are listed in Table 6.3.6-1 [INN 6.3.6-1]. The models are grouped into two major categories: performance assessment and detailed process models. The validation methods for each of these categories of models varies depending on the type and level of detail of the model. An extensive discussion on the verification and validation of the various codes and models, respectively is documented in ________ [INN 6.3.6-1].]

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Table 6.3.1.1-1 Screening Criteria for Retention of Processes and Events*

CRITERION	EXPLANATION
Presence	Site characterization data indicate presence of process/event at the site or within the region
Probability	Probability of occurrence is greater than 10^{-8} per year
Consequence	Process and event potentially increases radionuclide release
Consequence	Incorporation of process and event changes dose

*Processes and events that are physically or logically unrealistic and are expected to produce trivial consequences will be eliminated.

Note: This table will be completed using INN 6.3-1 and INN 6.3-2.

Table 6.3.1.2-1 List of Processes and Events Retained After Screening

Event	Impact on Performance Assessment Results
1. Climatic Change	(discussion and references)
2. Human Intrusion	
Process	**Impact on Performance Assessment Results**
1. Tectonism	(discussion and references)
2. Fracture Flow	
3. Gas Flow	

Note: This table will be completed using INN 6.3.1.2-1.

Table 6.3.1.3-1 Summary of Processes and Events That Were Eliminated

Process/Event Eliminated	Justification for Elimination
1. Meteor Impact	(show data, analyses, reports)
2.	
3.	
4.	

Note: This table will be completed using INN 6.3.1.3-1.

Table 6.3.2.2-1 Criteria Used for Scenario Screening

Criterion	Explanation
1. Probability	Probability of occurrence is less than 10^{-8}
2.	

Note: This table will be completed using INN 6.3.2.2-1.

Table 6.3.2.2-2 Level of Confidence Required to Eliminate Scenarios

Scenario and Description	Insignificant	Significant	Level of Confidence	Eliminate
1. -----		x		No
2. -----	x			

Note: This table will be completed using INN 6.3.2.2-2.

Table 6.3.2.2-3 Scenarios Retained After Screening

Scenario and Description	Discussion of Importance
1.	
2.	

Note: This table will be completed using INN 6.3.5-1

Table 6.3.3.3-1 Description of Analytical Methods Used for Scenario Analyses

Analytical Method	Application and Remarks
1. Computer Code	
2.	

Note: This table will be completed using INN 6.3.3.1-1

Table 6.3.4.1-1 Probability of Occurrence of Processes and Events

Process/Event	Probability of Occurrence	Uncertainty	Source
Tectonism			
Volcanism			

Note: This table will be completed using INN 6.3.4-1.

Table 6.3.4.2-1 Probability of Occurrence of Scenarios

Scenario	Probability/Frequency of Occurrence	Uncertainty	Source
Scenario 1			
Scenario 2			

Note: This table will be completed using INN 6.3.4-2

Table 6.3.4.3-1 Method Used to Estimate Probability

Technique Used	Criteria Used	Uncertainty	Source

Note: This table will be completed using INN 6.3.4-2.

Table 6.3.4.4-1 Uncertainties in Determination of the Probabilities of Transient Phenomena

Scenario	Explanation Regarding Time Dependent Probability	Uncertainty	Source

Note: This table will be completed using INN 6.3.4-2.

Table 6.3.5.2-1 Means Used to Produce the CCDF

Computer Code/Model	Source	Resultant Output and Application

Note: This table will be completed using INN 6.3.5.2-1.

Table 6.3.5.4-1 Uncertainties Remaining in the CCDF

Uncertainty	Discussion

Note: This table will be completed using INN 6.3.5.2-1.

Table 6.3.6-1 Verification and Validation of Computer Codes and Models

Model	Analyses	QA Status	Verified	Validated	Source
TOUGH2	UZ Flow				LBL
RIP	TSPA				Golder

Note: This table will be completed using INN 6.3.6-1.

Figure 6.3.2.1-1. Method of Constructing Scenarios [INN 6.3.2.1-1]

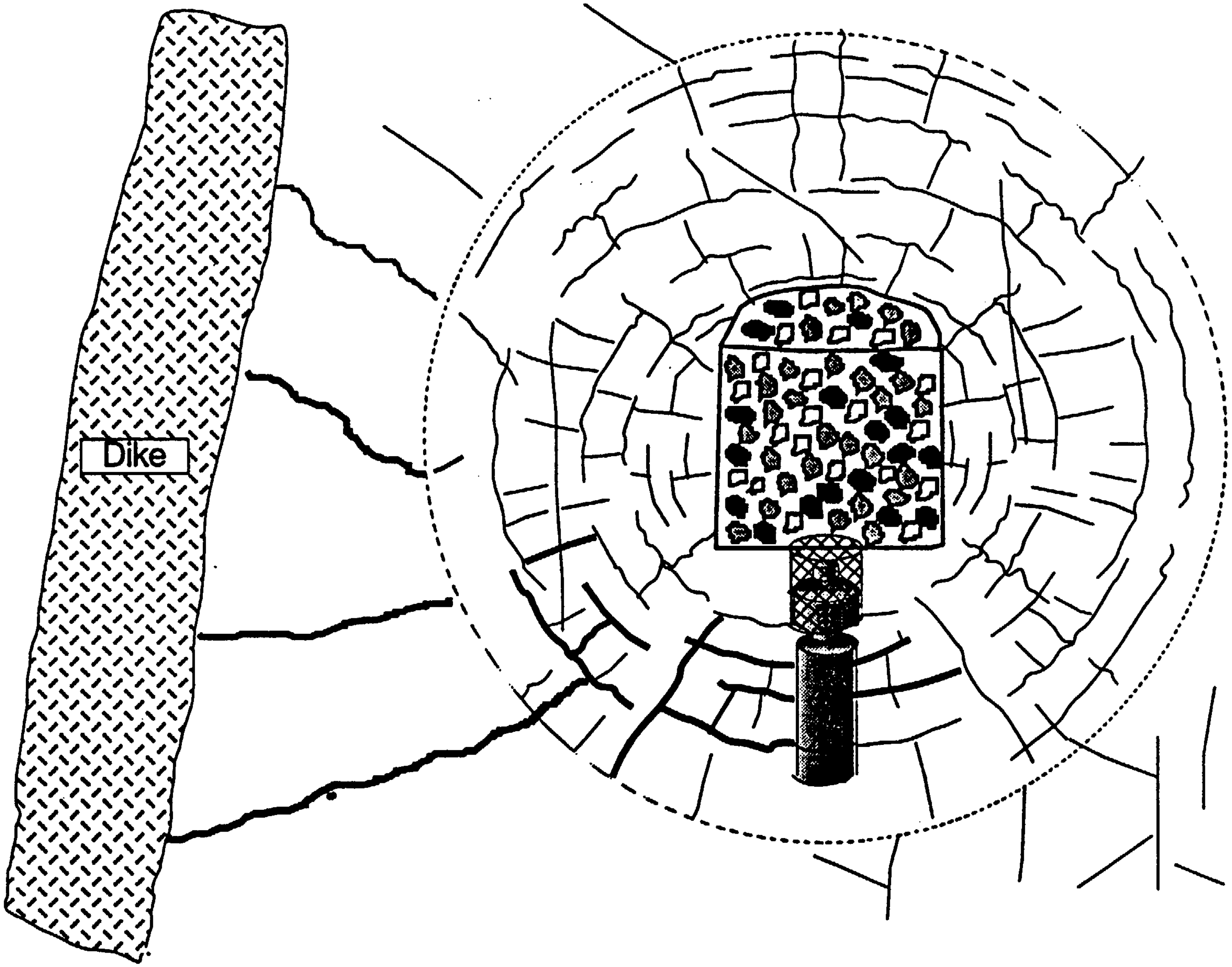

Figure 6.3.2.2-1 Waste Package Interaction with Nearby Magmatic Intrusion

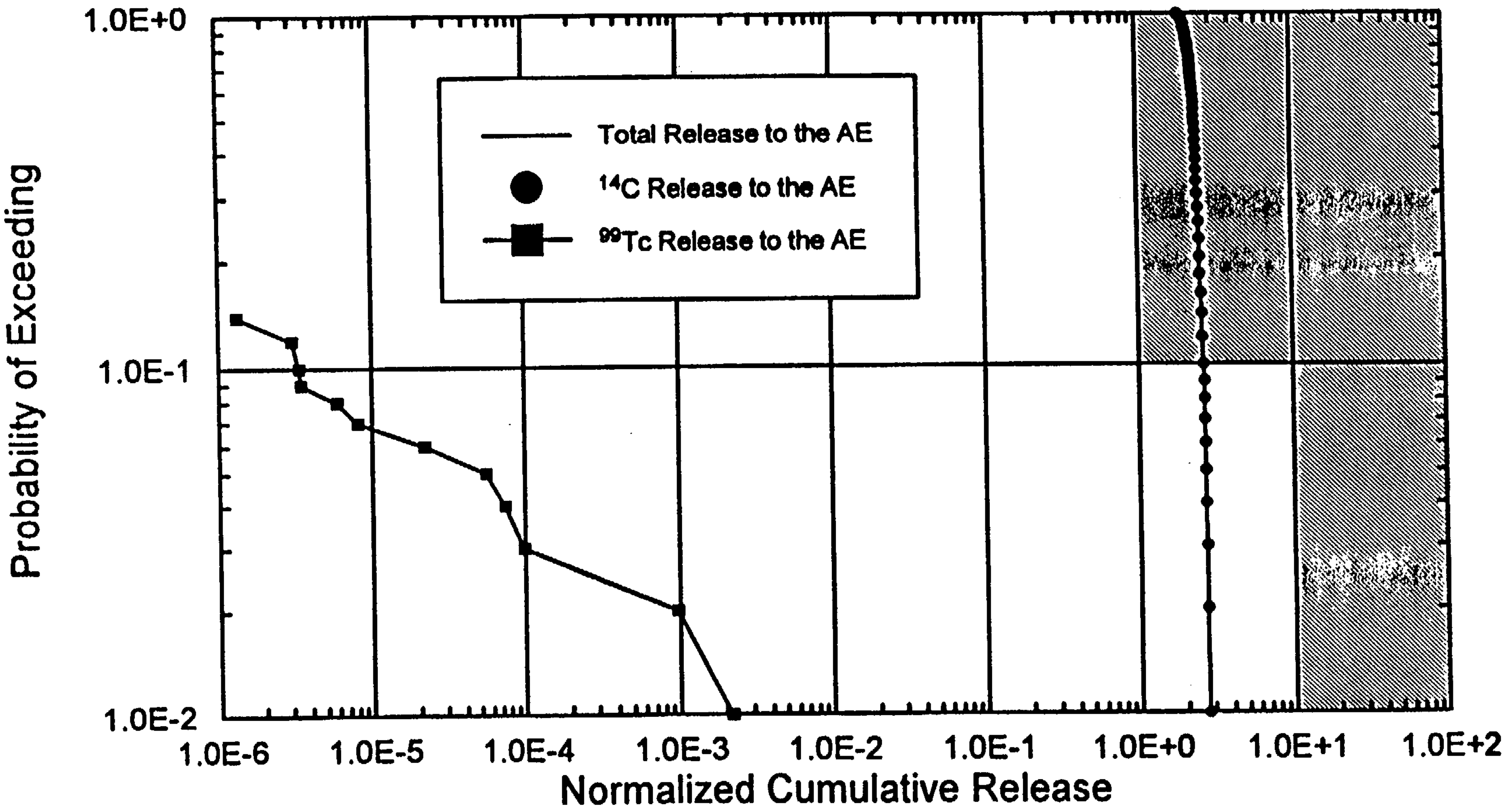

Figure 6.3.3.2-1 CCDFs for 10,000 Year Aqueous and Gaseous Releases to the Accessible Environment for the Composite Porosity Model (Andrews et al., 1994)

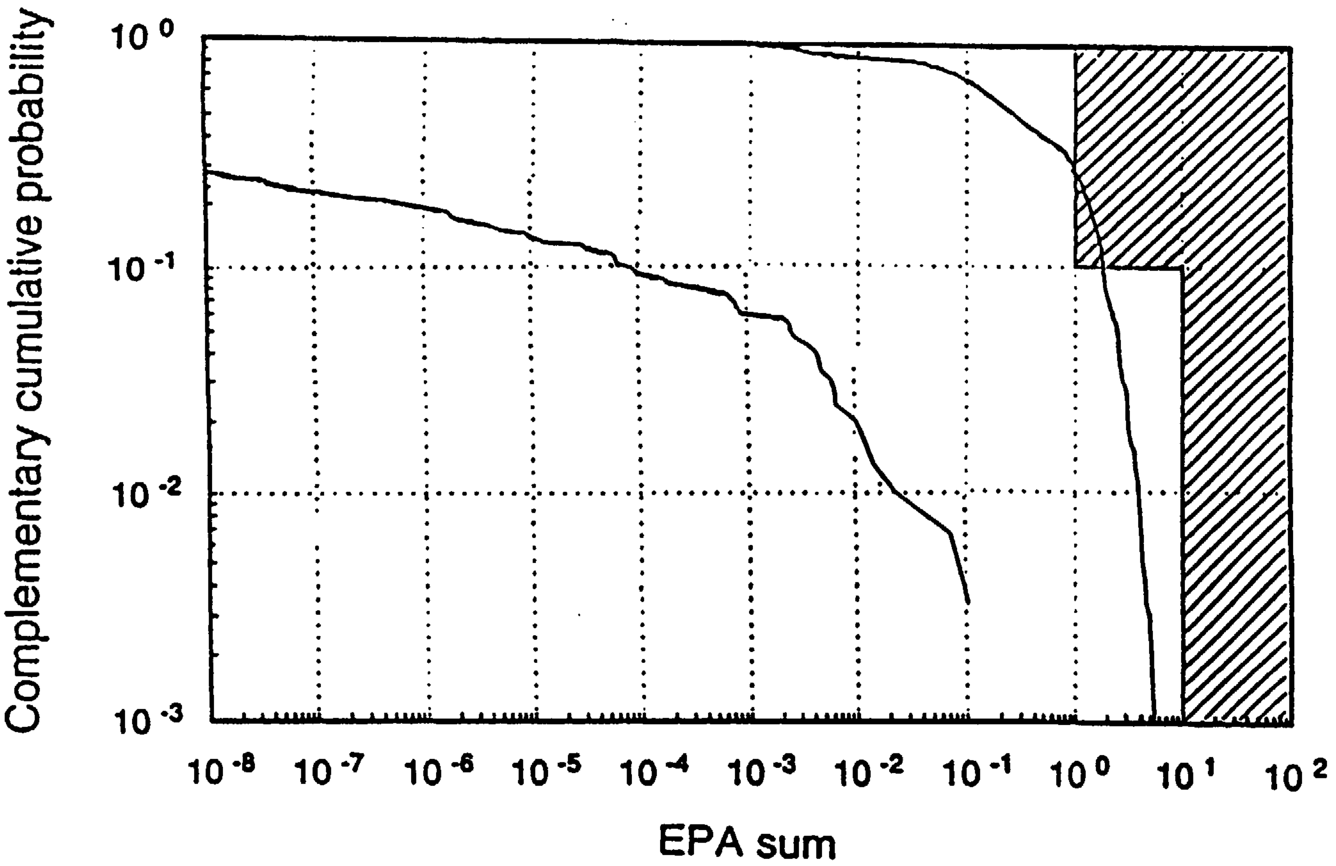

Figure 6.3.3.2-2 CCDFs for 10,000 Year Aqueous and Gaseous Releases to the Accessible Environment for the Composite Porosity Model. Wilson et al. (1994)

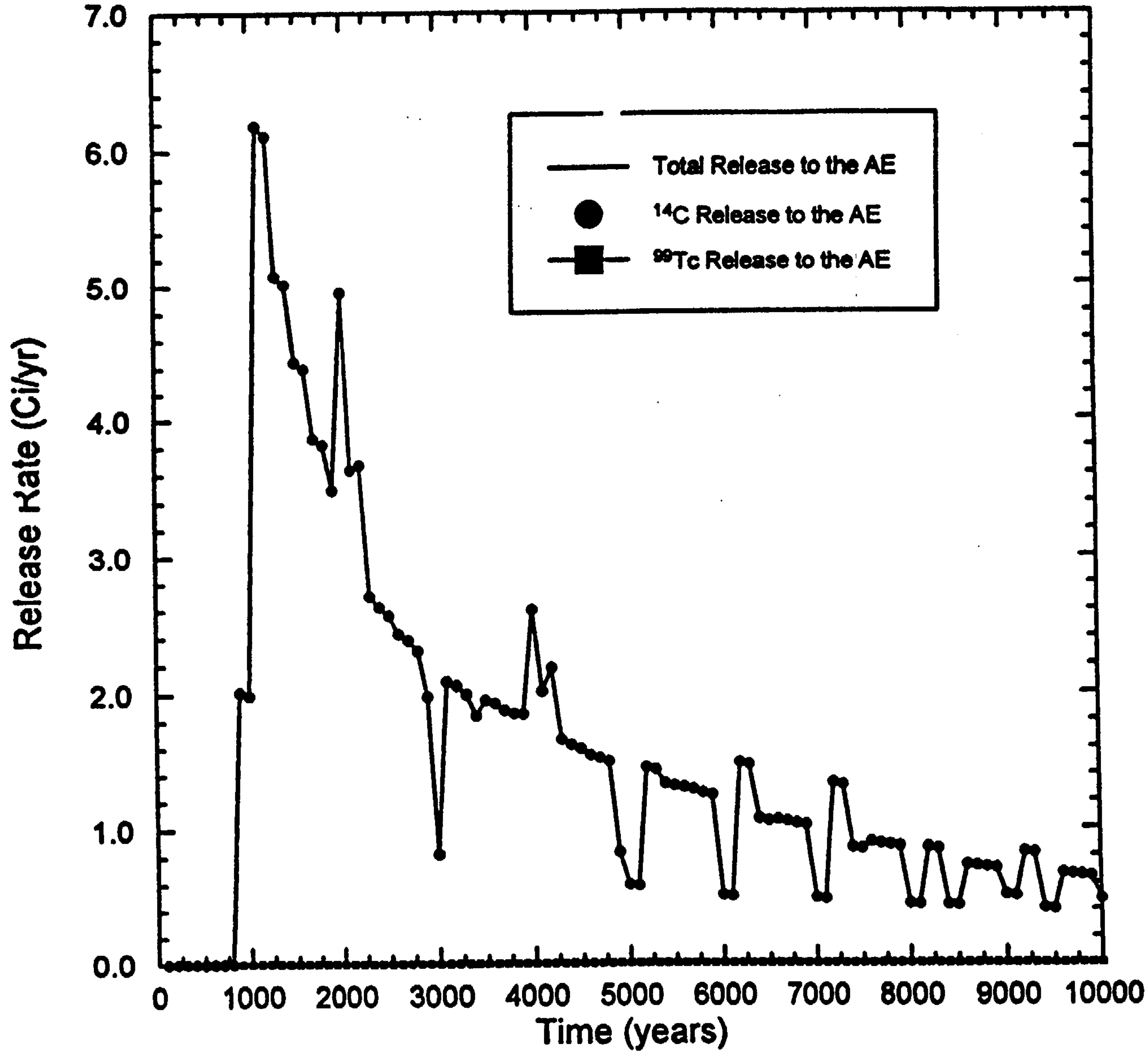

Figure 6.3.3.2-3 Expected Value Release Rates to the Accessible Environment Over 10,000 Years, Illustrating Dominant ^{14}C Peak at Early Time Due to Start of Container Failures

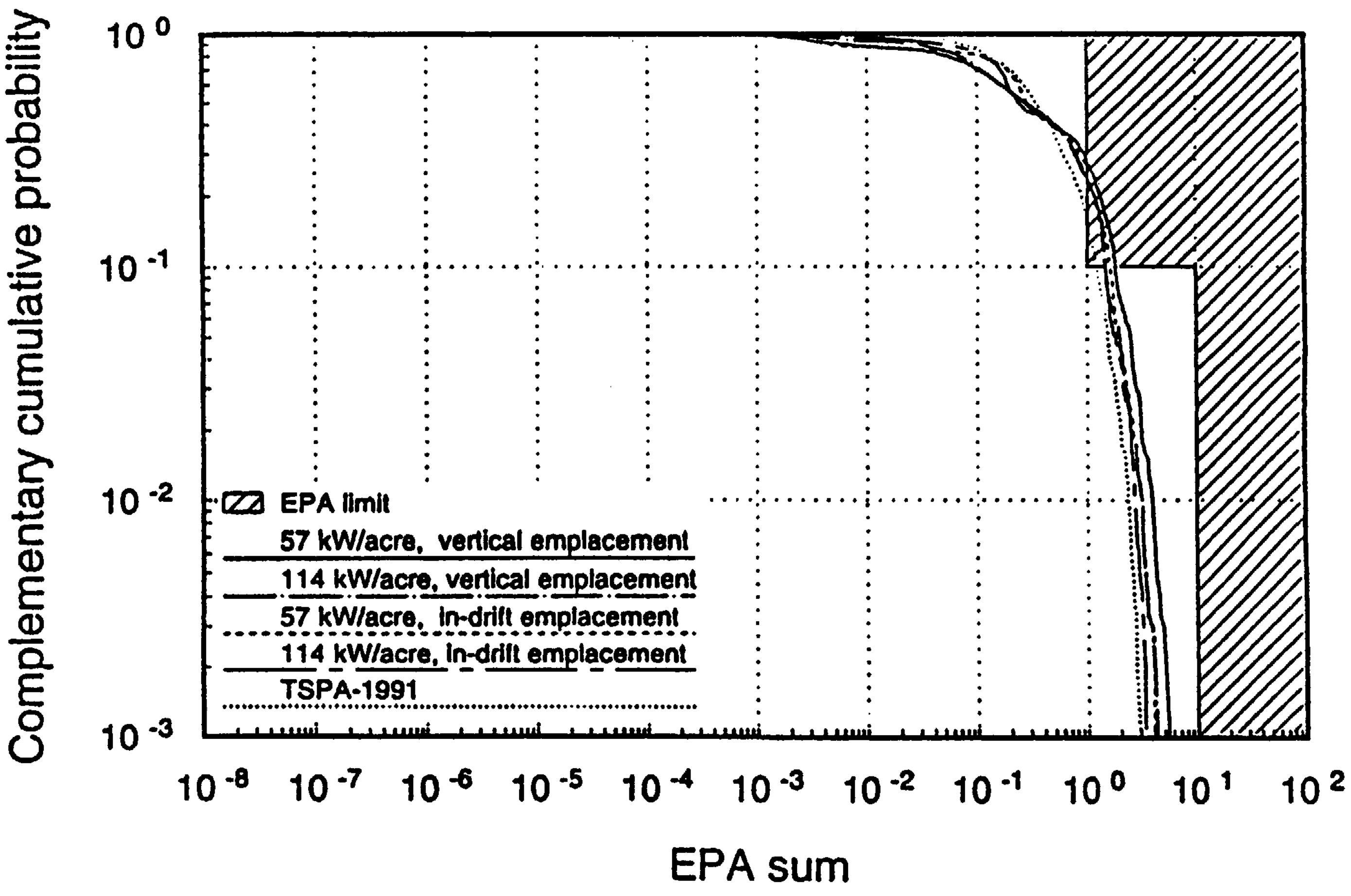

Figure 6.3.3.2-4 CCDF of Normalized Cumulative Nominal Release (Aqueous + Gaseous) Over 10,000 Years

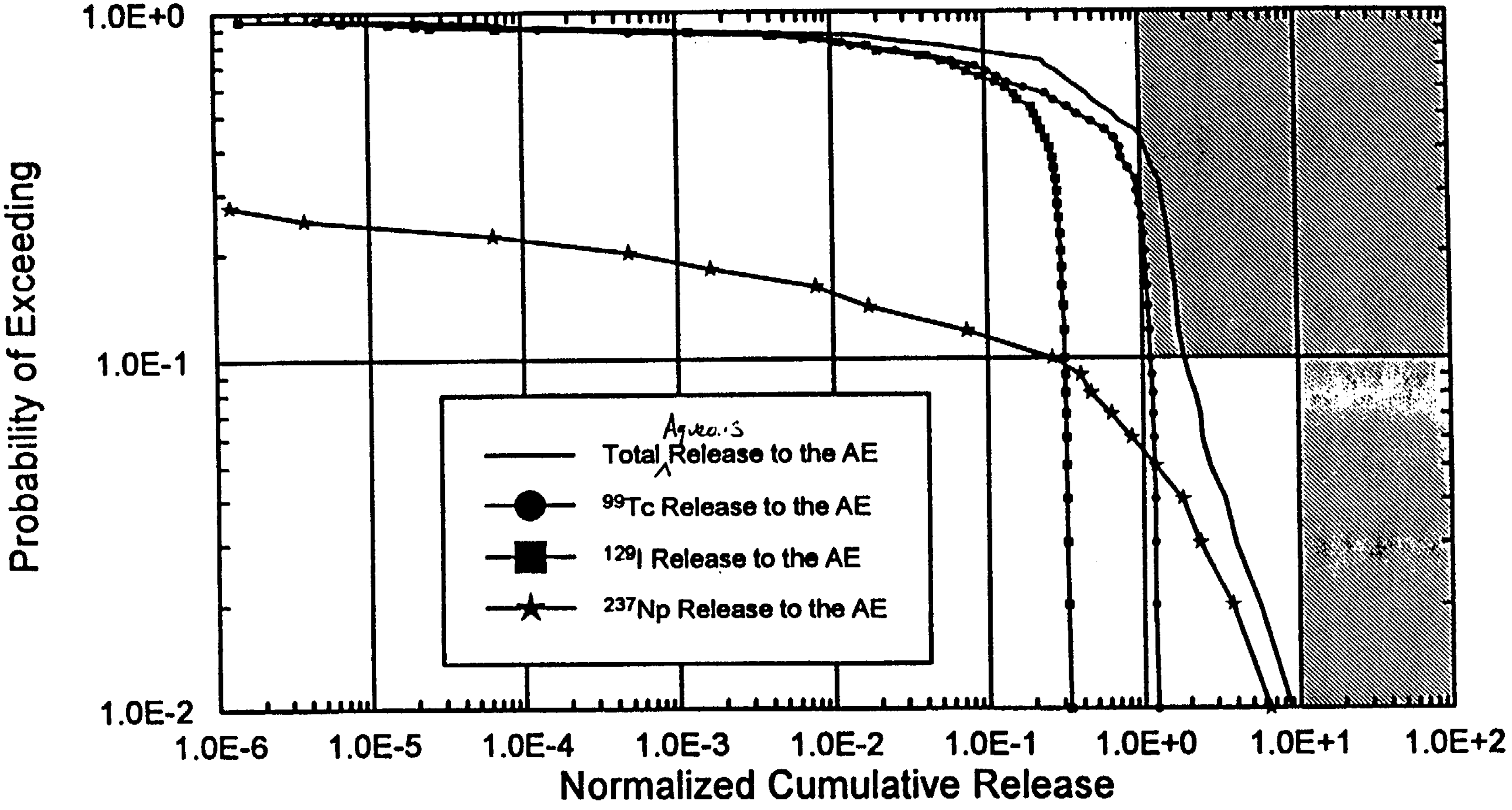

Figure 6.3.3.2-5 CCDFs for Normalized Cumulative Aqueous Releases to the Accessible Environment for 100,000 Years. Andrews et al. (1994)

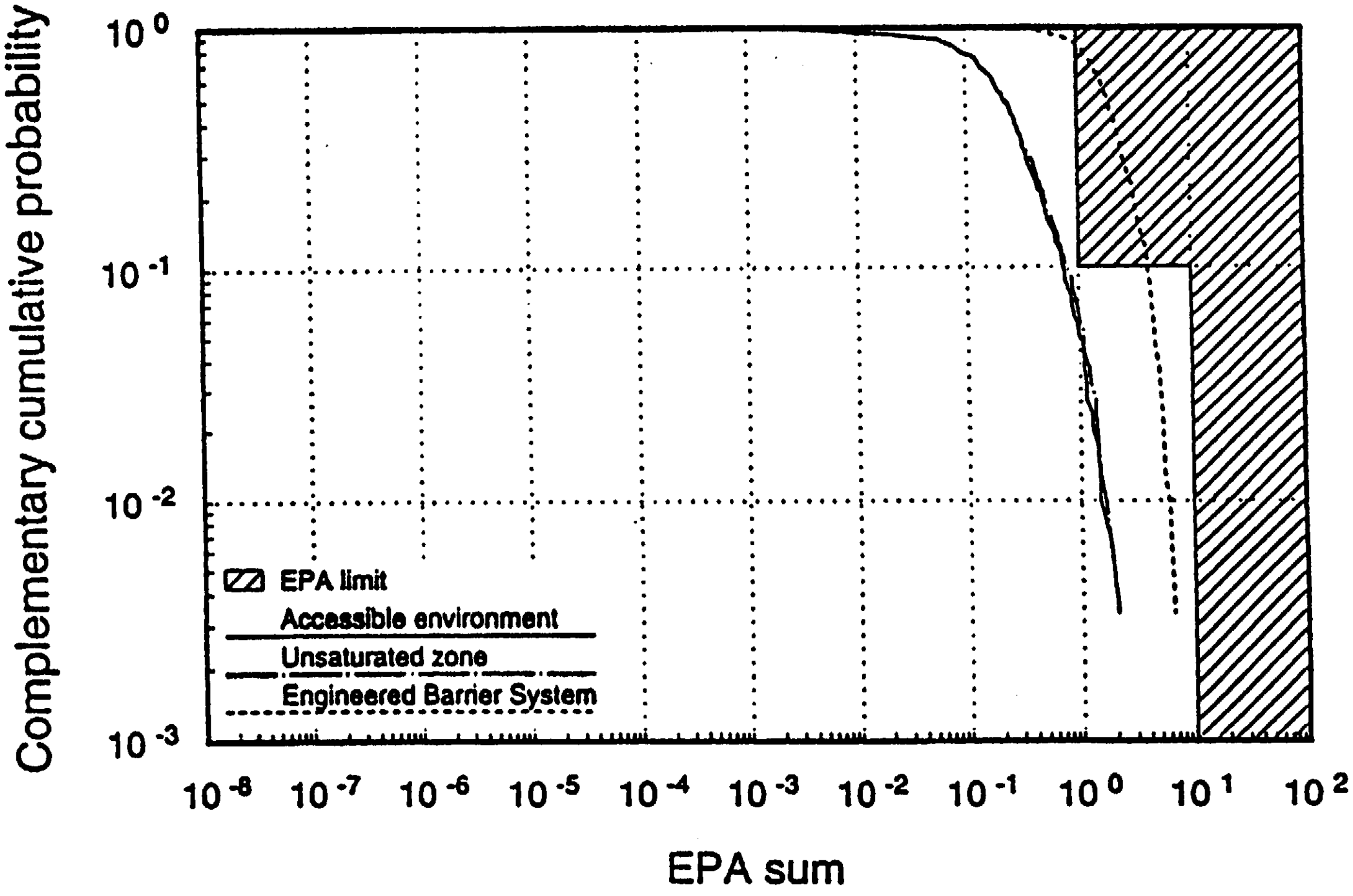

Figure 6.3.3.2-6 CCDF for Normalized Cumulative Aqueous Releases to the Accessible Environment for 100,000 Years. Wilson et al. (1994)

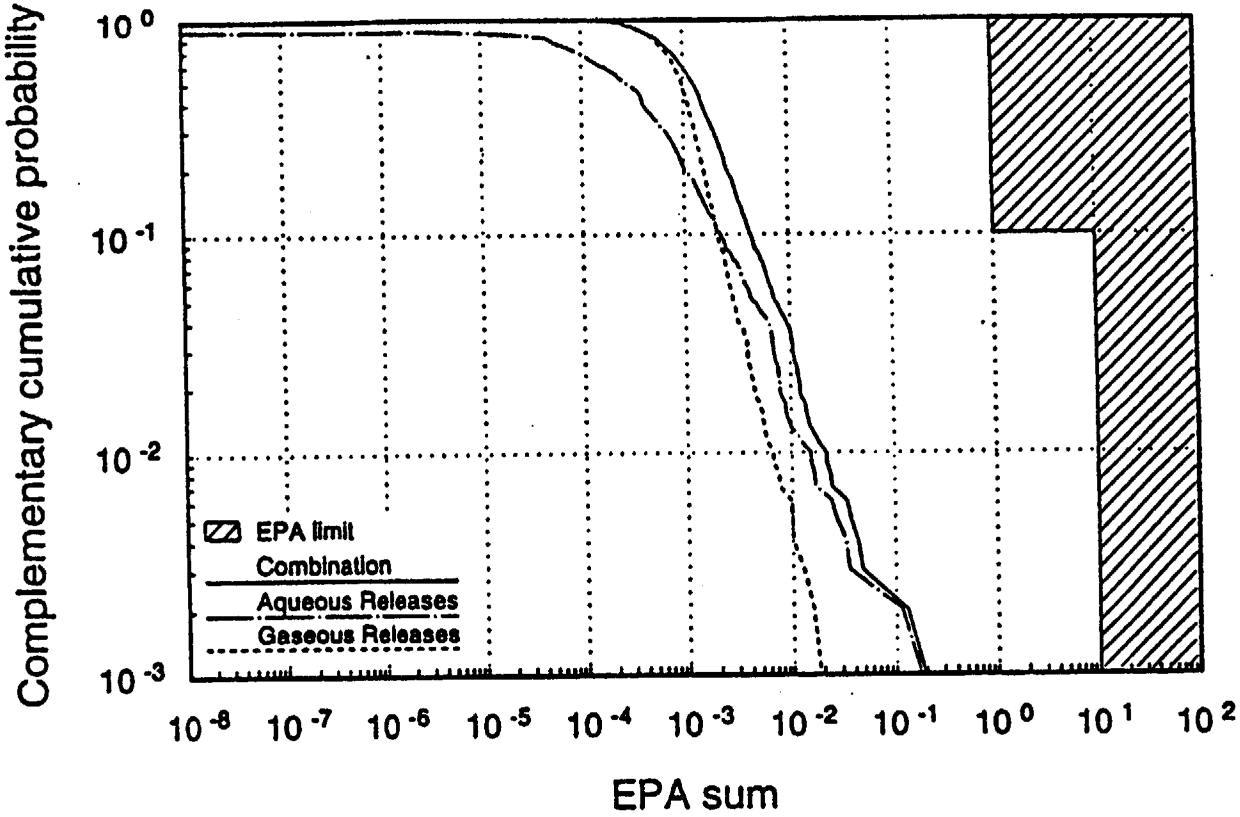

Figure 6.3.3.2-7 Conditional CCDFs of Cumulative Aqueous and Gaseous Releases to the Accessible Environment for 10,000 Years, Weeps Model

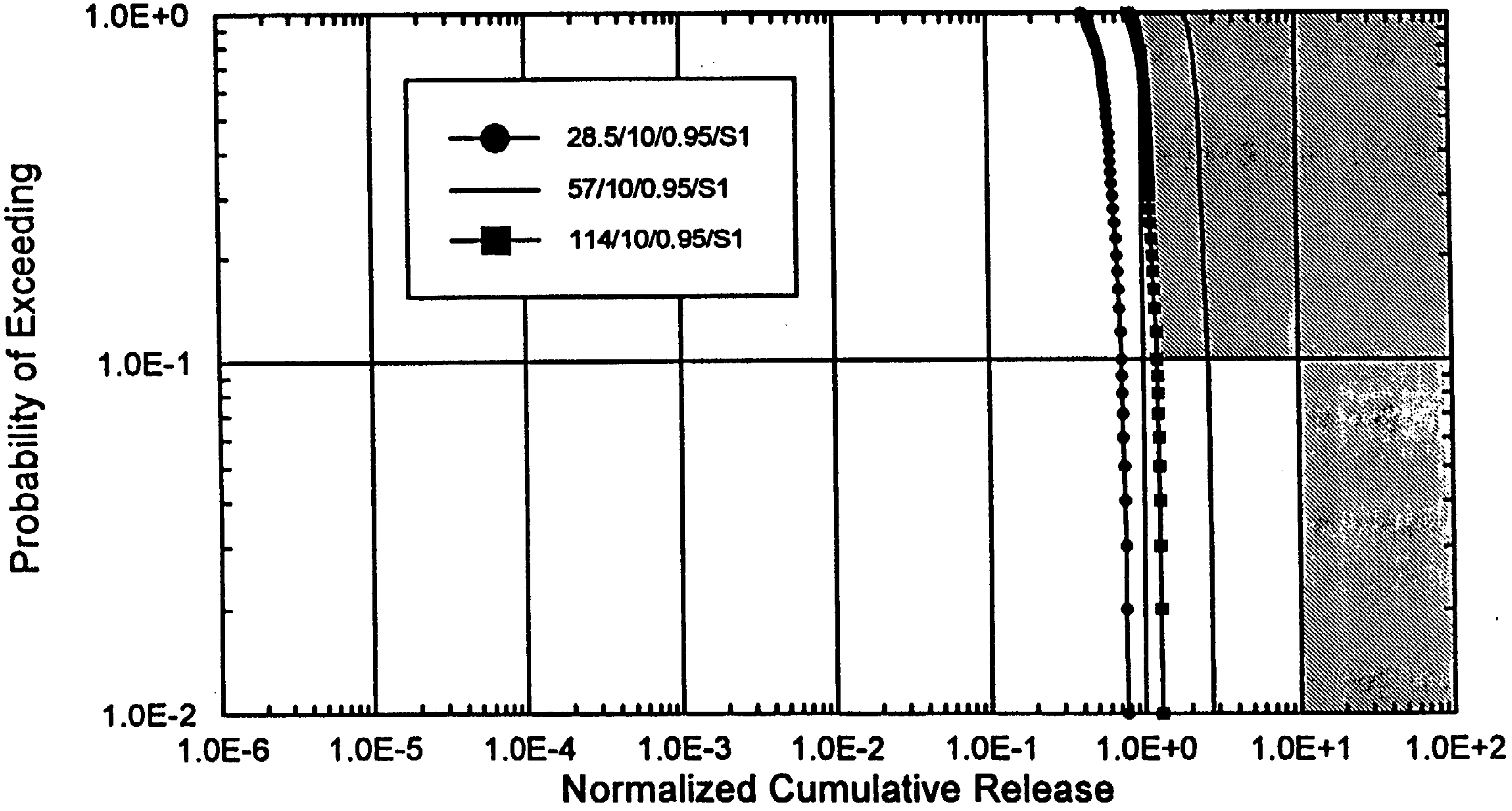

Figure 6.3.3.2-8 CCDF of Normalized Cumulative Release to the Accessible Environment at 10,000 Years for Three Thermal Loadings (70.4, 141, and 282 kW/ha; 28.5, 57, and 114 kW/acre) and 10 cm Overpacks. Andrews et al. (1994)

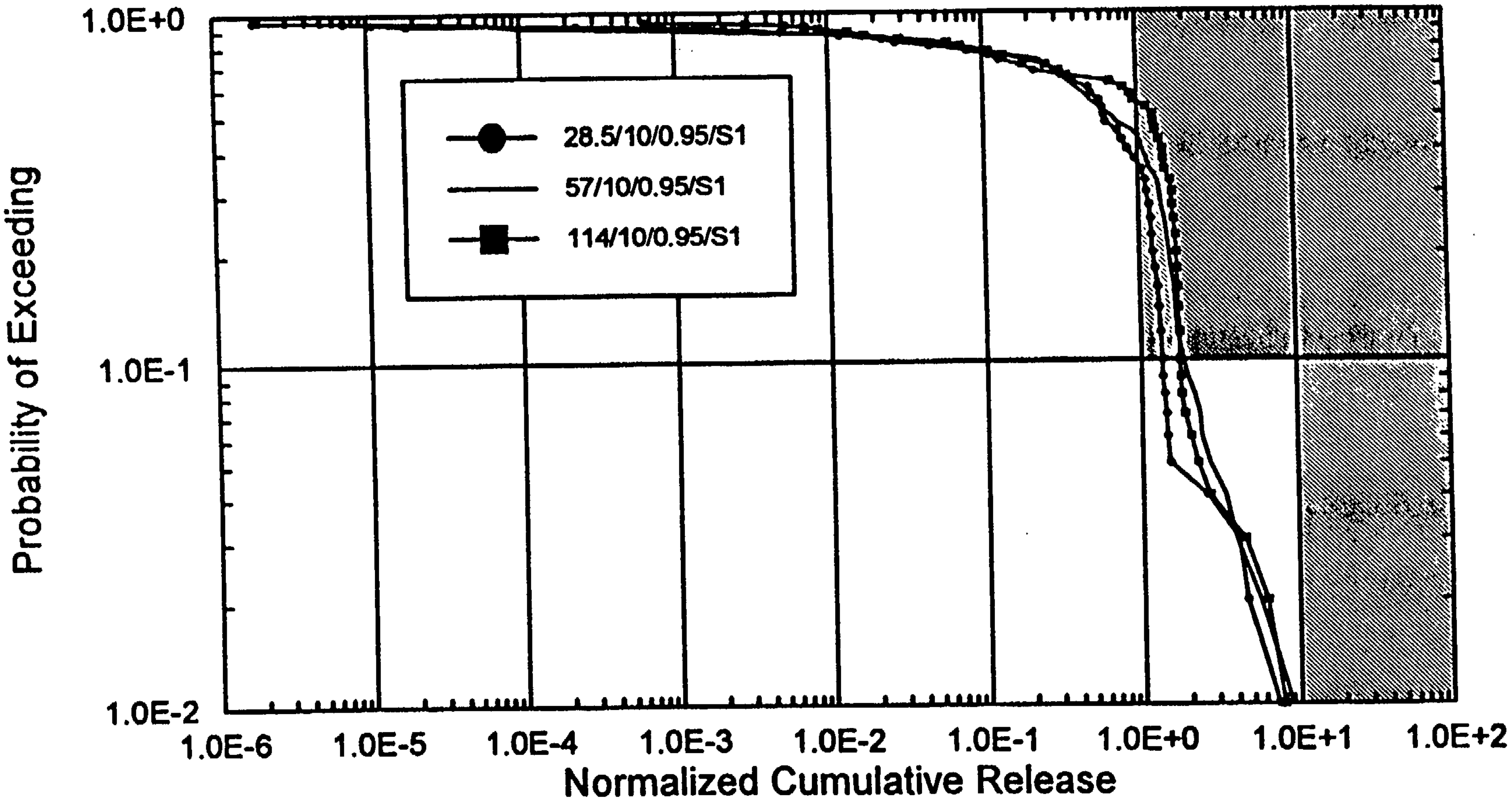

Figure 6.3.3.2-9 CCDF of Normalized Cumulative Release to the Accessible Environment at 100,000 Years for Three Thermal Loadings (70.4, 141, and 282 kW/ha; 28.5, 57, and 114 kW/acre) and 10 cm Overpacks. Andrews et al. (1994)

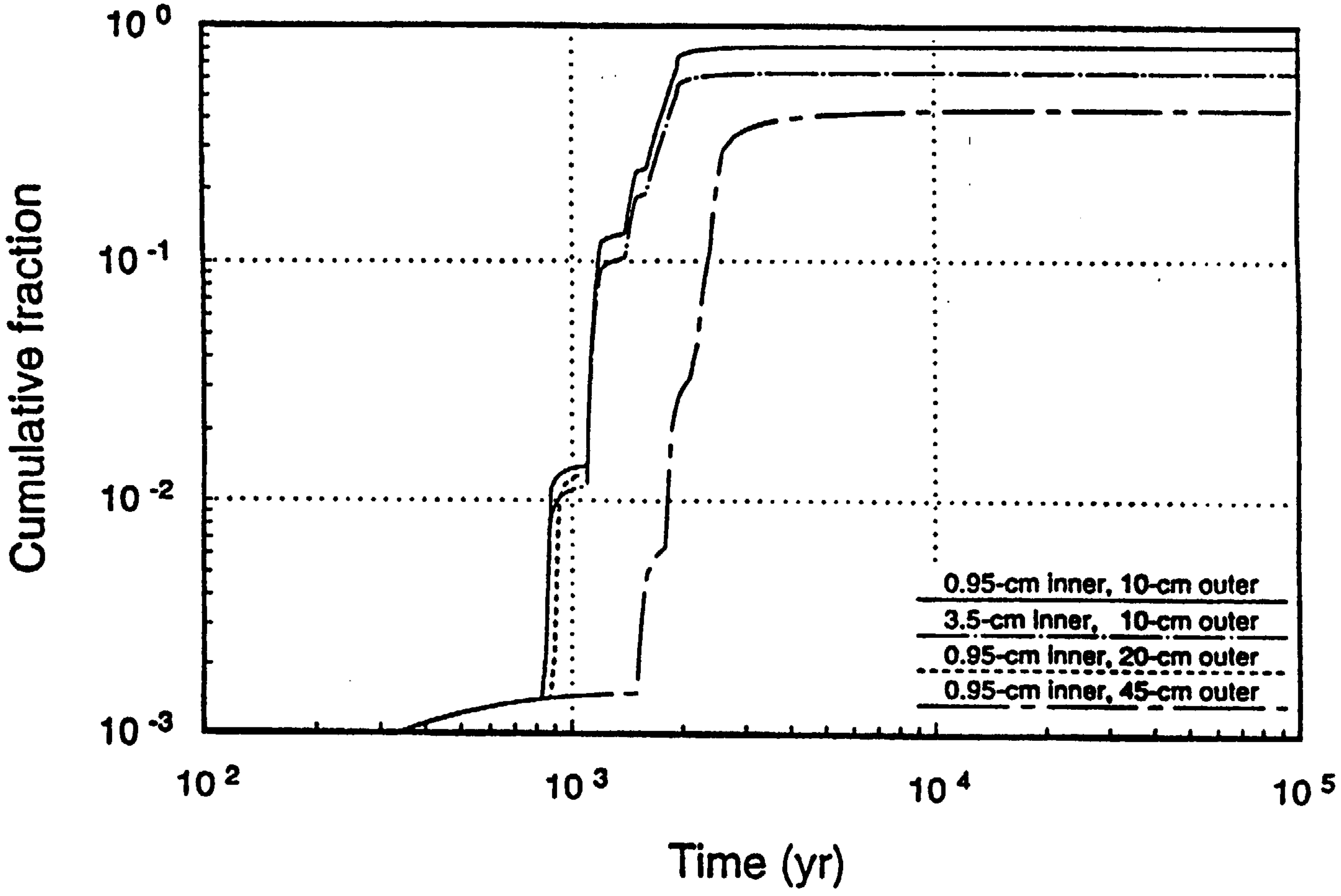

Figure 6.3.3.2-10 Mean Distributions of Container Failure Time for Alternative Thicknesses of Dual Wall Container

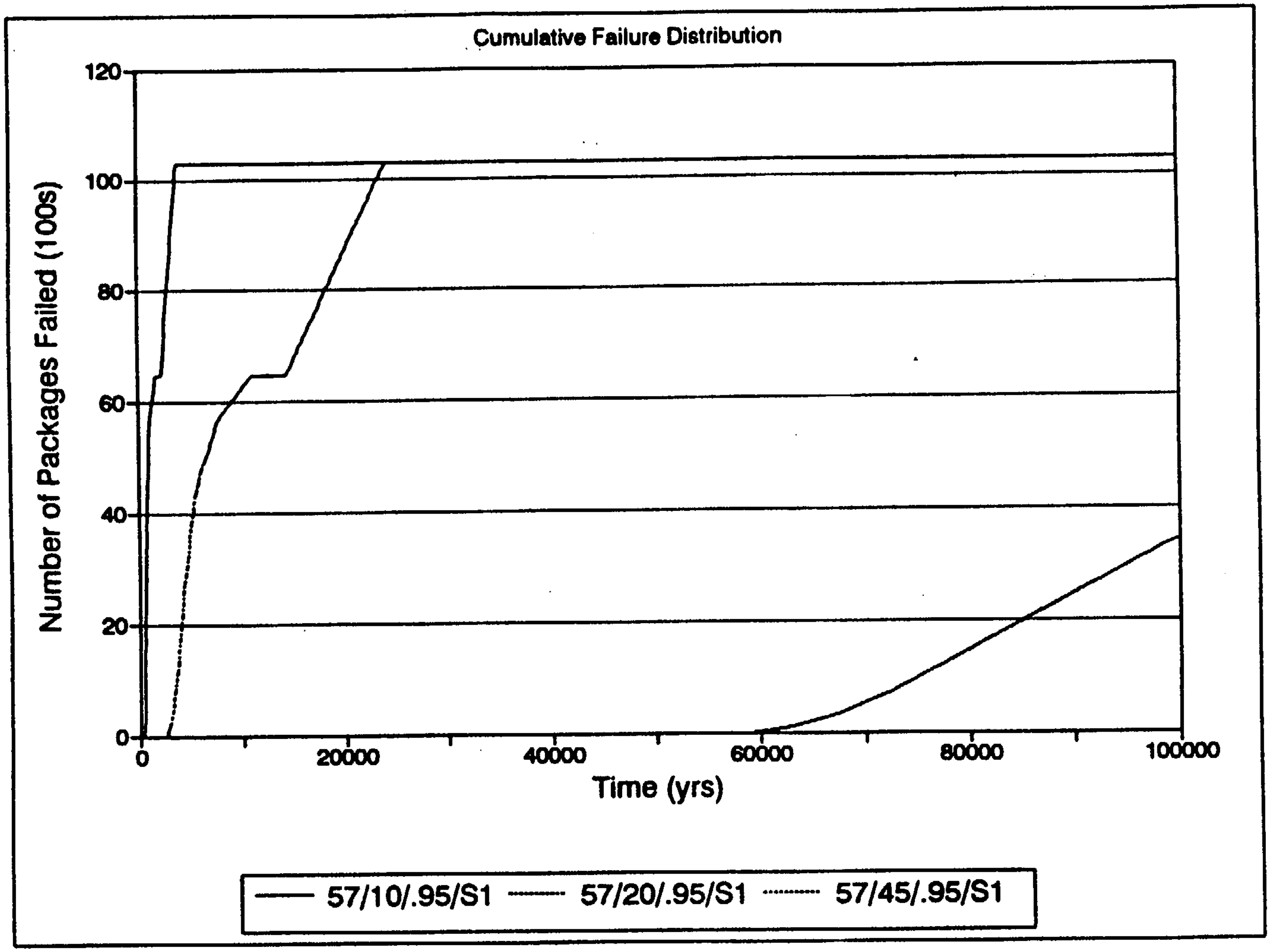

Figure 6.3.3.2-11 Waste Package Failure Distributions for Three Outer Container Thicknesses

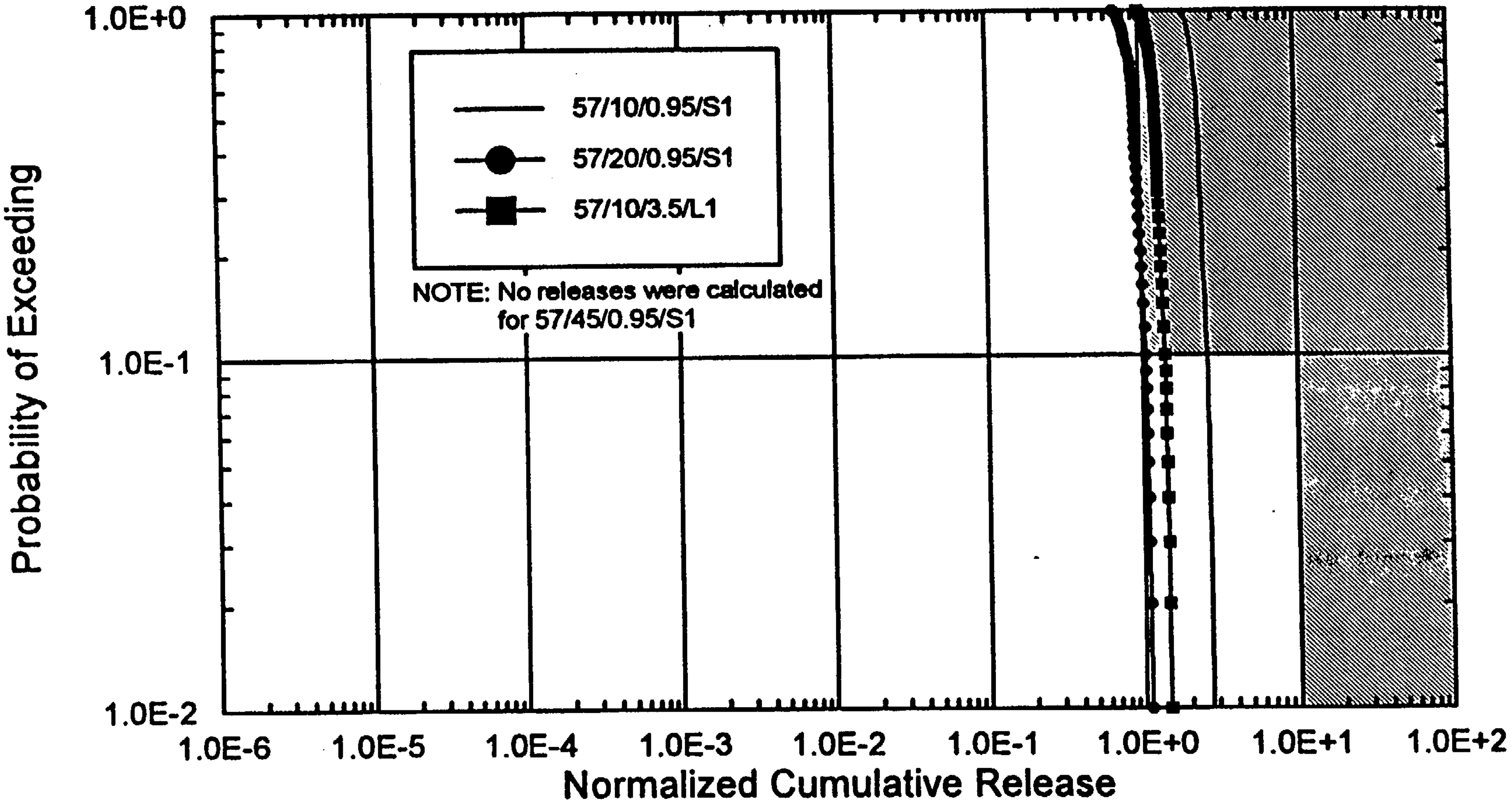

Figure 6.3.3.2-12 CCDF of Normalized Cumulative Release to the Accessible Environment at 10,000 Years for Four Inner/Outer Barrier Thickness Combinations

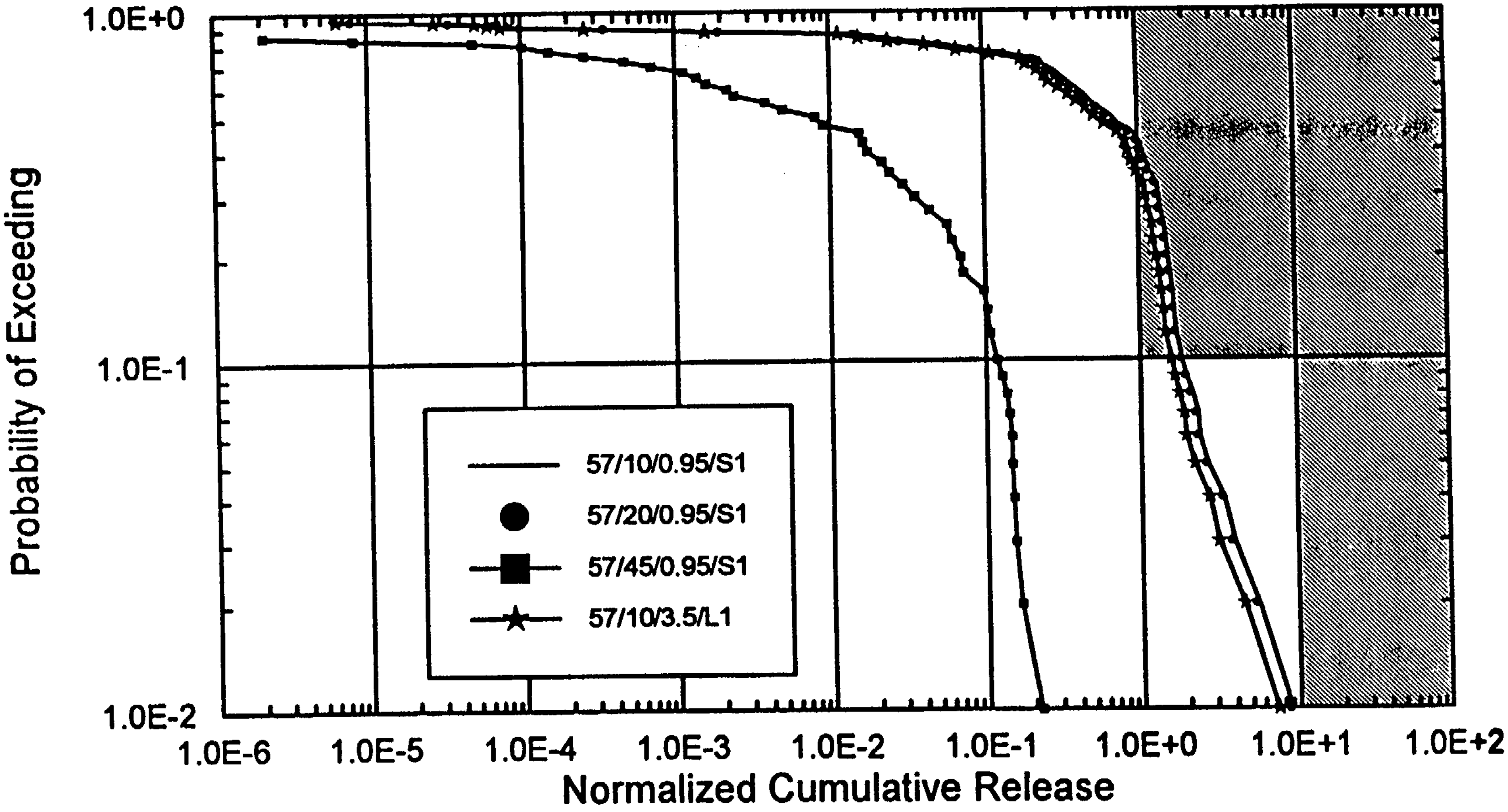

Figure 6.3.3.2-13 CCDF of Normalized Cumulative Aqueous Release to the Accessible Environment at 100,000 Years for Four Inner/Outer Barrier Thickness Combinations

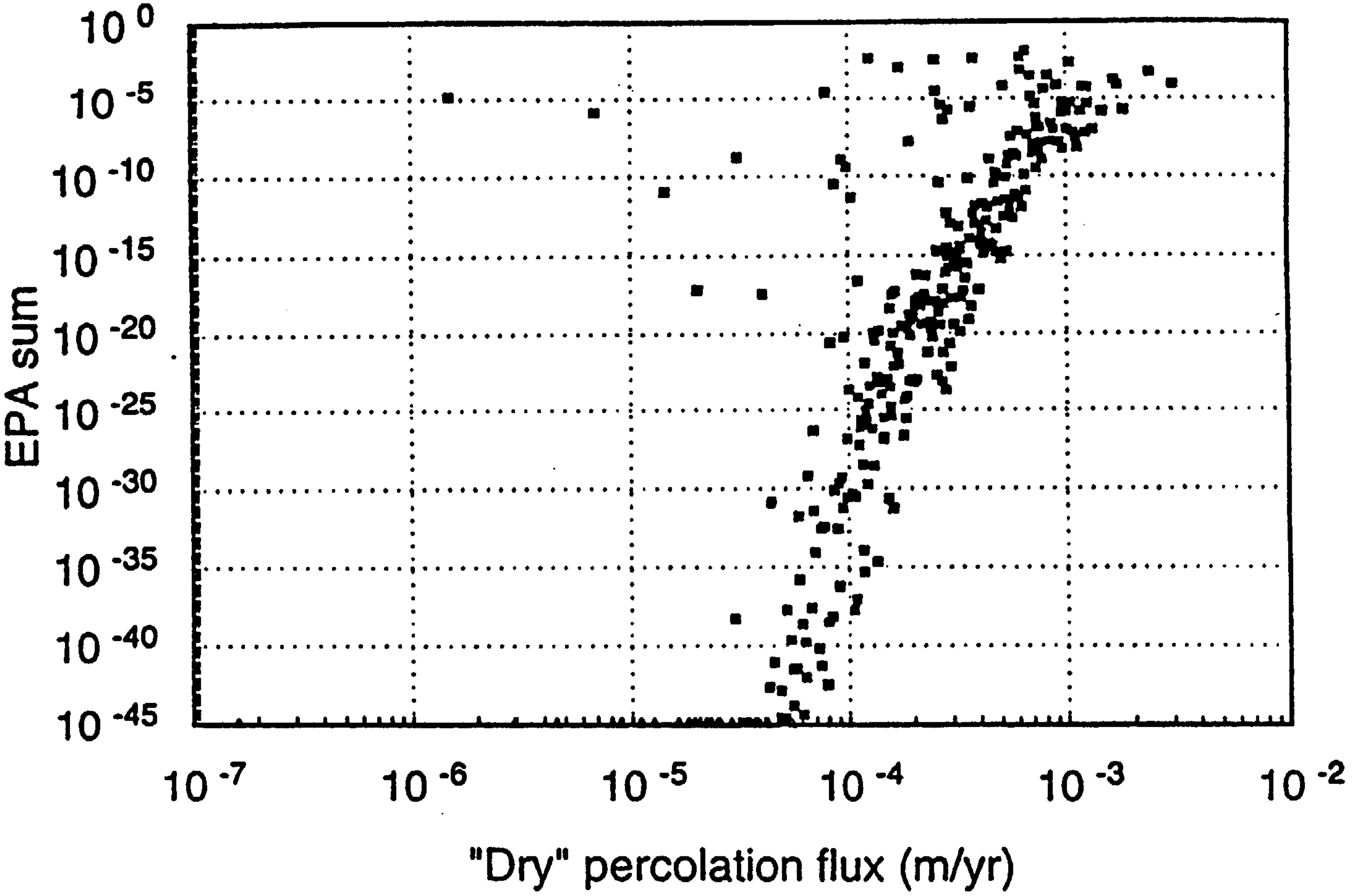

Figure 6.3.3.2-14 Scatter Plot of Normalized Cumulative Aqueous Release Over 10,000 Years Versus Dry Climate Percolation Flux

Figure 6.3.5.3-1. Composite CCDF for Yucca Mountain [INN 6.3.5.2-1]

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.1.1-1 and associated text
Explicit description of the needed information:	Screening criteria for processes and events. The documentation should include screening criteria used to eliminate processes and events from scenarios, the process used in development and ranking of scenarios, and the scenarios that should be evaluated as well as those that were developed but eliminated.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3-2
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Documentation of each iteration of TSPA. TSPA reports iteration 1 through that for the Safety Analysis Report.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3-3
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	The EPA standard for the Yucca Mountain site.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.1.2-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.1.2-1 and associated text
Explicit description of the needed information:	Processes and events retained and a discussion of their effects on performance assessment results. Total system performance assessment reports for iteration 1 through that for the Safety Analysis Report. These analyses should include the effects of processes and events on repository performance as well as the effects of scenarios derived from the credible processes and events.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.1.2-2
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Neptunium solubility. Laboratory testing that defines the range of Neptunium solubility under expected repository conditions.
Information will be used to support:	For input to performance assessment for compliance in Section 6.3.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.1.2-3
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Distribution coefficients. Distribution coefficients for radionuclides expected to be released from the repository at the accessible environment.
Information will be used to support:	Completion of text in Section 6.3.1.2.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

The above Annotated Outline text is guidance that may be used for the future development of an MGDS facility License Application.

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.1.3-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.1.3-1 and associated text
Explicit description of the needed information:	Methods used to eliminate insignificant processes and events, processes and events that were eliminated, and the justification for elimination of each. The methods used to develop scenarios through, the screening of processes and events, and the elimination of processes and events from further consideration should be described. The criteria for eliminating processes and events as well as entire scenarios should be included along with analyses which justify their elimination.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.2.1-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.1.1-1 and associated text
Explicit description of the needed information:	Method of combination of processes and events into scenarios.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.2.1-2
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Analysis of site information and field test data to support degree of fracture matrix interaction. Analyses of conceptual flow models (equivalent continuum, dual porosity, dual permeability, and discrete fracture) should be done and compared to site characterization data and test results to determine which, if any, of the conceptual models can be eliminated from consideration. Those models that are reasonably consistent with characterization and test results will have to be incorporated into the flow models used for calculation of groundwater travel time and performance assessment.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.2.2-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.2.2-1 and associated text
Explicit description of the needed information:	Criteria used for screening scenarios. Criteria used for screening scenarios should be described along with alternative criteria that were considered and rejected. Justification for the selection of the criteria used should be provided.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.2.2-2
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.2.2-2 and associated text
Explicit description of the needed information:	The level of confidence necessary for screening the scenarios (i.e., to determine whether or not a scenario was retained). Those processes, events, and scenarios which are reasonably close to the criteria threshold should be analyzed or at a minimum bounded to show that even though they could be eliminated by use of criteria alone they do not have a detrimental effect on performance. This will provide some measure of assurance that the criteria and the screening methods are reasonably correct.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.3.1-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.3.3-1 and Figures 6.3.2.2-1 through 6.3.2.2-1n and associated text
Explicit description of the needed information:	Methods used to analyze scenarios. Discussion of methods used in analyses of scenarios, repository, under expected conditions, and CCDFs of the results.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.3.2-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Distribution of percolation flux. Distribution of percolation flux at the site under current conditions.
Information will be used to support:	Completion of text in Section 6.3.3.2.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.3.2-2
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Future climatic conditions. Distribution of percolation flux for a range of expected climatic conditions.
Information will be used to support:	Completion of text in Section 6.3.3.2.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.3.2-3
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Correlation lengths for material property scaling.
Information will be used to support:	Completion of text in Section 6.3.3.2.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.3.2-4
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Analysis of the effects of container wetting. Analysis of the effects of container wetting caused by contact with rock or changes in flow paths or percolation flux. Contact with rock could be caused by rock fall, spalling, or contact with backfill.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.4-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.4.1-1 and associated text
Explicit description of the needed information:	Probabilities of occurrence of processes and events along with the uncertainty in their determination.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.4-2
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.4.2-1, 6.3.4.3-1, and 6.3.4.4-1 and associated text
Explicit description of the needed information:	Probabilities of occurrence of scenarios, processes, and events along with the uncertainty in their determination.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.5-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.2.2-3 and Figures 6.3.2.2-1 through 6.3.2.2-1n and associated text
Explicit description of the needed information:	The results of the scenario screening along with the results of their analyses. This documentation should include the scenarios retained after screening and the analyses of the effects of the scenarios on long-term repository performance.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.5.1-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Demonstration of site suitability and related analyses.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.5-2
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Figures 6.3.2.2-1 through 6.3.2.2-1n and associated text
Explicit description of the needed information:	Methods of formation of CCDFs and related uncertainty and sensitivity analyses.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.5.2-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.5.2-1 and 6.3.5.4-1 and Figure 6.3.3.2-1 and associated text
Explicit description of the needed information:	Methods of formulation of the CCDF. Discussion of the methods of production of the CCDF, uncertainties in its production, and alternative representations of CCDFs.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.3.6-1
Section Number and Title:	6.3 ASSESSMENT OF COMPLIANCE: CUMULATIVE RELEASE OF RADIOACTIVE MATERIALS
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.3.6-1 and associated text
Explicit description of the needed information:	Qualification (verification and validation) of all models and codes used for performance assessment. Discussion of verification and validation of all models and codes used for performance assessment, including their quality assurance documentation.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS License Application Annotated Outline

Section 6.4 Assessment of Compliance: Undisturbed Performance

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6.4.1-2	Analysis of partitioning of ^{14}C between the aqueous and gaseous phases
6.4.2-1	Documented results of the analyses of groundwater protection requirements
6.4.3-1	Documentation of the verification and validation of codes and models used in the analysis of individual and groundwater protection requirements

6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE

[This section summarizes the evaluation of the postclosure performance of the geologic repository assuming only anticipated processes and events. Calculations of CCDFs for individual scenarios, including those involving only anticipated processes and events, are provided in Section 6.3.5. Those analyses indicate the anticipated undisturbed postclosure performance of the geologic repository.

This section addresses two additional evaluations not addressed by the analyses in Section 6.3.5. The environmental standard cited in 10 CFR 60.112 specifies requirements for protection of individuals and protection of groundwater under undisturbed conditions [INN 6.4-1]. The evaluations to demonstrate compliance with these requirements are provided here.]

6.4.1 Individual Protection Requirements

[The assessment of the compliance of the repository with individual protection requirements considers all potential pathways for release of radionuclides to individuals. An analysis of each of the previously discussed scenarios was conducted for dose to an individual as well as evaluating the individual protection requirements for undisturbed conditions. The analyses include comparison of the calculated dose to individuals with the deterministic EPA Standards [INN 6.4-1]. The results of the analyses are documented in _______[INN 6.4.1-1] and the results will be used to complete Table 6.4.1-1 and this discussion.]

TSPA-1993 Predictions of Peak Dose in the Accessible Environment. Results of the composite porosity model simulations are presented in terms of the maximum radiation dose rate to an individual received by drinking contaminated water from the saturated zone at the accessible environment. The accessible environment is defined as the maximum distance allowed in 40 CFR 191 (EPA 1985); for aqueous releases the accessible environment is 5 km away from the repository, and for gaseous releases the accessible environment is the ground surface above the repository.

The peak dose is calculated as the highest dose a postulated maximally exposed individual may receive. The peak dose is calculated over the entire period from repository closure to one million years after closure. The peak dose calculation results reflect the arrival of the most significant radionuclide peak at the accessible environment boundary, which can occur several tens to hundreds of thousands of years after closure depending on waste package lifetimes, groundwater travel time, and the retardation and half-life of the particular radionuclide. The 1,000,000-year period was chosen to address the possibility that the new EPA health and safety standard may require an extended period of compliance (the current standard which does not apply to Yucca Mountain calls for a 10,000-year prediction).

Doses From Gaseous Releases.

Doses from the gaseous release of ^{14}C into the atmosphere above Yucca Mountain were not calculated. In past system assessments, prior to TSPA-1991, gaseous release of or dose from ^{14}C was either not calculated or assumed to be negligible as in Doctor et al. (1992), who assumed that since there was no population on Yucca Mountain, there were no gardens, and thus gaseous release of ^{14}C did not enter the human food chain. In TSPA-1991, doses from ^{14}C were calculated to be negligible by Eslinger et al. (1993). Eslinger et al. (1993) also calculated the peak dose based on the TSPA-1991 (Barnard et al., 1992) maximum gaseous release of ^{14}C. The Wilson et al. (1994) calculations considered higher unsaturated zone flux values, and a higher gas permeability for the overlying rock, which led to more rapid container failure rates and a more rapid release of ^{14}C. The results were a 0.12 mrem/yr dose at 3,550 years after closure, for a hypothetical and unlikely gardener on the top of Yucca Mountain. If the person living on top of Yucca Mountain, which is still somewhat unlikely, does not garden or ingest homegrown produce, the dose is an order of magnitude lower, or about 0.01 mrem/yr. When compared with an average U.S. natural background dose of 300 mrem/yr, as suggested by the National Council on Radiation Protection, these are negligible doses. At Yucca Mountain, natural background doses are likely to be higher than the United States average primarily because of its high elevation.

At lower temperatures, and at equilibrium, there is significant partitioning of ^{14}C into the aqueous phase, while at higher temperature $^{14}CO_2$ is much less soluble and hence there is less partitioning into the aqueous phase. This suggests that after the thermal pulse has abated, high unsaturated zone flux and/or fracture flow, especially if advective flow occurs in the waste package as the waste form is altering, could cause significant portions of the ^{14}C inventory to be released by way of the aqueous pathways.

Gas phase transport is delayed by $^{14}CO_2$ dissolving into and exsolving from the aqueous phase, in effect retarding its progress in comparison with gas movement. In TSPA-1993 (Wilson et al., 1994), an argument is made that over the long travel time between the repository and the saturated zone, dissolved ^{14}C will have sufficient opportunity to exsolve into the gas phase so that it is essentially all transported upward by the rapid gas flow. As water moves downward, away from the heat source, however, it is likely to experience a net increase in dissolved CO_2 content that it takes from solid carbonate surfaces in contact with the flow, and from the unsaturated zone atmosphere. The application of the weeps model, with its rapid advection from the waste form to the water table, may need to consider the dynamics of $^{14}CO_2$ partitioning into the aqueous and gaseous phases. This $^{14}CO_2$ partitioning may provide more realistic results for both the releases at the surface, which will be reduced, and the releases at the accessible environment, which will be increased, especially after the natural system begins to return to ambient temperature conditions [INN 6.4.1-2]. The isotopic dilution of $^{14}CO_{2(aq)}$ by $^{12}CO_{2(aq)}$ in both the unsaturated and saturated zones, and the fate of $^{14}CO_{2(aq)}$ as the saturated zone flow volume is perhaps reduced by evapotranspiration as it approaches a shallow discharge zone, may also need to be evaluated if a very stringent dose-based performance requirement is imposed by the new Yucca Mountain regulation.

Doses From Aqueous Releases.

Peak doses were calculated continuously over the entire period from closure of the potential repository to 1,000,000 years after closure. The value and times of those peak doses were saved as data from the 10,000-, 100,000-, and 1,000,000-year calculations. For the dose calculations, each of the participants selected slightly different variations from the reference case. For example, Andrews et al. (1994) showed all its dose results for a slightly different corrosion rate case, and Wilson et al. (1994) focus was on vertically emplaced waste packages, minus the 10 cm outer barrier of mild steel. However, in most instances Wilson et al. (1994) also presented the horizontally emplaced package that was here selected as the reference case. In any case, peak doses did not begin to occur in the simulations until about 40,000 years for the Wilson et al. (1994) calculations and Andrews et al. (1994) expected-value calculations suggested about 80,000 years for the first peak doses, which are in turn exceeded again after 300,000 years. Small differences in design and corrosion rate were found to be less meaningful at longer time frames, as will be illustrated later in this section. Hence, they are neglected in this discussion.

The timing and magnitudes of peak doses were calculated. For the reference case, Figure 6.4.1-1 shows the likelihood (vertical scale) of the peak calculated doses occurring later than the year indicated (horizontal scale). This figure suggests a 90% likelihood that the peak dose occurs later than 100,000 years. The stair-step pattern in the figure is a consequence of climate change occurrences. Figure 6.4.1-2 shows the likelihood of exceeding a given dose for an individual, at the accessible environment boundary, drinking two liters a day from a well that brings up water from a saturated zone flow path calculated of radionuclide transport. The 50% likelihood suggests that dose would exceed 5,000 mrem/year. A comparable plot from the Andrews et al. (1994) contribution suggests (Figure 6.4.1-3) a 50% likelihood that dose would exceed 40,000 mrem/year. The Andrews et al. (1994) contribution included pathways other than ingestion. Most of the calculated peak doses that occurred prior to 100,000 years were attributable to ^{99}Tc, and peak doses between 100,000 and 1,000,000 years were attributable to ^{237}Np in the drinking water of a postulated individual with a water well at the accessible environment boundary.

These results suggest that for a peak individual dose standard, for very long times, showing compliance does not look as likely as was the case for the other two performance measures addressed in this section. Clearly, if doses are expected to be in the rem/year range, as suggested by some results reported here, a danger may be posed to generations in the local area in the very distant future, hundreds of thousands of years from now. However, these predictions assume not only that current human behavioral and settlement patterns hold that far into the future, but also that no larger-scale geologic processes have made this portion of the planet into something very different from that which it is at present.

Sensitivities of the release and dose results to assumed parameters and processes are indicated by the order of magnitude difference between the Andrews et al. (1994) and Wilson et al. (1994) contributions. For example, Andrews et al. (1994) used dose conversion factors appropriate to an individual receiving dose by the ingestion of contaminated groundwater and the ingestion of food grown with contaminated irrigation water, while the Wilson et al. (1994) results assumed only ingestion of groundwater.

It should be noted that these are preliminary calculations and do not represent the final configuration of the repository nor do they incorporate important information expected from site characterization. Dramatic reductions in calculated long term dose could be achieved through an engineered barrier to water flow, creating an environment wherein transport is limited to diffusion from the waste packages. The assumed mixing depth in the saturated zone needs to be confirmed through further testing, and could either enhance or decrease long term dose predictions dramatically. The likelihood of some of the neptunium encountering somewhat less oxidizing conditions when mixed in the saturated zone also needs to be addressed. Finally, the existence of partially to wholly oxidized uranium deposits, largely located where they were formed when reducing environments prevailed, that have been in oxidizing environments for tens to hundreds of thousands of years also suggests that release rates from the waste form may be conservative, and that testing needs to focus on the processes controlling transport.

While the doses presented are preliminary in nature, they do give an indication of a fact about the Yucca Mountain site: it is arid. As a result Yucca Mountain is thought to be a good site in terms of the time delay for releases. Geosphere transport times are much longer than they would be at many sites (according to the composite-porosity model, at least); however, Yucca Mountain is not a particularly good site in terms of dilution. If radionuclides are released, there is not a great deal of water available for dilution, and peak dose rates for very long lived radioisotopes depend on only two things; release rate from the source and the amount of dilution after release.

If there is no time limit on a dose regulation, long transport times are not enough to guarantee low dose rates - low release rates are necessary, and how low depends on the amount of dilution after release. Low water velocity or high sorption can push the peak dose rate far into the future without lowering its magnitude if the particular radionuclide has a long half-life.. To obtain low peak dose rates from transport time alone, it is necessary for the transport time to be larger than the half-life of all the important radionuclides. Since the calculated doses are dominated by ^{237}Np, which has a half-life of about two million years, a ^{237}Np transport time greater than two million years would be necessary to reduce the peak dose rate significantly.

Peak Dose Rate Sensitivity Studies - Weeps Model. In terms of peak dose calculations for aqueous releases over 10,000, 100,000, and a million years, (Figure 6.4.1-4) the 10,000 year weeps results are higher than the composite-porosity model results for peak doses up to 10,000 years. This is consistent with aqueous releases being higher for this same time frame for the weeps results, plus that the redistribution of water during the thermal period causes earlier failures in some parts of the repository, resulting in releases from more highly radioactive waste with little travel time delay. This acceleration of early failures, followed by new weeps forming as the dry-out zone contracts, results in most failures and releases occurring prior to 10,000 years. In later times, fluxes are more widely distributed and failures are few and far between. As a result, the majority of peak doses occur prior to 10,000 years, as the 100,000- and 1,000,000-year results in Figure 6.4.1-4 indicate. By contrast, peak doses are generally distributed later in the composite-porosity model results, around a few 100,000 years. These later peak doses are largely the result of unsaturated zone travel times that are, in the probabilistic composite-porosity model realizations, multiple hundreds of thousands of years at the higher probabilities.

These differences in results for the weeps and composite-porosity conceptualizations illustrate the need for site data collection and testing. Choosing between, or even combining aspects of, these two conceptual models requires that the major hypotheses regarding flow in Yucca Mountain be identified, and that tests be designed that allow for a choice to be made. It may be that the composite-porosity model is sufficient for certain portions of the mountain at certain times, and the weeps model may be invoked in certain regions and at other, limited times. Regions of greater fracture density and vertical connectedness, especially during wetter climatic period, may experience the type of isolated fracture flow addressed by the weeps model.

Peak Dose Rate Sensitivity Studies - Saturated Zone Model. Given the uncertainty in the vertical mixing depth, a range was assumed to span from 50 to 500 m. This range, when multiplied by the horizontal mixing length, yielded a range for mixing area values that were rounded off to 2×10^4 to 2×10^6 m^2, and was assigned a log-uniform distribution. As may be seen in Figure 6.4.1-5, there is an inverse relationship between the peak dose and the saturated zone transport area, which is largely defined by the vertical mixing depth.

Figure 6.4.1-6 presents a scatter plot of the peak dose versus saturated-zone flux. This figure shows that the peak dose exposure over 10^6 years is slightly dependent on the saturated-zone flux, as increasing the saturated flux linearly decreases the concentration and the corresponding dose. It was expected that the saturated-zone flux would be the more dominant controlling factor on the peak dose, since as the magnitude of the flux increases, and thus the mixing volume, the peak-dose exposure would decrease. However, it appears this was not the case. Since the major portion of the radionuclide travel time is attributed to flow through the unsaturated zone, and not the saturated zone, the unsaturated-zone flux was the dominant dose controlling factor.

Peak Dose Rate Sensitivity Studies - Basaltic Volcanism. When the indirect effects of a nearby magmatic intrusion were added to the nominal case doses, the two resulting doses are similar. The negligible contribution from enhanced waste package failure due to an intrusive magmatic event is illustrated in a plot of probability versus peak dose for the nominal case and the nominal case with indirect volcanism which is shown in Figure 6.4.1-7. This figure does not include direct effects of a magmatic intrusion (i.e. entrainment of waste). This peak dose rate sensitivity analysis is included in this section on undisturbed performance to address the possibility of a long-term dose based EPA health and safety standard.

Peak Dose Rate Sensitivity Studies - Waste Package Lifetime. Figure 6.4.1-8 presents the peak dose for four combinations of waste package inner/outer barrier thicknesses. The peak dose, which occurs more than 500,000 years after closure, shows very little sensitivity to the waste package lifetime. After this long time, waste package failure rate differences are literally ancient history and have very little effect on the peak dose.

6.4.2 Groundwater Protection Requirements

[The assessment of the compliance [INN 6.4-1] of the repository with groundwater protection requirements was analyzed for each scenario as well as for undisturbed conditions. The results of these analyses are presented in Table 6.4.2-1 [INN 6.4.2-1]. (These analyses will include comparison of the calculated groundwater concentrations of radionuclides with the deterministic EPA standards when these standards are available. Currently the analyses are being compared to the groundwater protection requirements of 40 CFR 191.)]

6.4.3 Code Verification and Model Validation

[The codes and models that have been used in the undisturbed performance compliance analyses and those used to evaluate doses to an individual from the scenarios have undergone extensive verification and validation and the results have been discussed in_____ [INN 6.4.3-1]. Here, the term "validation" is not to be taken in the strict meaning of the word, but to mean "accepted to be correct through comparison with short-term experiments and natural analogs, and peer review of model formulation and results." (The results of the verification and validation will be used to complete Table 6.4.3-1 and [INN 6.4.3-1] will be used to complete this section. The information in this section will be cross referenced to Chapter 8 where applicable.)]

REFERENCES

40 CFR 191, Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes

National Council on Radiation Protection and Measurements (NCRP), 1987, Exposure of the Population in the United States and Canada from Natural Background Radiation, NCRP Report No. 94, NCRP, Bethesda, MD. (NNA.920403.0060)

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Barnard, R. W., M. L. Wilson, H. A. Dockery, J. H. Gauthier, P. G. Kaplan, R. R. Eaton, F. W. Bingham, and T. H. Robey, 1992. TSPA 1991: An Initial Total-System Performance Assessment for Yucca Mountain, SAND91-2795, Sandia National Laboratories, Albuquerque, NM.

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Wilson, M. L., J. H. Gauthier, R. W. Barnard, G. E. Barr, H. A. Dockery, E. Dunn, R. R. Eaton, D. C. Guerin, N. Lu, M. J. Martinez, R. Nilson, C. A. Rautman, T. H. Robey, B. Ross, E. E. Ryder, A. R. Schenker, S. A. Shannon, L. H. Skinner, W. G. Halsey, J. Gansemer, L. C. Lewis, A. D. Lamont, I. R. Triay, A. Meijer, and D. E. Morris, 1994 (in press). Total-System Performance Assessment for Yucca Mountain -- SNL Second Iteration (TSPA-1993), SAND93-2675, Sandia National Laboratories, Albuquerque, NM.

Table 6.4.1-1 Potential Pathways for Transport of Radionuclides to Members of the Public and Resulting Doses

Scenario/Pathway	Projected Dose
1. Scenario/Pathway	

Note: This table will be completed using INN 6.4.1-1.

Table 6.4.2-1 Concentrations of Radionuclides in Drinking Water and Resulting Doses

Scenario	Concentration	Individual Exposure
1. Scenario		

Note: This table will be completed using INN 6.4.2-1.

Table 6.4.3-1 Verification and Validation of Codes and Models Used for Analysis of Individual and Groundwater Protection Requirements

Model	Analyses	QA Status	Verified	Validated	Source
GENII	Dose to man				PNL
DITTY	""				""

Note: This table will be completed using INN 6.4.3-1.

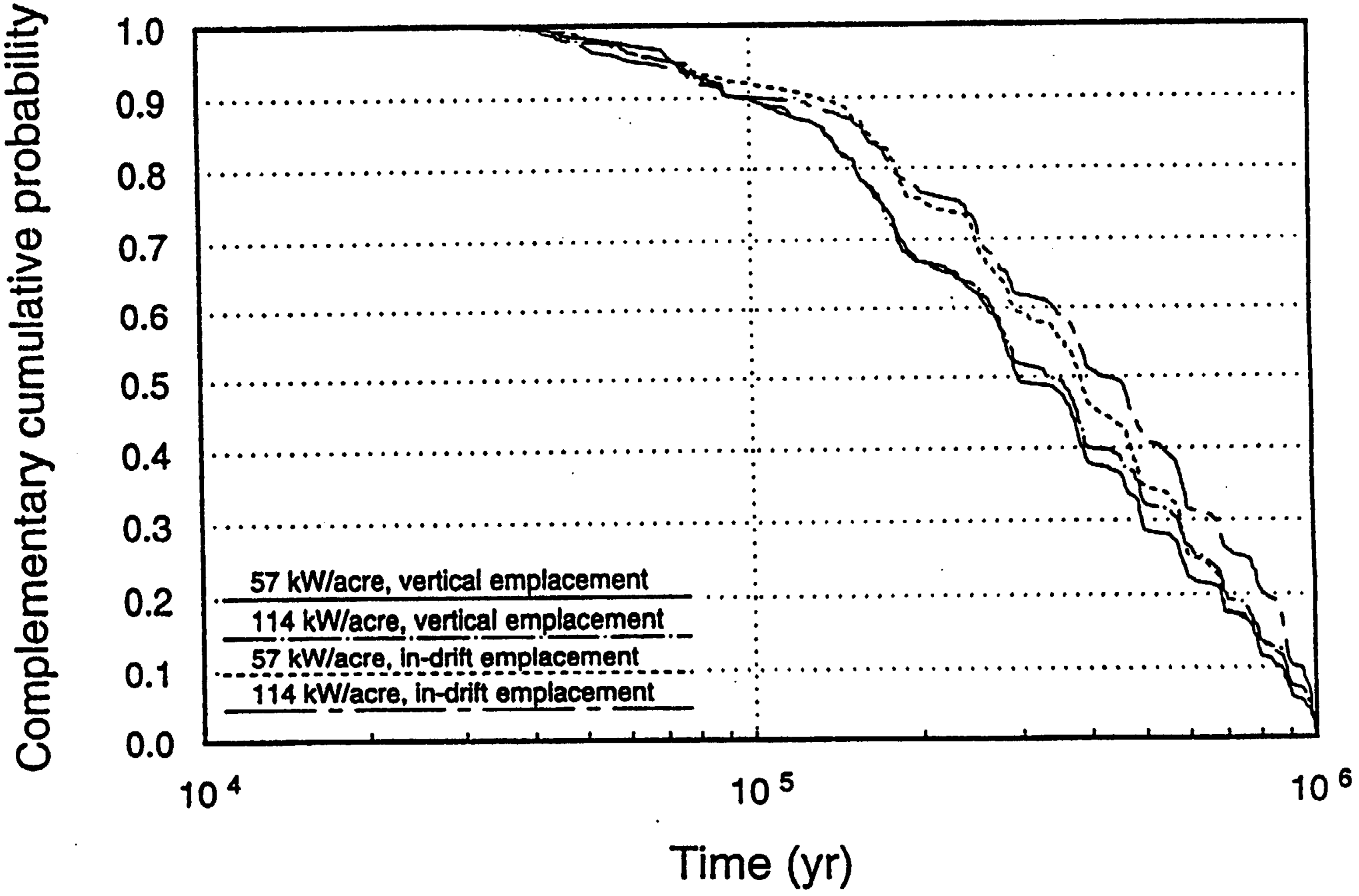

Figure 6.4.1-1 CCDF for the Time of Peak Dose; Composite Porosity Model. Wilson et al. (1994)

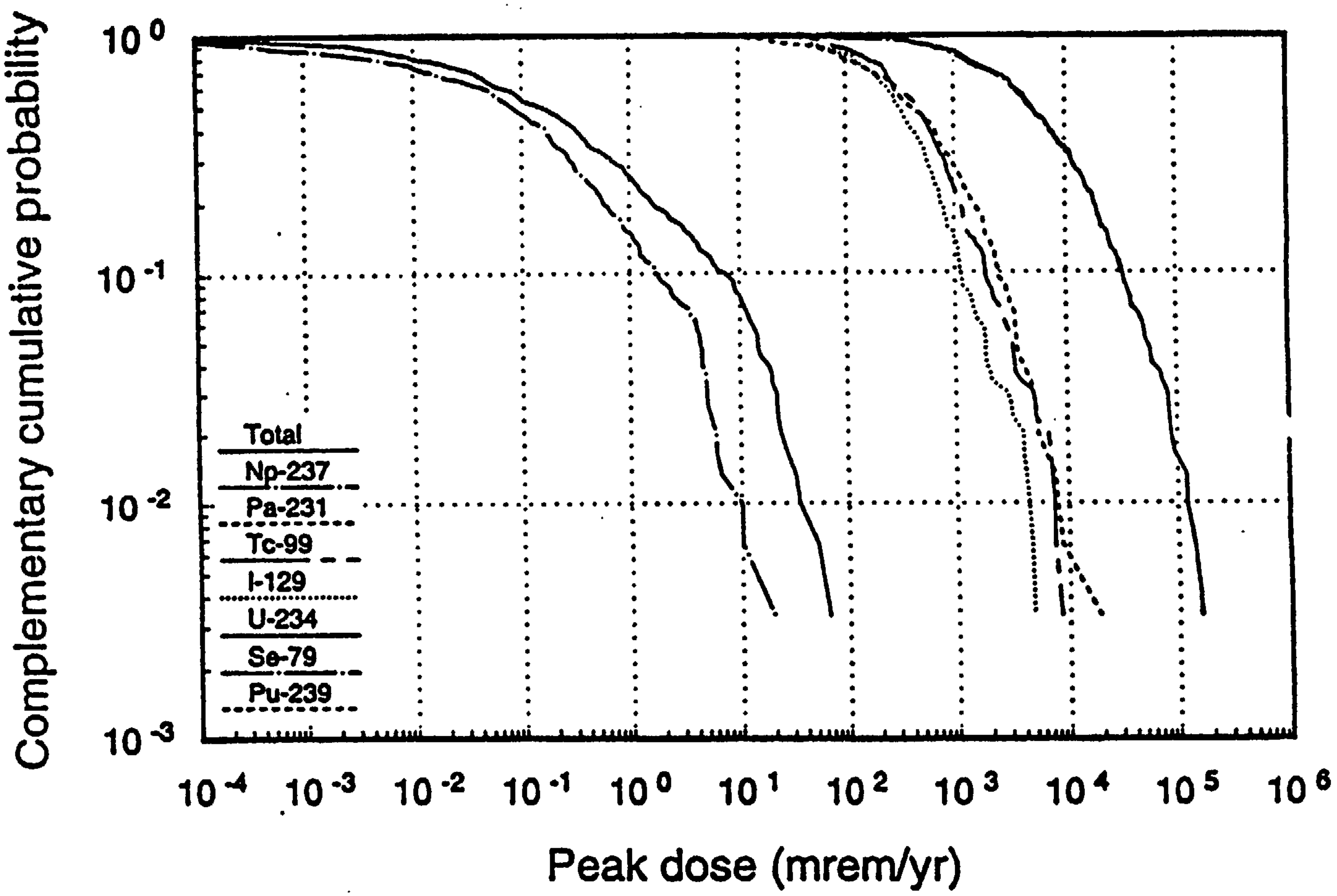

Figure 6.4.1-2 CCDF for Magnitude of Peak Dose for Individual Radionuclides; Composite Porosity Model (57 kW/acre, vertical emplacment). Wilson et al. (1994)

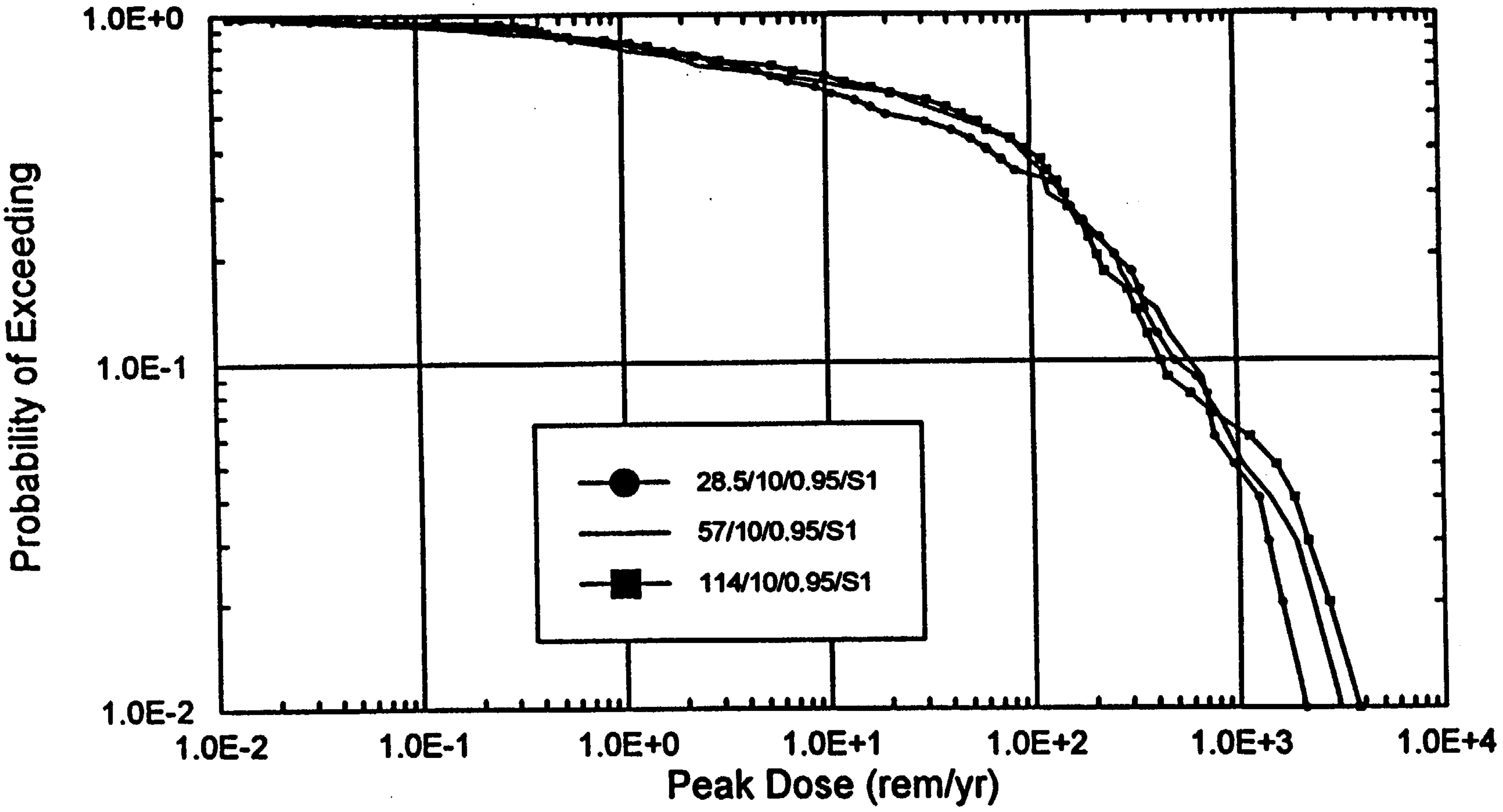

Figure 6.4.1-3 CCDF for Magnitude of Peak Dose; Composite Porosity Model (28.5 kW/acre, 57 kW/acre, and 114 kW/acre). Andrews et al. (1994)

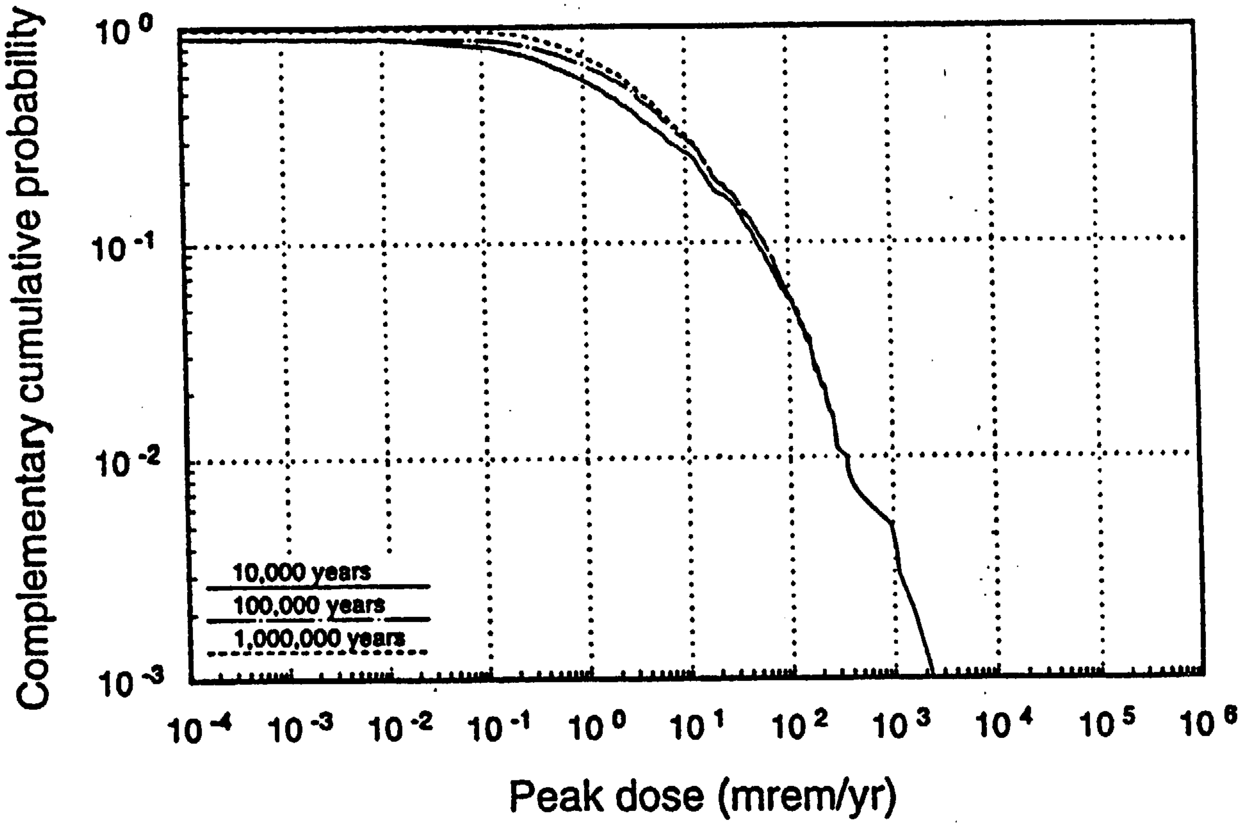

Figure 6.4.1-4 Conditional CCDFs of Peak Doses for Three Specified Time Periods (57 kW/acre, Vertical Emplacement), Weeps Model

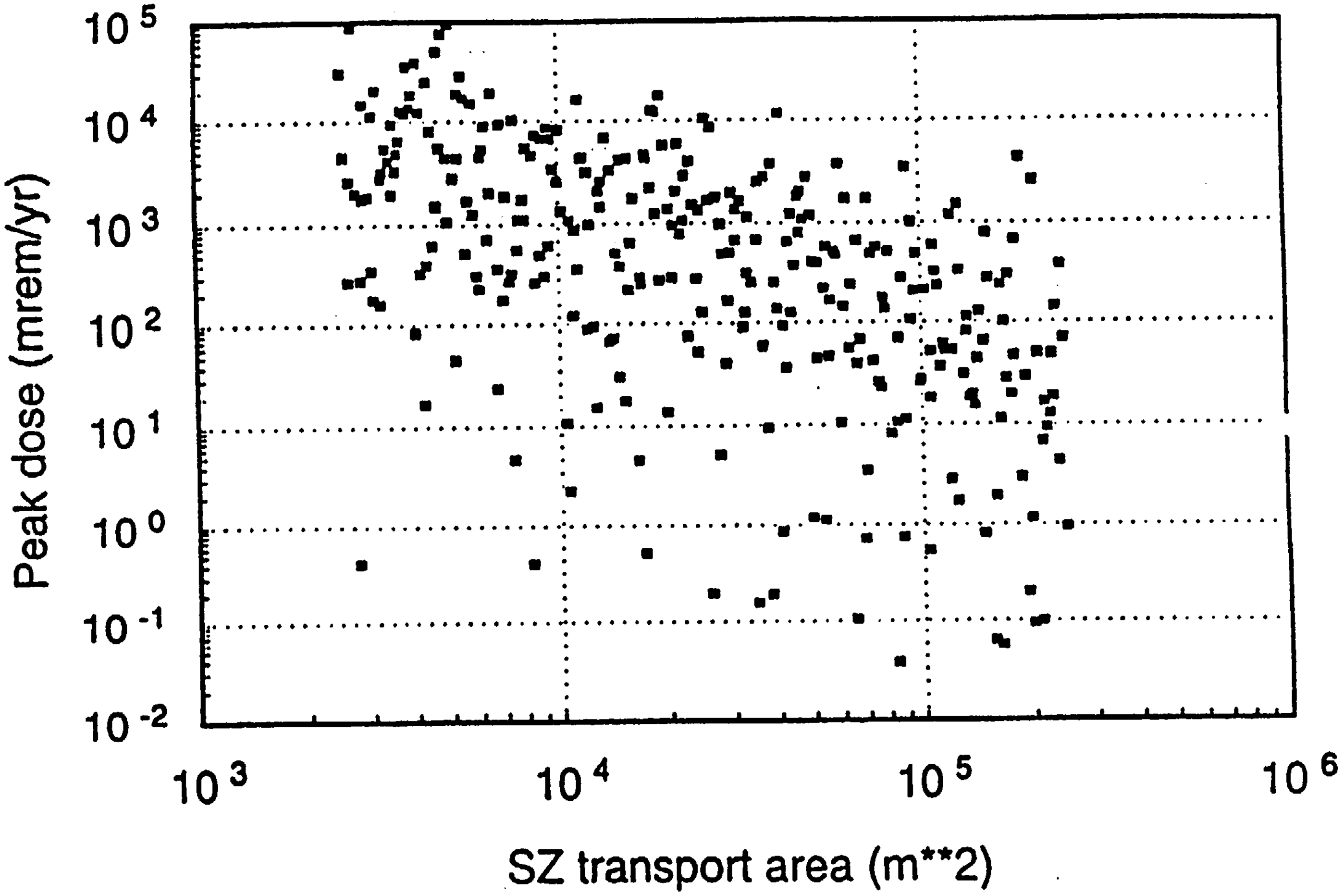

Figure 6.4.1-5 Scatter Plot of Peak Dose Versus Saturated Zone Transport Area (57 kW/acre, Vertical Emplacement, Column 8). Wilson et al. (1994)

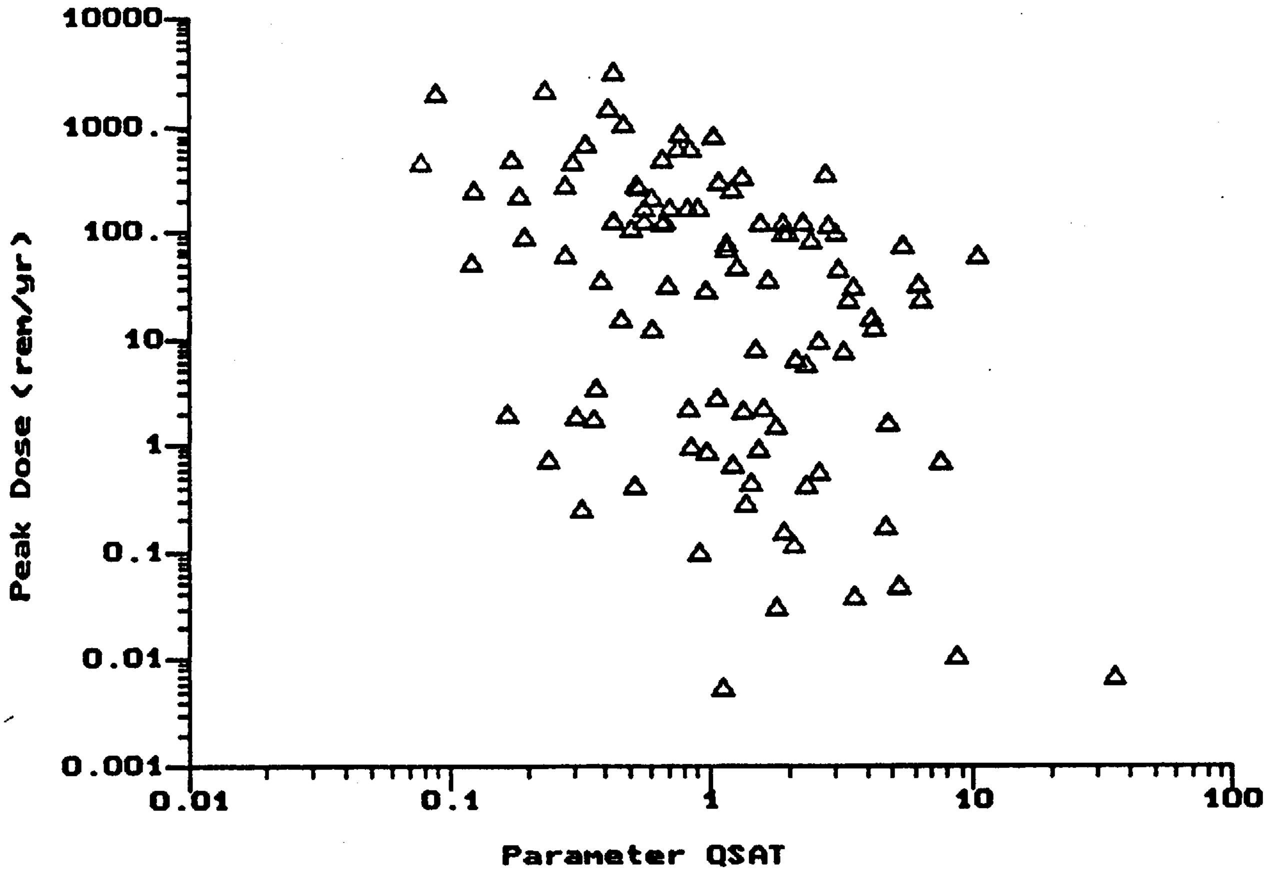

Figure 6.4.1-6 Scatter Plot of Peak Dose Versus Saturated Zone Flux (57 kW/acre). Andrews et al. (1994)

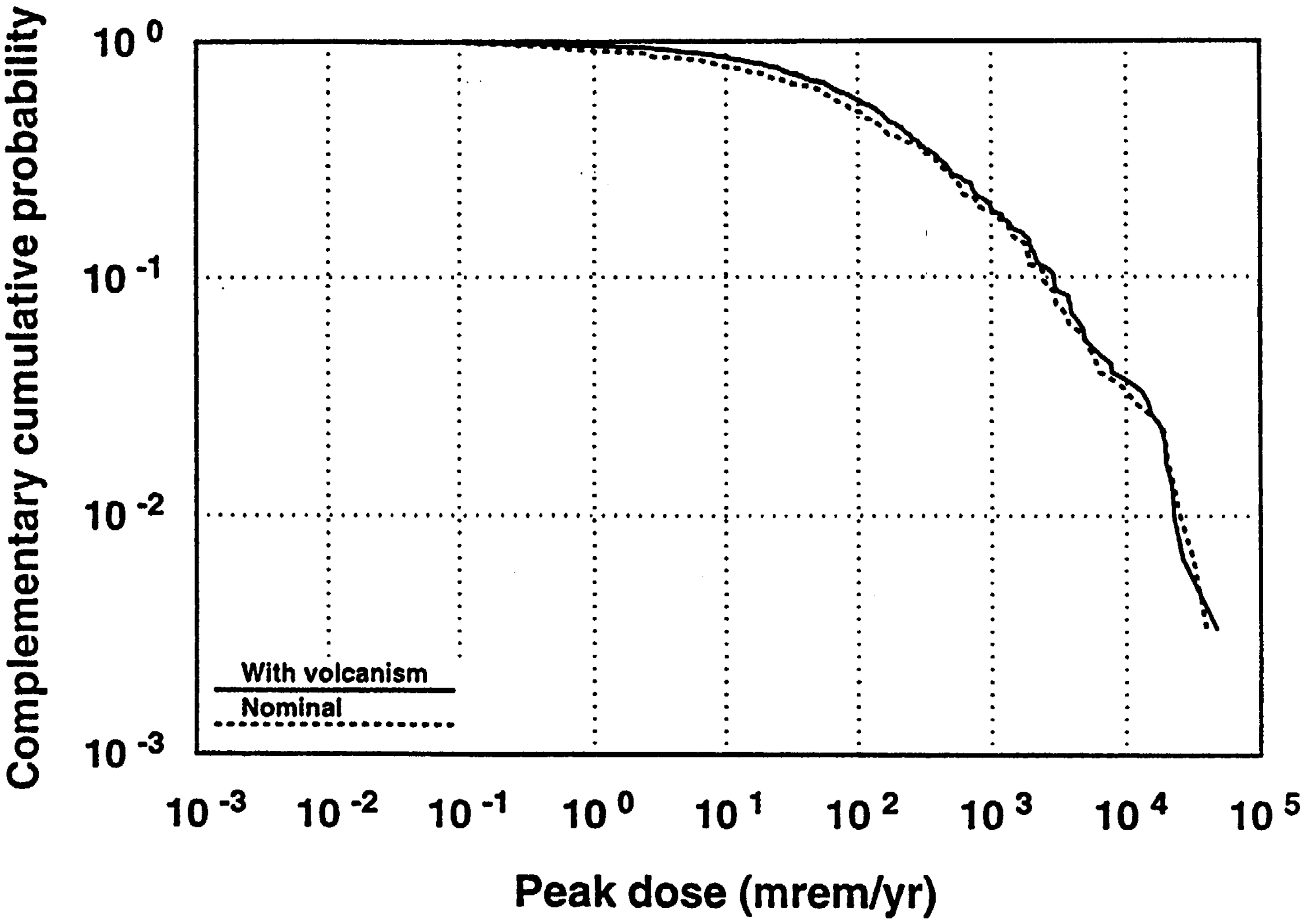

Figure 6.4.1-7 Comparison of Nominal Case CCDF for Peak Doses With and Without Indirect Effects from a Magmatic Intrusion

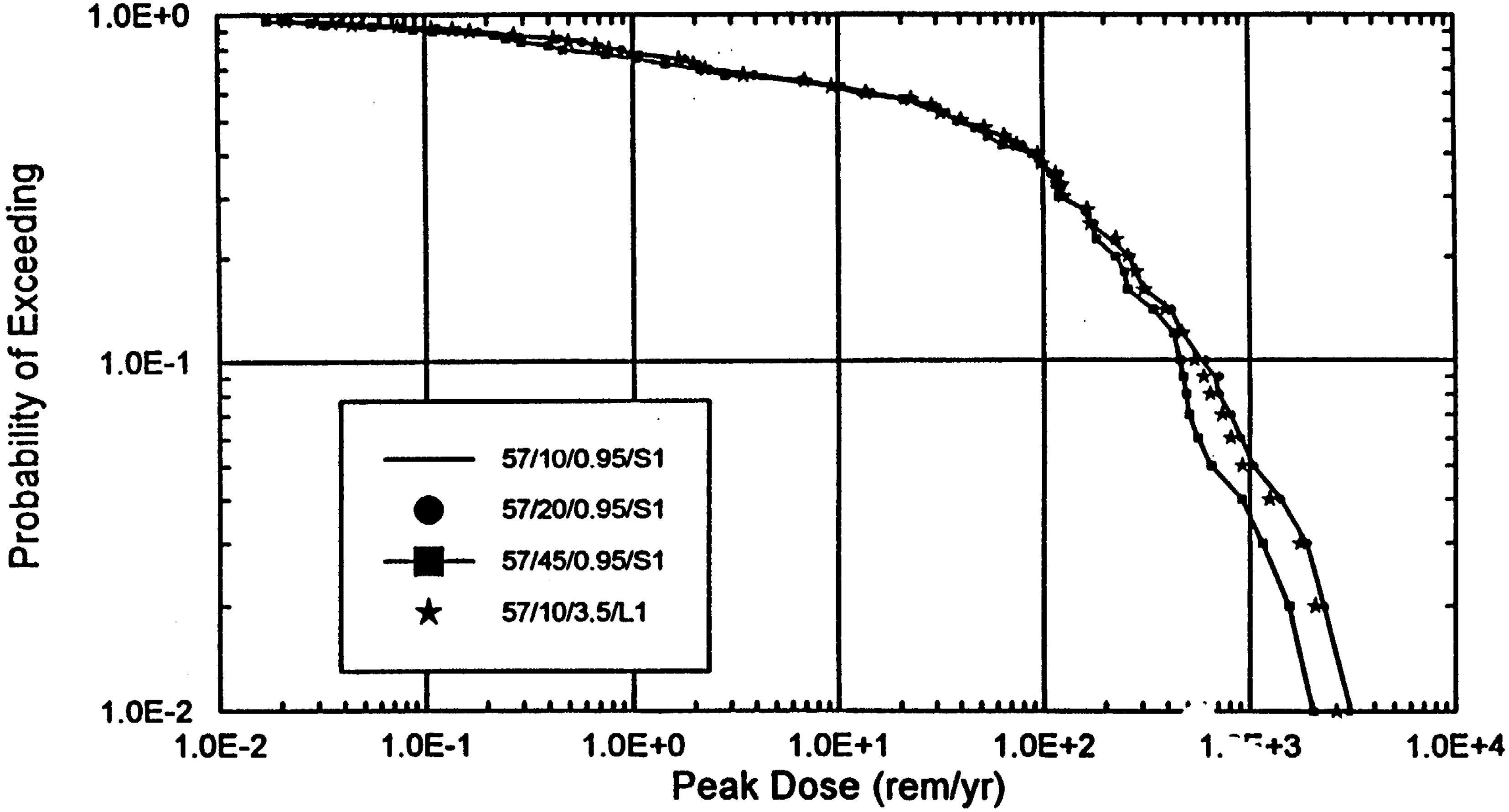

Figure 6.4.1-8 CCDF of Peak Dose Exposures Over 1,000,000 Years for Four Inner/Outer Barrier Thickness Combinations

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.4-1
Section Number and Title:	6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	EPA standard for the Yucca Mountain site.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

The above Annotated Outline text is guidance that may be used for the future development of an MGDS facility License Application.

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.4.1-1
Section Number and Title:	6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.4.1-1
Explicit description of the needed information:	Documented results of the analyses of individual protection requirements.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.4.1-2
Section Number and Title:	6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Analysis of partitioning of ^{14}C between the aqueous and gaseous phases.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.4.2-1
Section Number and Title:	6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.4.2-1
Explicit description of the needed information:	Documented results of the analyses of groundwater protection requirements.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.4.3-1
Section Number and Title:	6.4 ASSESSMENT OF COMPLIANCE: UNDISTURBED PERFORMANCE
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.4.3-1 and associated text
Explicit description of the needed information:	Documentation of the verification and validation of codes and models used in the analysis of individual and groundwater protection requirements.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS License Application Annotated Outline

Section 6.5 10 CFR 60 Criteria

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6.5.2.3-1	Potentially adverse condition scenarios.
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6.5 10 CFR 60 CRITERIA

[Compliance with the waste isolation performance objectives of 10 CFR 60.112 is discussed in this Section. The discussion includes both the favorable and potentially adverse conditions known to be present at the site. Favorable and potentially adverse conditions contained in 10 CFR 6.122 have been discussed previously in Section 3.3. The degree to which these conditions are present or absent is also discussed in Section 3.3 and in the section below. The favorable and potentially adverse conditions are combined into scenarios that could affect overall repository performance. The incorporation of these conditions into the conceptual models described in Section 6.2 is summarized here and the effects of these conditions on repository performance (which is discussed in Section 6.3) is also summarized below. The assessments necessary to eliminate or include favorable or potentially adverse conditions in scenarios and in site suitability determinations are also presented below.] [INN 6.5-1 and INN 6.5-2.]

6.5.1 Favorable Conditions

[Physical characteristics of the Yucca Mountain repository site provide conditions favorable to isolation of the waste. These characteristics contribute to containment of the waste in a variety of ways including retardation of radionuclides by the mineralized layers along the flow path to the accessible environment and control of radioactive gases by thin nearly saturated zones between the ground surface and the repository. These conditions are described in_____[INN 6.5-1].]

6.5.1.1 Listing of Favorable Conditions

[The favorable conditions at Yucca Mountain are summarized in Table 6.5.1.1-1 [INN 6.5-1]. These conditions have been identified during site characterization and their presence has been factored into the performance assessment analyses as required by 10 CFR 60.122(b).]

6.5.1.2 Justification of Presence of Favorable Conditions

[The favorable conditions at Yucca Mountain which were previously defined are fully described in__________, and their presence is fully documented [INN 6.5-1].]

6.5.1.3 Incorporation of Favorable Conditions into Scenarios

[The favorable conditions are included in the analyses conducted on the site as defined in _________[INN 6.5.1.3-1 and INN 6.5.1.3-2].]

6.5.2 Potentially Adverse Conditions

Potentially adverse conditions at the repository include physical characteristics which contribute to larger quantities or faster release of radionuclides affecting waste isolation within the controlled area. [Definition of these characteristics, along with their analyses, is presented in_______, and is summarized in Table 6.5.2-1 [INN 6.5-2].]

6.5.2.1 Listing of Potentially Adverse Conditions

[The potentially adverse conditions at Yucca Mountain are listed in Table 6.5.2-1 [INN 6.5-2] and a summary discussion of the effects of its presence is also provided.]

6.5.2.2 Incorporation of Potentially Adverse Conditions into Processes and Events

[The potentially adverse conditions were incorporated into appropriate processes and events_____[INN 6.5-2] and were modeled individually where possible or were incorporated into scenarios.]

6.5.2.3 Incorporation of Potentially Adverse Conditions into Scenarios

[The analyses which incorporate the potentially adverse conditions into scenarios are presented in______[INN 6.5.2.3-1] and the results are presented in summary form in______ [INN 6.5.2.3-2].]

REFERENCES

DOE/RW-0073, Final Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada, 3 Volumes.

YMP/CM-0023, Repository Design Requirements Document.

Crowe, B., R. Morley, S. Wells, J. Geissman, E. McDonald, L. McFadden, F. Perry, M. Murrell, J. Poths, and S. Forman, 1992. The Lathrop Wells Volcanic Center: Status of Field and Geochronology Studies. High Level Radioactive Waste Management; Proceedings of the Third International Conference Las Vegas, Nev., April 12-16, 1992, Vol. 2, American Nuclear Society, Inc., La Grange Park, Il., pp. 1997-2013. (NNA.920831.0001)

Table 6.5.1.1-1 Summary of Favorable Conditions

No.	Potentially Favorable Condition	L.A. Section	Exists ?	Reference	Performance Impact Evaluation Reference
1	The nature and rates of tectonic and geomorphic processes operating within the geologic setting during the Quaternary Period that, when projected, would not affect or would favorably affect the ability of the repository to isolate waste	3.3.1.1 (a)	No	Environmental Assessment (DOE, 1986)	
2	Conditions that permit emplacement of waste at a minimum depth of 300 meters below ground level	3.3.1.1 (b)	No	Repository Design Requirements Document (DOE, 1994)	
3	A low population density within the geologic setting and a controlled area that is remote from population centers	3.3.1.1 (c)	Yes	Environmental Assessment (DOE, 1986)	
4	The nature and rates of hydrogeologic operating within the geologic setting during the Quaternary Period that, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste	3.3.2.1 (a)	No	Environmental Assessment (DOE, 1986)	
5	Pre-waste emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment that substantially exceeds 1,000 years	3.3.2.1 (a)	Yes	Environmental Assessment (DOE, 1986)	
6	For disposal in the unsaturated zone, hydrogeologic conditions that provide:	3.3.2.1 (d)			
6a	Low moisture flux in the host rock and in the overlying and underlying hydrogeologic units	3.3.2.1 (d.1)			
6b	A water table sufficiently below the underground facility such that fully saturated voids contiguous to the water table do not encounter the underground facility	3.3.2.1 (d.2)	Yes	Environmental Assessment (DOE, 1986)	
6c	A laterally extensive low-permeability hydrogeologic unit above the host rock that would inhibit the downward movement of water or divert downward moving water to a location beyond the limits of the underground facility	3.3.2.1 (d.3)	No	Environmental Assessment (DOE, 1986)	
6d	A host rock that provides for free drainage	3.3.2.1 (d.4)	Yes	Environmental Assessment (DOE, 1986)	

Note: This table is preliminary and will be completed using INN 6.5-1

Table 6.5.1.1-1 Summary of Favorable Conditions (Continued)

No.	Potentially Favorable Condition	L.A. Section	Exists ?	Reference	Performance Impact Evaluation Reference
7	The nature and rates of geochemical processes operating within the geologic setting during the Quaternary Period that, when projected, would not affect or would favorably affect the ability of the repository to isolate waste	3.3.3.1.1	Yes	Environmental Assessment (DOE, 1986)	
8	Geochemical conditions that:	3.3.1.1.2			
8a	Promote precipitation or sorption of radionuclides	3.3.3.1.2	Yes	Environmental Assessment (DOE, 1986)	
8b	Inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides	3.3.3.1.2	Yes	Environmental Assessment (DOE, 1986)	
8c	Inhibit the transport of radionuclides by particulates, colloids, and complexes	3.3.3.1.2	Yes	Environmental Assessment (DOE, 1986)	
9	Mineral Assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration	3.3.3.1.3	Yes	Environmental Assessment (DOE, 1986)	
10	A climate regime in which the annual average historic precipitation is a small percentage of the average annual potential evapotranspiration	3.3.4.1	Yes	Environmental Assessment (DOE, 1986)	

Note: This table is preliminary and will be completed using INN 6.5-1

Table 6.5.2-1 Summary of Potentially Adverse Conditions

No.	Potentially Adverse Condition	L.A. Section	Exists ?	Reference	Performance Impact Evaluation Reference
1	Evidence of dissolutioning such as breccia pipes, dissolution cavities, or brine pockets	3.3.1.2 (a)	No	Environmental Assessment (DOE, 1986)	
2	Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period	3.3.1.2 (b)	Yes	Environmental Assessment (DOE, 1986)	
3	Historic earthquakes that could significantly affect the site if they were repeated	3.3.1.2 (c)	No	Environmental Assessment (DOE, 1986)	
4	Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency or magnitude of earthquakes may increase	3.3.1.2 (d)	Yes	Environmental Assessment (DOE, 1986)	
5	More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area of the geologic setting	3.3.1.2 (e)	No	Environmental Assessment (DOE, 1986)	
6	Evidence of igneous activity since the start of the Quaternary Period	3.3.1.2 (f)	Yes	(Crowe et al., 1992)	
7	Evidence of extreme erosion during the Quaternary Period	3.3.1.2 (g)	No	Environmental Assessment (DOE, 1986)	
8	The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that:	3.3.1.2 (h)	No	Environmental Assessment (DOE, 1986)	
8a	economic extraction is currently feasible or potentially feasible during the foreseeable future	3.3.1.2 (h.1)	No	Environmental Assessment (DOE, 1986)	
8b	such materials have greater gross or net value than the average for other areas of similar size that are representative of and located within the geologic setting	3.3.1.2 (h.2)	No	Environmental Assessment (DOE, 1986)	
9	Evidence of subsurface mining for resources within the site	3.3.1.2 (i)	No	Environmental Assessment (DOE, 1986)	
10	Evidence of drilling for any purpose within the site	3.3.1.2 (j)	No	Environmental Assessment (DOE, 1986)	

Note: This table is preliminary and will be completed using INN 6.5-2

Table 6.5.2-1 Summary of Potentially Adverse Conditions (Continued)

No.	Potentially Adverse Condition	L.A. Section	Exists ?	Reference	Performance Impact Evaluation Reference
11	Geomechanical properties that do not permit design of an underground opening that will remain stable through permanent closure	3.3.1.2 (k)			
12	Potential for flooding of the underground facility, whether resulting from the occupancy and modification of flood plains or from the failure of existing or planned man-made surface-water impoundments	3.3.2.2.1			
13	Potential for foreseeable human activity to adversely affect the groundwater flow system, such as groundwater withdrawal, extensive irrigation, subsurface injection of fluids, underground pumped storage, military activity, or construction of large-scale surface-water impoundments	3.3.2.2.2	No	Environmental Assessment (DOE, 1986)	
14	Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface-water impoundments could be created that could change the regional groundwater flow system and thereby affect the performance of the geologic repository	3.3.2.2.3	No	Environmental Assessment (DOE, 1986)	
15	Structural deformation such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system	3.3.2.2.4	No	Environmental Assessment (DOE, 1986)	
16	Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points	3.3.2.2.5	No	Environmental Assessment (DOE, 1986)	
17	Rock or groundwater conditions that would require complex engineering measures in the design and construction of the underground facility or in the sealing of boreholes and shafts	3.3.2.2.6	No	Environmental Assessment (DOE, 1986)	
18	Potential for the water table to rise sufficiently to cause saturation of an underground facility located in the unsaturated zone	3.3.2.2.7	No	Environmental Assessment (DOE, 1986)	
19	Potential for existing or future perched water bodies that may saturate portions of the underground facility or provide a faster flow path from an underground facility located in the unsaturated zone to the accessible environment	2.2.3.3.8			

Note: This table is preliminary and will be completed using INN 6.5-2

Table 6.5.2-1 Summary of Potentially Adverse Conditions (Continued)

No.	Potentially Adverse Condition	L.A. Section	Exists ?	Reference	Performance Impact Evaluation Reference
20	Groundwater conditions in the host rock, including chemical composition, high ionic strength, or ranges of Eh-pH that could increase the solubility or chemical reactivity of the engineered barrier system	3.3.3.2.1	No	Environmental Assessment (DOE, 1986)	
21	Geochemical processes that would reduce sorption of radionuclides	3.3.3.2.2	No	Environmental Assessment (DOE, 1986)	
22	Groundwater conditions in the host rock that are not reducing	3.3.3.2.3	Yes	Environmental Assessment (DOE, 1986)	
23	Potential for the movement of radionuclides in a gaseous	3.3.3.2.4			
24	Potential for changes in hydrologic conditions resulting from reasonably foreseeable climate	3.3.4.2	No	Environmental Assessment (DOE, 1986)	

Note: This table is preliminary and will be completed using INN 6.5-2

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.5-1
Section Number and Title:	6.5 10 CFR 60 CRITERIA
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.5.1.1-1 and associated text
Explicit description of the needed information:	Documentation of favorable conditions. This documentation should include justification of the presence of favorable conditions and an analysis of their effects on performance of a repository at Yucca Mountain.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.5-2
Section Number and Title:	6.5 10 CFR 60 CRITERIA
Lead Author/Support Author and Phone:	J. O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	Table 6.5.2-1 and associated text
Explicit description of the needed information:	Documentation of potentially adverse conditions. This documentation should include justification of their presence of potentially adverse conditions and analyses of their effects on performance of a repository at Yucca Mountain.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.5.1.3-1
Section Number and Title:	6.5 10 CFR 60 CRITERIA
Lead Author/Support Author and Phone:	J.O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Favorable condition scenarios. Discussion of scenarios involving favorable conditions that are present at the site.
Information will be used to support:	Completion of text for Section 6.5.1.3.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.5.1.3-2
Section Number and Title:	6.5 10 CFR 60 CRITERIA
Lead Author/Support Author and Phone:	J.O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	N/A
Explicit description of the needed information:	Analyses of performance attributed to favorable condition scenarios. Should include a discussion of how conditions are incorporated into conceptual models and of the effects of these conditions on overall repository performance.
Information will be used to support:	Completion of text for Section 6.2, 6.3, and 6.5.1.3.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.5.2.3-1
Section Number and Title:	6.5 10 CFR 60 CRITERIA
Lead Author/Support Author and Phone:	J.O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Potentially adverse condition scenarios. Discussion of how potentially adverse conditions are incorporated into scenarios.
Information will be used to support:	Completion of text for Section 6.5.2.3.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 6.5.2.3-2
Section Number and Title:	6.5 10 CFR 60 CRITERIA
Lead Author/Support Author and Phone:	J.O. Duguid (703) 204-8851
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Analyses of performance attributed to potentially adverse conditions. Should include a discussion of how these conditions are incorporated into conceptual models and the effects of these conditions on overall repository performance.
Information will be used to support:	Completion of text for Section 6.2, 6.3, 6.5.2.3.
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
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Date: 03/31/95

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MGDS License Application Annotated Outline

Section 7.0 Conduct of Repository Operations

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LIST OF INFORMATION NEEDS

7.0-1	A non-compromising summary of safeguards and security plans pursuant to Sections 1.4 and 1.5 of the MGDS License Application FCRG, DG3-003. **NOTE**: This INN should be deleted in view of (1) the FCRG Comment regarding the inclusion of safeguard and security plans inclusion in this section; (2) what has recently been written about the operation description.
7.0.1.2-1	Validate the statement "No repackaging of the contents of an MCP will be done to achieve thermal load balancing".
7.0.1.2-2	Describe the conditions requiring addition of filler to disposal vessels.
7.0.1.3-1	A description of the emplacement transporter; specifically, identification of the method of power (is it a locomotive)?
7.0.1.3-2	An evaluation of the need for portable shielding near the entrance of the emplacement drift.
7.0.1.4-1	Determination of the use of remote control/robotics within the emplacement drifts.
7.0.1.5-1	How long will the retrieval period last (presently assumed to be 100 years after emplacement begins)?
7.0.2.1-1	Identify/verify the methods for stabilizing the openings following excavation.

7.0 CONDUCT OF REPOSITORY OPERATIONS

This chapter fulfills regulatory requirements pertaining to a description of the conduct of repository operations [10 CFR 60, *Disposal of High-Level Radioactive Wastes in Geologic Repositories*, Section 21(c)(15) and 10 CFR 60.111].

After licensing is obtained and prior to closure the Mined Geologic Disposal System (MGDS) repository is operated in three principal modes: development, emplacement and retrieval. Development and emplacement operations may be conducted concurrently. The capability for waste package retrieval may be exercised if necessary or directed, at any time after emplacement. Waste Handling, Maintenance, Radiation Protection and Performance Confirmation Operations are performed continuously throughout the operational life of the repository. Surface and subsurface equipment operations, services and utilities support all operations.

This section presents a general description of the repository operations. Critical operations such as maintenance and radiation protection are presented in detail in the following sections. Plans and activities related to plant and personnel organization, procedure generation, inspection, testing and reporting are also presented.

NOTE: It is inappropriate to request safeguards and security information in this section since details cannot be presented and an overview/certification is already requested in Sections 1.4 and 1.5. A *Format and Content Reg Guide* (FCRG), DG-3003, comment form will be generated for this item. The reference to security and safeguards information in this section should be added if the FCRG is not modified as recommended in the FCRG comment. [INN 7.0-1]

7.0.1 Waste Handling

7.0.1.1 Waste Receipt

Upon the arrival of a loaded transportation cask subsystem at the repository boundary, the accompanying waste records are transferred to the repository personnel. The cask is inspected for contraband and radioactivity. The records are retained in the Management and Operations Control Center, which also maintains accountability control of the material throughout the MGDS, including emplacement and possible retrieval. Appropriate local corrective action is taken on casks that do not pass the contraband or radioactivity checks and inspections. If a cask shows a significant departure from the expected norms, such as a cask arriving with a possibility of sabotage, then that cask is taken to a safeguards area and handled with appropriate caution. After appropriate handling, the cask is inserted back into the regular flow of operations, which continue below.

After the cask has passed the arrival checks and inspections or has been handled appropriately in the safeguards area, the cask is taken to the gate of an area called the radiation controlled area (RCA). All nuclear waste handling facilities are within this area. Entry and exit to and from the RCA is controlled by health physics regulations. The RCA has separate parking areas for rail and truck casks. The cask is parked in the RCA. The cask stays in the RCA until the waste handling building (WHB) can accommodate it for unloading.

After the cask is parked in the RCA parking, the off-site prime mover, which brought the cask to the MGDS, is disconnected. The off-site prime mover exits the RCA after appropriate radiological inspections at the RCA gate. The site prime mover is connected to the cask, and the cask is taken to an area called the RCA shed.

The shed is where the cask is prepared for entry into the WHB. In the RCA shed, the cask's personnel barrier and impact limiters are removed. Any additional radiological inspections, such as the first radiological inspection--which, according to 10 CFR 20, *Standards for Protection Against Radiation*, must be done within three hours if the cask arrives during normal working hours and within eighteen hours if the cask arrives during off hours--is done in the RCA shed. The cask is now ready to enter the WHB.

The cask enters the WHB through an air lock. (The air lock helps keep the atmosphere in the WHB at a pressure slightly below the outside air pressure. Inside the WHB is a bay. The cask is parked in the bay. The site prime mover is disconnected from the cask, and the site prime mover exits the WHB. The upper and lower trunions are removed from the cask. The cask is now ready to be lifted off the carrier.

The radiological inspections already done on the cask should have given an indication about whether or not the cask needs to be decontaminated. If local decontamination procedures will suffice, the procedures are performed now in the WHB bay. If, however, the cask needs extensive decontamination, such as would be needed if the cask arrives weeping, then the weeping decontamination is also done before the cask goes any further into the WHB and spreads its contamination. (About eight percent of the casks are expected to arrive weeping. A weeping cask is one which started from the reactor without removable contamination on it but which arrives at the destination with removable contamination. Pool temperature, cleanliness, and the duration of submersion are factors that influence weeping.) If the cask needs extensive decontamination, it is taken, by the overhead bay crane, to the decontamination chamber and decontaminated. (The carrier is cleaned locally if necessary and taken out of the WHB to RCA parking. If the carrier needs extensive cleaning, it is taken to a carrier cleaning station outside the WHB.) From the carrier, or from the decontamination chamber, the cask is taken, again by the overhead bay crane, to the cask preparation area where the cask is prepared for unloading.

7.0.1.2 Waste Preparation

The cask lid is unbolted and the appropriate cask-to-port adapter is installed. The area is vacated and is secured for the unloading operation by moving the appropriate shielding into place, etc. The cask is raised until it is in the unloading position whereby the in-cell crane can engage the lid and the contents. The lid is removed and placed in a laydown position in the shielded cell.

The cask's contents are removed and transferred into the shielded cell. The cask lid is placed back onto the cask, and the cask is removed from the staging position and prepared for shipment off-site. The cask is taken to the adjacent Cask Maintenance Facility for examination and repair, if necessary, in preparation for shipment. The contents of the cask will be a Multi-purpose Canister (MPC), Spent Nuclear Fuel which may or may not be canisterized, or High-Level Waste canisters. MPC contents will be repackaged only if the MPC is damaged. No repackaging of the contents of an MPC will be done to achieve thermal load balancing [INN 7.0.1.2-1], nor will rod consolidation be performed. Temporary storage space is provided for the waste form in the shielded cell in preparation for transfer to the designated disposal package. The waste form is transferred to the designated disposal container along with any other engineered barriers (if necessary) such as fillers [INN 7.0.1.2-2]. The containers for the different waste forms can be variable in size. The waste transfer operation is manually conducted by operators using standard remote handling equipment which allows maximum flexibility in the handling operation. A lid is placed on the disposal container and welded in place to form a high integrity seal. The welding operation begins by engaging the automatic welding machine to the container and lid. The welding is initiated by the operator and monitored by in-cell instrumentation which sends the information to the operator. The weld is remotely inspected and tested to make certain that it meets containment requirements.

The sealed and decontaminated (if necessary) disposal container is transferred to a designated storage area for placement into the underground transfer cask. This area also contains the containers which are being stored for staging into the welding area. A container is taken to the welding station by the same overhead crane that moved the filled disposal container (i.e., waste package, since there is assumed to be no packing material external to the container) to the storage area.

The disposal container is transferred to the transporter loading area. It may be necessary to reorient the disposal container from a vertical position to a horizontal position in order to introduce it to the underground transport cask. The disposal container is transferred to the transporter which will take the container underground to the disposal area.

New, empty disposal containers, assumed fabricated at an external facility, are stored in a shed near the WHB. The transporter itself is used to transfer new disposal containers into the WHB. Each time the transporter comes to the WHB to pick up a new disposal container, the transporter also picks up a new container--of the same type as it is about to pick up from the WHB--from the storage shed and brings it to the WHB. The new container is first transferred into the WHB. Then the loaded container is put into the transporter for underground disposal.

7.0.1.3 Waste Package Transfer to Underground

The waste package is transferred to the transport cask loading area where it is placed into a transport cask that is shielded to "stand alongside levels". The waste transporter attaches to the loaded transport cask and transports it to the entrance to the emplacement drift. The transporter is a locomotive [INN 7.0.1.3-1]. Operation could be by a person on the transporter or by remote control or robotic systems. At the emplacement drift entrance, the transport cask is aligned with the emplacement drift. The emplacement drift has a shielding door across its entrance. Portable shielding is also provided for the workers in the access drift while the shielding door is open [INN 7.0.1.3-2]. The shielding door is opened, and the waste package is moved from the transport cask into the emplacement drift. The shielding door is closed, the portable shielding is moved from the access drift, and the transporter and the unloaded transport cask are returned to the surface facilities to be used for another waste package.

7.0.1.4 Waste Package Emplacement

The shield door is opened, a smaller emplacement transporter enters the emplacement drift, the shield door is closed, the emplacement transporter attaches to the waste package, and the waste package is transported to, and emplaced in, its emplacement location. Because of potential high radiation levels in the drift, all operations within the drift are via remote control or robotic systems [INN 7.0.1.4-1]. The waste package is permanently mounted on a rail car, for which the transport method is by locomotive. The drift is ventilated until all waste packages destined for the drift have been emplaced. Following emplacement, the emplacement transporter travels to the shield door, the shield door is opened, the emplacement transporter exits the emplacement drift, and the shield door is closed. Emplacement will begin once sufficient emplacement drifts (perhaps five or ten) have been developed. Thereafter, emplacement operations will occur concurrently with development operations, but emplacement does not occur in the development area.

7.0.1.5 Waste Package Retrieval

The retrievability period may last as long as 100 years following initiation of emplacement [INN 7.0.1.5-1]. If a decision is made to retrieve a waste package, the waste package is removed from the emplacement drift by following the emplacement and transfer steps in the reverse order. The waste package eventually is placed into a transport cask and transported to the surface facilities for further handling and processing.

Additional steps required for retrieval include cooling the emplacement drift before any equipment enters it and performing a remotely controlled inspection to determine if obstructions to travel exist. The desire to remove a specific waste package may require first removing other waste packages.

7.0.2 Subsurface Development

Underground openings are constructed and excavated rocks are handled, processed, stored and disposed of.

7.0.2.1 Underground Openings Construction

Underground openings are excavated, supported, and operation support services are installed. Openings are constructed to serve a variety of functions such as main accesses (shafts and ramps), ventilation, emplacement, maintenance, and personnel and materials handing (where using a tunnel boring machine was not feasible, other mechanical methods, such as a roadheader type machine, was used). When neither of these were feasible, drill-and-blast excavation was used. Comparable mechanical methods are also available for shaft excavation. Following excavation, the openings are stabilized using appropriate combinations of rockbolts, welded wire fabric, shotcrete, and steel sets or cast-in-place concrete and segmented precast linings [INN 7.0.2.1-1]. The ground support philosophy adopted is that emplacement drifts are designed to be stable through the retrievability period and not rely on planned maintenance. Shafts, ramps and all other drifts, which have no high temperatures or radiation levels, are designed to be stable, but may rely on periodic planned maintenance [INN 7.0.2.1-2]. Operational support services include the installation of utilities, the installation of inverts and rail for the transport of waste packages, and the installation of radiation shielding doors (see Subsection 3.4.1.3).

7.0.2.2 Excavated Rock Handling and Processing

Excavated rock is removed from the underground and hauled to the surface. The steps necessary to accomplish this are dependent on the methods of excavation and rock transportation being used. For drill-and-blast excavation, the rock first has to be picked up by some equipment. The tunnel boring machine and roadheader and its related equipment perform the load and transfer functions. Each rock transport method has a maximum particle size it can handle. Depending on the transport method to be used, some of the rock may require crushing to meet the size limits. This is most likely to be true for conveyor transport (the currently favored method for ramps and drifts) and least likely to be true for rail transport. For conveyor transport, rock excavated by drill-and-blast most likely will require crushing, rock excavated by a roadheader may require crushing, and rock excavated by a tunnel boring machine will not require crushing (an exception is if there is a rockfall right after or as part of the excavation). Following crushing, the rock is placed onto the transport method and hauled to the surface.

7.0.2.3 Excavated Rock Storage and Disposal

At the surface facility, the excavated rock is placed in a pile. If it is to be reused later for repository backfill, it is considered to be in storage; if it is not to be reused later for repository backfill, it is considered to be disposed of. This function includes environmental considerations for esthetics and to limit weathering of and leaching through potential backfill.

7.0.3 Performance Evaluation

7.0.3.1 Performance Confirmation

The operational phase of performance confirmation activities begin when waste is received at the repository, is placed in waste packages, and then emplaced in the geologic media. These activities collect all appropriate data and compare the measured values to performance values established prior to waste receipt. The data collection activities assume, based on the current emplacement concept, drift emplacement with a robust waste package, that relatively few measurements at spaced intervals are required.

7.0.3.1.1 In Situ Performance Monitoring

The in situ performance of both the natural barrier and engineered barrier are monitored. Monitoring of waste packages in one or more representative emplacement drifts is conducted. Periodic measurements are taken in the "performance confirmation drift(s)" on selected waste packages. These measurements include waste package surface temperature and surface and air radiation measurements. In addition, a video camera is used to visually inspect for corrosion or any other abnormal waste package conditions.

These measurements are taken periodically on waste packages representing the three types of waste packages to be used in the repository: MPC, HLW, and uncanistered fuel waste packages. Also periodically, but less frequently, measurements are taken in an emplacement drift other than the performance confirmation drift(s) to confirm that the performance confirmation drift(s) data adequately represents conditions throughout the repository. In all of these measurements, an instrumentation package is attached to an overhead rail system and remotely moved into the proximity of the waste package where measurements are taken. No permanent in situ instrumentation is utilized because of uncertainties regarding instrumentation life and calibration in the hostile radiation and thermal environment.

Monitoring of the natural barrier is conducted by periodically measuring temperatures of the geologic media to establish temperature profiles, measuring stress and strain in the rock, collecting water samples to determine water density, and monitoring water movement. These measurements are made in drill holes parallel to emplacement drifts or in empty emplacement drifts adjacent to emplacement drifts containing waste packages. These measurements will also be made with portable instrumentation.

All data from in situ measurements are compared against data from the appropriate performance confirmation models. If performance parameters are within the ranges anticipated, no further action is planned. If not, further action is required. (See Subsection 7.0.3.1.4).

7.0.3.1.2 Laboratory and Field Tests

At five year intervals, one of each of the three primary types of waste packages, (MPC, HLW, and uncanistered fuel waste) is removed from the performance confirmation drift(s) and transported to the WHB for non-destructive testing. No separate performance confirmation building with a hot cell is required. Each waste package is inspected for cracks and general and localized corrosion, including the areas around the waste package supports. The welds are also inspected. Photographs are taken of any corroded or cracked areas and depth of pitting noted.

If corrosion is noted, samples are removed from the waste package's surface for further examination by lightly scraping the surface to minimize waste package damage. If leakage is noted, the waste package is repaired or replaced as necessary. However, it is the intention of the laboratory tests to record the condition of each waste package and then return it in the same condition to the performance confirmation drift(s). No repairs are anticipated.

Surface temperatures of the waste package and surface radiation levels are also noted and compared to the levels measured prior to emplacement and those measured in situ. After the laboratory inspections are performed, the waste packages are returned to their same locations in the performance confirmation drift(s).

All samples from the ventilation system for emplacement operations and from the waste package handling building are continually monitored for radiation levels and types of gases and particulates. Wells at the periphery of the repository are also monitored for radiation levels and water chemistry. Other measurements at the repository include seismic activity, ambient temperature, barometric pressure, and relative humidity.

All data from the laboratory tests are compared against data from the appropriate performance confirmation models. If performance parameters are within the ranges anticipated, no further action is planned. If not, further action is required. (See Subsection 7.0.3.1.4).

7.0.3.1.3 In Situ Experiments

Monitoring of the natural barrier at one year intervals, in addition to the monitoring described above, is conducted to determine the performance of the natural barrier. Temperature profiles are determined from temperature measurements in selected locations throughout the repository. Humidity and water flow are also tracked at specific locations. Instrumentation packages are installed or remotely moved to a specific location just prior to taking measurements and then removed.

All data from the natural barrier in situ measurements are compared against data from the appropriate performance confirmation models. If performance parameters are within the ranges anticipated, no further action is planned except to use parameters to update the performance assessment models. If performance parameters fall outside the ranges anticipated, further action as described below is required.

7.0.3.1.4 Appropriate Action

As indicated, no further action is required if measured data fall within pre-established performance limits. If data are outside anticipated performance, appropriate action will be taken. For example, if waste packages are corroding more rapidly than anticipated, in the emplacement drift environments, the following actions may be appropriate:

- Increase frequency of inspections,
- Remove waste package for laboratory testing, or
- Relocate waste packages to other drifts, or
- Retrieve all waste packages.

If the emplacement drift environment is other than as anticipated, the following actions may be taken:

- Increase frequency of inspections,
- Determine if local problem,
- Relocate waste packages, or
- Retrieve all waste packages.

7.0.3.2 Laboratory and Field Tests

7.0.3.2.1 Performance Assessment Models

As in situ and laboratory data becomes available, the performance assessment models are updated. Actual thermal profiles will be compared to predicted profiles and geologic parameters modified where necessary to further refine models.

7.0.3.2.2 System Performance

Using updated performance assessment models, the performance of the engineered barrier and natural barrier are estimated, together with performance of the total system. Long term radiological consequences are also estimated. Any deviation, beyond statistical expectations, from earlier predictions is carefully examined.

7.0.3.2.3 System Compliance

Using the results of the updated performance models, the compliance of the engineered barrier and natural barrier are evaluated, together with the compliance of the total system.

7.0.3.3 Performance Assessment

Environmental data will be collected and the environmental impact assessed. These results are compared to the performance assessment analysis developed prior to the approval of the repository for waste receipt. Where environmental measurements fall outside the predicted analyses, more complete performance assessments will be conducted to determine whether these changes lead to long-term changes in predicted repository release.

7.0.4 Support Operations

Various utilities, services, and facilities are required to support the operational, caretaker, retrieval and monitoring activities throughout the course of the pre-closure period.

7.0.4.1 Provide Utilities and Services

The following services support MGDS operations: heating, ventilation, and air-conditioning (HVAC), communications, water supply, power, illumination, on-site transportation of people and equipment, sewer (sanitary) services, natural gas, compressed air, steam, and water control. Each of these is required for surface facilities and operations; natural gas and steam are not required for underground facilities and operations. With the exception of ventilation and water control underground, all of the utilities and services involve standard applications. Utilities in the underground are installed and extended as the excavation progresses.

HVAC services are an important part of the utilities at the Geologic Repository Operations Area (GROA). Each surface facility has its own independent HVAC system which is designed to serve its specific needs. Equipment and facilities on the surface supply and exhaust air from the underground facilities. Some of this air is monitored and passed through a nuclear rated HVAC system

Underground ventilation is probably the most complex of the utilities and services. The concept is to have separate ventilation systems for the development and emplacement areas (10 CFR 60.133(g)(3)). The separate systems help control the transport of radioactive gases and particulates within the repository and releases of these from the repository (10 CFR 60.133(g)(1)). As the repository emplacement drifts are developed and become available for emplacement, their ventilation systems are removed from the development ventilation system and added to the emplacement ventilation system. Ventilation is maintained in an emplacement drift until it has received all of its waste packages, after which ventilation ceases. Continuous flow-through ventilation is maintained in the repository accesses until closure; continuous ventilation through the emplacement drifts is an option to be studied. If retrieval is required, the emplacement drift is ventilated and cooled before beginning retrieval. Ventilation and cooling are maintained in an emplacement drift during retrieval operations.

Underground water control has two aspects: before water use and after water use. The first involves controlling the amount and location of water to be used; the second involves controlling the water after it has been used as well as controlling any water that flows into the accesses and drifts from other sources. The latter requires constructing slopes and sumps to collect such water and then pump it to the surface facilities.

Electricity is supplied from appropriate substations and is generated off-site. Emergency power is supplied as needed from on-site standby generators. A standby generator facility is provided to supply power to the various areas of the GROA. Some facilities have their own independent emergency generators.

Heat and steam are supplied from a central boiler plant in which water treatment systems are located. Compressed air, inert gas supply systems, and vacuum systems are incorporated into the design and operation of the surface facilities in which they are needed.

7.0.4.2 Provide Protective Services

Site protective services include, but are not limited to, security, interaction with health physics and radiological safety, fire protection, and emergency response systems. The protective services are integrated with those at the Nevada Test Site. These services include the operation and maintenance of security stations, perimeter fencing, and related monitoring systems. Control of human entry to the overall GROA and its individual plant sites is a major responsibility of protective services.

7.0.4.3 Administer General Support Services

The repository surface facilities are envisioned to operate five days a week, two shifts a day. Transportation casks arrive round the clock and are dispatched round the clock, but the casks are unloaded and otherwise worked upon only during working hours.

Most personnel are expected to live in the city of Las Vegas. Due to the long distance from the city to the repository, personnel are expected to use buses provided. Bus parking is provided at the repository. Buses are expected to be subcontracted, in which case the repository shall not be liable for the maintenance of the buses.

Some personnel, such as the health physics staff on overnight call, are expected to stay in Mercury. Accommodation facilities for such personnel already exists in Mercury. Transportation in the form of pick-up trucks is expected to be provided to such personnel.

General support services are needed for repository operation, to interface with the public, to maintain and service site equipment, and to support personnel activities in a remote location. Some support services such as a remote handling mockup laboratory, an analytical laboratory, and a low level counting laboratory provides technical confirmation and support. Personnel support includes a cafeteria, a training auditorium, a medical facility and a change house. A motor pool service station and vehicle storage yard is provided for vehicles used on-site. Maintenance shops include mechanical, electrical, and instrumental services to all portions of the site. A visitors center supports outreach programs and is used to inform the interested public about the salient features and activities of the repository. An administration building provides offices and services required to manage the workforce and the site programs.

7.0.4.4 Process Site-Generated Waste

Secondary wastes are generated at the repository as a result of the waste processing and disposal operation. The types of waste include low-level radioactive waste , mixed low-level radioactive waste, and conventional hazardous waste. An on-site waste treatment facility receives and processes both solid and liquid site-generated waste.

Contaminated solids and liquids that cannot be decontaminated and recycled feasibly or economically are treated for disposal. Means are provided for solidifying liquids unsuitable for recycling by fixing the residues in a solid matrix. The waste is treated and packaged according to the criteria developed for waste of similar radionuclide content. The disposal of low level waste is an important facet of the overall waste disposal issue.

Other, routine, non-hazardous site-generated waste is handled as municipal waste by collecting and dumping it into dumpsters which are emptied routinely and carried to regular landfills. Such waste is expected to come mostly out of the general site facilities area. Such waste coming out of the GROA is inspected for radioactivity before release for disposal as municipal waste. If such GROA waste indicates radioactivity, then it is treated as low-level site generated waste and handled accordingly.

7.0.4.5 Maintain Operating Facilities

The maintenance of all operating facilities is accomplished facility by facility with the overall site maintenance being managed and operated in the General Support Facilities Area. Facilities such as the WHB require specialized maintenance of the remote handling equipment and of the equipment which can be potentially contaminated. The routine maintenance of equipment and facilities is done according to procedures prepared for each facility and which is coordinated in the General Support Facilities Area facility.

7.0.4.6 Administer Quality Assurance (QA)

QA of all procedures used in all site operations is directed by QA personnel located in the Administration building. QA personnel are trained to understand all operating procedures, including specialized operations such as those involved in handling radioactive materials. [See Chapter 10.]

7.0.5 Closure

7.0.5.1 Subsurface Closure

Closing subsurface openings involves removing underground equipment, [preparing the openings to receive backfill, backfilling the openings,] emplacing repository seals, and implementing postclosure monitoring. Included in the definition of equipment to be removed are utilities and support services as appropriate (size and type would be considerations) and unsuitable materials. [Preparing the openings to receive backfill include installing utilities and equipment specifically for the backfilling operation. Backfilling involves obtaining material from the surface stockpile or other source, processing (screening) it if necessary to obtain the required grading, placing the processed material into a stockpile for subsequent loading and transfer to the underground emplacement location, and finally placing the backfill underground. No decision on the backfilling option has been made. The backfilling option will be reviewed and evaluated in terms of effects on potential effects on the total repository system performance. Selection and development of the backfill option ultimately will depend on the results of these evaluations.]

Placement of seals involves preparing the underground openings to receive the seals, obtaining and transferring seal material, and constructing the seals. Currently, it is assumed that seals are to be placed only in shafts, ramps, and boreholes. Backfill will probably be placed on both sides of each seal. Postclosure monitoring is described in Chapter 8.

7.0.5.2 Surface Decommissioning

At the end of the caretaker period (or at the end of the retrieval period, if retrieval is not necessary), the surface facilities are decommissioned and removed from service. Some decommissioning activities may occur upon termination of the waste emplacement activities. Conversion of a facility to another site function is not included in the decommissioning activities.

Decommissioning will include decontamination, dismantlement and facility removal activities. It is also planned to restore the site to as near to its prerepository condition as possible as part of these activities. Records of each activity are to be retained in the Management and Operations Control Center.

Decontamination is to ensure that residual contamination, both radioactive and hazardous, is within permissible levels for unrestricted use. Limits to the residual radioactivity are provided as guidance in Regulatory Guide 1.86 (1974). Decontamination activities for hazardous materials and substances is not anticipated but could occur.

It is expected that potential radiological contamination could occur anywhere unconfined radioactive materials (i.e., exposed intact spent fuel assemblies) are handled or where contamination is present on incoming containers within the WHB. In addition, contamination is expected to be generated within the Waste Treatment Building and the transporter washdown facility. Hot cells, decon stations, and HVAC ducts potentially require decontamination.

Decontamination activities includes the survey, identification, and characterization of contaminated areas and facilities. Decontamination activities also include determination of methods for removal, degree of treatment needed, packaging, in situ immobilization, and transportation to either an on-site or off-site disposal or storage location.

Facility dismantlement includes the dismemberment, distribution or removal from the site of facility systems, in whole or in part, for the purpose of salvage, interim storage, mothballing, reuse at another location, or safety. All facilities not part of the Institutional Barrier System functions are dismantled and removed from the site area. Almost all of the surface facilities require demolition of reinforced structures after removal of fixtures and equipment. Consideration for salvage, recycle and reuse of equipment, materials and fixtures is planned.

Removal of facilities is required to perform final site restoration activities. Facility removal activities includes the preparation and transportation of intact facilities and facility sections to off-site locations.

Reclamation includes the recontouring of all possible disturbed surface areas, surface backfill, soil buildup and reconditioning, site revegetation, and site water course configuration and erosion control implementation.

7.0.5.3 Institutional Barrier Establishment

Institutional barriers systems are incorporated at the termination of the retrieval period and final closure of the repository. Institutional barriers are both passive and active systems designed to inhibit human disturbance and disruption of the repository site, thereby supporting site performance. Active controls include site monitors and warning devices and patrols, and an education institution which will inform future generations. Passive controls include surface markers and obstacles.

REFERENCES

10 CFR 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories

ACRONYMS AND ABBREVIATIONS

ACD	Advanced Conceptual Design
ALARA	As Low As Reasonably Achievable
DOE	U.S. Department of Energy
FCRG	Format and Content Reg Guide
FY	Fiscal Year
GET	General Employee Training
GROA	Geologic Repository Operations Area
HVAC	Heating, Ventilation, and Air-Conditioning
M&O	Management and Operating Contractor
MGDS	Mined Geologic Disposal System
MPC	Multi-purpose Canister
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
QA	Quality Assurance
RCA	Radiation Controlled Area
TBD	To Be Determined
TBM	Tunnel Boring Machine
TLD	Thermoluminescent Dosimeter
WHB	Waste Handling Building

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0-1
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	A non-compromising summary of safeguards and security plans pursuant to Sections 1.4 and 1.5 of the MGDS License Application FCRG. Also include information describing the planned activities, processes and procedures as requested in the introduction to Section 7 of the FCRG. (NOTE: This will not be needed for this section if the FCRG comment is adopted.)
Information will be used to support:	
The Information is needed by/for (date or event):	TBD
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0.1.2-1
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Validate the statement "No repackaging of the contents of an MPC will be done to achieve thermal load balancing"
Information will be used to support:	An understanding of the concept of operations.
The Information is needed by/for (date or event):	
Mostly likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0.1.2-2
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Describe the conditions requiring addition of filler to disposal vessels.
Information will be used to support:	Description of waste preparation, Subsection 7.0.1.2, Paragraph 2.
The Information is needed by/for (date or event):	
Mostly likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0.1.3-1
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	A description of the emplacement transporter; specifically, identification of the method of power (is it a locomotive?)
Information will be used to support:	
The Information is needed by/for (date or event):	
Mostly likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0.1.3-2
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	An evaluation of the need for portable shielding near the entrance of the emplacement drift.
Information will be used to support:	
The Information is needed by/for (date or event):	
Mostly likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0.1.4-1
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Determination of the use of remote control/robotics within the emplacement drifts.
Information will be used to support:	
The Information is needed by/for (date or event):	
Mostly likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0.1.5-1
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	How long will the retrieval period last (presently assumed to be 100 years after emplacement begins)?
Information will be used to support:	
The Information is needed by/for (date or event):	
Mostly likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.0.2.1-1
Section Number and Title:	7.0 CONDUCT OF REPOSITORY OPERATIONS
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	
Explicit description of the needed information:	Identify/verify the methods for stabilizing the openings following excavation.
Information will be used to support:	
The Information is needed by/for (date or event):	
Mostly likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS License Application Annotated Outline

Section 7.1 Maintenance

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7.1.2-1	Expand and verify the identification of the maintenance plans, schedules and procedures followed by various shafts and ramps.
7.1.3-1	Expand and verify the identification of the maintenance plans, schedules and procedures followed by various subsurface facilities.

7.1 MAINTENANCE

7.1.1 Surface Facilities

[INN 7.1.1-1: More complete information will be available from Surface Design as follows:

a. Advanced Conceptual Design (ACD) - A better understanding of the actual facilities and their related systems should allow an enhancement of Table 7.1.1-1 upon completion of the ACD.

b. Preliminary Design - Clear understanding of the systems, subsystems, and major components should allow the development of outline maintenance plans.

c. Final Design - Detailed procedures with defined maintenance plans are developed only after completion of final design.]

7.1.2 Shafts and Ramps

Tables 7.1.2-1 and 7.1.2-2 identifies the various maintenance plans that are followed for the various shafts and ramps. The maintenance plans for the GROA shafts and ramps are presented as follows:

[INN 7.1.2-1: More complete information will be available from Shafts and Ramps Design department as follows:

- ACD - A better understanding of the actual facilities and their related systems should allow an enhancement of Table 7.1.2-1 upon completion of the ACD.
- Preliminary Design - Clear understanding of the systems, subsystems, and major components should allow the development of outline maintenance plans.
- Final Design - Detailed procedures with defined maintenance plans are developed only after completion of final design.]

7.1.3 Subsurface Facilities

Table 7.1.3-1 identifies the various maintenance plans that are followed for the various underground facilities. The maintenance plans for the GROA underground facilities are presented as follows:

[INN 7.1.3-1: More complete information will be available from Subsurface Design department as follows:

- ACD - A better understanding of the actual facilities and their related systems should allow an enhancement of Table 7.1.3-1 upon completion of the ACD.

- Preliminary Design - Clear understanding of the systems, subsystems, and major components should allow the development of outline maintenance plans.

- Final Design - Detailed procedures with defined maintenance plans will be developed only after completion of final design.]

REFERENCES

Table 7.1.1-1 GROA Surface Facilities Maintenance Plans [INN 7.1.1-1]

SURFACE FACILITIES **SYSTEMS/Operating Control Limits**	Waste Handling Building	Cask Maintenance Building	Lag Storage Building	Decon. Facility	Ancillary support Facilities	Waste Treatment
Container Handling and Loading	X	X	X	X		
Cutting and Welding	X	X				
Cleaning and Decon.		X		X		
Process Liquid Piping						X
Containment Boundary	X	X	X	X		X
HVAC	X	X	X	X		X
Shielding	X	X	X	X		X
Safety and Environmental Monitoring and Alarms	X	X	X	X	X	X
Fire Suppression	X	X	X	X	X	X
Controls and Instrumentation	X	X	X	X	X	X
Fire Barriers	X	X	X	X	X	X
Electrical Systems	X	X	X	X	X	X
Cooling	X		X		X	
Water Supply		X		X	X	
Compressed Air	X	X	X	X	X	X
Material Handling	X					X
Mixing and Pumping						X
Packaging or Containerizing						X
Storage		X	X			X
Emergency Egress	X	X	X	X	X	X
Security and Safeguards	X		X		X	
Transportation					X	
Waste Transfer	X	X	X	X	X	X
Inert Gas						

Table 7.1.2-1 GROA Waste, Muck, and Ventilation Shafts and Ramps Maintenance Plans [INN 7.1.2-1]

GROA SHAFTS AND RAMPS **SYSTEMS/Maint. Plans**	**Waste Ramp**	**Muck Shaft**	**Muck Ramp**	**Vent. Shaft - Intake**	**Vent. Shaft - Exhaust**	**Vent. Ramp - Intake**	**Vent. Ramp - Exhaust**
Portal	X		X			X	X
Collar		X		X	X		
Liners	X	X	X	X	X	X	X
Controls and Instrumentation	X	X	X	X	X	X	X
Waste Transporter	X						
Drainage	X	X	X	X	X	X	X
Ventilation Line and Filters	X	X	X	X	X	X	X
Backfilling Equipment							
Hoist		X					

Table 7.1.2-2 GROA Personnel, Material, Decommission, and Other Shafts and Ramps Maintenance Plans [INN 7.1.2-1]

GROA SHAFTS AND RAMPS	**Personnel & Material Ramp**	**Personnel & Material Shaft**	**Decom-mission System**	**Other Shaft or Ramp System**
SYSTEMS/Maint. Plans				
Portal	X			
Collar		X		
Liners	X	X		
Controls and Instrumentation	X	X		
Waste Transporter				
Drainage	X	X		
Ventilation Lines and Filters	X	X		
Backfilling Equipment			X	
Hoist		X		

Table 7.1.3-1 GROA Subsurface Facilities Maintenance Plans [INN 7.1.3-1]

GROA FACILITIES	Waste Ramp	Muck Shaft	Muck Ramp	Vent. Shaft - Intake			Vent Shaft - Exhaust
SYSTEMS/Maint. Plans							
HVAC							
Safety and Environmental Monitoring and Alarms							
Fire Suppression							
Controls and Instrumentation							
Electrical Systems							
Water Supply							
Waste Transfer							
Compressed Air							
Material Handling							
Emergency Egress							
Security and Safeguards							
Transportation							
Communications							
Liners and Ground Support							
Hoist							

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.1.1-1
Section Number and Title:	7.1 MAINTENANCE
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	Table 7.1.1-1
Explicit description of the needed information:	Expand and verify the identification of the maintenance plans, schedules and procedures followed by various surface facilities.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.1.2-1
Section Number and Title:	7.1 MAINTENANCE
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	Tables 7.1.2-1 and 7.1.2-2
Explicit description of the needed information:	Expand and verify the identification of the maintenance plans, schedules and procedures followed by various shafts and ramps.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	

MGDS LA Annotated Outline Form A: Information Need

Information Need Number:	INN 7.1.3-1
Section Number and Title:	7.1 MAINTENANCE
Lead Author/Support Author and Phone:	Ken Ashe (702) 794-7665
Primary LA AO Table or Figure INN supports (if applicable):	Table 7.1.3-1
Explicit description of the needed information:	Expand and verify the identification of the maintenance plans, schedules and procedures followed by various subsurface facilities.
Information will be used to support:	
The Information is needed by/for (date or event):	
Most likely source of the Information:	
Information Source Description:	
Does the supporting data need to be QA?	

INTEGRATOR (PMO):	
Date information will be available:	
Deliverable providing information:	
If the data needed is QA, then the QA source document number is:	