DOE/RW-0160

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Chapter 8

Section 8.3.4

P

Nuclear Waste Policy Act
(Section 113)

Consultation Draft

WASTE PACKAGE PROGRAM

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI

January 1988

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

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8.3.4 WASTE PACKAGE PROGRAM

The waste package program is organized to address two performance issues (Issues 1.4 and 1.5) and three design issues (Issues 1.10, 2.6 and 4.3) included in the issues hierarchy. This section describes the overall waste package postclosure compliance strategy and the design issues of the waste package program for the Nevada Nuclear Waste Storage Investigations (NNWSI) Project. The performance issues of the waste package program are discussed in Sections 8.3.5.9 and 8.3.5.10.

Section 8.3.4.1 provides an overview of the program. The design activities and site data needs for addressing the postclosure waste package requirements are described in Section 8.3.4.2 (Issue 1.10). This discussion includes a description of the studies and activities required to characterize the waste package emplacement environment. Section 8.3.4.3 describes the preclosure containment requirements for the waste package and discusses the information to be obtained on waste forms (Issue 2.6). Information needed to develop the technologies for production of the waste package is described in Section 8.3.4.4 (Issue 4.3).

Sections 8.3.5.9 and 8.3.5.10 discuss the waste form, package materials, and site data needs and describe the activities planned to demonstrate compliance with the performance objectives for waste package containment and engineered barrier system release.

All schedule and milestone information provided in this section should be regarded as preliminary and tentative. Section 8.5 describes the assumptions used for estimating milestone completion dates and provides a discussion of recent changes in the overall schedule for the repository program.

Waste package postclosure compliance strategy

The waste package postclosure compliance strategy is designed to resolve waste package issues in an integrated manner as shown in Figure 8.3.4-1. The waste package issues and information needs are based on the requirements in the U.S. Nuclear Regulatory Commission's (NRC) 10 CFR Part 60 with considerations of the Nuclear Waste Policy Act of 1982, the U.S. Environmental Protection Agency's 40 CFR Part 191, the U.S. Department of Energy's (DOE) 10 CFR Part 960, and the Generic Requirements for the Mined Geologic Disposal System (MGDS). Figure 8.3.4-1 provides an overview of the process that the NNWSI Project is following to develop a licensable cost-effective waste package design on the required schedule. This simplified format depicts only the key elements of the waste package program strategy and the major interactions among them. For the purposes of the site characterization plan, the NNWSI Project has adopted the DOE/Office of Geologic Repositories interpretations and design objectives for the regulatory terms "substantially complete containment," "engineered barrier system," and "anticipated processes and events."

Approaches taken by the Project for the waste package postclosure compliance strategy are to employ multiple barriers consistent with the NRC's philosophy and to use logical and defensible arguments based on scientific investigations and engineering analyses. From the existing data bases for waste forms, characteristics of the Yucca Mountain site, and the preliminary

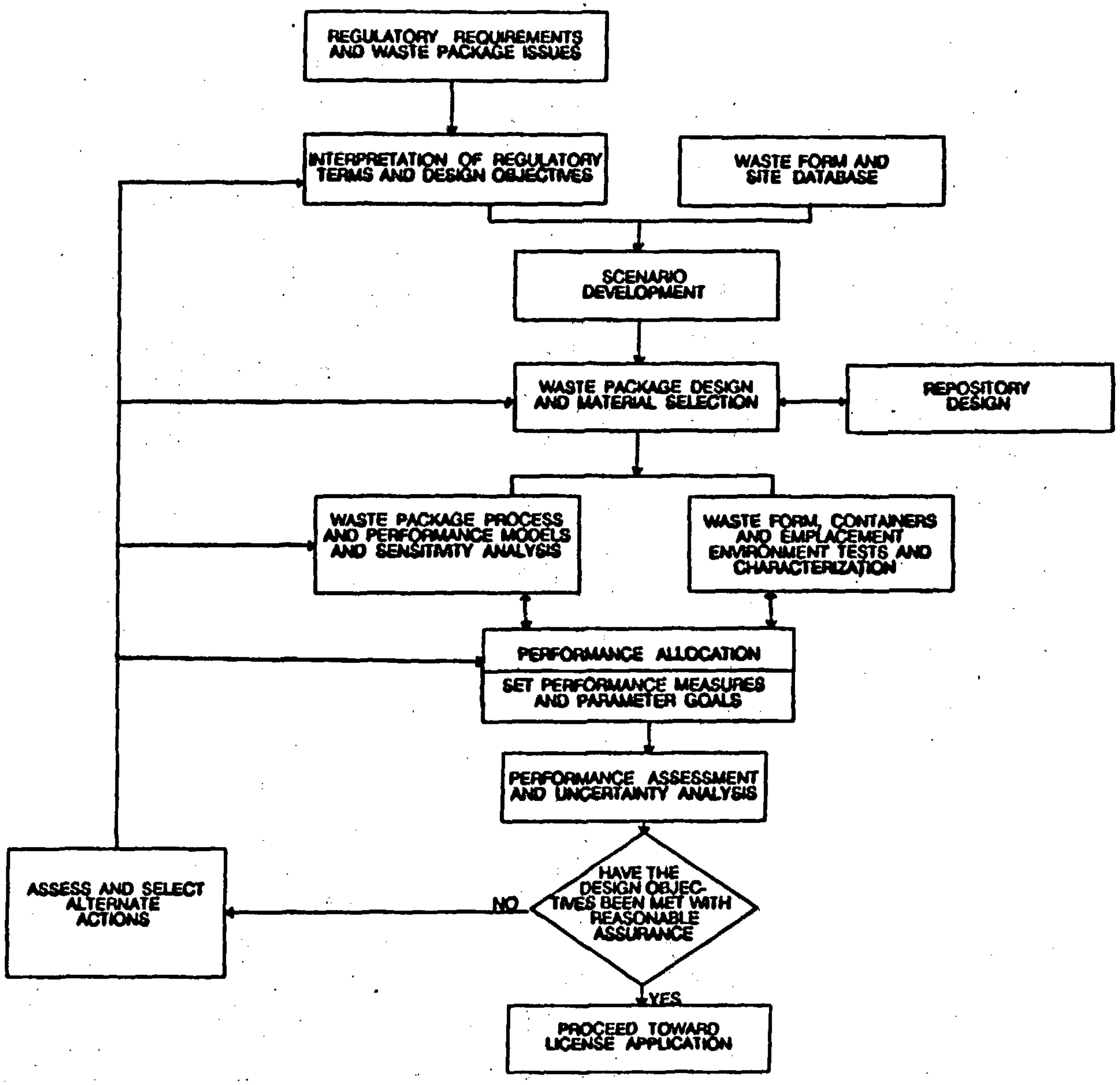

Figure 8.3.4-1. Waste package postclosure compliance strategy.

process and event scenarios, the Project has developed a waste package concept and a coupled waste package near-field environment scenario, from which a conceptual waste package design has evolved. The conceptual design in turn provides the basis for the development of the waste package testing and performance assessment activities utilizing computational models. These models are used to guide the design and testing programs and to aid in performance allocation to waste package components. Sensitivity analyses are performed to quantitatively relate performance measures (e.g., containers breached versus time) to design or environment parameters.

The essence of the waste package compliance strategy lies in the iterative process of performance allocation, performance assessment, testing to determine if goals are met, and, if not, evaluation and selection of alternative actions such as changes in waste package design or materials, modification of computational models, performance of additional tests to improve data bases for the waste package and the environment, or the reallocation of component performance. It is also possible that an alternative definition or interpretation of the regulatory terms "substantially complete containment" and the "engineered barrier system" by the NRC or the DOE may change the performance allocation. The iterative process continues until the design objectives are met with reasonable assurance. The selection of the alternative actions will be determined based on the results of performance assessment.

The NNWSI waste package postclosure compliance strategy is structured within an issues hierarchy, and the performance allocation process is used to resolve the issues. There are three interrelated issues on postclosure performance of the waste packages. Sections 8.3.4.2, 8.3.5.9, and 8.3.5.10 discuss the specific performance allocation strategies to resolve the issues 1.10, 1.4, and 1.5, respectively. The NNWSI Project has chosen to allocate performance to the components of the waste package, namely the container and the waste form, together with the near-field environment as altered through engineering design.

The waste package design strategy takes advantage of the unsaturated nature of the Yucca Mountain site. The near-field environment will also be engineered by designing the waste package emplacement configuration and thermal loading to enhance the unsaturated condition and inhibit liquid water contacting the waste packages during the containment period. For the bounding condition, the Project assumes that water will contact some of the packages and hence containment performance has been allocated to the package. However, the expected quality of the water is such that it will have little impact on the long-term integrity of the waste packages.

Containment during the initial 1,000-yr period following closure relies on the container and waste form. The NNWSI Project has selected six metallic corrosion-resistant container materials as candidates for further evaluation. These materials fall generally into two alloy families selected to avoid common mode failure due to localized corrosion modes. The material selection criteria, which will be peer-reviewed, include the material properties, fabricability and closure requirements, and the ability to model the performance of the container over time under anticipated repository conditions to predict with confidence that the containment and release rate goals can be met. As a backup alternative to metallic containers, the use of ceramic materials is also being evaluated. Performance is also allocated to the glass and spent fuel waste forms. For spent fuel, reliance is placed onthe cladding during the early years to limit the release of the short half-lived radionuclides. Reliance is also placed on the fuel matrix to limit the release of actinides and other radionuclides.

During the post-containment period, primary reliance is placed on the properties of the waste form to achieve the goal of limiting the release of radionuclides from the engineered barrier system.

Performance is allocated to the engineered environment for both periods. The expected condition is that the site will remain unsaturated for both the containment and post-containment periods. Use of the engineered near-field environment and the nature of the unsaturated site (i.e., high matric potential) will play an important role in limiting accessibility of liquid water to the waste packages.

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Section 8.3.4.1

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8.3.4.1 Overview

Section 8.3.4 describes the plans for completing the waste package design tasks through the sequence of design phases leading to the preparation of a license application. The tasks are organized to address three design issues included in the issues hierarchy. (See Section 8.2 for a listing of the issues and a description of the general approach to resolving these issues.) These three issues are

1.10 Characteristics and configurations of the waste packages, including the package environment (postclosure)

2.6 Characteristics and configurations of the waste packages (preclosure)

4.3 Waste package production technologies

These issues are discussed in Sections 8.3.4.2 (Issue 1.10), 8.3.4.3 (Issue 2.6), and 8.3.4.4 (Issue 4.3).

The tasks to be undertaken for these three issues are closely related to issues discussed in several other sections of this document. Requirements and constraints are imposed on the waste package designs by the postclosure regulatory performance objectives for the engineered barrier system. The performance issues that address these objectives are discussed in Section 8.3.5. These performance issues also provide the properties of the waste forms and container materials that are needed to design the packages. The waste package designs are closely coupled to the repository designs because one of the important missions of the repository is the assembly and emplacement of the waste packages. The detailed discussions of the repository design issues are in Section 8.3.2.

In one important respect, the division of the waste package design issues into preclosure and postclosure categories is somewhat artificial. Although the requirements and constraints on the package designs differ for the two time frames, there will be only one set of package designs. After emplacement, the environment that the packages will experience does not strongly depend on whether the repository is operational or closed. To avoid unnecessary duplication and to improve continuity of the discussions, the material discussed under the preclosure issues is primarily related to the production, handling, and emplacement of the packages. The postemplacement aspects of the package designs are discussed under the postclosure issue. The relationship between the package design issues, and their relationships to the repository design, and the directly relevant performance issues is shown in Figure 8.3.4.1-1.

As indicated in the figure, the waste package postclosure design issue (1.10) is linked directly to the two performance issues (Issues 1.4 and 1.5, discussed in Sections 8.3.5.9 and 8.3.5.10, respectively) related to the ability of the waste package and engineered barrier system to meet the performance objectives of 10 CFR 60.113. The reason for this relationship is twofold: (1) some of the information needed to perform the package design is developed in the activities described under the performance issues (1.4 and 1.5) and (2) the performance issues require information developed under the

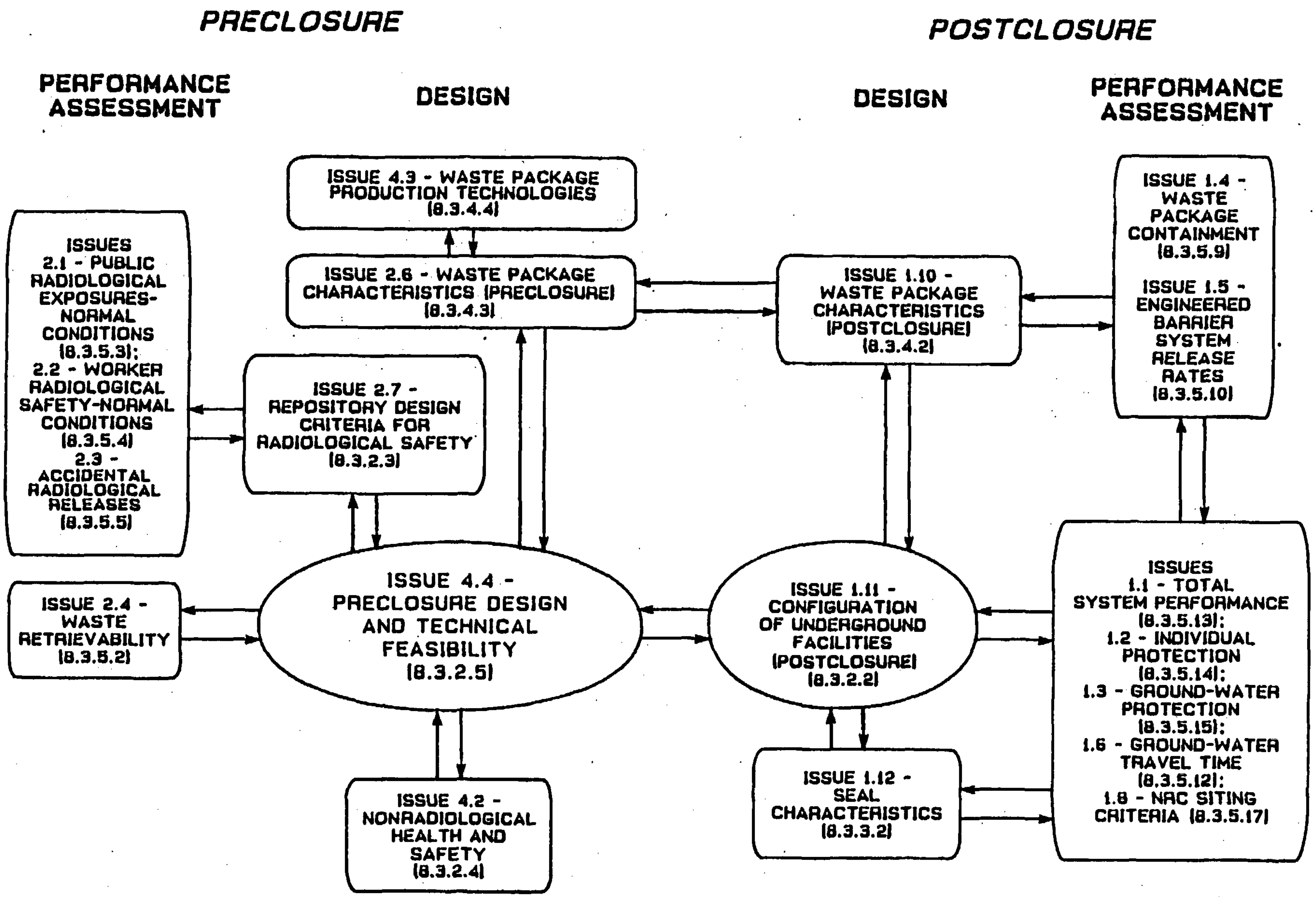

Figure 8.3.4.1-1. Relationships between design- and performance-related issues used directly in performance allocation.

design issue for their resolution. Specific examples of the information that must be exchanged between these issues include container material properties (from Issue 1.4, Section 8.3.5.9), waste form characteristics and configurations (from Issue 1.5, Section 8.3.5.10), and the postclosure environment of the waste packages and the package design configurations (from Issue 1.10, Section 8.3.4.2).

The required postclosure performance of the waste packages, together with the waste form and container material properties, presents a set of design criteria and constraints on the preclosure aspects of the package design. These criteria, and the feedback to the postclosure issues, are also depicted in Figure 8.3.4.1-1. The postclosure performance-derived criteria, together with the preclosure criteria, establish the design requirements to be translated into the package design in Issue 2.6 (Section 8.3.4.3) and reflected in the development of package production technologies in Issue 4.3 (Section 8.3.4.4).

The interaction of the waste package design issues with the repository design issues (both preclosure and postclosure) is handled by the transfer of design criteria and design evaluations between respective issues. Thus, Issues 2.6 and 4.3 will generate criteria for the design of those portions of the repository facilities, equipment, and operations that concern waste packaging, handling, and emplacement to be implemented in Issue 4.4 (Section 8.3.2.5). Similarly, design criteria for the postclosure repository configuration that will influence the waste packages will be generated in Issue 1.10 (Section 8.3.4.2) and implemented in Issue 1.11 (Section 8.3.2.2).

By establishing the relationships just described, a logical mechanism for integrating the waste package and repository subsystems is defined in a way that permits the necessary transfer of design information with minimum duplication; it also provides for adequate feedback between the subsystem designs to verify consistency. The designs are linked to the appropriate performance issues so that the assessments required to demonstrate compliance with the regulations can be made with confidence.

Of the three waste package design issues discussed in this section, only one directly involves the acquisition of site characterization data. Issue 1.10 requires the development of sufficient data, both from the site and in the laboratory, to define the ranges of the anticipated near-field environment conditions for which the emplaced waste packages will be designed. These data will be developed in the activities described in Section 8.3.4.2 and by reference to the relevant site investigations described in Section 8.3.1 (site program). The lack of in situ data on this environment represents a major uncertainty in the adequacy of the design concepts that have been developed in the past (Chapter 7). These data are vital to the successful completion of the waste package designs and the assessments of their performance. To provide resolution of this issue, the results of the waste package and repository design activities also are needed. This reference design information is transferred to the performance issues (1.4 and 1.5) to be used, in conjunction with the other information developed within those issues, in assessments of the engineered barrier system performance.

The other two issues addressed in this section, Issues 2.6 (Section 8.3.4.3) and 4.3 (Section 8.3.4.4), do not directly involve the acquisition of site characterization data. The package designs that evolve under Issue 2.6 must comply with the regulatory design criteria and restrictions on their contents and must be compatible with the repository operations, including maintaining the capability for waste retrieval. The performance-derived criteria and environmental design envelope as received from Issue 1.10 (Section 8.3.4.2) must be accommodated in the designs. Issue 4.3 (Section 8.3.4.4) is restricted to the establishment of technologies capable of producing the packages as designed with a high degree of reliability. These technologies do not require site data since the designs will reflect the requirements imposed by the site characteristics.

8.3.4.1.1 Waste package environment

The environment into which the waste package will be placed and the effect of the waste package on that environment are central elements of waste package design and performance analysis. Our present understanding of the environment at the repository level at Yucca Mountain is summarized in Section 7.1 and in the following paragraphs of this overview. The work that has been done to characterize alteration to the environment caused by emplacement of waste packages is described in Section 7.4.1.

The repository would be sited above the water table at Yucca Mountain. The emplacement holes are expected to remain free of standing water for the anticipated range of vadose water percolation rates through the repository level and expected permeability of the host rock. The rock characteristics indicate that the boreholes would remain open except for some sloughing of rock from the borehole wall. This implies that the waste packages will not be subjected to large pressures or stresses from rockfall. The pores in the rock at the repository level are filled with a mixture of air and water. This situation will result in oxidizing conditions in the vicinity of the waste package. The repository rock is expected to contain fractures spaced at intervals that are sufficiently close to produce at least one fracture intersection with each emplacement borehole. Site characterization will allow determination of the range of anticipated conditions.

The vadose water is expected to have a chemical composition of dissolved solids similar to that found in well J-13. The J-13 water is predominantly a dilute solution of sodium bicarbonate with moderate amounts of silica, calcium, and sulfate and small amounts of potassium, nitrate, chloride, and fluoride. This water has been used as the reference water for waste package testing. When water is available from the repository horizon, its composition will be compared with that from well J-13. A program of confirmatory testing will then be developed, based on the level of similarity of the vadose water to that of well J-13, to relate the testing using well J-13 water and the testing based on the vadose water composition.

The repository construction will cause changes in the characteristics of the emplacement environment. These changes could have a substantial impact on the subsequent performance of the waste package. As part of the performance allocation process, goals were established for the level of change that could be tolerated without resulting in an altered situation that would invalidate the waste package components testing program. These goals are discussed in Section 8.3.4.2.

8.3.4.1.2 Waste package components

The reference designs for NNWSI Project waste packages consist of various components that depend on the waste form. For spent-fuel waste packages, the components are the spent fuel (in the form of intact assemblies, boxed consolidated rods, or rods consolidated at the repository) and the container into which the spent fuel would be placed. Spent fuel is considered to consist of the uranium dioxide fuel encased in the cladding in which the fuel saw service in the reactor, together with any associated assembly structural materials. Reprocessed waste from the Defense Waste Processing Facility or the West Valley Demonstration Project will come to the repository as a borosilicate glass waste form inside a stainless steel pour canister. The canister will be placed into a metal container similar to that to be used for spent fuel.

For spent fuel waste packages, an additional component will be evaluated. Because of the uncertainties associated with stress corrosion cracking of metal alloys and because carbon-14 could escape from a waste package as gaseous carbon dioxide should the metal container become cracked, a container with an alumina ceramic inner liner will be evaluated for use with spent fuel. The liner would provide a crack-free, low-permeability barrier between the spent fuel and the metal barrier. The ceramic liner will be developed only if the case for performance of a metal barrier cannot be made with sufficient assurance. The glass waste forms do not have the potential for release of gaseous radioactivity; therefore, the liner will not be considered for use with that waste form.

8.3.4.1.3 Waste package designs

Waste package designs must provide for preclosure and postclosure performance objectives. The criteria for design are based on requirements discussed in Section 7.2.1. The waste package will be designed to provide containment under normal loads imposed by the handling and emplacement systems and will assist in containment under accident conditions. One design approach for the waste package is to obtain information relative to the loads imposed by the handling and emplacement systems and to design the waste package for those load configurations. A second approach is to design the waste package to meet the overall performance objectives and then to design the handling systems around the waste package strength criteria that resulted. The latter approach has been taken for the conceptual design discussed in Section 7.3. However, the waste package must be designed to consider the overall repository system, including considerations of identification, handling or lifting fixtures, and imposed loads. Thus, the waste package design may be modified in the advanced conceptual design report to reflect the overall repository system. Such modifications are not expected to affect the issue resolution strategy or the information needs.

The preclosure control of criticality and limitation of reactive materials and free liquids are independent of site characterization and will be provided for in the design of the operating system and the waste package. Under normal conditions, preclosure release control will be provided by the waste package container and is thus independent of site characteristics. During accident conditions, the waste package will contribute to the overall system, but again the performance is independent of site characteristics. Preclosure (but postemplacement) temperature limitation is not a function of the waste package alone but includes the emplacement configuration and rock thermal properties. The control of preclosure emplacement temperature will require information regarding thermal properties of the rock and is discussed in Section 8.3.2.2. The final requirement, that the design provide for the use of reasonably available technologies to fabricate, assemble, close, and inspect the waste package, is discussed in Section 8.3.4.4. The information needed to design the waste package for preclosure performance objectives is discussed in Section 8.3.4.3.

The postclosure performance objectives require that the waste package design consider site characteristics. Radionuclide containment will be provided during the 1,000 yr after closure by the waste package container and the properties of the waste forms. Therefore, the container must be designed to provide substantially complete containment in the emplacement environment. The materials, fabrication techniques, and material thicknesses will be specified after consideration of the site characteristics discussed in Sections 7.1 and 7.4.1, with additional information needed discussed in Section 8.3.4.2. After 1,000 yr, the performance objective is based on the controlled release rate from the engineered barrier system as specified in 10 CFR 60.113(a)(1)(ii)(B). Demonstration that this objective is met is based on waste form performance. There is no discussion of the waste form design in this section. The focus of NNWSI Project effort is to characterize the release rates of radionuclides from the waste forms under the postemplacement site environmental conditions. The performance allocation and issue resolution related to the postclosure performance assessment are discussed in Sections 8.3.5.9 and 8.3.5.10.

8.3.4.1.4 Waste package modeling

Waste package modeling will be required to support both design and performance information needs. Modeling will be performed to address both preclosure and postclosure information needs. Modeling efforts supporting design include stress analysis for preclosure handling, emplacement and retrieval scenarios, and analysis of stress caused by emplacement borehole failure. Further, design calculations are required for thermal analysis to determine temperatures of waste package components as a function of waste form characteristics.

Postclosure modeling is required to support performance assessment calculations. Much of this activity is included in the waste package performance assessment effort discussed in greater detail in Sections 7.4.5 and 8.3.5.10. Models of the processes that affect loss of containment and radionuclide release will be integrated into the performance assessment calculation models. These models will include the processes of waste form degradation and radionuclide release, barrier degradation, geochemical changes and transport of materials in the waste package environment, and transport analysis within the breached containers.

Many of these modeling activities will synthesize empirical data into mathematical constructs to represent processes that occur following waste package emplacement. The corrosion and waste form degradation and release models are likely to be of this form. Models of other processes mentioned previously will be formulated from the governing differential equations and constitutive relationships. Thermal and mechanical analyses, geochemical equilibrium and kinetics calculations, and hydrothermal flow and transport simulations are expected to be of this form.

The modeling activities will be conducted at two levels. The first level will be a rigorous attempt to simulate processes in two or three dimensions to identify the most sensitive model parameters and obtain a fundamental understanding of the processes. After these modeling activities are complete, a second level of modeling will be used to derive simpler models that are appropriate for use in performance assessment calculations.

Both levels of modeling must demonstrate that the processes are adequately represented for the required waste package performance predictions. Therefore, substantial effort will be required to verify and, to the extent possible, validate these models. The necessity for model validation provides a link to exploratory shaft, laboratory, and integrated testing activities. The understanding of processes can be used to efficiently design experiments that will ultimately provide data for validation purposes.

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Chapter 8

Nuclear Waste Policy Act
(Section 113)

Section 8.3.4.2

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WASTE PACKAGE CHARACTERISTICS (POSTCLOSURE)

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Chapter 8

Section 8.3.4.2

Nuclear Waste Policy Act
(Section 113)

WASTE PACKAGE
CHARACTERISTICS
(POSTCLOSURE)

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8.3.4.2 Issue resolution strategy for Issue 1.10: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.135 and (b) provide information to support resolution of the performance issues?

Regulatory basis for the issue

This issue deals with two aspects of the waste package postclosure behavior. The first aspect relates to the specific requirements contained in Section 135(a) of the NRC rule that states, in part:

(1) Packages for HLW shall be designed so that the in situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages or the performance of the underground facility or the geologic setting.

(2) The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions.

These requirements will be addressed by gathering the information detailed under Information Needs 1.10.1 (Section 8.3.4.2.1) and 1.10.4 (Section 8.3.4.2.4).

The second part of this issue is more global in its application. Many of the performance issues require information on the behavior of the waste package. To provide this information, appropriate testing and analyses of the waste package components and system must be done. To identify appropriate tests and analyses, the service environment for the waste package must be determined.

The waste package environment, upon initial emplacement of the package, will depend on the ambient conditions at the repository level and how those conditions are altered by repository construction and operation. The environment following emplacement will depend on the initial emplacement conditions and how those conditions are altered by the waste package characteristics. Therefore, there is an interactive process between design and environment characterization. The design is initially based on the ambient conditions and a prediction of how those conditions would alter under the stresses applied by repository construction and waste emplacement. Once a design is available, analysis of that design provides a set of environmental stress factors. Testing is then done to determine the effects of those stresses, such as thermal and radiation fields and mechanical stresses, on the package environment. Based on those tests and subsequent analyses, designs may be modified and the test and analysis cycle repeated. The relationships among design, environmental, and performance considerations are presented in Figure 8.3.4.2-1.

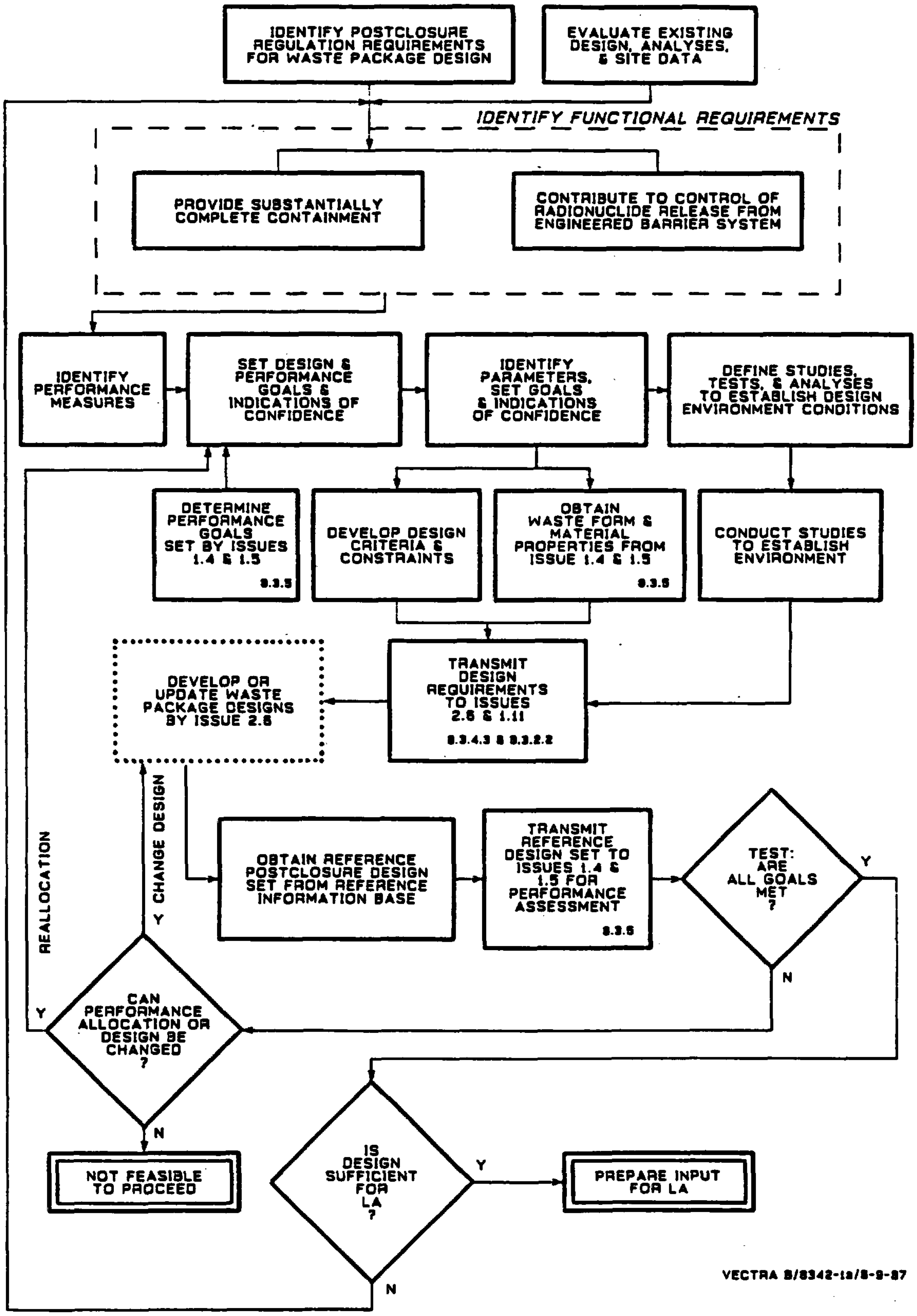

Figure 8.3.4.2-1a. Logic diagram for the resolution of Issue 1.10 (postclosure waste package characteristics). See Figure 8.3.4.2-1b for legend.

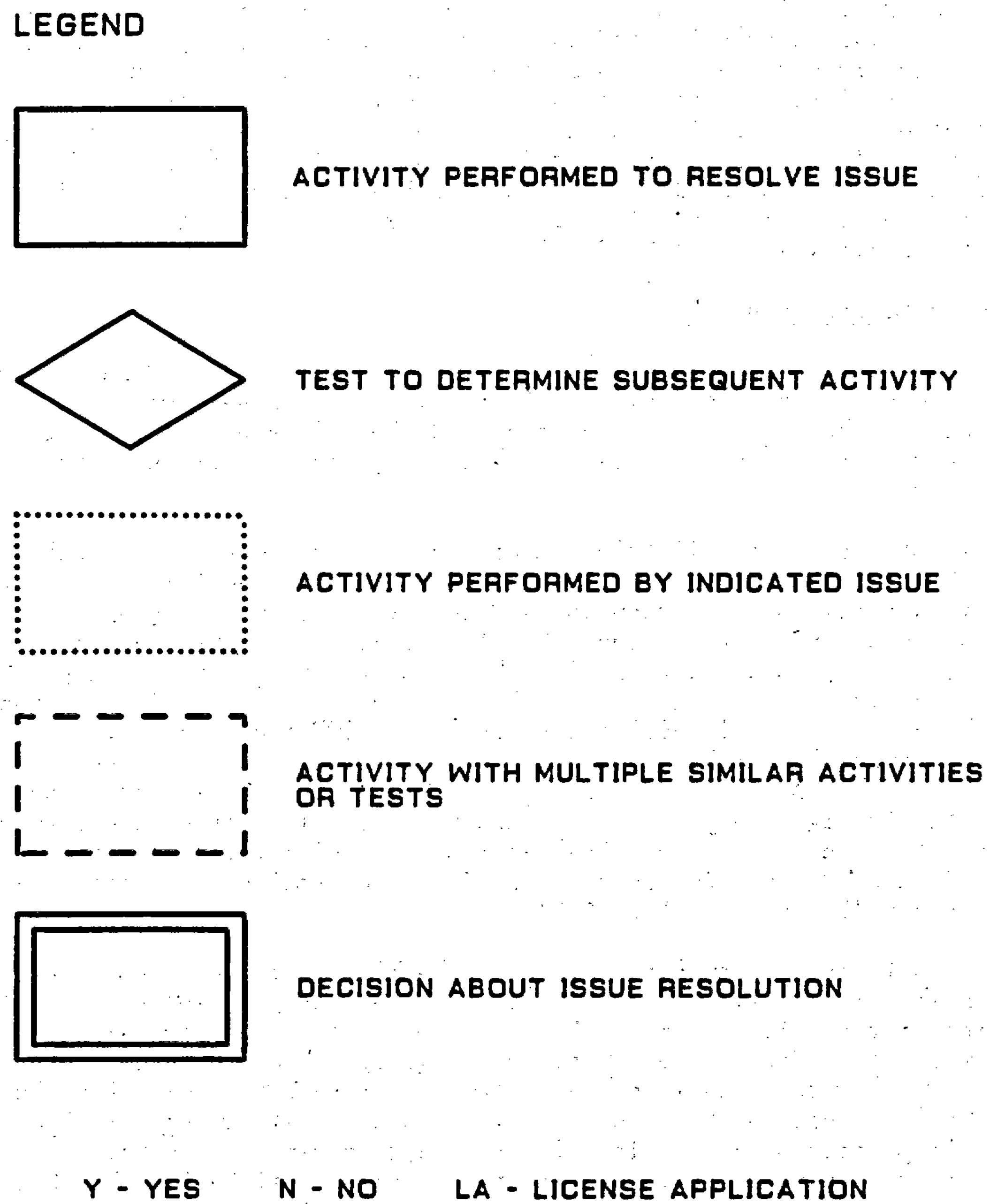

Figure 8.3.4.2-1b. Legend for Figure 8.3.4.2-1a.

The information gathered to resolve this issue will provide the waste package design information and environment description to be used in the performance issues that will describe engineered barrier system compliance with the regulations contained in 10 CFR 60.113. The design and environment description, together with the performance predictions developed under Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10), will provide input data on the source term for radionuclide release, which are necessary to resolve other issues. Source term data will be used in Issues 1.1 (Section 8.3.5.13), 1.8 (Section 8.3.5.17), and 1.9 (Section 8.3.5.18).

Approach to resolving the issue

There are many factors to be considered in the development of waste package designs and the analysis of the effect of those designs on the environment. To resolve this issue, a high degree of interaction between design, site characterization, and waste package component performance analyses is necessary.

Identified by highlighting in Figure 8.3.4.2-2 are the products, models, and submodels that provide input to resolution of Issue 1.10. Issue resolution is accomplished by producing a description of waste package/near-field interactions (Information Need 1.10.1) that addresses the factors identified in 10 CFR 60.135 and incorporating these interactions into waste package design considerations. In Table 8.3.4.2-1 the specific activities that provide data for model development are in the SCP sections indicated, along with the model hierarchy. The models and submodels also provide information necessary for resolution of Issues 1.4 and 1.5 through the input pathways indicated in Figure 8.3.4.2-2. In addition, development of the source term (Information Need 1.5.5) requires as input the near-field flow and transport model developed from the description of the postemplacement, near-field environment (Information Need 1.10.4).

To develop a description of the postemplacement, near-field environment and satisfy Information Need 1.10.4, it is necessary to identify anticipated physical interactions between the as-assembled waste package and the environment that may affect waste container integrity. These physical interactions will be expressed as performance measures that represent design goals for rock-induced load on the waste package, waste package thermal environment, tectonic processes, materials selection, and container handling. These performance measures and their tentative goals are given in Table 8.3.4.2-2. The performance parameters, their respective performance measures, their respective tentative goals, and the expected parameter values are given in Table 8.3.4.2-3. The activities that address these goals are described in Section 8.3.4.2.4.4.

To satisfy Information Need 1.10.4, it is also necessary to obtain input from studies that characterize the postemplacement mineralogy and water quality of the waste package environment (Section 8.3.4.2.4.1), the post-emplacement hydrologic features of the waste package environment (Section 8.3.4.2.4.2) and the postemplacement thermal and mechanical properties of the waste package environment (Section 8.3.4.2.4.3). These characterization activities are required to address performance parameters identified in Issues 1.4 and 1.5. The specific performance parameters, their respective characterization parameters and test bases, and the SCP section describing

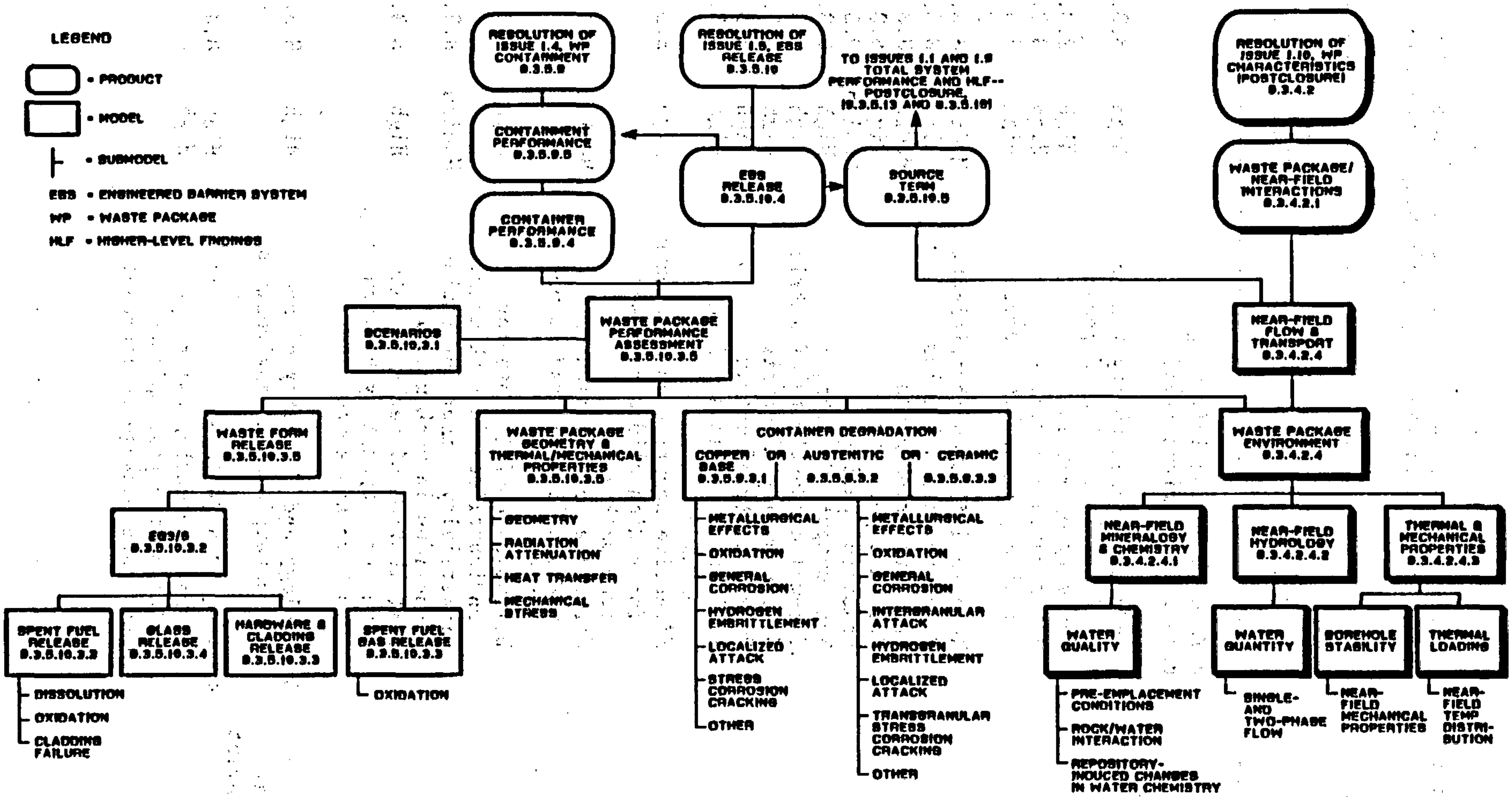

Figure 8.3.4.2-2. Model hierarchy for Issue 1.10 (waste package characteristics--postclosure).

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Table 8.3.4.2-1. Model hierarchy and model inputs for Issue 1.10 (waste package characteristics--postclosure) (page 1 of 3)

Model	Model input	Needed confidence	SCP section[a]
Near-field flow and transport	For Topopah Spring Tuff at repository horizon (TSw2)[b]:		
	Hydraulic conductivity tensor of matrix for liquid phase	High	8.3.1.2.2
	Porosity of matrix	High	8.3.1.2.2
	Water retention curves	High	8.3.1.2.2
	Relative permeability curves	High	8.3.1.2.2, 8.3.4.2.4
	Knudsen diffusion coefficients	Medium	8.3.1.2.2
	Fracture permeabilities	High	8.3.1.2.2
	Fracture orientation	Medium	8.3.1.2.2
	Fracture porosity	High	8.3.1.2.2
	Fracture spacing	Medium	8.3.1.2.2
	Heat output of packages	High	8.3.4.2.2
	Thermal conductivity of matrix	High	8.3.1.15.1
	Heat capacity of matrix	High	8.3.1.15.1
	Bulk density of matrix	High	8.3.1.15.1
	Radionuclide releases from container	High	8.3.5.10.4
	Effective sorption coefficients for radionuclides released from package	High	8.3.1.3.4
	Effective solubilities of radionuclides in vadose pore water	Medium	8.3.1.3.5
	Diffusion coefficients for radionuclides in rock matrix	High	8.3.1.3.6
	Dispersivity tensor for radionuclides in rock matrix	Medium	8.3.1.3.6
	Distribution of recharge rates through repository horizon in time and space	High	8.3.1.2.2
Waste package environment	Mineralogy and chemistry of pre- and postemplacement environment	High	8.3.4.2.4.1
	Near-field hydrology	High	8.3.4.2.4.2
	Thermal and mechanical properties of the postemplacement waste package environment	High	8.3.4.2.4.3

Table 8.3.4.2-1. Model hierarchy and model inputs for Issue 1.10 (waste package characteristics--postclosure) (page 2 of 3)

Model	Model input	Needed confidence	SCP section[a]
Mineralogy and chemistry	Mineralogy and water quality		
	Rock-water interaction at elevated temperature	High	8.3.4.2.4.1.1
	Repository material-induced changes in water chemistry	High	8.3.4.2.4.1.2
	Vadose water composition	High	8.3.4.2.4.1.3
	Dissolution-precipitation effects on water chemistry	Medium	8.3.4.2.4.1.4
	Radiation-induced changes in water chemistry	High	8.3.4.2.4.1.5
	Corrosion-induced changes in water chemistry	Medium	8.3.4.2.4.1.6
Near-field hydrology	Water quantity	High	8.3.4.2.4.2
	Single-phase fluid flow	High	8.3.4.2.4.2.1
	Two-phase fluid flow	High	8.3.4.2.4.2.2
Thermal and mechanical properties	Thermal loading	High	8.3.4.2.4.3
	Near-field temperature distribution	High	8.3.4.2.4.3.1
	Borehole stability	High	8.3.4.2.4.3
	Near-field mechanical properties	High	8.3.4.2.4.3.2
Borehole stability	Fracture orientation and density		
	Average spacing within each borehole	High	8.3.4.2.4.3.2
	Set identification	High	8.3.4.2.4.3.2
	Distribution of orientation	High	8.3.4.2.4.3.2
	Average dip of set	High	8.3.4.2.4.3.2
	Average azimuth of set	High	8.3.4.2.4.3.2
	Fracture stiffness		
	Aperture	Medium	8.3.4.2.4.3.2
	Normal stress	High	8.3.4.2.4.3.2
	Shear stress	High	8.3.4.2.4.3.2
	Joint roughness coefficient	Medium	8.3.4.2.4.3.2
	Fracture shear strength		
	Joint roughness coefficient	High	8.3.4.2.4.3.2
	Joint compressive strength	Medium	8.3.4.2.4.3.2
	Residual friction angle	High	8.3.4.2.4.3.2

Table 8.3.4.2-1. Model hierarchy and model inputs for Issue 1.10 (waste package characteristics--postclosure) (page 3 of 3)

Model	Model input	Needed confidence	SCP section[a]
	Emplacement geometry		
	Hole orientation	High	8.3.4.2.4.3.2
	Hole dimensions	Medium	8.3.4.2.4.3.2
	Thermal properties of rock		
	Coefficient of linear expansion	Medium	8.3.4.2.4.3.2
	Rock temperature	Medium	8.3.4.2.4.3.2
	Mechanical and thermal stress loading		
	Poisson's ratio	Medium	8.3.4.2.4.3.2
	Unit weight	Medium	8.3.4.2.4.3.2
	Principal stress magnitude	Medium	8.3.4.2.4.3.2
	Joint roughness	High	8.3.4.2.4.3.2
	Principal stress orientations	Medium	8.3.4.2.4.3.2
	Mineral alteration		
	Coefficient of thermal expansion	Medium	8.3.4.2.4.3.2
	Modal abundance of water-rock interaction products	Medium	8.3.4.2.4.1.1

[a]The SCP section references for the near-field flow and transport model refer to discussions on the information need level; specific activities for these input parameters are described in the information need discussions.

[b]TSw2 = welded Topopah Spring Member.

Table 8.3.4.2-2. Performance measures and goals for Issue 1.10 (waste package characteristics--postclosure)

System element	Performance measure	Tentative goal	Needed confidence
Engineered environment	Quantity of liquid water that can contact the container	See Issue 1.4 (Table 8.3.5.9-1 Section 8.3.5.9)	
	Quality of liquid water than can contact the container	See Issue 1.4 (Table 8.3.5.9-1 Section 8.3.5.9)	
	Rock-induced load on waste package	Container will not fail when subjected to design basis loads	High
	Temperature vs. time in waste package environment	See Issue 1.11 (Table 8.3.2.2-4, Section 8.3.2.2)	
	Tectonic processes	<0.5% of containers breached	High
Waste package	Select waste package material to contribute to containment	See Issue 1.4 (Table 8.3.5.9-4, Section 8.3.5.9)	
	Constrain waste-handling operations so as not to degrade isolation and containment performance of the waste package	See Section 8.3.2.5	

Table 8.3.4.2-3. Performance parameters and goals for Issue 1.10 (waste package characteristics--postclosure)

Performance measure	Performance parameter	Tentative goal	Needed confidence	Expected parameter value	Current confidence
Rock-induced load on waste package	Load on waste package	<1,000 kg/pkg for 1,000 yr <3,000 kg/pkg between 1,000 and 10,000 yr	High	TBD[a]	Medium
Tectonic processes	Breaching of containers by tectonic processes	<0.5% containers breached	High	See Section 8.3.1.8	

[a]TBD = to be determined.

the activity that addresses each characterization parameter are presented in Table 8.3.4.2-4.

The characterization parameters pertaining to water quality reflect the goal that the chemical characteristics of the water will be similar to those existing in the undisturbed environment in the unsaturated Topopah Spring tuff at Yucca Mountain. The characterization constraints are established because water chemistry is a very sensitive parameter in determining corrosion rates and mechanisms for metals and because changes in water chemistry strongly influence the rock-water interaction and hydrologic properties of the tuff. Typical values for water found below Yucca Mountain are discussed in Section 7.4.1.

The quantity of water that contacts containers is constrained as part of the design strategy to meet the containment and release rate performance objectives established in Issues 1.4 and 1.5. The parameters to be evaluated in meeting this goal concern the hydrologic characteristics of the repository site, which control the rate at which water can be expected to move through the rock.

The borehole stability and thermal loading constraints concern engineering practices that influence the integrity of the waste package. In addition, the thermal loading goals provide for an environment for a large fraction of the waste packages that will be above the boiling point of water for the period of time indicated in Issue 1.4 (Section 8.3.5.9). This goal contributes to the strategy to meet the release rate performance objective.

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 1 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5)	Water quality	Vadose water		8.3.4.2.4.1.3
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
		Rock-water interaction		8.3.4.2.4.1.1
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 2 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Rock-water interaction (continued)		
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
		Temperature	±5°C	
		Composition of solid reactants and products	±10 wt% of elemental abundance for those elements that comprise more than 5 wt% of minerals analyzable on the electron microprobe.	
		Reactant surface area	±20% for BET[b] surface area measurements	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 3 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Rock-water interaction (continued)		
		Modal abundance of solid reactants and products	±20% for optically identifiable phases	
		Dissolution and precipitation		8.3.4.2.4.1.4
		pH	±0.5 (1)	
		Mineral composition	±10 wt% of elemental abundance for those elements that comprise more than 5 wt% of minerals analyzable on the electron microprobe.	
		Composition of product fluid	±10% for those elements that constitute more than 10% (atomic) of the mineral phase.	
		Mineral structural state	±20% for the degree of disorder in the crystal lattice	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 4 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Repository materials effect on water chemistry		8.3.4.2.4.1.2
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
		Temperature	±5°C	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 5 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rat (Issue 1.5) (continued)	Water quality (continued)	Repository materials effect on water chemistry (continued)		
		Composition of solid reactants and products	±10 wt% of elemental abundance for those elements that comprise more than 5 wt% minerals analyzable on the electron microprobe.	
		Reactant surface area	±20% for BET surface area measurements.	
		Modal abundance of solid reactants and products	±20% for optically identifiable phases.	
		Radiation effects		8.3.4.2.4.1.5
		Temperature	±5°C	
		Radiation dose rate	0-100 krad/h	
		Degree of water saturation in experiment atmosphere	±20%	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 6 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Radiation effects (continued)		
		Nature of solid materials	Chemicals and structural characterization of material sufficient to allow fluid and gas composition to be experimentally reproduced to within ±20%.	
		pH	±1(1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 7 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Radiation effects (continued)		
		Cations present at >40 mg/L	±20 mg/L (1)	
		Formate ions	±30% (1)	
		Oxalate ions	±30% (1)	
		HNO_3	±20% (1)	
		Nitrite:nitrate ratio	±30% (1)	
		CO_2	±20% (g)	
		O_2	±20% (g)	
		NO_x	±20% (g)	
		N_2	±20% (g)	
		NH_3	±30% (g)	
		Corrosion products		8.3.4.2.4.1.6
		Temperature	±5°C	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 8 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Corrosion products (continued)		
		Composition and mineralogy of corrosion products	Chemical and structural material characterization sufficient to allow fluid and gas composition parameters to be experimentally reproduced to within ±20%	
		Degree of water saturation in experiment atmosphere	±20%	
		pH	±1 (1)	
		F^-, Cl^-	±1 mg/L (1)	
		PO_4^{3-}	±1 mg/L (1)	
		NO_3^-, SO_4^{2-}	±5 mg/L (1)	
		CO_3^{2-}, HCO_3^-	±30 mg/L (1)	
		Anions not specified	±1 mg/L (1)	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 9 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quality (continued)	Corrosion products (continued)		
		Cations present at <6 mg/L	±1 mg/L (1)	
		Cations present at 6 to 40 mg/L	±5 mg/L (1)	
		Cations present at >40 mg/L	±20 mg/L (1)	
	Water quantity	Single-phase fluid		8.3.4.2.4.2.1
		Nature of fluid phase	Liquid or gas	
		Number of rehydration and dehydration cycles	Number of cycles must be sufficient to attain steady state permeability	
		Temperature	±5°C	
		Relative permeability	±20%	
		Fracture permeability	±20%	
		Degree of saturation	±50%	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 10 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Water quantity (continued)	Single-phase fluid (continued)		8.3.4.2.4.2.2
		Resistivity	±15%	
		Magnitude of thermal gradient	±20%	
		Two-phase fluid flow		8.3.4.2.4.2.2
		Number of rehydration and dehydration cycles	Number of cycles must be sufficient to attain steady state permeability	
		Temperature	±5°C	
		Relative permeability	±20%	
		Fracture permeability	±20%	
		Degree of saturation	±50%	
		Resistivity	±15%	
		Magnitude of thermal gradient	±20%	
		Gas:liquid ratio	±20%	

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 11 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Thermal loading	Near-field temperature distribution		8.3.4.2.4.3.1
		Thermal properties (initial temperature, heat capacity, thermal conductivity) for TSw2 as identified in Section 8.3.2.2 (Issue 1.11, configuration of underground facilities (postclosure))	See Table 8.3.2.2-5	8.3.2.2
		Package emplacement geometry	TBD[c] by repository design	8.3.2.2.6
		Package spacing	TBD by repository design	8.3.2.2.6
		Heat output of waste packages	TBD by package design, Issue 2.6	8.3.5.10.1
	Rock-induced loading	Near-field stress distribution and rock displacements		8.3.4.2.4.3.2

Table 8.3.4.2-4. Input parameters for characterization models for Issue 1.10 (waste package characteristics--postclosure) (page 12 of 12)

Issue	Performance parameter	Characterization parameter	Test basis[a]	SCP section
Containment (Issue 1.4) and Release rate (Issue 1.5) (continued)	Rock-induced loading (continued)	Near-field stress distribution and rock displacements (continued)		
		Mechanical properties (Young's modulus, Poisson's ratio, compressive strength, etc.) for TSw2 as identified in Section 8.3.2.2 (Issue 1.11)	See Table 8.3.2.2-5	8.3.2.2
		Fracture (joint) characteristics (shear and normal stiffness, orientation, frequency, etc) for TSw2 as identified in Section 8.3.2.2 (Issue 1.11)	See Table 8.3.2.2-5	8.3.2.2

[a]Unless otherwise stated, the specified percentages and plus-and-minus values are characterization goals that indicate the maximum experimental uncertainty for measurements of the indicated parameter. (l) indicates species in the liquid phase, (g) indicates species in the gas phase.

[b]BET = Brunauer-Emmett-Teller.

[c]TBD = to be determined.

As part of the issue resolution strategy, a design envelope for the waste package has been developed. This envelope is based on present knowledge of the site characteristics (with due consideration for the associated uncertainties) and on the known properties of the waste forms (Chapter 7). In the following eight sections (A through H), the design envelope is described and the goals for characterization, design, or performance of each part of the design envelope are discussed.

A. <u>The emplacement hole geochemical system</u>

The characteristics of the host rock mineralogy and chemistry have been established by study of surface outcrop and drill core samples of Topopah Spring tuff located around the exploratory block. The welded, devitrified Topopah Spring tuff from the level of the potential repository shows little variation in chemistry. Because of the limited degree of variability expected in rock chemistry and mineralogy and the need for detailed characterization of the rock (Section 8.3.1.3), additional characterization goals related to rock chemistry are not needed.

Currently, the reference water chemistry is based on water from well J-13, which is located east of the repository block. This well was chosen because of the similarity of its water chemistry to that found in water below the exploratory block. Samples of vadose water from the repository horizon have not yet been obtained. Since the water chemistry plays a critical role in determining the performance of the waste package components, it is necessary to set a goal for the degree of characterization of water chemistry to be accomplished during site characterization. The test bases (or degree of characterization needed for this issue) for the water chemistry characterization parameters will be accomplished in the geochemistry program (8.3.1.3). These test bases are specified to establish the mean value of water chemistry parameters so that the standard deviation of the mean is no greater than the values given in the following list (note that this establishes only how well the mean value must be known; it does not constrain what the value must be). The bases for the limits were the effects of each of the parameters on waste package component performance.

<u>Characterization goal for water chemistry.</u> The characterization parameters for water chemistry are identified in Table 8.3.4.2-4 along with their test bases (or degree of characterization needed) for this issue. The characterization parameters and test bases for the geochemistry program follow:

Characterization parameters	Test basis
pH:	±1 pH unit
Anions:	±1 mg/L for F^-, Cl^-, PO_4^{3-}
	±5 mg/L for NO_3^- and SO_4^{2-}
	±30 mg/L for CO_3^{2-} plus HCO_3^-
	±1 mg/L for all other anionic species

Characterization parameters	Test basis
Cations:	±1 mg/L for species present at less than 6 mg/L
	±5 mg/L for species present at 6 to 40 mg/L
	±20 mg/L for species present at over 40 mg/L
Colloids:	±1 mg/L
Organics:	±1 mg/L
Neutral species:	±1 mg/L

The numerical values for these test bases are established so that they are analytically achievable and are sufficiently constrained so that they do not introduce large uncertainties into the metals and waste form testing results.

The pH is important because of the sensitivity of glass dissolution rates, actinide solubility and speciation, and metal corrosion mechanisms to pH. Fluoride and chloride are deleterious to metal performance, and phosphate can be corrosive to glass; therefore, their abundance in water must be well characterized. Carbonate and bicarbonate are beneficial in that they buffer the pH of the water but are detrimental in that they can form complexes with actinides. A moderate level of precision is needed for these species. Colloids and organic materials may significantly affect transport properties of radionuclides; therefore, a high level of precision is required. Other elements are needed to provide a complete analysis so that charge balance calculations can be used to evaluate the quality of the analysis.

If the site is found to be laterally inhomogeneous to the extent that the characterization goals cannot be met for the site considered as a single unit, the site will be separated into regions for which the characterization goals will apply.

B. The emplacement hole and near-field hydrologic system

The characteristics of the hydrologic system at Yucca Mountain will be determined in the geohydrology program (Section 8.3.1.2). A discussion of the expected hydrologic system in the unsaturated zone is provided in Chapters 3 and 7. Further studies will be conducted under activities described in Information Need 1.5.5 (Section 8.3.5.10.5). The hydrologic parameters that are most important to waste package design and performance are the percolation rate of water through the repository horizon and the flow paths for the water. Of particular interest are the proportion of the flow that occurs in fractures and the variation of the proportion of fracture flow as a function of percolation rate.

Studies will be conducted under activities described in Information Need 1.10.4 (Section 8.3.4.2.4.4) that will characterize the hydrology of the waste package environment. This characterization will establish the extent to which the near-field hydrologic system will contribute to meeting the performance goal set in Issues 1.4 and 1.5 for amount of water that can contact a waste container.

The heat associated with the waste package will perturb the near-field flow paths. Studies to investigate the amount of perturbation and its effects are described in Information Need 1.10.4 (Section 8.3.4.2.4).

The construction of the repository may alter the local hydrologic system. This alteration might be caused by disturbance of the rock mass, the introduction of water during construction, dehydration of the rock mass through use of ventilation systems, or other causes. Some of these alterations could be beneficial to waste package performance; others could be detrimental.

Because of the importance of water volumes, flow paths, and flow rates in the assessment of waste package performance, performance goals for the near-field hydrologic system have been set in Issues 1.4 and 1.5. The goals that are set for an individual waste package are based on a conservative estimate of the amount of water that could contact the ensemble of waste packages in a given year. The goals apply to anticipated processes and events.

The goals for the amount of water contacting waste packages are based on a conservative upper bound of current percolation rate through the repository horizon (i.e., 0.5 mm/yr (Montazer and Wilson, 1984)), and a factor of additional conser-vatism. At the 0.5-mm/yr flux, 0.25 L/yr is approximately the annual quantity of water that would pass vertically through the projected area above a 76-cm-diameter, vertical emplacement borehole. Applying a factor of 20 for added conservatism, one obtains an annual volume of 5 L passing through that projected area. Other values, either more or less conservative, may be obtained by similarly scaling the volumetric flow of 0.25 L/yr.

Note that these goals on the quantity of water contacting the waste packages are applied without considering whether the water could actually enter the borehole. In an unsaturated host rock, water would not normally enter a borehole unless a saturated region had formed above the borehole, large enough in the vertical direction to provide pore pressures sufficiently high to overcome the capillary pressures at the borehole surface. This condition is not currently anticipated in the unsaturated zone of the repository horizon.

Further, the quantitative values of these factors and the corresponding annual amounts of water are not intended to correspond to either saturated or unsaturated flow conditions. They are intended to provide guidance for the required performance of repository seals for anticipated processes and events. In addition, based on present knowledge of the hydrology of Yucca Mountain, these values are sufficiently large to compensate for uncertainties in our current level of understanding of the unsaturated zone at the repository level.

Analyses conducted under Issue 1.11 (Section 8.3.2.2) will determine if the goals have been achieved. Note that the water volumes allowed for long-term water control greatly exceed those expected based on the current estimates of upper bounds on percolation rates through the repository horizon.

Design goal for water flux control. The repository will be designed and constructed so that, for anticipated processes and events, the following conditions will be met with a high level of confidence:

1. There will be no liquid water in the emplacement borehole immediately before emplacement of the waste package, and conditions will be such that no liquid water can contact the waste package during the period from package insertion until repository closure.

2. For the first 300 yr after repository closure, no liquid water will contact 90 percent of the waste packages, and less than 5 L per package per yr will contact the remaining 10 percent.

3. During the period from 300 to 1,000 yr after repository closure, the amount of liquid water that will contact 90 percent of the waste packages will be less than 5 L per package per year, and less than 20 L per package per yr will contact the remaining 10 percent.

4. During the period from 1,000 to 10,000 yr after repository closure, the amount of water that will contact the waste packages will be less than 20 L per package per year.

C. Emplacement hole drainage

The previous section discusses the design goals for water contacting waste packages in a given year. These goals were based on water influx. It is also necessary to determine if water entering the borehole can drain at a sufficient rate to ensure that standing water does not accumulate. The use of a borehole liner might influence drainage in two ways. First, corrosion products from the liner might be flocculent and lead to plugging of the rock pores, thereby decreasing permeability of the rock matrix. Second, for a vertical borehole, a liner with an unperforated bottom plate would totally block drainage. For a horizontal emplacement hole, a liner placed in a hole that was not sufficiently inclined to promote drainage might lead to local accumulations of standing water. Another factor that might alter the drainage capability of emplacement boreholes is the choice of drilling method.

The accumulation of standing water in boreholes would lead to deleterious effects on the waste package performance. For that reason, as part of the performance allocation process, a design goal for drainage from the boreholes has been set. The analyses to show that this goal has been met are described under Issue 1.11 (Section 8.3.2.2).

Design goal for drainage of emplacement boreholes. The borehole and its engineered components, such as liners, shall be designed and constructed so that for anticipated processes and events, the following conditions will be met with a high level of confidence:

1. The borehole will not fill with standing water under anticipated

conditions at any time up to 10,000 yr following repository closure.

2. For the first 1,000 yr following repository closure, no more than 5 L of standing water per waste package will accumulate in emplacement boreholes.

D. Emplacement hole configuration and stability

The configuration of the emplacement boreholes is important in developing scenarios for waste package container degradation and subsequent radionuclide release rate analysis. For a horizontal emplacement configuration, one can envisage some conditions in which water could drip from a fracture onto a waste package. For a vertical borehole, this scenario seems very unlikely since the borehole plug will shield the package from dripping water.

The emplacement hole configuration may also affect the stability of the borehole and be a deciding factor in whether it will be necessary to use a borehole liner. As discussed previously, the liner can affect drainage from the borehole. The liner could also produce interactions with the waste package; this concern is discussed later under item H.

The need for information on the emplacement hole configuration will be met by close interaction between the repository and waste package designers (Information Need 1.10.3, Section 8.3.4.2.3). It is necessary to set a goal to establish what rock-induced loads must be borne by the waste package. Analyses to determine that the borehole stability meets the goal are conducted under Information Need 1.10.4 (Section 8.3.4.2.4) as shown in Tables 8.3.4.2-2 and 8.3.4.2-3.

Design goal for rock-induced load on the waste package. The emplacement hole will be designed and constructed so that the following conditions will be met with a high level of confidence:

1. Less than 0.5 percent of the containers will be breached by anticipated tectonic processes and events during the first 1,000 yr after closure.

2. For 1,000 yr after closure, the stability analysis will show with a high level of confidence that the rock-induced load on a waste package will be less than 1,000 kg.

3. For 10,000 yr after closure, the stability analysis will show with a moderate level of confidence that the rock-induced load on a waste package will be less than 3,000 kg.

4. Emplacement boreholes will be cleaned of debris before use.

E. Thermal loading of the waste package and the repository layout

The thermal loading of the waste package and the repository layout are interactive parameters. It may be necessary to vary the loading per package and the number of packages per unit area of repository to achieve the desired thermal effects. Thermal loadings that keep the waste package near-fieldenvironment above the boiling point of water will assist in achieving the goal set for the amount of water that can contact the waste packages. On the other hand, the thermal loadings must be kept sufficiently low so that waste form temperature limits are not exceeded. These temperature limits are based on the waste form properties and were set to limit degradation of the waste form performance from thermal transients in the early stage of repository history.

The primary information needed to design thermal loadings is the power output of the waste form. Most of the waste that will go into the repository has not yet been generated. Extrapolations of waste age, spent fuel burnup, and other parameters are necessarily uncertain. The design goal for thermal loading is based on two concepts. The first is to maintain adequate flexibility to allow for the uncertainties. The second is the setting of a characterization goal. This goal, combined with a flexible repository layout, will allow the thermal loading during the operation stages of the repository to achieve the desired thermal effects.

Design goal for thermal loading. The design goals for thermal loading include the following:

1. The repository layout will be designed so that the thermal loading characteristics will assist in keeping liquid water from contacting the waste packages for the first 300 yr after closure. It will also ensure that the design-limit temperatures for waste forms are not exceeded.

2. The waste forms will be characterized sufficiently well so that the radionuclide inventory at the time of emplacement will be known to within ±20 percent for each nuclide that represents 5 percent or more of the radioactivity in the packages at any time during the first 1,000 yr after emplacement.

The information to show that part 1 of the goal is met is developed in the resolution of Issue 1.11 (Section 8.3.2.2); part 2 is addressed in Section 8.3.5.10.1 under Information Need 1.5.1.

F. Waste package container material

The selection of the material from which to fabricate the waste package container is important for a variety of reasons. The material choice may be a factor in meeting the performance objective for the containment period and may affect the radionuclide source term for total system performance assessment. The issues related to long-term performance of the container material are discussed under Issue 1.4 (Section 8.3.5.9). This section discusses those aspects of container selection that influence the chemistry of the near-field environment and that influence the design of the waste package.

The effect of the container material on the near-field environment is through the interaction of container corrosion products with the environment. The corrosion rate for the material is determined under Issue 1.4 (Section 8.3.5.9); the effect of the corrosion products on water chemistry is evaluated under Information Need 1.10.4 (Section 8.3.4.2.4). To limit the volume of the corrosion products to be considered, a design goal on the rate of material loss caused by uniform corrosion has been set. The goal is set to provide information on the geometry of the container needed for use in resolving Issue 1.5 (Section 8.3.5.10).

The material choice influences waste package design through a number of considerations, which are evaluated under Information Needs 1.4.1, 1.4.2, and 1.4.3 (Section 8.3.5.9). First, the uniform corrosion rate establishes a minimum thickness of metal for the container. Second, mechanical properties of the container material determine some of the design parameters such as thickness, handling-device shape, and contours of the container. To allow for these considerations, a design goal has been established for the container material.

Design goal for the container material with respect to waste package design and environmental concerns. The container material will be selected so that the following conditions are met with a high level of confidence.

1. The container material will have mechanical properties such that the container will not fail due to mechanical causes when subjected to design basis loads under anticipated conditions for 1,000 yr.

2. The container material will have degradation rates by uniform oxidation and uniform corrosion so that no more than 90 percent of the container wall thickness will be removed by these mechanisms over the first 10,000 yr following repository closure.

The rationale for those conditions and the analyses required to show that these goals will be met are discussed in Section 8.3.5.9 (Information Needs 1.4.1, 1.4.2, and 1.4.3).

Goals for the container material that relate to meeting the containment period performance objective are discussed in Section 8.3.5.9.

G. Waste package fabrication and handling before emplacement

The waste package container material must be capable of being fabricated to design specifications in a reliable manner. The final closure for the container must be capable of being made and inspected under remote operating conditions, with a high level of confidence that defective closures will be detected. The fabrication and closure processes must not degrade the performance of the container material in ways that will preclude meeting the performance objectives discussed under Issue 1.4 (Section 8.3.5.9).

Design goal for fabrication. The fabrication process for the body of the container, including the unique container identification, will not cause an increase in the degradation rate of the material by a corrosion process that might operate in the repository to levels that would cause the performance goals set under Issue 1.4 (Section 8.3.5.9) not to be met.

Design goal for closure. The closure process will be capable of being done and inspected under remote conditions with a reliability such that the container would be capable of passing a standard helium leak test at the level of 1×10^{-7} atm-cm^3/s. The level of undetected defective closures will be shown to be less than 1 percent.

Analyses to show that these goals will be met are discussed under Information Need 1.10.2 (Section 8.3.4.2.2).

Design goal for handling. The surface-handling and emplacement operations might cause damage to the container. To limit such damage, care must be taken during the loading of the container, the closure of the container, any surface-handling and storage operations, and emplacement of the container into the repository.

To avoid damage from handling that affects performance, the following conditions are set:

1. The container will not be allowed to contact corrosive chemicals during the surface-handling and emplacement operations.

2. Any container that is subjected to an impact load equivalent to a free fall of 10 cm during handling will not be emplaced. The 10-cm free-fall condition is tentative.

3. Any container that is scratched so that the metal is thinned by 1 mm or more will not be emplaced.

4. Any container that has experienced an unusual process history that would cause new corrosion considerations to arise will not be emplaced.

These conditions are based on the criterion that the containment function of the waste package will be preserved during handling. The conditions are established to be achievable within the surface facility and repository setting.

H. Alteration to the environment caused by nonwaste package components

One of the largest areas of uncertainty and concern with respect to the package design envelope is the effect of repository construction materials on the local environment of the packages. To remove some of the uncertainties, as part of the performance allocation process, some limits have been established on the allowed effects on the environment from repository construction. These limits can generally be met by suitable choice of construction materials. In some instances, materials with undesirable effects on the vadose water chemistry can be used, as long as it can be shown that the affected water cannot contact a waste package.

The immediate vicinity of the waste package will be influenced by the choice of borehole liner material. Thus, two design goals for the liner material have been set. The other materials that might be present in sufficient quantities to cause major changes to water chemistry are the grout and concrete-type materials used for ground supports and for sealing shafts and boreholes. For vertical emplacement, either a specially designed material will be needed or a hole plug design that does not use conventional grout or concrete will have to be used. (Conventional grouts and concretes result in a very high water pH, which is unacceptable from the point of view of long-term waste form performance). For horizontal emplacement, conventional materials might be adequate, provided that the hydrologic system is sufficiently well understood to show that the grout-affected water cannot contact waste packages.

Two design goals were set for the borehole liner, and a single unified design goal was set for the alterations to water chemistry for water that might encounter waste packages.

Design goals for the borehole liner. The two design goals for the borehole liner are as follows:

1. The corrosion rate of the borehole liner by uniform corrosion will be within a factor of 2 of that for the container material. This will be demonstrated in analyses done under Information Need 1.4.2 (Section 8.3.5.9.2).

2. The borehole liner shall be a member of the same alloy family as the container material (i.e., if the container material is an austenitic stainless steel, then the liner will also be an austenitic stainless steel). The liner material used in repository designs will reflect this requirement for compatibility (Issue 1.11, Section 8.3.2.2).

These goals are established to avoid significant galvanic effects between the container and borehole liner and to avoid generation of colloids.

Design goal for alteration of water chemistry. Repository engineered barriers and shaft and borehole seals will be designed and constructed so that the changes in water chemistry resulting from interaction of those materials with the vadose water (characterized earlier under item A) for water that might contact a waste package will be within the limits established in Issue 1.4. Analyses to show that this has been achieved are given in resolution of Issues 1.11 (Section 8.3.2.2) and 1.12 (Section 8.3.3.2).

Limits to alteration of water chemistry. Interactive effects between ions in solution and the consequences of these interactions for container and waste form performance require that limits be placed on the extent to which the concentration of certain species may be modified by repository construction materials. The numerical values for these limits are as follows:

Characterization parameters	Test basis
pH:	± 1pH unit
Anions:	+1 mg/L for F^-, Cl^-, and PO_4^{3-}
	+10 mg/L for NO_3^- and SO_4^{2-}
	+50 mg/L for CO_3^{2-} plus HCO_3^-
	+1 mg/L for all other anionic species

Characterization parameters	Test basis
Cations:	+1 mg/L for species present at less than that level in the vadose water
	+10 mg/L for CA^{++}, K^{+}, and Mg^{++}
	+30 mg/L for Na^{+}
	-5 mg/L for Si^{4+}, no limit to increase
Colloids:	+1 mg/L
Organics:	+1 mg/L
Neutral species:	+1 mg/L

Interrelationships of the information needs

This issue involves development of the reference waste package designs and determination of the effect of those designs on the waste package environment. It also involves establishing that the designs comply with the requirements of 10 CFR 60.135. Because this latter item involves a specific set of requirements, it has been cast as a separate Information Need 1.10.1 (Section 8.3.4.2.1).

The reference waste package designs will be developed from a consideration of our understanding of the service environment. As such, Information Needs 1.10.2 (Section 8.3.4.2.2) and 1.10.4 (Section 8.3.4.2.4) are interactive. Information Need 1.10.3 (Section 8.3.4.2.3) relates to the emplacement configuration. It has been cast as a separate information need to highlight the uncertainties associated with the present situation, which includes both vertical and horizontal emplacement as options, and to facilitate issue resolution when the final emplacement mode is chosen.

When the emplacement mode is chosen, and when the waste package design is completed, the analyses required to satisfy Information Needs 1.10.1 (Section 8.3.4.2.1) and 1.10.4 (Section 8.3.4.2.4) will be performed. The results of these analyses, if favorable, will resolve the issue.

The schedule information provided for information needs in this section includes the sequencing, interrelationships, and relative durations of the studies in the information need. Specific durations and start/finish dates for the studies are being developed as part of ongoing planning efforts and will be provided in the SCP at the time of issuance and revised as appropriate in subsequent semiannual progress reports.

8.3.4.2.1 Information Need 1.10.1: Design information needed to comply with postclosure criteria from 10 CFR 60.135(a) for consideration of the interactions between the waste package and its environment

Technical basis for addressing the information need

The general design criteria contained in 10 CFR 60.135(a) are stated in the context of the in situ properties of the waste package and the interactions between the package and its emplacement environment. These properties and interactions are evaluated to ensure that the function of the waste packages, the performance of the underground facility, or the geologic setting is not compromised.

The criteria require that the design consider a number of factors relating to the performance of the waste packages and their interaction with the environment. The basis for addressing this information need will be to show that the relevant factors have been evaluated in the design.

Link to the technical data chapters and applicable support documents

The work that has been undertaken to date to characterize the performance of the waste package components and the interactions of the waste packages with the near-field environment is discussed in Chapter 7. Specifically, Section 7.4.1 describes the examination of the ambient environment and the changes induced by the introduction of the waste packages. Sections 7.4.2 and 7.4.3 describe the examinations of the performance of the package components under conditions representative of those expected in the repository.

Parameters

The parameters associated with this information need are the relevant postclosure properties and interactions that are stated in 10 CFR 60.135(a)(2) as factors to be considered and include the following:

1. Solubility.
2. Oxidation-reduction reactions.
3. Corrosion.
4. Gas generation.
5. Thermal loads and effects.
6. Mechanical strength and stress.
7. Radiolysis and radiation damage.
8. Radionuclide retardation and leaching.
9. Synergistic interactions.

Interactions and coupled effects involving some of these parameters are also discussed in Section 8.3.2.1.

Logic

The logic to be used in addressing this information need is basically one of integration. The information is developed within other information needs, where the nature of the in situ properties of the waste package and the interactions of the package with the near-field environment are characterized and analyzed.

8.3.4.2.1.1 Design Activity 1.10.1.1: Consideration of 10 CFR 60.135(a) factors

Objectives

This activity will explicitly show that the factors specified in 10 CFR 60.135(a) and listed as parameters for this information need have been considered in the waste package design. The evaluation will identify those factors that could potentially compromise the function of the waste package, the performance of the underground facility, or the geologic setting.

Parameters

The parameters for this activity are given in the list for the information need.

Description

The information to be used in the evaluation will be derived from the studies undertaken in other information needs. Specifically, the information to show that the factors that could potentially compromise the function of the waste package have been considered will be included in the performance analyses done in Information Need 1.4.5 (Section 8.3.5.9.5) and 1.5.4 (Section 8.3.5.10.4). The information to show that the interactions of the package with emplacement environment have been considered will be taken from the studies done in Information Need 1.10.4 (Section 8.3.4.2.4).

8.3.4.2.1.2 Application of results

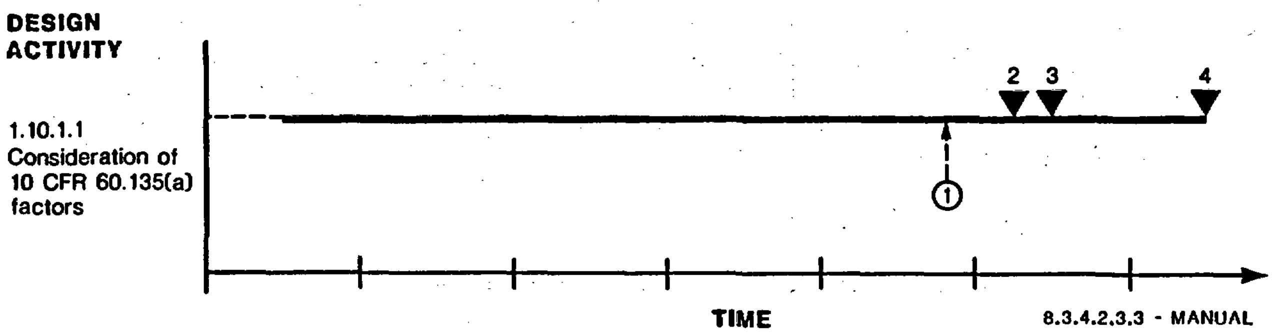
The results of the analysis done under this information need will be used to show explicitly that the factors enumerated in the regulation have been considered in the design and that the properties and interactions meet the requirements for not compromising the waste package functions, performance of the repository, or geologic setting. This analysis will then directly contribute to the resolution of this issue (1.10).

8.3.4.2.1.3 Schedule and milestones

This information need on waste package design information contains one design activity: 1.10.1.1 (consideration of 10 CFR 60.135(a) factors). In the figure that follows, the schedule information for this activity is presented in the form of a timeline. The timeline extends from the start of the activity to the issuance of the final products associated with the activity. Summary schedule and milestone information for this information need can be found in Section 8.5.4.

This information need involves experimental work and modeling that progress in parallel with other Issue 1.10 activities and that are currently ongoing. Activities in this information need are not currently constrained by other program elements. As the activity progresses, interfaces with other information needs become more important.

The activity number and title corresponding to the timeline are shown on the left of the following figure. The points shown on the timeline represent major events or important milestones associated with the activity. Solid lines represent activity duration, and dashed lines show interfaces. The data input and output at the interfaces are shown by circles.



The points on the timeline are described in the following table:

Point number	Description
1	Data input from Information Need 1.10.4 (near-field environment).
2	Milestone M264. Complete development of models for integrated testing of waste forms with ground water and container material.
3	Milestone Z471. Issue preliminary report on waste package interaction with the environment.
4	Milestone M271. Issue final waste package environment document.

8.3.4.2.2 Information Need 1.10.2: Reference waste package designs

Technical basis for addressing information need

Link to the technical data chapters and applicable support document

Conceptual waste package designs are described in Section 7.3. These designs have been developed during the conceptual design phase and include both reference designs (Section 7.3.1) and alternative designs (Section 7.3.2).

Parameters

The parameters that require documentation to fulfill this information need are in two categories: (1) physical characteristics and (2) output characteristics. The parameters are required for all waste forms planned for packaging and disposal. They include the variations in the characteristics that will occur as a result of both the inherent range of waste forms to be accommodated and the anticipated time-dependent variations over the operating life of the repository.

The physical characteristics include

1. Number of packages of each type as a function of time.

2. Internal and external configurations of the packages, with dimensions and tolerances.

3. Package weights and weight distributions.

4. Mechanical and thermal properties of the package component materials.

The output characteristics include

1. Decay-heat generation rates of the waste packages.

2. Ionizing radiation fluxes at the external surfaces of the packages.

Logic

The principal purpose of this information need is to provide a source of reference (and alternative) waste package design data that is traceable to the NNWSI Project technical baseline for use in the analysis of the projected performance of the engineered barrier system. In addition, the waste package characteristics are needed to support the definition of appropriate materials testing environments, both at laboratory and in situ scales, and to provide design input to the repository facilities, equipment, and operations design activities.

This information need does not require site characterization studies, tests, or analyses. The design information that is collected under this topic is developed as an integral part of the design process. A substantial portion of the information that supports the design process is baselined at the Office of Civilian Radioactive Waste Management Program level. Other baselined input is controlled at the NNWSI Project level in the technical baseline. The detailed waste package design studies and analyses will be documented in the advanced conceptual and license application design reports. Interim design information will be maintained and controlled in the NNWSI Project reference information base.

8.3.4.2.2.1 Application of results

The reference (and alternative) waste package design information will be used in Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10) to provide the configurations and output characteristics to be used in the analyses of the postclosure performance of the waste packages and the engineered barrier system. In addition, the information will be used in support of the repository design in Issues 1.11 and 2.7 (Sections 8.3.2.2 and 8.3.2.3). Within this issue, the waste package design information, in combination with the emplacement configuration information described in Information Need 1.10.3 (Section 8.3.4.2.3), will be used to determine the near-field temperature history for the waste packages.

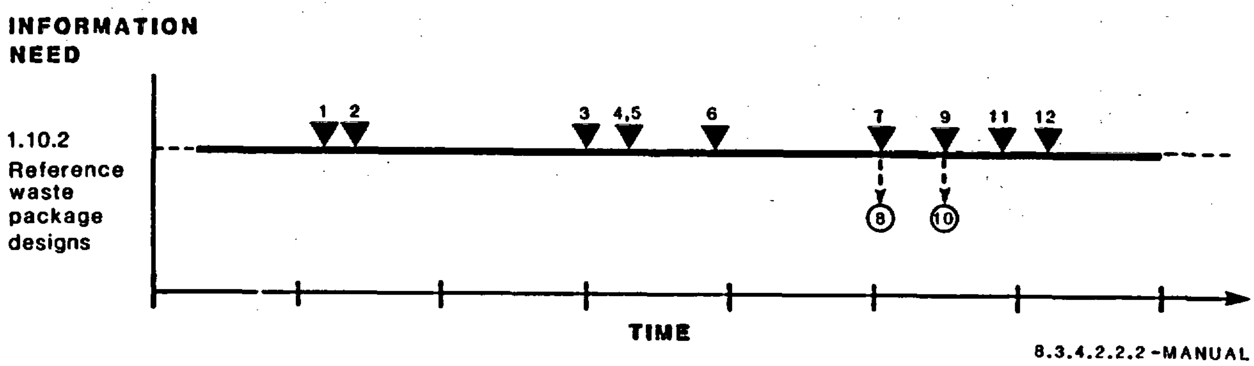
8.3.4.2.2.2 Schedule and milestones

This information need, addressing reference waste package designs, contains no formally designated activities, but includes identified milestones. In the figure that follows, schedule information showing the interrelationships of these milestones is presented in the form of a time-line. The timeline extends from ongoing efforts to complete the definition of the waste package design requirements to issuance of a design report on the waste package for license application. Summary schedule and milestone information for this information need can be found in Section 8.5.4.

Work in this information need is ongoing and involves design work that is progressing in parallel with other Issue 1.10 activities. Data from this information need will be provided to Issues 1.4 and 1.5 (containment by waste package and engineered barrier system release rates, respectively) and to the repository design issue.

An iterative process will be used during the performance of this activity until closure of the issue. Work under this information need is not currently constrained by other program elements. As the work progresses, interfaces with other activities become more important.

The information need number and title corresponding to the timeline are shown on the left of the following figure. Points shown on the timeline represent major events or milestones associated with the information need. Solid lines represent study durations, and dashed lines show interfaces. The data input and output at the interfaces are shown by circles.



The points on the timeline and the data input and output at the interfaces are described in the following table:

Point number	Description
1	Milestone T073. Complete waste package design requirements document for advanced conceptual design.
2	Milestone M233. Initiate waste package advanced conceptual design (ACD).
3	Milestone M267. Complete waste package design requirements document for license application design (LAD).
4	Milestone P274. Complete waste package ACD.
5	Milestone T074. Start waste package LAD.
6	Milestone M259. Issue waste package advanced conceptual design report.
7	Milestone P267. Final waste package environment definition provided to waste package performance assessment.
8	Output to Issues 1.4 and 1.5, waste package performance assessment.
9	Milestone M270. Complete waste package design input to repository license application document.
10	Output to repository license application design.
11	Milestone M275. Complete waste package license application document drawings and specifications.
12	Milestone M274. Issue waste package LAD report.

8.3.4.2.3 Information Need 1.10.3: Reference waste package emplacement configurations

Technical basis for addressing information need

Link to technical data chapters and applicable support documents

The waste emplacement configurations within the repository subsurface facilities that have been considered during the conceptual design phase are described in Chapter 6. The reference for the conceptual design is vertical emplacement of the waste packages in holes constructed in the floor of the emplacement drifts, with a single package installed in each hole. An alternative configuration, with multiple packages emplaced within a single horizontal hole, has also been considered.

In addition to the orientation of the emplacement holes, other details of the configuration need to be determined. The distribution of the thermal output of the waste forms is an important consideration that is necessary to assess the performance of the waste packages and the engineered barrier system. In addition, the physical distribution of the emplaced waste packages is determined by the spacing of the emplacement drifts, the pitch (spacing) of the holes, the dimensions of the holes, and the position of the waste packages within the holes. The conceptual designs of these elements for both emplacement orientations are also described in Chapter 6.

Some of the effects of the emplacement configuration on the performance of the waste package components are discussed in Sections 7.4.2 and 7.4.3.

Parameters

The parameters that require determination to fulfill this information need are in two categories: (1) physical characteristics and (2) output characteristics. The parameters are required to include the variations in the characteristics that will result from the types of waste packages to be emplaced and the anticipated time-dependent variations in package thermal output at the time of emplacement during the operating life of the repository.

The physical characteristics include

1. Emplacement orientation: vertical or horizontal.

   a. For vertical boreholes:

      i. Borehole diameter.

      ii. Borehole depth.

      iii. Configuration of other emplacement hole components (e.g., liners and shielding plugs).

   b. For horizontal boreholes:

      i. Borehole diameter.

ii. Borehole length.

iii. Package spacing in hole.

iv. Standoff distance from drift to package.

v. Configuration of other emplacement hole components (e.g., liners and shielding plugs).

2. Emplacement drift layout and dimensions.

3. Emplacement borehole spacing (pitch).

The output characteristics include

1. Planned spatial distribution by waste package types.

   a. Spent fuel.

   b. Glass waste forms from West Valley Defense Project and Defense Waste Processing Facility.

2. Planned spatial distribution by waste package thermal power during repository operating life.

Logic

The principal purpose of this information need is to provide a source of reference (and alternative) repository configuration design data that is traceable to the NNWSI Project technical baseline for use in the analyses of the projected performance of the waste packages and the engineered barrier system. In particular, this information, together with the thermal and hydrologic properties of the host rock, will determine the near-field temperature distribution as a function of time. In addition, the emplacement configuration characteristics are needed to support the definition of appropriate materials testing environments, both at laboratory and in situ scales, and to provide design input to the waste package design activities.

This information need does not require site characterization studies, tests, or analyses within this issue. The design information collected under this topic is developed as an integral part of the repository design process and is controlled in the NNWSI Project technical baseline. The detailed design studies and analyses will be documented in the advance conceptual and license application design reports. Interim design information will be maintained and controlled in the NNWSI Project reference information base. The design studies and analyses to determine the repository configu- ration characteristics are described in Section 8.3.2 (Issues 4.4 and 1.11).

8.3.4.2.3.1 Application of results

The reference (and alternative) emplacement configuration design information will be used in Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10) to provide the configuration used in the analyses of the postclosure performance of the waste packages and the engineered barrier system. Within this issue (1.10), the emplacement configuration information, in combination with the waste package design information described in Information Need 1.10.2, will be used to determine the near-field temperature distribution as a function of time for the waste packages. The information will be used as a part of the design basis for the waste package design in Issue 2.6 (Section 8.3.4.3).

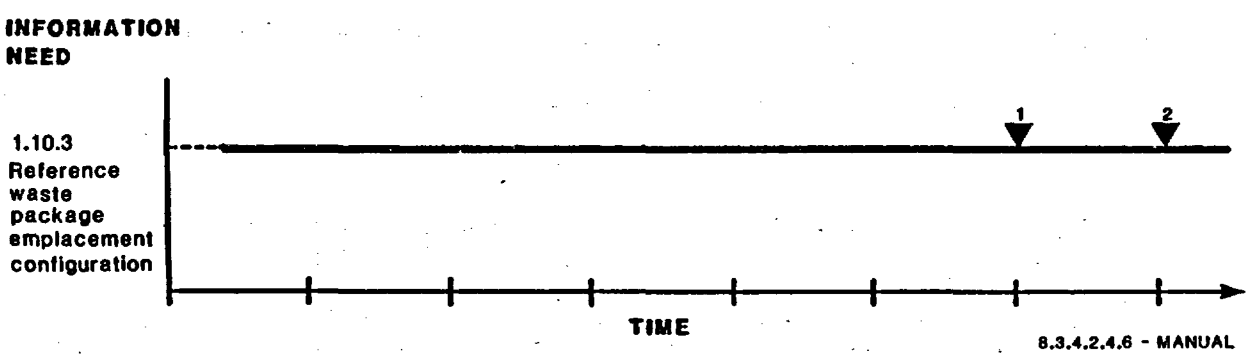
8.3.4.2.3.2 Schedule and milestones

This information need on the reference emplacement configuration contains no formally designated activities, but includes identified milestones. In the figure that follows, schedule information showing the interrelationships of these milestones is presented in the form of a timeline. The timeline extends from ongoing efforts to specify the reference emplacement configurations for the waste package to issuance of the repository license design report. Summary schedule and milestone information for this information need can be found in Section 8.5.4.

Work under this information need is ongoing and is progressing in parallel with other Issue 1.10 activities. An iterative process will be used during performance of this work until closure of the issue.

Work undertaken in this information need is not currently constrained by other program elements. As the activity progresses, interfaces with other activities become more important.

The information need number and title corresponding to the timeline are shown on the left of the following figure. The points shown on the timeline represent major events or important milestones associated with the information need. Solid lines represent work durations.



The points on the timeline are described in the following table:

Point number	Description
1	Milestone M468. Issue repository advanced conceptual design report.
2	Milestone M459. Issue repository license application design report.

8.3.4.2.4 Information Need 1.10.4: Postemplacement near-field environment

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The following sections of the data chapters provide a technical summary of existing data relevant to this information need:

SCP section	Subject
7.1	Emplacement environment
7.4.1.1	Stability of borehole openings
7.4.1.2	Anticipated thermal history
7.4.1.3	Reference water for laboratory studies
7.4.1.4	Radiation field effects
7.4.1.5	Thermal effects on water flow in the vicinity of waste packages
7.4.1.6	Numerical modeling of hydrothermal flow and transport
7.4.1.7	Rock-water interaction
7.4.1.8	Modeling rock-water interaction

The technical data discussed in these sections describe attributes that will influence the thermal history of the repository and establish the extent of chemical interaction expected in the waste package environment. Further work to address remaining uncertainties discussed in Sections 7.4.1.1, 7.4.1.3, 7.4.1.4, 7.4.1.5, 7.4.1.6, and 7.4.1.7 is outlined in Section 8.3.4.2.4.2.

Parameters

The following parameters will be measured or calculated as a result of the studies planned to satisfy this information need:

1. Near-field thermal history.

2. Postemplacement changes in the near-field mineralogy and fluid chemistry: volumes and compositions of mineralogical and fluid reaction products formed in hydrothermal tests, as a function of temperature, time, fluid composition, and radiation dose. Modeling of the laboratory systems will be carried out for purposes of code validation.

3. Postemplacement, near-field hydrologic properties: definition of the hydrologic properties of representative repository horizon rock, including characteristic curves for single- and two-phase systems, flow pathways in intact and fractured rocks (laboratory and field scale), and modeling of these parameters for code validation.

4. Near-field thermal and mechanical properties: borehole stability as a function of fracture characteristics, rock properties, and thermal environment.

Information that supports these parameters includes work that addresses the following information needs or investigations:

Information need or investigation	Subject
1.4.4	Degradation of containment barriers (Section 8.3.5.9.4)
1.10.3	Reference emplacement configuration (Section 8.3.4.2.3)
1.12	Identification of seals and grouts (Section 8.3.3.2)
8.3.1.2.2	Repository scale hydrologic model
8.3.1.3.4, 8.3.1.3.2	Repository scale mineralogy, petrology, and rock chemistry
8.3.1.3.8	Gaseous radionuclide retardation
8.3.1.15.1	Thermal and mechanical properties of rock

Logic

To ensure that interactions with the emplacement environment do not compromise the function of the waste packages, the composition of water that may contact the waste packages, the amount of water that may contact the waste packages, and the emplacement hole stability must be established. To provide this information in a form that will allow evaluation of the attributes of the near-field environment, it is necessary to establish within limits the chemical and physical characteristics of the interactive elements in the repository.

Since the water chemistry plays a critical role in determining the performance of the waste package components, goals have been established that define the degree of characterization necessary for water that may contact the waste package.

The attributes that affect water chemistry are

1. Interactive effects caused by the emplacement hole liner and other repository construction materials.

2. Repository thermal loading.

3. Emplacement hole configuration.

4. Radiation dose rate.

5. Near-field hydrologic properties.

6. Mineralogy of the near-field rock.

The planned analyses, evaluations, and activities described in the following section will establish the effects of these attributes.

These attributes will influence the thermal history of the repository and will establish the extent of chemical interaction between water present in the waste package environment, the repository host rock, and the waste package materials.

The stability of the emplacement boreholes must be investigated since instability of the borehole could result in unacceptable loading of the package by rock. Borehole stability considerations will be examined through activities and tests of the near-field waste package environment in the candidate repository horizon as part of the NNWSI Project exploratory shaft in situ testing program.

Waste package environment field tests will be configured to provide site-specific data on near-field hydrologic, thermal, mechanical, and chemical phenomena during an accelerated thermal cycle in the rock mass. Although near-field hydrologic phenomena (movement of water in rock pores or fractures) are of primary interest, thermal and mechanical phenomena are also of interest because of their roles in driving or influencing water migration. Chemical phenomena are important because of their potential influence on hydrologic behavior and because of possible effects on components of the engineered barrier system.

Engineered barriers (including borehole liners) and shaft and borehole seals may influence water composition. The character of seals is discussed in Section 8.3.3. Borehole liners and the effects of other materials are addressed in the following section describing Study 1.10.4.1.

8.3.4.2.4.1 Study 1.10.4.1: Characterize chemical and mineralogical changes in the postemplacement environment

The objective of this study is to establish, to the degree required in Performance Issues 1.4 and 1.5 (Sections 8.3.5.9 and 8.3.5.10), the compositional features of water that may contact the waste packages. To accomplish this objective, it is necessary to determine the effects of chemical reactions on the rock-water system of the repository horizon over a range of temperatures and chemical conditions that bound the postclosure waste package environment. Seven activities are planned to collect the data needed for this study.

8.3.4.2.4.1.1 Activity 1.10.4.1.1: Rock-water interactions at elevated temperatures

Objectives

The objective of this activity is to establish the identity and abundance of reaction products that form during hydrothermal interaction of tuff and reference ground water at elevated temperatures.

Parameters

The parameters of this activity include

1. Temperature.
2. Compositions of reactant and solid phases.
3. Fluid composition as a function of time.
4. Reactant surface area.
5. Modal abundance of solid reactants and products.

Description

The anticipated conditions for the waste package environment include an unsaturated rock system. Reaction rates in such an environment are exceptionally low, and the identity of solid reaction products can be difficult to establish. Therefore, tests to characterize in detail the chemical behavior of a water-saturated liquid and vapor environment will be conducted to bound the nature of hydrothermal reaction products, to provide a conceptual framework to aid interpretation of work carried out in an unsaturated environment, and to establish reaction characteristics for the unanticipated condition of a saturated environment. Tests and experiments similar to those described in Section 7.4.1.7 will be conducted at elevated temperatures (90 to 250°C) that will span the range of anticipated thermal conditions of the waste package host rock. Studies at lower temperatures are not being considered because reaction rates in geologic materials at such temperatures are too slow to provide meaningful results within the available time. Although it is not expected that significant quantities of liquid water will exist in the waste package environment when the temperature exceeds approximately 100°C, high-temperature (>100°C) studies will be conducted to characterize the stability fields of phases important in the low-temperature tests. These data will also provide information on reaction kinetics and rate laws appropriate for the phases involved in lower-temperature reactions and will provide means to extrapolate reaction behavior to lower temperatures.

The studies will examine the nature of reaction products in hydrothermal systems containing Topopah Spring tuff and water that is believed to be representative of vadose water in the repository horizon. Comparison of the reaction products with mineral assemblages and mineral compositions in natural systems will allow evaluation of the applicability of the laboratory results to the repository environment.

Sample material for the tests will be obtained from the appropriate geologic horizon. Wafers of the sample will be cut, polished on one side, examined using a scanning electron microscope (SEM) and electron microprobe, and mounted in the reaction vessel of a Dickson-type rocking autoclave or other appropriate reaction vessel. If studies of the solid reaction products are not to be undertaken, crushed tuff, rather than a rock wafer, will be placed in the reaction vessel. Sufficient fluid, of the appropriate composition, will be added to the reaction vessel to last the duration of the test. The reaction vessel will then be taken to the temperature and pressure considered for the test. The reaction vessel will be kept at these conditions for the time necessary for the rock-water system to approach equilibrium. Fluid will be periodically extracted from the reaction vessel for chemical analysis. At completion of the test, the rock wafer will be removed and examined for reaction products in the SEM and the electron microprobe. If crushed rock is used in the test, instead of a rock wafer, the material will be examined by x-ray diffraction and SEM.

8.3.4.2.4.1.2 Activity 1.10.4.1.2: Effect of grout, concrete, and other repository materials on water composition

Objectives

The objective of this activity is to test the rock-water interaction in the presence of concretes, grouts, and other repository materials (Section 8.3.3) when the identity of the other materials is established. The objective of these tests is to determine if the proposed material satisfies the requirements specified in the performance allocation for this issue relating to effects of engineered barriers, shafts, and seals on water chemistry. The parameters and laboratory methods appropriate to this activity will be established when the other materials are identified.

8.3.4.2.4.1.3 Activity 1.10.4.1.3: Composition of vadose water from the waste package environment

Objectives

The objective of this activity is to characterize the composition of vadose water in the unsaturated, preemplacement waste package environment.

Parameters

The parameter of this activity is the chemical composition of vadose water in tuff of the repository horizon.

Description

A test will be conducted to extract pore water from representative devitrified, welded tuff. The extracted fluid will be analyzed using standard inductively coupled plasma and ion chromatography procedures. This test will be designed to determine the method that produces the most representative fluid composition for the environment. Analyses of the collected fluid will be compared with theoretical models of rock-water interaction and known characteristics of vadose fluids in equilibrium with minerals present in the rock, to evaluate whether a particular extraction technique produces uncontaminated fluid. Once an extraction method is selected, vadose water will be extracted from core uncontaminated with drilling fluids and from exploratory shaft material collected at the repository horizon. The need for this activity is discussed in Sections 7.4.1.1, 7.4.1.3, and 7.4.1.7.

Design of these tests is in progress.

8.3.4.2.4.1.4 Activity 1.10.4.1.4: Dissolution of phases in the waste package environment

Objectives

The objective of this activity is to determine the dissolution kinetics of the phases present in the waste package environment.

Parameters

The parameters of this activity include

1. Temperature.
2. Solution pH.
3. Mineral composition and structural state.

Description

In rock-water interaction studies, dissolution of reactant phases and the concomitant precipitation of product phases control the rates of chemical reaction. To understand the kinetics of mineral precipitation and to interpret the evolution of the fluid composition in hydrothermal tests, knowledge of the dissolution kinetics of the phases present in the host rock is required. Data on the kinetics of dissolution of phases of interest are sparse and must therefore be obtained through laboratory studies, as discussed in Section 7.4.1.7.

Dissolution studies will be conducted over a range of temperatures and fluid pH to determine the sensitivity of the dissolution kinetics to temperature and variation in the chemistry of the environment. Phases used in the dissolution studies will include the principal constituents of the devitrified, welded tuff and the common secondary phases associated with rock-water interaction as identified in hydrothermal tests and experiments. Tests will also be conducted to determine the degree to which vapor-phase transport and dissolution will occur under conditions anticipated in the waste package environment.

The mineral of interest will be crushed to a specific size range and washed thoroughly to remove adhering fine particles. Brunauer-Emmett-Teller surface area measurements will be conducted to determine the surface area of the material. For tests at temperatures less than 95°C, the sample will then be weighed and placed in small flow-through dissolution cells. Each cell will be attached to a fluid stream of known pH and flow rate. The cell will then be placed in a controlled-temperature environment for specified periods of time. The fluid that passes through the cell will be collected and periodically analyzed for the elements of interest. Statistical analysis of the results, using transition state theory, will be used to model the kinetics of the dissolution process. Laboratory protocol for dissolution studies at temperatures in excess of 100°C is still in development.

8.3.4.2.4.1.5 Activity 1.10.4.1.5: Effects of radiation on water chemistry

Objectives

The objective of this activity is to determine the composition of water in the presence of a radiation field under postemplacement conditions.

Parameters

The parameters of this activity include

1. Temperature.
2. Radiation dose rate.
3. Degree of water saturation.
4. Nature of solid materials present in addition to tuff.

Description

In water-saturated air, the abundance and composition of the radiolysis products that develop in a radiation field are a sensitive function of the temperature and the radiation dose rate. In addition, chemical reactions may take place between the radiolysis products and any other material present in the system. For example, it remains unclear which chemical reactions occur in the presence of iron and manganese oxides that may influence colloid development, nitrite-to-nitrate ratio, and the relative abundances of other nitrogen-bearing compounds. This activity will determine the chemical composition of the water and air that develops at different radiation dose rates, over a range of temperatures, and in the presence of materials expected in the waste package environment.

Reaction vessels containing tuff, waste package container metal, and reference ground water are placed in a gamma radiation field. The reaction vessels are then subjected to a specified radiation dose rate, at a specific temperature, for an extended period of time. Samples of the solution that develop during the course of the exposure are then chemically analyzed. A matrix of tests over a range of temperatures and radiation dose rates will allow identification of the significance of individual reaction parameters.

The results of these tests are used as input to guide modeling of rock-water interaction in the presence of a radiation field. The rates of dissolution and precipitation of radiolysis products and the identification of solid products formed through interaction of tuff with irradiated fluid provide constraints on the modeling. The geochemical modeling code EQ3/6 (discussed in Section 7.4.4) will be used to extend to long time periods (and to conditions not represented in the matrix of tests) the chemical behavior of the tuff-water system in the presence of radiation and other materials.

8.3.4.2.4.1.6 Activity 1.10.4.1.6: Effects of container and borehole liner corrosion products on water chemistry

Objectives

The objective of this activity is to determine the effect of corrosion products on the composition of water in the package environment.

Parameters

The parameters of this activity include

1. Temperature.
2. Composition and mineralogy of corrosion products.
3. Degree of water saturation.

Description

The effect of corrosion products on the waste package environment and water chemistry will be established through a matrix of long-term tests in which tuff, reference ground water, and metal are commingled at elevated temperatures. The metals used in the test will be partially submerged, if liquid water is present, and will be exposed to the gaseous atmosphere present in the test vessel. Periodic sampling of the fluid phase will be conducted to determine the chemical evolution of the fluid through time. At the conclusion of the tests and experiments, the metal samples and the tuff will be examined by using SEM/electron dispersive spectroscopy to determine the abundance and nature of reactions and corrosion products, their modes of occurrence, and their composition.

8.3.4.2.4.1.7 Activity 1.10.4.1.7: Numerical analysis and modeling of rock-water interaction

Objectives

The objective of this activity is to examine effects and processes in natural systems for time periods and chemical conditions not duplicated by laboratory studies.

Parameters

The parameters of this activity include

1. Temperature.
2. Mineral assemblage.
3. Mineral species surface areas.
4. Reaction times.
5. Fluid composition.

Description

Laboratory studies are incapable of examining the effects of all the possible values of parameters significant for the system under consideration. Nor can laboratory studies be used to extend directly to periods of many years the behavior of natural systems studied in the laboratory over periods of months. However, the use of numerical studies, in conjunction with judiciously selected tests, can provide the capability to establish the behavior of natural systems for conditions not duplicated by laboratory tests.

The numerical analysis and modeling will be used to predict the results of previously completed tests for characterizing the reaction process. For any geochemical test under consideration, the computer code EQ3/6 (discussed in Section 7.4.4) will use as input the mineralogy of the reactant rock material, the surface area of the reactant solid phases, and the composition of the water. The code then computes (for the temperature of the test and the reaction interval step chosen) the composition of the fluid at each reaction step, the degree of saturation of appropriate mineral phases, and the quantity of minerals precipitated from solution. This approach also allows characterization of reaction processes under conditions not duplicated by the laboratory studies and can be used to extrapolate the results of laboratory studies to repository time and distance scales. The uncertainties in the thermodynamic and kinetics data used in the calculations will be evaluated.

8.3.4.2.4.2 Study 1.10.4.2: Hydrologic properties of waste package environment

The objectives of this study are to establish the hydrologic properties of the near-field repository rock and the effect of thermal perturbation on these hydrologic properties, over the range of anticipated postemplacement conditions. This study will establish the conditions under which fracture flow will predominate over matrix flow and will determine the relative hydrologic importance of gas versus liquid-phase transport under isothermal and polythermal conditions appropriate for the waste package environment. This study will also determine the degree to which thermal effects will modify the ambient hydrologic properties. Isothermal components will provide input for simulation of conditions during the controlled release period and provide partial validation for nonisothermal codes.

Waste package performance assessment calculations will require boundary conditions representing the host rock environment. A hydrothermal flow and transport model will be developed to simulate moisture and contaminant movement in the matrix and fractures of the host rock. The flow model will be composed of the conservation equations for fluid mass, momentum, and energy in a fractured porous media. Thermodynamic relationships will be included for the water-steam phase changes. Constitutive relationships will include the equation of state for vapor and air components. In addition to flow calculations, this model will also provide the temperature of the surrounding rock mass and the state of saturation for all fluid phases as functions of space and time.

The transport model will use the pore velocities calculated by the flow model and then solve the transport equation for each radionuclide. Transport processes will include advection, molecular diffusion, and dispersion. Radionuclide decay, sorption, and solubility limits also influence the concentrations of radionuclides, and these processes will be included. This model will provide the concentrations of ground-water chemical species of interest to the representation of the waste package environment. In addition, the concentrations of released radionuclide species, both in the ground water and sorbed to the rock matrix, may be determined as a function of time and space.

The flow and transport models will be used to establish the quantity of water that may contact waste containers. Consideration will be given to the range of flow pathways identified in field and laboratory tests and to anticipated and unanticipated hydrologic conditions defined by activities that establish the Yucca Mountain site hydrology (Section 8.3.1.2). These flow and transport models will provide the basis for establishing the extent to which near-field hydrologic properties will contribute to satisfying water quantity performance goals set in Issues 1.4 and 1.5.

Conclusions regarding fluid transport behavior in a thermally perturbed environment will be verified through field studies in the exploratory shaft, as described in Sections 7.4.1.1 and 7.4.1.5, and through work under Characterization Program 8.3.1.2. Study 1.10.4.2 consists of three laboratory and modeling activities.

8.3.4.2.4.2.1 Activity 1.10.4.2.1: Single-phase fluid system properties

Objectives

The objectives of this activity are

1. To establish the single-fluid-phase hydrologic properties of fractured and unfractured tuff under isothermal conditions.

2. To establish the single-fluid-phase hydrologic properties of fractured and unfractured tuff in a thermal gradient.

Parameters

The parameters of this activity include

1. Temperature.
2. Relative permeability.
3. Degree of saturation.
4. Nature of the fluid phase.
5. Number of rehydration-dehydration cycles.
6. Resistivity.
7. Magnitude of thermal gradient.

Description

Dehydration-rehydration processes may modify the hydrologic properties of the near-field rock through precipitation-dissolution effects or through induced changes in fracture surface characteristics. The pattern of fluid flow that may develop as a result of heat transfer and mass transport may take several forms, including convective flow and "heat pipe" geometries. Such processes have the potential of developing regions where fluids may condense or areas where transported solutes may concentrate. These processes could change the chemistry, mineralogy, and hydrology of the waste package environment and therefore must be characterized to satisfy Information Need 1.10.4 (Section 8.3.4.2.4).

Fractured and unfractured samples will be used to examine the fluid flow properties of single-phase (gas or liquid) systems. Tests will be run in isothermal conditions and in thermal gradients to determine the fluid flow behavior in different thermal regimes. These tests will be run under pressure conditions that simulate loading at the repository level. These tests will address data needs described in Section 7.4.1.6. The characteristics of fluid flow in these different environments will be documented by using computed impedance tomography. Computed impedance tomography is an imaging technique that uses electrical resistivity measurements taken sequentially around a circumference of a rock core to obtain variations in resistivity within the core. The resistivity measurements may be converted to degree of liquid saturation, thereby providing a two-dimensional map of liquid saturation on a plane normal to the cylinder axis. Modification of fracture surfaces and pores will be documented.

8.3.4.2.4.2.2 Activity 1.10.4.2.2: Two-phase fluid system properties

Objectives

The objectives of this activity are

1. To establish the two-phase hydrologic properties of tuff under isothermal conditions.

2. To establish the two-phase hydrologic properties of tuff in a thermal gradient.

Parameters

The parameters of this activity are

1. Temperature.
2. Relative permeability.
3. Degree of saturation.
4. Gas-to-liquid ratio.
5. Resistivity.
6. Number of rehydration-dehydration cycles.
7. Magnitude of temperature gradient.

Description

Tests in the two-phase system will be designed to establish the effects of a two-phase fluid on the hydrologic properties of the tuff, to allow comparison with results from the single-phase fluid tests. The single-phase and two-phase studies will characterize the tuff-fluid system over the range of conditions anticipated in the postemplacement waste package environment.

The laboratory protocol for the two-phase activities is similar to that for the single-phase activities, with the exception that the ratio of liquid to gas is an additional parameter that will be controlled in the tests. These tests are performed in a pressure vessel under simulated in situ conditions. The work described here addresses needs described in Sections 7.4.1.1, 7.4.1.5, and 7.4.1.6.

8.3.4.2.4.2.3 Activity 1.10.4.2.3: Numerical analysis of flow and transport in laboratory systems

Objectives

The objective of this activity is to use laboratory-scale tests for initial development and validation of the flow and transport code.

Parameters

The parameters of this activity are

1. Temperature.
2. Distribution of liquid-phase saturation.
3. Permeability.
4. Hydraulic conductivity.

Description

The hydrothermal flow model will require validation over a range of conditions sufficient to cover those required in the use of the model. Validation requires that model predictions be compared with controlled tests, from both laboratory and in situ investigations. The laboratory measurements of two-phase flow in rock cores conducted under Study 1.10.4.2 (Section 8.3.4.2.4.2) will partially satisfy the validation needs of the hydrothermal flow model. The primary variables to be used for validation will be the core temperature and saturation distributions. Other properties required will include the thermal properties of the core material. The parameters subject to validation will be the permeability and the expressions used to represent matric potential and relative conductivity as functions of saturation. By using these test results, the model can be tested on one- and two-dimensional systems under controlled but varying thermal and flow conditions. This validation will concentrate on simulation of flow in a small core and, therefore, will provide a limited validation before testing on a scale representative of the waste package environment.

8.3.4.2.4.3 Study 1.10.4.3: Thermal and mechanical attributes of the waste package environment

The objectives of this study are to establish the thermal and mechanical attributes of the waste package environment host rock. The need for this information is discussed in Sections 7.4.1.1 and 7.4.1.2. The thermal studies will address the history, magnitude, and nature of the thermal perturbation associated with waste packages in the emplacement configurations under consideration. This history establishes the thermal conditions under which rock-water interaction may occur. The mechanical studies will examine the mechanical response of the near-field rock to the engineering and thermal regimes resulting from development of the repository and emplacement of the waste packages. The mechanical properties determine the extent to which borehole wall failure can be expected to load the waste package containers. Two activities are present in this study.

8.3.4.2.4.3.1 Activity 1.10.4.3.1: Waste package environment temperature-field analysis

Objectives

The objective of this activity is to define the time-dependent thermal field of the package environment.

Parameters

The parameters of this activity are

1. Emplacement configuration.
2. Repository layout.
3. Waste package configurations.
4. Waste package heat generation characteristics.

Description

The magnitude of the temperature field that develops around a waste package is a complex function that depends on how the packages are spaced within the repository and how much heat the packages dissipate through time. Additional variables include the relative diameters of the borehole and the container and whether the borehole has been lined.

Modeling of the thermal history of the near-field environment will be conducted by using a test matrix consisting of the variables that influence the temperature field of the waste package environment. A computer code for hydrothermal flow in unsaturated rock will be used to evaluate the effect of each variable over the range of conditions anticipated for the repository. The results will be used to establish the thermal behavior of the near-field environment.

8.3.4.2.4.3.2 Activity 1.10.4.3.2: Waste package environment stress field analysis

Objectives

The objective of this activity is to estimate the time-dependent stress field and displacements of the rock in the waste package environment.

Parameters

The parameters of this activity are

1. Emplacement configuration.

2. Repository layout.

3. Temperature fields (Section 8.3.4.2.4.3.1).

4. Mechanical properties of rock in repository horizon (TSw2) including, for example, Young's modulus, Poisson's ratio, deformation modulus, coefficient of thermal expansion, and strength-related properties.

5. Fracture (joint) characteristics of rock in repository horizon (TSw2) including, for example, shear and normal stiffness, orientation, and frequency and degree of persistence.

Description

The extent to which waste containers can be loaded by rock-induced stresses will be evaluated. One of the potential mechanisms for such loading is slip of discrete blocks of rock along preexisting fractures. Field data describing the attributes of the fractures will be used with repository design information, predicted temperatures, and mechanical properties of the host rock to predict the possible extent and modes of block failure for the range of conditions anticipated in the repository horizon. The integration of the field data with the design specifications for the emplacement geometry, container spacing, and the liner will be accomplished by using computer modeling and, if necessary, model tests.

8.3.4.2.4.4 Study 1.10.4.4: Engineered barrier system field tests

The laboratory tests described in Activities 1.10.4.1.1 through 1.10.4.1.7 (Sections 8.3.4.2.4.1.1 through 8.3.4.2.4.1.7) and 1.10.4.2.1 through 1.10.4.2.3 (Sections 8.3.4.2.4.2.1 through 8.3.4.2.4.2.3) require validation through in situ field tests in the repository horizon to establish the applicability of the laboratory studies to the repository block. These tests will be conducted in the exploratory shaft facilities at the repository horizon. The activities listed below indicate the objectives of the work to be completed and the parameters to be determined. Detailed descriptions of the activities will be available when the indicated test plans are completed. The work described in these activities addresses needs described in Sections 7.4.1.1, 7.4.1.5, and 7.4.1.6. The three activities in this study are described in the following sections.

Before initiation of the in situ tests that support this study, prototype tests to develop and validate the test procedures and protocols are planned. These prototype tests will be conducted in the G-tunnel test facility located in a similar hydrogeologic setting in Rainer Mesa at the Nevada Test Site. The prototype tests are designed to simulate the test conditions and evaluate the installation procedures and performance characteristics of the instrumentation planned for the in situ tests to be deployed in the Yucca Mountain exploratory shaft facility.

8.3.4.2.4.4.1 Activity 1.10.4.4.1: Repository horizon near-field hydrologic properties

Objectives

The objective of this activity is to determine the in situ hydrologic properties of rock in the repository horizon under thermally perturbed conditions.

Parameters

The parameters of this activity are

1. Degree of liquid water saturation.
2. Relative permeability.
3. Matric potential.
4. Fluid flow pathways.
5. Fluid flow rates.
6. Fracture characteristics.
7. Thermal loading.
8. Mechanical and thermal properties of the rock.

Description

Geotechnical and hydrologic instrumentation will be deployed to monitor selected near-field environmental parameters in situ. These measurements will allow characterization of the parameters just enumerated. In addition, laboratory-scale hydrologic studies will be completed, with computed impedance tomography techniques, on samples obtained from the repository horizon. Comparison of the data obtained from the field studies and laboratory studies with those obtained from earlier laboratory tests will extend the applicability of the laboratory tests to the in situ waste package environment.

8.3.4.2.4.4.2 Activity 1.10.4.4.2: Repository horizon rock-water interaction

Objectives

The objective of this activity is to determine the effect on water chemistry of thermal perturbation of the near-field environment.

Parameters

The parameters of this activity are

1. Temperature.
2. Temperature gradient.
3. Water chemistry.
4. Mineralogical changes.

Description

Geotechnical and hydrologic instrumentation will be deployed to monitor selected near-field environmental parameters in situ. In addition, laboratory tests and analyses will be conducted as described in the test plan. These measurements will provide the background for characterization of the parameters enumerated above. Once established, comparison of these parameters with those obtained from previous laboratory tests will extend the applicability of the laboratory tests to the in situ waste package environment. Pretest and posttest rock and water samples will be analyzed for changes in mineralogy and chemistry. These activities will provide data for integration with laboratory-scale measurements. These activities will address needs described in Sections 7.4.1.1, 7.4.1.5, and 7.4.1.7.

8.3.4.2.4.4.3 Activity 1.10.4.4.3: Numerical analysis of fluid flow and transport in the repository horizon near-field environment

Objectives

The objective of this activity is to validate and calibrate fluid flow and transport models by using waste-package-scale field studies.

Parameters

The parameters of this activity are

1. Fracture attributes.
2. Temperature.
3. Degree and distribution of saturation.
4. Time.
5. Sorption.
6. Water composition.

Description

The flow and transport model will require calibration on a scale representative of the waste package environment. Testing on this scale, as described in Activity 1.10.4.4.1 (Section 8.3.4.2.4.4.1), will allow the influence of fractures on the flow of liquid water and steam to be observed. Tests at the repository horizon in the exploratory shaft will provide the ability to test the model at a scale approximating the waste package emplacement conditions. To perform this calibration and validation, temperature and degree of liquid saturation of the rock mass and concentration of tracers and sorbed substances must be observed under different simulated emplacement conditions. Other measurements such as pressure of the gas phase in matrix and fractures would be useful but may not be practical. The primary benefit of these tests will be to test the effect of fractures on moisture movement in the rock mass.

The transport capability of the flow and transport model will be used to describe the movement of radionuclides and naturally occurring aqueous chemical constituents in the near field; that is, the first several meters of host rock surrounding an emplacement hole. These calculations will be used respectively in tracking releases and assigning boundary conditions for performance calculations. Therefore, the transport portion of the model must also be validated.

In situ tests will be conducted to monitor the movement of sorbing and nonsorbing species. These measurements will include the concentration of species in the pore water as a function of time and space and the concentration of species sorbed onto the tuff matrix at specified times and locations. Calibration of the transport routines will consist of deriving dispersivities and effective diffusion coefficients for the test location. Since measurements will be used to calibrate and validate the transport routines of the hydrothermal model, it will be necessary to design the tests so that several data sets will be available for a given set of geologic parameters.

8.3.4.2.4.5 Application of results

The information derived from activities described above will be used in addressing the following information needs and investigations:

Information need or investigation	Subject
1.4.2	Material properties of the containment barrier (Section 8.3.5.9.2)
1.4.3	Scenarios and models needed to predict the time to loss of containment and the ensuing degradation of the containment barrier (Section 8.3.5.9.3)
1.4.4	Containment barrier degradation (Section 8.3.5.9.4)
1.5.2	Material properties of the waste form (Section 8.3.5.10.2)
1.5.3	Scenarios and models needed to predict the rate of radionuclide release from the waste package and engineered barrier system (Section 8.3.5.10.3)
1.5.4	Release rates of radionuclides from the engineered barrier system for anticipated and unanticipated events (Section 8.3.5.10.4)
1.10.1	Design information needed (consideration of waste package-environment interactions) (Section 8.3.4.2.1)
1.10.3	Waste package emplacement configuration (Section 8.3.4.2.3)
1.10.4	Postclosure near-field environment (Section 8.3.4.2.4)
1.11	Configuration of the underground facility (Section 8.3.2.2)
1.12.2	Seal materials (Section 8.3.3.2.2)
8.3.1.7.1	Rates of dissolution of crystalline and noncrystalline components in tuff.

The activities described previously will define the chemical and physical attributes of the waste package environment, which is information required to satisfy the listed information needs.

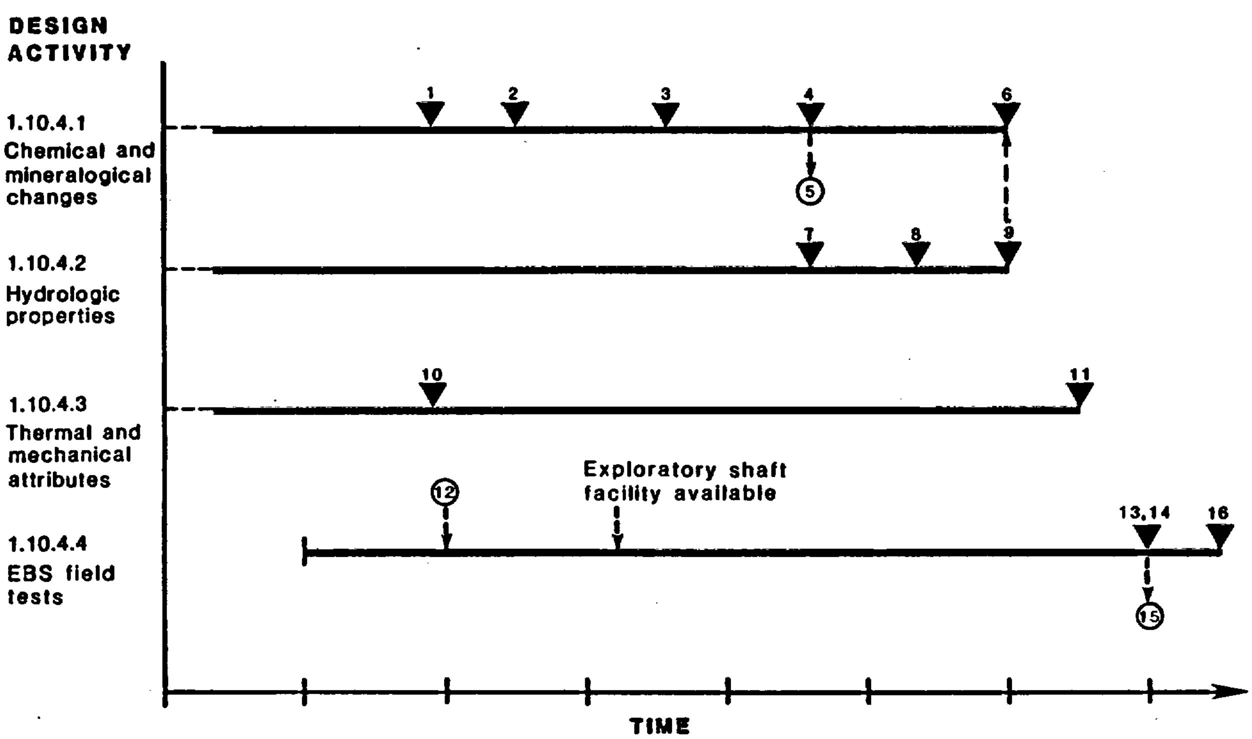
8.3.4.2.4.6 Schedule and milestones

This information need contains four studies that are divided into fourteen activities. The description of the schedules and milestones is presented at the study level. The four studies include: 1.10.4.1 (characterize chemical and mineralogical changes in the postemplacement environment), 1.10.4.2 (hydrologic properties of waste package environment), 1.10.4.3 (thermal and mechanical attributes of the waste package environment), and 1.10.4.4 (engineered barrier system field tests). In the figure that follows, the schedule information for these studies is presented in the form of timelines. The timelines extend from implementation of the approved study plans to the issuance of the final products associated with the studies. Summary schedule and milestone information for this information need can be found in Section 8.5.4. Additional schedule information for exploratory shaft activities may be found in Section 8.5.1.2.

Work on three of the studies described under this information need is currently ongoing. This information need involves experimental work and modeling that is progressing in parallel with other Issue 1.10 activities. Data will also be provided to Issue 1.4 (containment by waste package) and 1.5 (engineered barrier system release rates). An iterative process will be used during the performance of these parallel activities until closure of the issue.

Studies in this information need are not currently constrained by other program elements with the exception of Study 1.10.4.4, which awaits the development of the exploratory shaft facility. As the studies progress, interfaces with other studies will become more important. The schedule for this information need is directly tied to the completion of the exploratory shaft facility.

The study numbers and titles corresponding to the timelines are shown on the left of the following figure. The points shown on the timelines represent major events or important milestones associated with the studies. Solid lines represent study durations, and dashed lines show interfaces. The data input and output at the interfaces are shown by circles.



The points on the timeline and the data input and output at the interfaces are described in the following table:

Point number	Description
1	Milestone P222. Complete extraction of vadose water from tuff.
2	Milestone P489. Initiate modeling of rock/water interactions using concentrated solutions.
3	Milestone M004. Issue summary report on single-phase dissolution kinetics.
4	Milestone M007. Issue report on effects of grout on groundwater chemistry and grout-affected water on waste form dissolution.
5	Data output to Issue 1.5, waste form dissolution.
6	Milestone Z464. Issue report on characterization of potential chemical and mineralogical changes in the post-emplacement environment.
7	Milestone M008. Issue final report on the results of fracture flow studies.
8	Milestone Z465. Issue report on hydrologic properties of the waste package environment.
9	Milestone P204. Issue final report on radionuclide source term.
10	Milestone Z463. Issue report on near-field thermal history.
11	Milestone Z466. Issue report summarizing the thermal and mechanical attributes of the waste package environment.
12	Prototype testing results available.
13	Milestone Z467. Issue report summarizing the results of the engineered barrier system field tests.
14	Milestone M271. Issue final report on waste package environment.
15	Data output to Issues 1.4 and 1.5 (containment by waste package and engineered barrier system release rates, respectively) and Information Need 1.10.1 (waste package design information).
16	Milestone M650. Complete final report on the results of the waste package system test.

DOE/RW-0160

Chapter 8

Section 8.3.4.3

P

Nuclear Waste Policy Act
(Section 113)

WASTE PACKAGE CHARACTERISTICS (PRECLOSURE)

Consultation Draft

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI

January 1988

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

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Chapter 8

Nuclear Waste Policy Act
(Section 113)

Section 8.3.4.3

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8.3.4.3 Issue resolution strategy for Issue 2.6: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the preclosure design criteria of 10 CFR 60.135 and (b) provide information for the resolution of the performance issues?

Regulatory basis for the issue

This issue deals with two aspects of the waste package design considerations. The first relates to the specific criteria explicitly established in the NRC regulations in 10 CFR 60.135. Compliance with these criteria will be addressed by analyses of the designs and comparison with the criteria under Information Needs 2.6.1 and 2.6.2 (Sections 8.3.4.3.1 and 8.3.4.3.2). Information is also needed on the physical characteristics of the spent fuel and high-level waste that is to be accepted into the disposal system. This information will be provided to the NNWSI Project by other elements of the DOE Office of Civilian Radioactive Waste Management (OCRWM) in the form of waste acceptance specifications, receipt rate projections by waste type and characteristics, and other descriptions. This information is expected to be provided in documents controlled within the OCRWM technical baseline and revised periodically to reflect the most current data available. These specifications and characteristics will reflect the regulatory criteria that establish restrictions on the form and content of the wastes to be received, packaged, and disposed of in the repository. Information Need 2.6.3 (Section 8.3.4.3.3) will accumulate the information for use in the waste package design development.

None of the information needed to address the preclosure waste package design criteria mentioned previously requires the acquisition of site characterization data, as it primarily involves information about, or restrictions on, the waste forms and specific criteria for characteristics of the waste packages.

The second part of this issue is much broader in scope and involves the actual development of the waste package designs and the integration of the designs into the repository system. The approach to resolution of this issue is described in the following section.

Approach to resolving the issue

The approach to be used in resolving this issue is similar to that used in the issues that address design of the repository as described in Section 8.3.2. In that section, the requirements that arise in other issues that involve specific aspects of the repository, for both the preclosure and postclosure periods, are consolidated for design purposes within Issue 4.4 (Section 8.3.2.5). The design is developed and placed in the reference information base. Specific design features are then evaluated for consistency with the requirements for performance as required by the other issues.

The issues hierarchy (Section 8.2) divides the information needed to develop and evaluate the performance of the waste package designs into five issues, three of which directly address the design aspects. This division, although logical in the context of the regulatory provisions that place different requirements on the waste packages during the preclosure and post-closure periods, results in a complex design management process because the various requirements are imposed on a single set of physical objects. To integrate the waste package design process, the logic shown in Figure 8.3.4.3-1a has been developed.

In this framework, the design criteria and constraints that are derived within Issue 2.6 from the preclosure functional requirements through the performance allocation process are consolidated with the requirements and other design inputs developed in Issue 1.10 (Section 8.3.4.2). An integrated document, the waste package design requirements, is compiled and provides the definitive guidance for development of the designs.

A significant product of the waste package design effort will be the specification of the production processes to be used in the fabrication, closure, and inspection of the containers. A direct supporting element to the design process is therefore identified separately in Issue 4.3 (Section 8.3.4.4), where the evaluation and testing of these production technologies are described.

The design process is planned to progress through multiple phases, starting with an advanced conceptual design phase and continuing through a license application design phase before submission of a license application. During each of these design phases, the design products, including the supporting analyses, will be transferred to the NNWSI Project reference information base. The design information will then be assessed for compliance with the goals imposed by the appropriate performance issues and transferred to the repository design Issue 4.4 (Section 8.3.2.5). Figure 8.3.4.3-1a also shows the decision paths that must be addressed in the event that performance assessments of the designs indicate that revisions are required to achieve the goals. These assessments will be performed both within the design issue and within the performance issues, as determined by the source of the goal.

Table 8.3.4.3-1 lists the major preclosure functions or characteristics that are derived from the regulatory criteria for the waste packages. Performance measures, goals, and levels of confidence are indicated for these functions needed to resolve this issue (2.6).

8.3.4.3.1 Information Need 2.6.1: Design information needed to comply with preclosure criteria from 10 CFR 60.135(b) for materials, handling, and identification of waste packages

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The functional requirements, performance criteria, and constraints derived from the regulatory criteria for this information need and used in the conceptual waste package designs are defined in Section 7.2.1.1, generic preclosure requirements. The preliminary allocation of performance to components in response to these requirements is discussed in Section 7.2.3.1, preclosure performance.

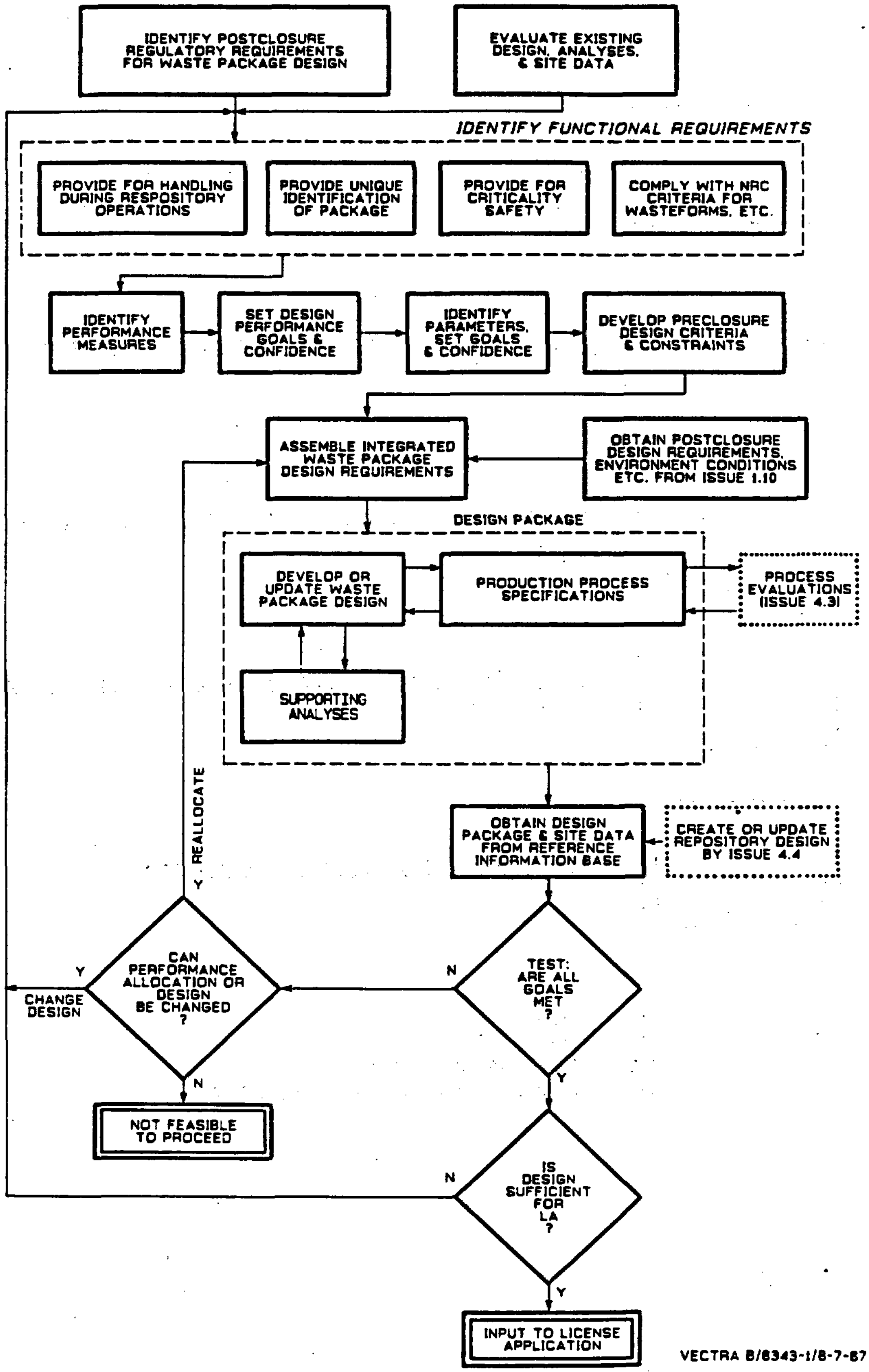
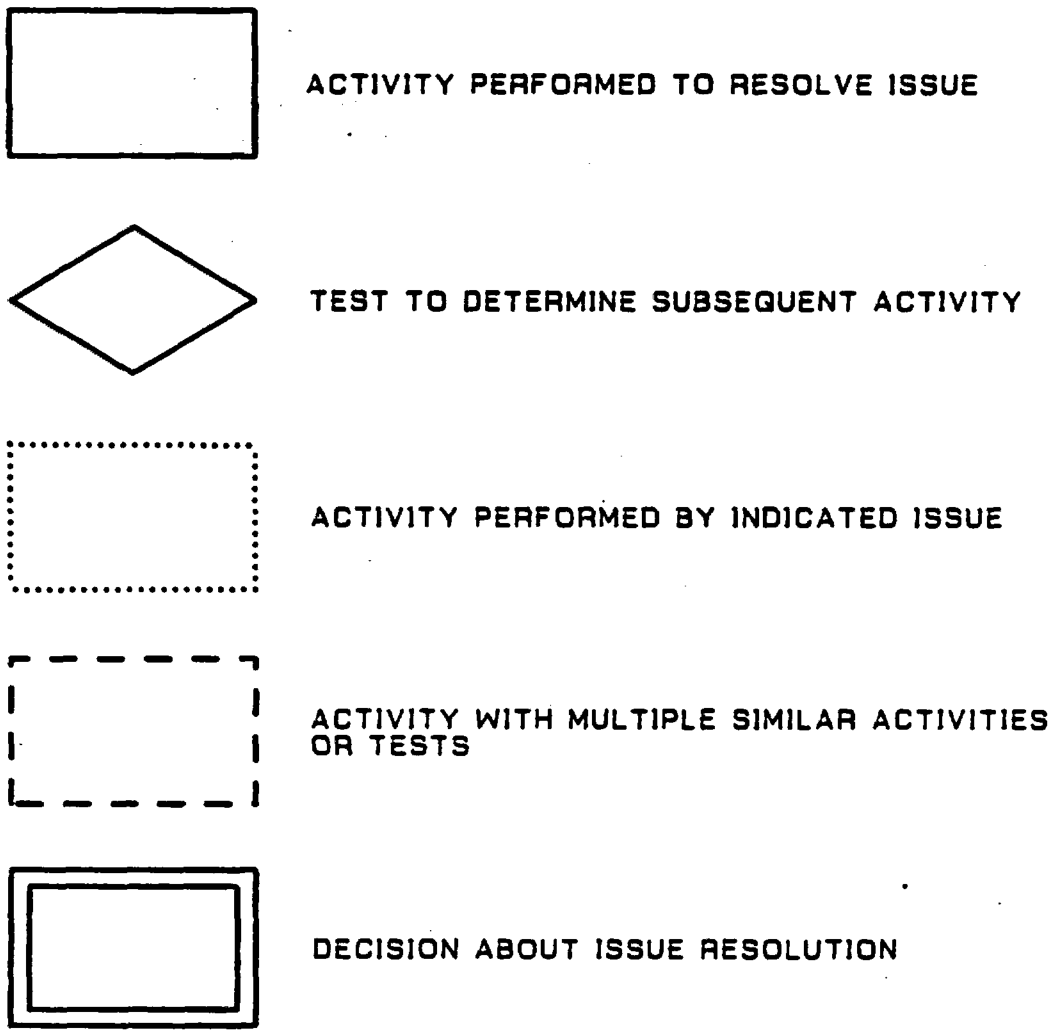


Figure 8.3.4.3-1a. Logic diagram for the resolution of Issue 2.6 (waste package characteristics–preclosure). See Figure 8.3.4.3-1b for legend.

LEGEND



Y - YES
N - NO
LA - LICENSE APPLICATION
NRC - NUCLEAR REGULATORY COMMISSION

Figure 8.3.4.3-1b. Legend for Figure 8.3.4.3-1a.

Table 8.3.4.3-1. Performance allocation for Issue 2.6 (waste package characteristics--preclosure)

System element	Function or characteristic	Performance measure	Goal	Confidence needed
Waste package	Contain waste during repository operations	Fraction of containers intact at end of preclosure	>98% intact	High
	Limit potential criticality in waste packages	Effective neutron multiplication factor (K_{eff})	<0.95	High
	Provide unique identification of packages	Identification legible at end of preclosure	>99% legible	Medium
Waste form	Comply with NRC criteria for acceptance	Waste form characteristics	>99% (Ci) of waste received in compliance with criteria	High
Container	Capable of being handled by repository systems	Package-handling fixtures	100% through emplacement, >95% through preclosure	High

Parameters

The specific waste package design criteria established in 10 CFR 60.135(b)(1) through (4) require that the following parameters be addressed in the design:

1. Explosive, pyrophoric, and chemically reactive materials.
2. Free liquids.
3. Containment during transportation, emplacement, and retrieval.
4. Unique identification.

Logic

The information needed to comply with the criteria of 10 CFR 60.135(b) requires that the waste package designs (together with the characteristics of the waste forms and the preclosure environments that the packages will experience) be analyzed to establish that the criteria will be met. The parameters to be addressed are quite diverse, as are the preclosure environments.

Criteria (1) and (2) in 10 CFR 60.135(b) are limitations on classes of materials in waste packages that could compromise the performance of the packages or other engineered or natural system components. An analysis of the designs, including the waste forms, and the repository operations will be required to show that these classes of materials will not be present or, if present, the quantities will not exceed the criteria.

Criterion (3) is an explicit design requirement that the waste packages maintain waste containment during handling operations. For the waste packages to meet this criterion under all possible loading conditions, the package designs would include structures much stronger than those dictated by any other requirement. An analysis of the containment capability of the waste packages under both normal and off-normal loads will be performed. Loading conditions that result in loss of containment by the packages will be evaluated for significance in view of the repository facility ventilation and other containment systems. These systems are addressed in the information needs under Issue 4.4 (Section 8.3.2.5).

Criterion (4) is an explicit design requirement that each waste package be uniquely identified, with the identifier legible during the preclosure period, consistent with the permanent written records, and that it not impair the integrity of the package. An assessment of the alternatives available for complying with this requirement and an analysis of the selected method will be performed.

The regulatory criteria will be reflected in the waste package design requirements, and the analyses to show that the performance goals have been met will be an integral part of the design activities. The analyses will be documented in the advanced conceptual and license application design reports.

8.3.4.3.1.1 Application of results

The results of the analyses conducted will be used to show compliance with the regulatory criteria and will also be a part of the design information used in the assessment of the performance of the repository system in Issues 2.1 through 2.4 (Section 8.3.5).

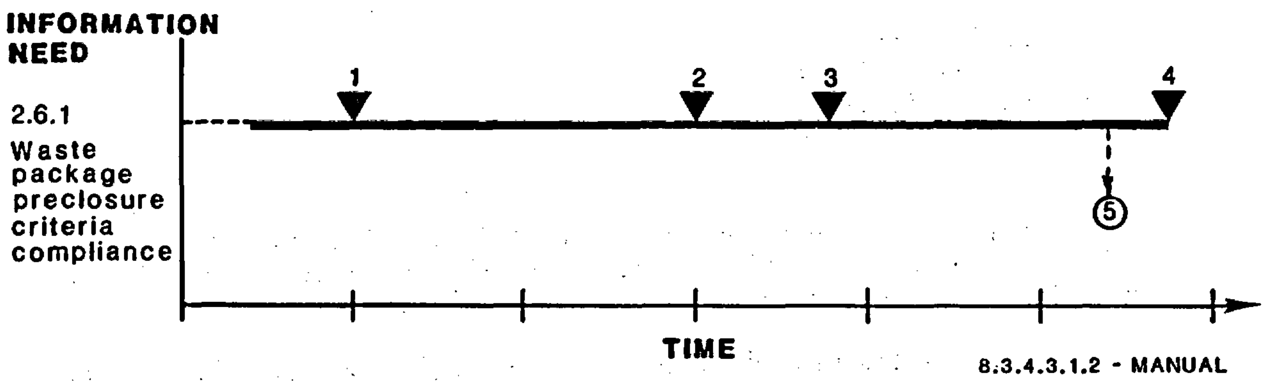
8.3.4.3.1.2 Schedule and milestones

This information need, addressing design information needed on preclosure waste package characteristics, contains no formally designated activities, but several milestones have been designated. In the figure that follows, schedule information showing the interrelationships of these milestones is presented in the form of a timeline. The timeline extends from the initiation of the advanced conceptual design of the waste package to the completion of the design report for the waste package license application. Summary schedule and milestone information for this information need can be found in Section 8.5.4. Additional schedule and milestone information is presented under Information Need 1.10.2 (Section 8.3.4.2.2).

Work on this information need is ongoing and involves design information needed to comply with preclosure criteria from 10 CFR 60.135(b) for materials, handling, and identification of waste packages. Data from this information need will be provided to Issues 2.1 through 2.4 (Sections 8.3.5.2 through 8.3.5.5).

An iterative process will be used during performance of this activity until closure of the issue. Work under this information need is not currently constrained by other program elements, but as the work progresses, interfaces with other activities become more important.

Points shown on the timeline represent major events or milestones associated with the information need. Solid lines represent study durations, and dashed lines represent interfaces. The data input and output at the interfaces are shown by circles.



The points on the timeline and the data input and output at the interfaces are described in the following table:

Point number	Description
1	Milestone M233. Initiate waste package advanced conceptual design.
2	Milestone M259. Issue waste package advanced conceptual design report.
3	Milestone T074. Start waste package license application design.
4	Milestone M274. Issue waste package license application design report.
5	Data output to Issues 2.1 through 2.4 (Sections 8.3.5.2 through 8.3.5.5).

8.3.4.3.2 Information Need 2.6.2: Design information needed to comply with preclosure criteria from 10 CFR 60.135(c) for waste forms

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

The functional requirement and performance criterion that has been derived from one of the regulatory criteria for this information need is defined in Section 7.2.1.1, generic preclosure requirements. A brief discussion of the waste form design considerations is included in Section 7.2.3.1, preclosure performance. Additional information related to the waste forms is in Section 7.3.1.1, reference waste form descriptions, and Section 7.4.3, waste form research and testing.

Parameters

The specific high-level waste (HLW) form design criteria established in 10 CFR 60.135(c)(1)-(3) require that the following parameters be addressed:

1. Solidification.
2. Consolidation to limit particulates.
3. Combustibles.

Logic

The criteria established in 10 CFR 60.135(c) prescribe three attributes or limitations on the physical form of the HLW to be disposed in the repository. These are reflected in the parameters listed above.

The information needed to demonstrate compliance with these criteria requires that the HLW form designs be analyzed to establish that the criteria will be met. The physical characteristics of the waste forms to be received at the repository for disposal are determined by the DOE waste acceptance specifications. The approach to determining that the waste forms comply with the criteria will be to compare them with the DOE waste acceptance specifications. Therefore, the approach to determining that the waste forms comply with the criteria will be to compare the waste acceptance requirements and specifications obtained in Information Need 2.6.3 (Section 8.3.4.3.3) with the criteria.

One additional criterion is imposed within this section of the regulations that is not strictly related to waste forms. All HLW must be "placed in sealed containers." Although the DOE acceptance requirements for unreprocessed spent fuel do not include this provision, the criterion will be met by the addition of a sealed container at the repository before emplacement in the underground facility.

This information need will be met by the development of the waste form acceptance specifications (Section 8.3.4.3.3). A documented comparison of these specifications with the regulatory criteria will be presented in the advanced conceptual and license application design reports.

8.3.4.3.2.1 Application of results

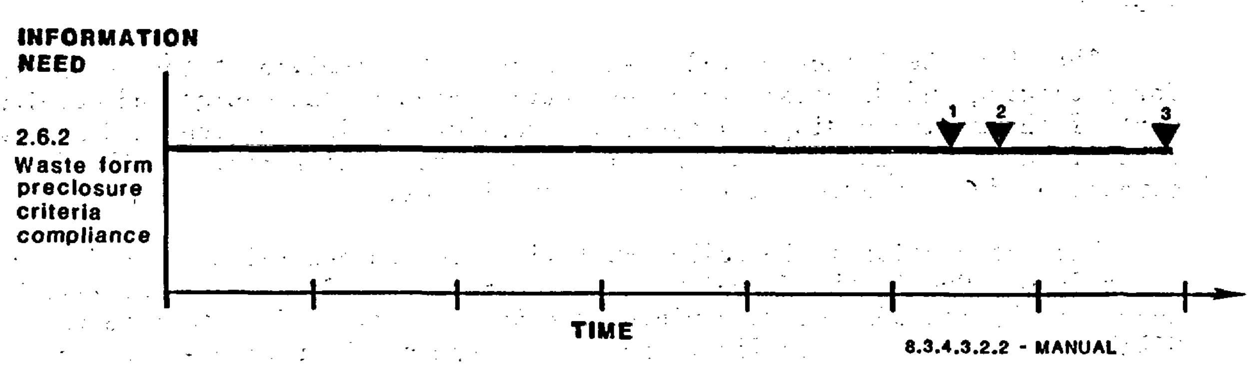
This information need provides a comparison to establish compliance with the regulatory criteria and does not have other direct application in the resolution of the issue. The detailed physical characteristics of the waste forms will be addressed in other documents, such as the Office of Geologic Repository generic requirements and will be reflected in the NNWSI Project waste package design requirements.

8.3.4.3.2.2 Schedule and milestones

This information need, addressing waste-form design information, contains no formally designated activities, but several milestones have been designated. In the figure that follows, the schedule information for this information need is presented in the form of a timeline. The timeline extends to the issuance of the final products associated with the studies. Summary schedule and milestone information for this investigation can be found in Section 8.5.4.

This information need is linked with Information Needs 2.6.3 and 1.5.2 resulting in the one activity shown on the accompanying timeline. Information Need 2.6.3 provides the waste acceptance specifications to be used in this Information Need. Information Need 1.5.2 provides the necessary waste form and materials data.

The information need number and title corresponding to the timeline are shown on the left of the following figure. The points shown on the timeline represent major events or important milestones associated with the information need. The solid line represents durations.



The points on the timeline are described in the following table:

Point number	Description
1	Milestone P256. Complete waste form and materials testing in support of the draft environmental impact statement.
2	Milestone Z468. Issue report on the comparison of waste form acceptance specifications with regulatory criteria.
3	Milestone P258. Complete documentation of the results of waste form testing to support draft environmental impact statement.

8.3.4.3.3 Information Need 2.6.3: Waste acceptance specifications

Technical basis for addressing the information need

Link to the technical data chapters and applicable supporting documents

Reference is made to the waste acceptance specifications and requirements in Sections 7.2.3.1 and 7.3.1.1 under discussions of preclosure performance and reference waste form descriptions, respectively.

Parameters

The parameters to be addressed in this information need are

1. Acceptance specifications for unreprocessed spent fuel.
2. Acceptance specifications for West Valley high-level waste.
3. Acceptance specifications for DOE defense high-level waste.

Logic

The characteristics of all waste forms to be received at the repository for packaging and disposal are an essential input to the design and development of the geologic disposal system. Therefore an information need has been identified to provide a mechanism within the issues hierarchy for the development and documentation of these characteristics.

The information to be collected falls into two general classes for each waste form. One is the formal waste acceptance specifications that will be developed by the DOE for determining the acceptability of waste into the OCRWM system. These specifications will determine the parameters to be investigated in the waste form performance testing activities and establish the range of variability of the waste forms. Once established, these acceptance specifications are not expected to change significantly.

The other class of information is the baselined projections of the time-dependent characteristics of the waste streams. These projections are the basis of the waste package and repository designs for packaging and handling facilities and equipment, capacities, and receipt rates. This information is expected to change with time as more accurate projections, especially for waste forms that have not been manufactured yet, become available.

The analyses and activities required to provide the waste acceptance specifications and other waste form characteristics are the direct responsibility of the DOE. Technical support will be provided by the NNWSI Project as appropriate to assist in developing the information. The details of these studies and analyses are beyond the scope of the site characterization plan.

8.3.4.3.3.1 Application of results

The information provided through this information need is central to the basis for resolution of virtually all the waste package design and performance issues. The timely availability of this information is, therefore, critical. It will be maintained and controlled throughout the design and development phase of the project within the NNWSI Project reference information base as a part of the technical baseline.

8.3.4.3.3.2 Schedule and milestones

The schedule and milestones associated with this information need are tied to other elements of the DOE OCRWM system and the Spent Fuel Working Group and Waste Acceptance Committee. There are no NNWSI Project milestones for this information need.

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Chapter 8

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P

Nuclear Waste Policy Act
(Section 113)

WASTE PACKAGE PRODUCTION TECHNOLOGIES

Consultation Draft

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

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8.3.4.4 Issue resolution strategy for Issue 4.3: Are the waste package production technologies adequately established for the resolution of the performance issues?

Regulatory basis for the issue

This issue arises from the provision of 10 CFR 960.5-1, the preclosure system guidelines, that the qualifying conditions require that the repository operation be demonstrated as feasible on the basis of reasonably available technology. The waste packages are a "product" of the repository operation and therefore must be technically feasible on the same basis.

In addition to their technical feasibility, the processes selected for producing the waste packages affect the design of the packages, the design and operation of the repository surface facilities where they are produced, and the performance of the packages after they are emplaced in the repository subsurface facilities.

Rather than differentiate between the feasibility, package and facility design, and package performance aspects of the production processes and describe the plans for each separately, the planned activities to provide information for all these topics are addressed in this issue.

Approach to resolving the issue

Several production technologies are required to fabricate, assemble, and inspect the waste packages. These processes, in addition to being reasonably available, must be responsive to the performance-derived requirements for the waste packages and relevant to the design concepts. Thus, this issue (4.3) is closely coupled to the waste package design requirements document and the design concepts that are generated as a part of Issue 2.6 (Section 8.3.4.3). The relationship between these issues is shown in Figure 8.3.4.4-1. To minimize the interfaces between this issue and other design issues (both for the repository and the waste package), this issue interacts directly only with Issue 2.6.

Interactions with the other design issues are implemented within Issue 2.6 through the NNWSI Project reference information base. These interactions are shown in Figure 8.3.4.4-1.

The approach to resolving this issue will involve a set of studies directed at identifying and evaluating production processes in each of the technology areas. Selection criteria for each technology will be established. Candidate processes will be identified and evaluated against the selection criteria. The leading candidate processes will be used to produce representative test specimens. These test specimens will be analyzed to determine their properties, and the properties will be compared with the criteria derived from the performance requirements. Process selection will then be made on bases that will include performance, as well as other criteria such as reliability, adaptability to repository facility operations, and cost. The final step in the studies will be the use of the selected processes to produce full-scale prototype components and assemblies, including testing of the prototypes to demonstrate both feasibility and compliance with the requirements.

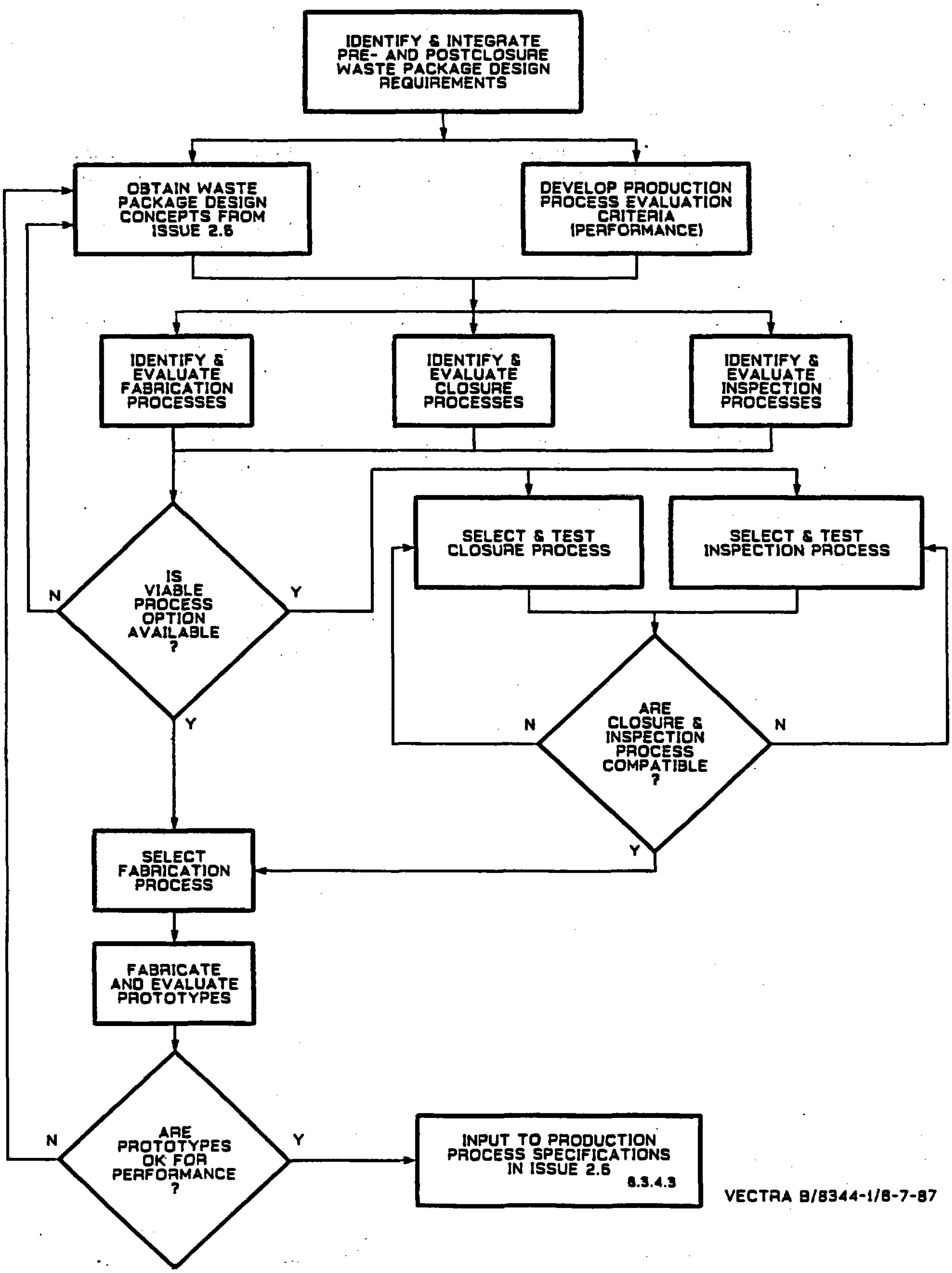


Figure 8.3.4.4-1. Logic diagram for the resolution of Issue 4.3 (waste package production technologies).

8.3.4.4.1 Information Need 4.3.1: Identification and evaluation of production technologies for fabrication, closure, and inspection of the waste package

Technical basis for addressing the information need

Link to the technical data chapters and applicable support documents

This information need has only an indirect relationship to the characteristics of the site. That relationship is established through the need for the processes selected for production to be responsive to the requirements placed on the waste package design by the anticipated service environment and the performance of the package components. The existing data on this environment is summarized in Section 7.1 and discussed further in Section 7.4.1. The implications of the production processes on the performance of the package components are discussed briefly in Section 7.4.2. A brief discussion of the required processes is found in Section 7.3.1.4.

Parameters

The general parameters to be addressed in this information need are the waste package production technologies. Within each of the technologies, specific parameters associated with the identification, testing, evaluation, selection, and demonstration of the processes are defined. These specific parameters are identified in the activity that addresses each technology.

Logic

The logic to be followed in developing the production technologies is described in the issue resolution section for this issue and follows the conventional approach to production engineering activities as shown in Figure 8.3.4.4-1.

8.3.4.4.1.1 Design Activity 4.3.1.1: Waste package fabrication process development

Objectives

The objective of this activity is to determine, by using the logical sequence described for this issue, the processes to be used in fabricating the nonwaste form components of the waste packages.

Parameters

The parameters of this activity involving fabrication technologies are

1. Requirements and selection criteria.
2. Candidate process identification.
3. Process testing.
4. Process evaluation.
5. Process selection.
6. Prototype fabrication and testing.

Description

Fabrication is defined as those processes required to produce the package components other than the waste forms. These components are assumed to be produced at commercial facilities and, after inspection to ensure compliance with procurement specifications, delivered to the repository for assembly. The processes to be used may include production of container and other component materials; forming and joining processes such as rolling, welding, casting, forging, extruding, or combinations of these; heat treating; nondestructive testing and inspection; and packaging, shipping, and storage.

Each of the applicable process steps will be evaluated, and a process will be selected and demonstrated as necessary to show compliance with the requirements established for each package component.

8.3.4.4.1.2 Design Activity 4.3.1.2: Waste package closure process development

Objectives

The objective of this activity is to determine, by using the logical sequence described for this issue, the process to be used in the final closure of the waste package containers.

Parameters

The parameters of this activity involving closure technologies are

1. Requirements and selection criteria.
2. Candidate process identification.
3. Process testing.
4. Process evaluation.
5. Process selection.
6. Full-scale demonstration.

Description

The closure process is required to provide a high-integrity seal of the containers. The closure must be performed under hot cell conditions by equipment operated by remote control. Additional requirements will be imposed by the need for a highly reliable process that can be qualified on the basis of monitored process variables and remote equipment maintenance. The process may be a conventional joining process or may require developments of the state of the art.

The candidate closure processes will be evaluated, and a process will be selected and demonstrated as necessary to show compliance with the requirements established for final package closure.

8.3.4.4.1.3 Design Activity 4.3.1.3: Waste package closure inspection process development

Objectives

The objective of this activity is to determine, by using the logical sequence described for this issue, the process to be used in the inspection of the final closure of the waste package containers.

Parameters

The parameters of this activity involving inspection technology are

1. Requirements and selection criteria.
2. Candidate process identification.
3. Process testing.
4. Process evaluation.
5. Process selection.
6. Prototype subsystem design and specification.

Description

Following the final closure of the waste package containers, the integrity of the closure will require a verification by a nondestructive inspection. This inspection process, which will also be made by equipment operated by remote control, must operate with high reliability to ensure adequate defect detection and yet avoid false rejections. The high ionizing radiation field present will limit the alternatives available for this process.

The candidate closure inspection processes will be evaluated, and a process will be selected and demonstrated as necessary to show compliance with the requirements established for closure inspection. An inspection subsystem will be designed and specified for this process.

8.3.4.4.1.4 Application of results

The results of this study will be used directly to resolve this issue (4.3). Additionally, they will be used interactively with information from the waste package design development in Issue 2.6 (Section 8.3.4.3) to establish the production process specifications, which are an integral part of the design documentation.

8.3.4.4.1.5 Schedule and milestones

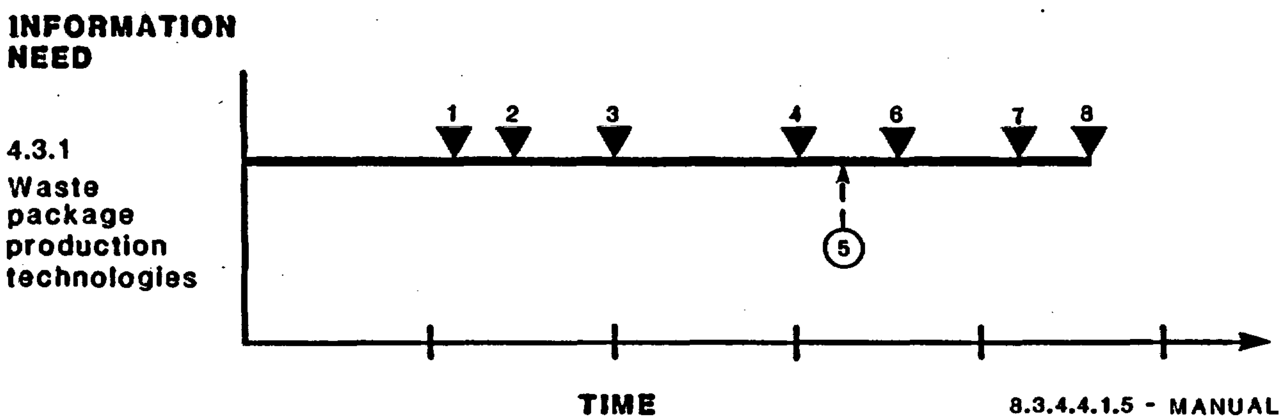
This information need contains three design activities: 4.3.1.1 (waste package fabrication process development), 4.3.1.2 (waste package closure process development), and 4.3.1.3 (waste package closure inspection process development). In the figure that follows, the schedule information for these activities is presented in the form of a combined timeline. The timeline extends to the issuance of the final products associated with the activities.

Summary schedule and milestone information for this information need can be found in Section 8.5.4.

All three design activities under this information need are ongoing and involve development work that is progressing in parallel with activities described in Issue 1.10.2 (Section 8.3.4.2.2). Data collected under this information need will be provided to Issue 1.10 (waste package characteristics--postclosure) and to the repository design issue. An iterative process will be used during the performance of these activities until closure of the issue.

Activities under this information need are currently not constrained by other program elements, but as the activity progresses, interfaces with other studies become more important.

All the milestones for the various design activities have been combined onto a single timeline. The points shown on the timeline represent major events or important milestones associated with the information need. Solid lines represent study durations, and dashed lines show interfaces. The data input and output at the interfaces are shown by circles.



The points on the timeline and the data input and output at the interfaces are described in the following table:

Point number	Description
1	Milestone P275. Issue report on container fabrication process development.
2	Milestone P276. Issue report on container closure process development.
3	Milestone Z055. Issue final report on the inspection process and nondestructive evaluation system specifications.

Point number	Description
4	Milestone Z054. Issue report on prototype closure joints and closure process for license application design.
5	Advanced Conceptual Design (ACD) available from Information Need 1.10.2 (Section 8.3.4.2.2) (Milestone M259).
6	Milestone M245. Complete fabrication of waste package ACD prototype(s).
7	Milestone M262. Complete engineering tests of ACD prototype waste package.
8	Milestone P203. Document prototype waste package testing results.