DOE/RW-0160

DOE/RW-0160

Chapter 8

Nuclear Waste Policy Act
(Section 113)

Section 8.3.3

Consultation Draft

SEAL PROGRAM

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

Volume VI

PART B

January 1988

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

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8.3.3 SEAL PROGRAM

This section describes the activities required to develop designs and demonstrate performance of seals to be placed in shafts, ramps, drifts, and boreholes. Section 8.3.3.1 provides an overview of the NNWSI Project seal program and describes the technical approach of the development program. It is important for the reader to understand the planning basis for the seal program. Various aspects of the seal program are discussed in different places in this document (i.e., site hydrology in Chapter 3, seal concepts in Section 6.2, and seal analyses in Section 6.4). The following topics are discussed in more detail in the sections noted:

1. Seal environment--the anticipated environment used to ascertain the need for and performance of sealing components (Section 8.3.3.1.1).

2. Seal components testing--the laboratory and field testing currently planned in support of the seal program (Section 8.3.3.1.2).

3. Seal design--current designs and design concepts for seals (Section 8.3.3.1.3).

4. Seal modeling--modeling and code development for designing and assessing performance of seals (Section 8.3.3.1.4).

Section 8.3.3.2 (Issue 1.12, seal characteristics) describes the future work planned in support of the sealing program with emphasis upon those activities that use data from site characterization. The discussion includes a preliminary performance allocation for the sealing system as evidenced by the performance measures and goals established for the system and its components. In addition, the site characterization data (parameters) needed in support of the seal program are identified. The discussions of future activities are organized on the basis of four information needs that must be satisfied to resolve the seal characteristics issue.

While the specific wording of Issue 1.12 appears to address only shaft and borehole seals, a broader interpretation is adopted in Section 8.3.3.2. To provide a complete and unified discussion of the sealing system for the proposed Yucca Mountain mined geologic disposal system (MGDS), Issue 1.12 addresses all sealing components within the underground facility in addition to the seals for shafts, ramps, and boreholes.

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.

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Chapter 8

Section 8.3.3.1

Nuclear Waste Policy Act
(Section 113)

SEAL OVERVIEW

Consultation Draft

Site Characterization Plan

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8.3.3.1 Overview of the seal program

The primary objective of the NNWSI Project repository sealing program is to develop sealing designs that will act to ensure that water will not compromise the containment and isolation of radionuclides from the accessible environment.

Because of the timing of the activities, the seal program is somewhat different from other design-related activities. The repository surface facilities, the accesses, and portions of the underground facility will be constructed shortly after construction is authorized; the waste packages and the remainder of the underground facilities will be constructed during repository operations. The seals, on the other hand, will not generally be installed until the repository is decommissioned. A part of the reason for this delay in emplacing the seals is because the anticipated hydrology at the site; specifically, the lack of aquifers above the waste emplacement horizon at the Yucca Mountain site, makes it unnecessary to install either permanent or temporary shaft or ramp seal components at the time of access construction. The shaft liner can be removed to emplace seal components later.

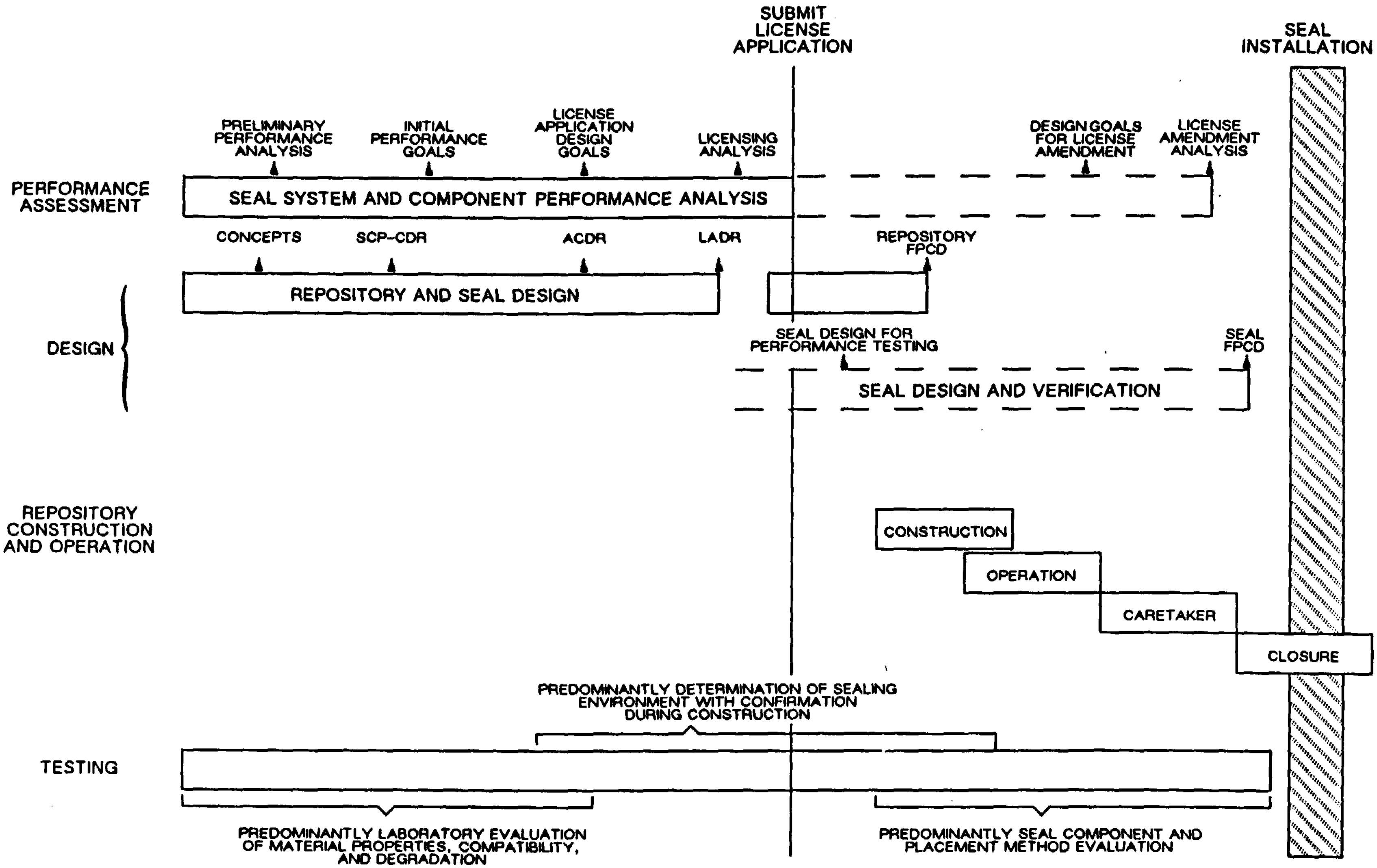
The sequencing of testing in support of the seal program is also dependent upon the planned timing for the installation of the seals. As noted in Figure 8.3.3.1-1, there is substantial time for testing of seal components after the initiation of repository construction. The timing is consistent with the NRC requirements (10 CFR 60, Subpart F) for the performance confirmation program, which note

1. It is anticipated that testing will be conducted "During early or developmental stages of construction..." (10 CFR 60.142(a)).
2. "Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts" (10 CFR 60.142(d)).

Both of these statements indicate clearly that the sealing testing is not anticipated to be completed by the time of license application and that testing is expected to be done after repository construction is initiated.

The seal designs included in the license application design (LAD) may not be the designs used for actual construction of the seals since several (possibly as many as 50) years will pass before the seals are installed. During these years, many of the assumptions made in the development of the seal designs will be evaluated as data from access and underground facility construction becomes available. Similarly, data obtained from potential testing of seal components during repository operations will be available as a basis for design modifications. It is reasonable to expect that additional knowledge will be incorporated into the final design of the seals. The role of the LAD for seal components is, therefore, to serve as the basis for analyses that will be included with the license application to establish the following:

1. The technology for constructing seals is reasonably available.



SCP - CDR - SITE CHARACTERIZATION PLAN - CONCEPTUAL DESIGN REPORT
ACDR - ADVANCED CONCEPTUAL DESIGN REPORT
LADR - LICENSE APPLICATION DESIGN REPORT
FPCD - FINAL PROCUREMENT & CONSTRUCTION DESIGN

Figure 8.3.3.1-1. Anticipated sequencing of sealing activities.

K-5/21/87-FIG 8.3.3-1

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2. There is reasonable assurance that the seals have been designed so that, following permanent closure, they do not become pathways that compromise the geologic repository's ability to meet the postclosure performance objectives.

The specific activities and tests to be conducted after submittal of the license application have not been defined as yet; hence, the discussions of the seal program in this document are structured around the efforts leading up to and required for the construction authorization application. The seal program includes the following activities:

1. Defining the sealing concepts.
2. Establishing performance goals and design requirements.
3. Developing the conceptual designs for sealing components.
4. Developing the license application design.
5. Establishing the properties of the sealing materials planned for use.
6. Evaluating the performance of sealing components at each stage in the design process.

8.3.3.1.1 Seal environment

The site hydrology is the dominant aspect of the environment for the seals. The current understanding of the site hydrology is described in Chapter 3. The partially saturated nature of the Topopah Spring Member in which the repository would be located, the anticipated relatively low water flux through the unit, and the potential for flow through discrete fractures or faults are important hydrologic aspects that require further evaluation. Other aspects of the seal environment that require consideration are related to surface rainfall and the potential for flooding, the stress and temperature fields to which the seals would be exposed, the bulk chemistry of the formation and the chemistry of the ground water, the potential for seismically induced forces or motion, and (principally for the borehole seals) the flow-related characteristics of the regions in the saturated zone below the repository.

Specific site information needed for the design and evaluation of the seals is identified in Section 8.3.3.2.1. Information such as the saturated hydraulic conductivity, gradational analyses, compressibility of shaft fill, borehole construction, and geologic logs associated with specific boreholes, will support the design process in the selection of the appropriate methods to emplace sealing components. Site information needed to validate analytical methods may include hydrologic characterization of the Topopah Spring Member (TSw2). Specific properties required are unsaturated matrix properties and the drainage capacity of the TSw2 unit. Prevalence of water-producing zones, if any, and the hydrologic nature of the Ghost Dance fault, the area underlying Drill Hole Wash, and the rock matrix will all be important site information needed to select the most appropriate sealing designs. The description of data needed in support of establishing or confirming the seal environment is based in part on the analysis work completed to date and the seal design concepts being used; these analyses and designs are summarized in Sections 6.4.3.2 and 6.2.8, respectively.

8.3.3.1.2 Seal components

In the Yucca Mountain mined geologic disposal system (MGDS), discussed in Section 8.2, the seals are identified as parts of two subsystems:

System Element	Description
2.2.3	Shaft and borehole seals subsystem
2.2.2.3	Repository seals and backfill subsystem (part of the repository engineered barriers)

A sealing component is a specific engineered structure that is part of one of these two system elements. The components (or sealing system elements) discussed below are based mostly on the work of Fernandez and Freshley (1984), which specifically addressed a repository located in the unsaturated portion of Yucca Mountain; the concepts of Fernandez and Freshley were modified during the development of the Site Characterization Plan-Conceptual Design Report (SCP-CDR) (SNL, 1987). These design changes are reflected in Section 6.2.8.

For a shaft, the components of the seals being considered are surface cover, shaft collar cores, anchor-to-bedrock plug and seal, settlement plugs, shaft fill, and the repository station seal (refer to Section 6.2.8 for further discussion of the components). For the Yucca Mountain site, ramps are planned (in addition to shafts) as a means of repository access. The seal components for the ramps are similar to those for the shafts. For the current concepts, the principal component of the seals for the boreholes is the seal in the portion of the borehole that penetrates the tuffaceous beds of Calico Hills; the remainder of the borehole may be filled with a granular material or a cementitious material. Further, it is believed that not all boreholes in the vicinity of the site will require sealing; for example, boreholes that are upgradient or long distances from the repository may not require sealing. Decisions on which boreholes may need to be sealed will be made for each specific borehole near the site. Further discussion of the logic regarding which boreholes may need to be sealed is provided in Fernandez and Freshley (1984) and in Section 8.3.3.2.

For the repository seals, the principal concern is related to options for sealing a discrete fault or fracture zone that may contain water. Options under consideration are discussed in Section 6.2.8.6 for a wide range of inflow. The determination of whether or not such inflow is credible at the Yucca Mountain site is one of the reasons for tests to be conducted in the exploratory shaft relative to structural features (Ghost Dance fault, Drill Hole Wash). Potential components for these options range from excavation of a channel in a drift floor to constrain flow, to small dams placed in drifts to impede lateral flow of water, to emplacement of physical barriers of bentonite, clay, or cementitious materials on each side of the flow to divert the flow downward and away from the waste packages.

The long-term compatibility of sealing components with their environment must be considered to ensure that long-term performance of the sealing components is acceptable. The testing program to provide data for assessing this compatibility is described in Section 8.3.3.2.2. These tests are intended to quantify the initial and (where possible) the altered physical, hydrologic, mechanical, and thermal properties of the seal materials. Additionally, the chemical stability of the materials and their reactivity with the surrounding formation are being assessed for various components.

8.3.3.1.3 Seal designs

The current designs for the seals are described in Section 6.2.8. More detail is provided in the SCP-CDR (SNL, 1987) and in the sealing concepts report (Fernandez and Freshley, 1984) published earlier. The technical basis for an initial set of design requirements and performance goals for the sealing components have been published (Fernandez et al., 1987). This technical basis consists of numerous evaluations of hydrologic conditions that exist at the site and that might exist in the future.

The advanced conceptual design and the license application design will be the next two phases in the design of seals. For each phase of the design, tradeoff studies will be performed to aid in the selection of appropriate configurations for seal components, selection of placement methods, and selection of the materials to be used. These tradeoff studies will also allow refinement and reevaluation of the design requirements and performance goals. Several different types of design analyses have been identified in Section 8.3.3.2.4.2. These include analyses to evaluate the potential for drainage through drift floors, shafts, and ramps.

Additional evaluations to estimate the quantities of water that might enter shafts, ramps, and repository drifts from discrete faults and episodic flooding events are planned. The potential for flow through backfilled drifts will also be evaluated. These types of analyses will allow more definition of strategies for sealing discrete water-producing zones (if any are found), for dissipating water that might enter from extreme events, and for selecting materials to be proposed for use. Nearly all these analyses require site characteristics; the testing required to verify the conclusions reached in the preliminary studies will therefore be focused on confirming the site characteristics that are being (and have been) used as the basis for the design. As identified in Figure 8.3.3.1-1, the testing program for verification of the designs can then be developed in detail on the basis of the additional data collected for the site.

8.3.3.1.4 Seal modeling

Modeling seal performance is an integral part of the design activity for the seals. As indicated in the preceding section, modeling is used to establish the need for seals, the performance requirements, and the anticipated performance of the various components.

The logic for how seal performance is evaluated is given in Section 8.3.5.11, and the strategy for resolving the sealing issue is presented in Section 8.3.3.2. Models are needed for both saturated and partially-saturated flow. Both numerical and analytical models have been used; the results published to date are described briefly in Section 6.4.3. The types of numerical and analytical approaches used to date are in Section 6.4.3.1. It is anticipated that no new fluid-flow codes will be required specifically for use in the seal program. Rather, codes that are being developed, verified, and validated for use in other hydrologic performance analyses will be used for the seal program. Some potentially applicable computer codes, their capabilities, material models, and the status of their documentation are described in Section 8.3.5.19. Detailed evaluations of the applicability of the codes for the complexities of the seal program will be completed, and it is likely that verification or benchmark problems will be set up to consider sealing needs.

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Chapter 8

Nuclear Waste Policy Act
(Section 113)

Section 8.3.3.2

Consultation Draft

SEAL CHARACTERISTICS

Site Characterization Plan

Yucca Mountain Site, Nevada Research and Development Area, Nevada

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8.3.3.2 Issue resolution strategy for Issue 1.12: Have the characteristics and configurations of the shaft and borehole seals been adequately established to (a) show compliance with the postclosure design criteria of 10 CFR 60.134 and (b) provide information for the resolution of the performance issues?

This issue is concerned with developing seals needed for shafts, ramps, exploratory boreholes, and the underground facility. The regulatory basis for this issue, the strategy for resolving the issue, and the future work needed in support of developing and evaluating seal designs are described.

Regulatory basis for the issue

There are several sections in 10 CFR Part 60 that relate to sealing, specifically 60.134(a) and (b), 60.112, 60.113(a), and 60.142(a), (b), (c), and (d).

Section 60.134 of 10 CFR Part 60, "Design of seals for shafts and boreholes," states

(a) General design criterion. Seals for shafts and boreholes shall be designed so that following permanent closure they do not become pathways that compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure.

(b) Selection of materials and placement methods. Materials and placement methods for seals shall be selected to reduce, to the extent practicable: (1) the potential for creating a preferential pathway for ground water; or (2) radioactive waste migration through existing pathways.

Section 60.112 of 10 CFR Part 60 addresses the overall system performance for the geologic repository after permanent closure. The section states

> The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the U.S. Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

Section 60.113 of 10 CFR Part 60, "Performance of particular barriers after permanent closure," specifically addresses the engineered barrier system:

> (a) General provisions. (1) Engineered barrier system. (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when

radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times . . . (ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that: (A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 60.113(b) provided that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and (B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1% of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

The NRC defines the engineered barrier system as the waste packages and the underground facility, and the underground facility as the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

Section 60.142 of 10 CFR Part 60 addresses the design testing associated with confirming performance of backfill and shaft and borehole seals. This section is as follows.

60.142 Design testing.

(a) During the early or developmental stages of construction, a program for in situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted.

(b) The testing shall be initiated as early as is practicable.

(c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.

(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts.

To provide a complete and unified discussion of the sealing system, this issue (1.12) addresses the shafts and boreholes and their seals as well as all sealing components within the underground facility and ramps.

Approach to resolving the issue

The logic used to resolve this issue is illustrated by Figure 8.3.3.2-1. The approach used to resolve this issue involves several steps, defined below, resulting in the preparation of design requirements, design constraints, and the identification of information that must be defined to resolve the issue. These requirements, constraints, and information related to repository design are then transmitted to Issue 1.11 (Section 8.3.2.2) which defines the reference postclosure design and integrates the seal designs with other postclosure concerns. The integrated reference postclosure design together with selected site and test data from the reference information base (RIB) is used to determine if the performance goals established for the sealing subsystem can be met. This process is performed for each design phase as indicated by Figure 8.3.3.2-1a. The performance allocation process related to this issue (steps A through G, indicated on this figure) are briefly summarized in the following:

Step A. Using the regulatory requirements and the existing design, analyses, and site data, identify the sealing components that make up the sealing subsystem.

Step B. Define the functional requirements for the seals (i.e., the function that each selected, sealing component is to perform and the process that must be considered in assessing its ability to perform its function).

Step C. Identify the performance measure that can be used to show how well the sealing component performs its intended function.

Step D. Establish the tentative goals for the related performance measure as well as the confidence needed in reaching the goal.

Step E. Define the parameters, establish tentative parameter goals, and estimate the level of needed and current confidence in meeting the parameter goals.

Step F. Develop the design requirements that apply to sealing options and identify the design constraints that are imposed on nonsealing system elements from the sealing system.

Step G. Identify information needed to resolve this issue. The information defined as being needed will be obtained as part of the activities that will satisfy various information needs including those under this issue, as well as under some other issues, particularly Issue 1.11 (Section 8.3.2.2, configuration of underground facilities--postclosure). The application of each of these steps to this issue is presented in the following sections.

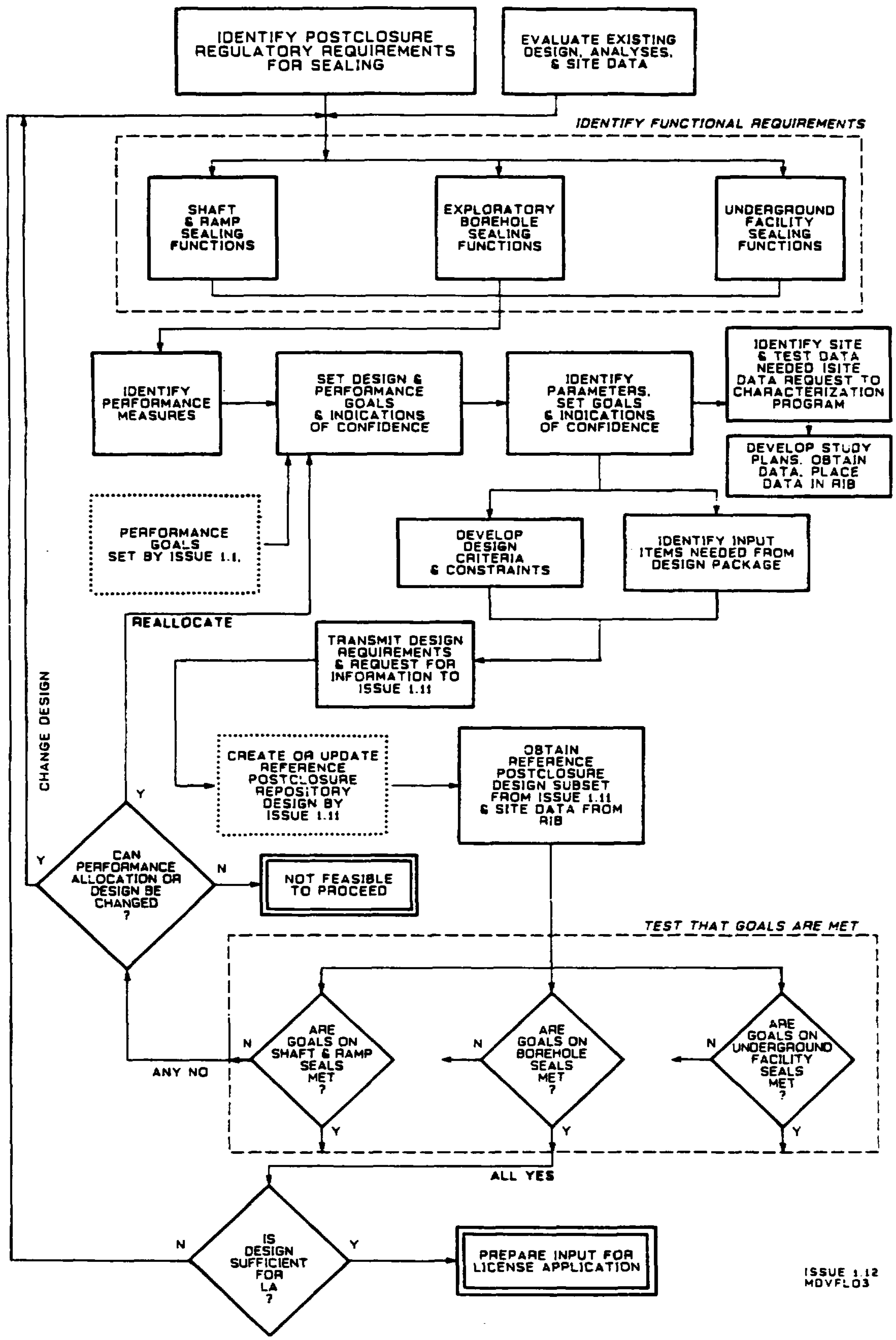
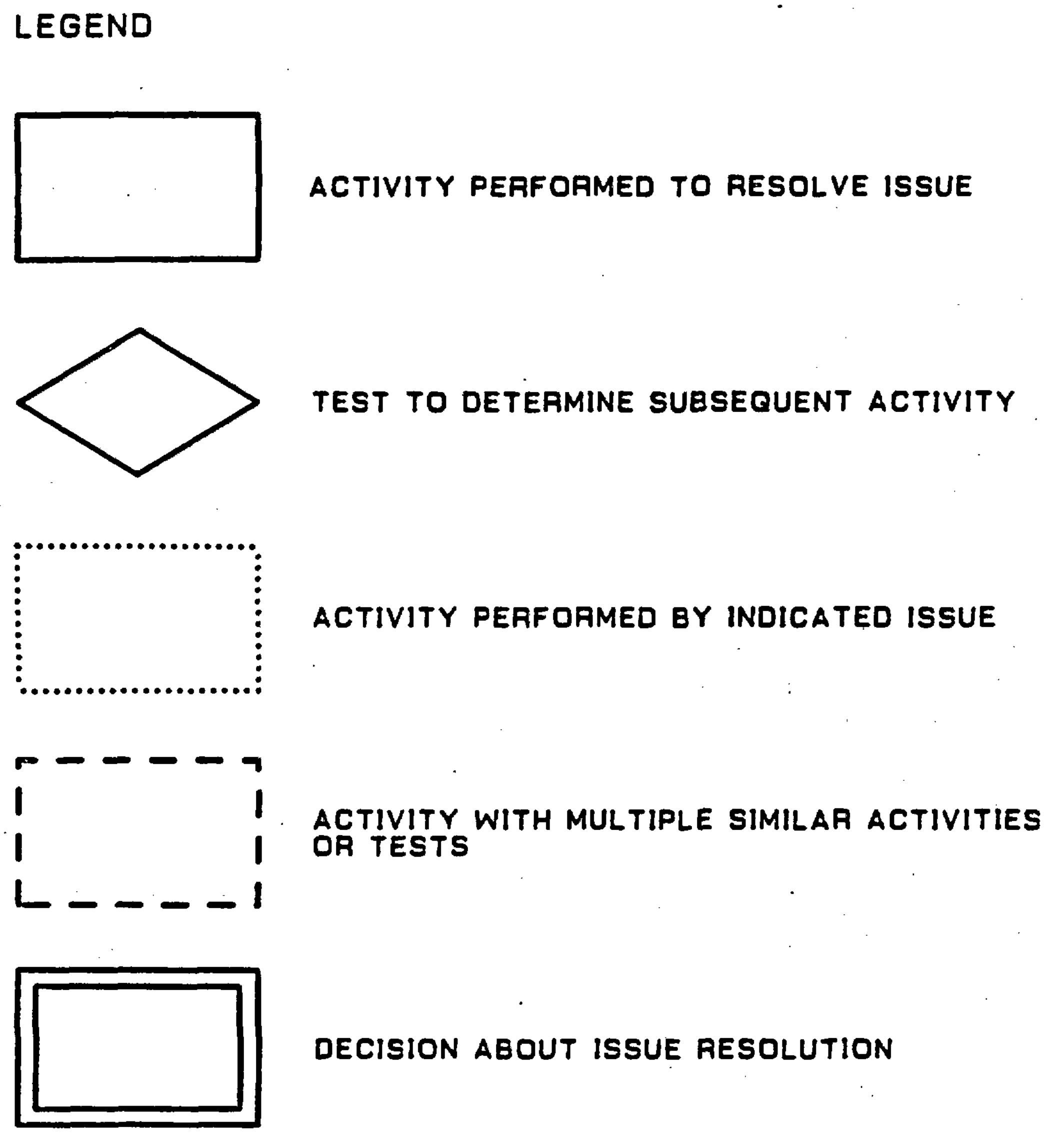


Figure 8.3.3.2-1a. Logic diagram for issue 1.12 (seal characteristics). See Figure 8.3.3.2-1b for legend. Section 8.3.2.1 describes the relationships and interfaces between design and performance issues.



Y - YES
N - NO
LA - LICENSE APPLICATION
RIB - REFERENCE INFORMATION BASE

Figure 8.3.3.2-1b. Legend for Figure 8.3.3.2-1a.

Step A: Sealing components

The sealing components presented in the following discussion were originally described in Fernandez and Freshley (1984). Sealing components can be associated with shafts, ramps, the underground facility, and boreholes. In the current design, there are four shafts: the men and materials shaft, the emplacement exhaust shaft, and the two exploratory shafts (ES-1 and ES-2). There are also two ramps: the waste emplacement ramp and the tuff handling ramp. There are numerous boreholes in the vicinity of the repository. Figure 8.3.3.2-2 indicates the system elements that make up the sealing subsystem as discussed here, the potential locations of seals, and the potential sealing components being considered for each location. These sealing components are also identified in Table 8.3.3.2-1, together with their associated functions, processes, material properties, performance measures, and tentative goals. Sealing-related repository design constraints and goals are identified in Table 8.3.3.2-2. The site data needed to support resolution of the sealing issue are identified in Tables 8.3.3.2-3 and 8.3.3.2-4.

There are primarily three sealing components in the shafts and ramps: the anchor-to-bedrock plug/seal, the general fill, and the station plug. A fourth sealing component, the Topopah Spring Member at the base of shafts and ramps, although a physical feature of the site, is included here because water drainage through this sealing component is part of the sealing strategy. Although not specifically indicated on Figure 8.3.3.2-2, additional plugs/seals can be installed at various locations within the shaft to accomplish the same functions as any of the sealing components just identified. Similarly, if anomalous conditions occur (such as flow in fault zone), consideration will be given to components specific to the situation. In the ramps, numerous dams placed along the length of the ramp could interrupt flow periodically along the floor of the ramp. Placement of a single repository station seal at the end of the ramp could possibly accomplish the same function as these numerous dams. Therefore, installation of a single sealing component (a repository station seal) could represent a simplification in the proposed number of sealing components.

In the underground facility several sealing design options are proposed. These include single dams or bulkheads, double bulkheads, backfilled sumps, backfilled channels, plugs in horizontal emplacement boreholes, and drift backfill. The identification of these sealing components does not suggest that all these components will be used in the underground facility. Rather, they represent options that can be emplaced in the underground facility to accommodate a broad range of water inflows, ranging from small continuous or discontinuous flows to larger, periodic flows. For example, a backfilled sump could be used where the inflows are small and it is desired to drain the inflow at or near the source of water. Larger flows could be handled by directing waters to specific areas in nonemplacement drifts by the use of backfilled drifts or channels. Once at these specific locations, the water could be retained by single dams or bulkheads, depending upon the quantity of water.

Exploratory boreholes drilled from the surface could potentially provide pathways for radionuclide migration from the repository to the water table. As of May 1986, there are five existing boreholes within the proposed

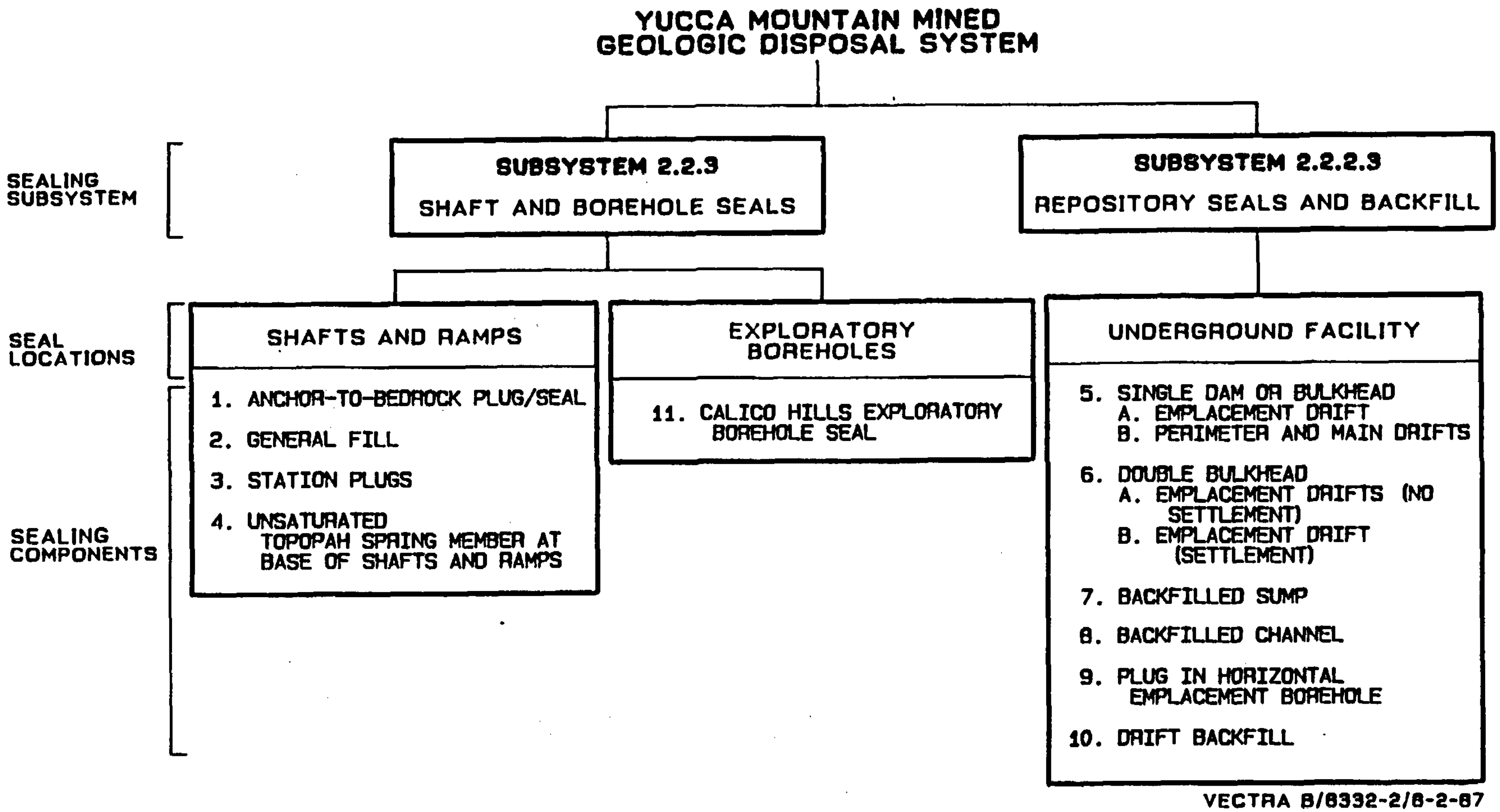


Figure 8.3.3.2-2. Sealing subsystem, seal locations, and seal components. (Identifying numbers of sealing components correspond to those used in Table 8.3.3.2-1.)

Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 1 of 4)

Step A	Step B		Step C		Step D	
Sealing component	Function	Process	Material properties	Performance measure	Tentative design goal[a]	Needed confidence
SHAPT AND RAMP SEALING COMPONENTS						
1. Anchor-to-bedrock plug/seal	Reduce amount of water that could potentially reach the waste disposal rooms	Water entering the upper portion of the shaft or ramp	Permeability	Quantity of water	1A. Limit surface waters entering shaft to 1,700 m/yr from 0 to 500 yr and 23,000 m^3/yr at the end of the sealing period	High
	Reduce the potential for human intrusion into the repository	Penetrability through sealing components	To be determined through design tradeoff studies	Physical presence	1B. Deter human entry	Medium
2. General fill	Reduce the amount of water that could potentially reach the waste disposal rooms	Infiltration of surface and subsurface waters reaching the base of the shafts	Permeability of fill	Quantity of water	2A. Restrict flow	Low
	Reduce the air flow up through shafts	Air flow up through the shaft due to convective air movement	Air permeability of fill	Percentage of gaseous radionuclides preferentially exiting shafts	2B. Restrict gaseous releases through shaft to 1% of Environmental Protection Agency allowable release limits to accessible environment	Low
	Reduce the potential for human intrusion into the repository	Penetrability through sealing components	To be determined through design tradeoff studies	Physical presence	2C. Deter human entry	Medium
3. Station plugs	Reduce the amount of water that could potentially reach the waste disposal rooms	Water passage from the base of shaft to the waste emplacement drifts	Permeability	Quantity of water	3A. Limit surface and subsurface waters from entering the underground facility to 1,000 m^3 per yr from 0 to 500 yr and 14,000 m^3 per yr at end of the sealing period	High

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Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 2 of 4)

Step A	Step B		Step C		Step D		
Sealing component	Function	Process	Material properties	Performance measure		Tentative design goal[a]	Needed confidence
4. Unsaturated Topopah Spring Member (TSw2) at base of shafts	Encourage drainage from base of shafts	Flow through the bulk rock, at base of shaft, both lined and unlined cases	Bulk rock hydraulic conductivity	Drainage capacity	4A.	Ensure uninhibited flow from the base of exploratory shaft 1 (ES-1) and the man and material (MM) shaft	High
			UNDERGROUND FACILITY SEALING COMPONENTS				
5. Single dam or bulkhead[b] in emplacement drifts	Retain and drain water entering emplacement drifts where water entry occurs	Lateral migration of water in drifts	Permeability	Quantity of water	5A.	Retain a portion of the ground water inflow near source by providing adequate storage volume and drainage capacity and limit flow through dam to 47 m^3 per yr from 0 to 300 yr and 220 m^3 per yr to the end of the sealing period (500 yr)	Medium
Single dam or bulkhead in perimeter and main drifts	Retain and drain water entering nonemplacement drifts	Lateral migration of water in drifts	Permeability	Quantity of water	5B.	Promote drainage through drift floor upgradient from dam by limiting leakage through the dam or bulkhead to 10% of the drainage capacity of the drift floor upgradient from the dam, i.e., <200 m^3 per yr	High
6. Double bulkheads[b] in emplacement drifts (no settlement)	Retain and drain water entering emplacement drifts where water entry occurs	Lateral migration of water in drifts	Permeability	Quantity of water	6A.	Retain inflow between two bulkheads by providing adequate storage volume and drainage capacity and limit flow through bulkhead to 24 m^3 per yr per bulkhead from 0 to 300 yr and 110 m^3 per yr per bulkhead at the end of the sealing period (500 yr)	Low

Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 3 of 4)

Step A	Step B		Step C		Step D	
Sealing component	Function	Process	Material properties	Performance measure	Tentative design goal[a]	Needed confidence
			UNDERGROUND FACILITY SEALING COMPONENTS			
Double bulkheads[b] in emplacement drifts (settlement)	Retain and drain water entering emplacement drifts where water entry occurs	Lateral migration of water in drifts	Permeability	Quantity of water	6B. Retain a portion of the inflow near source by providing adequate capacity and limit flow through bulkhead to 24 m^3 per yr per bulkhead from 0 to 300 yr and 110 m^3 per yr per bulkhead at the end of the sealing period (500 yr)	Low
7. Backfilled sump[b]	Retain and drain water entering drifts	Drainage through bulk rock in floor of drift	Bulk permeability of rock at floor of drift	Quantity of water	7A. Retain ground-water inflow near source by providing ≥ 5 m^3 temporary storage capacity ≥ 100 m^3 per yr	Low
8. Backfilled channel[b]	Divert water away from waste emplacement areas	Drainage through channel fill	Permeability of channel fill	Quantity of water	8A. Channel ground water away from waste packages at rates sufficient to handle inflow	Low
9. Plug in horizontal emplacement boreholes[c]	Reduce the amount of water entering horizontal emplacement boreholes	Infiltration through fault system	Permeability	Quantity of water	9A. Limit flow past plug to 12 m^3 per yr from 0 to 300 yr and 56 m^3 per yr to the end of sealing period	Low
10. Drift backfill	Reduce the potential for subsidence	Failure of rock mass above drifts		Amount of fill	10A. Backfill to within 0.5 m of roof	Low
	Reduce the potential of human intrusion into the repository	Penetrability through sealing components	To be determined through design tradeoff studies	Physical presence	10B. Deter human entry	Low
			EXPLORATORY BOREHOLE SEALING COMPONENTS			
11. Calico Hills exploratory borehole seal[d]	Reduce the potential for water transported radionuclides to be preferentially transported through boreholes	Preferential ground-water flow through the repository, Calico Hills unit and the saturated zone	Equivalent hydraulic conductivity of the borehole system	Percentage of flow	11A. Control the potential for vertical flow through boreholes to 1% or less of the potential for vertical flow through the entire rock mass	Low

Table 8.3.3.2-1. Sealing components and associated functions, processes, material properties, performance measures, and goals (page 4 of 4)

Footnotes

[a]As used here a design goal applies to a specific sealing component and a performance goal applies to sealing subsystems such as the shafts and ramps subsystems and the underground facility subsystem. Tentative performance goals for the sealing subsystems are given in Table 8.3.3.2-5.

[b]Specific sealing components will be selected as part of the design process.

[c]Probably will not be used because it is most likely that no waste would be emplaced in boreholes with water inflow.

[d]Borehole system includes the borehole seals, the interface zone, and the modified permeability zone surrounding the borehole seal. Boreholes are categorized for sealing purposed in Table 8.3.3.2-1a.

Table 8.3.3.2-1a. Exploratory borehole categories for sealing[a]

Within repository limits	Category A: Distance from edge of repository					Category B
	1 km	2 km	3 km	4 km	5 km	
USW H-5	UE-25A#4	UE-25WT#4	UE-25WT#5	UE-25WT#14	UE-25WT#15	USW H-3
USW G-4	UE-25A#5	USW WT-1	UE-25C#1		UE-25WT#13	USW G-3
UE-25A#6	UE-25A#7		UE-25P#1			USW UZ-1
USW H-4	UE-25B#1					USW G-1
USW WT-2	UE-25A#1					USW H-1

[a]Category A boreholes represent potential pathways to the accessible environment. Category B boreholes are not believed to be potential pathways to the accesible environment but because of their proximity to the repository boundary are currently planned to be sealed.

Table 8.3.3.2-2. General design constraints passed to Issue 1.11, configuration of underground facilities (postclosure), for major repository features from sealing program (page 1 of 3)

Step A	Step B		Step C	Step D	
Major repository feature	Function	Process	Performance measure	Tentative design goal	Needed confidence
12. Shafts and ramps	Provide entry into repository	Water flow in shafts and ramps	Location of surface entry	12A. Place portals of shaft and ramps in nonflood-prone areas	High
		Water flow in shafts and ramps	Number of entry points into the repository	12B. Restrict the number of shafts and ramps	High
13. Shafts	Provide entry into repository	Retain capability for permanent seal installation	Ease of liner removal	13A. Ensure shaft liner can be removed, especially at the base of the shaft	High
		Limit potential for preferential pathway	Depth of shaft	13B. No shafts (excluding exploratory shaft 1 (ES-1)) should penetrate into the Calico Hills unit	High
		Encourage shaft inflow drainage at base of shaft	Water storage capacity at base of shaft	13C. 150 m^3 (backfilled assuming porosity of 0.3)	High
		Limit potential for preferential pathway	Effective thickness of the zeolitic portion of the Calico Hills unit between the lowest portion of the ESF and the ground-water table	13D. The thickness between the bottom of ES-1 or any exploratory shaft facility (ESF) drifting and the groundwater table should be greater than the minimum thickness of the Calico Hills above the water table anywhere within the repository boundary	High

Table 8.3.3.2-2. General design constraints passed to Issue 1.11, configuration of underground facilities (postclosure), for major repository features from sealing program (page 2 of 3)

Step A	Step B		Step C	Step D	
Major repository feature	Function	Process	Performance measure	Tentative design goal	Needed confidence
14. Underground drifting	Provide access to waste disposal areas	Potential water flow in underground facility	Drift grade	14A. Establish drainage pattern from emplacement drifts to non-emplacement drifts	High
			Drift grade in vicinity of ES-1, ES-2 and MM shafts	14B. Establish drift grade so that the drifts associated with the ESF, the waste emplacement support shops and the development support shops drain towards the ES-1 or man and material (MM) shafts	High
			Drift grade	14C. Establish grades access and emplacement drifts so that no drainage occurs into ES-1 and MM shaft	High
			Water storage capacity in low point of repository	14D. Provide 10,000 m^3 of water storage capability before any water enters the waste emplacement drifts (assume drifts are backfilled with backfill having porosity of 0.3)	High

Table 8.3.3.2-2. General design constraints passed to Issue 1.11, configuration of underground facilities (postclosure), for major repository features from sealing program (page 3 of 3)

Step A	Step B		Step C	Step D		
Major repository feature	Function	Process	Performance measure		Tentative design goal	Needed confidence
			Ease of restoring drift floors to enhance drainage	14E.	Ensure the compacted tuff on drift floors in selected areas can be removed and the floor reconditioned to enhance drainage	High
15. Underground facility	Prevent complication of seals installation	Standoff from exploratory boreholes	Ease in sealing exploratory boreholes within the repository boundary	15A.	Drifting should be at least 15 m from exploratory boreholes	High
16. Shafts and underground facility	Prevent complication of seal evaluation and emplacement	Limit chemical alteration in seal environment	Ease of emplacing a grout curtain in selected locations where seals are currently proposed	16A.	No grouting should take place at these locations during the construction period	High
		Limit blast-induced permeability changes	Ease of restoring the modified permeability zone in selected locations where drift seals are proposed	16B.	Reduce the potential for fracturing rock in selected seal locations by exercising as much control as possible and practical, while excavating the shaft, ramps or drifts in these locations	High

[a]As used here a design goal applies to a specific sealing component and a performance goal applies to sealing subsystems such as the shafts and ramps subsystem and the underground facility subsystem. Tentative performance goals for the sealing subsystem are given in Table 8.3.3.2-5.

Table 8.3.3.2-3. Hydrologic-related site parameters needed to support resolution of Issue 1.12 (seal characteristics) (page 1 of 3)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 2A, 3A	Saturated hydraulic conductivity of alluvium	Within 75 m of shaft location	1×10^{-5} to 1×10^{2} cm/s	Medium	Low	1×10^{-2} to 10^{-3} cm/s	8.3.1.2.2
1A, 2A, 3A	Saturated bulk rock hydraulic conductivity of Tiva Canyon Member		1×10^{-5} to 1×10^{-2} cm/s	Medium	Low	1.2×10^{-3} cm/s	8.3.1.2.2
1A, 2A, 3A	Morphology of bedrock surface	In order of priority: downgradient, ingradient, and about 160 m from shaft locations	Determine contours to within ±3 m	Medium	Low	Contours accurate to 3 m	8.3.1.14.2
1A, 2A, 3A	Thickness of alluvium	Within 75 m of shaft locations	Determine thickness to within ±10%	Medium	Low	0 - 10m	8.3.1.14.2
1A, 2A, 3A	Quantity of water due to surface flooding events 100 and 500 yr flood & probable maximum flood including area of inundation and debris load of flows	Determine parameter at shaft and ramp locations	Inundation maps with elevation of inundated area to within ±2 m	Medium	Low	(see Figure 6-8)	8.3.1.16.1
			Estimates of debris quantity and category	Low	Low	Not available	8.3.1.16.1
			Determine topography of drainage area using 2 m contours	Medium	Medium	Contours to 2 m	8.3.1.14.1
1A, 2A, 3A	Continuous saturation profile of alluvium to bedrock-alluvium interface	At shaft locations	±10% of natural saturation every meter	Medium	Low	To be determined	8.3.1.2.2 8.3.1.14.2

Table 8.3.3.2-3. Hydrologic-related site parameters needed to support resolution of Issue 1.12 (seal characteristics) (page 2 of 3)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 2A, 3A	Gradation of alluvium	At shaft locations predominantly within 15 m from shaft locations	Determination through standard sieving analyses	Not applicable	Low	Soils classified as GP to GM as per ASTM D-2487-83[c]	8.3.1.2.2 8.3.1.14.2
1A, 2A, 3A	Extent and hydraulic conductivity of the modified permeability zone (MPZ)	MPZ in TCw and TSw2	Less than or equal to 60 times the undisturbed, rock mass hydraulic conductivity (saturated), averaged over one radius from the wall of the shaft	Medium	Low	1 to 20 times undisturbed, rock mass hydraulic conductivity	8.3.1.2.2
1A, 2A, 3A	Unsaturated	TSw2, especially hydraulic, matrix properties	1×10^{-8} to 1×10^{-15} m/s in vicinity of shafts	Medium	Low	1×10^{-8} to 1×10^{-15} m/s	8.3.1.2.2
5A, 5B, 6A, 6B, 7A, 8A	Drainage capacity	TSw2 at selected drift floor locations at repository horizon	Saturated, bulk rock hydraulic conductivity $k_{SAT}d > 1 \times 10^{-5}$ cm/s	High	Low	1.2×10^{-3} cm/s	8.3.1.2.2
4A	Drainage capacity	TSw2 at base of shafts	Saturated, bulk rock hydraulic conductivity $k_{SAT} > 1 \times 10^{-5}$ cm/s	High	Low	1.2×10^{-3} cm/s	8.3.1.2.2
4A, 11A	Saturated, bulk rock hydraulic conductivity	CHn1 at base of ES-1 and in boreholes	Saturated, bulk rock hydraulic conductivity $k_{SAT} > 1 \times 10^{-5}$ cm/s	Low	Low	2.4×10^{-4} cm/s	8.3.1.2.2

Table 8.3.3.2-3. Hydrologic-related site parameters needed to support resolution of Issue 1.12 (seal characteristics) (page 3 of 3)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
4A	Magnitude of water entering shafts	At ES-1, ES-2, MM and EE shafts	<150 m^3/yr per per shaft considering anticipated processes	Low	Low	0-100 m^3/yr	8.3.1.2.2
1A, 2A, 3A	Erosion potential	At ES-1, ES-2, MM and EE shafts	<1 m per 1,000 yr preferential erosion or shaft entry points	Low	Low	< 40 cm per 1,000 yr preferential erosion at shaft entry points	8.3.1.16.1 8.3.1.6.2 8.3.1.6.1

[a]Design goals identified here are from Table 8.3.3.2-1.

[b]Thermal/mechanical units used in the modifier column are as follows: TSw2 = Topopah Spring, welded (repository horison); CHn1 = Calico Hills, nonwelded. Other abbreviations are as follows: ES-1 and -2 = exploratory shafts 1 and 2; MM = man and material shaft, EE = emplacement area exhaust shaft.

[c]GP = poorly graded gravel; GM = silty gravel.

[d]K_{SAT} = saturated hydraulic conductivity.

Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 1 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A, 2A, 3A, 10A, 11A	Compressive strength of rock mass	TCw at shaft and ramp locations	No more restrictive than for Issue 1.11	Medium	Low	See Table 6-12	8.3.1.4.2 8.3.1.15.2
		TSw2	No more restrictive than for Issue 1.11	Medium	Low	See Table 6-12	8.3.1.4.2
		CHn1	No more restrictive than for Issue 1.11	Medium	Low	See Table 6-12	8.3.1.15.2
1A, 2A, 3A, 10A, 11A	In situ stresses	In TCw, TSw2 and CHn1	Vertical stress accurate to ±1 MPa	Low	Low	4 to 10 MPa vertical	8.3.1.15.2
			Horizontal stress accurate to ±2 MPa			Horizontal to vertical ratio 0.3 to 1.0	8.3.1.15.2
1A, 2A, 3A, 5A, 5B, 6A, 6B, 7A, 11A	Seismic response spectra	At shaft and ramp location (surface and repository horizon) At selected location in underground facility In Calico Hills unit for boreholes within boundary of the underground facility	To be determined through design studies	High	Low	Acceleration <0.65g	8.3.1.8.2
1A	Meteorological environment						
	Temperature variations at ground surface	At ground surface At shaft and ramp entry points	To be determined by laboratory testing and activities	To be determined by laboratory and design activities	Low	-14 to 114°F	8.3.1.12.1

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Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 2 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
1A	Meteorological environment (continued)						
	pH of rainfall	At shaft and ramp location	>4.5	Medium	Low	pH >6	8.3.1.12.1
1A	Chemistry of alluvium	At end upgradient from shaft location					
	Dissolved sulphates SO_4^{2-}	At end upgradient from shaft location	<0.10% soluble SO_4^{2-} in soils or surface water <150 ppm dissolved SO_4^{2-}	Low	Low	<15 mg/L (see Table 3-3)	8.3.1.14
	pH of alluvium	At end upgradient from shaft location	>4.5	Medium	Low	>7 (see Table 3-3)	8.3.1.14
1A, 3A, 5A, 5B, 6A, 6B, 7A, 11	Geochemistry	TCw, TSw2, CHn1v, CHn1s	No more restrictive than for Issue 1.1	Medium	Low	See Section 4.1.1	8.3.1.3.2
1A, 3A, 5A, 5B, 6A, 6B, 7A, 10A, 11A	Maximum temperature at seal locations	Upper portion of shaft	<90°C	High	Low	<90°C	8.3.2.2.6
		At repository horizon around shaft	To be determined through design tradeoff studies			<115°C	
		At selected drift locations in repository horizon	To be determined through design tradeoff studies		Low	<150°C	
		Calico Hills unit in boreholes below the repository	<90°C	High	Low	<90°C	

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Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 3 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
3A, 5A, 5B, 6A, 6B, 7A, 9A, 11A	Thermal expansion heat capacity, and thermal conductivty of seal emplacement environment	TSw2 CHnl	To be determined thru design tradeoff studies	Medium	Low	See Table 6-16	8.3.1.4.2 8.3.1.14.2
2A, 2B	Shaft and ramp fill properties						
	Saturated hydraulic conductivity		1×10^{-2} cm/s	High	Low	1×10^{-2} to 1×10^{-6} cm/s	8.3.3.2.2 8.3.3.2.4
	Gradational analyses, angle of internal friction, compressi-bility		To be determined through design tradeoff studies	High	Low	Not applicable	8.3.3.2.2 8.3.3.2.4
1A, 3A, 5A, 5B, 6A, 6B, 7A, 8A, 10A	Fracture char-acteristics	TCw TSw2 CHnl at base of ES-1 PTn	<20 fractures/m <40 fractures/m <5 fractures/m <10 fractures/m	High High High High	Low Low Low Low	<20 fractures/m <40 fractures/m <5 fractures/m <10 fractures/m	8.3.1.2.2, 8.3.1.4.1, 8.3.1.15.1
5A, 5B, 6A, 6B, 7A, 8A, 10A	Chemistry of waters (if any) in fault includ-ing sediment content		Elemental con-centration similar to those contained in Table 4-6	Medium	Low	See Table 4-6	8.3.1.3.1
5A, 5B, 6A, 6B, 7A, 8	Grade of emplace-ment drifts and drift dimensions	In repository	1-10%	Not appli-cable	High	1-10%	8.3.2.5.8, 8.3.2.2.7

Table 8.3.3.2-4. Miscellaneous information needed to support resolution of Issue 1.12 (page 4 of 4)

Related design goal[a]	Performance or design parameters	Modifiers[b]	Tentative parameter goal	Needed confidence	Current confidence	Expected parameter values	SCP section providing data
11A	Casing location and condition for exploratory boreholes	All boreholes in categories A & B[c]	Location of casing to ±5 m. Conditions determined by logging and drilling records	High	Medium	See Fernandez and Freshley (1984)	8.3.3.2.4
11A	Unit contacts in exploratory boreholes	All boreholes in categories A & B[c]	Contact location ±5 m	High	Low	Not applicable	8.3.3.2.4

[a]Design goals identified are from Tables 8.3.3.2-1 through -3.

[b]Thermal/mechanical units used in the modifier column are as follows: TCw = Tiva Canyon, welded; TSw2 = Topopah Spring, welded (repository horizon); CHnlv = Calico Hills, nonwelded, vitric; CHnls = Calico Hills, nonwelded, Zeolitic; PTn = Paintbrush nonwelded

[c]Category A boreholes represent potential pathways to the accessible environment. Category B boreholes are not potential pathways to the accessible environment but because of their proximity to the repository boundary are currently planned to be sealed. These boreholes are identified in Table 8.3.3.2-1a.

repository perimeter that penetrate to the water table. These boreholes provide a simple potential vertical pathway from the repository to the water table. About 25 additional boreholes penetrate to the water table within 5 km of the repository perimeter. Among these holes, a potential pathway exists for those holes, which are downdip from the repository, if water were to drain through the repository floor and then were to become perched at a stratigraphic contact.

The strike of each of the stratigraphic contacts beneath the repository and above the ground-water table is generally north-south or northwest-southeast, so that if any of the contacts (which dip to the east or northeast) act as barriers to downward infiltration, flow would occur downdip to the east or northeast. Generally, boreholes that occur to the west of the repository, as well as those to the south and north, cannot act as pathways for radionuclide migration.

Most of the boreholes identified in Table 8.3.3.2-1a penetrate through the underground facility and into the ground-water table. Shallow boreholes that penetrate into the Topopah Spring Member or overlying members are not included in this table because they do not represent pathways to the accessible environment. For the purpose of this table, boreholes that are currently planned to be sealed have been divided into Categories A and B. Category A boreholes are those that represent potential pathways to the accessible environment. The further the borehole is located from the repository boundary, the lower its potential to act as a pathway to the accessible environment. Those boreholes located generally to the northeast, southeast, and east of the underground facility fall into Category A. Category B boreholes are those boreholes that are not believed to represent potential pathways to the accessible environment but, because of their proximity to the repository boundary, will probably be sealed. Those boreholes immediately to the south and north of the underground facility are included in Category B. Those boreholes located to the west, 5 km or more from the edge of the repository boundary, and to the far north and far south are not included in either category because they are not believed to represent potential pathways to the accessible environment, nor are they close to the planned boundaries of the repository.

Step B: The functional requirements

The primary functional requirements identified for the NNWSI Project seal program are to (1) reduce the potential for radionuclide release by controlling water flow and (2) reduce the potential for radionuclide release by discouraging human intrusions. The functions and processes mentioned in the following discussion address these functional requirements. Correlations between the sealing components and the functions and processes are illustrated in Table 8.3.3.2-1.

Two ways in which the shaft and ramp sealing components can reduce the radionuclide releases from the repository are to reduce the amount of water that could potentially reach the waste emplacement drifts and reduce the amount of airborne radionuclides that could preferentially exit from the repository. The physical processes of concern for these functions include water entry into the shafts and past sealing components and release of airborne radionuclides caused by convective air movement resulting from thermal effects in the repository.

Sealing components associated with shafts and ramps could also be relied upon to reduce the potential for human intrusion into the repository. To reduce the potential for human intrusion into the repository, the process of concern is penetrability through the sealing component, either the anchor-to-bedrock plug/seal or the general fill. Perhaps a much more effective means of deterring reentry is to backfill all drifts in the underground facility. However, it is anticipated that a society with the capability to obtain access to the underground facility would also have the technology to remove the backfill.

Not all the sealing components will be relied on to achieve the functions identified previously. Conversely, several may be relied on to achieve the same function. For example, the anchor-to-bedrock plug/seal, the repository station seal, and shaft fill can be emplaced to reduce the amount of water entering the waste emplacement drifts. The unsaturated Topopah Spring Member (unit TSw2) at the base of the shafts could also be used to encourage drainage from the base of the shafts (if any water reached the base) by allowing flow through the rock mass at the base of the shaft. Multiple barriers present the possibility of redundancy in achieving performance goals. The anchor-to-bedrock plug/seal and the shaft fill can be emplaced to reduce the potential for human intrusion. Again, emplacement of different sealing components is believed to represent a conservative approach in achieving the performance goals.

The primary function for seals located in the underground facility would be to retain and drain water entering emplacement drifts by restricting lateral migration of water on the drift floors. Drainage of water through floors of nonwaste emplacement areas could also add a level of redundancy into the design. Such areas could include those used for development shops, warehouse, emplacement shops, and nonemplacement drifts. Diversion of waters entering the shaft to nonwaste disposal areas would potentially achieve the function of reducing the amount of water entering the waste emplacement drifts.

For borehole seals, the primary function is to reduce the potential for water-transported radionuclides to be preferentially transported through boreholes. The physical process of concern would be preferential groundwater flow through the repository, Calico Hills unit, and into the saturated zone.

Step C: Identify the performance measure

Performance measures, as presented for this issue, are qualitative measures that will be used to determine the performance of each sealing component. There are several performance measures selected within the seal program. The primary performance measure is the quantity of water passing sealing components. Others include the percentage of a certain type of flow as in the case of borehole seals and shaft seals for airborne release. Reduction of the potential for human intrusion would require the physical presence of material in the shaft. When the function is to enhance the vertical drainage of water through the Topopah Spring Member, the performance measure is drainage capacity. The correlation between the performance measures and the sealing components is given in Table 8.3.3.2-1.

Step D: Performance and design goals

As part of the performance allocation process, tentative hydrologic performance goals were established for the sealing subsystem. Details of these evaluations are documented in a report by Fernandez et al. (1987). The logic used in establishing the goals will be described in succeeding paragraphs. The hydrologic performance goals refer to the allowable amounts of water that could contact the waste packages and not result in releases that exceed (even for the unanticipated flow scenarios considered) the annual release rates established by the NRC in 10 CFR 60.113(a)(1)(ii)(B). This is shown schematically in Figure 8.3.3.2-3 as the maximum allowable performance goals. To add additional conservatism to the sealing activities, this curve is interpreted in sealing discussions as the amount of free water allowed to enter the underground facility (not just that allowed to contact the waste). Even more conservatism has been added by the selection of the design-basis performance goals (particularly during the first 1,000 yr after closure) to be substantially less than the maximum allowable values. The design-basis performance goals for the sealing subsystem are identified in Table 8.3.3.2-5. The goals for the total quantity of flow are then divided (allocated) between the shafts and ramps and the underground facility. The subsystem goals were then further subdivided into the tentative design goals for the various sealing components; these goals for the components are provided in Table 8.3.3.2-1.

To determine the extent of sealing needed for a repository at Yucca Mountain, the potential flow conditions were estimated. As noted in the schematic diagram (Figure 8.3.3.2-3) the maximum water-flow rates for conditions anticipated for up to 10,000 yr after closure at Yucca Mountain are well below both the maximum allowable and design-basis flow rates. When unanticipated scenarios were evaluated, it was predicted that none of these scenarios could produce sufficient water flow into the underground facility to exceed the maximum allowable flow rates. There were a few scenarios in which the design basis performance goals could potentially be exceeded if the unanticipated events occurred during the first 500 to 1,000 yr after closure. Hence, the results of the preliminary evaluation and allocation of performance (Fernandez et al., 1987) indicate that performance is required only of selected components for mitigating the effects of selected unanticipated scenarios, and only for 500 to 1,000 yr after closure of the repository. It was therefore concluded that limited sealing measures are sufficient to isolate properly the radioactive waste in the repository. Nevertheless, a broad range of sealing design components and associated hydrologic requirements are proposed to provide a greater degree of assurance that the hydrologic performance goals can be met even if unanticipated hydrologic flows occur at the surface or in the underground facility.

For seals not affected by hydrologic performance goals described above, design goals are established to restrict flow through the seal to 10 percent of the drainage capacity of the floor area behind the seal. A design that meets this goal will be expected to ensure that flow in nonwaste emplacement

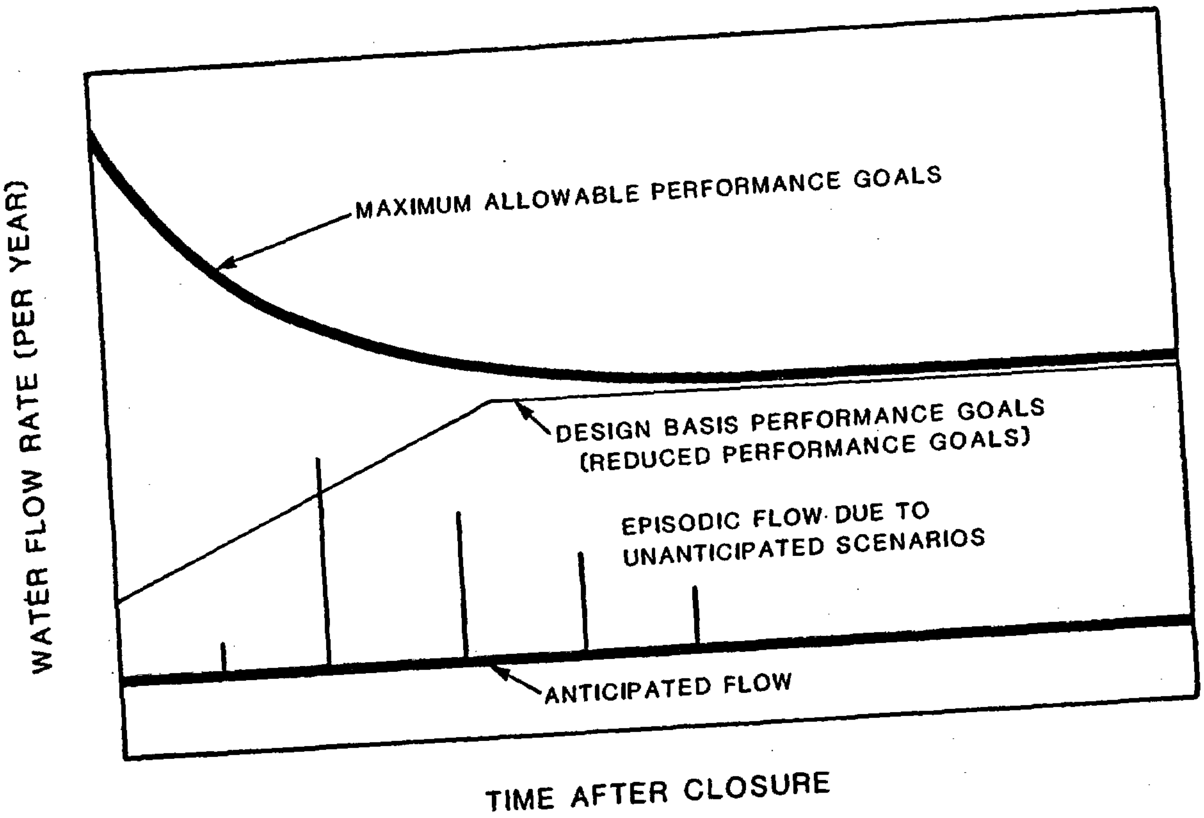


Figure 8.3.3.2-3. Schematic diagram of performance goals and relationship to anticipated and unanticipated episodic flows for sealing. (Yearly flow rate is used since the release criteria are specified on a per year basis.)

Table 8.3.3.2-5. Design-basis performance goals for the sealing subsystem[a]

Time after closure (yr)	Design basis performance goals (m^3/year) Goals for underground facility	Goals for shafts and ramps	Total design-basis performance[b]
0-300	1,180	0	1,180
400	2,600	0	2,600
500	5,600[c]	90	5,690
600	5,600	6,700	12.300
700	5,600	20,900	26,500
800	5,600	50,300	55,900
900	5,600	110,400	116,000
1,000	5,600	130,400[c]	136,000
1,000-10,000	5,600	130,400	136,000

[a]Source: Fernandez et al. (1987).
[b]The total design-basis performance goal is the sum of the performance allocation for the underground facility and that for shafts and ramps.
[c]Beyond this point in time the design basis performance goal (i.e., allowable flow rate) exceeds potential flow due to anticipated and unanticipated events. No performance of the sealing components at these locations is required after this time.

areas is dominantly vertical infiltration through the floor, and not lateral flow to waste emplacement areas or the low point of the repository.

Design goals are also developed for borehole seals and the airflow through shaft seals. The design goal established for borehole seals is that the potential for vertical flow through boreholes should be no greater than 1 percent of the potential for vertical flow through the entire rock mass over which lateral flow along stratigraphic contacts is assumed to occur. A similar design goal is applied to shaft fill for airborne release (i.e., releases of gaseous radionuclides out of the shaft should be restricted to 1 percent of the allowable EPA release limit for each applicable radionuclide).

The design goals identified in this section are also given in Table 8.3.3.2-1. These goals can be changed as more site data become available, as more detailed analyses are completed, or as future design considerations indicate the need to redefine sealing components and their functions.

In addition to the identification of the tentative design goals for each sealing component, the needed confidence in achieving the goal is also expressed in Table 8.3.3.2-1. When the needed confidence for a goal is indicated as "low," it generally means that the performance allocation evaluations (Fernandez et al., 1987) have not required performance from that component in order to meet the overall performance goals for the system. Such ratings may also reflect the evaluation that the component is not a preferred option for performing the needed function or, because of anticipated site conditions, is unlikely to be emplaced. Additionally, where the performance measure is selected as the physical presence of a component, no site data are identified as being needed to meet the associated goal of deterring human entry. A greater degree of needed confidence is generally associated with shaft and ramp sealing components in restricting flow than is associated with the underground facility sealing components. The logic is based upon the anticipated potential for larger inflow through the shaft or ramps; confirmation of site hydrology assumptions and data are needed to allow such comparisons to be evaluated.

In the case of diverting water from waste emplacement areas, the needed confidence associated with the backfilled channels is low because a greater reliance is placed on the passive features, such as the drift grades, to achieve this same goal. Because the preferred option is to store no waste in emplacement drifts or holes where water is encountered, fault seals may not be routinely used in the repository. Additionally, because of the uncertainty in the reliability of a fault seal to achieve a specific goal, particularly in the presence of a high temperature field, an additional sealing element would possibly be used to achieve the design goal and thereby provide redundancy.

Finally, the physical presence of drift backfill is proposed to be used with shaft fill to reduce the potential for human intrusion. The needed confidence level selected is low because it is anticipated that an intruder with the capability to obtain access to the underground facility (after accesses have been sealed) would have the ability to remove the backfill because subsidence will be controlled by the strength and fracturing characteristics of the rock mass. For welded tuff, if drift collapse were to occur, it is anticipated that the bulking of the rock during the collapse would be sufficient to contain the rubble zone entirely within the Topopah Spring Member. Backfilling the drifts would further limit the extent of a possible rubble zone; hence the needed confidence is indicated as being low.

Step E: Parameters, goals, and confidences

The parameters required to address each information need are described under the appropriate information need. The hydrologic and miscellaneous parameter needs are shown in Tables 8.3.3.2-3 and -4 and discussed in more detail in Section 8.3.3.2.1. In general, the needed confidence for most parameters is identified as being either high or medium. For some parameters a low needed confidence is assigned for meeting the tentative performance goals when a parameter is not expected to be a significant variable in licensing-related analyses. This may occur as a result of the confidence needed in the related component performance being low or the anticipation (based on engineering judgment or preliminary analysis results) that the component performance is relatively insensitive to plausible variability in the value of the parameter.

Step F: Design requirements and constraints

As indicated in the first part of this section, sealing design requirements and constraints will be transmitted to Issue 1.11 (Section 8.3.2.2) to develop an appropriate postclosure design. Design requirements primarily include the quantitative and qualitative requirements imposed on the seal components to achieve a desired performance. The technical basis for the design requirements are presented elsewhere (Fernandez et al., 1987).

Some general constraints placed on major repository elements by the seal program are given in Table 8.3.3.2-2. The majority of the performance measures relate to grading drifts within the underground facility to achieve the specified performance goals and to restoring the drift floors to encourage vertical drainage of water through drift floors. Other constraints include no grouting within rock in selected locations where components are proposed and ensuring that penetration into the Calico Hills unit is controlled. Finally, because drifting across exploratory boreholes could compromise the sealing efforts for these boreholes, a constraint is imposed on drifting. This constraint is not to intersect the boreholes and also to maintain a minimum distance from the boreholes. Directional logs for boreholes within the repository boundaries will be needed to aid in ensuring that this constraint can be met.

Further, the design requirements developed at this stage in the design development process are guidelines for design analyses and future materials testing, and the requirements are very preliminary. Current design requirements are presented elsewhere (Fernandez et al., 1987). Revisions and additional design requirements are expected to emerge from the advanced conceptual design (ACD) and during the license application design (LAD).

Step G: Information needed

As indicated in Figure 8.3.3.2-1, identification of information needed to respond to this issue must also be identified and transmitted to Issue 1.11 so that the postclosure, underground facility design can be developed. This needed information is defined in Tables 8.3.3.2-3 and 8.3.3.2-4 and is described in the parameter sections under the appropriate information need.

Seal system performance and seal component designs are addressed directly by this issue (seal characteristics) as presented in the preceding discussion.

The planned investigations, which will be used to assess the performance of proposed sealing designs and to develop design information necessary for the license application design, are defined in the following table:

Information need	Description
1.12.1	Site, waste package, and underground facility information needed for design of seals and their placement methods (Section 8.3.3.2.1).
1.12.2	Materials and characteristics of seals for shafts, drifts, and boreholes (Section 8.3.3.2.2).
1.12.3	Placement methods for seals for shafts, drifts, and boreholes (Section 8.3.3.2.3).
1.12.4	Reference design of seals for shafts, drifts, and boreholes (Section 8.3.3.2.4).

Information Need 1.12.1 identifies information that will be obtained from sources outside the NNWSI Project repository seal program and that will influence the design and performance of the repository seals.

Information Need 1.12.2 identifies activities, primarily related to laboratory testing, needed to determine the properties of seal materials that may be used in an unsaturated tuff environment.

The placement methods of sealing components (Information Need 1.12.3) depend on the need for sealing components as determined by the appropriate activities defined by Information Need 1.12.4 and the selection of sealing materials as determined through the laboratory testing defined by Information Need 1.12.2. The bulk of the design work, including design selection, trade-off analyses, development of design requirements and design descriptions, and modeling associated with the performance of sealing components, is incorporated into the activities defined as part of Information Need 1.12.4. No computer code development is currently anticipated as part of the NNWSI Project seal program. Existing computer codes developed in support of other performance analyses will be used in seal design analyses. Computer codes that have been or may be used in the seal program are named in Section 6.1.3.2.3. Depending on the verification requirements, some efforts may be required to verify results using the identified codes.

<u>Interrelationships of information needs</u>

The question raised by this issue is aimed at determining if the emplacement of shaft and borehole seals and seals for backfill in the underground facility shows compliance with the postclosure performance objectives.

The available site and underground facility data from Information Need 1.12.1 (Section 8.3.3.2.1) can be used to develop seal performance goals and design requirements for specific sealing components. The development of these design requirements can then be used to select designs of seals for shafts, ramps, drifts, and boreholes (Information Need 1.12.4, Section 8.3.3.2.4). Evaluation of the performance of sealing components is an integral part in the selection of the appropriate designs and, therefore, is part of Information Need 1.12.4 (Section 8.3.3.2.4). The selection of materials and characteristics for seals (Information Need 1.12.2, Section 8.3.3.2.2) and their emplacement methods (Information Need 1.12.3, Section 8.3.3.2.3) can then be made to achieve the performance established for the sealing components. Further, because the underground facility must contribute to repository performance, its design could reduce the reliance placed on drift seals. (Drift seals are part of the underground facility, but shaft and borehole seals are not.) The characteristics and configuration of the underground facility as they relate to the postclosure design criteria of 10 CFR 60.133 are discussed in Section 8.3.2.2 (configuration of underground facilities). The general criteria for the underground facility state that "the underground facility...shall contribute to the containment and isolation of radionuclides." Performance goals were assigned to the sealing system, however, without taking advantage of any contribution the underground facility could add to the seal performance.

The schedule information provided for information needs in this section includes the sequencing, interrelationships, and relative durations of the activities in the information need. Specific durations and start/finish dates for the activities 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.

8.3.3.2.1 Information Need 1.12.1: Site, waste package, and underground facility information needed for design of seals and their placement methods

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed in the following paragraphs by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

As mentioned in the discussion under Step E, the information identified in this information need will be obtained outside the NNWSI Project seal program. This information falls into two categories: site and underground facility design. Under site, the primary information needed is an understanding of the water inflow into the repository and the hydrologic characteristics of selected geologic units. This type of information is discussed in Section 3.6 (regional hydrologic reconnaissance of candidate area and site). In particular, the description of the hydrologic units and hydraulic characterization of principal hydrogeologic units will be important from a sealing perspective. Information obtained in Section 3.9 (site hydrogeologic system) as well as surface flooding in Section 3.2 (floods) will also be used in resolving this issue.

The underground design is described in Section 6.2.2, which describes the overall design of the repository, and Sections 6.2.5 and 6.2.6, which describe the shaft and ramp designs and the subsurface design. Additional details of the repository design are provided in the conceptual design report developed in support of the site characterization plan (SCP-CDR) (SNL, 1987).

Parameters

A variety of site and repository design parameters are required as part of this information need. Table 8.3.3.2-3 lists the hydrologic parameter needs, the ranges of parameters, and the confidence needed in meeting the performance goals. Table 8.3.3.2-4 presents the same information for miscellaneous (site or design) parameters. Additionally, these tables indicate what SCP sections describe the information needs that will provide values for the parameters. In all instances, a correlation is made between the design goal and the required parameter.

The majority of the parameters and parameter ranges for shaft and ramp sealing components deal with defining the potential for surface water infiltration to enter shafts. Realistic estimates can be obtained by characterizing near-surface geologic units such as alluvium and the Tiva Canyon Member. For alluvium, required parameters include saturated hydraulic conductivity, gradation, sieve analysis, saturation profiles, unsaturated properties, and thickness. The saturated hydraulic conductivity of the Tiva Canyon is also identified as a parameter need. In addition to these near-surface site parameters, the quantity of water due to surface flooding events is also identified as a parameter need. The modified permeability zone (MPZ) is the zone immediately surrounding an underground excavation in which the permeability of the rock mass has been altered due to stress redistribution and blast damage effects. Because water flow down the shaft (under saturated conditions) can be controlled by the MPZ, knowledge of the MPZ characteristics is needed. The parameter goal range is taken from a report that developed a model for the zone surrounding a vertical penetration in welded tuff (Case and Kelsall, 1987).

If water reaches the base of the shaft, it is important to know the drainage capacity of the sump locations so that the anticipated amount of water entering the shaft can be dissipated effectively. Similarly, the drainage capacity of water through drift floors is an additional parameter for consideration in the seal program. The acceptable parameter range for the saturated, rock-mass hydraulic conductivity depend on the design option proposed and the amount of water to be drained. Nevertheless, a lower limit of 1×10^{-6} cm/s is proposed based on current design efforts. Finally, erosion potential is listed as a parameter need so that excessive erosion does not occur at the shaft entry points and subsequently increase the potential for water to enter the shafts.

In Table 8.3.3.2-4 nonhydrogeologic parameters are identified. They include the following:

1. Design information such as the dimensions of all openings where seals may be emplaced. This includes dimensions for shaft, ramps, and drifts. Information on drift grades is also required to properly design dams or bulkheads in the underground facility. Variations in drift grade do occur in the current design. Such

variations can influence the area of drift floor that becomes inundated and subsequently the drainage capacity of the area upgradient from the dam or bulkhead.

2. Borehole construction and geologic logs are routinely obtained as part of the site investigation work within the NNWSI Project and are necessary to establish a strategy in effectively sealing boreholes.

3. The thermal and mechanical properties (strength, modulus, conductivity, etc.) of the rock mass for selected geologic units and in situ stresses at potential seal locations are required to assess the structural response of these seals. Because structure failure could incur a decrease in hydrologic performance, it is possible that some sealing elements may not achieve their design goals. Therefore, tradeoff studies would be required to evaluate the impact of structural deformations of the rock mass (if any) on the performance of specific sealing elements. Seismic forces could also modify the properties of the sealing elements. Therefore, the seismic response spectra would be required at seal locations to evaluate the potential for modifying the properties of sealing elements.

4. Performance of near-surface sealing elements can be affected by meteorological and chemical conditions that exist at the surface. For this reason temperature variations at the ground surface together with two chemical parameters, pH and soluble sulphate, are identified.

5. These chemical parameters and parameter ranges are based on the current concept that the sealing material at the surface is concrete. The parameter ranges, therefore, are specifically associated with a concrete located at the surface. If it is determined through design studies, as part of the advanced conceptual design phase, that concrete is not needed and another material may be better suited, then this parameter need will be dropped.

6. Chemistry of the seal environment is included so that durability of the seal material can be assessed. The chemistry of alluvium; Tiva Canyon, welded (TCw); Topopah Spring, welded (TSw2); Calico Hills, vitric (CHv); and Calico Hills, zeolitic (CHz) are identified as being required to assess geochemical durability of the sealing element.

7. A limit on the temperatures at two potential seal locations (i.e., at the upper portion of shaft and ramps and at the Calico Hills borehole seal locations) are given in Table 8.3.3.2-4. Such limits will reduce the potential for alteration of the seal materials.

8. Calculations presented elsewhere (Fernandez et al., 1987) have shown that infiltration of surface waters into a shaft fill can be acceptably reduced and retarded if the saturated hydraulic conductivity of the shaft fill is less than 10^{-2} cm/s. Air flow through shaft fill can also be acceptably reduced assuming the same saturated, hydraulic conductivity. Gradational analyses, angle of internal

friction, and compressibility of the shaft fill will also be necessary to determine if excessive settlement of the shaft fill could occur. Excessive settlement, if taken to the surface (assuming the emplacement of no anchor-to-bedrock seal), could increase the potential for more surface waters to enter the shaft.

9. Sealing fractures around selected sealing elements may be required to achieve a desired level of performance. Therefore, the thermal/mechanical units that may require some fracture characterization would be Tiva Canyon, welded (TCw); Topopah Spring, welded (TSw2); Calico Hills, nonwelded (CHnl); Yucca Mountain, nonwelded (PTn); and the Pah Canyon, nonwelded (PTn). Using this data, effective plans to seal these fracture zones could be developed.

10. The remainder of the required parameters may not be available at the time that testing is completed in the exploratory shaft facility. Specifically, if water-producing zones are encountered it would be appropriate to characterize the chemistry of the fault zone waters including the sediment content, if any. This data could then be used to evaluate the potential for reducing the drainage capacity of the drift floor or perhaps reducing the effectiveness of the seal component that it contacts. The measurement of the volume of waters draining into drifts could also suggest the amount that could enter horizontal emplacement holes.

Logic

The geomorphology, meteorology, and surface hydrology of the shaft and ramp locations, the risks of flash flooding, the configurations of the shafts and ramps, and the geotechnical properties of the near-surface alluvium and bedrock are required for the design of the shaft sealing components. The properties and depth of the alluvium must also be known to predict the potential for ground-water inflow to the shafts through the alluvium.

Information about the hydrologic properties of the stratigraphic units penetrated by the shafts is needed to determine the potential for ground-water inflow into the shafts and the underground facility. Initially, the inflow will be predicted based on data obtained from boreholes, available analytical solutions, and the hydrologic properties of the stratigraphic units at Yucca Mountain. Later, an indication of the potential inflow will be determined from direct observation of water inflow during and after construction of the exploratory shafts and the underground test facility. The stratigraphy of the shaft and the configuration of the shaft, including the shaft station, will be used to determine suitable locations for shaft seals should they be necessary. For example, seals may be necessary below certain stratigraphic contacts at which ground-water perching could occur. The drainage capacity of the base of the shaft will be assessed to determine whether ground-water inflow would drain from the sump rather than flow into the repository.

The waste emplacement mode (i.e., vertical or horizontal) selected for the repository may influence the types of seals that are selected. For example, if the horizontal mode is selected, ground-water inflows to drifts may have no impact on the waste. The location of the repository including the ramps with respect to faults may influence the occurrence of ground-water inflow from discrete fault zones. The amount of inflow may be influenced by the hydrologic properties (permeability and porosity) of the fault zones and by the size of the underground opening and its orientation with respect to the fault. Initially, the amount of ground-water inflow will be predicted from surface observations and borehole data. Later, the predictions will be revised according to observations of inflows and fracture characteristics in the exploratory shaft test facility. The predicted rates of inflow will then be compared against the measured drainage capacity of the drift floors. During the testing associated with the exploratory shaft facility, drainage capacity of the densely welded tuff will be determined. The bulk permeability and infiltration tests will provide data on the ability of the repository to drain waters that may enter the repository.

Construction details associated with exploratory boreholes drilled from the surface are required to select appropriate seal designs. Characteristics of interest include location, depth, drilling history (including any lost circulation zones), and casing configuration.

Information about the physical, mechanical, chemical, and thermal properties of stratigraphic units, including those encountered in the shafts and ramps as well as in the repository, are required to ensure that seals, as designed, can withstand in situ hydraulic, structural, chemical and thermal loads. The extent and properties of the modified permeability zone around openings are needed for analysis of total ground-water flow through seal zones and, possibly, for the design of seal emplacement methods. In situ stresses, seismicity, and the temperature at possible seal locations are also required for structural and thermal analyses.

All the data required to satisfy this information need will be obtained from site characterization activities described elsewhere in the SCP. Sealing-related activities are included in the discussions in Sections 8.3.3.2.2, seal material; 8.3.3.2.3, placement methods; and 8.3.3.2.4, reference seal designs.

8.3.3.2.1.1 Application of results

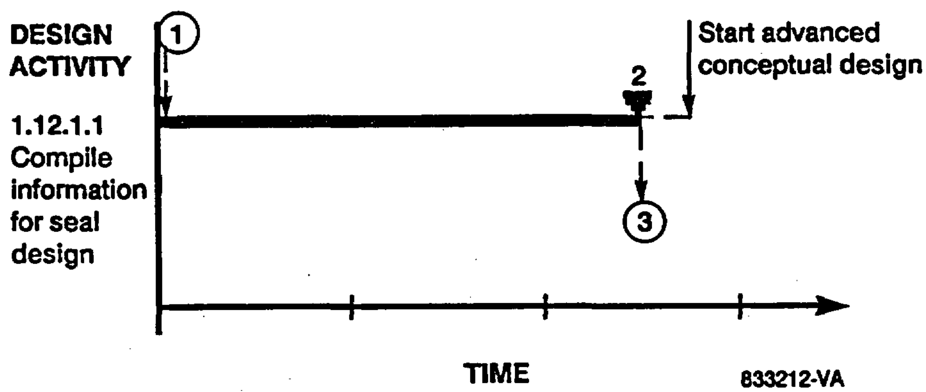
The data obtained from this information need will be used to support all aspects of the seal program, including evaluating the performance of sealing elements, developing detailed designs, and planning of laboratory and field tests. The primary focus will be Information Need 1.12.4 (8.3.3.2.4). The output from Information Need 1.12.4 will then be transmitted to Information Need 1.11.7 (Section 8.3.2.2.7), reference postclosure underground facility designs.

8.3.3.2.1.2 Schedule and milestones

Information Need 1.12.1 specifies the site, waste package, and underground facility information needed for design of seals and development of their placement methods. This information need contains one activity:

1.12.1.1 (compile information for seal design). The schedule information for this ongoing activity is presented in the form of a timeline, which extends to the issuance of the final products associated with this work effort. Summary schedule and milestone information can be found in Sections 8.5.3 and 8.5.6. This information need is iterative with other information needs contained within Issue 1.12 as illustrated in the following figure.

The activity number and title corresponding to the timeline are shown on the left of the following figure. The numbered points shown on the timeline represent major events or important milestones associated with this work effort. Solid lines represent activity durations, and dashed lines show the interfaces. The data input and output at these 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	Input site characterization data from site investigations 8.3.1.2 (geohydrology), 8.3.1.3 (geochemistry), 8.3.1.5 (climate), 8.3.1.6 (erosion), 8.3.1.8 (postclosure tectonics), 8.3.1.14 (surface characteristics), 8.3.1.15 (rock properties), 8.3.1.16 (hydrology), and 8.3.1.17 (preclosure tectonics) and data/information from Information Needs 1.10.2 (reference waste package designs), 1.11.6 (thermal loading/thermal response), 1.12.2 (seal characteristics), and 4.4.7 (design analyses).
2	Milestone Z108. List of information needed for seal design.
3	Output information/data to Information Needs 1.12.2 (seal characteristics), 1.12.3 (placement methods), and 1.12.4 (reference seals design).

8.3.3.2.2 Information Need 1.12.2: Materials and characteristics of seals for shafts, drifts, and boreholes

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed below by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

Two basic areas that will support the seal material development effort include geochemistry of the emplacement horizon and the in situ and anticipated alterations on the rock mass due to the existence of the repository. Information on geochemistry is included in Section 4.1, geochemistry of the host rock and surrounding units. Information on the alteration of the host rock is included in Section 4.2 (geomechanical effects of waste emplacement); Chapter 2 (dealing with the geoengineering properties of the rock mass due to excavations); and Section 7.1 (emplacement environment).

The main purpose in obtaining the geochemical information will be to confirm the geochemistry of the ground waters and rock units at the repository horizon. Additional geochemical information will be needed if seal materials are chemically different from the medium into which they are placed. Geochemical information collected will also be used to confirm the predicted effects due to the presence of the repository, specifically the temperature elevation in the emplacement medium.

Parameters

Materials and material properties of concern will be defined following the development of the design requirements. Repository seals, if needed, will be designed to limit the ground-water flow into or out of the repository. Since the most important parameters or material characteristics are yet to be determined through the continuing design requirements effort (Information Need 1.12.4, Section 8.3.3.2.4), potentially important material properties only can be defined. These potential material properties are presented in Table 8.3.3.2-6. Material properties include those related to placement as well as performance.

Parameter ranges and confidence in parameter ranges for seal properties are not presented in Table 8.3.3.2-6. These values will be determined by the design activities described in Section 8.3.3.2.4. Selection of the parameter ranges will depend on the ability and need to achieve the performance goals discussed in Section 8.3.3.2.1 (information needed for seal design). Parameter ranges and confidence levels for pertinent site information are given in Section 8.3.3.2.1.

To accommodate the potential need for man-made materials and crushed tuff, laboratory testing is proposed. The testing scope will be modified, if necessary, as the seal design requirements are defined. Because emplacement

Table 8.3.3.2-6. Potentially important material properties of concern for sealing components

Categories of properties	Specific material properties	Reason required
Initial and altered physical properties of materials	Density, porosity, compressive strength, Young's modulus, Poisson's ratio, modulus of rupture, shear strength, expansivity, bond strength, viscosity, slump (concrete, grouts), tensile strength, creep of seal material, drying shrinkage strain	Structural analysis, settlement analysis, interface stress development, selection of emplacement method
Initial and altered hydrologic properties of materials	Compressibility gradation, porosity (total and effective), saturated hydraulic conductivity, interface hydraulic conductivity	Hydrologic analysis
Initial thermal properties of materials	Thermal conductivity, specific heat, heat of hydration (concrete, grouts), thermal expansion	Thermomechanical analysis, interface stress development
Material reactivity and stability (longevity) in seal zone	Overall composition, composition and proportion of phases, particle size, solubility of phases and precipitation, phase transformations (including dehydration), microbial activity, thermodynamic properties, chemical properties of leachate	Evaluation of durability of seal materials

conditions may vary within the underground facility, a broad range of environmental conditions will be considered in the laboratory testing of cementitious-based materials. The data obtained as part of the site characterization effort, that is, the geochemistry of the emplacement horizon and the repository design activities (temperature histories and mechanical properties of the repository unit), will confirm environmental conditions to be encountered. Any information on seal materials and their characteristics that is needed will be obtained as part of this information need.

Logic

Physical and mechanical properties of candidate seal materials must be known to select materials that will resist imposed structural loads. Early age properties of some materials (e.g., slump and viscosity in grouts or concretes) are required for selection of appropriate placement methods.

Hydrologic properties of candidate seal materials must be known to select suitable materials that meet design requirements for reduction of ground water. Additionally, hydrologic properties are also required for performance assessment of the seal system.

Thermal properties of candidate seal material must be known for analysis of the response of seals to thermal loads. The mineralogy and chemistry of candidate seal material must be known to evaluate possible adverse interactions between the materials and the host rock and ground water.

Emplacement conditions (e.g., temperature, confinement presence of free water) and emplacement method (e.g., degree of consolidation of concretes or degree of compaction of granular materials) can influence the material properties. These conditions will be considered in the selection and design of seals.

8.3.3.2.2.1 Study 1.12.2.1: Seal material properties development

8.3.3.2.2.1.1 Activity 1.12.2.1.1: Detailed property determination of cementitious-based and earthen materials

Objectives

The objective of this activity is to initiate laboratory testing to determine material properties for sealing elements needed to resolve this issue.

Description

Before initiating laboratory testing, a detailed plan will be prepared indicating the parameters to be measured and how these parameters will be used to resolve the issue of materials longevity. Currently, it is believed that this plan will include details of laboratory testing involving potential alteration of sealing materials and response of sealing materials in restrained environments.

Because the durability of sealing materials in anticipated environments cannot be evaluated in real time, thermodynamic models, supported by laboratory experiments, will be used to understand the potential for alteration of sealing material and their properties. Input from theoretical studies (i.e., thermodynamic models such as the degradation model) will be used to define suitable materials for testing. The program will then include periodic characterization and testing to determine progressive alteration in properties after the materials are subjected to various experimental conditions (such as temperature and moisture conditions) for successively greater lengths of time. Experimental conditions will also consider the conditions of the seal environments. Other tests may determine the volume stability of the seal material within a block of tuff to determine the long-term performance of the interface. In general, material properties such as those identified in Table 8.3.3.2-6 will be determined to assess if the design goal for a sealing components can be achieved.

8.3.3.2.2.1.2 Activity 1.12.2.1.2: Hydraulic conductivity and consolidation testing of crushed tuff

Objectives

The objective of this activity is to establish the hydraulic conductivity and consolidation behavior of crushed tuff to support the development of criteria for shaft fill and drift backfill.

Description

To establish an acceptable hydraulic conductivity, gradation, and density of compacted shaft fill, laboratory studies will be required. Because mining and processing of tuff create very fine-grained material, tests will be performed on at least two gradations of welded tuff: one optimally graded to enhance drainage and reduce settlement and one that contains fine-grained particles. The source material for this laboratory analysis will be tuff extracted through the mining of the exploratory shaft. Specific tests will characterize the gradation, compaction characteristics, and the saturated hydraulic conductivity for the various samples.

8.3.3.2.2.2 Design Activity 1.12.2.2: A degradation model for cementitious materials emplaced in a tuffaceous environment

Objectives

The objective of this activity is to develop a degradation model that will provide insight into how material properties of sealing components, especially permeability and strength, could alter after being in contact with tuff.

Description

Because the phase assemblages of grout and concrete probably will not be in thermodynamic equilibrium with tuff, phase transformations may occur. The rate of alteration will be enhanced because of the elevated temperatures surrounding the waste package. Therefore, one approach in developing a degradation model is to assess the impact that alteration of the phases present can have on the material properties of concern. Testing will be required to obtain the data on phase transformations, dissolution, or precipitation in the seal-host system.

Changes in mineralogy may affect solubility of phases in the cementitious material, induce volumetric changes that could increase or decrease the permeability and strength of the grout, and change the matrix and bond strengths. Therefore, the final output from this task will be a qualitative assessment of how the structural, hydrologic, and chemical properties of cementitious-based sealing material can change in their emplacement environment.

8.3.3.2.2.3 Application of results

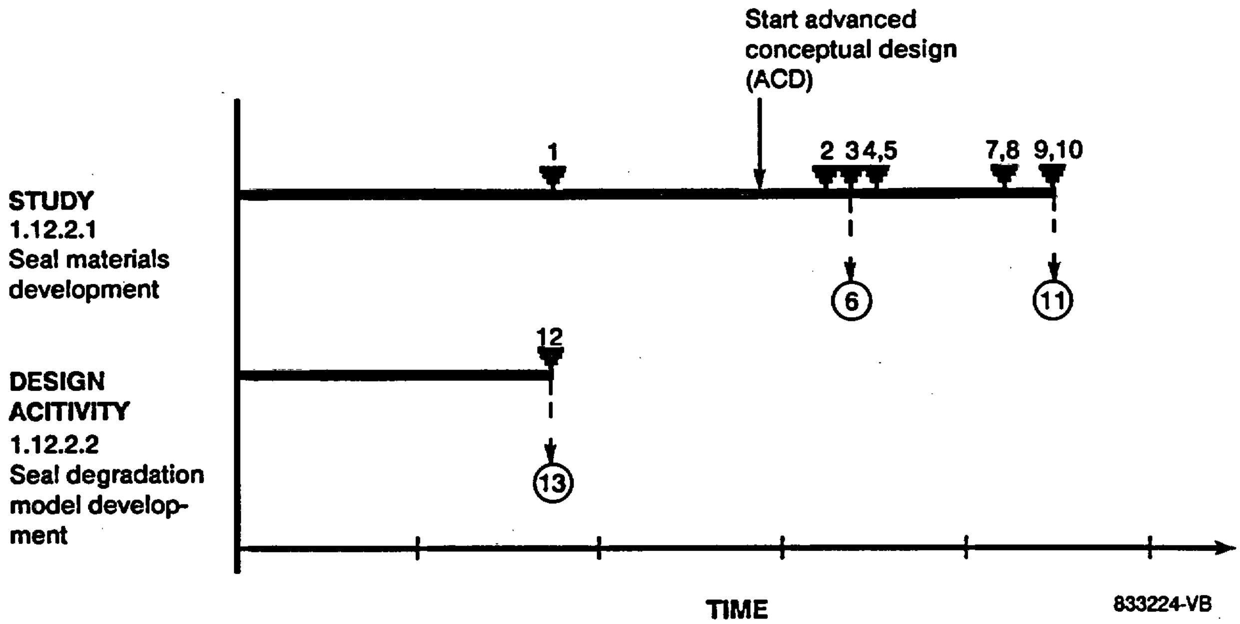
The information obtained in this information need will be provided to the reference NNWSI Project data base and will be used in Information Needs 4.4.10 (technology for seals emplacement, Section 8.3.2.5.10), 1.12.3, and 1.12.4.

8.3.3.2.2.4 Schedule and milestones

Information Need 1.12.2 is designed to determine the properties of the materials to be used for seals for shafts, ramps, drifts, and boreholes. This information need is subdivided into one study, 1.12.2.1 (seal material properties development), and one design activity, 1.12.2.2 (a degradation model for cementitious materials emplaced in a tuffaceous environment). The schedule information for this information need is presented in the form of a timeline, which extends from the start of the activity to the issuance of the final products associated with this work effort. Summary schedule and milestone information for this information need can be found in Section 8.5.3.

Study 1.12.2.1 and Design Activity 1.12.2.2 are considered ongoing work efforts. This information need provides output to Information Need 1.12.4 on seal material longevities and durabilities. This relationship is illustrated in the following figure.

The study or activity number and title corresponding to the timeline are shown at the left of the figure. The numbered points shown on the timelines represent major events or important milestones associated with this work effort. Solid lines represent activity durations. Dashed lines show the interfaces between this work effort and Information Need 1.12.4. The data input and output at these 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 R280. Issue detailed test plan for longevity testing.
2	Milestone Z111. Begin pipe restraint test.
3	Milestone R283. Complete Phase I testing associated with longevity testing.
4	Milestone R284. Complete Phase II testing associated with longevity testing.
5	Milestone Z112. Begin crushed tuff properties test.
6	Output information/data on seal material longevity and other available test results to Information Need 1.12.4.
7	Milestone R281. Issue report on the results of pipe restraint tests.
8	Milestone R285. Prepare report on Phase I testing.
9	Milestone R282. Issue report on the results of crushed tuff properties test.
10	Milestone R286. Issue report on the results of Phase II seal materials longevity testing.

Point number	Description
11	Output information/data on longevity tests, pipe restraint tests, and crushed-tuff properties tests to Information Need 1.12.4.
12	Milestone R279. Issue report on development of a degradation model for cementitious sealing materials.
13	Output information/data on degradation model to Information Need 1.12.4.

8.3.3.2.3 Information Need 1.12.3: Placement method for seals for shafts, drifts, and boreholes

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed below by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

Seals may be required to limit ground-water flow through shafts, drifts, or boreholes that could contribute to release of radionuclides from the repository. These seals, if required, must be designed to be emplaced using adequately established technology and must be emplaced so that seal performance is acceptable. Once the reference designs are selected as part of Information Need 1.12.4, data required to select appropriate placement methods will be obtained.

Information that will be required in selecting a suitable placement procedure for sealing components includes the design of the repository, conditions of man-made and natural penetrations that must be sealed and the required properties of the sealing materials/systems. Design of the repository is presented in Section 6.2 of the SCP and in the SCP-CDR (SNL, 1987). Knowledge of the conditions to be encountered in the underground facility, the shafts, and ramps will be obtained through observations at the time of the excavation of the exploratory shaft facility. The design portion of the NNWSI Project repository seal program uses the approach that a range of hydrogeologic conditions may be encountered as the repository is developed. These variable conditions could, therefore, require variable placement options. The general descriptions of water entering the exploratory shafts and the exploratory shaft facility will provide an increased data base on water-producing zones that may require sealing and hence, consideration of the appropriate placement technique.

Data on borehole conditions are currently being recorded. Borehole conditions are briefly described in Chapter 6 of the SCP.

Parameters

Several properties of candidate seal materials are directly affected by placement methods and conditions. Conversely, the selection of a feasible emplacement method may be influenced by properties of the material. Data needed to address this information need include the available placement or construction methods for proposed seal components and those properties of seal materials that affect or are affected by emplacement.

For earthen materials (clays, rockfill), these properties are

1. Density-water content relation.
2. Particle gradation.
3. Hydraulic conductivity related to density.
4. Swelling capacity related to density.

For cementitious materials, these properties are

1. Density.
2. Heat of hydration.
3. Slump, viscosity.
4. Workability.
5. Set time and working time.
6. Maximum particle size of aggregate phases.

The data represented in the preceding list are those variables that can be modified to accommodate the placement strategy to be used for the sealing component. Because multiple placement strategies will be proposed to accommodate varying site conditions, no site parameters will be required to establish the appropriate placement methods. Site conditions as encountered will focus on the appropriate placement method. Design information on the underground facility and existing boreholes is also necessary to select the appropriate placement method. Laboratory analyses will be performed as part of Study 1.12.2.1 (Section 8.3.3.2.2.1) under Information Need 1.12.2 to define the properties of earthen and cementitious-based materials identified previously.

Logic

For granular materials (e.g., clays, crushed rock), the method and degree of compaction may have a strong effect on density and porosity, hydraulic conductivity, and swelling pressure. The required in situ properties may influence the selection of emplacement method, principally according to the degree of compaction necessary. Selection may also be influenced by the gradation and moisture content of the material. For example, pneumatic methods may be limited to certain gradation and moisture ranges. Performance of cementitious materials may be affected by the method of consolidation, the presence of free water, and temperature during emplacement and curing. Selection of placement methods will be influenced by properties such as the heat of hydration, working time, harshness, and viscosity. For example, the heat of hydration of a concrete mix may limit the thickness of any lift that can be emplaced to prevent undue thermal stresses in the seal zone.

There are no planned design activities identified for this information need. Any tradeoff design activities evaluating the appropriate placement method will be performed as part of the advanced conceptual design or the license application design (Information Need 1.12.4, Section 8.3.3.2.4). Development of properties of earthen and cementitious-based materials will be obtained as part of Information Need 1.12.2 (Section 8.3.3.2.2).

8.3.3.2.3.1 Application of results

The data obtained in this information need will be used directly in deriving practical seal designs (Information Need 1.12.4). The data will contribute to other information needs addressing design and performance issues. The two information needs are 1.11.7, reference postclosure underground designs (Section 8.3.2.2.7), and 4.4.9, technology for underground facilities (Section 8.3.2.5.9).

8.3.3.2.3.2 Schedule and milestones

The schedule and milestones for this information need are the same as those for Information Need 1.12.4 (reference design of seals for shafts, drifts, and boreholes).

8.3.3.2.4 Information Need 1.12.4: Reference design of seals for shafts, drifts, and boreholes

Technical basis for addressing the information need

The technical basis for addressing the information need is discussed below by first identifying the contents of related sections of the SCP and other documents. Needed parameters are then described. The logic for the technical activities is described and planned design activities are identified.

Link to the technical data chapters and applicable support documents

This information need will provide the seal design that will become part of the overall repository design. The seal design, therefore, is described in Section 6.2, current repository design description. A further description of the seal component design will be given in the SCP-CDR (SNL, 1987). As part of this information need the seal design, which is based on design requirements, will be developed.

Parameters

To develop the seal design, site and repository design information is required. The parameters needed for design are defined in the parameters subsection of Information Need 1.12.1, Section 8.3.3.2.1. Using the designs provided in this information need description, the appropriate materials

(Information Need 1.12.2, Section 8.3.3.2.2) and placement methods (Information Need 1.12.3, Section 8.3.3.2.3) will be selected.

Logic

The seal design effort integrates the parameters from Information Need 1.12.1. If seals are found to be necessary, the design requirements for the seal system can be developed. The design requirements are those properties that the seal system must attain, such as low overall hydraulic conductivity, to meet regulatory guidelines for radionuclide releases.

Design requirements will also specify the requirements for materials to be used in the seals or seal components. These will include the properties needed to attain seal performance requirements. These design requirements form a basis for materials testing (Information Need 1.12.2) and for selection of materials to be included in the seal designs. The placement technology study to be performed as part of the tradeoff studies associated with the advanced conceptual design activities will provide additional input to the design regarding suitable construction methods and their effects on seal performance. Thus, the design study and the materials and emplacement studies interface closely and require a degree of iteration between design requirements and materials properties testing.

Both of the design activities defined below are divided into three areas: define design requirements, perform tradeoff studies, and develop seal designs.

8.3.3.2.4.1 Design Activity 1.12.4.1: Development of the advanced conceptual design (ACD) for sealing

8.3.3.2.4.1.1 Design Subactivity 1.12.4.1.1: Define subsystem design requirements

<u>Objectives</u>

The objective of this subactivity is to develop design requirements that will assist the designer in the development of sealing components.

<u>Description</u>

Currently, the following tasks will be performed to support the advanced conceptual design:

1. Define sealing components.

2. List state and local regulations to establish the basis for design.

3. Develop functional requirements for the sealing subsystem, including the subsystems role in ensuring long-term waste containment and isolation.

4. Define the performance criteria for the sealing system to establish the level of performance required of the sealing system.

5. Identify the interfaces between the sealing system and other systems.

6. Define constraints in limitations placed on the sealing system or on other systems by the sealing system.

7. Describe the design-basis assumptions (if any) to be used in designing the sealing system.

8.3.3.2.4.1.2 Design Subactivity 1.12.4.1.2: Perform tradeoff studies to support advanced conceptual design development

Objectives

The objective of this subactivity is to provide technical justification for the selection of specific design options.

Description

The primary focus of the advanced conceptual design (ACD) work will be the resolution of design and engineering issues through the use of engineering tradeoff studies. These tradeoff studies would

1. Evaluate the potential suitability of gradations for the shaft and drift fill. If materials from the exploratory shaft are unavailable before the development of the design, only an analytical assessment of shaft settlement will be performed using a simple consolidation theory and available material properties.

2. Evaluate strategies for dissipating water at the floor of ramps and drifts.

3. Evaluate strategies for sealing discrete, water-producing fault or fracture zones encountered in horizontal emplacement holes and drifts.

4. Evaluate the need for settlement plugs by determining the consolidation behavior of various shaft fills and the subsequent consequence if no plugs are emplaced.

5. Assess the effectiveness of sealing components to deter human entry and propose preferred methods.

6. Assess the techniques available for emplacing various sealing components and the resulting seal performance that can be expected from each emplacement technique.

7. Assess how different materials can accommodate potential variations in stress, temperature, moisture, and geochemical conditions.

8.3.3.2.4.1.3 Design Subactivity 1.12.4.1.3: Develop advanced conceptual design for seals

Objectives

The objective of this subactivity is to provide design details that can be used to develop the license application design and to support the performance assessment activities.

Description

The advanced conceptual design (ACD) will summarize the results of the tradeoff studies performed as part of Subactivity 1.12.4.1.2. The following would be included:

1. The basis for sealing designs.
2. A description of the designs.
3. The design alternatives and a description of how the preferred design is selected.
4. Definition of the uncertainties/design issues associated with the preferred designs.

Some secondary information included as part of the ACD would include preliminary cost estimates for emplacing sealing components (this cost estimate will also include the cost associated with additional research and development that may be required to answer the performance-related questions and finalize designs), a schedule for emplacing sealing components as part of the decommissioning process, and a discussion of activities required to support the performance confirmation program.

8.3.3.2.4.2 Design Activity 1.12.4.2: Development of the license application design for sealing

8.3.3.2.4.2.1 Design Subactivity 1.12.4.2.1: Define subsystem design requirements

Objectives

The objective of this subactivity is to refine design requirements that will assist in the development of sealing components for the license application design (LAD).

Description

The development of design requirements for the LAD is expected to be similar to the categories for Subactivity 1.12.4.1.1. The basis for changes would be the results from Subactivities 1.12.4.1.2 and 1.12.4.1.3, as well as results from ongoing performance assessment activities. Changes are anticipated in the development of performance criteria, design interfaces, and constraints identification.

8.3.3.2.4.2.2 Design Subactivity 1.12.4.2.2: Perform tradeoff studies to support license application design development

Objectives

The objective of this subactivity is to provide technical justification for the selection of the final seal designs.

Description

The intent of this task is to perform the remaining tradeoff studies that will be necessary to select final seal designs. The remaining design and licensing issue is also expected to be resolved by these studies. Some tradeoff analyses would

1. Select the preferred strategies for retaining and dissipating water encountered in the underground facility considering material durability and design adequacy in achieving the desired performance.

2. Define the potential licensing issues and propose a resolution of the issues with consideration of the preferred sealing options.

3. Select the preferred method of backfilling the underground facility and evaluate the most effective way in which to expedite sealing of the drifts.

Although not specifically part of the tradeoff studies, a performance assessment of sealing components will be initiated during the advanced conceptual design phase and continue into license application design phase. Results from this assessment will be used to develop and refine the design requirements and performance criteria. The plans for evaluating seal performance are discussed in Section 8.3.5.11.

8.3.3.2.4.2.3 Design Subactivity 1.12.4.2.3: Develop license application design for seals

Objectives

The objective of this subactivity is to provide the license application design for seal components.

Description

The license application design will include the design details primarily for the preferred sealing designs that result from details associated with the tradeoff studies performed as part of Subactivity 1.12.4.2.2 and specific activities performed as part of this task. The following activities would be performed as part of this task.

1. Develop final designs and emplacement procedures for the preferred sealing options.

2. Quantify the physical construction requirements for the emplacement procedures established previously.

3. Develop a reliable cost estimate and a schedule of construction activities needed to emplace the sealing components in the repository. The cost estimates will include a detailed statement of the costs incurred to emplace seal components. Manpower, materials, and equipment requirements will be included.

4. Develop contingency plans for sealing in the event that unforseen geologic conditions are encountered.

8.3.3.2.4.3 Application of results

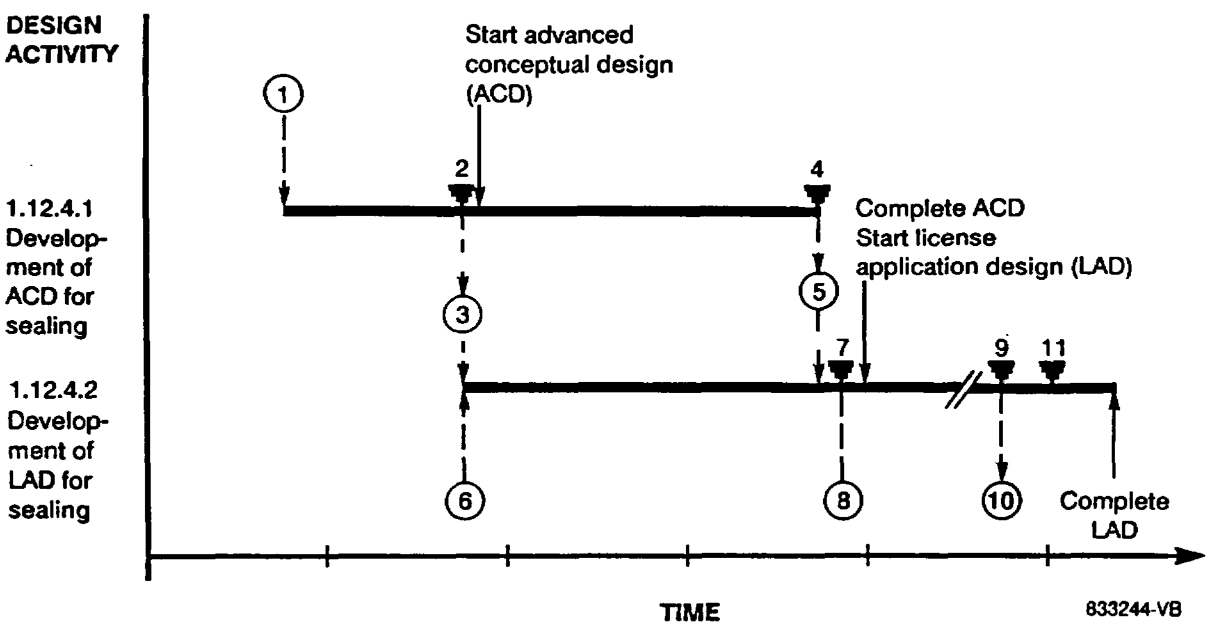
The information that is obtained in meeting this information need will contribute directly to the design and performance analysis of the repository seal system. The data will also be used to help satisfy other information needs related to design issues for postclosure repository design (Issue 1.11, Section 8.3.2.2) and preclosure repository design and technical feasibility (Issue 4.4, Section 8.3.2.5). The information will also be used in support of evaluating postclosure performance objectives related to containment, release rates from the engineered barrier system, and total system performance analyses.

8.3.3.2.4.4 Schedule and milestones

Information Need 1.12.4 provides reference designs for seals for shafts, ramps, drifts, and boreholes. It is subdivided into two design activities: 1.12.4.1 (development of the advanced conceptual design for sealing) and 1.12.4.2 (development of the license application design for sealing). The schedule information for this information need is presented in the form of timelines. These timelines extend from the start of the activity to the issuance of the final products associated with the work effort. Summary schedule and milestone information for this information need can be found in Sections 8.5.3 and 8.5.6.

This work associated with this information need is an out-year effort.

The relationships between this information need, site characterization investigations, issues, and information needs are illustrated in the following figure. The design activity numbers and titles corresponding to the timelines are shown on the left of the following figure. The numbered points shown on the timelines represent major events or important milestones associated with this work effort. Solid lines represent activity durations. Dashed lines show the interfaces between this work effort and other site characterization programs, issues, and information needs. The data input and output at these 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	Input site characterization data from site investigations 8.3.1.2 (geohydrology), 8.3.1.3 (geochemistry), 8.3.1.5 (climate), 8.3.1.6 (erosion), 8.3.1.8 (postclosure tectonics), 8.3.1.14 (surface characteristics), 8.3.1.15 (rock properties), 8.3.1.16 (preclosure hydrology), and 8.3.1.17 (preclosure tectonics); data/information from Information Needs 1.11.6 (thermal loading), 1.12.2 (seal characteristics), and 4.4.7 (design analyses); and Milestones P404 and N432.
2	Milestone M461. Sealing conceptual design for incorporation into ACD report.

Point number	Description
3	Output sealing conceptual designs information/data to Design Activity 1.12.4.2 (Milestone M492) and Information Need 4.4.7.
4	Milestone R276. Recommendations for materials for license application design (LAD) and performance assessment studies.
5	Output information/data on seal material recommendations to Design Activity 1.12.4.2 and Information Needs 1.11.7 (reference postclosure repository design), 4.4.5 (reference preclosure repository design) and 4.4.10 (seal technology).
6	Input site characterization data from site investigations 8.3.1.2, 8.3.1.3, 8.3.1.5, 8.3.1.6, 8.3.1.8, 8.3.1.14, 8.3.1.15, 8.3.1.16, and 8.3.1.17 and data/information from Information Needs 1.11.6, 1.12.2, and 4.4.7. (See point 1 for section contents.)
7	Milestone M492. LAD sealing criteria incorporated into repository design requirements.
8	Output information/data on sealing criteria to Information Need 4.4.3 (repository operations plan).
9	Milestone M449. Report on sealing subsystem performance assessment.
10	Output information/data on seal performance assessment to Information Need 1.1.6 (estimates of total system releases).
11	Milestone Z186. Issue report on technology requirements for seal design, materials, and emplacement for repository LAD.