FINAL DRAFT

IDENTIFICATION AND PRIORITIZATION OF MAJOR NNWSI DESIGN COMPONENTS

Prepared for:

U.S. Nuclear Regulatory Commission

Prepared by:

Itasca Consulting Group, Inc.
Suite 210
1313 5th Street SE
Minneapolis, Minnesota 55414

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DRAFT

IDENTIFICATION AND PRIORITIZATION

OF MAJOR NNWSI DESIGN COMPONENTS

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Task Description: preparation of a list of major design components for a high-level nuclear waste repository at Yucca Mountain; identification of those items which require site characterization testing; listing of parameters to be measured and associated tests; and prioritizing the components with respect to possible radiological consequences caused by failure of the component.

Prepared by: Itasca Consulting Group, Inc.
Suite 210
1313 5th Street SE
Minneapolis, Minnesota 55414

Authors:

____

Loren J. Lorig
Itasca Consulting Group, Inc.
Date: ____________

Reviewer:

____

Jaak Daemen
Consultant
(University of Arizona)
Date: ____________

PREFACE

This report presents an initial attempt to identify major NNWSI design components which require site characterization testing. This list was assembled by reviewing references which described preliminary repository concepts. Midway through preparation of the report, a draft copy of the CDR was made available for review at NRC's Las Vegas site office. Cursory review of this document did not result in significant changes to the list of major design components assembled earlier.

This report also prioritizes the importance of each component relative to possible radiological consequences (i.e., safety and waste isolation). Identification and prioritization of these items are not supported by any analysis but, rather, are based on conservative engineering judgement. More rigorous determination of items important to safety and waste isolation can be found in the following references.

1. "Draft NNWSI Site Characterization Plan Conceptual Design Report"

   (a) Section 4.6, "Systems, Structures and Components Important to Safety, Waste Isolation or Retrievability"

   (b) Appendix F, "Preclosure Radiation Safety Study"

   (c) Appendix L, "Items Important to Safety, Waste Isolation and Retrievability at Yucca Mountain"

2. Laub and Jardine (1986)

3. Jardine et al (1987)

All of these references became available during the course of preparation this report. No attempt was made to incorporate any information from these references into this report except for the author's notes on § 4.6 of the draft CDR, which are presented in Appendix B for completeness.

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1.0 INTRODUCTION

This report presents an initial attempt to identify major NNWSI design components which require site characterization testing and to prioritize the importance of each such component relative to possible radiological consequences of the component. It should be noted that no attempt has been made here to distinguish between systems, structures and components. All three are collectively referred to as "components". As part of the site characterization plan, DOE is required to provide a similar listing. Specifically, DOE should provide "the methodology for determining the scope of items and activities important to safety and waste isolation, a preliminary Q-list,* and a description of the 10 CFR Subpart G QA Program applicable to items and activities on the Q-list for the site characterization phase" [NRC (1986), p. 20].

In developing a Q-list for license application, DOE will follow a rigorous approach involving (1) detailed analysis of the repository design to identify potential initiating events/accident scenarios capable of causing radiological consequences and (2) failure consequence assessment. However, the NRC staff recognizes that changes in the level of detail and content of the Q-List are likely to occur between the SCP and the license application based on increased level of knowledge and maturity of design. Accordingly,

> DOE should provide a provisional Q-list in the SCP based on available information. This provisional list should include items and activities important to safety and waste isolation and should be supported by conservative analyses to assure all potential items and activities are identified at least at the system and major component level [NRC (1986), p. 21].

This paper is limited to consideration of items at the major component level. A consequence of this is that many subcomponents are lumped together under a single major design component. For example, a waste-handling building may have hundreds of subcomponents but, for the purposes of this study, they are all included under one major design component. Identification and prioritization of these major items are not supported by any analysis but, rather, are based on conservative engineering judgement.

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*The Q-list contains items and activities subjected to Quality Level I QA requirements.

The first step in identifying major NNWSI design components requiring site characterization testing was to assemble a list of all major design components. This list is presented in Section 2.0. Next, this list was reduced to include only those design components likely to require significant or unique site-specific characterization in order to satisfy NRC requirements. This revised list is presented in Section 3.0. In Section 4.0, each component requiring site characterization is prioritized with respect to possible radiological consequences of failure. Section 5.0 describes site characterization considerations for major NNWSI design components discussed in Sections 3 and 4.

2.0 MAJOR NNWSI DESIGN COMPONENTS

This section presents a list of major NNWSI design components for a high-level nuclear waste repository at Yucca Mountain. This list, presented in Table 2-1, has been developed by taking, as an initial approach, simply a comprehensive list of all major components that could conceivably be relevant. Each major component can be subdivided into numerous subcomponents. The references used in developing the list of design components are:

(1) "NNWSI Repository Design Presentation and Issues Resolution Strategy", February 11-13, 1986, Albuquerque, New Mexico (DOE);

(2) "NNWSI Preliminary Repository Concepts Report", SAND 83-1877 (Jackson, J. L.); and

(3) "Two Stage Repository Development at Yucca Mountain: An Engineering Feasibility Study", SAND84-1351 (MacDougall, Hugh R.).

A brief description of each of the components in Table 2-1 is presented in Appendix A.

Table 2-1

LIST OF MAJOR DESIGN COMPONENTS FOR A HIGH-LEVEL NUCLEAR WASTE REPOSITORY AT YUCCA MOUNTAIN

A. SURFACE SUPPORT

1. Waste-Handling Building(s)
2. Muck Pile
3. Underground Personnel Facility
4. Office Buildings
5. Warehouse and Storage Yard
6. Emplacement Exhaust Fan and Filter Buildings
7. Men and Materials Shaft Intake Fan Buildings
8. Maintenance Shops

B. SHAFTS AND RAMPS

1. Waste Ramp
2. Emplacement Intake Shafts (exploratory shaft and escape shaft)
3. Men and Materials Shaft
4. Muck Ramp
5. Emplacement Ventilation Exhaust Shaft
6. Decommissioning System

C. REPOSITORY HORIZON

1. Drifts and Pillars
2. Emplacement Hole and Waste Package
3. Monitoring Systems
4. Muck Handling System
5. Operations Support Systems
6. Emplacement Borehole Drilling Machine
7. Waste Package Retrieval Equipment
8. Transfer Cask
9. Waste Transporter
10. Ventilation Control Devices

3.0 MAJOR NNWSI DESIGN COMPONENTS REQUIRING SITE CHARACTERIZATION

An argument can be made for considering that all major design components listed in Section 2.0 require information about the site for design purposes. However, the list presented in this section is restricted to those components which require unique or site-specific characterization in order to avoid or mitigate radiological consequences. For example, footing design for surface offices require routine information concerning the geo-engineering properties of the underlying soil and/or rock. For this design component, improper or inadequate site characterization may have operational consequences (i.e., loss of availability of offices for some time) but no radiological consequences. Consequently, surface office buildings are not included in the list of major NNWSI design components requiring site characterization. On the other hand, improper or inadequate characterization of the foundation conditions of the waste-handling building(s) could have radiological consequences if an earthquake led to large differential displacements in the building(s), causing radwaste pipes to break, canisters to be breached, or unshielded fuel rods to be exposed to the outside atmosphere through changes in ventilation or failure of the enclosing structure. Consequently, the waste-handling building(s) is(are) included in the list of major design components requiring site characterization.

Table 3-1 is an initial attempt at identifying major NNWSI design components which require site characterization. Professional judgement has been used to determine which design components should be included on the list. In determining which design components require site characterization, two categories of potential radiological consequences have been considered: (1) those which are realized prior to permanent closure; and (2) those which are realized after permanent closure. The next section prioritizes each of the major design components with respect to these two consequences.

Table 3-1

MAJOR UNDERGROUND DESIGN COMPONENTS REQUIRING SITE CHARACTERIZATION

A. SURFACE SUPPORT

1. Waste-Handling Building(s)
2. Emplacement Exhaust Shaft Fan and Filter Buildings

B. SHAFTS AND RAMPS

1. Waste Ramp
2. Emplacement Intake Shafts
3. Emplacement Ventilation Exhaust Shaft
4. Decommissioning System

C. REPOSITORY HORIZON

1. Drifts and Pillars
2. Emplacement Hole
3. Waste Package Retrieval Equipment
4. Monitoring Systems

4.0 PRIORITIZATION OF MAJOR NNWSI DESIGN COMPONENTS RELATIVE TO RADIOLOGICAL CONSEQUENCES

Some failures* or accidents in a repository, whether initiated by external or internal events, can lead to a breach of containment barriers and release of radionuclides. The release may be airborne or transported through groundwater; the effects (i.e., radiological consequences) can be measured in terms of radiation dose. Different waste forms in the repository have different emission levels and radiological properties which affect radionuclide release and transport mechanisms. Understanding the potential severity of radiological consequences is a necessary pre-requisite to licensing, construction and operation.

No quantitative assessment of radiological consequences of failure have been made as part of this report. Rather, based on engineering judgement, each major design component has been assigned a priority level (i.e., high, medium or low) with respect to their pre-closure importance to safety or their post-closure importance to waste isolation.

Design components important to safety are engineered structures, systems or components which are essential to prevention or mitigation of credible accidents resulting in a radiation dose to body or organ ≥ 0.5 rem at or beyond the nearest boundary of an unrestricted area at any time until permanent closure.

The requirement for DOE to present a list of major design components in the SCP is given in "GTP on Design Information Needs in the SCP" [NRC (December 1985), p. 5], as follows:

> The DOE should identify and present the bases for which structures, systems and components of the geologic repository have been determined to be important to safety in the SCP. If an item is considered important to safety, then an assessment should be conducted to establish what site characterization data are needed to properly design the item considering 10 CFR 60.131.b requirements, to avoid or mitigate off-site radionuclide releases. Items that are important to safety must be covered by a quality assurance program as required by 10 CFR 60.151.

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*"Failure" implies the inability of the system to perform its intended function (NRC, 1985b).

DOE has performed such an analysis and, according to Laub and Jardine (1986), "No items were found to be important to safety" (p. 2).

Design components important to waste isolation relate to inhibiting transport of radioactive material to the accessible environment during the post-closure period. These components include engineered and natural barriers essential for compliance with the 10 CFR 60 objectives for overall system performance and particular barriers after permanent closure. 10 CFR 60 gives performance objectives in the following areas:

(1) groundwater travel time (10 CFR 60.113(a)(2);

(2) waste package containment (10 CFR 60.113(a)(1)(ii)(A));

(3) engineered barrier controlled release (10 CFR 60.113 (a)(1)(ii)(B)); and

(4) the overall system (10 CFR 60.112).

4.1 Surface Support Components

The regulatory basis for design of all surface facilities rests primarily with 10 CFR 60.131 and .132. The important surface support components discussed here are the waste-handling building(s) and the emplacement exhaust shaft fan and filter buildings. These components are considered important from a safety standpoint only and do not significantly impact waste isolation. The radiological consequences of failure of these components are uncertain without analysis but may be significant because of their proximity to workers and population. Failure scenarios which impact site characterization involve two natural phenomena external initiating events (earthquakes and floods) and one man-made external event (underground nuclear explosions). Site characterization is required to reduce the risk of these events causing significant radiological consequences (10 CFR 60.131b).

4.1.1 <u>Waste-Handling Building(s)</u> — including facilities for receipt and retrieval of waste, surface facility ventilation, radiation control and monitoring, and waste treatment.

subcomponents

- waste-handling/packaging systems
- operating support systems
- operating cells
- transfer corridors
- operating support areas

prioritization in terms of radiological consequences

- safety (high priority)
- waste isolation (low priority)

reason

The waste handling buildings are judged to have a high priority with respect to safety because of the many canister-handling events involved over a long period of time and the potential for operational accidents (e.g., fuel assembly drop in hot cell). It should be noted that commercial high-level waste (CHLW) and Defense high-level waste (DHLW) will be emplaced as received, in canisters, unless inspection reveals that the packaging of these wastes has been damaged. Spent reactor fuel will be sent to the repository as intact fuel assemblies. Packaging for emplacement will occur in the waste handling building(s). In order to reduce the total number of spent fuel disposal packages, consolidation of fuel assemblies is being considered. Because of its greater radioactivity and handling requirements, the spent fuel poses the greater safety threat. Site characterization can do little to reduce the risk of operational accidents. On the other hand, failure scenarios initiated by an earthquake, underground nuclear explosion, flood, and involving radwaste piping, ventilation, etc. do require site characterization.

Because the waste handling buildings will not be operations in the post-closure period, they should have minimal importance with respect to waste isolation.

4.1.2 <u>Emplacement Exhaust Shaft Fan and Filter Buildings</u> —

subcomponents

- normal exhaust fans
- emergency filtration (HEPA)
- stack
- controls

prioritization in terms of radiological consequences

- safety (medium priority)
- waste isolation (low priority)

reason

During the pre-closure period, exhaust fans are required to pull the ventilation air through the waste emplacement area, creating a negative pressure. Fan failure would result in loss of negative pressure in the waste emplacement area. Loss of the pressure gradient in the emplacement area could result in airborne radionuclides traveling up through the intake shaft(s) or ramp. During normal (fan) operations, if radioactive particulates are detected, the HEPA filters on the surface will collect the particulates before discharging this ventilation air to the atmosphere. Exhaust fans are not operative during the post-closure period.

4.2 Shafts and Ramps

The regulatory basis for design of shafts and ramps rests primarily with 10 CFR 60.131 and .133. The regulatory basis for design of the decommissioning system (e.g., seals) rests primarily with 10 CFR 60.134. Because all shafts and ramps connect the repository horizon with the accessible environment, they are important from a waste isolation viewpoint because they provide both a source for water inflow and a credible migration path to the accessible environment. In addition, because shafts and ramps on the emplacement side are all parts of the ventilation circuit, they may also be considered important to safety. Pre-closure failure scenarios relate primarily to localized but substantial collapse, resulting in altered air flow patterns. Because all shafts and ramps will likely be lined, substantial collapse would only likely result from external events such as earthquakes or underground nuclear explosions.

[DOE has provisionally assumed in the draft CDR (p. 2-56) that the peak accelerations at the emplacement level are one-half those at the surface. Presumably, therefore, peak accelerations for shafts and ramps will range from 1.0 to 0.5 times the surface acceleration, depending on the depth below the surface. The draft CDR also states (p. 2-54) that "significant efforts are underway, as a part of the NNWSI seismic tectonic position paper, to develop a methodology for predicting the maximum ground motion values and potential fault displacements at the site that result from natural seismicity for use in the next phase of the design."]

All shafts and ramps have the following subcomponents in common:

(1) lining;
(2) rock reinforcement (if used);
(3) collar or portal;
(4) station; and
(5) inspection/monitoring systems

4.2.1 Emplacement Intake Shafts — (exploratory shaft, ES-1, and escape shaft, ES-2)

prioritization in terms of radiological consequences

- safety (medium priority)
- isolation (high priority)

reason

The emplacement intake shafts are judged to have a medium importance with respect to safety because they are part of the waste ventilation circuit, and blockage of this shaft could result in altered ventilation patterns.

Proposed penetration of the exploratory shaft into the Calico Hills may have an adverse effect of the ability of that unit to retard radionuclide travel, particularly if heated water resulting from contact with waste canisters alters zeolites in the Calico Hills member. For this reason, the emplacement intake shafts (especially ES-1) have been judged to be more important with respect to waste isolation than other shafts and ramps.

4.2.2 Waste Ramp

prioritization in terms of radiological consequences

- safety (medium priority)
- isolation (medium priority)

reason

The waste ramp is judged to have a medium priority with respect to safety because, based on empirical evidence, the most susceptible part of all underground openings to dynamic loads are the portals. During the pre-closure period, rock fall could conceivably cause obstruction of the ramp, leading to a change in ventilation pattern. With respect to isolation, the waste ramp represents both a potential water inflow path and a radionuclide migration path. The importance of ramps for waste isolation is discussed in more detail in the section on shaft and ramp decommissioning systems.

4.2.3 Emplacement Ventilation Exhaust Shaft

prioritization in terms of radiological consequences

- safety (medium priority)
- isolation (medium priority)

reason:

The emplacement ventilation exhaust shaft is a major component of the ventilation system. Failure scenarios involving partial or complete collapse of the shaft would alter the ventilation pattern, resulting in consequences similar to those resulting from fan failure (described in Section 4.1.2). Therefore, the emplacement ventilation exhaust shaft is judged to have a medium priority with respect to safety.

With respect to isolation, the emplacement ventilation exhaust shaft represents both a potential water inflow path and a radionuclide migration path. The importance of shafts for waste isolation is discussed in more detail in the section on shaft and ramp decommissioning systems.

4.2.4 Shaft and Ramp Decommissioning System

subcomponents

- seals
- backfill (if used)
- bulkheads (plugs?)
- shaft and portal covers
- settlement plugs

prioritization in terms of radiological consequences

- safety (low priority)
- isolation (high priority)

reason

Seals have only limited functions during the pre-closure period and, therefore, are judged to have a low priority with respect to safety. 10 CFR 60.134a requires that seals prohibit "pathways that compromise the geologic repository's ability to meet the performance objectives for the period following permanent closure..." The importance of seals to waste isolation at NNWSI depends, in large part, on the hydraulic conductivity of the host rock and the amount of inflow. Seals may be most important at intersections of faults with shafts, ramps, or boreholes. Failure of such seals may allow water to enter the shafts, ramps or boreholes. Flow of water in shafts, ramps or boreholes to the repository horizon depends on the conductance of the backfill and the total head of the water. Seals are also important with respect to radionuclide vapor phase migration in air.

4.3 Repository Horizon (Underground Facility)

The regulatory basis for design of the underground facility rests primarily with 10 CFR 60.131 and 60.133. Components of the underground facility are important both with respect to safety and waste isolation. Failure scenarios during the pre-closure time period generally involve a sequence of failures involving breached canisters, altered ventilation, etc. Initiating events may be either dynamic (e.g., earthquakes) or static (e.g., support system failure as a result of exposure to heat). It should be noted that no seismic design criteria have yet been specified for the underground facility.* Failure scenarios during the post-closure period initiate with loss of containment of the waste package followed by loss of containment of the engineered barrier(s).

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*"It is provisionally assumed that the peak accelerations at the emplacement level are 1/2 those at the surface. This assumption is based on a conservative estimate of attenuation of ground motion with depth available from UNE Test data and other published information on earthquakes (SAND85-7104[+], UCID-20505)."

+SAND85-7104 is URS/Blume (1985).

4.3.1 <u>Drifts and Pillars</u> — includes perimeter drift, main drifts (waste, tuff, service), emplacement drifts, panel access drifts, and pillars

subcomponents

- rock reinforcement (if used)
- liner/support (if used)

prioritization in terms of radiological consequences

- safety (medium priority)
- isolation (low priority)

reason

Radiological consequences would require a sequence of failures prior to permanent closure (i.e., would require release from engineered barriers/emplacement/hole) and from emplacement areas (according to present design most likely to be isolated from the access drifts - ventilation circuit).

The importance of drifts and pillars with respect to waste isolation is difficult to assess without analysis. From a regulatory standpoint, the drifts and pillars can be considered to be within the disturbed zone. If they are not part of groundwater travel time calculation, they may be judged to have a low priority with respect to waste isolation. However, performance of drifts and pillars will impact the performance of emplacement holes (and subcomponents). These impacts are considered as part of the emplacement hole, discussed next.

possible failure scenarios

A possible failure scenario might involve the following sequence:

(1) radiological contamination of air in emplacement ventilation system—e.g., as a result of canister failure:

- release along emplacement hole/emplacement room/ ventilation (access) drift or;
- release through rock from package to access drifts

(2) ventilation drift failure—e.g., localized but substantial collapse, resulting in altered air flow pattern

It should be noted that canister failure (e.g., as a result of rockfall during the pre-closure period), while in a drift, is not a very credible event. The reason for this is that spent fuel and other waste forms will be surrounded by multiple metallic confinement barriers such as cladding, canisters, containers and casks. Gross failure of these confinement barriers as the result of rock fall impact likely has a low probability.

Presumably failure consequences can be minimized by monitoring ventilation circuit (e.g., air velocities, pressures), which should instantaneously detect any substantial blockage. An argument can be made that, with reliable and appropriate monitoring, a failure of this type should be detected readily. With appropriate provisions for standby equipment and crews, failures of this type should be amenable to rapid clean up and repair.

Similarly, an argument can be made that regular inspection and monitoring of all ventilation drifts should allow early detection of deterioration, and hence preventive and remedial action.

In sum, although failure scenarios can be developed that suggest a conceptual radiological release, numerous corrective and preventive measures can be taken and incorporated in the repository design, resulting in a low probability of substantial radiological releases.

4.3.2 Emplacement Hole and Waste Package

subcomponents

- liner (if used)
- hole shield plug
- backfill (if used)
- cover
- support hardware (plates, dollys, etc.)

prioritization in terms of radiological consequence

- safety (high priority)
- isolation (high priority)

reason

Detailed and precise prioritization would require a failure and consequence analysis. However, it appears intuitively (and superficially) that radiological consequences prior to and following closure might exist due to liner/package failure (e.g., as a result of:

- discontinuous (e.g., earthquake-triggered) large deformations along a fault intersecting an emplacement hole

- highly unequal/non-uniform package/canister loading as a result of localized emplacement hole failure);

- accelerated corrosion of liner and/or package due to point loading. [The draft CDR mentions an annual corrosion rate of 0.002 in/year (§ 3.2.1.2). (Presumably, this rate is an average rate and not indicative of accelerated corrosion resulting from point loading.)]

Pre-closure radiological consequences could result from retrieval complications (e.g., with enhanced risk of radiological exposure during retrieval as consequence of canister damage resulting from effects, as per above).

The regulatory basis rests in the potential for retrieval complications, risk of radiological exposure during operations, risk of radiological exposure during retrieval, uncertainty about meeting containment performance, and uncertainty about meeting isolation (release rate) requirements.

4.3.3 Waste Package Retrieval Equipment

Subcomponents for Off-Normal Retrieval Operations (from draft CDR)

- shield plug coring system
- borehole inspection equipment
- removal sleeve system
- coring system
- liner cutting system
- liner repair system
- borehole reaming system
- shielded drill system

prioritization in terms of radiological consequences

- safety (high priority)
- isolation (low priority)

reason

10 CFR 60.133(c) requires that the underground facility be designed to permit retrieval of waste in accordance with the performance objectives of 60.111. The possibility of breaching the waste canister during retrieval exists—particularly if the long horizontal waste emplacement configuration is adopted. Steel liners are under study as a means of enhancing the retrievability. Complication may result from deterioration and/or deformation of the steel liner due to (1) stress-induced corrosion and (2) potential significant rock displacement against the liner. Complication could result from binding of the waste packages in the liner. The NRC staff has identified retrieving breached canisters out of a long horizontal emplacement hole as presenting major technical problems that may be insurmountable.

The radiological consequences of failure during post-closure are negligible and, therefore, the waste package retrieval system is not important to waste isolation.

4.3.4 Monitoring Systems

subcomponents

- radiation monitoring system
- environmental monitoring system
- geotechnical monitoring system

prioritization in terms of radiological consequences

- safety (medium priority)
- isolation (low priority)

reason

As mentioned previously (see Section 4.3.1, Drifts and Pillars), present design concepts call for ventilation monitoring in all access drifts throughout the retrievability period. Presumably, failure consequences can be minimized by reliable and appropriate monitoring, with appropriate provisions for early detection and, hence, preventative and remedial action.

The monitoring systems are not judged to be very important to waste isolation since few would be operating during the postclosure period.

5.0 SITE CHARACTERIZATION CONSIDERATIONS FOR MAJOR NNWSI DESIGN COMPONENTS

This section briefly presents the initial parameters which need to be measured during site characterization testing for each of the major design components previously identified as requiring site characterization (Section 3). In addition to noting which parameters are to be measured, it is also important to quantify the uncertainty associated with each parameter in order to make meaningful calculations with it.

For each overall grouping (i.e., surface support, shafts and ramps, and repository horizon), an introductory discussion is presented which identifies parameters and associated tests common to all components in the group. The subsequent subsections discuss any unique parameter requirements.

(5) response of site soil and rock to dynamic loading; and

(6) dynamic (earthquake and underground nuclear explosion) design bases.

Tests that need to be performed are:

(1) Geologic Features

- tests to determine if rocks or soils are present that might be unstable because of their mineralogy, partially-cemented nature, water content, or potentially undesirable response to seismic or other events.

- geologic mapping and characterization

(2) Engineering Properties of Soil and Rock

- tests to determine soil grain properties

- weight-volume tests of soil aggregate

- tests to determine hydraulic properties of soil and rock

- test to determine soil consolidation characteristics (if any)

- tests to determine mechanical (i.e., stress deformation-strength) properties of soil and rock

- tests to determine dynamic (e.g., seismic modulus) properties of soil and rock

- tests to determine modulus of subgrade reaction

- tests to determine allowable bearing pressure

(3) Seismic Profiles of the Site

- seismic refraction and reflection surveys

- in-hole and cross-hole explorations

(4) Groundwater

- periodic monitoring of local wells and piezometers in all critical strata (e.g., flood-prone areas, river washes)

(5) Response of Soil and Rock to Dynamic Loading

- determine effects of previous underground nuclear explosions or earthquakes on site

- laboratory dynamic tests to determine susceptibility of soils to liquefaction

(6) Dynamic Design Basis

- determine the dynamic basis for earthquakes and underground nuclear explosions

In addition, the following analysis should be performed:

Analysis of Flood Potential — The surface facilities are located in a low area and may be susceptible to flooding. In particular, the flooding near the proposed location of WHB2 needs to be evaluated.

5.2 Shafts and Ramps

Much of the site characterization testing for these components relates to the design of seals. The particular data needed for sealing design include the following:

(1) infiltration and percolation rates for Yucca Mountain;

(2) drainage capacity of Topopah Spring tuff;

(3) determination of permeability (matrix and fracture) of rock surrounding shafts and ramps;

(4) quantification of water inflow from discrete sources; and

(5) rock/water/seal (concrete, bentonite) chemistry.

In addition, geoengineering parameters (both soil and rock) are required for routine stability analysis. Because the shafts and ramps will be built in both soil and rock, standard parameters required for design of the surface (Section 5.1) and underground facility (Section 5.3) will also be necessary for shafts and ramps.

Parameters that need to be measured include:

(1) geologic parameters;

(2) geomechanics parameters;

(3) hydrologic parameters;

(4) parameters to evaluate flood potential;

(5) construction-related parameters; and

(6) rock mineralogy, chemical composition.

Tests that need to be performed include:

(1) Geologic

- mapping
- exploratory coring

(2) Geomechanics

- soil tests similar to those for the surface support components
- rock tests
  - unconfined compression
  - triaxial compression
  - joint strength tests
  - thermal expansion
  - thermal conductivity/specific heat
  - in-situ stress measurements

(3) Hydraulic

- tests to determine conductivity of rock matrix
- tests to determine conductivity of discrete fractures in response to changes in normal stress, shear displacement and permeating fluid (i.e., air or water)
- periodic measurements of piezometers
- tests to determine properties of perched water zones
- tests to determine rock mass hydraulic properties of unsaturated welded tuff (permeability tests)
- perched water tests

(4) Flood Potential

- infiltration tests

(5) Construction

- shaft convergence
- overbreak mapping
- support monitoring
- blast vibrations
- damaged zone extent/properties

(6) Geotechnical

- tests to assess effect of water on Calico Hills if shaft penetrates Calico Hills and is used for a sump (for emplacement intake shaft—i.e., exploratory shaft only)

5.2.1 Emplacement Intake Shafts — The exploratory shaft is a major component of site characterization effort and will likely involve numerous tests and data collection (some of which may not be related to its use as the emplacement intake shaft).

The Ghost Dance Fault is located in close proximity. If faults occur in swarms, some minor faults may cross these shafts.

In addition to those parameters listed in Section 4.2, some geochemical parameters (e.g., rock mineralogy and chemical composition, as well as groundwater chemistry) will be required as part of site characterization for the emplacement intake shaft ES-1. Tests to assess the effect of heated water on Calico Hills (if shaft penetrates and is used as a sump) will need to be performed.

5.3 Repository Horizon (Underground Facility)

Site characterization testing required for the underground facility is aimed at characterizing host rock response to thermally-, hydrologically-, mechanically-, and chemically-induced changes. Parameters are required on several different scales—i.e., canister scale, drift scale, and repository scale. In addition, because of the large extent of the underground facility, site characterization activities must address the representativeness issue (i.e., is the information basis sufficient to provide reasonable assurance that all (or most) components will perform satisfactorily?).

Excavation, emplacement hole and pillar stability depend on in-situ conditions—i.e., stability predictions require site characterization, including:

- rock strength (in the broad sense—i.e., including effects of discontinuities, thermal loading, chemical alterations, etc.)

- stress field

- rock deformation (particularly with regard to liner loading, package loading (especially if unlined), liner deformation, etc.)

Parameters which need to be measured include:

(1) rock mass strength parameters;

(2) rock mass stiffness parameters;

(3) in-situ stresses;

(4) rock mass classification parameters, including discontinuity characteristics; and

(5) thermal parameters.

Tests that need to be performed include:

(1) rock mass characterization tests (strength, stiffness); and

(2) discontinuity characterization, orientation, spacing, persistence, etc.

5.3.1 Drifts and Pillars

Maintaining ventilation circuits will require stable drifts. Present design concepts (Jackson, 1984) call for monitoring ventilation in all access drifts throughout the retrievability period. Assuming that no parallel ventilation component will be provided, this implies that no substantial rock fall can be tolerated, as this would potentially alter airflow patterns

Site characterization is required in order to perform drift design, reinforcement/support design, and long-term stability evaluation.

The final EA (DOE, 1986a), states that "An indepth study of the effects of heating on the proposed repository horizon, as well as on structural elements like grouted bolts will be completed during site characterization."

Tests that need to be performed include:

(1) drift excavation and displacement monitoring; and

(2) sequential mine-by test(s).

5.3.2 Emplacement Hole and Waste Package

Parameters that need to be measured specifically for the emplacement hole and waste package are primarily environmental parameters (see NRC, 1985b, p. 6), including

- — temperature field
- — groundwater chemistry
- — groundwater flow rates
- — groundwater flux and flow mechanisms
- — air composition and flow rate

Tests that need to be performed are

(1) emplacement hole performance demonstration tests (such as waste package environment tests and canister-scale heater tests); and

(2) liner corrosion tests

5.3.3 <u>Waste Package Retrieval Equipment</u> — The final EA states (p. 4-66) that "During the summer of 1985, the DOE developed a position on retrievability to fully describe and document all design, construction, operation, and maintenance equipment requirements associated with retrievability. Progress has been made in evaluating the effects of these requirements on design and in assessing the associated equipment needs. These retrieval effects will be analyzed and addressed during the site characterization period and subsequent design phases supporting the license application."

Tests that need to be performed are primarily emplacement hole performance demonstration tests (such as waste package environment tests and canister-scale heater tests)

5.3.4 <u>Monitoring Systems</u> — In order for monitoring systems to be reliable, they must be (1) designed for the environment in which they are intended to function and (2) capable of making accurate measurements within the predicted response range. Analyses must be performed to predict the response range and environment in which the monitors must perform.

REFERENCES

Jackson, J. L. Nevada Nuclear Waste Storage Investigations Preliminary Repository Concepts Report. SAND83-1877. September 1984.

Jardine, L. J., C. W. Ma, R. C. Sit, and R. J. Donahue. "Preliminary Preclosure Safety Analysis for a Prospective Yucca Mountain Repository," presented at Waste Management '87 conference, Tucson, March 1987.

Laub, T. W., and L. J. Jardine. "Initial Q-List for the Prospective Yucca Mountain Repository Based on Items Important to Safety and Waste Isolation (Draft)," SAND 86-1985A, September 1986.

MacDougall, Hugh R. Two-State Repository Development at Yucca Mountain: An Engineering Feasibility Study. SAND84-1351. December 1984.

UCID-20505 (referenced in Draft SCP, p. 2-56)

URS/Blume. "Ground Motion Evaluation at Yucca Mtn, Nevada, with Application to Repository Conceptual Design and Siting," SAND85-7104, May 1985.

U.S. Department of Energy. "NNWSI Repository Design Presentation and Issues Resolution Strategy," Albuquerque, New Mexico, February 11-13, 1986a.

U.S. Department of Energy. Nuclear Waste Policy Act (Section 112) Environmental Assessment Yucca Mountain Site, Nevada Research and Development Area, Nevada (Vols.I-III plus Overview and Recommendation By the Secretary of Energy of Candidate Sites for Site Characterization for the First Radioactive-Waste Repository. May 1986b.

U.S. Nuclear Regulatory Commission. "Draft Generic Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to 10 CFR 60 Quality Assurance Requirements," July 1986.

U.S. Nuclear Regulatory Commission. "Draft Generic Technical Position — Design Information Needs in the Site Characterization Plan," December 1985(a).

U.S. Nuclear Regulatory Commission. "Generic Technical Position — Waste Package Reliability Analysis for High-Level Nuclear Waste Repositories," December 1985(b).

APPENDIX A

DESCRIPTION OF MAJOR NNWSI DESIGN COMPONENTS

This appendix contains a brief description of the major NNWSI design components listed in Table 2-1. The order in which they are presented here is the same as that listed in Table 2-1.

Waste-Handling Building(s) — buildings for receiving, unloading and preparing radioactive waste for transfer to underground disposal

Muck Pile — surface stock pile of excavated rock (muck) from drifts, boreholes, shafts, ramps, etc.

Underground Personnel Facility — contains a laundry, lockers, showers and toilets for men and women regularly employed in underground mining, waste emplacement and monitoring activities

Office Buildings — administrative and computer buildings which include office space for people involved with administration, waste transportation, waste-handling operations, plant management, safety, training, and visitors

Warehouse and Storage Yard — facilities for the inventory, control, and storage of a three-month supply of consumables (including spare parts, tires, tools, etc.)

Emplacement Exhaust Fan and Filter Buildings — contain exhaust fans and high-efficiency particulate air (HEPA) filters. (Exhaust air drawn through the underground waste emplacement and exhaust airways and up the shaft bypass the HEPA filters unless radioactivity is detected in the exhaust.)

Men and Materials Shaft Intake Fan Buildings — buildings housing fans for supplying ventilation air through the men and materials shaft to mining operations

Maintenance Shops — shops for maintaining motor pool, transporters, surface mechanical equipment, etc.

Waste Ramp — ramp used to transport waste to the disposal horizon (The waste-handling ramp is ventilated by a downcast air flow.)

Emplacement Intake Shafts — exploratory shaft (ES-1) and emergency egress shaft (ES-2) which provide access to the exploratory shaft facility (ESF) and intake air for the waste emplacement area

Men and Materials Shaft — shaft which provides access to the mining area for men and materials and intake ventilation air (downcast) for the mining area

Muck Ramp — ramp used to convey excavated rock (muck) and exhaust air from the mining area; includes muck conveyor transfer station

Emplacement Ventilation Exhaust Shaft — shaft which exhausts air from the waste emplacement area

Decommissioning System — system composed of seals, backfill, etc. used to remove shafts, ramps and boreholes from operation so that, following permanent closure, they do not become pathways for water inflow or radionuclide migration that might compromise the repository's ability to meet the performance objectives

Drifts and Pillars — three main entry drifts (tuff main, waste main, and service main) run through the center of the main repository block which will be used for waste transport, muck handling and bulk materials transport systems, and ventilation. (A rock pillar separates the main entries from the waste emplacement panels. The layout and spacing of the main entries are designed to separate the ventilation air circuits for the mining areas and waste emplacement areas. Other drifts include the perimeter drift, emplacement drifts, and panel access drifts.)

Emplacement Hole and Waste Package — The emplacement hole is a hole bored vertically or horizontally from the emplacement drift into the host rock for the purpose of emplacing the waste package(s). The waste package is the primary container that holds solidified high-level radioactive waste, spent fuel, or other radioactive materials and any overpacks. Emplacement holes are presently envisaged to be fully lined (horizontal option) or partially lined (vertical option) with a steel liner (about 1/2" thick).

Monitoring Systems — systems for monitoring repository environment, including air temperature, radioactivity, air flow, rock movement, rock temperature, etc.

Muck Handling System — system for removing muck from the mining area (The system may include LHD, panel access conveyor, main haulage conveyor, storage bin and apron feeder)

<u>Operations Support Systems</u> — systems for distributing water, air, electricity, etc. to the underground facility

<u>Emplacement Borehole Drilling Machine</u> — machine used for drilling emplacement boreholes for either the vertical or horizontal emplacement option

<u>Waste Package Retrieval Equipment</u> — Under normal circumstances, the waste packages will be removed from the emplacement boreholes with the same equipment used for emplacement—i.e., the waste transporter. However, for off-normal conditions (e.g., borehole collapse and rupture or jammed canisters), special retrieval equipment will be required.

<u>Transfer Cask</u> — a specially-designed container that provides shielding and containment for waste disposal packages during transfer from the surface facility to the disposal locations underground (also known as a facility cask)

<u>Waste Transporter</u> — vehicle used to transport waste packages from the waste-handling building to the disposal area (The transporter is equipped with a shielded cask mounted such that the cask can be rotated into position for placing the canister into an emplacement borehole.)

<u>Ventilation Control Devices</u> — devices such as bulkheads, airlocks, doors, regulators, and fans with ducting; used to control ventilation in various parts of the repository

APPENDIX B

NOTES ON § 4.6 OF THE DRAFT NNWSI SCP CONCEPTUAL DESIGN REPORT

This section contains notes on Section 4.6 of the Draft NNWSI SCP Conceptual Design Report which was reviewed on NRC's Las Vegas Site Office on 25 February 1987. The draft of the NNWSI SCP CDR was available for review mid-way through the preparation of this report. These notes are presented here for completeness.

Section 4.6 is entitled "Systems, Structures and Components Important to Safety, Waste isolation or Retrievability" and contains three sub-sections:

(1) Section 4.6.1, Items Important to Safety;

(2) Section 4.6.2, Items Important to Waste Isolation; and

(3) Section 4.6.3, Items Important to Retrieval.

Section 4.6.1 — Items Important to Safety

This section listed seven steps followed in determining which systems, structures or components are important to safety. The methodology is as follows:

(1) develop facility and system models;

(2) identify and screen initiating events;

(3) perform accident scenario;

(4) perform probability and consequences analysis for each accident scenario;

(5) quantify event trees;

(6) screen accident scenario for those events which lead to conditions exceeding criteria; and

(7) analyze those accident scenarios which exceeded the screening criteria to identify which systems, structures or components involved in the scenarios are important to safety.

In order for an accident to be considered, it must be credible. Credible accidents are defined as having a probability of occurrence of 10^{-5}/year or greater. The results of the analyses indicate that there were no items important to safety. Items which were potentially important to safety were presented in Table 4-9 (reproduced below).

Table 4-9

ITEMS POTENTIALLY IMPORTANT TO SAFETY
FOR THE YUCCA MOUNTAIN REPOSITORY

ITEM	LOCATION	REMARKS
vehicle stop	cask receiving and preparation area	accident induced by a vehicle falling into pit
fire protection system	waste-handling facility	fire
hot cell structure, crane	unloading hot cell	earthquake
hot cell structure, crane	consolidation hot cell	earthquake
hot cell structure, crane	package hot cell	earthquake
structures	transfer tunnels (in surface facilities)	earthquake

Section 4.6.2, Items Important to Waste Isolation

The procedure followed in establishing this list was to first develop a set of bounding scenarios which were evaluated for probability and consequences (performance assessment models). Next, the probabilities were compared with 40 CFR 191.13(a). Items that are relied upon to satisfy the criteria are then described as being important to waste isolation. The analysis showed that two specific geologic units of the site are required to meet the overall system performance objective. These two units are the Calico Hills non-welded zeolithic unit and the Calico Hills non-welded vitric unit.