WBS: 1.2.1.5
SCPB: N/A
QA: L

Civilian Radioactive Waste Management System
Management & Operating Contractor

Performance Confirmation Plan

B00000000-00841-4600-00002 REV 00

September 1997

Prepared for:

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September 1997

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HISTORY OF CHANGE PAGE

Informal DOE Review Draft Issued, REV. 00A New Draft Document	March 10, 1997
Status Draft Issued, REV. 00B Revision of Draft Document	June 23, 1997
Review and Check Draft Issued, REV. 00C M&O QAP-3-5 Review Draft	August 27, 1997
Concurrence Draft Issued, REV. 00D Revision of Draft Document	September 22, 1997
Final Approved Document, REV. 00	September 29, 1997

EXECUTIVE SUMMARY

The *Performance Confirmation Plan* defines the activities necessary to conduct the Performance Confirmation Program as specified in 10 CFR Part 60, Subpart F. This plan specifies monitoring, testing, and analysis activities to be conducted for evaluating the accuracy and adequacy of the information used in the License Application to determine that the performance objectives for the period after permanent repository closure will be met.

This document is to be used as a basis for detailed planning of the Performance Confirmation Program and is to be integrated with the Mined Geologic Disposal System (MGDS) Test and Evaluation Program, in accordance with the *Office of Civilian Radioactive Waste Management Test and Evaluation Master Plan* (DOE 1995a) and as discussed in the *MGDS Viability Assessment Test and Evaluation Plan* (CRWMS M&O 1997b).

The Performance Confirmation Program objectives are 1) to confirm that subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the License Application; 2) confirm that natural and engineered systems and components that are required for repository operations, or that are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated; 3) evaluate compliance with U.S. Nuclear Regulatory Commission (NRC) postclosure performance requirements; and 4) evaluate the repository readiness for permanent closure.

The performance confirmation approach is comprised of six major steps. The first step is to define a performance confirmation baseline. This baseline identifies the processes and parameters important to postclosure performance. The second step is to predict values and variations of critical performance measures for the parameters in the performance confirmation baseline, which establish expectations during construction and operations. The third step is to establish tolerances or limits on deviations from predicted performance. The fourth step is to monitor performance, perform tests and collect data. The fifth step is to analyze and evaluate the data, including process model validation, analysis, statistical tests, and total system performance assessment. The sixth step is to recommend and implement appropriate actions, if there are deviations from what was predicted or assumed. If there are no deviations, or when the closure criteria are satisfied, the Program will evaluate the repository readiness for permanent closure.

It is important to note that the parameters and concepts identified for performance confirmation are based on the current understanding of natural and engineered barrier processes, the mathematical models formulated for these processes, the computer codes that have been developed to simulate these processes, and the parameters required for these computer codes. Uncertainties still exist regarding many of these processes, such as rock matrix and fracture flow interactions and waste package corrosion. As new understanding is gained during site characterization, construction, and operations, the process models and simulations of the processes are expected to change. These changes will necessitate changes in the list of performance confirmation parameters which could, in turn, necessitate changes in the *Performance Confirmation Plan.*

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1. PERFORMANCE CONFIRMATION PROGRAM

This section introduces and summarizes the Performance Confirmation Program and defines the Performance Confirmation Program objectives, planning and design, responsibilities, and schedule.

1.1 INTRODUCTION

1.1.1 Purpose

The purpose of the *Performance Confirmation Plan* is to specify monitoring, test, and analysis activities to be conducted for evaluating the accuracy and adequacy of the information used in the License Application to determine that the performance objectives for the period after permanent repository closure will be met.

1.1.2 Scope

The *Performance Confirmation Plan* establishes test and analysis requirements in the form of scope sheets, which provide brief descriptions of objectives, responsibilities, and requirements for facilities, equipment, data acquisition, evaluation, and reporting for each test or analysis related to postclosure performance objectives. All test and evaluation activities including those which are not related to postclosure performance objectives are addressed in the *MGDS Viability Assessment Test and Evaluation Plan* (CRWMS M&O 1997b). The performance confirmation test and evaluation activities covered include process modeling, performance predictions, site monitoring and testing, waste package monitoring and testing, repository monitoring and testing, test data analysis, evaluation, and performance assessment. The scope of tests and analyses are defined to ensure:

- Integration with mined geologic disposal system (MGDS) design, with developmental testing and evaluation, and with operational test and evaluation planning

- A basis is established for detailed performance confirmation planning.

Based on the general requirements, the Performance Confirmation Program "shall have been started during site characterization and it will continue until permanent closure" (10 CFR 60.140(b)). During site characterization, the plan covers activities necessary for the development of the performance confirmation baseline and a transition of responsibilities for monitoring those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization. The development of the performance confirmation baseline will consist of primarily evaluation activities. The transition of monitoring activities is expected to occur as site characterization activities, currently conducted under study plans, are concluded in their support for the License Application. As investigations that support the License Application are concluded, those activities which have been identified as needing additional support as a part of performance confirmation will be transitioned and conducted under the *Performance Confirmation Plan*. At this time and for this initial version of the *Performance Confirmation Plan*, it is not possible to show an explicit tie between uncertainties in assessments in the License Application and performance confirmation activities that will follow submittal of the License Application. The assessments for the License Application have not been completed, but conceptually these ties are indicated by

following the parameter screening process described later in Sections 2.3 through 2.5. As the assessments for the License Application are made, an explicit tie between these uncertainties and performance confirmation activities will be made.

1.1.3 Application

The *Performance Confirmation Plan* is to be used as input to detailed planning of performance confirmation testing and analyses. The management and operating contractor (M&O) organizations, identified as responsible organization, performing organization, and supporting organization, are responsible for compliance with the scope sheets compiled in Section 4.

1.1.4 Revisions

The *Performance Confirmation Plan* will be updated as required until final approval and submittal as part of the License Application to the U. S. Nuclear Regulatory Commission (NRC). Potential revision of this plan may be required to support the amendment of the License Application to receive and possess waste.

Future revisions of the *Performance Confirmation Plan* will be needed as information which supports the License Application matures. The information will be based on Site Characterization testing, repository and engineered barrier system requirements development and design, process level modeling, and total system performance assessments. Future revisions will also be better able to address issues such as prioritization of performance confirmation testing activities. Prioritization of testing will need to be based on a firm set of performance requirements and assessments of postclosure performance, including uncertainties. The current uncertainties related to postclosure performance requirements for the repository are expected to be resolved and the design basis will be better established in order to support the License Application. Following submittal of the License Application, the U.S. Department of Energy anticipates addressing residual uncertainties regarding issues of items important to performance.

1.1.5 Civilian Radioactive Waste Management System Overview

An overview of the Civilian Radioactive Waste Management System (CRWMS) is provided for background. The text in this section has been paraphrased from the *Civilian Radioactive Waste Management System Requirements Document* (DOE 1996a). Additional information about CRWMS is available in that document.

The top-level function of the U.S. Department of Energy (DOE) CRWMS is to "Dispose of Waste," which includes directing or controlling any physical activity, operation, or process to accept title and possession of spent fuel and high-level waste, and transporting these wastes to an interim storage facility, if approved, and to the repository for emplacement and isolation. The three subfunctions supporting the function that the CRWMS must perform are:

- Accept and Transport Waste
- Store Waste
- Emplace and Isolate Waste.

These subfunctions are accomplished by three system elements:

- Waste Acceptance and Transportation (Accept and Transport Waste)
- Interim Storage Facility (Store Waste)
- MGDS (Emplace and Isolate Waste).

The three system elements work in conjunction to fulfill a variety of functional and performance requirements intended to make the transportation, storage, and permanent emplacement and isolation of waste in a geologic repository safe, environmentally acceptable, and cost effective.

The CRWMS performance period begins with the start of site characterization; involves the acceptance, transportation, interim storage, and emplacement of waste in the repository; and continues through the isolation of the waste from the accessible environment for at least 10,000 years following permanent closure of the repository.

1.1.6 Mined Geologic Disposal System Overview

The mission of the Mined Geologic Design System (MGDS) is to provide for the emplacement and isolation in the geologic repository of commercial spent nuclear fuel, DOE spent nuclear fuel, and civilian and defense high-level waste, such that the public health and safety and the environment are protected. The MGDS is composed of the site, repository, and engineered barrier. This is based on the MGDS architecture which is described in the Mined Geologic Design System-Requirements Document (MGDS-RD), but the architecture is currently being changed to be consistent with the System Description Documents and current design. The *Performance Confirmation Plan* will be revised to adopt the new architecture once it is approved and is incorporated into the technical document hierarchy.

The repository will be able to accommodate waste generated from 70,000 metric tons of heavy metal, which is assumed to include:

- 63,000 metric tons of heavy metal of spent nuclear fuel from commercial reactors.

- Approximately 4,700 metric tons of heavy metal equivalent high-level waste from reprocessing of defense materials and commercial spent nuclear fuel.

- Approximately 2,300 metric tons of heavy metal of DOE spent nuclear fuel.

The steady state receipt rates planned are 3,000 metric tons of heavy metal of commercial spent nuclear fuel per year and 400 metric tons of heavy metal of high-level waste or DOE spent nuclear fuel per year.

The Yucca Mountain Site is located approximately 100 miles northwest of Las Vegas, Nevada. It is currently being characterized to support the determination of its viability to host the repository.

The candidate host rock in which the subsurface facilities are constructed is the Topopah Spring Tuff, a welded tuff unit of the Paintbrush Group. The Topopah Spring Tuff is approximately 330 m

The candidate host rock in which the subsurface facilities are constructed is the Topopah Spring Tuff, a welded tuff unit of the Paintbrush Group. The Topopah Spring Tuff is approximately 330 m (1,100 ft) thick. The unit dips about six degrees to the east. Potentially usable repository areas are outlined by major faults. These areas include a primary area and expansion areas.

The emplacement area is located entirely within the primary area and west of the Ghost Dance fault. Location of the repository horizon provides a minimum overburden of 200 meters. The regional water table is several hundred meters below the potential horizon for the emplacement of the disposal containers. The disposal containers will contain the waste and are the major component of the engineered barrier system.

MGDS facilities comprise repository surface and subsurface operational and support facilities. All facilities are required to comply with applicable safety, health, and environmental regulations; quality assurance requirements; and appropriate operations and maintenance standards, including 10 CFR Part 60 requirements for maintenance of structures, systems, and components. The location of operational and support facilities directly related to handling of nuclear waste determines the surface and subsurface geologic repository operations area.

The disposal container conceptual design consists of two cylindrical barriers and calls for prevention of breaching for at least 1,000 years and, as a goal, no more than 10 waste packages breaching within 3,000 years after closure (CRWMS M&O 1997a). The conceptual inner barrier material is Alloy 625 (nickel base alloy), and the conceptual outer barrier is A516 carbon steel.

The MGDS will be developed and operated in six phases as follows. The performance confirmation related activities are briefly listed in each phase.

Site Characterization Phase–This phase includes activities necessary to collect and evaluate data to determine the characteristics of the site; prepare repository designs to support Viability Assessment, License Application, and construction; predict and assess the system performance; prepare the License Application for construction authorization and support its review; prepare the Environmental Impact Statement and support its review; and plan for the remainder of the phases. The Exploratory Studies Facility (ESF) was constructed during this phase. Performance confirmation activities conducted in the site characterization phase include collecting relevant site characterization data; developing models and identifying processes; completing performance analysis; identifying major performance measures; identifying key parameters and development requirements; defining and developing the performance confirmation baseline; verifying the performance of engineered barrier system designs and evaluating the predictive modeling that will be contained in the Total System Performance Assessment-License Application; developing and implementing the *Performance Confirmation Plan*; and designing performance confirmation systems.

Construction Phase–This phase includes transitioning the ESF to repository facilities, construction and equipping of surface facilities, refurbishing ESF openings, continued excavation and equipping of initial subsurface facilities, gathering data to support predictions of the repository performance, demonstration of some repository operations, and preparation of an updated License Application to receive, package and emplace waste. Performance confirmation activities conducted in the

construction phase include updating and revising the *Performance Conformation Plan*; continuing construction tests and data acquisition; acquiring and transmitting test data; performing field tests and experiments; performing laboratory tests; performing test data analyses and comparing data with predictions; validating models and reporting performance; recommending and implementing corrective actions; and updating models and predictions.

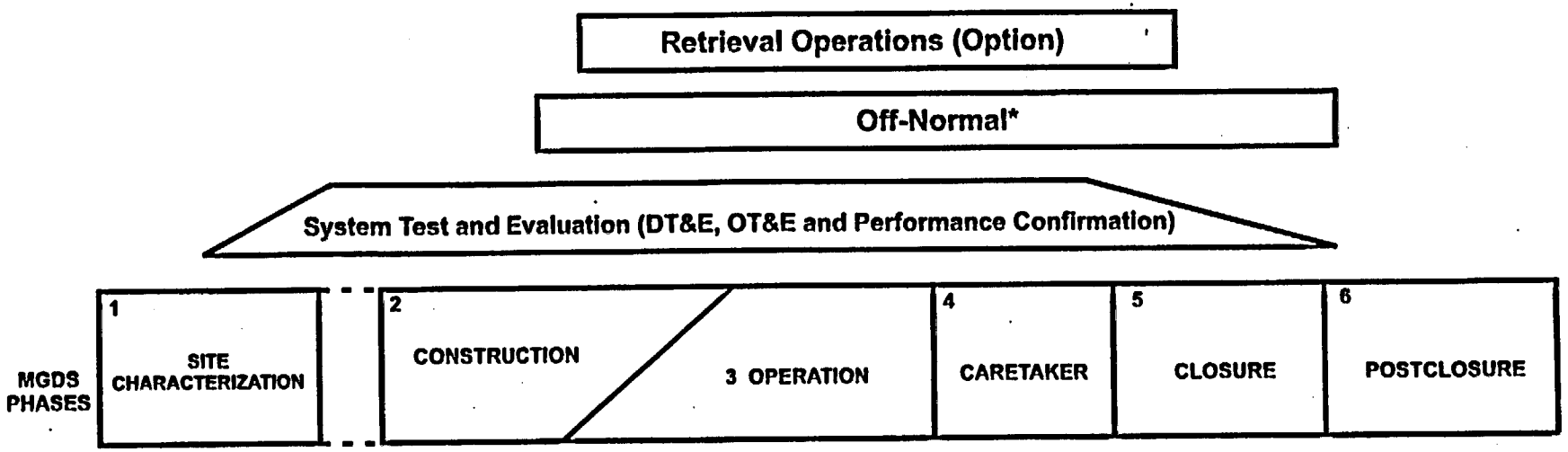
Waste Handling and Emplacement Operation Phase–This phase includes receiving the waste, packaging the waste in disposal containers, emplacing loaded disposal containers in the repository, gathering data to support evaluations of repository performance, and initial caretaker and maintenance activities. The expected duration of this phase is 24 years. Performance confirmation activities conducted during waste emplacement include updating and revising the *Performance Confirmation Plan*; continuing construction tests and data acquisition; expanding monitoring and testing per plan; acquiring and transmitting test data; performing field tests and experiments; performing laboratory tests; performing test data analysis and comparing data with predictions; validating models; assessing reporting and performance; recommending and implementing corrective actions; and updating models and predictions.

Caretaker Phase–This phase begins when all the waste has been emplaced and includes safeguarding the waste, maintaining surface and subsurface facilities, maintaining the retrieval option, gathering data to support evaluations of the repository performance, and preparing the License Application amendment for permanent closure of the repository. This phase will be terminated by a direction to retrieve the waste or an authorization to close the repository. The expected duration of this phase is no longer than 76 years. Performance confirmation activities conducted during the caretaker phase include maintaining the performance confirmation system; continuing selected tests begun during the operation phase, monitoring and related evaluation, assessing and reporting tasks; checking closure criteria; and planning test and monitoring options for closure and postclosure phases, if required.

Closure Phase–This phase includes closing and sealing the subsurface facilities; decontaminating, decommissioning, removing the surface facilities, constructing monuments, creating institutional barriers, and returning the site to natural conditions as required by the NRC. The expected duration of this phase is no longer than six years. Performance confirmation activities have been concluded, but deactivation of the performance confirmation system and implementation of closure will occur. If required, a program for postclosure monitoring may be implemented.

Postclosure Phase–The postclosure phase is the period following permanent closure during which the wastes are to be contained by the engineered barrier system and permanently isolated by natural barriers. During postclosure, the government will use the detailed records and information supplied during closure as well as legal means—such as lows, permits, and zoning—to control access to the site, thus creating institutional barriers. In addition, fences and warning signs will be maintained. Performance confirmation activities have concluded. If required, a program of postclosure monitoring may be conducted.

A diagram of these phases and the operational content of each phase is presented in Figure 1-1. The previous sections describe the operations for each of these phases. Figure 1-1 shows a transition time between the Site Characterization phase and the Construction phase. In this timeframe, the NRC is reviewing the License Application for construction. The activities in the timeframe include



1. **SITE CHARACTERIZATION**
   - Surface-Based Tests
   - ESF Construction
   - ESF Testing and O&M
   - Material Tests
   - Viability Assessment
   - Modeling
   - TSPAs
   - PC

2. **CONSTRUCTION**
   - Surface Facilities and Equipment
   - Subsurface Facilities and Equipment including Drifts for Waste Emplacement
   - Development Tests
   - Pre-Operation Demonstrations
   - PC

3. **OPERATION**
   - Receive Waste
   - Assemble Waste Package
   - Underground Transportation
   - Emplace Waste Packages
   - Operational Tests
   - PC
   - Maintain Safety/Security
   - O&M
   - Protect Retrieval

4. **CARETAKER**
   - Maintain Safety/Security
   - PC
   - O&M
   - Protect Retrieval

5. **CLOSURE**
   - Backfill/Seal and Close Subsurface Facilities
   - Decommission and Dismantle Surface Facilities
   - Establish IBS
   - Reclaim Site

6. **POST-CLOSURE**
   - Confine Waste
   - Isolate Waste

Retrieval (Option)
- Prepare for Retrieval
- Retrieve Waste
- Perform Post-Retrieval Activities

Off-Normal
- Accidents
- Natural Disasters
- Equipment Failures
- Other Occurrences

Performance Confirmation (PC)
- In-Situ Monitoring of Geologic Setting
- Waste Package Monitoring and Tests
- Radiological Measurements/Tests
- Laboratory Tests and Field Experiments
- Barrier and Seal Tests
- Develop and Maintain Processes and Performance Assessment Models
- Predict and Assess Performance
- Recommend Actions

Abbreviations:

ESF - Exploratory Studies Facility
IBS - Institutional Barrier System
O&M - Operation & Maintenance
WP - Waste Package
DT&E - Development Test & Evaluation
OT&E - Operational Tests & Evaluation
PC - Performance Confirmation
TSPA - Total System Performance Assessment

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Figure 1-1. MGDS Phases and Operations

design, support of the licensing process, and performance confirmation. For Performance Confirmation, this timeframe is called the interim period. Performance Confirmation test and evaluation during the interim period is discussed in Section 3.8 of this plan. System test and evaluation activities are conducted during most of these phases and are described in the following section.

A majority of the text in this section was reprinted from the *Preliminary Mined Geologic Disposal System Concept of Operations* (CRWMS M&O 1996h) document with updates based on recent design assumptions in the *Controlled Design Assumptions Document* (CRWMS M&O 1997a). Additional information about the MGDS can be found in these documents.

1.1.7 Mined Geologic Disposal System Test and Evaluation Program

The MGDS Test and Evaluation Program is described in the *Mined Geologic Disposal System Viability Assessment Test and Evaluation Plan* (CRWMS M&O 1997b). Additional information about the program and the process can be found in the subject document. The *Performance Confirmation Plan* is a subtier document of the *MGDS Viability Assessment Test and Evaluation Plan*. A brief summary of the functions of the MGDS Test and Evaluation Program is provided here to show the relationship of the two programs and scope of the two plans.

The Test and Evaluation Program functions include determining suitability of the Yucca Mountain Site for housing a geologic repository; investigating and documenting design concepts to reduce development risk; verifying structures, systems, and components compliance with design requirements and specification; performing system tests to validate MGDS requirements including the receipt, handling, retrieval, and disposal of waste; conducting periodic performance testing to verify preclosure requirements and demonstrate safe and reliable MGDS operation; and for Performance Confirmation, performing modeling, test, and analysis to verify postclosure regulatory requirements (CRWMS M&O 1997b). To perform these functions, the MGDS Test and Evaluation Program is divided into five major functional areas or programs; Site Characterization; Developmental Test and Evaluation; Operational Test and Evaluation; Periodic Performance Testing; and Performance Confirmation.

1.1.8 Performance Confirmation Program Objectives

The objectives of the Performance Confirmation Program are:

- To confirm that subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the License Application.

- To confirm that natural and engineered systems and components that are required for repository operations, or that are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated.

- To evaluate compliance with NRC requirements that are related to postclosure performance.
- To evaluate repository readiness for permanent closure.

1.1.9 Mined Geologic Disposal System Postclosure Performance Measures

The disposal regulations (10 CFR Parts 60.112 and 60.113) establish postclosure performance objectives for the overall repository system and for components of the natural and engineered barrier systems. These objectives are expected to change because the Energy Policy Act of 1992 directed the Environmental Protection Agency (EPA) to promulgate a standard specifically for a repository at Yucca Mountain based on and consistent with the recommendations of the National Academy of Sciences in the *Technical Bases for Yucca Mountain Standards* (NAS 1995). The document recommends the use of a standard that sets a limit on the risk of adverse health effects to individuals from radioactive releases from the potential repository and compliance with the standard measured at the time of peak risk (out to approximately one million years). When the EPA has completed the drafting of this standard, the NRC will revise 10 CFR Part 60 to be consistent with the standard.

The individual barrier performance standards apply to subsystems of the MGDS, including two for the engineered barrier system and one for the natural barrier, and are contained in 10 CFR Part 60.113. The waste package performance standard applies to waste containment within the waste packages. The engineered barrier system performance standard applies to the barrier as a whole such that small fractional releases to the geologic setting occur over long times. Collectively, the engineered barrier system will consist of the waste packages, waste package support hardware, and performance enhancing barriers. The natural barrier performance standard establishes a minimum limit on the groundwater travel time.

In the interim, the DOE has provided guidance for planning purposes, to limit peak dose to individuals from releases from the repository (DOE 1997d). Once the new regulations are issued, the *Performance Confirmation Plan* will be revised as necessary.

1.1.10 Activity Scope Sheet Description

Activity scope sheets are used to define the scope and requirements of each performance confirmation test and evaluation activity. The scope sheets are compiled in Section 4. Figure 1-2 provides an example of the general content of an activity scope sheet. The scope sheets provide a unique identifier and a descriptive title for the activity. Current organizational responsibility, performing and supporting organizations are specified, and the location of the activity is identified. A brief description of the activity and the objectives are provided, and requirements are specified, including constraints, schedule and pretest requirements, hardware/software and facility requirements, data acquisition requirements, and reporting requirements.

ACTIVITY SCOPE SHEET

ID#:

TITLE: **Descriptive Title for Test or Analysis**

RESPONSIBLE ORGANIZATION:

PERFORMING ORGANIZATION:

SUPPORTING ORGANIZATIONS:

LOCATION:

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST & SCHEDULE REQUIREMENTS:

E. HARDWARE/SOFTWARE/FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ANALYSIS/ASSESSMENTS REPORTS:

Figure 1-2. Format of Activity Scope Sheet

1.1.11 Performance Confirmation Plan Organization

The *Performance Confirmation Plan* is organized in the following manner. The executive summary provides a conceptual description of the objectives and approach. Section 1 includes an introduction, a Performance Confirmation Program summary description, performance confirmation planning and

design, management and organizational responsibilities, and the program schedule. Section 2 includes the requirements and inputs applicable to the Performance Confirmation Program, functions that must be performed to accomplish the program, postclosure performance measures, processes and models, basic parameters and technical data needs. Section 3 consists of a description of the performance confirmation baseline definition, performance predictions, a summary of test facilities and support elements, evaluations and corrective actions, reporting, training, quality control, interim period test and evaluation, integration with other test and evaluation activities, and detailed test and evaluation planning. Section 4 consists of the scope sheets for the planned test and evaluation activities. Section 5 presents the conclusions and recommendations. Section 6 contains the references. Appendices of supporting information are provided.

1.1.12 Quality Assurance

An activity evaluation performed for the development of the *Performance Confirmation Plan* resulted in the determination that the work performed to supplement performance confirmation requirements and develop the Plan is quality-affecting. The *Performance Confirmation Plan* will identify testing and analysis requirements for the MGDS to determine if the items important to waste isolation are functioning properly. Therefore, this activity is related to testing items important to waste isolation. The *Q-List* (DOE 1997c) includes certain engineered barriers such as the waste package and underground excavations. The document also includes certain natural barriers such as the Topopah Spring welded hydrogeologic unit and the Calico Hills nonwelded hydrogeologic unit. This activity will define the sample and data collection, evaluations, and analyses necessary for performance confirmation; however, the activity will not require the classification of items in accordance with QAP-2-3, *Classification of Permanent Items*. Determination of importance evaluations, in accordance with NLP-2-0, *Determination of Importance Evaluation* will not be required since the development of the Plan and test and evaluation activities are not field activities.

Appropriate quality assurance procedures, particularly QAP-3-5, *Development of Technical Documents* will be used in the preparation, review, approval and revision, if necessary, of the *Performance Confirmation Plan*. The use of QAP-3-12, *Transmittal of Design Input* will apply to design input transmitted between organizations and not controlled by other quality assurance procedures. Other areas of the *Quality Assurance Requirements and Description* (DOE 1997a) will apply to activities, such as Section 11, Test Control. The appropriate quality assurance controls will be applied to those activities.

The use of computer software is not expected for the development of the *Performance Confirmation Plan*. Any analyses that may be required to remove a To Be Determined (TBD) in the Plan will be performed under appropriate procedures such as QAP-3-9, *Design Analysis;* and if computer software is needed, it will be controlled by applicable procedures. The results of these analyses will be used as input to the Plan.

The NLP-3-15, *To Be Verified (TBV) and To Be Determined (TBD) Monitoring System* will not be used to identify or track unqualified design input used in this Plan because it will not be used to support construction, fabrication, or procurement, and will not be used as part of a verified design package to be released to another organization for use in other design work.

1.2 PERFORMANCE CONFIRMATION PROGRAM SUMMARY

1.2.1 Performance Confirmation Approach

Figure 1-3 summarizes the approach to performance confirmation. This approach to the MGDS performance confirmation is provided in this section. Note that the first three items require model development, computations, sensitivity analyses, and periodic total system performance assessments. The approach is as follows:

- Define a performance confirmation baseline which identifies and documents performance measures for waste containment and isolation, performance confirmation parameters to be monitored, and analytical process models and performance assessment models to be used to predict and evaluate performance. This baseline will be documented as part of the License Application.

- Predict preclosure values and variations of performance measures and performance confirmation parameters. These predictions will be provided as part of the License Application. Postclosure predictions are conducted as part of Total System Performance Assessment.

- Establish tolerances or acceptable limits (screening levels) of deviations from predicted performance, including acceptable ranges of key parameter values, regulatory limits and model validity or credibility limits, and criteria and guidelines for recommended corrective actions to be taken if tolerances are exceeded.

- Monitor performance, perform tests, and collect data.

- Analyze and evaluate data including process model validation, analysis, statistical tests and total performance assessment, addressing changes with respect to site characterization data as a result of construction, waste emplacement, and operation; deviation from predicted performance; and regulatory compliance.

- Recommend and implement corrective actions, continued operation, or permanent closure.

1.2.2 Performance Confirmation Parameter Selection

The *Performance Confirmation Concepts Study Report* (CRWMS M&O 1996f) identifies the natural and engineered barrier processes needing analysis on the basis of regulatory and MGDS design requirements and the associated functional analyses. These processes determine which conceptual and mathematical models are needed and which computer codes are available for the analyses. See Section 2.4. These in turn determine specific parameters necessary for the analyses. See Section 2.5. The parameters are listed in a set of six tables identifying the processes and available computer codes requiring them as input or generating them as output. See the *Performance Confirmation Concepts Study Report*, Appendix B.

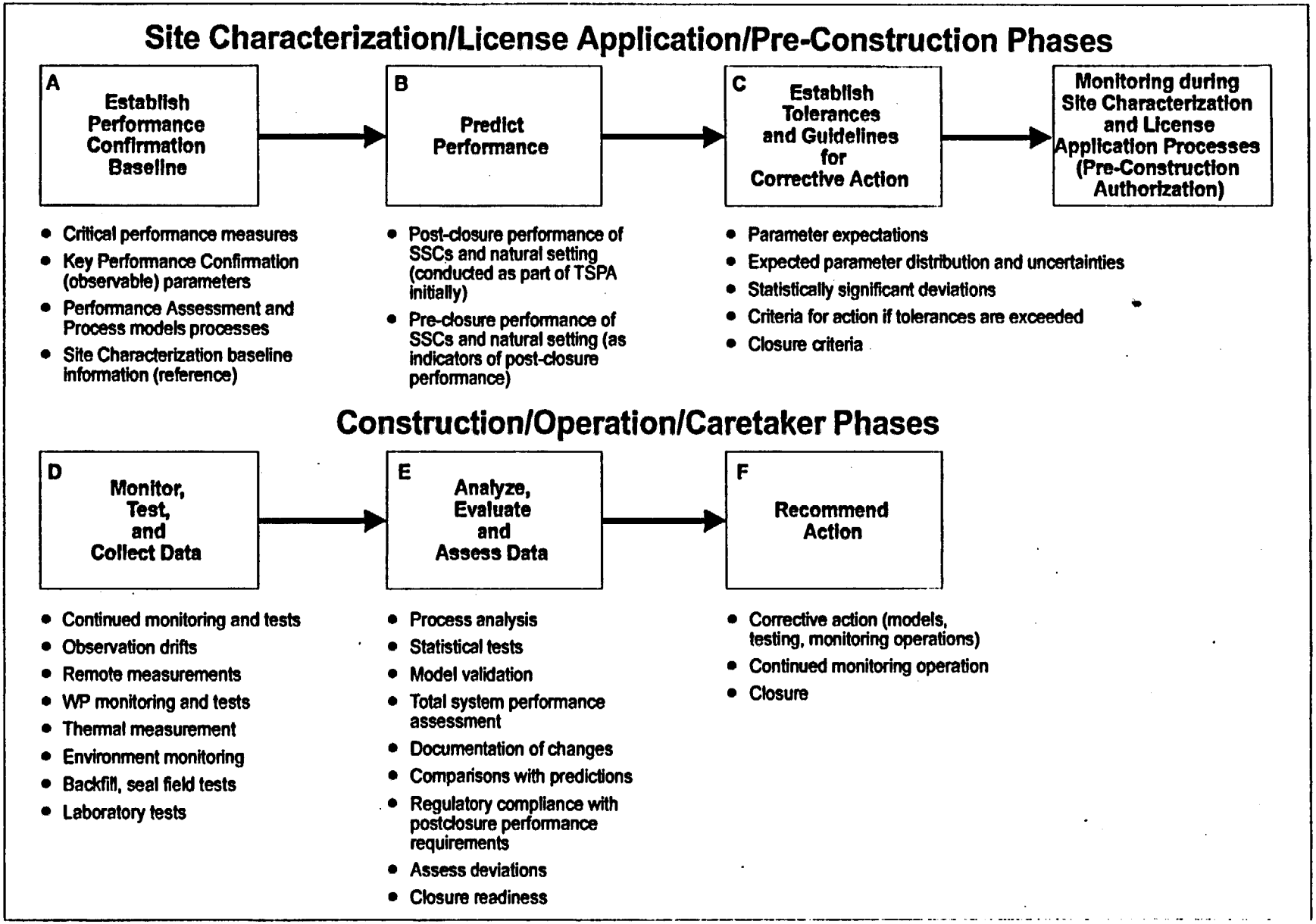

Figure 1-3. MGDS Performance Confirmation Approach

Parameter selection criteria were identified that consider regulatory, functional, measurement, modeling, and uncertainty aspects to select the parameters that need to be measured, monitored, observed, or tested during performance confirmation. This selection process is described in Section 2.5 of this plan and is summarized in Table 2-1 and in the flowchart of Figure 2-6. All of the parameters were then listed in a second set of six tables against the selection criteria and these tables were then used to select the performance confirmation parameters. See the *Performance Confirmation Concepts Study Report*, Appendix C.

A subset of these parameters, identified as key performance confirmation parameters for design, were then identified whose data acquisition needs to be considered in the MGDS design. See the *Performance Confirmation Concepts Study Report*, Appendix C. For the *Performance Confirmation Plan*, this list was expanded by adding the remaining performance confirmation parameters from the *Performance Confirmation Concepts Study Report*, Appendix C. The expanded list of these additional parameters to be measured and tested by surface-based means is provided in Appendix D of this plan. This list, together with the associated natural and engineered barrier processes and components, forms the basis for the planned performance confirmation monitoring, tests, facilities, and support.

1.2.3 Performance Confirmation Parameters

Performance confirmation parameters were selected in the *Performance Confirmation Concepts Study Report* in accordance with the process summarized in Section 1.2.2. They are needed to evaluate the natural and engineered barrier processes and components important for postclosure MGDS performance. Only those postclosure performance parameters or measures that can be observed, monitored, measured, and tested during the preclosure phase of the repository are selected as performance confirmation parameters. Thus, postclosure performance parameters are not included if the associated processes are not expected to occur in the preclosure phase and consequently can not be monitored or tested. Examples are radionuclide concentrations in the ground water, future populations that would be affected by postclosure radionuclide releases, and radiation doses to these populations.

The selected performance confirmation parameters are grouped in accordance with the following subsystems of the MGDS:

- Site parameters pertaining to the site in general
- Unsaturated zone
- Saturated zone
- Repository excavations and boreholes
- Waste packages
- Backfills and seals.

General site parameters that can be confirmed during the preclosure phase include topography, climatological and meteorological characteristics, seismicity, the occurrence of natural resources, and background radiation levels. Unsaturated zone performance confirmation parameters include stratigraphy and altered zone/near-field pneumatic, ground-water, geochemical, geomechanical, and thermal characteristics. Characteristics of unsaturated-zone fracture zones, including faults, are

identified separately from the rock matrix in general. Only water table elevations, ground-water flux, and ground-water travel time have been selected for performance confirmation for the saturated zone because no other changes are expected during the preclosure phase[1]. This list may need to be expanded in a revision to the *Performance Confirmation Plan* because a hot repository is predicted to affect not only fluid flow, but also temperatures and geochemistry in the saturated zone below the potential repository.

Repository excavation performance confirmation parameters include rock-stability-related characteristics, air temperature and humidity, rates and chemical composition of ground-water inflow, and quantities and chemical alteration of tracers, fluids and materials that are expected to remain in the potential repository after its closure. Waste package performance confirmation parameters include the waste form and waste package geometry, radionuclide inventory, internal gas composition, rates and coefficients for all mechanisms of waste form and container degradation, chemical compositions of all degradation products, nuclear criticality parameters, and waste package center and wall temperatures. Although no aqueous radionuclide release is expected from the waste packages, continuous radiation monitoring of ventilation air would alert to any gaseous radionuclide releases. For the initial issue of this Plan, performance confirmation parameters for backfills and seals have not yet been selected. The development of seals parameters will follow concept development and design next year. Backfill is not in the reference design for the Viability Assessment, but will be retained as an option. Therefore, backfill parameters are yet to be determined. **TBD - PC Parameters for Seals, TBD - PC Parameters for Backfills**

The parameter selection is based on current and expected regulatory requirements, understanding of natural and engineered barrier processes, conceptual and mathematical models and computer codes, and MGDS design. The selection also made assumptions with respect to the state of knowledge expected to exist at the time of the submittal of the License Application. Changes in the selected parameters can therefore be expected as site characterization, MGDS design, and the Performance Confirmation Program proceed. More details on parameter selection and the parameters are provided in Section 2.5.

1.2.4 Requirements Development

Performance confirmation requirements have been and will continue to be established based on applicable regulations and as a result, the requirements will focus on the following:

- Non-exceedance of critical performance measures
- Continued measurements indicating that conditions are remaining within ranges that were documented in the License Application

[1]Groundwater temperature was not originally selected as a performance confirmation parameter since it is not expected that thermal effects would be observed in the saturated zone during the preclosure period. The parameter should be reconsidered in updates of the list of performance confirmation parameters for a number of reasons, but primarily because it is more likely that the repository will impact the temperature of the uppermost saturated zone than water-table elevations and it is imprudent to measure one without the other.

- Optimization of the number of measurements to achieve a required degree of confidence. while minimizing cost.

1.2.5 Performance Confirmation Monitoring, Test and Support Elements

Figure 1-4 shows preliminary lists of monitoring test and support elements. Each of these elements is further described in Section 3.3.

1.2.6 Performance Confirmation Test and Evaluation Facilities

The facilities that support Performance Confirmation test and evaluation operations include:

- Subsurface test facilities including emplacement drifts, observation drifts, test and instrumentation alcoves, and boreholes

- Surface test and support facilities, including surface facilities for data acquisition and computers, offices, laboratory, sample storage, a multi-purpose hot cell for destructive testing of recovered waste packages, as a contingency, and surface test and monitoring stations

- Offsite laboratories including laboratory facilities and services that will be procured to perform tests on rock samples, waste package material specimens, and waste form samples.

1.2.7 Test Equipment and Instrumentation

Test support equipment that will be used for performance confirmation includes:

- Performance assessment and process level model computing hardware and software

- Site repository and waste package monitoring and testing equipment and instrumentation, including equipment for geologic mapping, fault monitoring, and underground and surface environmental measurements

- Data acquisition system including sensor, data communicator, control, and processing

- Surface support equipment including waste package handling equipment, for destructive as well as nondestructive testing.

1.2.8 Performance Confirmation Program Flow

Figure 1-5 is a flow diagram of performance confirmation operations. The operations are discussed in detail in Section 3.

SITE MONITORING AND TESTING

- Subsurface Geologic Mapping and Sampling
- Surface-based Unsaturated Zone Hydrology
- Subsurface Fault Zone Hydrology
- Thermal Testing
- General Surface-Based Testing

REPOSITORY MONITORING AND TESTING

- In Situ Seal Testing
- In Situ Backfill Testing
- Follow-on Drift Heater Testing
- Subsurface Seismic Monitoring
- Remote Observation and Inspection of Emplacement Drifts

SUBSURFACE TEST FACILITIES AND SUPPORT

- Permanent Observation Drifts
- Emplacement Drift Ventilation Monitoring
- Recovery of WPs for Performance Confirmation, if required
- Alcove Testing in Non-emplacement Areas
- Subsurface Mapping during Drift Construction
- Rock Sample Collection during Drift Construction
- Remotely Operated Systems for Emplacement Drift Monitoring

WASTE PACKAGE (WP) MONITORING AND TESTING

- Offsite Laboratory WP Testing
- In Situ WP Monitoring
- Recovered WP Testing, if required
- Recovered Dummy WP Testing
- Recovered Non-radioactive Specimen Testing

SURFACE TEST FACILITIES AND SUPPORT

- Performance Confirmation and Multi-Purpose Hot Cell
- Performance Confirmation Support Area

FIG-3 CDR124.DIR:CTSUM 8/11/97

Figure 1-4. Performance Confirmation Preliminary Test and Support Elements

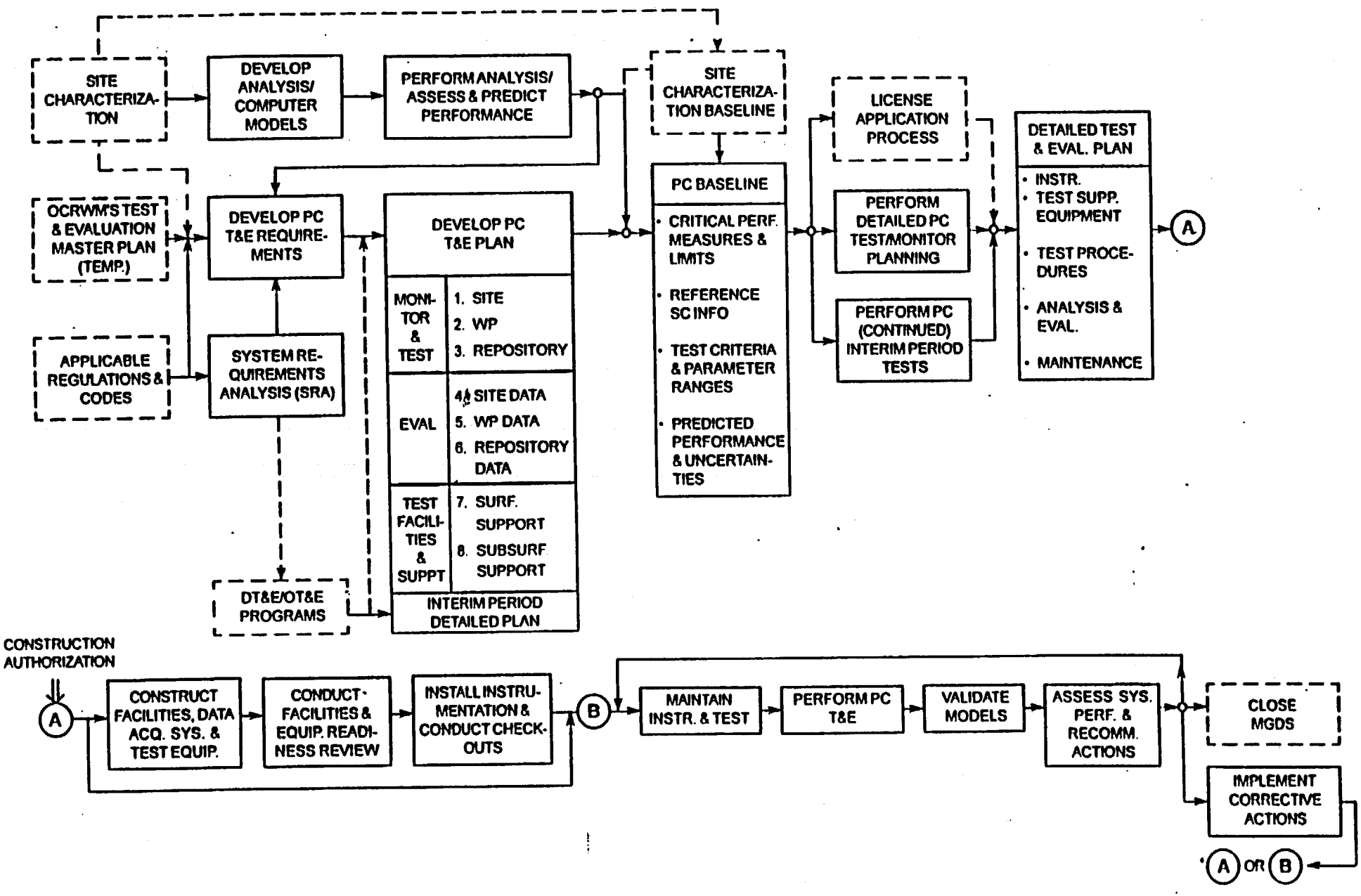

Figure 1-5. Performance Confirmation Program Flow

1.3 PERFORMANCE CONFIRMATION PLANNING AND DESIGN

The *Performance Confirmation Plan* is a lower level plan under the *MGDS Test and Evaluation Plan* (CRWMS M&O 1997b). The *Performance Confirmation Plan* will perform conformance verification for those requirements associated with postclosure performance objectives only. The *MGDS Test and Evaluation Plan* will cover all requirements, and calls out the *Performance Confirmation Plan* in the current draft.

1.4 PERFORMANCE CONFIRMATION PROGRAM MANAGEMENT AND ORGANIZATIONAL RESPONSIBILITIES

The *MGDS Viability Assessment Test and Evaluation Plan* (CRWMS M&O 1997b) will identify organizational structure and responsibilities for the Test and Evaluation Program. The management and organizational responsibilities of the Performance Confirmation Program will be defined consistent with the organizational responsibilities defined in the Test and Evaluation Plan, which is currently in development. The Performance Confirmation Program will be started during site characterization and will continue until closure of the repository. During this time, many organizations may be involved in the management and conduct of the Program. This Plan will identify the current DOE and M&O organizational structures and responsibilities for performance confirmation activities conducted during site characterization. Activity scope sheets, compiled in Section 4.0, also identify activities planned to occur in phases of the Performance Confirmation Program after site characterization. In these scope sheets, the current M&O organizational structure is used to identify the most appropriate group for responsibility, performance, and support of the activities.

1.4.1 Department of Energy Management and Organizational Responsibilities

During site characterization, the DOE function related to performance confirmation is to review the development of the *Performance Confirmation Plan* to assess and ensure compliance with the 10 CFR Part 60 Subpart F requirements. The DOE is responsible for providing funding sufficient to implement the Plan. Explicit, written criteria do not exist which specify when or whether an M&O-developed plan, like the *Performance Confirmation Plan*, should become a DOE document. This determination is made by a DOE and M&O management decision. The *Performance Confirmation Plan* will support the License Application and, at the time of submittal of the License Application, it must be consistent with the design and total system performance assessment used in the License Application. The importance of this plan would support a decision for the plan to come under DOE ownership prior to License Application. During site characterization, the *Performance Confirmation Plan* is to implement the Performance Confirmation Program. It is recommended that the *Performance Confirmation Plan* remain a CRWMS M&O document in the near future and prior to the License Application it should become DOE document.

1.4.2 CRWMS M&O Management and Organizational Responsibilities

The CRWMS M&O is responsible for development, review, approval, and revision of the *Performance Confirmation Plan*. The development task is managed by CRWMS M&O MGDS Systems Analysis and Modeling and will include the following CRWMS M&O affected

organizations: Waste Package Development; Waste Package Materials; Site Evaluation Program Operations; Repository Design; Performance Assessment; Licensing; MGDS Safety Assurance; MGDS Requirements and Integration/Configuration Management; Environment, Safety and Regional Programs; and Technical Database Management. Baseline approval of the Plan will occur when appropriate. Implementation of the Plan activities during site characterization will be the responsibility of the CRWMS M&O.

The activity scope sheets, compiled in Section 4, identify the following organizations as either responsible or necessary to support the defined activities: Performance Assessment; Site Evaluation Program Operations; Licensing; Technical Data Management; Repository Design; Environment, Safety and Regional Programs; Waste Package Materials; Site Construction and Operations, and Systems Engineering/Integration.

1.5 PROGRAM SCHEDULE

Two schedules are provided to show the timing for phasing site characterization activities into performance confirmation activities. The first schedule, shown in Figure 1-6, separates the complete set of testing activities into three categories. The first category consists of those tests conducted as part of the Site Characterization program to support the development of the License Application and the development of the performance confirmation baseline. This category is ongoing and will phase out when the development of the performance confirmation baseline is complete. The second category consists of other testing, including site characterization testing in support of the Site Recommendation, to demonstrate conformance of the design to the requirements, such as preclosure safety testing. Aspects of this ongoing testing activity are expected to continue through the waste emplacement time period. The third category consists of testing in support of the Performance Confirmation Program. This activity starts at the time of Viability Assessment, prior to the end of site characterization, and phases into a full program at approximately the time of License Application. The second schedule, shown in Figure 1-7, provides a conceptual view of the data flow between the waste isolation reasonable assurance testing, the Performance Confirmation testing activities, total system performance assessment, and the activities required to plan and develop the Performance Confirmation Program.

The Performance Confirmation Program Summary Schedule is shown in Figure 1-8. This figure shows an initial task prior to the start of the Performance Confirmation program, in Fiscal Year 1998, to prepare for implementation of the Performance Confirmation Program. These activities include further development of the *Performance Confirmation Plan* with the intent of being ready to conduct Performance Confirmation-related tests and/or analyses subsequent to the Viability Assessment. This will entail supporting meetings with the NRC pertaining to the Performance Confirmation Program. The task will integrate and provide management oversight during the performance predictions for the Performance Confirmation parameters identified. Other activities include reviewing the progress of the MGDS Design organizations in satisfying the Performance Confirmation-related requirements delineated in the Controlled Design Assumptions document and/or the System Description documents. This task will ensure that the appropriate support is provided to the development of the Viability Assessment cost estimate to confirm that the latest Performance Confirmation program cost estimates are reflected in the Viability Assessment cost estimate. An exercise will be conducted to test the Performance Confirmation approach identified

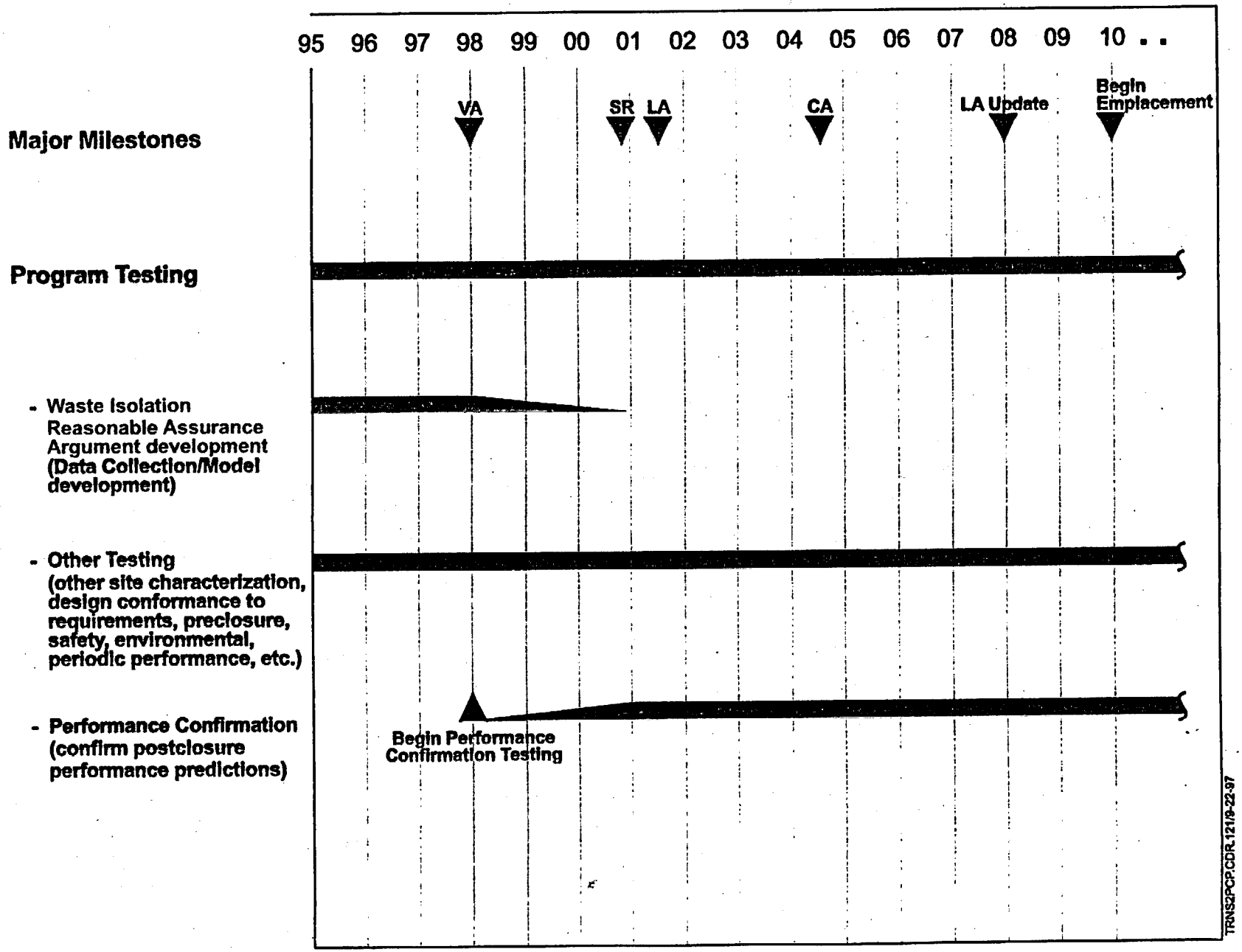

Figure 1-6. Transition to Performance Confirmation Program Testing

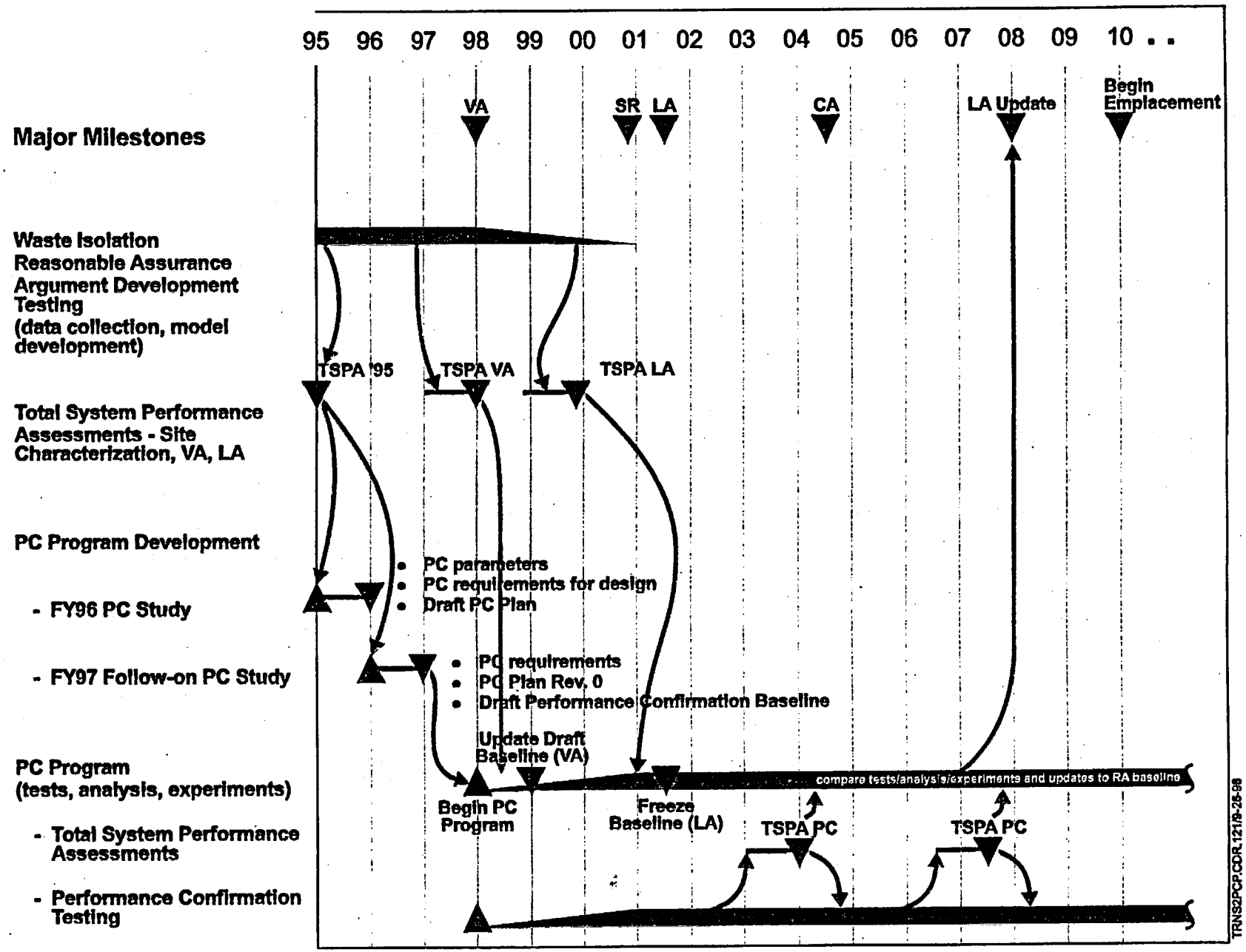

Figure 1-7. Development and Conduct Approach Performance Confirmation Program

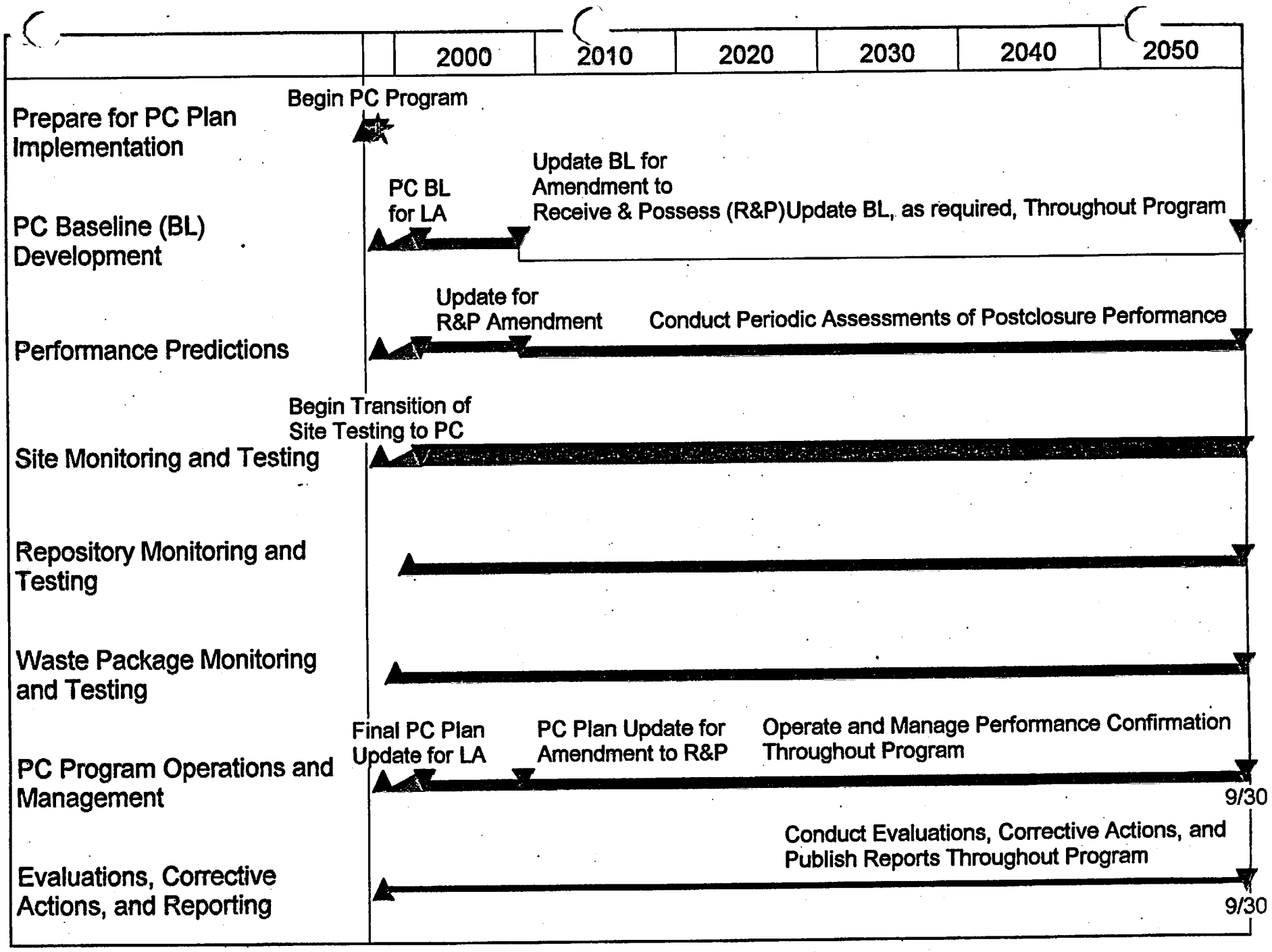

Figure 1-8. Performance Confirmation Summary Schedule

in the *Performance Confirmation Plan* and determine its adequacy for implementation for the planned start of the Performance Confirmation Program in October 1998.

The activities to be conducted at the start of the Performance Confirmation Program will include Performance Confirmation Baseline development and transition of a limited set of Site Characterization Testing activities into the Performance Confirmation Program. The baseline development activity will ramp up with the set of baseline information available for the License Application. Updates of this baseline information will be conducted throughout construction to support the amendment of the license application to receive and possess waste. After that time updates of the baseline will be accommodated, as required, throughout the program.

During site characterization, performance predictions will also be conducted which support Performance Confirmation Baseline development, detailed test planning, and design and development of specifications for performance confirmation facilities and equipment. These predictions will continue during construction and support the amendment of the license application to receive and possess waste. Throughout the life of the program, continued periodic predictions and assessments of postclosure performance that include performance confirmation test data will be needed.

The testing planned for Performance Confirmation is categorized into three areas: Site, Repository, and Waste Package. The subset of Site Characterization testing planned for transition to Performance Confirmation will begin in October 1998. There are testing activities in each of these three areas that continue throughout the program. A lower level breakout of the schedule for the testing activities is provided in Section 3.10.

Performance Confirmation Program Operation and Management will continue throughout the program and will support the major licensing milestones by providing updates to the *Performance Confirmation Plan* and ensuring implementation of the Program according to the plan.

Evaluations, corrective actions, and reporting will be performed throughout the program. As data from testing is obtained, the data will be evaluated and compared with the predictions. Deviations from predetermined limits will be used as indicators for additional analyses of postclosure performance assessments. These analyses will lead to the identification of corrective actions commensurate with the assessed impacts. Implementation of the corrective actions will be verified. Reports of the testing and evaluation will be developed throughout the program.

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2. REQUIREMENTS, FUNCTIONS, MODELING, AND PARAMETERS

2.1 REQUIREMENTS FOR PERFORMANCE CONFIRMATION

Although the Civilian Radioactive Waste Management System (CRWMS) technical baseline is currently undergoing changes which will affect the hierarchy of technical documents, these issues were not resolved when the Plan was developed. Currently, the CRWMS controls, as part of the Project technical baseline, the *Mined Geologic Disposal System Requirements Document* (DOE 1996c), which provides the source of requirements for this Plan. As the planned changes to the technical document hierarchy are completed, the *Mined Geologic Disposal System Requirements Document* will be revised. Any revisions to requirements documents and their hierarchy are not expected to markedly affect performance confirmation requirements. Any such changes will be incorporated into the *Performance Confirmation Plan.*

The Yucca Mountain Site Characterization Project (YMP) technical document hierarchy also consists of design requirement documents such as the *Engineered Barrier Design Requirements Document* (DOE 1994b), *Repository Design Requirements Document* (DOE 1994c), and the *Site Design and Test Requirements Document* (DOE 1995b). The first two documents were developed in July 1993, and have not since been completely revised. In September 1994, a document change notice indicated to potential users changes that may occur in derived requirements, including the fact that some inputs might be identified as unqualified. Thus, the Project baseline documents have not incorporated subsequent changes made in the *Mined Geologic Disposal System Requirements Document.* The *Controlled Design Assumptions Document* (CRWMS M&O 1997a) has been used to document assumptions and design bases consistent with the technical and programmatic changes made in and to complement the baseline versions of the *Engineered Barrier Design Requirements Document* and the *Repository Design Requirements Document.* The assumptions from the *Controlled Design Assumptions Document* related to performance confirmation are discussed in Section 2.1.3.1.

2.1.1 Mined Geologic Disposal System Requirements Document Requirements for Performance Confirmation

The following requirements from the *Mined Geologic Disposal System Requirements Document* were selected because they make reference to the Performance Confirmation Program or to 10 CFR Part 60.137 or any section of Subpart F, which includes sections 60.140 through 60.143. After each requirement or group of requirements, an assessment of applicability to the *Performance Confirmation Plan* is provided, determining whether it is an input.

3.2.1 Performance Characteristics

C. (R, E)[1] An objective of the GROA [Geologic Repository Operations Area] is to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance

[1] The parenthetic notation preceding this requirement designates the MGDS segment to which the requirement is allocated. "R" indicates Repository Segment; "E" represents the Engineered Barrier Segment.

confirmation program and NRC [Nuclear Regulatory Commission] review of the information obtained from such a program. To satisfy this objective, the GROA shall be designed so that any or all of the emplaced waste could be retrieved during an appropriate period of operation of the facility on a reasonable schedule starting at any time up to 100[2] years after waste emplacement operations are initiated. A reasonable schedule for retrieval would be equal in length to the time required for the construction of the repository and the emplacement of the waste. [10CFR60.111(b)(1), (3)] [NWPA 42USC10142] [CRD 3.7.4.2.M]

Assessment of Mined Geologic Disposal System Requirements Document 3.2.1.C–This is a system-level requirement on the MGDS and the waste retrieval capability of the geologic repository operations area, but it implies that the completion of a Performance Confirmation Program and NRC review of the information obtained from the Program should be completed within 100 years after waste emplacement operations are initiated. For the fulfillment of this requirement, the criteria for completion of the Performance Confirmation Program must be established and the content of the Program must be established in less than or equal to the 100-year requirement. Thus, this requirement is an input to the plan.

3.7.1.3 Site Characterization Requirements

... B. Requirements. The requirements listed below apply to design of site characterization systems and facilities, as appropriate (some are not applicable to the SBTF [Surface Based Testing Facilities]).

1. Site characterization facilities and systems are to be designed and constructed in accordance with applicable design requirements derived from the 10 CFR Part 60 regulations listed below such that they do not preclude the ability of the Repository and Engineered Barrier Segments to meet the requirements in this MGDS-RD...

az. The requirements of 10CFR60.137 shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

ba. The requirements of 10CFR60.140(b) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

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[2]Although the above citation is a verbatim quote from the MGDS-RD, the disposal regulation, 10 CFR Part 60, specifies a 50 year retrievability period. The MGDS-RD conservatively requires the repository to be designed for a 100 year retrievability period.

bb. The requirements of 10CFR60.140(c) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bc. The requirements of 10CFR60.140(d)(1) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bd. The requirements of 10CFR60.141(a) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

be. The requirements of 10CFR60.141(b) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bf. The requirements of 10CFR60.141(c) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bg. The requirements of 10CFR60.141(d) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bh. The requirements of 10CFR60.141(e) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bi. The requirements of 10CFR60.142(a) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bj. The requirements of 10CFR60.142(b) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bk. The requirements of 10CFR60.142(c) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bl. The requirements of 10CFR60.142(d) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bm. The requirements of 10CFR60.143(a) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bn. The requirements of 10CFR60.143(b) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bo. The requirements of 10CFR60.143(c) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

bp. The requirements of 10CFR60.143(d) shall be imposed on the design of permanent components of the Site Segment, unless non-applicability is justified in writing. [NUREG 1439 App C] [CRD 3.7.4.2.K.8]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.1.3.B.1. az. through bp–These requirements are imposed on the design of permanent components of the site segment. If any specific requirements for the site are identified they will be noted with appropriate traceability. Thus, these requirements may not be specifically used as input to the Plan.

3.7.2.7 Performance Confirmation Requirements

A. General Requirements

1. The GROA shall be designed to include the capability to support tests appropriate or necessary for the administration of the regulations of 10CFR60. These tests may include tests of (1) radioactive waste, (2) the geologic repository including its structures, systems, and components, (3) radiation detection and monitoring instruments, and (4) other equipment and devices used in connection with the receipt, handling, or storage of radioactive waste. [10CFR60.74(a)] [CRD 3.3.1.1.B]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.A.1–All requirements in Section 3.7.2.7 have been allocated to the repository segment. This requirement to have the capability to support tests is the responsibility of the geologic repository operations area. Because of *Mined Geologic Disposal System Requirements Document* 3.7.2.7.A.2, this requirement

includes performance confirmation tests, although the listed tests in this requirement are not necessarily performance confirmation tests. Performance confirmation tests are conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met. The capability of testing the listed items is required to ensure that the performance of the geologic repository operations area through the time of permanent closure is met. Therefore, the four type of tests are not considered inputs to this Plan, unless they are determined also necessary for performance confirmation..

2. The tests required in section 3.7.2.7.A.1 shall include a performance confirmation program carried out in accordance with Subpart F of 10CFR60. [10CFR60.74(b)] [10 CFR 60.137] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.A.2–The combination of this requirement and the first sentence in 3.7.2.7.A.1 is a requirement responsibility of the geologic repository operations area to establish and maintain the capability to support performance confirmation tests and is therefore an input to the Plan.

3. The performance confirmation program shall provide data that indicates, where practical, whether: (1) Actual underground[3] conditions encountered and changes in those conditions during construction and waste emplacement operations are within limits assumed in the licensing review; and (2) Natural and engineered systems and components required for repository operation, or that are designed or assumed to operate as barriers after permanent closure, are functioning as intended and anticipated. [10CFR60.140(a)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.A.3–This requirement, based on 10 CFR Part 60, Subpart F, states the primary objectives of the Performance Confirmation Program and therefore is an input to the Plan.

4. The program shall include in situ monitoring, laboratory and field testing, and in situ experiments, as appropriate, to accomplish the objectives stated in 10CFR60.140(a) (3.7.2.7.A.3) above. [10CFR60.140(c)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.A.4–This requirement identifies testing concepts to be used in the Performance Confirmation Program. These concepts will be used unless they are determined to be inappropriate in meeting the objectives of the Program. Therefore, this requirement is an input to the Plan.

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[3]Although the above citation is a verbatim quote from the MGDS-RD, the disposal regulation, 10 CFR Part 60, uses subsurface versus underground.

5. The program shall:

a. Not adversely affect the ability of the natural and engineered elements of the geologic repository to meet the performance objectives (as specified in 3.7.2.2.B, 3.7.2.6.J.3, and 3.7.3.2).

b. Provide baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.

c. Monitor and analyze changes from the baseline condition of performance of the geologic repository.

d. Provide an established plan for feedback and analysis of data, and implementation of appropriate action. [10CFR60.140(d)] [CRD 3.7.4.2.K.5] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.A.5–This requirement puts a constraint on the Program to not adversely affect the ability to isolate waste. In part a., above, the performance objectives are specified in three MGDS-RD sections 3.7.2.2.B, 3.7.2.6.J.3, and 3.7.3.2. Each of these is now discussed. *Mined Geologic Disposal System Requirements Document* 3.7.2.2.B., a reserved requirement in the section for geologic setting requirements, is vacant. *Mined Geologic Disposal System Requirements Document* 3.7.2.6.J.3, is a requirement on seals to contribute to meeting the Environmental Protection Agency (EPA) requirement, referred to in 10 CFR Part 60.112. *Mined Geologic Disposal System Requirements Document* 3.7.3.2 contains all the general requirements on the Engineered Barrier Segment including the EPA requirement referred to in 10 CFR Part 60.112, substantially complete containment, and controlled release from 10 CFR Part 60.113. It also provides other objectives of the Performance Confirmation Program, based on 10 CFR Part 60, Subpart F, and therefore is an input to the Plan.

6. The repository shall be capable of monitoring underground conditions and evaluating them against design assumptions. [10CFR60.141(b)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal Requirements Document 3.7.2.7.A.6–This requirement is allocated to the Repository to have a capability to monitor underground conditions and a requirement on the Performance Confirmation Program to evaluate the underground conditions against design assumptions. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

B. Testing. During the early developmental stages of construction, the Repository Segment shall be capable of supporting in situ testing of such features as borehole and access seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater. [10CFR60.142(a)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.B–This requirement is allocated to the Repository to have a capability to support in situ testing of several features. It places a specific constraint on the timing of certain types of tests. The requirement is based on 10 CFR Part 60 Subpart F, and it is an input to the Plan.

C. Rock Measurements. The Repository Segment shall be capable of measuring, as a minimum, rock deformations and displacement, changes in rock stress and strain, rate and location of water inflow into underground areas, changes in groundwater conditions, rock pore water pressures, including those along fractures and joints, and the thermal and thermomechanical response of the rock mass as a result of development and operations of the geologic repository. [10CFR60.141(c)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.C–This requirement is allocated to the Repository to have a capability to support measurement of specific rock conditions. It is a constraint on specific types of measurements and when they need to be measured. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

D. Thermomechanical Response. The Repository Segment shall be capable of in situ monitoring of the thermomechanical response of the underground facility until permanent closure to ensure that the performance of the natural and engineering features are within design limits. [10CFR60.141(e)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.D–This requirement is allocated to the Repository to support the capability to perform in situ monitoring of the thermomechanical response. It is a specific constraint on the type of parameters to be measured and the duration of monitoring. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

E. Laboratory Experiments.

1. To support the waste package monitoring program required by 10CFR60.143(a) and (b), the GROA shall be designed to include facilities (to the extent appropriate for on-site work) capable of supporting laboratory experiments that focus on the internal condition of the waste packages. [10CFR60.143(c)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.E.1–This requirement is allocated to the Repository to have facilities, if appropriate, to support laboratory experiments in support of the waste package monitoring. A constraint on the repository would need to be applied if this type of lab work is determined to be performed on site. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

2. To the extent practical, the environment experienced by the emplaced waste packages within the underground facility during the waste package monitoring program shall be duplicated in the laboratory experiments. [10CFR60.143(c)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.E.2–This requirement is on the representativeness of the waste package monitoring program laboratory experiments. It is a constraint on the laboratory experiments. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

F. Backfill Test. 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. [10CFR60.142(c)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.F–This requirement is placed on the Repository to allow space for a backfill test section which focuses on constructability and timing of the test. It is a constraint on the repository design regarding space to perform this. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

G. Borehole and Access Seal Tests. Test sections shall be established to test the effectiveness of borehole and access seals before full-scale operation proceeds to seal boreholes and accesses. [10CFR60.142(d)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.G–This requirement is placed on the Repository to allow space for test sections for boreholes and access seals and the objective and timing of the test. It is a constraint on the repository design to provide space for this test. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

H. A program of in situ testing shall begin as early as practicable after construction authorization to meet the requirements of 10CFR60.142 (section 3.7.2.7 in the MGDS-RD document). [10CFR60.142(b)] [CRD 3.7.4.2.L]

Assessment of Mined Geologic Disposal System Requirements Document 3.7.2.7.H–This requirement is on timing of the in situ testing. It is a constraint on the timing of these tests and that may influence the design. The requirement is based on 10 CFR Part 60, Subpart F, and it is an input to the Plan.

As evidenced by the requirements listed in the previous section and the associated assessments, the majority of the design inputs selected are either directly from 10 CFR Part 60, Subpart F or from

slight variations from them. The MGDS-RD provides well-traced inputs from 10 CFR Part 60. Subpart F. The resulting design requirements and criteria from this plan should be placed in the *Controlled Design Assumptions Document* or the appropriate *System Description Document*.

2.1.2 Selected Design Inputs Related to Performance Confirmation

Additional inputs to the report are listed below:

1. *Total System Performance Assessment–1993: An Evaluation of the Potential Yucca Mountain Repository* (CRWMS M&O 1994) and *Total-System Performance Assessment for Yucca Mountain - SNL Second Iteration (TEPA-1993)* (SNL 1994b)

2. *Total System Performance Assessment–1995: An Evaluation of the Potential Yucca Mountain Repository* (CRWMS M&O 1995c).

3. *OCRWM Test and Evaluation Master Plan (TEMP)* (DOE 1995a).

4. *Mined Geologic Disposal System Functional Analysis Document* (CRWMS M&O 1996e).

5. *Performance Confirmation Concepts Study Report* (CRWMS M&O 1996f).

The total system performance assessment documents are used in the plan to determine the importance of parameters for inclusion in the Performance Confirmation Program. Although the total system performance assessment documents were not developed under quality-affecting procedures and are therefore considered as unqualified data, they nonetheless represent the best available information for the intended purpose. A general knowledge of the results from the total system performance assessment is needed to complete the parameter selection process. The *OCRWM Test and Evaluation Master Plan (TEMP)*, is used as input and general guidance in developing an understanding of the overall Test and Evaluation Program. The Performance Confirmation Program is just one of several elements of this master plan. Finally, the *MGDS Functional Analysis Document* and the *Performance Confirmation Concepts Study Report* were developed under quality-affecting procedures. Specific sections related to the Evaluate System Performance function and the Confine and Isolate Waste function of the *MGDS Functional Analysis Document* are used as inputs to develop performance confirmation functions. The selected performance confirmation parameters from Appendix C of the listed study report are used as input in the plan.

2.1.3 Assumptions

Section 2.1.3.1 lists assumptions concerning performance confirmation in the *Controlled Design Assumptions Document* (CRWMS M&O 1997a). Specific assumptions used for this Plan are documented in Section 2.1.3.2.

2.1.3.1 Controlled Design Assumptions Related to Performance Confirmation

The *Controlled Design Assumptions Document* contains several assumptions that, although not directly attributed to performance confirmation, represent current design assumptions related to performance confirmation. These assumptions are listed with discussion of applicability to this Plan:

Assumption Identifier: Key 053
Subject: Off-Normal Waste Handling

> The mined geologic disposal system (MGDS) shall have the capability to handle canistered waste forms that require remedial processing. This includes remediation due to inability to load waste into a disposal container in the canistered configuration. Such off-normal handling includes opening the canister, removing the waste form, discarding the canister, and repacking the waste form in a disposal container.

In the rationale for this assumption, the following is stated:

> A separate, single operation cell will provide for the required remedial operations on an off-normal basis. This cell is proposed to prevent special operations from interfering with normal waste handling operations. The cell will need to be adaptable to multiple functional roles for one-time or low-volume events. Probable events and best remedial methodology will need to be investigated before operations and equipment can be defined for this area.

Applicability of the Assumption to this Plan: The ability to perform special types of handling and operations on a waste package or waste form are assumed and the rarity of the frequency of their occurrence is assumed. These operations are assumed to be similar to those required for performance confirmation. This Plan will establish requirements on these type and frequency of operations, but the assumption listed is also used. Since the waste handling building will have some capability to perform similar functions, the requirements and design concepts developed will redefine the specific hot cell needs and will not result in large deviations of the advanced conceptual design for the waste handling building.

Assumption Identifier: Key 060
Subject: Interim Postclosure Standard

> Until a new Environmental Protection Agency (EPA) standard is promulgated, the Yucca Mountain Site Characterization Office(YMSCO) will use the following interim requirement and goal as a planning basis for evaluating postclosure performance of the repository:

The interim system-level requirement is a quantitative statement of the necessary performance for the first 10,000 years after closure. It is followed by a system-level performance goal that recognizes there needs to be sufficient defense-in-depth in the repository's multiple barriers system to ensure that public safety is protected beyond 10,000 years. This is a serious system performance goal. It is qualitative because of the increasing uncertainties beyond the first 10,000 years.

Requirement

The expected annual dose to an average individual in a critical group living 20 km from the repository shall not exceed 25 mrem from all pathways and all radionuclides during the first 10,000 years after closure.

Goal

Conduct analyses past 10,000 years to gain insight into longer-term system performance. For this period, the expected annual dose to an average individual in a critical group living 20 km from the repository should be below the 10,000 year requirement.

Applicability of the assumption to this plan: This assumption on the interim postclosure performance standard is applicable to the plan because one criterion in the parameter screening process is the parameter's importance to overall postclosure system performance. This assumption provides guidance on the postclosure performance requirement and goal. This assumption should be used in the future screening of performance confirmation parameters (see Section 2.5). In the *Performance Confirmation Concepts Study Report* (CRWMS M&O 1996f), an input to this plan, several possible measures of postclosure performance were used in the parameter screening process. This was due to uncertainty in the form of the final Environmental Protection Agency standard, at that time. Three possible standards were considered: 1) limiting the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal based on the remanded standard in the 1985 issue of 40 CFR Part 191; 2) limiting the risk to individuals of adverse health effects from releases from the repository for a time out to about one million years, which is based the National Academy of Sciences recommendations on *Technical Bases for Yucca Mountain Standards* (NAS 1995); 3) limiting peak dose to individuals from releases from the repository for 10,000 years, as identified in DOE planning guidance (DOE 1996f) and in the DOE recommendations to the National Academy of Sciences (DOE 1994a). Due to the change in the guidance, it is recommended that the parameter screening process be revisited and performance confirmation parameters be updated next year to be consistent with the Viability Assessment design and sensitivity studies to support the total system performance assessment for the Viability Assessment.

Assumption Identifier: Engineered Barrier Design Requirements Document 3.2.5.1.2.B.1
Subject: Engineered Barrier System Reliability

Reliability of the EBS shall be as follows:

1. Waste Package–The probability of failure (breach) of an individual waste package during the preclosure phase should be demonstrated to be less than 10^{-6} per year based on credible hazards.

Applicability of the Assumption to this Plan: The likelihood of a waste package breach during the preclosure phase is roughly 10^{-4} over the 100 year period. Thus, the expected number of waste packages to breach is 1.0, assuming approximately 10,000 waste packages (Key Assumption 003 of the *Controlled Design Assumptions Document*). This information is used as rationale for the lack of necessity for monitoring for aqueous radionuclide releases. It is assumed that if a gaseous radionuclide release is detected in the subsurface at any time prior to closure, the source of the release will be determined. If the origin of the release is from the breach of a waste package, the breached waste package will be recovered, the reason for breach determined, and remediation of the failure will be performed, including remediation of any significant amount of radionuclides released from the waste package. Therefore, coupled with the previous assumption, during the preclosure time frame it is expected that approximately one waste package breach would occur and then a release of gaseous radionuclides would occur. There also is no credible mechanism for aqueous transport even if a waste package breaches in the preclosure time frame and its breach is undetected. This one expected release, even if undetected, does not justify monitoring for aqueous releases from the engineered barrier system or in the natural barrier.

2.1.3.2 Specific Plan Assumptions

Several assumptions have been made to allow continuation of the Plan. These assumptions are as follows:

- It is assumed that the list of candidate parameters in the performance confirmation data matrices, which is described in the *Performance Confirmation Concepts Study Report* is sufficiently complete to include the key parameters or the drivers of the Performance Confirmation Program.

- It is assumed certain parameters and processes that are important to performance will be sufficiently known at the time of the License Application so that additional characterization will not be necessary, based on the fact that at the time of construction authorization there will be reasonable assurance that the postclosure performance objectives will be met, thus establishing that many of the processes and associated parameters are sufficiently known due to site characterization activities. The specific parameters that fall into this category were identified in Appendix B of the Performance Confirmation Concept Study Report (CRWMS M&O 1996f). Through the development of the performance confirmation baseline, test data from site characterization will be identified which validate the assumption.

2.2 FUNCTIONS OF PERFORMANCE CONFIRMATION

The functional analysis of performance confirmation is done to identify the key activities necessary to conduct the Performance Confirmation Program. The following sections define the approach that has been used, the primary functions, definitions of the functions, and an introduction to lower level functions.

The establishment of performance confirmation functions is necessary for the definition of requirements and allocation of these requirements to design elements for implementation. In defining the performance confirmation functions, considerations were given to:

1. Confirmation of the Confine and Isolate Waste function of the MGDS

2. Program requirements related to performance confirmation listed in Section 2.1, referring primarily to 10 CFR Part 60, Subpart F requirements to verify natural and engineered barrier functions and evaluate their effectiveness.

3. Performance confirmation as a test function and an evaluate function which is both an element of the *OCRWM Test and Evaluation Master Plan* (DOE 1995a) and MGDS Evaluate System Performance function.

The Confine and Isolate Waste function is one of the key functions of MGDS. It is described in the *Mined Geologic Disposal System Functional Analysis Document* (CRWMS M&O 1996e) as follows (Function 1.4.5):

> The Confine and Isolate Waste function confines the waste in the disposal container and inhibits the transport of radioactive material to the accessible environment. This function starts when the waste is sealed in the disposal container and continues until the MGDS and the accessible environment return to acceptable levels.

Since performance confirmation focuses on postclosure performance of the repository, on the containment and isolation of the waste, its principal function may be defined as the confirmation of the Confine and Isolate Waste function.

In 10 CFR Part 60, Subpart F, it is required to confirm the natural and engineered systems are functioning as intended and to collect data on subsurface conditions including geotechnical conditions, design performance functions, waste package, backfill, if required, and seals. In the *Site Characterization Plan* (DOE 1988) and the *License Application Annotated Outline* (YMP 1995), it is also stipulated that Performance Confirmation will confirm baseline conditions and barrier performance.

The *OCRWM Test and Evaluation Master Plan* (DOE 1995a) specifies two types of testing. development test and evaluation and operations test and evaluation. Performance confirmation is considered to be the "operational effectiveness" phase of operations test and evaluation.

Performance confirmation must also address analyses and tests that integrate the various conformance verification requirements specified in the design requirement documents. In summary, the performance confirmation functions to be defined were required to:

- Establish and maintain a direct correspondence to and cover all the primary subfunctions of the Confine and Isolate Waste function
- Reflect compliance with 10 CFR Part 60, Subpart F.
- Permit integration and differentiation of test and evaluation planning.

2.2.1 Mined Geologic Disposal System Functions Related to Performance Confirmation

The *MGDS Functional Analysis Document* (FAD) (CRWMS M&O 1996e) identifies the functions of the MGDS and defines functional hierarchy. This hierarchy includes five principal functions that include Function 1.4.4, Evaluate System Performance; and Function 1.4.5, Confine and Isolate Waste. These functions are related to the activities conducted or evaluated in the Performance Confirmation Program, which will test and evaluate the structures, systems, and components important to waste isolation to confirm proper functioning.

Function 1.4.4.3, Confirm Waste Isolation Performance, is a subfunction of Function 1.4.4, Evaluate System Performance, with two other subfunctions: Function 1.4.4.1, Test and Evaluate System Design and Development; and Function 1.4.4.2, Test and Evaluate System Operation. The logic diagram, which shows the logical relationship of the functions, for the Evaluate System Performance function is shown in Figure 2-1. Definitions of these functions are provided in the *MGDS Functional Analysis Document* (CRWMS M&O 1996e).

2.2.2 Definition of Performance Confirmation Related Functions

Six performance confirmation related functions have been decomposed from Function 1.4.4.3, Confirm Waste Isolation Performance. Figure 2-2 shows the logic diagram for these functions. These functions described in the *MGDS Functional Analysis Document* (CRWMS M&O 1996e) are as follows:

1.4.4.3.1 Develop and Validate Computer Models

The develop and validate computer models function defines those activities related to the development of computer modeling software which predicts the system performance of the Waste Isolation System. This function also

1.4.4 Evaluate System Performance

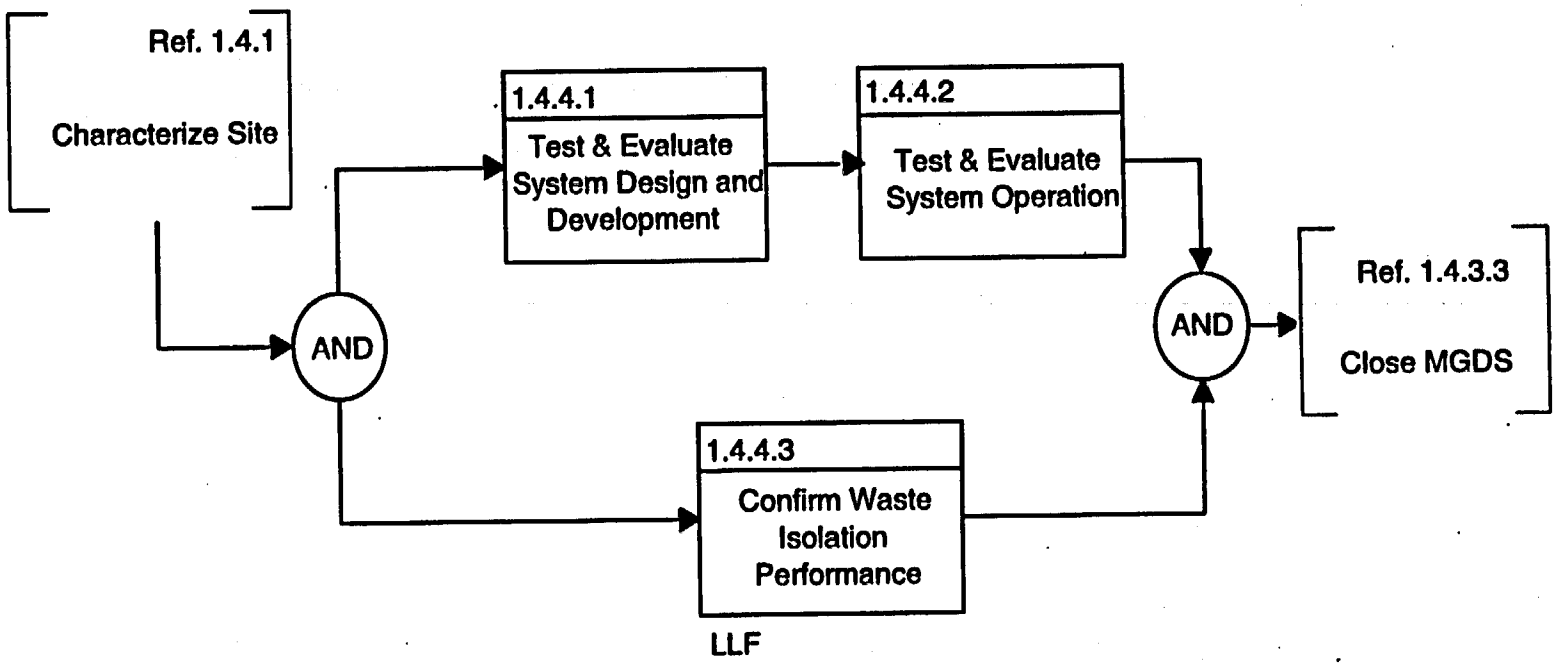

Figure 2-1. MGDS Evaluate System Performance Function

1.4.4.3 Confirm Waste Isolation Performance

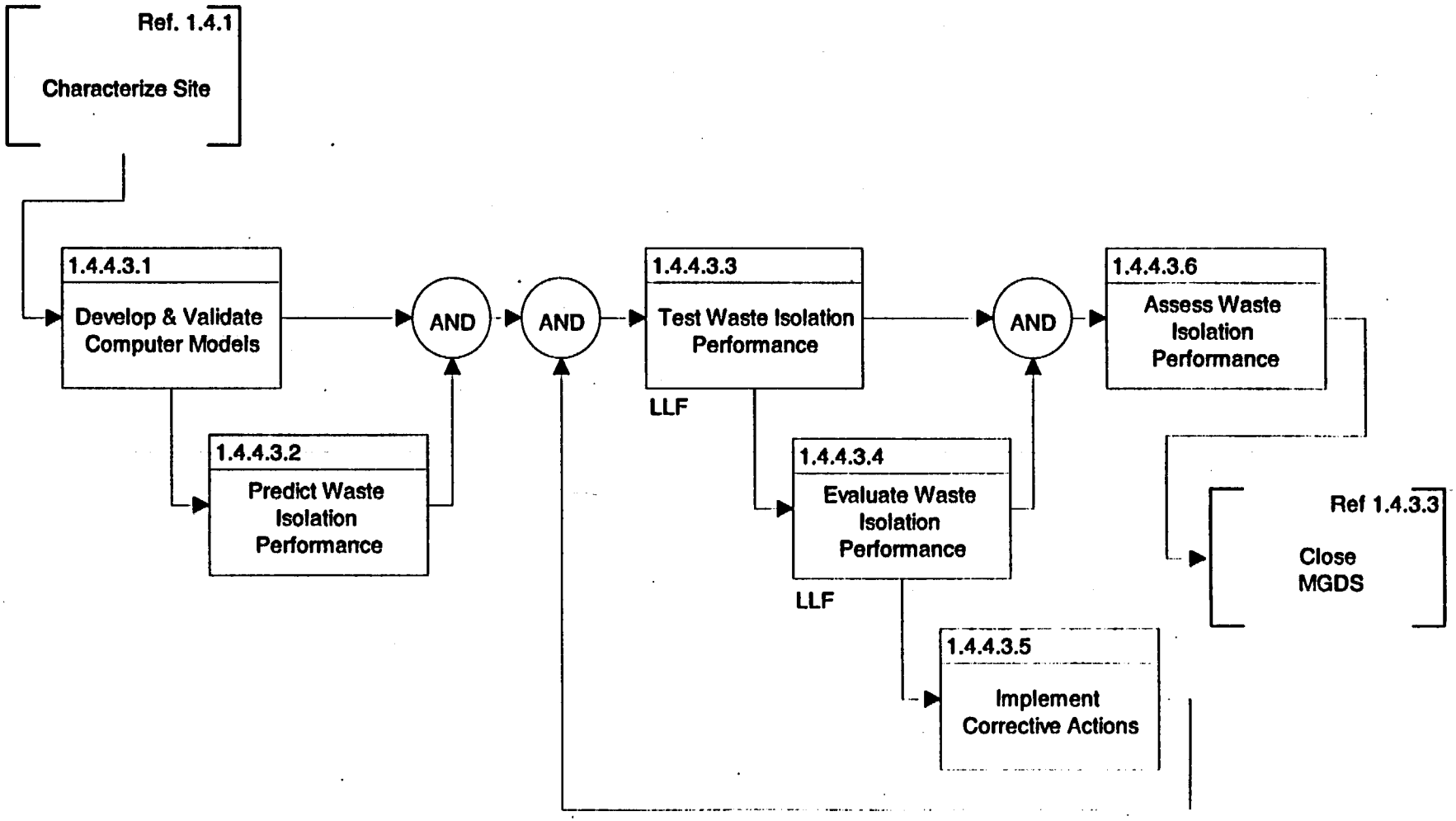

Figure 2-2. Performance Confirmation Related Functions

includes the necessary steps to validate the software per *Quality Assurance Requirements and Description* (DOE 1997a) requirements. This function begins with results from site characterization and ends with the ability to predict Waste Isolation System performance.

1.4.4.3.2 Predict Waste Isolation Performance

The predict waste isolation system performance function utilizes approved modeling software to predict the Waste Isolation System performance. The predicted results establish the bounding calculations for the waste isolation performance baseline to be utilized in the License Application. This function begins with validated computer models and ends with predicted results available for the License Application.

1.4.4.3.3 Test Waste Isolation Performance

The test waste isolation performance function will test critical parameters associated with the natural environments, induced environments, and the engineered barrier system. This function begins with waste emplacement and ends with the acquisition of data needed for waste isolation performance assessment.

1.4.4.3.4 Evaluate Waste Isolation Performance

The evaluate waste isolation performance function analyzes the critical processes of the natural barrier system and engineered system performance elements and predicts the performance of the waste isolation system. The function evaluates waste package performance, engineered barrier effectiveness, natural barrier effectiveness, human intrusion, and effects of the natural and induced environments. The function begins with the receipt of critical performance test data and ends with evaluation of the data to confirm the parametric limits.

1.4.4.3.5 Implement Corrective Action

The implement corrective action function defines the actions necessary to resolve discrepancies between the test data collected and the analytical evaluation of the modeled processes. The function could involve revision to the process models, updates/revisions to the software coding, enhancement in the test program, or revision to the waste isolation system design. The function begins when discrepancies are identified between the results from the Test and Evaluation Program and the process modeling and ends when the corrective action is implemented.

1.4.4.3.6 Assess Waste Isolation System Performance

The assess waste isolation system performance function analytically verifies the waste isolation system meets or exceeds the required limits. The assessment will utilize qualified software and qualified supporting test data. The function begins with the completion of gathering all applicable test data, resolution of modeling parameters, and final concurrence on the predicted environmental and waste degradation process and ends when the final analytical results are approved and a recommendation for closure is obtained.

The logic diagrams for Function 1.4.4.3.3, Test Waste Isolation Performance, and Function 1.4.4.3.4, Evaluate Waste Isolation Performance, are shown in Figures 2-3 and 2-4, respectively. The remaining performance confirmation related functions 1.4.4.3.1, 1.4.4.3.2, 1.4.4.3.5, and 1.4.4.3.6 have not yet been further decomposed. It is noted that the models identified in function 1.4.4.3.1 are developed during site characterization and may be revised as a result of the performance confirmation program.

The test functions (1.4.4.3.3.x), shown in Figure 2-3, provide test data based on observations or measurements required for evaluation. The latter evaluate functions (1.4.4.3.4.x), shown in Figure 2-4, correspond one-to-one to Function 1.4.5, Confine and Isolate Waste function, as defined in the *MGDS Functional Analysis Document*. These lower level performance confirmation related test and evaluate functions defined in the MGDS Functional Analysis Document are as follows:

1.4.4.3.4.1 Evaluate Waste Package Performance

The evaluate waste package performance function evaluates the waste package's capability to confine waste by limiting the release of radionuclides from the waste package boundary. This function begins with a modeled waste package and ends with confirmation of the waste package performance.

1.4.4.3.4.2 Evaluate Engineered Barrier Effectiveness

The evaluate engineered barrier effectiveness function evaluates the engineered barrier's capability to limit radionuclides release to the natural barrier. This function evaluates the rate of radionuclides transport from the waste package to the natural barrier (after waste package breach), effects that the underground environments have on radionuclides transport, external criticality, and effectiveness of the total engineered barrier system. This function begins with a modeled engineered barrier system and ends with the closure of the repository.

1.4.4.3.3 Test Waste Isolation Performance

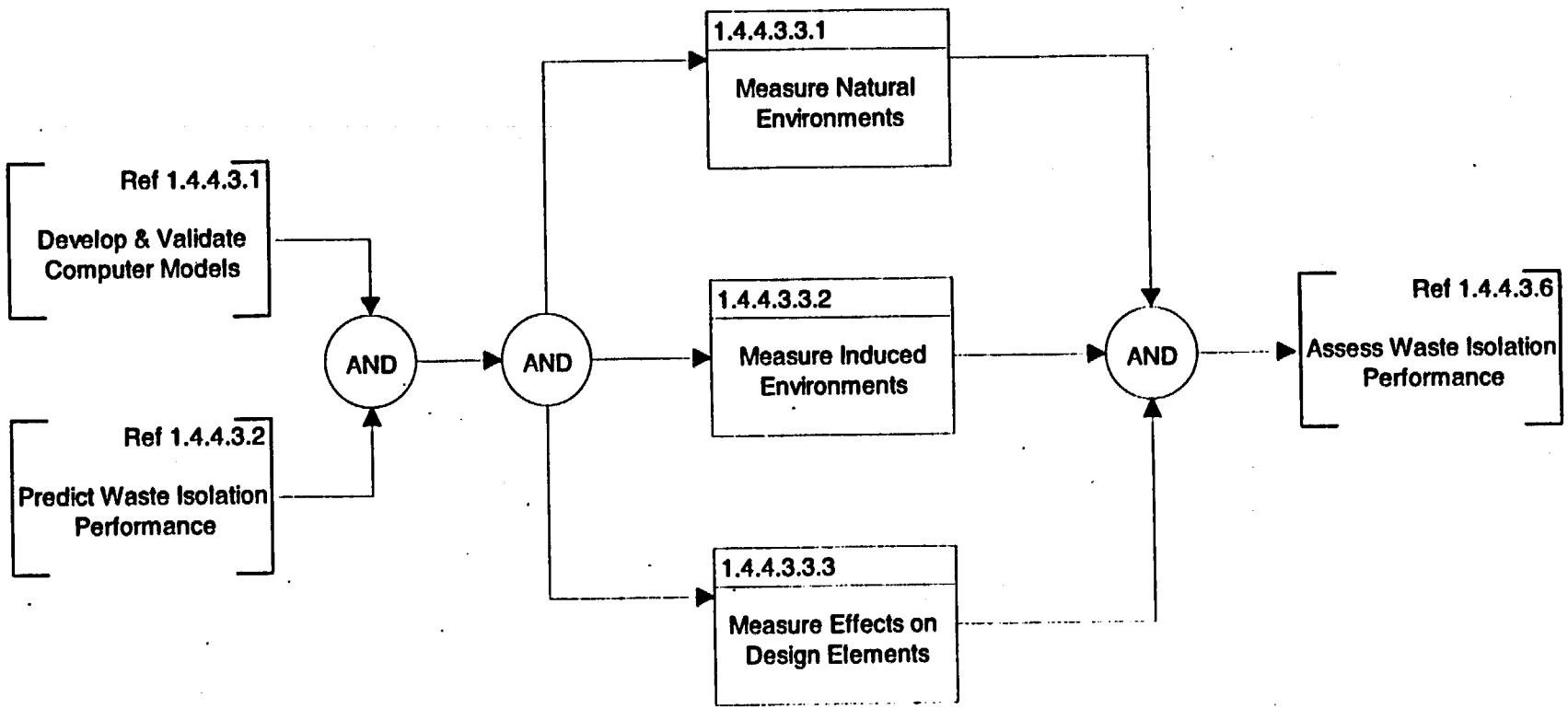

Figure 2-3. Performance Confirmation Test Functions

1.4.4.3.4 Evaluate Waste Isolation Performance

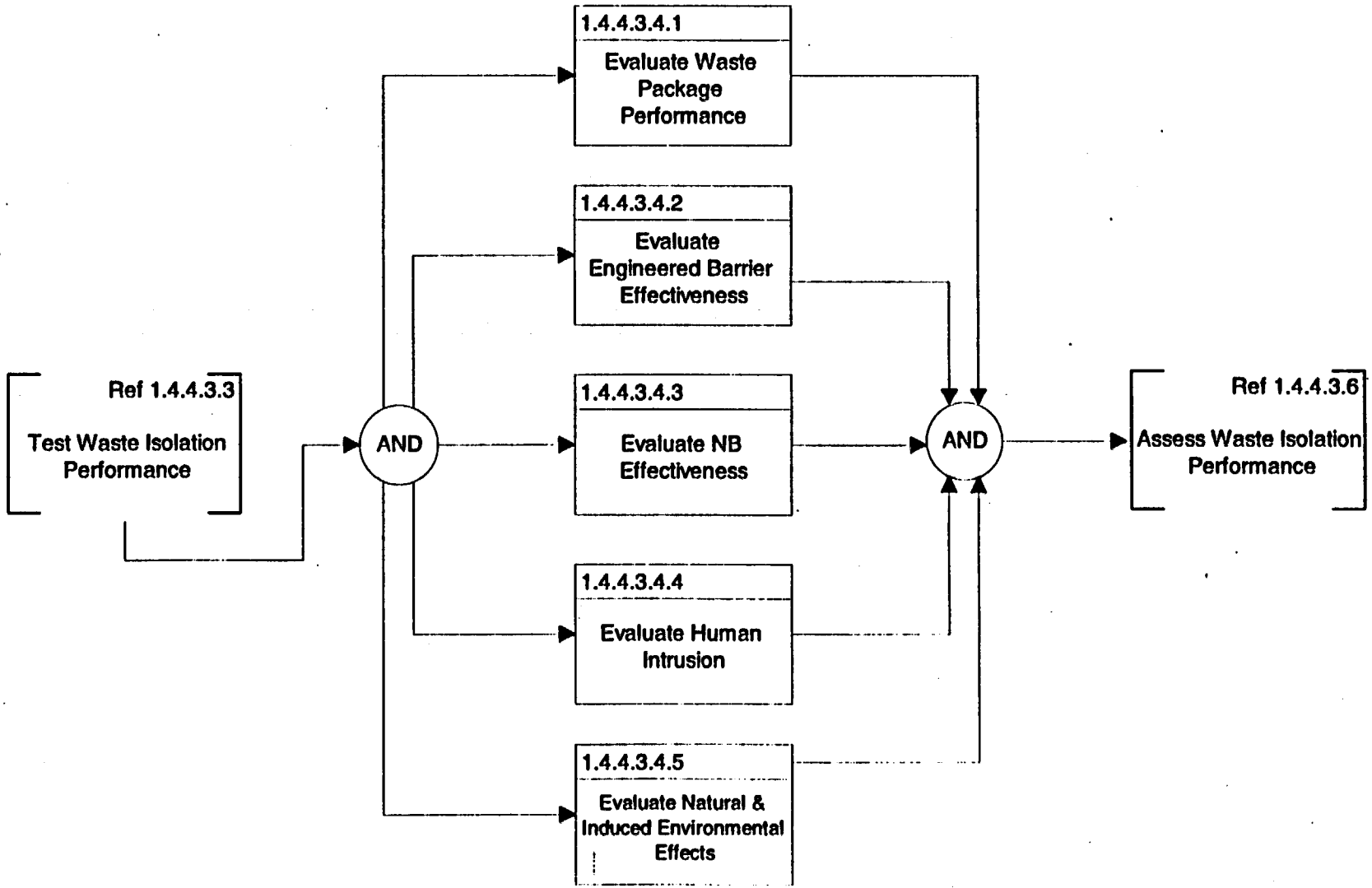

Figure 2-4. Performance Confirmation Evaluation Functions

1.4.4.3.4.3 Evaluate Natural Barrier Effectiveness

The evaluate natural barrier effectiveness function evaluates the existing capability of the natural barrier to limit release of radionuclides to the accessible environment. This function evaluates the potential dose to the population at the accessible environment boundary. This function begins with the natural barrier model and ends with closure of the repository.

1.4.4.3.4.4 Evaluate Human Intrusion[4]

The evaluate human intrusion function evaluates the repository's ability to limit human intrusion. This function specifically evaluates changes in human population data, access controls at the repository, and the permanent marker system. This function begins with the human intrusion threat model and ends with closure of the repository.

1.4.4.3.4.5 Evaluate Natural and Induced Environmental Effects

The evaluate natural and induced environment effects function verifies the impact limits of the natural environments on the engineered system and system operation effects on the natural environments. This function begins with the environmental effects model and ends with the closure of the repository.

1.4.4.3.3.1 Measure Natural Environments

The measure natural environments function provides test data and extends the site characterization baseline (natural phenomena and rock characteristics) and monitors effects on the site as a result of waste emplacement. The function starts with construction and ends with closure of the repository.

1.4.4.3.3.2 Measure Induced Environments

The measure induced environments function provides test and monitoring data for surface and subsurface environments induced by the disposal of waste. These environments include thermal, thermo-hydrologic, structural-mechanical, thermo-chemical and radiation environments. The function begins with waste emplacement and ends with closure of the repository.

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[4]The Evaluate Human Intrusion function description currently does not contain a description of evaluations needed to ensure economic desirability is minimized. The function 1.4.5.4.1, Minimize Economic Desirability, function is in the lower level decomposition of the function 1.4.5.4, Limit Human Intrusion, on which the Evaluate Human Intrusion function is based. Thus, the description of evaluating for economic desirability should be included.

1.4.4.3.3.3 Measure Effects on Design Elements

The measure effects on design elements function measures the effects on repository design elements caused by the natural and induced environments. These elements include the waste package, emplacement drifts construction, backfill, and seals. Also included are in situ, laboratory, and experimental testing related to these elements. The function begins with waste emplacement and ends with closure of the repository.

2.3 POSTCLOSURE PERFORMANCE MEASURES OF EFFECTIVENESS

The measures of effectiveness are based on demonstrating compliance with postclosure performance standards. Postclosure performance assessments are required to demonstrate compliance with the numerical standards of 10 CFR Part 60. These standards apply to the whole disposal system and apply separately to individual barriers or subsystems.

2.3.1 Total System Performance Standards

Total system performance standards are included in 10 CFR Part 60 issued by the Nuclear Regulatory Commission (NRC), which references environmental (radiological health) standards issued by the EPA. For many years, there has been uncertainty in the total system performance standard. 40 CFR Part 191, as promulgated in 1985, was used as one measure of total system performance, but was remanded by court decree in 1987 (U.S. Court of Appeals 1987). The Energy Policy Act of 1992 directed the EPA to promulgate a standard specifically for a repository at Yucca Mountain based on, and consistent with, the recommendations of the National Academy of Sciences (NAS 1995). When the EPA has completed drafting this standard, the NRC will revise 10 CFR Part 60 to be consistent with the EPA standard. In the interim, the DOE has provided guidance (DOE 1996d), for planning purposes, to limit peak dose to individuals from releases from the repository for 10,000 years.

Nuclear Regulatory Commission

10 CFR Part 60.112 *Overall System Performance Objective for the Geologic Repository after Permanent Closure*
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 Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

Interim Postclosure Standard

The *Controlled Design Assumption Document* (CRWMS M&O 1997a) (see Section 2.1.3.1) contains the following assumption.

Until a new U.S. Environmental Protection Agency (EPA) standard is promulgated. the Yucca Mountain Site Characterization Office (YMSCO) will use the following interim requirement and goal as a planning basis for evaluating postclosure performance of the repository.

The interim system-level requirement is a quantitative statement of the necessary performance for the first 10,000 years after closure. It is followed by a system-level performance goal that recognizes there needs to be sufficient defense-in-depth in the repository's multiple barriers system to ensure that public safety is protected beyond 10,000 years. This is a serious system performance goal. It is qualitative because of the increasing uncertainties beyond the first 10,000 years.

Requirement–The expected annual dose to an average individual in a critical group living 20 km from the repository shall not exceed 25 mrem from all pathways and all radionuclides during the first 10,000 years after closure.

Goal–Conduct analyses past 10,000 years to gain insight into longer-term system performance. For this period, the expected annual dose to an average individual in a critical group living 20 km from the repository should be below the 10,000 year requirement.

2.3.2 Individual Barrier Performance Standards

The individual barrier performance standards apply to subsystems of the MGDS, including two for the engineered barrier system and one for the natural barrier, and are contained in 10 CFR Part 60.113 *Performance of Particular Barriers after Permanent Closure, (a) General Provisions*. The National Academy of Sciences (NAS 1995) has expressed concern about the use of subsystem performance objectives; they may not appear in the revision of 10 CFR Part 60 that will incorporate the expected EPA new regulations for Yucca Mountain.

Waste Package Performance Standard

The first part of the engineered barrier system performance standard applies to waste containment within the waste packages as follows:

> 10 CFR Part 60.113(a)(1)(i)(A).
> (i) The engineered barrier system shall be designed so that assuming anticipated processes and events, (A) containment of high-level waste will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay.

10 CFR Part 60.113(a)(1)(ii)(A).
(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that (A) containment of high level waste (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 Sec. 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.

Engineered Barrier System Performance Standards

The second part of the engineered barrier system performance standard applies to the barrier as a whole:

10 CFR Part 60.113(a)(1)(i)(B).
(i) The engineered barrier system shall be designed so that, assuming anticipated processes and events, (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.

10 CFR Part 60.113(a)(1)(ii)(B)
(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that 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.

Natural Barrier Performance Standard

The natural barrier performance standard establishes a minimum limit on the pre-waste-emplacement ground water travel time as follows:

10 CFR Part 60.113(a)(2) *Geologic Setting*
The geologic repository shall be located so that pre-waste-emplacement ground-water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

Potential Modifications of Requirements

Modifications of the requirements are possible:

> 10 CFR Part 60.113(b)
> On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period or pre-waste-emplacement ground-water travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied.

That paragraph then lists five factors that the NRC may take into account to relax these requirements.

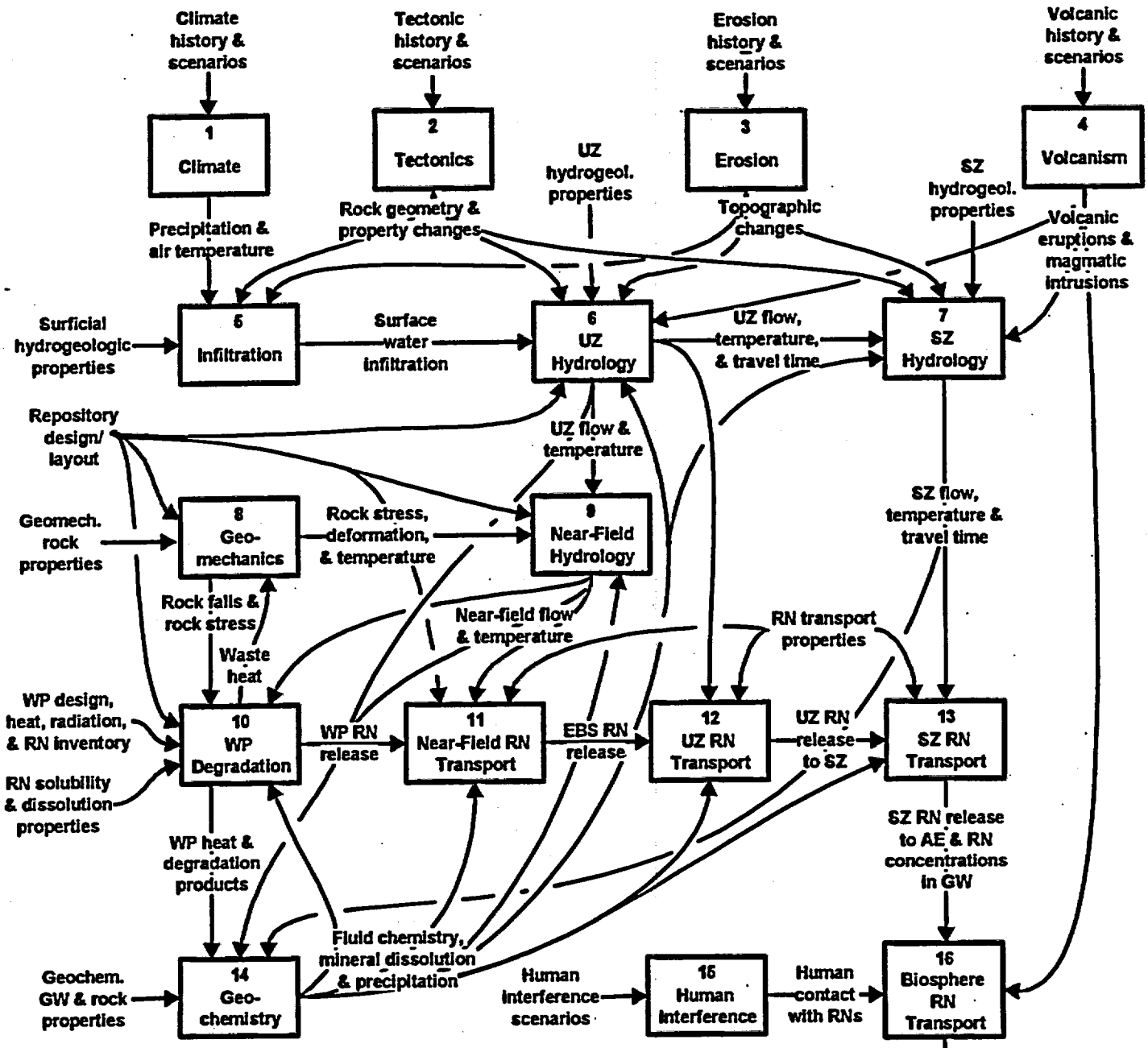
> 10 CFR Part 60.113(c)
> Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

2.4 POSTCLOSURE PERFORMANCE ASSESSMENT MODELING

Measurements, monitoring, observations, and test results will be compared with predictions of the performance of the natural and engineered barriers during the performance confirmation period, that is, prior to permanent repository closure, to establish confidence that the natural and engineered barriers are performing as evaluated in the License Application. Following are summaries of the processes to be modeled, of their input and output parameters, and references to the computer codes available for simulating these processes.

Postclosure performance assessment includes conceptual and mathematical modeling of natural and engineered barrier processes that may affect the MGDS postclosure performance, or waste isolation. It consists of a hierarchy of modeling of individual processes, coupled processes, and the total system as part of the evaluation of expected compliance with the regulatory standards. Figure 2-5 depicts a simplified performance assessment flow diagram of the individual processes listing the major inputs and outputs of that modeling. The figure shows that major inputs are derived from site characterization and waste package and repository design. Major outputs are the parameters required by the regulatory postclosure performance standards described in Section 2.3.

Following are brief descriptions of the major processes, in the same sequence as in the flow diagram of Figure 2-5 of this Plan and in the parameter matrices in the *Performance Confirmation Concepts Study Report* (CRWMS M&O 1996f), Appendix B, which lists the parameters necessary for the mathematical model of each process and examples of the computer codes developed for the mathematical simulation of each process. The parameters are described in Section 2.5. Some of the processes are also simulated by total system performance assessment software, which is described after the discussion of the process models. The parameters include data provided by site characterization and MGDS design.



Abbreviations:

AE = accessible environment
EBS = engineered barrier system
GW = ground water
RN = radionuclide
SZ = saturated zone
UZ = unsaturated zone
WP = waste package

A list of the computer codes that are being used or that could be used for postclosure performance assessments is provided in Appendix C. The table lists the names of the computer codes, the most recent version numbers and dates, the primary processes being modeled, the principal applications for the YMP, and references for code documentation. Appendix C includes mathematical models and computer codes that may need to be modified as new site information becomes available, as the engineered system design develops, and as new understanding of natural and engineered barrier characteristics and processes is gained. The listed models and codes may need additional verification and validation before they can be qualified for use in a License Application for a MGDS at the Yucca Mountain site. Qualification means that the documentation, verification, and validation of the computer codes and mathematical models complies with the *Quality Assurance Requirements and Description* (DOE 1997a).

Some of the listed computer codes are being used in support of MGDS design and Yucca Mountain site characterization but are not yet used in performance assessments. They are listed because they could be used to support future performance assessments. Because of the evolution in the understanding of natural and engineered barrier processes and computer technology, not all of the listed computer codes are expected to be used in support of the License Application.

The selected performance confirmation concepts and parameters are based on the current understanding of natural and engineered barrier processes, the mathematical models that have been formulated for these processes, the computer codes that have been developed to simulate these processes, and the parameters that are required for these computer codes. Uncertainties still exist regarding these processes such as rock matrix and fracture flow interactions, waste package barrier corrosion, and emplacement drift deformation and collapse. As new understanding is gained during site characterization, including research on engineered component behavior, the models and computer codes may change. The same may occur during performance confirmation. Consequently, changes in both site characterization and performance confirmation may be necessary to reflect new understanding, conceptual and mathematical models, computer codes, and parameter needs.

2.4.1 Climate

Climate affects the surface water infiltration rate, which affects the percolation flux at depth in the unsaturated zone, ground-water flow in the saturated zone, and the water table elevation. Climate modeling predicts principally future precipitation and air temperatures as input to estimating the surface water infiltration over the one-million year time frame of potential regulatory concern. Major inputs to climate modeling are scenarios regarding future climatic changes, principally the cycles of arid and humid periods, including ice ages. Commonly, sinusoidal relationships are assumed for these long-term climatic variations. Different approaches are possible, including direct modeling of climatic changes on the basis of the paleoclimatic record to compute precipitation and air temperatures, or embedding sinusoidal relationships for infiltration directly into the ground-water flow models themselves without explicitly modeling precipitation and air temperatures. Mathematical models and computer codes using the first approach include the global climate model GENESIS and the regional climate model RegCM2. RegCM2 receives its boundary conditions from GENESIS. The second approach was employed in *Total System Performance Assessment - 1995: An Evaluation of the Potential Yucca Mountain Repository* (Total System Performance Assessment-1995) (CRWMS M&O 1995c).

2.4.2 Tectonics

Tectonic activity such as earthquakes, faulting, folding, and local and regional uplift and subsidence, which result from plate tectonics and tectonic stress fields may change the geometry and hydrological and geomechanical characteristics of the natural barrier, including changing the relative elevations of ground-water recharge and discharge locations and thus water table elevations and aquifer gradients. Earthquakes may also result in short-duration fluctuations of the water table without associated changes in ground surface elevations and the geologic structure. Tectonic activity associated with fault movement may affect the hydrological and geomechanical characteristics of fracture zones. Tectonic activity may result in deformations, disruptions and rearrangements of surface-water systems, such as warping, landslides, lateral offset of stream alignments along faults with associated effects on ground-water recharge and discharge areas, which could also change the local distribution of infiltration into the Yucca Mountain unsaturated zone. Mathematical models and computer codes have not yet been selected (SNL 1996b). Computer codes, such as ELFPOINT, have been used, however, for special studies in support of a seismic ground-water pumping analysis, to compute seismically induced elastic rock deformations resulting from shear and tensile faulting (ANS 1996).

2.4.3 Erosion

Erosion of the ground surface by wind and water is unlikely to significantly reduce the planned depth of a potential repository and is unlikely to significantly affect surface features that influence surface water infiltration during the performance period. Because evaluations to date indicate that the potentially adverse condition "evidence of extreme erosion during the Quaternary Period" is not present at Yucca Mountain (DOE 1993), development of a mathematical model and computer code for extreme erosion and deposition is not planned.

2.4.4 Volcanism

The possibility of future volcanic processes needs to be considered in postclosure performance assessment if the probability of these processes occurring within some reasonable distance of the potential repository is greater than a specified limit on the order of 10^{-4} over 10^{4} years. The results of the *Probabilistic Volcanic Hazards Analysis for Yucca Mountain, Nevada* (CRWMS M&O 1995e) are that the expected annual frequency of intersection of the repository footprint by a volcanic event is $1.5 \cdot 10^{-8}$. Scenarios for basaltic igneous activity at Yucca Mountain have been formulated. Direct effects of volcanic processes imply the direct exhumation of a percentage of the waste. The direct effects are controlled by the geometric and physical properties of a future extrusive magma body (reflected by the volcanism box in the flowchart). Indirect effects are related to changes in the ambient rock properties, including thermal, mechanical, hydrologic, and geochemical properties, caused by a future intrusive magma body in the vicinity of the potential repository (not shown in the flowchart) and resulting changes on the unsaturated and saturated zones. While it may be possible to predict the magnitude of such changes by perturbing the ambient process models, it is likely that other indirect effects will be controlled by the physical/chemical attributes of the intruding body itself. One approach to addressing the indirect effects uses natural analogs of similar intrusive bodies in similar geologic and hydrogeologic settings.

Specific mathematical models and computer codes have not yet been selected. Preliminary analyses of magmatic intrusion into a potential repository are included in Total System Performance Assessment -1991 (SNL 1992a) and Total System Performance Assessment -1993 (PNL 1993b: SNL 1994b). These studies use existing process models to analyze the effects of the assumed intrusion on rock and ground-water conditions and radionuclide release.

2.4.5 Infiltration

A numerical water-balance model of infiltration at Yucca Mountain has been developed and is described in Flint et. al. (USGS 1996a). The numerical infiltration model was used to calculate the spatially variable infiltration flux input to the site-scale unsaturated-zone flow model constructed and calibrated to support the Yucca Mountain Project Viability Assessment (LBNL 1997b). For present climatic conditions, infiltration is derived from measurements of present climatic variables, principally precipitation, air temperatures, solar radiation, and potential evapotranspiration, soil/alluvial/colluvial moisture measurements in shallow boreholes, vegetative cover, and the surface geology, including areal distribution of the alluvium, colluvium, rock exposures, and known and suspected fracture zones. Wind is another important parameter for modeling evapotranspiration. For postclosure predictions, spatially distributed annual precipitation may be sufficient, while seasonal variations may require consideration in predicting unsaturated zone moisture conditions and flow, especially if ground-water age dating and observations in the ESF indicate the existence of fast flow paths along rock fractures. Because of the potential for fast pathways of ground water from the ground surface to the repository horizon, individual rainstorm events may have to be analyzed as well to evaluate how fast, and how much percolation from individual rainstorm events could reach the potential repository.

2.4.6 Far-Field Unsaturated Zone Hydrology

The far-field unsaturated zone hydrology includes hydrologic processes within the domain of the three-dimensional site-scale unsaturated-zone flow model described by Bodvarsson et. al. (LBNL 1997b). This model, which was constructed and calibrated to support the Yucca Mountain Project Viability Assessment, encompasses the area from about 1 km west of the Solitario Canyon fault to Bow Ridge fault on the east, and from Yucca Wash on the north to an east-west line about 2.5 km south of the Exploratory Studies Facility south portal. Vertically, the model extends from the ground surface to the water table. The far-field model does not include the effects of the waste heat and repository excavation on the unsaturated zone hydrology (this is covered by the near-field unsaturated zone hydrology). Far-field unsaturated zone hydrologic processes include percolation of water through the unsaturated zone resulting from surface water infiltration, including the effects of climate changes; and flow of air and gases through the unsaturated zone. Isothermal conditions are usually assumed; effects of geothermal gradients and of the waste heat are not considered.

The principal output parameters of the site-scale unsaturated zone hydrologic modeling are fluid potentials, including air pressure; rock moisture content, including relative humidity; and flow rates and velocities of water, air and gas, including their directions, flow paths, and flow times. The output includes the unsaturated zone component of the pre-waste emplacement ground-water travel time as required by 10 CFR Part 60.113(a)(2) and initial conditions for the post-emplacement non-isothermal modeling (described for the near-field unsaturated zone hydrology).

Mathematical models and computer codes have been developed using different assumptions regarding the coupling of fracture flow with porous matrix flow, numerical solution techniques, and other considerations. The principal computer codes currently being used for the Project are FEHM/ FEHMN, NUFT, TOUGH2, and V-TOUGH. Other computer codes have been used for special purposes, such as GWRAND for unsaturated zone ground-water travel time analyses, LYNX for representing the geometry of excavations and hydrostratographic units and for performing related analyses, and WEEPTSA for probabilistic analysis of interactions of discrete fracture flow with waste containers. FRACMAN and MAFIC have been developed specifically for statistical analysis of fracture geometry data and for simulating flow in discrete fracture networks.

2.4.7 Saturated Zone Hydrology

The saturated zone hydrology includes hydrologic processes within the three-dimensional regional and site-scale saturated zone models being developed. The regional three-dimensional saturated-zone model is documented in D'Agnese et. al. (in press; USGS 1997b) and the preliminary site-scale model is described in Czarnecki (USGS 1997c). It is identified as the regional and site-scale saturated zone flow model in the Total System Performance Assessment -1995 report (CRWMS M&O 1995c), Chapter 10. Far-field saturated zone hydrologic processes include recharge of the saturated zone resulting from surface water infiltration, including the effects of climate changes; flow of water through the saturated zone, discharge of water at natural discharge locations, including springs and evaporation; and ground-water pumping from wells. On the regional scale, isothermal conditions are usually assumed; effects of geothermal gradients and of the waste heat are not considered. On the site-scale, thermal effects of the waste heat must be considered if they reach below the water table.

The principal output parameters of regional-scale saturated zone hydrologic modeling are fluid potentials, including water table elevations; and ground-water flow rates, including directions, flow paths, and flow times. The regional-scale output includes the initial and boundary conditions for the site-scale saturated zone modeling. The same output parameters result from the site-scale saturated zone hydrologic modeling, but with the consideration of heat, other outputs may include rock and water temperatures; and flow rates and velocities of water vapor/steam, including directions, flow paths, and flow times. The site-scale output includes the saturated-zone component of the pre-waste emplacement ground-water travel time as required by 10 CFR Part 60.113(a)(2).

Mathematical models and computer codes have been developed using different assumptions regarding the coupling of fracture flow with porous matrix flow, coupling of fluid and heat flow, numerical solution techniques, and other considerations. The principal computer codes currently being used by the Project are FEHM/FEHMN, MEDFLY, NUFT, TOUGH2, and V-TOUGH, which, with the exception of MEDFLY, are the same codes used for unsaturated flow calculations. Other computer codes have been used for special purposes, such as FRACFLOW/MAFIC for flow in discrete fracture networks, SATTRAK for saturated zone ground-water travel time analyses, and MLAEM and SLAEM for regional saturated ground-water flow analyses to establish boundary conditions for site-scale saturated zone modeling.

2.4.8 Geomechanics

Geomechanics include thermal and thermal-mechanical processes within the thermally affected zone of the repository. Thermal and thermal-mechanical processes include heat conduction and diffusion through the rock; deformation and displacement of the rock, including excavation collapse and rock falls in excavations; and thermal-mechanical effects on near-field hydraulic characteristics of the rocks. The principal output parameters of thermal-mechanical modeling are rock stress and strain and geometric changes, such as deformation, displacement, and rock falls.

Numerous thermal and thermal-mechanical models have been developed for the construction and mining industry for different assumptions regarding the nature of the stresses and deformations. Thermal-mechanical analyses are just starting for postclosure performance assessment. The main use of these analyses has been to support subsurface ESF and repository design. The heat conduction and diffusion code COYOTE has been used extensively by the Project. Thermal-mechanical computer codes being used for design purposes at present are 3DEC, ABAQUS, ANSYS, FLAC/FLAC3D, JAC/JAC2D/JAC3D, UDEC, and UNWEDGE.

2.4.9 Near-Field Unsaturated Zone Hydrology

The near-field unsaturated zone hydrology includes hydrologic processes within that portion of Yucca Mountain whose temperatures will be affected by the waste heat. It includes both the drift-scale and repository-scale unsaturated zone thermal-hydrologic model identified in the Total System Performance Assessment -1995 report (CRWMS M&O 1995c), Chapter 10. Near-field unsaturated-zone hydrologic processes include percolation of water through the unsaturated zone resulting from surface water infiltration; flow of air and gases through the unsaturated zone; perturbation of the water, air and gas flow by the waste heat of a potential repository, including the creation of water vapor/steam; and effects of the waste heat and repository excavation on rock hydraulic characteristics.

The principal output parameters of near-field unsaturated zone hydrologic modeling are rock and ground-water temperatures; fluid potentials, including air pressures; rock moisture content, including relative humidity; and flow rates and velocities of water, water vapor/steam, and air and gases, including their directions, flow paths, and flow times. Modeling is generally at a finer scale than for the far-field hydrology in order to more accurately represent the greater fluid and thermal gradients expected in the vicinity of the engineered barrier system.

Mathematical models and computer codes have been developed using different assumptions regarding the coupling of fracture flow with porous matrix flow, coupling of fluid and heat flow, numerical solution techniques, and other considerations. The principal computer codes being used at present are the same as for the far-field modeling, namely FEHM/FEHMN, NUFT, TOUGH2, and V-TOUGH. Other computer codes have been used for special purposes, such as A-TOUGH, CLIMATE, and CLIMSIM to compute the moisture removal from the excavations by the underground ventilation system; MPSalsa for thermal-hydrological modeling of unsaturated zone air and water flow; and STAFF3D for hydrothermal analyses in support of site characterization.

2.4.10 Waste Package Degradation

Waste package degradation covers the changes with time of the waste itself and of the barriers protecting the waste. It includes both the waste form dissolution model and the waste package degradation model in the Total System Performance Assessment -1995 report, (CRWMS M&O 1995c), Chapter 5. Waste package processes include:

- Radioactive decay
- Heat generation
- Radiation
- Thermal-mechanical deformation
- Waste package barrier corrosion by different mechanisms
- Galvanic protection of the inner barrier by the outer barrier
- Fluid flow such as liquid, water vapor, steam, air and gases within the waste package
- Waste form dissolution
- Aqueous and gaseous radionuclide release from the waste package into the emplacement drift, including diffusive and advective transport
- Waste form and waste package barrier-related geochemical reactions
- Internal and external criticality
- Performance of the cladding, if credit is taken for performance or if degradation adversely affects performance of other waste package components.

The principal output parameters areas are:

- Initial time of radionuclide release as required for the determination of the containment time in accordance with 10 CFR Part 60.113(a)(1)(i)(A) and 10 CFR Part 60.113(a)(1)(ii)(A)
- Temperatures of the waste package components, including at the waste form center and on the exterior walls
- Mechanical stresses, strains and deformations of the waste package barriers
- Crack formation as a result of mechanical stress and corrosion
- Reduction of barrier thickness as a result of the different corrosion mechanisms

- Radionuclide dissolution rates

- Aqueous and gaseous radionuclide release rates from the waste package into the emplacement drift

- Conditions conducive to or preventing internal and external criticality.

Mathematical models and computer codes have been developed for different waste package processes and using different assumptions. They include AREST, AREST-CT, PIGS, WAPDEG, and YMIM. MCNP and SCALE are being used for criticality calculations. In addition, ORIGEN2 provides the radionuclide inventory, radiation output, and heat output of spent fuel as a function of time. These data are required as input to the waste package degradation and near-field environment modeling, including temperature, fluid flow, mechanical stresses, and chemistry.

2.4.11 Near-Field Radionuclide Transport

Near-field radionuclide transport includes the movement of aqueous and gaseous radionuclides from the waste package into the engineered barrier, into the host rock and within the thermally altered zone. It is covered by the drift-scale radionuclide transport model in the Total System Performance Assessment -1995 report (CRWMS M&O 1995c), Chapter 10.

Near-field radionuclide transport processes include:

- Radioactive decay

- Diffusive (molecular), dispersive (hydrodynamic), and advective transport of aqueous and gaseous radionuclides from the waste package through the emplacement drift, including through any backfill materials and through any rock materials resulting from rock falls and drift collapse

- Diffusive and advective transport of aqueous and gaseous radionuclides through the altered zone

- Formation and effects of colloids on radionuclide transport

- Sorption of radionuclides on any backfill and rock materials in the emplacement drifts

- Sorption of radionuclides on the rock in the altered zone

- Thermal-chemical effects on radionuclide transport and sorption.

The principal output parameters are:

- Aqueous and gaseous radionuclide concentrations in any backfill and rock materials in the drifts

- Aqueous and gaseous radionuclide concentrations in the rock within the altered zone

- Radionuclide release rate from the engineered barrier system as required by 10 CFR Part 60.113(a)(1)(i)(B) and 10 CFR Part 60.113(a)(1)(ii)(B).

Mathematical models and computer codes have been developed using different assumptions regarding radionuclide transport mechanisms, coupling with fluid flow and geochemical calculations reactions, numerical solution techniques, and other considerations. The principal computer codes currently being used by the Project are FEHM/FEHMN, NUFT, and TRACR3D/TRACRN. WEEPTSA is being developed for probabilistic analyses of the interaction of water flowing in discrete fractures with waste containers, radionuclide release from the waste containers, and radionuclide transport to the water table.

2.4.12 Far-Field Unsaturated Zone Radionuclide Transport

Far-field unsaturated zone radionuclide transport includes the movement of aqueous radionuclides from the thermally altered zone to the water table, if and when the altered zone does not extend to the water table, and of gaseous radionuclides from the thermally altered zone to the ground surface, if and when the altered zone does not extend to the ground surface. It is covered by the site-scale unsaturated zone radionuclide transport model in the Total System Performance Assessment -1995 report (CRWMS M&O 1995c), Chapter 10.

Far-field radionuclide transport processes include:

- Diffusive (molecular), dispersive (hydrodynamic), and advective transport of aqueous and gaseous radionuclides from the altered zone through the unsaturated zone to the water table (aqueous radionuclides) and ground surface (gaseous radionuclides)

- Formation and effects of colloids on radionuclide transport

- Sorption of radionuclides on the rock in the unsaturated zone.

The principal output parameters are aqueous and gaseous radionuclide concentrations in the rock within the unsaturated zone, and the aqueous and gaseous radionuclide release rate from the unsaturated zone to the water table and ground surface.

Mathematical models and computer codes have been developed using different assumptions regarding radionuclide transport mechanisms, coupling with fluid flow and geochemical calculations reactions, numerical solution techniques, and other considerations. The principal computer codes currently being used by the Project are the same as for the near-field unsaturated zone radionuclide transport, namely FEHM/FEHMN, NUFT, and TRACR3D/TRACRN. As for the near-field radionuclide transport, WEEPTSA could be used for probabilistic analyses of the interaction of water flowing in discrete fractures with waste containers, radionuclide release from the waste containers, and radionuclide transport to the water table.

2.4.13 Saturated Zone Radionuclide Transport

Saturated zone radionuclide transport includes the movement of aqueous radionuclides from the water table below the potential repository to the accessible environment, or where required by new regulations. It is covered by the site-scale saturated zone radionuclide transport model in Chapter 10 of the Total System Performance Assessment-1995 report (CRWMS M&O 1995c)

Saturated zone radionuclide transport processes include:

- Radioactive decay
- Diffusive (molecular), dispersive (hydrodynamic), and advective transport of aqueous radionuclides from the water table below the potential repository to the accessible environment
- Formation and effects of colloids on radionuclide transport
- Sorption of radionuclides on the rock in the saturated zone.

An important aspect, and uncertainty, is the mixing of radionuclides with depth below the water table, and thus the dilution of radionuclides in the saturated zone. A future test at the second testing complex may help resolve these issues to include mixing in the modeling efforts.

The principal output parameters are aqueous radionuclide concentrations in the saturated zone (previously required by the ground-water protection requirements of 40 CFR Part 191.16 for the first 1000 years following waste emplacement), and the aqueous radionuclide release rate to the accessible environment, if and where required by a new regulation replacing 40 CFR Part 191.13.

Mathematical models and computer codes have been developed using various assumptions regarding radionuclide transport mechanisms, coupling with fluid flow and geochemical calculations reactions, numerical solution techniques, and other considerations. The principal computer codes currently being used by the Project are the same as for the near-field and far-field unsaturated zone radionuclide transport, namely FEHM/FEHMN, NUFT, and TRACR3D/ TRACRN.

2.4.14 Geochemistry

Geochemistry includes the effects of geochemical processes on all other processes. For the purposes of this report plan, it was not split into the categories listed in the Total System Performance Assessment -1995 report (CRWMS M&O 1995c), Chapter 10. Those categories are waste-package thermal-chemical model, drift-scale thermal-chemical model, and site-scale unsaturated zone geochemical model.

Waste package and drift-scale thermal-chemical processes include:

- Waste form dissolution itself, also listed under waste package degradation
- Chemical aspects of waste package barrier degradation

- Generation of waste package degradation products

- Interactions of the latter with any backfill, rock fall, and man-made materials in the emplacement drifts

- Thermal-chemical reactions in the surrounding rock, including thermal-hydrological-mechanical changes as a result of the excavations and waste heat, effects of the thermal-chemical regime in the emplacement drifts, and mineral dissolution and precipitation.

Site-scale geochemical processes include geochemical changes resulting from changes in hydraulic characteristics of the rocks because of faulting, seismic fracturing, and other tectonic deformations; surface water infiltration; changes in water table elevations; and future human activities.

The principal output parameters of geochemical and thermal-chemical modeling are the chemical concentrations, Eh, and pH of the fluids and solids in drifts, backfill materials, and rock pores and fractures.

Currently, the principal geochemical model and computer code in the YMP is EQ3/6. Geochemical aspects are also being considered in computer codes for other processes, such as AREST-CT for waste package degradation modeling and OS3D/GIMRT for multicomponent reactive mass transport. The computer code VNETPC has been used to compute the removal of construction equipment exhaust gases by the underground ventilation system.

2.4.15 Human Interference

Inadvertent human interference refers to activities by people that could affect waste containment and isolation following permanent repository closure and includes:

- Direct drilling of boreholes into and through the repository (to be addressed in the License Application)

- Hydrocarbon (oil, gas and coal) and mineral exploration and extraction within and near the repository boundary (to be addressed in the License Application)

- Ground-water use, such as industrial and irrigation (to be addressed in the License Application)

- Liquid and solid waste disposal within the area affecting ground-water flow and radionuclide transport with respect to the potential Yucca Mountain repository (to be addressed as part of the Environmental Impact Statement process).

The potential for human interference will be evaluated during site characterization and the results will be documented in the License Application. Information on the potential for hydrocarbon, metallic mineral and water resources, as well as industrial mineral, and geothermal resources occurring in the region and in the conceptual controlled area will be documented in the License Application. This information provides input to an evaluation of the potential for inadvertent human intrusion. The

issue of liquid and solid waste disposal is being addressed as part of the repository Environmental Impact Statement effort.

Direct drilling into the repository could result in a drill penetrating a waste package or contaminated rocks between or below the waste packages, resulting in immediate radiological exposures of the drillers. Hydrocarbon and mineral exploration would have the same consequences as the direct drilling if boreholes are involved. It could also entail excavation of tunnels and shafts, with radiological consequences to the miners and other workers. In addition, the use of any extracted hydrocarbons or minerals by people could expose them to radiation because of the potentially contaminated hydrocarbons or minerals. Drilling and excavations could also alter the hydrogeologic conditions at Yucca Mountain. Ground-water use and liquid waste disposal could change the moisture content of the unsaturated zone and the water table elevation, and thus the hydraulic gradients of the saturated zone. Both liquid and solid waste disposal could change the geochemistry of the unsaturated and saturated zone. Ground-water use and liquid and solid waste disposal could therefore change ground-water travel times, radionuclide dilution and sorption, and radionuclide concentrations in the ground-waters.

Mathematical models and computer codes have not been developed specifically for human interference. They are not needed because the processes involved, such as ground-water flow, geochemical reactions, geosphere and biosphere radionuclide transport, and radiological exposures, can be simulated with existing mathematical models and computer codes. The principal output parameters are determined by the process models that are needed for a particular type of human interference.

2.4.16 Biosphere Radionuclide Transport

For the purposes of this Plan, biosphere radionuclide transport includes direct radiation, the movement of radionuclides above the ground surface, and radiological exposures of people following permanent repository closure. Direct radiation exposures occur from contaminated air, soils, and surface water bodies such as lakes, reservoirs, and rivers, when a person is located in contaminated air, on contaminated ground, on shores of water bodies, or in water craft on the water bodies. Biosphere radionuclide transport includes:

- Advection and dispersion of gaseous and solid radionuclides by wind
- Advection and dispersion of dissolved radionuclides by surface water bodies
- Plant uptake of radionuclides from contaminated soils or through irrigation with contaminated water
- Movement of radionuclides through the animal food chain. Radiological exposures from these mechanisms include inhalation of contaminated air and dust, absorption of radionuclides through the skin, drinking of contaminated ground or surface water, eating of contaminated crops and animal products, and swimming in contaminated surface water bodies.

The principal output parameters of the biosphere radionuclide transport modeling are radiation doses received by members of the public, previously required by the individual protection requirements of 40 CFR Part 191.15 for the first 1000 years following waste emplacement. For current simulations. exposures have been calculated for an individual obtaining drinking water from a contaminated source five kilometers from the repository boundary as a function of time for up to one million years. The calculation of exposure to a representative or critical population group may be necessary if adopted by any new regulations. Also, the current risk model for assessing public health risk to an assumed dose of radiation is based on a linear no threshold model. Currently, it is being reassessed and the popular and/or accepted risk model will probably change in the future. This change could have an impact on the necessary models and parameters.

Mathematical models and computer codes have been developed for different transport and exposure mechanisms. The principal computer codes currently being used by the Project are GENII and MACCS. A new biosphere model is being developed specifically for the environmental conditions of the Yucca Mountain site; this model will also consider long-term bio-accumulation impacts of preclosure radioactive releases. Other codes that are being used or examined include PGEMS, CG Mathew/ADPIC, HOTMAC/RAPTAD and PAVAN for giosphere dispersion assessments.

2.4.17 Nuclear Criticality

Nuclear criticality could occur inside the waste package, in the altered zone surrounding the waste packages, and in the far-field, the geologic domain not affected by waste heat. Whether nuclear criticality occurs depends on the location, type, mass, and geometry of fissile materials, neutron absorber materials, and neutron moderators. See Appendix B for definitions. Examples of absorbers are criticality control materials placed into the waste packages, such as boron containing alloys, and radionuclide-sorbing geologic media. Examples of moderators are water and silica (SO_2). Analyses of these conditions involve:

- Thermal-hydrological analyses to predict the effects of water and water vapor on waste package and waste form degradation, including the neutron absorber to be placed in the waste packages

- Geochemical analyses to predict the chemical composition of degradation products and affected fluids

- Radionuclide transport analyses to determine radionuclide concentrations in the ground-water and rocks, including precipitation, sorption, and potential accumulation to critical levels at specific locations

- Chain reaction calculations if conditions for criticality are predicted by these other analyses. The computer code MCNP is an example of software used for the chain-reaction calculations. Thermal-hydrological, waste package and waste form degradation, and geochemical analyses were described in previous sections.

2.4.18 Total System Performance Assessment

Total system performance assessment involves the simulation of all major processes that potentially affect postclosure performance of the potential repository in order to compute system and major subsystem performance measures. The system and subsystem performance measures defined by regulatory requirements are summarized in Section 2.3. Past and present total-system performance assessments involved the computation, for up to one million years, of:

- Waste package containment time
- Annual radionuclide release rate from the engineered barrier system
- Radionuclide concentrations in the saturated zone
- Cumulative radionuclide release to the accessible environment with its associated cumulative complementary distribution function
- Radiation doses to an individual obtaining drinking water from a contaminated source five kilometers from the repository boundary.

These computations can be accomplished either with a single computer code such as RIP, or an assembly of individual process codes that are connected through common inputs and outputs, like TSA. In total system performance assessments, the effects of input parameter uncertainties on output parameter uncertainties are generally simulated as well. This is generally accomplished through repeated simulations, where each simulation selects different parameter values from the range of expected values. In RIP, this is accomplished automatically by randomly selecting parameter values from probability density functions of the uncertain parameters. As many as 1000 simulations, also called realizations, may be necessary to obtain valid statistics on the uncertainties of the computed outputs.

The multiple simulations require simplifications for modeling the individual processes because of the complexity of the mathematical models of the individual processes and computer hardware limitations, and to attain reasonable simulation times. These simplifications, called abstractions of process models, generally result in response functions or surfaces representing the relationships between input and output parameters in place of complex partial differential equations. Response functions and surfaces represent algebraic functions relating the output variables to the input variables of a mathematical model. They are derived from results of multiple runs of the detailed process-level computer codes for a range of values of the input variables. They are usually represented by multi-dimensional tables, which require interpolation to calculate the value of the output variables for specific values of the input variables. A major current performance assessment effort is to derive and test abstractions to be used for the total system performance assessment in support of the viability assessment (CRWMS M&O 1996k, l).

2.5 PARAMETERS AND TECHNICAL DATA SUMMARY

The summary of the process modeling in Section 2.4 identifies the major input and output parameters for each natural and engineered barrier systems process. From these parameters, the performance confirmation parameters were selected using the following steps:

- Preparation of a set of six tables listing all parameters and relating them to major process models. See the *Performance Confirmation Concepts Study Report*, Appendix B.
- Development of criteria for selecting performance confirmation parameters. See Section 2.5.2.
- Preparation of a new set of six tables for selecting performance confirmation parameters. See the *Performance Confirmation Concepts Study Report*, Appendix C.
- Extracting the performance confirmation parameters from these six tables into a single table. See Appendix D of this Plan.

Following are descriptions of the steps involved in the selection of the performance confirmation parameters and the key parameters whose data acquisition needs to be considered in the MGDS design.

2.5.1 Identification of Candidate Performance Confirmation Parameters

The first step in the selection of performance confirmation parameters was the preparation of six tables that list in the left column all parameters that are required as:

- Input to waste package and repository design
- Input to postclosure performance assessments
- Result of waste package and repository design
- Output of postclosure performance assessments.

Because of the large number of parameters, the lists were split into six tables corresponding to the following six major subsystems of the natural and engineered barrier systems:

- General site parameters
- Saturated zone parameters
- Unsaturated zone parameters
- Repository excavation and borehole parameters
- Waste package parameters
- Backfill and seal parameters.

The other columns of these tables show which major performance assessment process model requires them as input or produces them as output. These tables are included in the *Performance Confirmation Concepts Study Report,* Appendix B. The processes have been described in Section 2.4.

Within each table, the parameters are organized by category. For instance, the saturated zone parameter table includes the categories alluvium/colluvium and rock matrix, rock fracture zones including faults, and ground water.

Within each category, the parameters are grouped by subcategory. For instance, in the saturated zone parameter table, the alluvium/colluvium and rock matrix category includes subcategories stratigraphy, biological characteristics, chemical/mineralogical characteristics, and hydraulic characteristics.

2.5.2 Criteria for Selection of Performance Confirmation Parameters

The second step consisted of formulating a process for selecting performance confirmation parameters, including key performance confirmation parameters whose data acquisition needs to be considered in the MGDS design. The process considers regulatory requirements, natural and engineered barrier processes, and the associated parameters. More specifically, the process considers the following factors in order to arrive at performance confirmation parameter selection criteria:

- Regulatory requirements or expectations by 10 CFR Part 60, Subpart F, specifically as reflected in Program level requirements documents and listed in the design inputs Section 2.1.2.

- Functional requirements as reflected in the *Mined Geologic Disposal System Functional Analysis Document* (CRWMS M&O 1996e).

- Analysis needs by the *Highlights of the United States Department of Energy's Updated Waste Containment and Isolation Strategy for the Yucca Mountain Site* (DOE 1996b). The waste isolation and containment strategy is still evolving as a draft document. Thus, it was not used as part of the final screening process in the preparation of this Plan, but it should be considered in revisions when the strategy is approved. **TBD - Update of PC Parameter Screening Process.**

- Performance assessment needs as reflected by Total System Performance Assessment-1995 (CRWMS M&O 1995c) recent performance assessment process modeling, and expected future total system performance assessment and performance assessment process modeling, including the total system performance assessment planned in support of the Viability Assessment (CRWMS M&O 1996k and l)

- Expected variability of parameters as a result of construction and waste emplacement

- Measurability and predictability of parameters

- Need and ability to reduce the uncertainty in parameter values

- Need for considering the data acquisition for performance confirmation of parameters in the MGDS design.

On that basis, the following twelve selection criteria were formulated, with the rationale printed in italic at the end of each numbered criterion:

1. The parameter is required to be measured, monitored, observed, or tested by 10 CFR Part 60, Subpart F. A list of specific parameters or parameter categories is provided with the referenced requirement and the regulatory source:

   - Radioactive waste, the geologic repository including its structures, systems and components, radiation detection and monitoring instruments, and other equipment and devices used in connection with the receipt, handling, or storage of radioactive waste; from the *Mined Geologic Disposal System Requirements Document* 3.7.2.7.A.1, which cites the regulatory source as 10 CFR Part 60.74(a).

   - Borehole and access seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and ground water; from the *Mined Geologic Disposal System Requirements Document* 3.7.2.7.B, which cites the regulatory source as 10 CFR Part 60.142(a).

   - Rock deformations and displacement, changes in stress and strain, rate and location of water inflow into underground areas, changes in ground-water conditions, rock pore water pressures, including those along fractures and joints, and the thermal and thermomechanical response of the rock mass; from the *Mined Geologic Disposal System Requirements Document* 3.7.2.7.C, which cites the regulatory source as 10 CFR Part 60.141(c).

   - Thermomechanical response; from the *Mined Geologic Disposal System Requirements Document* MGDSRD 3.7.2.7.D, which cites the regulatory source as 10 CFR Part 60.141(e).

   - Waste package monitoring, internal condition from the *Mined Geologic Disposal System Requirements Document* MGDSRD 3.7.2.7.E, which cites the regulatory source as 10 CFR Part 60.143(c).

   - Backfill placement and compaction, from the *Mined Geologic Disposal System Requirements Document* 3.7.2.7.F, which cites the regulatory source as 10 CFR Part 60.142(c).

   - Borehole and access seals, from the *Mined Geologic Disposal System Requirements Document* 3.7.2.7.G, which cites the regulatory source as 10 CFR Part 60.142(d).

The requirements of 10 CFR Part 60, Subpart F, are the main reasons for the Performance Confirmation Program and thus a key selection criterion. Included in this criterion are several requirements, as listed.

2. The parameter is a determinant of the proper functioning of a structure, system, or component that has been allocated performance requirements relating to a confine and isolate waste function.

   The confine and isolation waste function and its subfunctions, defined by the Mined Geologic Disposal System Functional Analysis Document (CRWMS M&O 1996e) have to be addressed to ensure that the data are available for demonstrating compliance with the regulatory requirements of 10 CFR Part 60.112 and 60.113.

3. The parameter is required to test the hypotheses of the waste containment and isolation strategy (DOE 1996b).

   Parameter needs of the waste containment and isolation strategy need to be considered to assure that its hypotheses can be tested and confirmed.

4. The parameter was used in Total System Performance Assessment-1995 (CRWMS M&O 1995c) and is expected to be used in the total system performance assessment for the Viability Assessment and for the License Application or the parameter is currently and/or planned to be used in design and performance assessment process level models of the natural and engineered barrier systems.

   All parameters needed for postclosure performance assessments, including for detailed natural and engineered barrier process modeling and for total system performance assessments, have to be considered.

5. The parameter needs to be measured, monitored, observed, or tested to confirm that actual subsurface conditions encountered are within the limits assumed in the licensing review in accordance with 10 CFR Part 60.140(a)(1).

   Because site characterization measurements will be at a limited number of locations and depths, interpolations and extrapolations are required for MGDS design and performance assessments in support of the License Application. The assumptions involved may need to be confirmed as subsurface repository construction proceeds.

6. The parameter is appreciably affected by the subsurface construction process or by the emplacement of waste.

   An important aspect of the confirmation of subsurface conditions is whether the parameter values are affected by the repository construction and waste emplacement. Since these changes may affect postclosure performance, confirmation of the changes predicted prior to submittal of the License Application may be needed.

7. The parameter is a variable such as moisture content or rock temperature, that varies with time. Note that material properties, such as hydraulic conductivity, that vary with time are not considered for this criterion.

   A parameter may change with time even if it is not affected by repository construction and waste emplacement, for instance, because of climatic changes, earthquakes, and magmatic intrusions. Assumptions used in the License Application in this regard may therefore need to be confirmed. This criterion is not applied to material properties because their prediction is implicit in the modeling of the variables.

8. The parameter can be directly measured or derived from the results of analyses of measurements, tests or experiments.

   A parameter cannot be a performance confirmation parameter if it cannot be directly measured or derived from the results of analyses of other measurements, tests, or experiments. Examples of parameters that cannot be directly measured include lifestyles of future populations and radiation doses to people resulting from radioactive releases from the repository.

9. Spatial interpolation and/or future values of the parameter and tolerance or uncertainty bands for the parameter values can be predicted or estimated.

   A parameter must be predictable and it must be possible to estimate the uncertainties in the predictions. Unless predictions can be made, performance confirmation is not necessary.

10. The parameter is a significant qualifier, disqualifier, or determinant of overall postclosure system performance, the postclosure performance of particular barriers such as substantially complete containment and controlled release. The Total System Performance Assessment-1995 (CRWMS M&O 1995c); and/or process model analysis reports is expected to be a significant qualifier, disqualifier, or determinant in future analyses in accordance with 10 CFR Part 60.140(a)(2).

    Even if all other screens are passed, if the parameter is not important as a qualifier, disqualifier, or determinant of postclosure subsystem or system performance, its performance confirmation is superfluous.

11. The parameter has a reasonable amount of uncertainty, the uncertainty or our confidence in the range of uncertainty can be reduced by performance confirmation, and the consequence is large if the parameter is found to deviate from tolerance bounds.

    If the parameter is well known, such as radionuclide half lives or design parameters, it does not need to be confirmed. If the nature of its measurement is such that any existing uncertainty cannot be reduced, it does not need to be confirmed. And even if the uncertainty is large, if the consequence of that uncertainty regarding postclosure performance predictions is not significant, the parameter does not need to be confirmed.

If a parameter passes all previous screens and this criterion applies, the parameter is a performance confirmation parameter.

12. The acquisition of the parameter significantly influences the design, construction, operations, cost, or schedule of the repository segment or engineered barriers segment.

    The considerations have to apply for a performance confirmation parameter to be selected as a key performance confirmation parameter, that is, its data acquisition needs to be considered in the MGDS design.

Cost and schedule are not considered as criteria for selecting performance confirmation parameters because technical factors were considered sufficiently important that they should not be influenced by cost and schedule considerations. Cost and schedule, however, influence the MGDS design and hence are factored into deciding if a performance confirmation parameter should be a key performance confirmation parameter. Cost is primarily a factor in evaluating alternative performance confirmation concepts regarding locations, frequency, and duration of the performance confirmation data acquisition.

2.5.3 Selection of Performance Confirmation Parameters

In the third step of the performance confirmation parameter selection process, a new set of six tables was prepared listing the same parameters as the first set of tables in the left column and the selection criteria described as additional columns. These tables C-1 through C-5 are included in the *Performance Confirmation Concepts Study Report*.

The twelve selection criteria were grouped into five sequential screens on the basis of interrelationships and entered as columns in those six tables, using abbreviated titles. A parameter had to pass each screen to be considered for the next screen. Finally, a selected performance confirmation parameter would be designated as a key performance confirmation parameter if its data acquisition needs were considered in the MGDS design. This screening process, using the abbreviated forms for the twelve selection criteria, is depicted in Table 2-1 and in the flowchart in Figure 2-6.

Since the intent of the screening process is to identify performance confirmation on technical grounds based on the current understanding of the site and the current status of the MGDS design, a parameter required by 10 CFR Part 60, Subpart F, may not be selected as a performance confirmation parameter. If this is the case, resolution with the NRC would be needed, as indicated in the table and flowchart as an additional question following Screen 5. In general, Subpart F concentrates on identifying conditions, processes, and general changes that need to be confirmed. It does not identify specific parameters for most requirements with the exception of 10 CFR Part 60.141(c). The results are that all parameters listed in that paragraph were selected as performance confirmation parameters since they passed the entire screening process on the other technical grounds.

Table 2-1. Performance Confirmation Parameter Selection Process

Screen 1: 1. 10 CFR Part 60 Subpart F 2. Confine & Isolate Waste function 3. Containment & Isolation strategy 4. Total System Performance Assessment and Performance Assessment process models	A parameter had to pass only one of these criteria to move to the next screen since confirmation may be needed if any one would apply
Screen 2: 5. Subsurface conditions 6. Affected by construction/emplacement 7. Time dependent variable	A parameter had to pass only one criterion to move to the next screen since confirmation may be needed if any one would apply
Screen 3: 8. Can be measured or derived 9. Can be predicted or estimated 10. Important to performance	A parameter had to pass all three of these criteria to move to the next screen, since if any one did not apply, the parameter could not be or would not have to be confirmed
Screen 4: 11. Reduce uncertainty	A parameter had to pass this screen since it would not have to be confirmed if its uncertainty was acceptable or irreducible
Screen 5 (screening results): Performance confirmation parameter 12. Key parameter affecting design 13. Required by 10 CFR Part 60, Subpart F	A parameter passing screen 4 would be a performance confirmation parameter; a performance confirmation parameter affecting MGDS design would be a key parameter for design; if a parameter required by Subpart F would not be selected, resolution with the NRC would be required

The screening was performed by a team representing systems engineering, repository design, waste package design, site characterization, and performance assessment. The tables in the *Performance Confirmation Concepts Study Report*, Appendix C, show the results of that screening. From these tables, a new table was created that lists only the performance confirmation parameters, since only those are relevant to the *Performance Confirmation Plan*. This table is provided in Appendix D.

Of the 435 parameters listed in the six tables in the *Performance Confirmation Concepts Study Report*, Appendix C, 126 were selected as performance confirmation parameters and 94 of these were selected as key performance confirmation parameters. The actual number will be greater since some parameters, such as geochemical compositions, consist of several different measurements. Many parameters were not selected since they are expected to be sufficiently known from site characterization by the time a License Application will be submitted. This assumption may be incorrect because of uncertainties still existing in the site characterization program. Consequently, it is recommended that the parameter selection process be revisited on an annual basis to ensure that no parameters are overlooked in the Performance Confirmation Program.

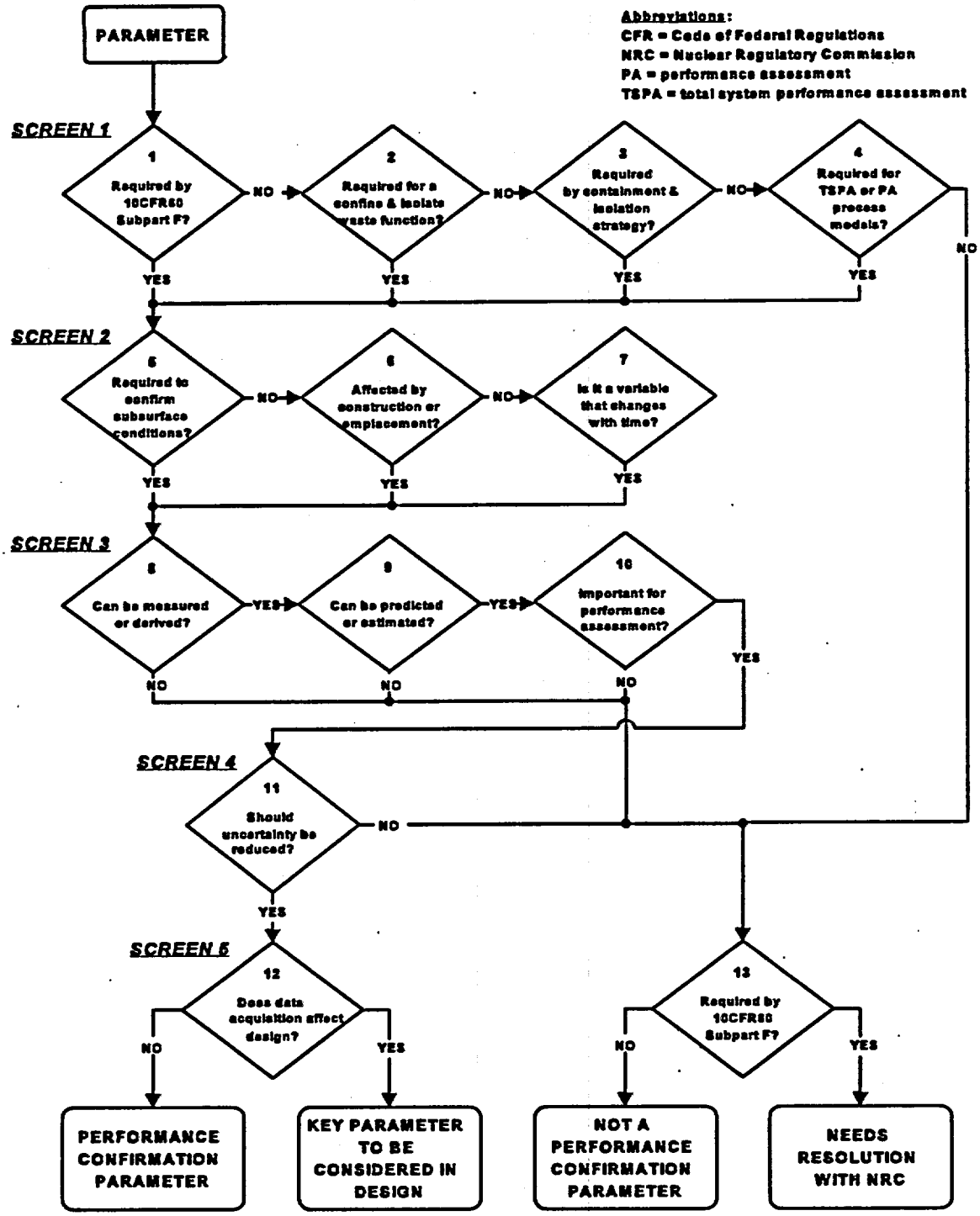


Figure 2-6. Selection Process for Performance Confirmation Parameters

The emphasis of the Performance Confirmation Program is to confirm that subsurface conditions encountered during repository construction and waste emplacement and changes in the natural and engineered barrier systems regarding postclosure performance resulting from repository construction and waste emplacement will be as assumed in the License Application. Although the *Site Characterization Plan* (DOE 1988), Section 8.3.5.16, indicates that some of the performance confirmation activities are expected to be continuations of site characterization activities, many site characterization activities will be terminated, while other activities, primarily regarding natural and engineered system performance prior to repository closure, will be new. Details are provided in the description of the planned performance confirmation activities in Section 3.

2.5.4 Descriptions of Performance Confirmation Parameters

Following are descriptions of the key performance confirmation parameters that must be considered in the design of the engineered barrier system to ensure that the planned performance confirmation activities can be performed. The descriptions are by category and subcategory, in the same sequence as in the parameter tables in the *Performance Confirmation Concepts Study Report*, Appendix B and Appendix C, and as in the performance confirmation parameter table in Appendix D of this Plan.

2.5.4.1 General Site Parameters

The list of general site parameters in the *Performance Confirmation Concepts Study Report.*, Appendix B, includes those site characteristics that apply to both the unsaturated and saturated zones or to the site in general. It covers features of the site and vicinity approximately bounded by Crater Flat in the west, Rainier Mesa in the north, Jackass Flats in the east, and the Amargosa Valley in the south.

The general site parameters are organized into the following categories: physiography; future geologic events and processes; postclosure human interference; and postclosure demography, lifestyles, and public exposure mechanisms.

Physiography includes the following subcategories: topography, vegetation, climate and meteorology, and surface hydrology. Future geologic events and processes include the following subcategories: future erosion and deposition, future uplift and subsidence, future volcanic eruptions and magmatic intrusions, and future seismicity. Postclosure human intrusion includes the following subcategories: postclosure borehole drilling directly into the engineered barrier system; postclosure hydrocarbon (coal, oil, and gas) and mineral exploration and extraction; postclosure ground-water use, such as for industrial and irrigation purposes, and liquid waste disposal; and postclosure solid waste disposal. Postclosure demography, lifestyles and public exposure mechanisms include the following subcategories: postclosure population; postclosure crops; livestock and food; other postclosure exposure mechanisms such as swimming and boating; and postclosure public health risk. The latter subcategory includes potential postclosure radiological performance standards for peak radiation dose to the maximally exposed individual and to a representative population group. Although these would be important postclosure performance assessment parameters, they were not selected as performance confirmation parameters since no radiation doses to the public are expected from potential postclosure processes before repository closure.

From the general site parameter list, 13 parameters were selected as performance confirmation parameters, five of which are key performance confirmation parameters. These parameters are briefly described below.

Topography–The only parameter defining topography is the ground-surface elevation, which has been measured by geodetic surveys of the U.S. Geological Survey and is reflected by elevation contour lines on topographic maps of the site. Confirming these elevations at geodetic control points is planned during and after geologic events that are suspected of causing elevation changes, such as major earthquakes. Changes in the topography could influence surface water runoff and infiltration, and combined with changes in the distance to the potential repository horizon, affect the rate of water percolation reaching waste packages.

Vegetation–Plant type and areal distribution of each plant type were selected as performance confirmation parameters since they affect evapotranspiration; that is, ground-cover affects water evaporation from the ground surface and the plant types affect water transpiration from the plants, determining the amount of the water infiltration at the ground surface percolating to the potential repository horizon. Annual seasonal surveys are planned to establish a record of changes as a function of weather and other factors, to be used as a basis for postclosure predictions.

Climate and Meteorology–From the many climatological and meteorological factors, only precipitation, dry bulb temperature, atmospheric pressure, and relative humidity were selected as performance confirmation parameters since they are the more important parameters for estimating surface water infiltration and evapotranspiration and the other parameters are expected to be sufficiently known at the time of the submittal of the License Application. Continued monitoring of these parameters at the Project weather stations is planned.

Future Seismicity–A surface-based monitoring network exists at present that records seismic activity at the site and surrounding areas. Continuation of the surface-based monitoring and measurements of subsurface acceleration/ground motion are recommended for the following reasons:

- To confirm that facility and excavation design assumptions are correct
- To provide a record of earthquakes should any damage occur
- To provide a basis for evaluating any subsurface rock falls, rock deformations, and fault movement
- To provide a basis for above ground changes, including topographic changes
- To confirm damping or reduction of acceleration/ground motion with depth.

The measurements to be taken and/or derived from the monitoring include the location and depth of epicenters, the earthquake magnitude, and the acceleration/ground motion. The site monitoring and testing program is needed to evaluate potentially adverse conditions in accordance with 10 CFR Part 60.122(c)(12), (13), and (14) regarding the repetition of historic earthquakes or a potential increase in the frequency and magnitude of earthquakes that are typical for the area.

Postclosure Hydrocarbon (Coal, Oil, and Gas) and Mineral Resource Exploration and Extraction–Current site information indicates that no recoverable hydrocarbons and minerals, other than common construction materials, exist at the Yucca Mountain site. Based on this the parameter's significance will be reassessed in later screenings of the parameters. Geologic mapping and associated laboratory analyses of rock samples are recommended if any indications of hydrocarbon and mineral resources other than common construction materials are found during the subsurface excavation process. The location of the sampling must be recorded, and if any hydrocarbons or minerals are found, the type of coal, oil, gas, or mineral must be determined and the potential recoverable quantity must be estimated since it could be a potentially adverse condition in accordance with 10 CFR Part 60.122(c)(17).

Public Radiological Health Risk–Continued monitoring of background radiation levels is planned to distinguish between them and any public radiological health risk from the repository operation and to confirm background radiation assumptions for postclosure radiological risk assessments.

2.5.4.2 Unsaturated Zone Parameters

The list of unsaturated zone parameters in the *Performance Confirmation Concepts Study Report*, Appendix B, includes those site characteristics that apply specifically to the unsaturated zone. Currently, the hydrology of the unsaturated zone at the Yucca Mountain site is defined by the conceptual three-dimensional site-scale model of the unsaturated zone for the Viability Assessment (LBNL 1997b). Available background on the unsaturated zone is contained in LBNL 1996a. This model includes all hydrogeologic units between the ground surface and the water table. It covers an area that is bounded by straight lines 1 km west of the Solitario Canyon fault to the west, Yucca Wash to the north, the Bow Ridge fault to the east, and by an west-east line approximately 2.5 km to the south of the potential repository boundary. The lateral extent of this model may be extended depending on new site information and conceptual designs for the subsurface repository. This may affect activities related to performance confirmation parameters in general, but not key performance confirmation parameters whose data acquisition is restricted to the waste package, subsurface repository, and associated laboratory activities. A more detailed conceptual model will be issued in the *Updated Conceptual Model of the Unsaturated Zone at Yucca Mountain, Nevada* (USGS 1996c).

The unsaturated zone parameters are organized into the following categories: alluvium/ colluvium and rock matrix; rock fracture zones, including faults; ground water in the rock matrix, fractures, fault zones, and other discontinuities; and subsurface air and gases in the rock matrix, fractures, fault zones, and other discontinuities.

The first two categories include properties of the rocks, while the latter two categories include properties of the subsurface fluids, such as water, water vapor/steam, air, and other gases. Rock properties are typically unchanged in a steady-state system, while fluid properties are changing. Appendix E provides a list of input/output variables, boundary conditions, and parameters for the unsaturated zone parameters. Subcategories include stratigraphy of the alluvium/colluvium and rock matrix, geometry of fracture zones, biological, chemical/mineralogical, hydraulic, pneumatic, mechanical, and thermal characteristics, naturally occurring radon, and aqueous and gaseous radionuclide transport. The pre-waste-emplacement ground-water travel time requirement of

10 CFR Part 60.113(a)(2) is one of the parameters in the unsaturated zone parameter list, but not a key performance confirmation parameter.

From the unsaturated zone parameter list, 54 parameters have been selected as performance confirmation parameters, of which 45 are key performance confirmation parameters. Some of these parameters, such as ground-water chemical composition, include more detailed characteristics, resulting in a larger number of key performance confirmation parameters. The selected parameters are briefly described in the following section.

2.5.4.2.1 Alluvium/Colluvium and Rock Matrix

The alluvium/colluvium and rock matrix includes porous rocks within the unsaturated zone whose fractures, if any, can be represented using an equivalent porous medium or dual-continua methods for ground-water flow, radionuclide transport, and rock stability/deformation/displacement modeling. The applicability of the equivalent porous medium assumption depends on the spatial scale of the model selected and the objectives of the analyses, and thus, may vary between analyses.

Stratigraphy of Alluvium/Colluvium and Rock Matrix–The stratigraphy of the hydrogeologic units, including depth, thickness and lateral extent, is essential information for MGDS design and performance assessments. Description and evaluation of the rock types and mineralogy encountered during subsurface excavation will confirm the design and performance assessment assumptions made for the License Application. Rock types and mineralogy are basic information for spatial extrapolations of point measurements of other rock characteristics, such as hydraulic conductivity, radionuclide sorption coefficients, and geochemical reaction analyses.

Hydraulic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone– Hydraulic characteristics of the unsaturated zone are required for ground-water flow and radionuclide transport modeling. The flow modeling requires the saturated hydraulic conductivity and relationships between the hydraulic potential, also called soil moisture tension, and moisture content; and the moisture content and unsaturated hydraulic conductivity. These relationships are based on experimental evidence such as in the case of Van Genuchten (1980). The transport modeling requires, among other things, the effective porosity and the dispersivity or dispersion coefficient. These measurements are typically obtained through laboratory testing of rock samples from a limited number of locations. Extrapolation and interpolation is then used to derive initial values prior to excavation and waste emplacement for the entire model domain. Modeling is used to predict changes with time resulting from the excavation and waste emplacement. Performance confirmation is recommended for only the thermally altered zone.

Pneumatic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone–Among the various pneumatic rock characteristics, only the air permeability in the altered zone was selected as a key parameter because of its importance in modeling two-phase ground-water flow, liquid water and water vapor/steam, resulting from the waste heat.

Mechanical Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone– In situ rock stress, strain such as from the change of rock length per unit length of rock or of rock volume per unit volume of rock, deformation, and displacement, may affect the hydraulic characteristics

such as hydraulic conductivity and porosity of the rocks, and thus ground-water flow. Parameter values are needed for thermal-mechanical analyses to predict potential rock falls and emplacement drift collapse that may deform waste packages; change the stress distribution in waste packages, affecting waste package barrier corrosion; and directly fracture waste packages. Values are also needed for thermal-mechanical-hydrological analyses to predict the changes in the hydraulic characteristics of the thermally altered zone.

Thermal Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone–The rock temperature will change as a result of the waste heat, and in turn, affect ground-water flow, both liquid and water vapor/steam, which are important processes for waste package performance. Consequently, the accuracy of the rock temperature predictions in the License Application are crucial for confirming the waste package and total system performance assessment predictions. Both near- and far-field measurements are planned to determine the extent of the thermally altered zone.

2.5.4.2.2 Rock Fracture Zones, Including Faults

Rock fracture zones, including faults, are those parts of the unsaturated zone whose fracture characteristics need to be considered in ground-water flow, radionuclide transport, and rock stability/deformation/displacement calculations, which cannot be adequately represented by an equivalent porous medium assumption. The need for considering the fracture characteristics separately from the porous rock matrix characteristics depends on the spatial scale of the model selected and on the objectives of the analyses; thus, they may vary between analyses.

Geometry, Including Future Displacements of Rock Fracture Zones, Including Faults–Rock fracture zones, including faults, depending on characteristics, can be conduits or barriers to ground-water flow and radionuclide transport. Fracture zones affect the mechanical stability/deformation/displacement of the rocks induced by the excavations and the waste heat. A basic component of fracture zone characterization is geometry, consisting of location, orientation, length, and width; and for faults, displacement. Important with respect to ground-water flow and radionuclide transport are the apertures of the fractures and the fracture density, the number of fractures per unit width of rock, since they determine the permeability of the fracture zones to ground-water flow and the pore and fracture space available for radionuclide transport. Although not listed, the connectivity of the fractures must be inferred from other measurements because of importance to potentially fast flow and transport pathways; fracture zone parameters are currently essentially unknown or poorly constrained.

Biological Characteristics of Rock Fracture Zones, Including Faults–Biological activity, including microorganisms, may affect the ground-water chemistry and thus waste package corrosion, waste dissolution, and radionuclide transport. Sampling and laboratory analysis will be needed when fracture zones are encountered during the emplacement drift excavation and as a function of time following waste emplacement.

Chemical/Mineralogical Characteristics of Infillings of Rock Fracture Zones, Including Faults–The chemical and mineralogical characteristics of infillings, including the apparent age of the minerals, provide information about the evolution of the fractures, including hydraulic characteristics. These characteristics can be used to predict changes that may affect water, water

vapor/steam, air, and gas flow, including through the repository excavations, and aqueous and gaseous radionuclide transport through the fracture zones.

Hydraulic Characteristics of Rock Fracture Zones, Including Faults–The same hydraulic parameters described for the rock matrix are also needed for rock fracture zones, including faults, for the same reasons. Hydraulic characteristics of fracture zones are essentially unknown.

Pneumatic Characteristics of Rock Fracture Zones, Including Faults, of Altered Zone–The fracture air permeability for the altered zone is needed for the same reasons as for the rock matrix. In addition, the gaseous dispersion coefficient is a key parameter because of importance to gaseous radionuclide transport.

Thermal Characteristics of Rock Fracture Zones, Including Faults, of Altered Zone–The same reasons apply as for the rock matrix.

2.5.4.2.3 Ground Water in Rock Matrix, Fractures, Fault Zones, and Other Discontinuities

The ground water in the unsaturated zone includes all water and water vapor and steam in the pores and fractures between the ground surface and the water table.

Chemical Characteristics of Ground Water–The chemical characteristics of ground water affect the corrosion of waste packages, waste dissolution, rock permeability and porosity through precipitation and dissolution of minerals, and radionuclide sorption on the rocks. Performance confirmation is recommended for the altered zone to confirm chemical changes resulting from the waste heat and associated ground-water flow effects. Chemical characteristics include the concentrations of anions and cations, the pH, the Eh, and several other parameters. Typical parameters measured in the past in two wells in the saturated zone are listed in the *YMP Reference Information Base (RIB)*, Section 1.612e, Table 1 (DOE 1995c). Following is a list of the Reference Information Base parameters, plus others that may have to be measured for the unsaturated zone:

Cations: aluminum (Al^{+++}), calcium (Ca^{++}), iron (Fe^{++}), lithium (Li^{+}), magnesium (Mg^{++}), manganese (Mn^{++}), potassium (K^{+}), sodium (Na^{+}), strontium (Sr^{++}), and zinc (Zn^{++}).

Anions: chloride (Cl^{-}), bicarbonate (HCO_3^{-}), fluoride (F^{-}), nitrate (NO_3^{-}), phosphate (PO_4^{-}), and sulfate (SO_4^{-}).

Other: Eh (not included in the RIB) -- a measure of the oxidation potential, also called redox potential; (expressed in volts or millivolts);
pH -- a measure of the acidity or alkalinity; the reciprocal of the logarithm of the hydrogen-ion concentration; (neutral water has a hydrogen-ion concentration of 10^{-7} g/L and thus a pH of 7);
aqueous silica (SiO_2);
dissolved organic carbon (DOC);

specific conductance/conductivity (a measure of the total dissolved ionic solid concentration);
tritium ($^3H^+$); and
various measures related to age dating.

Additional constituents may need to be added on the basis of new research and performance assessment results regarding importance for natural and engineered barrier postclosure performance.

Hydraulic Characteristics of Ground Water–The in situ fluid potential, also called moisture tension, constitutes the driving force for ground-water flow. In the unsaturated zone, it is related to moisture content, which in turn affects the unsaturated hydraulic conductivity. (See the description of hydraulic rock characteristics for the unsaturated rock matrix.) The adequacy of the prediction of its spatial distribution in the entire unsaturated portion of the natural barrier, especially the effects of the waste heat in the thermally altered zone, is an important aspect of performance confirmation because of importance to ground-water flow in the forms of liquid, water vapor, or steam, waste package performance, and radionuclide transport.

Thermal Characteristics of Ground Water of Altered Zone–The ground-water temperature as affected by the waste heat is a key output of the performance assessments and must be confirmed because of importance to ground-water flow, geochemical processes, waste package performance, and radionuclide transport.

Pneumatic Characteristics of Subsurface Air and Gases–The air pressure is the key parameter driving air, gas, and water vapor/ steam flow. It will be predicted by performance assessments and therefore needs to be confirmed for the same reasons as the fluid potential of ground water.

2.5.4.3 Saturated Zone Parameters

The list of saturated zone parameters, in the *Performance Confirmation Concepts Study Report*, Appendix B, includes those site characteristics that apply specifically to the saturated zone. For the purposes of this Plan, the saturated zone is assumed to be bounded by Crater Flat in the west, Rainier Mesa in the north, Jackass Flats in the east, and the Amargosa Valley in the south.

The saturated zone parameters are organized into the following categories: alluvium/ colluvium and rock matrix; rock fracture zones, including faults; and ground water in the rock matrix, fractures, fault zones, and other discontinuities.

The first two categories include properties of the rocks, while the last category includes properties of the ground water. Subcategories include stratigraphy of the alluvium/colluvium and rock matrix, geometry of fracture zones, biological, chemical/mineralogical, hydraulic, mechanical, and thermal characteristics, and aqueous radionuclide transport. The latter subcategory includes potential postclosure performance standards for radionuclide concentrations in the ground water and the aqueous radionuclide release rate to the accessible environment. Although these would be important postclosure performance assessment parameters, they have not been selected as performance confirmation parameters since no radionuclide releases to the saturated zone are expected before repository closure.

From the saturated zone parameter list, six parameters have been selected as performance confirmation parameters, none of which is a key performance confirmation parameter since data acquisition for the selected performance confirmation parameters would not affect MGDS design. The selected parameters are briefly described in the following section.

Hydraulic Characteristics of Ground Water in Rock Matrix, Fractures, Fault Zones, and Other Discontinuities–Among the selected performance confirmation parameters, the ground-water table elevation is the only measurable parameter. It determines the gradient for saturated-zone ground-water flow, and thus with other parameters, is a required input for saturated-zone ground-water flow modeling. Ground-water temperature was selected as a performance confirmation parameter since it is not expected that thermal effects would be observed in the saturated zone during the preclosure period. The parameter should be reconsidered in updates of the list of performance confirmation parameters for a number of reasons, but primarily because it is more likely that the repository will impact the temperature of the uppermost saturated zone than water-table elevations and it is imprudent to measure one without the other. The other selected performance confirmation parameters, ground-water flux and pre- and post-waste emplacement ground-water travel times will be calculated from that modeling.

Aqueous Radionuclide Transport of each Important Radionuclide–Radionuclide concentrations in the ground-water of the saturated zone will be the most important factor for determining potential radiological risks to future populations. Although no radioactive releases are expected from the repository during the preclosure phase, annual monitoring in selected boreholes is planned to establish a defensible baseline prior to repository closure. More frequent monitoring may be needed if concentrations above expected ambient levels are detected. The other selected performance confirmation parameter, radionuclide release rate to the accessible environment, which is required by 10 CFR Part 60.112, is determined from saturated-zone ground-water flow and radionuclide transport calculations. No radionuclide release to the saturated zone, and thus, accessible environment, is expected during the preclosure phase. This parameter may be dropped in future regulations.

2.5.4.4 Repository Excavation and Borehole Parameters

The list of repository excavation and borehole parameters, in the *Performance Confirmation Concepts Study Report*, Appendix B, includes characteristics within the excavations and boreholes. Characteristics in the rock adjacent to the excavations and boreholes are included in the general site, unsaturated zone, or saturated zone parameter tables, depending on the location of the characteristic within the natural barrier system and the parameter itself.

The repository excavation and borehole parameters are organized into the following categories:

- Excavation geometry
- Subsurface repository excavation environment inside ramps, shafts, alcoves, and emplacement and other drifts
- Waste emplacement for each waste type and waste package design

- ESF and repository construction fluids and materials remaining after repository closure, other than backfills and seals

- Engineered barrier system radionuclide release. Note that the characteristics of the waste packages and of the wastes are included in the waste package parameter table.

The excavation geometry category includes the geometry of ramps, shafts, alcoves, transportation drifts, waste emplacement drifts, and surface-based and underground boreholes. This category includes potential geometry changes with time, such as those caused by excavation deformation and convergence, by rock falls, and by excavation and borehole collapse. The subsurface repository excavation environment category includes physical, chemical, and radiological characteristics inside the excavations. The waste emplacement category includes the number of waste packages for each waste type and waste package design, the location of waste packages within the repository and drifts, and the thermal and areal mass loading. The construction fluids and materials category includes quantities and chemical composition/alteration of construction and fire water, including accidental spills; hydrocarbons, including accidental spills; and concrete, steel, ground support, pedestals, and any other fluids and materials remaining in the repository after closure. The EBS radionuclide release category includes aqueous and gaseous radionuclide release rates to the host rock and concentrations in the emplacement drift walls. This category also includes the postclosure performance standard of 10 CFR Part 60.113(a)(1)(ii)(B) regarding the fractional annual engineered barrier system radionuclide release, following the containment period, relative to the 1,000-year inventory. Although this is a postclosure performance standard, it has not been selected as a key performance confirmation parameter since no radionuclide releases from the engineered barrier system are expected before repository closure. Waste package recovery would be considered if any radionuclides escape from the waste packages, as detected by repository ventilation air monitoring.

From the repository excavation and borehole parameter list, 18 parameters were selected as performance confirmation parameters, of which 16 are key performance confirmation parameters. Some of these parameters, such as the chemical composition of fluids and materials remaining permanently in the repository, include more detailed characteristics, resulting in a larger number of key performance confirmation parameters. The selected parameters are briefly described in the following section.

2.5.4.4.1 Excavation Geometry

The excavation geometry includes the geometry of subsurface repository excavations and of both surface-based and underground boreholes. Only the geometry of excavations has been selected as a key performance confirmation parameter. For boreholes, inspection of any deformation prior to sealing as part of the sealing program has been considered sufficient.

Geometry of Waste Emplacement Drifts–Although the initial geometry of the waste emplacement drifts is defined by the repository design, any changes resulting after the excavation need to be monitored because of the potential impacts of drift deformation and convergence, rock falls, and drift collapse on waste package performance.

2.5.4.4.2 Subsurface Repository Excavation Environment, Including Ramps, Shafts, Alcoves, and Emplacement Drifts

The subsurface repository excavation environment includes characteristics within the excavations themselves and some parameters defined at the excavation walls.

Physical Characteristics of Excavation Environment–The air temperature and relative humidity in the drifts and any ground-water inflow including rate and temperature directly affect waste package performance. Because of the heterogeneity of the Yucca Mountain hydrogeologic units, locations and rates of ground-water inflow cannot be predicted with any precision. Consequently, it is important to detect and monitor any inflow encountered during the repository excavation and following waste emplacement. The drift-averaged air temperature and relative humidity can be predicted with fair accuracy, but random effects by ground-water inflows and other natural barrier heterogeneities require that the accuracy of these predictions be confirmed.

Chemical Characteristics of Excavation Environment–The same parameters listed under chemical characteristics of the ground water in the unsaturated zone must to be measured for the same reasons for any ground-water inflow into the repository drifts. Although it would be useful to know also the chemical composition of the ground-water outflow from the excavations, it is not practical to measure that and therefore will be computed if needed to determine any chemical alterations of the surrounding rocks and related postclosure performance implications.

Engineered Barrier Release of each Important Radionuclide–The fractional annual radionuclide release relative to the 1000-year radionuclide inventory, required by 10 CFR Part 60.113(a)(1)(ii)(B), is a performance confirmation parameter that has to be calculated from the waste package radionuclide release and the radionuclide transport into the surrounding rocks. Although no release is expected in the preclosure phase, the occurrence of any potential release would be detected by ventilation air and waste package monitoring. See sections 3.3.2.5.3 and 3.3.2.

2.5.4.4.3 Construction Fluids and Materials Remaining after Repository Closure (Other than Backfill and Seals)

Tracers, fluids, and materials introduced by the ESF and repository construction and operation, including waste emplacement, may affect the postclosure performance of the natural and engineered system barriers, because of changes that they induce to these barriers prior to repository closure, and because of effects of any tracers, fluids, and materials remaining in the repository after closure. It is assumed that record keeping is maintained and identification of tracers, fluids, and materials remaining in the subsurface excavations is part of the construction and operation activities. Performance confirmation is required regarding only the tracers, fluids, and materials expected to remain permanently in the subsurface, including determining the quantities remaining and confirming expected chemical alterations during the preclosure period.

Construction and Fire Water, Including Accidental Spills– Water is used during the excavation of ramps and drifts as part of the tunnel boring operation, for drilling of rock bolt holes, for muck conveyor dust suppression, for washing of excavation walls prior to geologic mapping, and perhaps for fire fighting. Part of the introduced water is removed with the muck and part with the ventilation

air. The water remaining in the rock could affect ground-water flow and associated waste package performance and radionuclide transport. Although records of water use and potential spills are required when they occur, confirmation of the quantities and chemical composition remaining in the rock is recommended.

Hydrocarbons, Including Accidental Spills–Hydrocarbons are used in construction equipment, such as coolants, lubricants, and internal combustion engine fuel. A large part of gaseous hydrocarbons are expected to be removed by the ventilation air. Records of direct and indirect hydrocarbon use, including accidental spills, their locations and chemical compositions will be part of the construction and operation record. Confirmation of the quantities remaining and their chemical composition are recommended.

Concrete–Inverts that form the base for rail transport of the waste packages to be emplaced will be made of precast concrete, and lining of the emplacement drifts with precast concrete segments is being contemplated. The amount, chemical composition, and locations of concrete used will be part of the design and construction record. Performance confirmation is recommended for the chemical composition and alteration of the concrete as a function of time.

Steel–Steel will be used for the rails, waste package supports, and ground support. As with concrete, the amount, type, and locations of steel will be part of the design and construction record. Performance confirmation is recommended for the chemical composition and alteration of the steel as a function of time.

Ground Support–Ground support consists of precast concrete linings, cast-in-place concrete linings, steel sets, rock bolts, shotcrete, and other materials to make the excavations safe following excavation and during waste emplacement. The materials used may include concrete, steel, and plastics. As before, design and construction records will be the basis for the initial quantities, chemical compositions, and locations. Performance confirmation is recommended for the chemical alteration and composition of the materials remaining in the repository as a function of time.

Pedestals–A gantry is planned to be used for transporting waste packages to the emplacement locations and placed on pedestals. Design and emplacement records will be the basis for the number, chemical compositions of constituent materials, and locations. Performance confirmation is recommended for the chemical alteration and composition of the materials remaining in the repository as a function of time.

Other Fluids and Materials Remaining in Repository after Closure, if Required–Numerous other fluids and materials are expected to be used for the construction and operation of materials. The *Determination of Importance Evaluation for Subsurface Exploratory Studies Facility* (CRWMS M&O 1996b) can be used as an initial indication of the types of fluids and materials and potential impact, if any, on waste isolation. Design, construction, and emplacement records will track those that may have a waste isolation impact. Performance confirmation is recommended for the chemical alteration and composition of any fluids and materials to be identified by future determinations of importance or performance assessments.

2.5.4.5 Waste Package Parameters

The list of waste package parameters, in the *Performance Confirmation Concepts Study Report*, Appendix B, includes characteristics of the waste packages and of the wastes contained within them. Waste emplacement characteristics, including the locations of the waste packages within the repository and emplacement drifts and associated thermal and areal mass loadings, are included in the repository excavation and borehole parameter table.

The waste package parameters are organized into the following categories:

- Waste form characteristics of spent fuel and defense high-level waste glass
- Radionuclide characteristics
- Waste package geometry
- Corrosion and other degradation characteristics of each waste package barrier
- Chemistry of each waste package barrier, including of degradation products
- Hydraulic, mechanical, and thermal characteristics of each waste package barrier
- Waste package radionuclide containment and release for each waste form, waste package design, and important radionuclide. These categories have not been further divided.

Waste package characteristics include data on the individual radionuclides in the wastes, including half life, chain-decay relationships, radioactivity, and weight. For postclosure performance assessments, data and simulations are needed for only those radionuclides important to demonstrating compliance with postclosure regulatory standards for radionuclide releases and radiation doses. The following 39 radionuclides were included in Total System Performance Assessment -1995: actinium-227, americium-241, -242M, and -243, carbon-14 (gaseous), cesium-135, chlorine-36 (gaseous), curium-244, -245, and -246, iodine-129 (gaseous), lead-210, neptunium-237, nickel-59 and -63, niobium-93M and -94, palladium-107, plutonium-238, -239, -240, -241, and -242, protactinium-231, radium-226 and -228, samarium-151, selenium-79, technetium-99, thorium-229, -230, and -232, tin-126, uranium-233, -234, -235, -236, and -238, and zirconium-93. Since radionuclide characteristics are well known, they have not been not selected as performance confirmation parameters.

From the waste package parameter list, 35 parameters have been selected as performance confirmation parameters, of which 28 are key performance confirmation parameters. Some of these parameters, such as the chemical composition of waste package barrier corrosion products, include more detailed characteristics, resulting in a larger number of key performance confirmation parameters. The selected parameters are briefly described in the following section.

2.5.4.5.1 Waste Form Characteristics (e.g., of Spent Fuel and Glass Defense High-Level Waste)

Waste form characteristics include parameters for all potential waste forms that may be considered for emplacement in a potential Yucca Mountain repository, including spent fuel, distinguishing between boiling water and pressurized water reactor fuel; burnup rates; and other differences in the geometry and radiological composition of the spent fuel important from a postclosure performance standpoint. It includes defense high-level waste glass, again distinguishing between types, as necessary, for postclosure performance assessment. Also needed would be characteristics of other wastes such as foreign radioactive waste, to be emplaced, as authorized by any future national nuclear waste policy act.

Since the waste containers will be sealed and the inside environment will be chemically inert, it is expected that confirmation of some of the parameters in this section will not be necessary unless there is a waste package breach. Accordingly, confirmation of these parameters, requiring retrieval and analysis of a waste package, will be undertaken only if a breach is suspected or detected. The determination of some parameters, including various aspects of waste form oxidation and dissolution and waste package material galvanic protection, will be a continuation of an ongoing, offsite laboratory research since sufficient knowledge is not expected to be available when the License Application is submitted.

Geometry/Dimensions of Waste Form–For high-level waste glass or intact spent fuel, the initial geometry and dimensions of the total waste form within the waste package will be known from the specifications for the waste form and from studies of test materials. For failed fuel, additional information on the nature of the failures will presumably be collected at the time of waste acceptance. The geometry of the waste form is needed principally for analyzing ground-water and humid air contact, waste dissolution, and potential internal waste package criticality.

Since the inside of a waste package will be an inert environment, significant changes to the geometry and dimensions are not expected in an intact waste package. Accordingly, measurements should be undertaken only if containment failures are detected, in which case, changes to the geometry and dimensions should be determined by opening the disposal container and examining the waste. It is viewed as a target of opportunity. The waste should be examined first by nondestructive methods, then by destructive methods if warranted. Nondestructive methods include inspection of accessible cladding surfaces to estimate the amount of cladding oxidation that has occurred and to determine the sizes and locations of cladding breaches. To detect cladding breaches on interior fuel rods, the fuel assembly could be immersed in water and the water analyzed for actinides and fission products. If nondestructive methods prove to be inadequate, destructive tests should be considered. Destructive testing would require removal of end fittings and cutting of spacer grids so that each fuel rod would be accessible for inspection.

Geometry/Dimensions of Waste Pellets/Particles–As with the total waste form geometry, the geometry of the waste pellets or particles is needed primarily for analyzing ground-water and humid air contact, waste dissolution, and potential internal waste package criticality. The performance confirmation efforts for this parameter should be dependent on measures taken to confirm the geometry and dimensions of the waste form as discussed above. Since fuel pellets or particles are

encased in cladding, no degradation of the fuel is expected if the cladding is intact. However, since the cladding also renders ineffective the methods described in the previous section, additional destructive tests would be necessary. These could include sectioning of fuel rods and microscopy to determine the volume of fuel that has been oxidized, and x-ray diffraction to identify the oxidized phases and their quantities. Sectioning of fuel rods would also allow determination of the thickness of the remaining cladding.

Surface Area of Waste Pellets or Particles–The surface area of the waste pellets or particles is one of the more important parameters for calculating waste dissolution. This parameter will change as the result of both oxidation of the fuel and dissolution. As for the parameter geometry/ dimensions of waste pellets/particles discussed, the performance confirmation efforts for this parameter should be dependent on measures taken to confirm the geometry and dimensions of the waste form. Since the cladding encases the fuel, destructive testing is necessary. The fuel rods would be sectioned and samples taken for surface area determination. Appropriate methods include quantitative microscopy and the Brunauer-Emmett-Teller adsorption method. Mercury porosimetry would produce a mixed waste and should be avoided if possible.

Weight and Radioactivity of Each Radionuclide–The weight and radioactivity of each radionuclide are needed to determine radiation in the vicinity of the waste package and radionuclide release from the waste form. Since the two are interrelated through well-established physical ratios, only one or the other needs to be defined as a design parameter. The weight and activity change with time because of radioactive decay, waste dissolution, and radionuclide transport from the waste form into the repository excavation. With the possible exception of failed spent fuel, the initial weight of each radionuclide in the waste form will be known, at least approximately, from waste characterization or neutronic calculations. For failed spent fuel, the weights for intact spent fuel will provide an upper bound on the weight of each radionuclide.

While the waste containers remain intact, changes in the weights will be readily predicted by decay calculations, and no performance confirmation effort is needed. If waste container failures are detected during the performance confirmation period, the containers should be retrieved and inspected or tested, as discussed in the previous sections. As needed, additional tests or measurements may be performed to determine the amount of release. Possible measurements include sampling of emplacement drift surfaces to measure the level of contamination.

Gas Composition Inside Fuel Element–The isotopic composition and quantity or activity of radioactive gases within the spent fuel elements are needed for calculating radioactive gas release from the waste packages and potential internal criticality. The principal radioactive gases from a radiological risk perspective include carbon-14, chlorine-36, and iodine-129. The same discussion for other waste form parameters applies regarding confirming internal spent fuel element gas compositions.

Dry Oxidation Rate–The question of dry oxidation products is closely related to that of dry oxidation rates. Experiments to date have shown that oxidation of UO_2 to U_4O_9 is significantly faster than oxidation of U_4O_9 to U_3O_8. Both oxidation steps have a strong temperature dependence. For isothermal exposure at a modest temperature (< 250°C), oxidation to U_4O_9 proceeds essentially to

completion, but further oxidation has not been detected. At higher temperatures (325°C to 360°C), the fuel oxidizes rapidly to U_3O_8.

Dry oxidation rate is of interest because it determines the amount of each oxide that is available for dissolution, and different oxides may have different dissolution rates.

Dry Oxidation Products–Uranium can take on various oxidation states, so it has different oxide forms. Nuclear fuel is normally called uranium dioxide (UO_2), but it contains a small amount of excess oxygen; a typical composition is $UO_{2.02}$. Uranium dioxide is essentially stable in air at or near room temperature, but at slightly elevated temperatures, it can react to form higher oxides. Upon exposure to an oxidizing environment at appropriate temperatures, uranium dioxide oxidizes to U_4O_9 and eventually to U_3O_8 (Einziger 1994, p. 554). Uranium dioxide contracts slightly on oxidation to U_4O_9, but it expands by about 36% on oxidation to U_3O_8 (Lide 1995, p. 4-94). The initial contraction tends to increase the free space inside the fuel cladding, but the subsequent expansion will cause the fuel to expand and press against the cladding. Oxidation to U_3O_8 is particularly harmful for system performance in that it can split the cladding and increase exposure of the fuel to the environment.

Because of the changes in volume and crystal structure that accompany oxidation of uranium dioxide, oxidation tends to degrade the mechanical integrity of the fuel. Oxidation to U_4O_9 cracks the grain boundaries and increases surface area; oxidation to U_3O_8 reduces the fuel particles to a fine powder and increases surface area even more.

Since there is no source of free oxygen in either an intact waste package or an intact fuel rod, fuel cannot oxidize unless the containment barriers and the cladding are all breached. Dry oxidation can therefore be prevented by keeping the cladding intact or by providing containment barriers that will control the supply of air until the fuel temperature has dropped.

Dissolution Rate of Original Waste Form–It is expected that most of the spent nuclear fuel will be protected from oxidation (by either the containment barriers or the cladding) for a long time. As a result, the fuel will be in an inert environment until most of the radioactive decay heat is gone and temperature has dropped to nearly ambient conditions. If this scenario applies, the fuel will remain essentially unchanged by oxidation, and the dissolution rate will be that of the original waste form. The dissolution of the original waste form would thus be important in predicting releases from the engineered barrier system.

Dissolution Rate of Oxidation Products–Some of the spent nuclear fuel may be exposed to air while the repository is still hot. If the temperature is high enough, this fuel would be expected to oxidize as described under "Dry Oxidation Products" above. The dissolution rate of the higher oxides may be different from that of UO_2, so the intrinsic dissolution rate for each of the oxides must be known for predicting the releases from the engineered barrier system.

2.5.4.5.2 Geometry of Waste Package

The initial geometry of the waste packages is defined by the waste package design, which is expected to be verified for the actual waste packages at the time of waste acceptance. The geometry is expected to change with time because of thermal-mechanical stresses from the waste heat and from potential rock falls and emplacement drift collapse and waste package barrier corrosion.

Corrosion Effects on Barrier Thickness and Shape–Corrosion is expected to thin and roughen the containment barriers over time, which affects the mechanical integrity of the barriers and corrosion, potentially leading to weakening and eventually failure of the barriers. Because of importance in waste package degradation, a significant effort has been expended on corrosion research and additional effort during performance confirmation is appropriate.

During the preclosure period, the spent-fuel and high-level radioactive waste containers will be hot, and with few exceptions, are expected to remain dry, so there will be little corrosion of the containers. As a result, there is little to be gained by measuring changes in barrier thickness by retrieving and inspecting or testing actual waste containers. Alternative methods must be used.

One alternative method is to develop a section of the repository for performance confirmation. This section might be left unheated to simulate the low temperatures and high humidities that will prevail at long times. These conditions are expected to increase the aggressiveness of the environment and thus make measurement of corrosion rates and depths more practical. Monitoring and retrieval of samples from the performance confirmation section would be straightforward because there would be no radiation field and the temperature would be low.

A second alternative method is to use laboratory tests. These could simulate anticipated conditions, or they could impose more severe conditions to accelerate corrosion or account for conditions that are unexpectedly severe.

Except in an accelerated laboratory test, the amount of corrosion that occurs during the preclosure period is unlikely to be sufficient to cause a waste container to fail. Accordingly, experiments must be supplemented by structural analysis. Structural analyses of degraded waste containers are in progress and should be completed before the License Application. Little additional analysis should be needed during performance confirmation.

Mechanical Effects on Barrier Thickness and Shape–Ground support for the emplacement drifts may eventually degrade to the point that rocks fall from the crown of the drifts. Fallen rocks could eventually fill the drifts. One of the largest uncertainties regarding this parameter is the size of the rocks that will fall and the time of occurrence and frequency of rock falls. Since these reflect the properties of the host rock, laboratory measurements are not particularly helpful, and in situ monitoring is required.

During the preclosure period, it is expected that there will be little degradation of the waste containers and only modest degradation of the ground support. The performance confirmation effort should accordingly be fairly small. For waste packages subjected to large rock falls for which significant mechanical damage is suspected, retrieval should be retained as a possible contingency measure.

Because of the mechanical strength of the waste containers, it is unlikely that any rock falls will cause mechanical damage of the containers during the preclosure period. However, characterizing debris found in the emplacement drifts will provide data that could be used to develop a distribution of rock sizes and fall frequencies. Such a distribution could be combined with structural analyses of degraded waste containers to predict the rate of mechanical failures.

Location and Geometry of Criticality Control Materials–Current waste package designs call for criticality control by a "basket" of borated stainless steel. The basket is an assembly of slotted, interlocking plates that form a set of square cells inside the disposal container. The plates separate each fuel assembly from its neighbors. The boron in the plates is a strong neutron absorber and will effectively prevent nuclear chain reactions.

Because of the inert environment inside an intact waste package, no degradation of the basket is expected before the containment barriers are breached. At that time, humid air and even liquid water may begin to enter the package. Although the rate of filling is expected to be slow, the waste package could fill with water and result in corrosion of the basket materials. If that situation occurs, the rate of corrosion and the transport of boron from its original location will have significant effects on the control of criticality.

Because of the long waste package containment lifetime and the small rate of filling, it is not possible to study degradation of the basket materials in actual waste packages. Instead, the basket materials may be exposed directly to air in unheated drifts to simulate degradation in a breached package at times long after emplacement. Corrosion rates may also be measured for samples immersed in a suitable corrodent, possibly in the presence of a radiation field.

Damage to the criticality control materials could conceivably occur as a result of rock fall and mechanical damage to an unbreached waste package. As with mechanical effects on barrier thickness and shape, retrieval should be retained as a possible contingency measure to be used for waste packages that are subjected to large rock falls and for which significant mechanical damage is suspected.

2.5.4.5.3 Corrosion and Other Degradation Characteristics of Each Waste Package Barrier

Characteristics of waste package barrier degradation address various forms of corrosion resulting from dry and humid air and from water. The performance confirmation methods for these parameters rely on retrievable samples, coupons, rather than on retrieval of entire waste packages. An exception is cladding failure rate, discussed in the following section and for which performance confirmation relies on laboratory tests. Samples tested in a laboratory could be exposed to whatever environment is deemed appropriate. Retrievable samples placed in the repository could be either clamped to actual waste packages or exposed to ambient conditions in a performance confirmation

section of the repository. The former location closely replicates the environment of the actual waste package materials; the latter may approximate the conditions that will prevail at long times. Because of the substantial thermal conductivity of the containment barriers. the outer surface of the waste package will be essentially isothermal, and the position of a sample on the waste package will be immaterial. To determine the effects of welding, some of the samples would presumably include weld joints.

Polarity of Current for Galvanic Protection–Corrosion of metals involves both anodic (oxidation) reactions and cathodic (reduction) reactions. At the anode, metal atoms are oxidized and electrons are produced; a typical anodic reaction is $Fe \rightarrow Fe^{++} + 2e^{-}$. The electrons flow through the unoxidized metal to the cathode, where they are consumed by a cathodic reaction such as $H_2O + \frac{1}{2}O_2 + 2e^{-} \rightarrow 2OH^{-}$ or $2H^{+} + 2e^{-} \rightarrow H_2$. To maintain the electrical neutrality of the metal, the rate of electron production by the anodic reactions must equal the rate of electron consumption by the cathodic reactions.

In cathodic protection, two dissimilar metals are electrically coupled. One of these is designed to be the anode; the other is designed to be the cathode. The anode corrodes sacrificially to protect the cathode. If the polarity of the current is reversed, however, the anode and cathode are also reversed, and the wrong metal corrodes.

In current waste package designs, the corrosion resistant barrier is intended to be cathodic to the corrosion allowance barrier. If the corrosion allowance barrier is breached, the remaining area of the corrosion allowance barrier serves as an anode to protect the exposed portion of the corrosion resistant barrier.

Common Potential for Galvanic Protection–If a metal sample corrodes in isolation, its potential eventually reaches a constant value called the free corrosion potential. In cathodic protection, however, the two metals are electrically coupled, so they are forced to be at the same potential. This potential will be somewhere between the free corrosion potentials of the two individual metals, and the exact value will depend on the exposed surface areas of the two metals and the details of their electrode kinetics.

The value of the common potential is important for cathodic protection because the corrosion rate is a function of the potential. For effective cathodic protection, the common potential must be one that produces a very low corrosion rate for the protected part.

Threshold Humidity For Humid-Air Corrosion–The value of this parameter defines at what relative humidity, humid-air corrosion of a waste package barrier will start. It is therefore an important parameter for predicting the containment period for the waste and the eventual release of radionuclides from the waste packages. The relative humidity of the emplacement drifts is expected to drop during construction and emplacement as a result of ventilation. After emplacement, the humidity is expected to drop further because of heating by the waste packages. The humidity in the emplacement drifts during the preclosure period is therefore expected to be below the threshold for humid-air corrosion.

The threshold humidity will depend on the type and amount of contamination that is present on the waste package surface. Contaminants may include oils, salts, and dust. It would be appropriate to place coupons of the outer barrier materials in a few selected emplacement drifts. The coupons would be retrieved after several years and used in experiments to determine the threshold humidity for the contamination that had accumulated.

Dry Oxidation Rate–This parameter represents the rate of uniform waste package barrier corrosion caused by dry emplacement drift air. It is expressed as the change in barrier thickness as a function of time. Dry oxidation is expected to be negligible for the corrosion resistant materials, which form a thin, highly protective oxide coating upon exposure to air. The depth of dry oxidation is also expected to be small for the corrosion allowance materials because of the modest surface temperature of the waste packages. Dry oxidation might be studied by the methods used for humid-air general corrosion, as discussed below. To determine how much damage is due to each mechanism, however, laboratory tests in dry air would probably be necessary.

Humid-Air General Corrosion Rate–This parameter represents the rate of uniform waste package barrier corrosion caused by the moisture in the emplacement drift air, expressed as the change in barrier thickness as a function of time. As previously discussed, the relative humidity in the emplacement drifts is expected to be below the threshold for humid-air corrosion during the preclosure period, so measuring the general corrosion rate by inspecting filled waste containers would be ineffective. Two effective approaches would be to expose coupons in a performance confirmation drift and to continue laboratory studies on humid-air corrosion. Both of these are discussed in Section 2.5.4.5.2.

Aqueous General Corrosion Rate–This parameter represents the rate of uniform waste package barrier corrosion caused by bulk liquid water contacting a waste package barrier, expressed as the change in barrier thickness as a function of time. No aqueous general corrosion is expected during the preclosure period. In contrast to humid-air corrosion, aqueous corrosion is also not expected if samples are exposed in a performance confirmation drift. Information on aqueous general corrosion can therefore be obtained only by laboratory tests.

Preparation is nearly complete for tests to determine general corrosion rates in a variety of aqueous environments. A large number of samples will be exposed for several years. It is expected that many of these tests, particularly those in aggressive environments, can be discontinued after a few years since the corrosion rates will be shown to be unacceptably high. A smaller number of experiments might be continued through the performance confirmation period to demonstrate that the corrosion rate continues to be acceptably low.

Humid-Air Pit Corrosion Rate–This parameter represents the rate of pit initiation, spatial distribution, and growth on a waste package barrier caused by the moisture in the emplacement drift air, usually expressed as the change in pit depth as a function of time. If pitting in humid air occurs, the pit depth and pit density, the number of pits per unit surface area of the waste package barrier, can be measured from samples intended for measurement of humid-air general corrosion. See the paragraph on humid-air general corrosion rate.

Aqueous Pit Corrosion Rate–This parameter represents the rate of pit initiation, spatial distribution, and growth on a waste package barrier caused by liquid water contacting a waste package barrier, usually expressed as the change in pit depth as a function of time. Like aqueous general corrosion, aqueous pitting corrosion rates can only be measured effectively in the laboratory. However, experiments on pitting are more difficult than those on general corrosion because pitting often requires a long initiation time. Since the corrosion rate accelerates upon pit initiation, simply monitoring a sample with no pits is apt to produce severe underestimates of the degradation rate.

A possible method for overcoming this difficulty is to study pit repassivation. By imposing an anodic potential on the sample, pits would be forced to initiate. The potential would then be removed and the sample allowed to reach its free corrosion potential. If the pits stop growing, repassivating, pitting does not occur for the environment under test.

If the chemistry of water for a waste package exposed to dripping water can be determined, only a few samples need be used to determine pitting behavior.

Microbial Corrosion Rate–Many metals are subject to microbially influenced corrosion. For actual waste packages, the surfaces are expected to be hot and dry, and therefore hostile to microbial growth, during the preclosure period. As a result, microbial corrosion tests must be performed in the laboratory. Water chemistries relevant to repository conditions, and nutrient supplies, other than the metal, should be strictly limited. Although the emplacement drifts may be sterilized by heat and radiation during the preclosure period, it is expected that microbes will eventually be transported to the drifts by water flow in fractures. Accordingly, the metal samples should be tested with various microbes, or mixtures of microbes, that are typical of Yucca Mountain.

Cladding Failure Rate–Fuel cladding is subject to degradation by a variety of mechanisms. For fuel in an intact or perforated waste package, perhaps the most important degradation mechanisms are creep rupture of the cladding, oxidation of the cladding, and oxidation of the uranium dioxide fuel. All three mechanisms are thermally activated. Creep rupture is driven by the pressure of gas inside the cladding. This mechanism can proceed in an inert environment, but it is expected to produce only tiny breaches in the cladding. Oxidation of the cladding and fuel both require an oxidizing environment, so they will not occur in a waste package while at least one containment barrier is intact. In addition to the mechanisms listed above, the cladding may fail as a result of mechanical stress if the container is degraded to the point of losing its own mechanical integrity.

Disposal containers are being designed to control all three types of degradation, so retrieval of waste packages is not expected to provide significant new insights. Instead, laboratory studies are suggested if current understanding is inadequate for confident prediction of future performance. Currently, studies of fuel oxidation are in progress; however, studies of oxidation, creep rupture, and mechanical properties of irradiated cladding may also be required.

2.5.4.5.4 Chemistry of Each Waste Package Barrier, Including Degradation Products but Excluding Backfill

The initial composition of the containment barriers will be set by specifications for the materials and compliance of the compositions with the specifications will be verified as part of the quality assurance program for manufacturing. The composition of the metallic part of the barriers will not vary with time, but the composition of the corrosion products may depend on the conditions under which corrosion occurs. The composition may be significant in revealing the mechanisms of corrosion.

An appropriate performance confirmation effort is to analyze the composition and structure of products of corrosion observed on coupons retrieved from the performance confirmation section of the repository. If corrosion is observed on actual waste containers, it may also be worthwhile to collect samples of these for analysis.

Gas Composition Inside Waste Container–The current waste package design includes the injection of helium into the waste container during waste package fabrication (CRWMS M&O 1996m). When the containment barriers are breached, the helium will gradually be replaced by air. Air in a hot waste package could result in oxidation of the fuel and cladding. If waste packages are retrieved from the repository, it would be appropriate to determine the composition of the fill gas and estimate the rate of leakage. It is possible that the gasses within the waste package will have equilibrated to ambient conditions before the breach could be detected. An analysis should be performed to determine the likelihood of a breach being detected and there still being helium in the waste package. Depending upon the results of the analysis, this parameter would need to be reevaluated as a performance confirmation parameter.

Chemical Composition of Criticality Control Materials–Degradation of criticality control materials has been discussed. However, corrosion of these materials does not, in itself, reduce their ability to control criticality if the neutron absorbing nuclides remain in place, trapped in the products of corrosion. Through laboratory experiments, this performance confirmation effort can clarify the amount of boron that will remain in the corrosion products. This effort will be integrated with the effort described.

No change in the composition of the criticality control materials is expected while the containment barriers are intact, so waste package retrieval will not be used to confirm this parameter unless a container breach is suspected or detected.

The borides in the criticality control materials are distributed as discrete particles, not as a continuous phase. Accordingly, there will be no chemical attack on a given boride particle until the surrounding matrix is removed and the particle is exposed to the corrodent.

Oxidation Product Composition–Efforts to determine the composition of the products of dry oxidation will be integrated with measurements of the dry oxidation rate as described. Samples of the products of oxidation from laboratory tests will be examined by x-ray diffraction and scanning electron microscopy. The examinations are expected to show which oxide phases are present, what their compositions are, and whether their structure is compact or porous. Information on the oxides

and their structure will be helpful in understanding the oxidation mechanisms. Like dry oxidation rate, oxidation product composition can be confirmed by retrieving samples. This issue is discussed in Section 2.5.4.5.3.

Aqueous Corrosion Product Composition–As with the determination of oxide product composition, efforts to determine the composition of the products of aqueous corrosion will be integrated with measurements of aqueous corrosion rates as described above. Samples of the products of oxidation from laboratory tests will be examined by x-ray diffraction and scanning electron microscopy. As for dry oxidation, the examinations are expected to show which oxide phases are present, what their compositions are, and whether their structure is compact or porous. Information on the oxides and their structure will be helpful in understanding the corrosion mechanisms. Like aqueous general corrosion rate, aqueous corrosion product composition can be confirmed by retrieving samples. This is discussed in Section 2.5.4.5.3.

Physical/Chemical Degree of Embrittlement–Particularly for the corrosion resistant materials. long exposures to moderately elevated temperatures can lead to ordering and formation of brittle phases. For the container materials, these reactions are expected to be extremely slow even at the highest expected temperatures. Significant embrittlement of the container materials is not expected if the emplacement drifts are not backfilled. Somewhat greater embrittlement of fuel basket materials may occur, since they reach higher temperatures than do the container materials. Thermal embrittlement of both basket and container materials would be increased if the waste packages are covered with backfill. Confirmatory tests on basket materials may be appropriate. The tests would expose sample of the basket material to elevated temperatures for long periods of time. After exposures, the samples would be mechanically tested. If significant changes in mechanical properties are observed, microscopy and x-ray or electron diffraction might be used to determine which phases are present.

Embrittlement of metals can also occur upon exposure to gaseous hydrogen. Hydrogen gas can be generated by aqueous corrosion, particularly under acidic conditions. However, the expected rates of corrosion are so low that any hydrogen concentration will be low and hydrogen embrittlement will not be significant.

Thermal embrittlement can be studied by laboratory testing and by retrieving samples that are clamped to waste packages. Thermal embrittlement is extremely slow at ambient temperature, so no samples should be placed in an unheated performance confirmation section of the repository. As is discussed in Section 2.5.4.5.3, samples of container materials that are clamped to the surface of a waste package will experience conditions that closely replicate those of actual waste package materials. Accelerated tests can be performed in the laboratory by increasing the temperature.

Basket materials also will be subject to thermal embrittlement, but they will be at temperatures well above that of the waste package surface. For these materials, long-term laboratory tests can reproduce the conditions inside a waste package. Waste package retrieval could also be used, but it would probably be more expensive because each new sample would require retrieval of another package.

Physical/Chemical Weld Integrity–Because of nonuniformities in heating and cooling, the closure weld of the waste container is expected to produce stresses in the surrounding material. These stresses can be reduced by using a narrow groove geometry and vibratory stress relief. The ideal approach would be to heat treat the weld, but this maybe precluded by temperature limits that are intended to protect the fuel cladding. In any case, the initial stresses near the closure weld will be measured as part of the manufacturing development program. Chemical analysis of the weld and microstructural analysis of the weld and heat-affected zone will also aid in determining how the weld will affect container performance.

It is expected that one or more waste package mockups would be built and the closure welds thoroughly characterized by nondestructive and destructive testing. Such mockups would not contain waste and would never be emplaced. If additional confirmation of weld performance is desired, scale-model rings or rings and lids could be clamped to actual waste packages and later retrieved.

2.5.4.5.5 Mechanical Characteristics of Each Waste Package Barrier (Excluding Backfill)

Mechanical characteristics cover the physical properties of waste package barrier materials and stress, strain, and deformation.

In Situ Stress and Strain–The initial mechanical stress and resulting strain in the waste package barriers are caused by the manufacturing, including the closure welding process. They change with time because of the decay of waste heat, and after emplacement, because of potential rock falls, drift collapse, and corrosion.

During the period of performance confirmation, thermal effects are expected to be the most significant cause of changes in stress. Rock falls should be rare, and corrosion will not cause significant loss of material. As a result, the best way to confirm thermal stresses is to instrument and electrically heat a waste package mockup. In contrast to an actual waste package, a mockup would allow instrumentation of both internal and external components. The tests could be performed in a laboratory. Because of the relatively large thermal diffusivity of waste package materials, the gradual reduction in decay heating could be accelerated without significantly disturbing the steady state heat flows in the mockup.

2.5.4.5.6 Thermal Characteristics of Each Waste Package Barrier, Excluding Backfill

Thermal characteristics of the waste package barriers include the waste package center and exterior wall temperatures, and the thermal conductivity, thermal expansion coefficient, and heat capacity of each barrier material. These characteristics are important for predicting mechanical stress/strain/deformation of the waste package barriers, barrier corrosion, and waste dissolution. They also affect the thermal environment in the drifts and surrounding rocks. Only the barrier wall temperature was selected as a key performance confirmation parameter.

Barrier Wall Temperature–The waste package center temperature cannot be measured directly without violating the integrity of the containment barriers. It can be derived from measurements of waste package surface temperature using heat transfer models. Current models could be validated

by putting electrical heaters or even actual spent nuclear fuel into an instrumented disposal container, or by comparison with data from dry cask storage demonstration projects.

The primary reason for monitoring waste package center temperature would be to determine the amount of degradation of spent fuel cladding. However, that effort is justified only if credit is taken for the cladding. See Section 2.5.4.5.3.

If it is decided to monitor the surface temperature of actual waste containers, thermocouples could be attached to the surface of the containers. Thermal calculations indicate that the surface of the waste container is practically isothermal, so it is not necessary to determine a temperature distribution. Except during the initial heating phase, the temperatures are not expected to change rapidly, so an alternative method would be to measure temperatures periodically with temperature sensors on a remotely operated vehicle.

2.5.4.5.7 Waste Package Radionuclide Containment and Release for Each Waste Form, Waste Package Design, and Important Radionuclide

This category includes parameters that define the radiological performance of the waste forms and waste package. No waste package failure, and thus radionuclide release from the waste packages, is expected before repository closure. Radiation monitoring of the emplacement drift air, which is required as part of the environmental, health, and safety program, is expected to be sufficient to detect any radionuclide leakage from waste packages. Although none is expected to be detected, if it should occur, recovery of the defective waste package(s) may be required.

Waste Package Life or Time of Initial Radionuclide Release–The calculation of waste package life or time to initial radionuclide release, also called waste package containment period, is required by 10 CFR Part 60.113(a)(1)(ii)(A). Although no radionuclide release from waste packages is expected before repository closure, this is a key performance confirmation parameter because waste package recovery may be required if there should be a waste package failure before repository closure.

Radionuclide Release Rate from Waste Form–This parameter is an important input to the calculation of radionuclide release from the waste packages. This is a key performance confirmation parameter for the same reason as given for waste package life.

2.5.4.6 Backfill and Seal Parameters

TBD - Description of Seal Performance Confirmation Parameters
TBD - Description of Backfill Performance Confirmation Parameters

2.5.5 Expected Parameter Ranges and Regulatory Compliance

Performance confirmation activities need to confirm one or more of the following aspects of the performance confirmation parameters:

- Spatial interpolation and extrapolation of point measurements is within predefined bounds of error
- Temporal changes in parameter values resulting from the excavation and waste emplacement are within predefined bounds of error.
- Compliance with the regulatory postclosure performance standards of 10 CFR Part 60 can be demonstrated, in spite of changes to parameter values.

The first two aspects are the key considerations for designing the data acquisition methods, locations, and frequency for each parameter. The first aspect must be confirmed as subsurface excavation proceeds to obtain data before they are affected by waste emplacement. The second aspect must be confirmed over longer time periods during and following excavation and waste emplacement, (for some parameters until permanent repository closure) in order to measure the excavation and waste emplacement effects as functions of space and time. Deviations from the predefined limits will be used as screens for conducting additional analyses, like compliance assessments.

The third aspect relates to the evaluation of the collected data regarding expected regulatory compliance and is therefore of overriding importance. Deviations of individual parameter values between expected and measured values do not necessarily mean that regulatory standards cannot be met. Because of the nonlinear aspects of natural and engineered system processes, deviations by one parameter could be offset by deviations of another parameter and compliance with the regulations could still be possible. Consequently, the demonstration of regulatory compliance with the parameter values acquired during performance confirmation is more important and significant than the comparison of individual parameter values.

These considerations lead to two different approaches for evaluating whether the conditions of the natural and engineered barriers before permanent repository closure are as assumed in the License Application:

- Compare individual parameter values, including statistical measures such as averages and standard deviations
- Predict postclosure performance with the performance confirmation parameter values and compare with NRC requirements that are related to postclosure performance.

The first approach requires predicting values of parameters that are expected during the performance confirmation period and comparing the predictions with the actual measurements. This approach can be accomplished by predicting and comparing values at specific locations and times or by comparing some statistical measures of the parameters, like spatial averages and standard deviations at specific times, or running averages with time at specific points. Deviations from the limits would indicate the need to conduct analyses of the second approach.

The second approach is more meaningful from a regulatory standpoint since decisions regarding whether the site should be disqualified should be based on regulatory criteria related to overall system postclosure performance rather than on individual parameter values.

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3. CONCEPT OF OPERATIONS

This section describes the concept of operations for the Performance Confirmation Program. The first five subsections reflect the activities defined in Section 2.2.2 regarding performance confirmation related functions. These sections provide a description of the the Performance Confirmation Baseline, followed by a description of the performance predictions. The site monitoring and testing elements and associated test facilities and support concepts are discussed, and evaluations of the site monitoring and testing data are described. These evaluations include comparisons of the data with predictions and total system performance assessments. The identification and implementation of corrective actions are discussed for data that do not confirm assumptions or that indicates that limits established in the License Application have been exceeded.

The next sections of the concept of operations discuss several activities that must be performed to support the described activities. Reports and reporting of performance confirmation activities are discussed, as are training and quality control. The interim period test and evaluation activities are discussed, followed by a discussion on relationships with other test and evaluation activities. Finally, detailed test and evaluation planning requirements are discussed.

3.1 PERFORMANCE CONFIRMATION BASELINE DEFINITION

This section defines the contents of the Performance Confirmation Baseline, which will be established during site characterization and will develop information on subsurface conditions and natural systems important to postclosure performance. Changes in this baseline information as a result of site characterization activities will be monitored and analyzed. This information will be used to predict changes resulting from construction and operation.

Activities during the performance confirmation period will verify that actual subsurface conditions and changes resulting from construction and operation are within acceptable performance, and that the natural and engineered systems and components are functioning as required. This information will be used to support the License Application submittal to the NRC requesting amendments to receive and possess waste and to close the repository.

The performance measures of postclosure performance objectives and their limits will be included in the Performance Confirmation Baseline, which establishes the reference conditions or state of parameters or process variables important to waste containment and isolation. Predictions of expected values of these parameters and associated uncertainties will also be established. Test criteria, such as confidence levels for determining significance of deviations, will also be part of the Performance Confirmation Baseline. The predicted values, uncertainties, and test criteria could be used to establish limits on the deviations from these expectations. These tolerance limits or existing required limits will be included in the Performance Confirmation Baseline. Deviations from this baseline will be used as indicators of when additional analyses are needed. A draft version of the Performance Confirmation Baseline is provided in Appendix H.

3.1.1 Performance Measures and Limits

Performance measures will be defined for each postclosure performance objective. These measures will be used to show conformance with requirements on the mined geologic disposal system (MGDS) or structures, systems, and components important to waste isolation. These requirements will be defined in the technical document hierarchy. In particular, the *Mined Geologic Disposal System Requirements Document* (DOE 1996c) will establish performance requirements related to postclosure performance. It is expected that analysis will be the method specified to show conformance with these requirements. The method of conformance is typically specified in the conformance verification matrix. The requirement will be measurable and the specified limit will be verifiable. The information identified in the Performance Confirmation Baseline will be measurable, either by direct observation or through analysis of observed conditions. The performance measures and limits on the range of performance measures will be included in the Performance Confirmation Baseline. Deviations from these limits will be identified, appropriate analyses conducted, and appropriate action will be implemented.

3.1.2 Reference Site Characterization Information

The Performance Confirmation Baseline will contain information that establishes the state of a system, subsystem, component or condition, such as the geologic setting, that may change as a result of site characterization, construction or emplacement activities. The information collected during site characterization will be included as part of the Performance Confirmation Baseline. This information may include parameter sample means, observed ranges, standard deviations, or description of parameter distributions. This reference site characterization information will be established for each performance confirmation parameter. The level of completeness of site characterization will be when this information is compiled.

3.1.3 Predicted Performance and Uncertainties

The performance and uncertainties for each performance confirmation parameter will be predicted. These predictions will define the expected state of a system, subsystem, component or condition that may change as a result of site characterization, construction or emplacement activities. Uncertainties in the prediction of the parameter state will be established. This information may include estimates of parameter expected value, variance, or a description of the parameter distribution. These data may be both temporally or spatially variable. This information will be developed prior to construction and emplacement activities. Later, observations of the parameter will be made and an evaluation will be performed to compare observed values with the predicted values.

3.1.4 Test Criteria and Parameter Limits or Ranges

Test criteria for each parameter, which could be stated in the form of a confidence or significance level for statistical tests or in the form of parameter tolerance limits or ranges or screening levels, will be established. Since uncertainty is a part of many of the parameters, the test criteria will establish the required level of statistical significance or if the deviations between measured and predicted values are statistically significant. These criteria or limits will be established so that from observations of the parameters, predictions can be confirmed and deviations from the acceptable test

criteria can be evaluated. If the test criteria are not met, appropriate analyses will be conducted, and appropriate action will be taken.

3.1.5 Closure Criteria

The criteria for completing the Performance Confirmation Program and recommending the repository closure will be specified as part of the Performance Confirmation Baseline. Closure criteria are necessary to ensure that the *Performance Confirmation Plan* is sufficient to support the recommendation for closure. Performance confirmation is the program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine that the performance objectives for the period after permanent closure will be met. The closure criteria **TBD - MGDS closure criteria**, may specify the level of accuracy and adequacy needed and the duration of time in which additional information is obtained. The additional information obtained through the conduct of the Performance Confirmation Program will support evaluation of the postclosure performance objectives or the results of this program will identify information in the License Application that was unexpected, resulting in implementation of appropriate action.

3.2 PERFORMANCE PREDICTIONS

Confirmation of the performance of the natural and engineered barrier systems and the overall MGDS will include comparisons of model predictions with measured data. These comparisons will involve:

- Establishing a baseline of pre- and postclosure performance predictions before the submittal of the License Application
- Evaluating the accuracy and validity of the models for postclosure performance predictions after the submittal of the License Application
- Assessing changes in predicted compliance with regulatory requirements
- Affecting corrective actions if necessary.

This section describes the performance predictions that in conjunction with performance confirmation data will form the basis for these comparisons. The comparisons, evaluations and corrective actions are described in Section 3.4.

3.2.1 Pre- and Post-License Application Predictions

The following sets of performance predictions will be made:

- Pre-License Application predictions of the expected preclosure performance of the natural and engineered barriers using the License Application database. (Note: These preclosure predictions will be inputs to postclosure performance assessments.)

- Post-License Application predictions of the preclosure performance of the natural and engineered barriers using the performance confirmation data to evaluate any changes in the expected performance as a result of data changes or corrective actions, involving comparisons with the listed predictions

- Post-License Application predictions of the expected postclosure performance of the natural and engineered barriers and the overall MGDS using the performance confirmation data to evaluate changes in compliance with regulatory requirements. This involves comparisons with postclosure predictions in the License Application, which are not described here since they are not performance confirmation activities, but are part of the total system performance assessment for the License Application.

The first two activities involve modeling of specific processes for predicting parameter values to be measured in the site monitoring and test activities of the performance confirmation program. The specific analyses for the first two activities and their relevance to site monitoring and test activities are described in Section 3.2.2. The third activity involves modeling the processes important for overall MGDS postclosure performance, as described in Section 2.4. The interrelationships of these activities with respect to timing and scope are depicted in Table 3-1. The table lists not only the performance predictions described in this section (first table row for each activity), but also the performance confirmation and associated activities described in Section 3.4.

Table 3-1. Timing, Scope and Data of Performance Predictions

Act.	Timing	Scope	Data Used
1	Once or twice before submittal of License Application	Predictions of preclosure natural and engineered system performance	Site characterization data and pre-License Application performance confirmation data
		Recommendations for model improvements, performance confirmation program changes, and MGDS design, construction and operation changes	
2	Repeatedly after submittal of License Application	Predictions of preclosure natural and engineered system performance	Site characterization data and pre- and post-License Application performance confirmation data
		Comparisons with pre-License Application preclosure performance predictions (Activity 1)	
		Evaluation of the accuracy and validity of the models	
		Recommendations for model improvements, performance confirmation program changes, and MGDS design, construction and operation changes	
3	Repeatedly after submittal of License Application	Predictions of postclosure natural and engineered system and overall system performance	Site characterization data and pre- and post-License Application performance confirmation data
		Comparisons with License Application postclosure performance predictions	
		Evaluations of regulatory compliance	
		Recommendations for model improvements, performance confirmation program changes, and MGDS design, construction and operation changes	

The first activity, as defined, precedes the submittal of the License Application. It may be performed twice: as soon as can be scheduled to provide initial guidance to the specifications for the performance confirmation site monitoring and testing; and shortly before the submittal of the License Application, using the same applicable data as used for the License Application.

The second and third activities are performed after the submittal of the License Application and could be performed in parallel or in sequence. These activities will be performed repeatedly to learn from the results of the measurements, testing, and modeling, and consequently, to affect model improvements, changes in the Performance Confirmation Program, and changes in the MGDS design, construction, and operation, if necessary. See Section 3.4. The intervals between these iterations will be determined on the basis of the results of previous iterations.

The new data and the advance of general knowledge and understanding of natural and engineered system and component processes may indicate the need for new conceptual and mathematical models and computer codes. Thus, the new predictions may be using new or changed conceptual and mathematical models compared to those used for the License Application. This situation could change the results of the performance predictions even if all other aspects, such as parameter values, repository layout, and waste emplacement, remain unchanged. Performance confirmation will include the effects of mathematical model and computer code changes regarding demonstrating compliance with the regulatory standards. Although the actual improvement of mathematical models and computer codes is not within the scope of performance confirmation, the evaluation will result in recommendations for model improvements, if needed.

Similarly, the new data and the advance of general knowledge and understanding of natural and engineered system and component processes may indicate the need for changes in the Performance Confirmation Program, involving additional measurement points or testing or reducing the scope of the planned measurements and testing. The evaluation will therefore result in recommendations for changes in the Performance Confirmation Program, if necessary.

And finally, the results of the predictions and associated evaluations may call for a change in the MGDS design, construction, and operation.

3.2.1.1 Pre-License Application Predictions of Preclosure Performance

The confirmation of postclosure performance has to rely on preclosure measurements and testing to demonstrate compliance with the postclosure standards of 10 CFR Parts 60.112 and 60.113. Performance assessment predictions are therefore required to establish the baseline for the expected behavior of the natural and engineered barriers from the beginning of construction, through waste emplacement, and for the caretaker period from the last waste emplacement until permanent repository closure. Through sensitivity and uncertainty analyses, these predictions will establish expected ranges of parameter values at the measurement locations and times of the planned testing and measurement activities. These predictions will provide feedback to the formulation of detailed test and measurement specifications, which could result in revisions of the planned testing and measurement activities.

To date, performance assessments have concentrated on the preclosure radiological safety of the workers and the general public (CRWMS M&O 1996d) and on the postclosure performance of the natural and engineered barriers (SNL 1992a; PNL 1993b; SNL 1994b; CRWMS M&O 1994; CRWMS M&O 1995c). In addition, design analyses and operational safety analyses have included waste package, drift stability, and ventilation analyses (CRWMS M&O 1996d).

However, complete analyses have not yet been performed that would predict the preclosure response of the natural and engineered system and components important for postclosure performance. The simulation period of previous postclosure performance assessments usually started with the permanent closure of the repository, assuming the final radioactive waste inventory at the beginning of the simulation period as the initial condition for the predictions. For performance confirmation predictions for the preclosure period, however, the planned progression of construction and waste emplacement will be considered.

Pre-License Application predictions of both preclosure and postclosure performance will be conducted as part of the total system performance assessment for the License Application. These analyses are expected to include all of the evaluations described in this Section and are included in the *Performance Confirmation Plan* for completeness. Predictions will be made for all processes to be evaluated and performance confirmation parameters to be measured. These predictions will predict the performance of the natural and engineered barriers during the preclosure period to provide the basis for the comparison with the performance confirmation data. The predictions will consider the planned progression of repository construction and waste emplacement, including the planned types and locations of wastes to be emplaced. The modeling analyses will include predictions of both in situ and laboratory measurements as defined in the performance confirmation site monitoring and testing concepts. The analyses will not predict the full three-dimensional transient state of the natural and engineered barriers, but will be tailored to predict the parameters to be measured only at the locations and times of the planned performance confirmation activities. The analyses will demonstrate, however, that the more limited analyses and measurements will be sufficiently representative of the total system behavior. The specific modeling analyses planned and their relationships to the planned performance confirmation site monitoring and testing concepts are described in Section 3.2.2.

3.2.1.2 Post-License Application Predictions of Preclosure Performance

The same modeling analyses of the expected preclosure performance of the natural and engineered barriers that will be performed before the submittal of the License Application will be repeated after its submittal. These predictions will use the original License Application database supplemented with the parameter values obtained by the performance confirmation site monitoring and testing. The purpose of these analyses will be to evaluate the adequacy of the conceptual and mathematical models for predicting natural and engineered barrier performance, that is, to establish the validity and accuracy of the models.

These predictions will consider not only the new data collected after the submittal of the License Application, but also the as-built conditions, the actual progression of repository construction and waste emplacement including the actual types and locations of wastes emplaced. The predictions will considered current repository layout and waste emplacement configuration. This includes any

changes during construction as a result of underground conditions encountered different from the assumptions in the License Application. The predictions will consider the time of actual waste receipt at the repository and the characteristics of the waste emplaced, such as the category of waste, radionuclide inventory, burnup rate, age at emplacement, and waste package barrier design may also be different from those planned. The specific modeling analyses planned and relationships to the planned performance confirmation site monitoring and testing concepts are described in Section 3.2.2.

3.2.1.3 Post-License Application Predictions of Postclosure Performance

The same modeling analyses of the expected postclosure performance of the natural and engineered barriers and of the overall MGDS that will be performed for the License Application will be repeated after its submittal. These predictions will use the original License Application database supplemented with the parameter values obtained by the performance confirmation site monitoring and testing. The purpose of these analyses is to evaluate the effects of changes, including site data, conceptual and mathematical models, and as built-waste package and repository conditions, on the predictions, and consequently, on the expected ability to comply with the regulatory standards of 10 CFR Parts 60.112 and 60.113.

These predictions will consider not only the new data collected after the submittal of the License Application, but also the as-built conditions at the time of repository closure. The new data will include the actual repository layout and the actual locations, types, and characteristics of wastes emplaced, and any unexpected changes, such as rockfalls and waste package recovery, before repository closure. These predictions will consider the current repository layout and waste emplacement configuration may include changes during construction as a result of underground conditions encountered that are different from the assumptions in the License Application. The predictions will considered the time of actual waste receipt at the repository and the characteristics of the waste emplaced, such as the category of waste, radionuclide inventory, burnup rate, age at emplacement, and waste package barrier design, may also be different from those planned.

3.2.2 Specific Preclosure Process Modeling

The confirmation of parameters includes confirmation that:

- Initial site properties, such as hydraulic conductivity and intrinsic porosity, inputs to process modeling, are as expected.

- Natural and engineered barrier variables, such as rock moisture content and waste package wall temperature, outputs of process modeling, are as predicted.

Establishing the baseline for the first aspect involves interpolating and extrapolating site parameter values measured at discrete points, such as in surface-based boreholes and in the Exploratory Studies Facility, during site characterization to obtain values for the entire mountain, usually at a numerical grid suitable for numerical modeling. This interpolation and extrapolation may be accomplished by simple arithmetic calculations, by calibration of mathematical process models, and by inverse process modeling. The values of the site properties are being developed as part of several conceptual

models of the site, including the geologic framework model (CRWMS M&O 1996a), the unsaturated zone hydrological model (LBNL 1997b), the unsaturated zone flow and transport model (LANL 1995a), the mineralogical model (LANL 1997a), the hydrochemical/geochemical model (USGS 1997a), the saturated zone flow model (USGS 1997c; USGS 1996b; LBNL 1997a), and the groundwater chemistry model (LANL 1997b). For performance confirmation, the site properties determined by these models will be compared with performance confirmation measurements.

Establishing the baseline for the second aspect involves predicting excavation- and waste-induced changes in site variables with models of specific processes. These modeling analyses are listed. Site monitoring and testing concepts, test facilities and support concepts, and site monitoring locations associated with each analysis are provided in bold italic type.

Some parameters do not require prediction for the preclosure period since they will not be affected by the repository construction and waste emplacement and since they are input, rather than output, of process modeling. Examples are topography, ground surface elevation; vegetation, plant type and areal distribution; climate and meteorology, precipitation, dry bulb temperature, atmospheric pressure, and relative humidity; and background radiation levels. Changes in these parameters, however, will be considered in other modeling. For instance, the infiltration resulting from actual rainstorms occurring during the performance confirmation period will be calculated to confirm expected ground-water percolation into the repository drifts from episodic weather events. These calculations would also consider the effects of changes in topography and vegetation on infiltration.

Other parameters do not have to be predicted for the preclosure period since the associated processes are not expected to occur during that period. Examples are radionuclide releases, including from the waste form, waste package, and engineered barrier system, from the unsaturated zone to the saturated zone, and to the accessible environment, both to the atmosphere above the repository and across the boundary of the controlled area in the saturated zone. Also included are associated gaseous and aqueous radionuclide concentrations. If unexpected releases should occur, however, radionuclide transport and radiological health risks would be modeled for health and safety reasons, rather than performance confirmation purposes.

Appendix E identifies performance confirmation parameters will be confirmed by:

- Direct measurements and testing, without model predictions
- Comparisons with conceptual model values
- Comparisons with the specific process model predictions for the preclosure period.

An important part of the last two parameter identification methods is to evaluate the validity and accuracy of the conceptual and mathematical models for the natural and engineered barrier processes. Although the measurements, testing, predictions, and comparisons are defined in terms of specific parameters, the most important aspect will be to confirm the understanding of the natural and engineered barrier processes that will be included in the License Application.

The following sections provide guidance for the type of modeling to be involved for performance confirmation. The descriptions in these sections are presented in a summary table format in Appendix E and Appendix F. Appendix E, *Modeling of Performance Confirmation Parameters*, identifies performance confirmation parameters that are parameters of specific process modeling. Appendix F, *Modeling of Performance Confirmation Concepts*, identifies the modeling planned for each site monitoring and testing concept. Duplication in the descriptions of specific parameter confirmations is occurring because different modeling requires similar or the same data. These confirmations need to be conducted as separate efforts even if the same parameters are involved, because different models, for example, may use different interpolations of spatially distributed data merely because they use different numerical grids.

3.2.2.1 Climate

No climatological and meteorologic modeling is planned for performance confirmation purposes. Confirmation will entail continued monitoring of meteorological parameters at the Yucca Mountain Project weather stations as part of the ***general surface-based testing*** (Section 3.3.1.5).

3.2.2.2 Tectonics

No modeling of tectonic activity is planned for performance confirmation purposes. Confirmation will entail continued monitoring of seismic activity at the Yucca Mountain Project surface seismic stations, the installation and monitoring of subsurface seismic stations in the potential repository by the ***subsurface seismic monitoring concept*** (Section 3.3.2.4), and site monitoring of seismic effects on faults and fault displacements and other site characteristics as part of other performance confirmation concepts.

3.2.2.3 Erosion

No erosion modeling is planned for performance confirmation purposes. Confirmation will include periodic ground-surface elevation surveys as part of the ***general surface-based testing*** (Section 3.3.1.5).

3.2.2.4 Volcanism

No volcanism modeling is planned for performance confirmation purposes. Confirmation will include periodic ground-surface elevation surveys as part of the ***general surface-based testing*** (Section 3.3.1.5).

3.2.2.5 Infiltration

Confirmation of infiltration involves the comparison of site unsaturated zone hydrological model assumptions with infiltration measurements during the preclosure phase. Infiltration assumptions will also be confirmed indirectly through calculation of percolation flux and measurement of rock moisture content at the potential repository level and in surface-based boreholes and comparisons with model predictions of percolation flux and rock moisture content. See sections 3.2.2.6 and

3.2.2.9. Direct confirmation of infiltration assumptions will be determined at selected times and locations of the ***general surface-based testing*** (Section 3.3.1.5) until repository closure.

3.2.2.6 Far-Field Unsaturated Zone Hydrology

Isothermal ground-water flow modeling will predict fluid flow in the unsaturated zone before waste emplacement and outside the thermally altered zone after waste emplacement. Confirmation of isothermal flow modeling assumptions and predictions will include:

- Ground-surface elevations assumed at geodetic survey points of the ***general surface-based testing*** (Section 3.3.1.5)

- Stratigraphy observed in non-emplacement areas, such as perimeter drifts and permanent observation drifts, and selected emplacement drifts as part of the ***subsurface geologic mapping and sampling*** (Section 3.3.1.1) during repository excavation.

- Hydraulic and pneumatic characteristics and the moisture content of the rock adjacent to the excavation locations where samples for laboratory hydrologic analyses will be taken as part of the ***subsurface geologic mapping and sampling*** (Section 3.3.1.1) during repository excavation.

- Rock temperature, moisture content, in situ fluid potential, and air pressure in the rock at the locations for the ***subsurface fault zone hydrology*** concept (Section 3.3.1.3) when fault zones are expected to be encountered during repository excavation.

- Rock temperature, moisture content, air pressure, relative humidity, and in situ fluid potential at the locations of instrumentation that measures these parameters in surface-based boreholes of the ***surface-based unsaturated zone hydrology concept*** (Section 3.3.1.2) from before waste emplacement until repository closure.

Note that although isothermal conditions are assumed in this modeling, rock temperature requires measuring to ensure that the assumption of isothermal conditions is correct.

3.2.2.7 Saturated Zone Hydrology

Saturated zone ground-water flow modeling will predict saturated zone ground-water flow and dispersion. Confirmation of saturated-zone ground-water flow and dispersion modeling assumptions and predictions will include:

- Ground-surface elevations assumed at geodetic survey points of the ***general surface-based testing*** (Section 3.3.1.5)

- Stratigraphy observed and hydraulic characteristics determined in surface-based boreholes penetrating the water table as part of the ***general surface-based testing*** (Section 3.3.1.5) after borehole drilling.

- Seasonal and annual change in water table elevations at water table boreholes as part of the ***general surface-based testing*** (Section 3.3.1.5) until repository closure.

- Seasonal and annual change in saturated-zone ground-water flux and the tracer dispersion and dilution at pump and tracer test times and locations as part of the ***general surface-based testing*** (Section 3.3.1.5).

- Potential changes in groundwater temperature and chemistry.

3.2.2.8 Geomechanics

Geomechanical and coupled thermal-mechanical modeling will predict mechanical stresses and deformation of the rock, including rock falls, surrounding the potential repository excavations. Confirmation of coupled thermal-mechanical modeling assumptions and predictions will involve:

- Ground-surface elevations assumed at geodetic survey points of the ***general surface-based testing*** (Section 3.3.1.5)

- Stratigraphy observed in permanent observation drifts and selected emplacement drifts as part of the ***subsurface geologic mapping and sampling*** (Sections 3.3.1.1, 3.3.4.5 and 3.3.4.6) during repository excavation.

- Thermal and mechanical characteristics of the rock adjacent to the excavation locations where samples for laboratory hydrologic analyses will be taken as part of the ***subsurface geologic mapping and sampling*** (Sections 3.3.1.1, 3.3.4.5 and 3.3.4.6) during repository excavation.

- Rock temperature, mechanical stress, strain, and deformation/displacement at the locations and for the duration selected for the ***thermal testing*** (Section 3.3.1.4).

- Rock temperature, mechanical stress, strain, and deformation/displacement in the ***permanent observation drifts*** (Section 3.3.4.1) and associated boreholes from before waste emplacement until repository closure.

- Temperature, mechanical stress, strain, and deformation/displacement of the rock adjacent to selected emplacement drifts for the ***remote observation and inspection of emplacement drifts*** (Section 3.3.2.5) from the time of excavation until initial waste emplacement in each drift.

- Size and location or related statistics of probable rock falls within selected emplacement drifts for the ***remote observation and inspection of emplacement drifts*** (Section 3.3.2.5) from the time of excavation until repository closure.

3.2.2.9 Near-Field Unsaturated Zone Hydrology

Coupled-thermal-hydrological and ventilation modeling will predict fluid flow in the unsaturated zone surrounding the potential repository and in the saturated zone beneath it as a result of expected surface infiltration and the effects of the excavations, including ventilation; and emplaced waste. Confirmation of coupled thermal-hydrological and ventilation modeling assumptions and predictions will include:

- Ground-surface elevations assumed at geodetic survey points of the ***general surface-based testing*** (Section 3.3.1.5)

- Stratigraphy observed in permanent observation drifts and selected emplacement drifts as part of the ***subsurface geologic mapping and sampling*** (sections 3.3.1.1, 3.3.4.5 and 3.3.4.6) during repository excavation.

- Hydraulic, pneumatic, and thermal characteristics and the moisture content of the rock adjacent to the excavation locations where samples for laboratory hydrologic analyses will be taken as part of the ***subsurface geologic mapping and sampling*** (sections 3.3.1.1, 3.3.4.5 and 3.3.4.6) during repository excavation.

- Rock temperature, moisture content, in situ fluid potential, and air pressure in the rock at the locations for the ***subsurface fault zone hydrology*** concept (Section 3.3.1.3) when fault zones are expected to be encountered during repository excavation.

- Rock temperature, moisture content, relative humidity, and air pressure at the locations and for the duration selected for the ***thermal testing*** (Section 3.3.1.4).

- Air temperature and relative humidity in the excavation at the ***in situ waste package monitoring*** locations (Section 3.3.3.2) for the duration of the testing.

- Rock temperature and moisture content of the rock adjacent to selected emplacement drifts for the ***remote observation and inspection of emplacement drifts*** (Section 3.3.2.5) from the time of excavation until repository closure.

- Air temperature and relative humidity in selected emplacement drifts for the ***remote observation and inspection of emplacement drifts*** (Section 3.3.2.5) from the time of excavation until repository closure.

- Rock, water, and air temperatures, rock moisture content, air pressure, relative humidity, and in situ fluid potential at the locations of instrumentation that measures these parameters in the ***permanent observation drifts*** (Section 3.3.4.1) and associated boreholes and from surface-based boreholes of the ***general-surface-based testing*** (Section 3.3.1.5) from before waste emplacement until repository closure.

3.2.2.10 Waste Package Degradation

Two types of modeling are planned. Waste package and near-field thermal modeling will predict temperatures on the waste package surfaces and the surrounding excavation walls. Waste package degradation modeling will predict waste package barrier, including cladding, degradation, principally the different forms of corrosion and their rates. See Section 3.2.2.17 for modeling planned waste form alteration modeling. Confirmation of waste package and near-field thermal modeling assumptions and predictions and of waste package degradation modeling assumptions and predictions will include:

Thermal characteristics of the rock surrounding the ***in situ waste package monitoring*** locations (Section 3.3.3.2) at the beginning of the in situ waste package monitoring, of the rock surrounding the ***permanent observation drifts*** (Section 3.3.4.1) prior to waste emplacement, and of the rock surrounding the selected emplacement drifts for the ***remote observation and inspection of emplacement drifts*** (Section 3.3.2.5) prior to waste emplacement.

- Temperatures, mechanical stress, and strain at the surface of actual and dummy waste packages at ***in situ waste package monitoring*** locations (Section 3.3.3.2) for the duration of the testing.

- Temperature at the surface of the waste packages and the excavation walls at the locations of instrumentation measuring these parameters through boreholes from the ***permanent observation drifts*** (Section 3.3.4.1) from before waste emplacement until repository closure.

- Temperature at the surface of real and/or dummy waste packages at the ***in situ waste package monitoring*** locations (Section 3.3.3.2) for the duration of the testing.

- Change in waste package barrier (including cladding) thickness of specimens exposed in ***off-site laboratory waste package testing*** (Section 3.3.3.1).

- Change in waste package barrier (including cladding) thickness of real and/or dummy waste packages as result of all significant forms of corrosion at the ***in situ waste package monitoring*** locations (Section 3.3.3.2) and as determined in ***recovered waste package testing*** (Sections 3.3.3.3 and 3.3.4.3), ***recovered dummy waste package testing*** (Section 3.3.3.4), and ***recovered nonradioactive specimen testing*** (Section 3.3.3.5).

- Change in waste package coupon barrier (including cladding) thickness at selected ***recovered nonradioactive specimen testing locations*** (Section 3.3.3.5) from the time of coupon emplacement until planned coupon removal and analysis.

3.2.2.11 Near-Field Radionuclide Transport

Near-field radionuclide transport modeling for performance confirmation purposes will be limited to establishing the input data for postclosure performance predictions. No preclosure radionuclide transport predictions are planned because no radionuclide release from the waste packages into the surrounding rocks and excavations is expected during the preclosure period. This assumption will be confirmed by ***emplacement drift ventilation monitoring*** (Section 3.3.4.2).

3.2.2.12 Far-Field Unsaturated Zone Radionuclide Transport

Far-field radionuclide transport modeling for performance confirmation purposes will be limited to establishing the input data for postclosure performance predictions. No preclosure radionuclide transport predictions are planned because no radionuclide release to the unsaturated zone is expected during the preclosure period. No confirmation of this assumption is planned.

3.2.2.13 Saturated Zone Radionuclide Transport

Saturated-zone radionuclide transport modeling for performance confirmation purposes will be limited to establishing the input data for postclosure performance predictions. No preclosure radionuclide transport predictions are planned because no radionuclide release to the saturated zone is expected during the preclosure period. No confirmation of this assumption is planned.

3.2.2.14 Geochemistry

Geochemical modeling will predict the geochemical environment in terms of ground-water composition, waste package degradation products, and introduced tracers, fluids and materials that may affect waste package degradation, waste form alteration, and radionuclide release and transport. Confirmation of geochemical modeling assumptions and predictions will include:

- Geochemical characteristics of the rock and ground-water adjacent to the excavation locations where samples for laboratory hydrologic analyses will be taken as part of the ***subsurface geologic mapping and sampling*** (sections 3.3.1.1, 3.3.4.5 and 3.3.4.6) during repository excavation.

- Ground-water chemistry at the locations and for the duration selected for the ***thermal testing*** (Section 3.3.1.4).

- Ground-water chemistry adjacent to the ***permanent observation drifts*** (Section 3.3.4.1) and associated boreholes from before waste emplacement until repository closure.

- Ground-water chemistry adjacent to the ***in situ waste package monitoring*** locations (Section 3.3.3.2) for the duration of the testing.

- Composition of chemical alteration products resulting from waste package corrosion at the ***in situ waste package monitoring*** locations (Section 3.3.3.5) for the duration of the testing.

- Composition of chemical alteration products resulting from ***recovered nonradioactive specimen testing*** (Section 3.3.3.5) corrosion for the selected locations and durations.

- For the ***remote observation and inspection of emplacement drifts*** (Section 3.3.2.5), the chemical alteration of tracers, fluids and materials in selected emplacement drifts introduced into the repository in the preclosure period and remaining after permanent repository closure, including steel, concrete, ground support, pedestals, etc., from their introduction into the repository until repository closure.

3.2.2.15 Human Interference

No modeling of human interference is planned for performance confirmation purposes because institutional controls will prevent any inadvertent human interference during the preclosure period.

3.2.2.16 Biosphere Radionuclide Transport

Biosphere radionuclide transport, including radiation dose exposure modeling for performance confirmation purposes will be limited to establishing the input data for postclosure performance predictions.

3.2.2.17 Nuclear Criticality

Nuclear criticality modeling for the preclosure period will address potential changes in the internal composition and geometry of the waste package and of near- and far-field conditions that could lead to nuclear criticality. Because nuclear criticality is not expected, confirmation will be limited to examining any changes in the waste package configuration during ***recovered waste package testing and off-site laboratory waste package testing*** (Sections 3.3.3.1, 3.3.3.3 and 3.3.4.3).

3.2.3 Postclosure Performance Modeling

No detail on specific process modeling is provided for the postclosure performance predictions because the modeling required will be determined by the analyses to be performed for the License Application, for which detailed plans have not yet been prepared. All processes and total system performance, as described in Section 2.4, are expected to be modeled for the postclosure performance predictions.

Total system performance assessment will combine the effects of all individual and coupled modeling and predict the performance of the overall waste isolation system with respect to the subsystem and total system performance standards. Total system performance assessment includes modeling of radionuclide release from the engineered barrier system, radionuclide transport from the potential repository to the accessible environment, and radiation doses to the public. Because none of that is expected to occur during the preclosure period, comparisons with measured data will not be needed, and the comparisons will be with the License Application predictions, including any changes in the assessment of compliance with the overall system postclosure performance standards.

3.3 TEST AND SUPPORT CONCEPTS

This section describes the performance confirmation concepts for measuring, monitoring, observing, and testing the performance confirmation parameters selected in Section 2.4 and evaluating the natural and engineered barrier processes described in Section 2.3. These concepts describe the types of activities necessary for performance confirmation data acquisition and for performance confirmation facilities and support. Each concept is defined, as applicable, in terms of the parameters to be confirmed and the facilities and equipment to be used. Generally, the concepts do not identify specific locations and frequencies for the activities, instrumentation, and site monitoring and testing procedures; these will be defined in separate design specifications and activity plans.

The performance confirmation concepts are organized into two major groups: site monitoring and testing concepts, and test facilities and support concepts.

Each group is then divided into subgroups corresponding to major MGDS components or evaluation approaches. The specific concepts for each group and subgroup are listed in Table 3-2.

Table 3-2. Performance Confirmation Concepts

Group	Subgroup	Package/Concept
1. Monitoring and testing concepts	Site monitoring and testing	Subsurface geologic mapping and sampling Surface-based unsaturated zone hydrology Subsurface fault zone hydrology Thermal testing General surface-based testing
	Repository monitoring and testing	In situ seals testing In situ backfill testing Follow-on drift heater testing Subsurface seismic monitoring Remote observation and inspection of emplacement drifts
	Waste package monitoring and testing	Off-site laboratory waste package testing In situ waste package monitoring Recovered waste package testing Recovered dummy waste package testing Recovered non-radioactive specimen testing
2. Test facilities and support concepts	Subsurface test facilities and support	Permanent observation drifts Emplacement drift ventilation monitoring Recovery of waste packages Alcove testing in non-emplacement areas Subsurface mapping during drift construction Rock sample collection during drift construction Remotely operated systems for emplacement drift monitoring
	Surface test facilities and support	Performance confirmation and multi-purpose hot cell Performance confirmation support area

The site monitoring and testing concepts are subdivided into three subgroups: site, repository, and waste package. This breakout is based on the initial categorization of parameters and the performance confirmation parameters table in Appendix D. Each parameter in that table is considered in the development of the concepts. The parameters are organized into logical groupings

for the types of instrumentation needed, the locations where information is needed, and the reasons for monitoring and testing the parameters. Each site monitoring and testing concept is supported by a test facilities and support concept, which include data and sample collection and handling.

The site monitoring and testing concepts are composed of a number of testing packages, including subsurface geologic mapping and sampling, surface-based unsaturated zone hydrology, subsurface fault zone hydrology, and thermal testing, and general surface-based testing.

The repository monitoring and testing concepts consist of in situ seal testing, in situ backfill testing, if required, follow-on drift heater testing, subsurface seismic monitoring, and remote observation and inspection of emplacement drifts. The remote observation and inspection includes visual, thermal, and radiological monitoring; remote manipulation for waste package coupon and sample recovery; and small rock debris removal.

The waste package monitoring and testing concepts include off-site laboratory waste package testing, in situ waste package monitoring, and testing of recovered waste packages and materials, including actual waste packages as a contingency, dummy waste packages, and materials specimen and coupons. The dummy waste packages would have the same dimensions, configuration, and materials as the real waste packages, but would contain heating elements instead of real waste to simulate the heat output of real waste packages.

The activities associated with these site monitoring and testing concepts will be performed in the repository subsurface, on the Yucca Mountain surface, and at onsite and offsite test facilities. A facility is considered onsite if it is located within the boundaries of the preclosure controllerd area, or of the postclosure controlled area, or both.

The test facilities and support concepts are divided into two subgroups: repository subsurface and repository surface. The subsurface test facilities and support concepts consist of permanent observation/monitoring drift(s), emplacement drift ventilation monitoring, recovery of actual waste packages for performance confirmation as a contingency, testing in alcoves in non-emplacement areas, interfaces of geologic mapping and rock sample collection with emplacement drift construction, and remotely operated vehicles for emplacement drift monitoring. The underground handling of data and samples are also considered, including interfaces with the subsurface site monitoring and testing concepts.

The surface test facilities and support concepts consist of a performance confirmation and multi-purpose hot cell (this area is also called the waste package remediation cell), which is located in the waste handling building, and a performance confirmation support area. Surface-based handling of samples and data is also considered and includes interfacing with the subsurface test facilities and support concepts, surface-based site monitoring and testing concepts, and offsite testing and analysis.

The performance confirmation concept chart (Figure 3-1) provides an overview of the concepts and indicates the flow of data and samples throughout the Performance Confirmation Program. Data and samples are collected with the site monitoring and testing concepts and processed through the test facilities and support concepts. The specific parameters obtained with each concept are also listed in the figure.

The figure depicts the two options for the surface processing of subsurface samples. depending on the sample type:

- A dummy or actual waste package, if necessary, recovered from the subsurface will be transported to the waste handling building (performance confirmation and multi-purpose hot cell). The output data will then be delivered to the performance confirmation support area; samples, if required, will be sent to an offsite laboratory. The data could be analyzed onsite or could be sent offsite for evaluation and reporting, and the findings as data returned to the performance confirmation support area, which will be the central location for all performance confirmation information.

- Rock samples and non-radioactive waste package specimens will be transported to the performance confirmation support area. The samples, if required, will be sent to an offsite laboratory and then the data will be returned. The option to perform onsite or offsite laboratory testing should be resolved though a trade study after further specification of the laboratory testing needs. The data could be evaluated onsite or could be sent offsite for evaluation and reporting and then results returned as data to the performance confirmation support area.

Output data from the subsurface, the surface, an offsite laboratory, or offsite evaluation and reporting will be sent to the performance confirmation support area. Any data could be analyzed onsite or followed by offsite evaluation and reporting.

3.3.1 Site Monitoring and Testing

The key performance confirmation parameters for design related to the natural barrier system are covered by four testing packages or concepts. This grouping simplifies the presentation of details on personnel, instrumentation, drilling, coring, sampling, laboratory analyses, and requirements for the repository operator who will conduct the post-License Application performance confirmation program. Future efforts will be needed within the testing community to develop detailed testing requirements in specific implementation documents.

3.3.1.1 Subsurface Geologic Mapping And Sampling

This concept will provide information on stratigraphy, such as lateral extent, depth, thickness, rock type, mineralogy, and fracture density; and characteristics of major fracture sets and faults, such as location, width, length, aperture, orientation, displacement, and mineralogy of in-fillings, from subsurface mapping and sampling. A sampling and offsite laboratory program to confirm subsurface conditions will be undertaken for performance confirmation parameters related to rock hydrologic properties, such as saturated hydraulic conductivity, effective porosity, moisture content, hydraulic potential-moisture content relationship, and moisture content-hydraulic conductivity relationship,

Performance Confirmation Concept

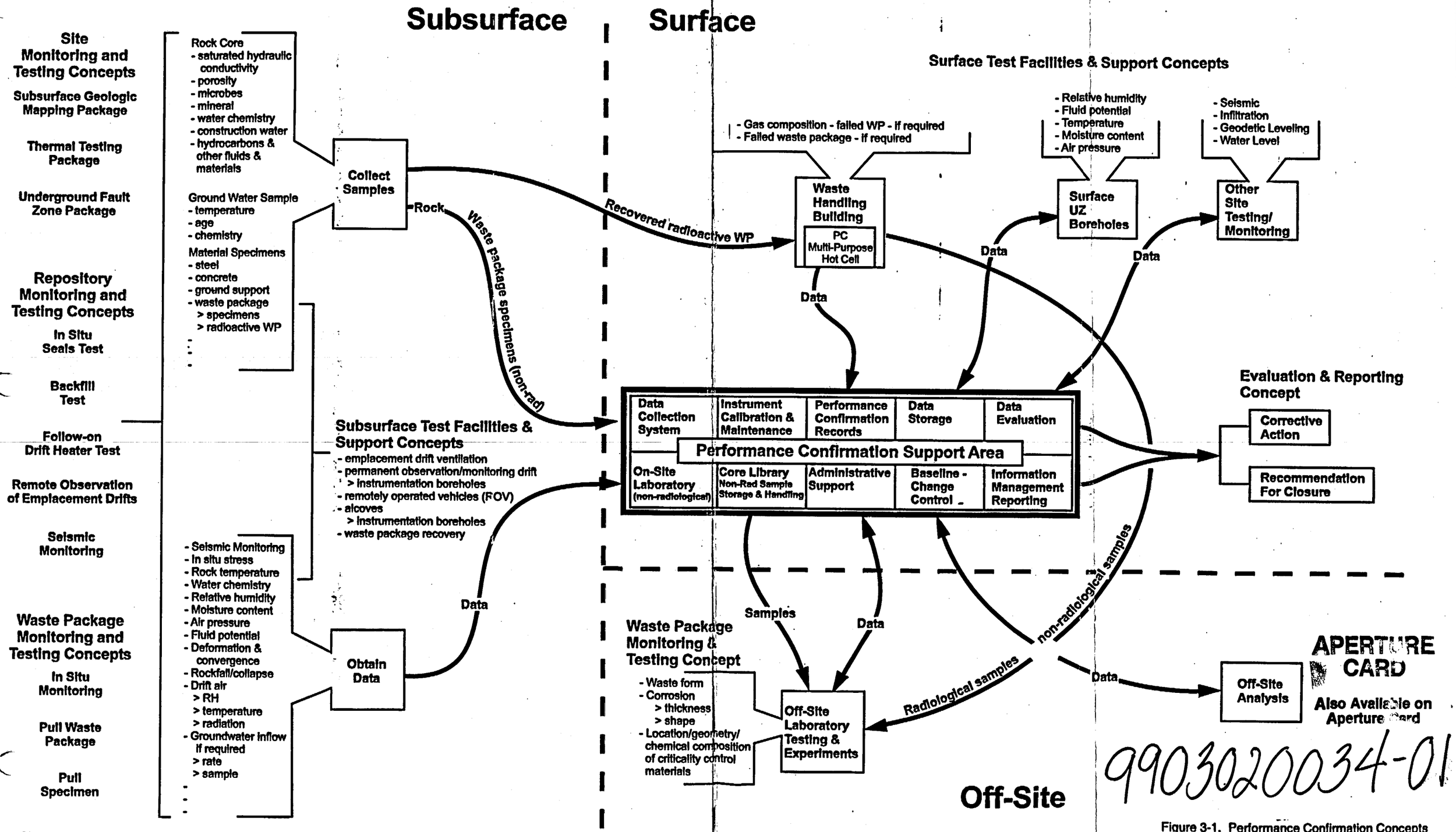

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Figure 3-1. Performance Confirmation Concepts

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as well as biological characteristics of fractures and faults. In addition, if unanticipated geologic conditions are encountered, it may become necessary to address issues related to percolation flux through the repository horizon, such as apparent ages of fracture minerals and apparent age of unsaturated zone water by environmental isotope measurements, such as Cl-36 and H-3. The performance confirmation parameters related to postclosure hydrocarbon and mineral resource exploration and extraction will be addressed if unanticipated geologic conditions are encountered. These contingencies will require sampling and offsite laboratory analyses.

The recommended strategy for mapping during repository construction is to: 1) map approximately 10 percent of emplacement drifts, based on the current drift spacing and layout; 2) map non-emplacement drift openings; and 3) observe rock mass conditions for anomalous conditions during construction. The rationale for mapping 10 percent of the emplacement drifts is that the frequency of mapped drifts is selected to assure intersection of features anticipated to affect repository performance. Present surface mapping shows several faults with approximately 200 - 300 m fault trace length within the repository block. Most of these faults are expected to penetrate the host repository horizon and extend downward to the water table. The importance of these faults to repository performance is currently uncertain. A frequency of mapping approximately 10 percent of the emplacement drifts, at the current spacing, would provide reasonable confidence of intersecting these surface mapped features at depth. The specific locations of the mapped emplacement drifts may also depend upon observations at the excavation headings. Also, detailed mapping of an emplacement drift near the Performance Confirmation observation drifts provides needed rock mass characterization for the thermal monitoring and testing of emplacement drifts. Appendix G, *Discussion on Strategy for Mapping*, provides additional information about mapping and the recommended strategy.

Some sampling for hydrologic data will require short intact core undisturbed by excavation processes. Other sampling could be performed by chipping off hand samples of varying size following excavation. The personnel collecting samples will have an understanding of the purpose of the samples. The laboratory facilities will not be required to be in close proximity to the repository and samples could be shipped to other appropriate facilities.

3.3.1.2 Surface-Based Unsaturated Zone Hydrology

This concept will provide rock and water temperature, gas pressure, moisture content, and in situ fluid potential, (derived from thermocouple psychrometer measurements of temperature and relative humidity, from surface-based borehole monitoring). The instrumentation should ideally be retrievable for recalibration and/or replacement since monitoring may take place until repository closure. Currently, the flexible borehole liner and Westbay systems provide some of these capabilities. Instrumentation required for this package will include: gas pressure, two borehole transducers per interval; in situ fluid potential, including temperature and relative humidity; two borehole thermocouple psychrometers per interval; moisture content, periodic borehole geophysical logging, neutron log.

In most cases, the instrumentation currently used in boreholes for site characterization is not ideal for long-term monitoring since it is frequently grouted in place and therefore is not retrievable. For this reason, new boreholes will be drilled. Where possible, the new boreholes will be located near

existing, well-characterized boreholes, using the same pad, which will make coring and direct measurement of geologic and hydrologic properties unnecessary. The nearby existing boreholes will be sealed, if a test interference evaluation indicates that need, to ensure that measurements in the instrumented new boreholes are representative of undisturbed rock mass conditions. Boreholes drilled away from existing boreholes will provide lithologic and hydrologic data by geophysical logging, as opposed to collecting core and conducting laboratory analyses. Multiple intervals will be packed off within each borehole and each of the major hydrogeologic units will be monitored: namely, the Tiva Canyon welded tuff hydrogeologic unit, the Paintbrush nonwelded tuff hydrogeologic unit, the Topopah Spring welded tuff hydrogeologic unit, and the Calico Hills nonwelded tuff hydrogeologic unit. The flexible borehole liner Pneumatic System currently being used by the United States Geologic Survey has this capability. The number and locations of boreholes to be monitored will depend on several factors, including the repository configuration and thermal load. These details will be included in separate design specifications and activity plans.

3.3.1.3 Subsurface Fault Zone Hydrology

This concept will provide rock and water temperature, gas pressure, moisture content, and in situ fluid potential, derived from thermocouple psychrometer measurements of temperature, and relative humidity, derived from subsurface monitoring and sampling. The instrumentation, identical to that described in the previous section, should ideally be retrievable for recalibration and/or replacement purposes, since site monitoring may take place until repository closure. See discussion of Surface-Based Unsaturated Zone Hydrology Package. Depending upon the results on current fault testing, site monitoring will be conducted in existing alcove(s) to continue to monitor transient conditions in the Ghost Dance Fault after waste emplacement.

In addition, if other major anticipated or unanticipated faults are encountered in the subsurface during construction, they may be characterized and monitored in a manner similar to that planned for the Ghost Dance Fault studies in the Exploratory Studies Facility. One concept may be to take advantage of the close proximity of the western edge of the repository to the Solitario Canyon Fault. If other faults need to be characterized, other measurements will need to be performed. These will include in-hole and/or cross-hole air permeability measurements, and coring and offsite laboratory work to determine hydrologic properties, such as saturated hydraulic conductivity, effective porosity, moisture content, hydraulic potential-moisture content relationship, and moisture content-hydraulic conductivity relationship.

The activities related to faults encountered during construction will be accommodated by drilling into the fault zone on a later encounter or from an observation drift above the main repository. The current assumption is that the configuration and number of subsurface-drilled boreholes required is similar to that used in Exploratory Studies Facility activities for the Ghost Dance Fault studies. The key to this activity will be to develop testing, monitoring, and experimental concepts that minimize interference with repository construction and emplacement operations, but still supply adequate information about the encountered fault.

3.3.1.4 Thermal Testing

This concept will provide rock and water temperature. gas pressure. moisture content. relative humidity, water chemistry, in situ rock stress, and rock deformation/convergence from subsurface monitoring and sampling. Instrumentation for this package will include:

- Gas pressure - borehole transducers
- Temperature - borehole thermocouples and/or resistance temperature detectors. as well as infrared thermal imaging of rock surface
- Relative humidity - humicaps and/or psychrometers
- Moisture content - periodic borehole geophysical logging (neutron log) and/or electrical resistivity tomography
- Water chemistry - flexible borehole liner sensors and/or periodic sampling and off-site laboratory analysis
- In situ rock stress - borehole stress meters
- Rock deformation/convergence - multiple point borehole extensometer.

All instrumentation will be retrievable and/or replaceable. To facilitate instrument retrievability and/or replacement, some of the instrumented boreholes will be drilled from a long observation drift above the emplacement horizon. In-hole and cross-hole air permeability will be measured before and after the alcove thermal test and before and during the emplacement drift monitoring. See discussion of repository subsurface test and support facilities concepts in Section 3.3.4.

In addition, rock cores will be analyzed in offsite laboratories to determine rock chemistry and hydrologic properties, such as saturated hydraulic conductivity, effective porosity, moisture content, hydraulic potential-moisture content relationship, and moisture content-hydraulic conductivity relationship before and after the alcove thermal test and before and during the emplacement drift monitoring. The instrumentation, monitoring, coring, sampling, and laboratory work described will be similar to that planned for the Exploratory Study Facility drift-scale heater test. To provide early data acquisition and to allow design adjustments, the thermal testing will be conducted either entirely or primarily in the early stages of repository operations.

This testing package is related to two test facilities and support concepts, which are described in more detail in sections 3.3.4.1 and 3.3.4.4. Briefly, these include permanent observation drifts above some emplacement drifts, and thermal testing in an alcove setting using heaters, possibly inside dummy waste packages.

3.3.1.5 General Surface-Based Testing

This concept covers the planned site monitoring and testing of parameters that were not selected as key performance confirmation parameters. All of them are parameters to be measured from the surface, which includes measurements in surface-based boreholes. The parameters are surface elevation; types and areal distribution of vegetation; meteorological characteristics such as precipitation, air temperature, atmospheric pressure, and relative humidity; seismicity in terms of location, magnitude, and acceleration/ground motion; background radiation; surface water infiltration; ground-water table elevation; ground-water flux; and radionuclide concentrations in the saturated zone.

General surface-based testing includes a broad set of parameters. Regarding physiography, the topography and, specifically, the surface elevation above and around the repository will be confirmed by geodetic surveys. Initial baseline data will be used and later surveys will monitor for potential uplift or subsidence, future erosion, deposition, and seismicity. The surveys will be periodically scheduled, but may be conducted after a significant disruptive event. Areal vegetation surveys will be periodically conducted.

There are currently nine full meteorological stations in the Yucca Mountain area operating for the project. The above listed meteorological characteristics are measured at these stations, along with other related information. These data are recorded over intervals ranging from one second to one hour. There are also seventeen continuous precipitation stations. In addition, information collected by outside organizations is obtained and integrated into the understanding of the climate of the Yucca Mountain area. These sources of information include validated data from the National Climatic Data Center from regional National Weather Service first-order and cooperative observer stations. Other data have been obtained directly from the National Oceanic and Atmospheric Administration weather organization operating in support of Nevada Test Site operations.

Existing surface-based seismic stations will be used for confirming seismicity in terms of location, magnitude, and acceleration/ground motion. This information measured at the surface will be used in conjunction with data from the same event collected from subsurface seismic monitoring stations (see Section 3.3.2.4).

As part of the general surface-based testing, the primary objectives of radiological environmental monitoring activities are to establish the variability of levels of radioactivity present in the environs of the Yucca Mountain site (background radiation), and to monitor changes in levels of radioactivity that may have been caused by YMP activities (e.g., an site disturbing activity that uncovers a previously unknown area of radioactive contamination). The data generated by these activities will be used for EPA and Nuclear Regulatory Commission (NRC) regulatory determinations. Radiation is a part of the natural environment. Naturally occurring radionuclides are present in soil, plants, and gases that compose the atmosphere. The amounts of specific radionuclides in the environment can be attributed to many factors, including variations in geology, industrial activities, and the testing of nuclear weapons. Airborne radioactive particulate can originate from resuspension of radionuclides in soil, attachment of radioactive gases and their progeny to airborne particulate, or as air effluent discharged from a facility. Radioactive radon gas is generated from naturally occurring elements in the environment. Site characterization activities that could modify the rate at

which radon is generated include moving radon-generating elements to the surface and exposing these elements through the movement of surface soils.

The radiological environmental monitoring activities include the quantification of radioactive particulates, ambient gamma radiation, and ambient radon. Environmental media sampled are air, small mammals, soil, and vegetation. All of these media are currently radiochemically analyzed by a vendor. A synopsis of the results of this program are presented in the Annual Site Environmental Report which is generated each calendar year.

Other general surface-based testing concepts include shallow surface-based boreholes for surface water infiltration monitoring and existing deep boreholes that will be used for groundwater table elevation or groundwater radionuclide concentration monitoring. Ground-water flux is a parameter that is calculated based on a number of other general surface-based concept and surface-based unsaturated zone hydrology concept parameters.

3.3.2 Repository Monitoring and Testing

10 CFR Part 60 requires several testing programs that are to be initiated "during the early or developmental stages of construction...". Included are tests of potential sealing systems for boreholes and shafts, backfill testing, and heater testing. In addition, subsurface seismic monitoring has been identified as a performance confirmation activity that should be performed during repository operations. Also, capabilities to observe or monitor emplacement drift environments are included in the repository monitoring and testing concepts.

3.3.2.1 In Situ Seal Testing

The general objective of in situ seal testing for performance confirmation would be to meet the hydrologic design goals for the repository established in the *Repository Seals Requirements Study* (CRWMS M&O 1997q). Seal design will utilize these requirements and is expected to occur in fiscal year 1998. Result of this design work in important to planning seals testing and in particular seal locations are important to testing. As additional information becomes available through site characterization, design goals will be updated and the test should demonstrate satisfaction of the design goals.

In situ seal testing for performance confirmation may require multiple test locations. It is expected that they will be performed in the upper portion of the Topopah Spring or the Paintbrush formations at the selected sealing locations. The tests can be performed in alcoves that simulate TBM excavation. The tests would resolve design issues associated with large scale construction not previously resolved by laboratory or small-scale in situ testing and to prove hydrologic performance.

3.3.2.2 In Situ Backfill Testing

10 CFR Part 60.142 , Design Testing, section (a) describes an in situ testing program to assess the effects of backfill. This test is prescribed to start "during the early or developmental stages of construction ...". Subsequently, section (b) describes a "backfill test section," which is intended to "... test the effectiveness of backfill placement and compaction procedures ...". This test, however,

must only be completed "... before permanent backfill placement is begun." Backfill may be emplaced between seals and in main drifts, ramps, and shafts. Backfill of emplacement drifts, however, is not currently in the reference design, but is considered as an option. Consequently, the backfill testing plans described and the related repository subsurface test facilities and support concepts (see Section 3.3.4.4) are preliminary.

Two backfill tests are described for this Plan, which may occur up to 90 years or so apart: a backfill performance test and a backfill constructability test. See Section 3.3.4.4.2.

The earlier backfill performance test would likely to be conducted on a reasonably small scale, tens of meters, in a test alcove-type environment. If the potential repository is ultimately licensed without requiring emplacement drift backfill, then the early heated backfill test would likely not be required. If emplacement drift backfill is required, the specific functions and parameters to be tested and observed depend on the results of this referenced study.

The backfill constructability test will be more for constructability and will likely be conducted on a scale approaching the emplacement drift length, which is hundreds of meters. It will not need to be conducted until just prior to backfill placement. This test will be used to test the viability of the backfill process and equipment, and to gather information on productivity, availability, and the condition and uniformity of the emplaced backfill.

3.3.2.3 Follow-on Drift Heater Testing

Although there will be ample opportunity during repository operations to examine the heating of the emplacement drifts and surrounding rock, there will be no cool-down experienced during the preclosure period. Predicted drift temperatures at closure, up to 100 years after emplacement, are within a degree or two of the peak temperatures occurring in the 40- to 60-year range. For this reason, a follow-on drift heater test will be run for a sufficient duration to heat up a significant amount of the surrounding rock so that, when the heat is turned off, the thermohydrologic activity associated with repository cool-down can be examined. Such a test is alluded to in 10 CFR Part 60.142(a), which requires "... a program for in situ testing of ... thermal interaction effects of the waste packages, backfill, rock, and groundwater ...".

Several issues determine whether this particular heater test will actually be required. A series of thermal tests has been identified in the long range plan. It includes in situ testing in a single element heater test and a drift scale heater test, which the Project may use to demonstrate compliance with the intent of 10 CFR Part 60.142(a). Some of the issues requiring resolution are:

1. What information can be obtained from this testing that does not already exist for the License Application and cannot be obtained by other means, ignoring the timing?

2. Is the timing of the testing important? Does the NRC want this testing done again prior to the License Application update to receive and possess, but on a larger scale and with a better definition of the final design?

TBD - Need for follow-on drift heater test While it may ultimately be possible to combine the backfill test with the heater test, this Plan assumes that separate tests will be required. The heater test is assumed to resemble the large-scale long-duration test described in the *Updated In Situ Thermal Testing Program Strategy* (CRWMS M&O 1997f).

3.3.2.4 Subsurface Seismic Monitoring

Subsurface seismic activity monitoring, specifically of acceleration/ground motion, will provide information on seismic events which may occur during the preclosure period. Such information collected at the repository horizon, when used in conjunction with data from the same event collected from surface monitoring stations, could provide important information regarding the attenuation of seismic activity with depth. Although this parameter is considered a site parameter, it is included in the repository testing section because of its similarity with other repository monitoring activities.

3.3.2.5 Remote Observation and Inspection of Emplacement Drifts

Observation and inspection of the waste emplacement drifts will be performed by remotely operated systems because of the expected radiation and temperatures. Several mechanisms will be used for performing observations and inspections in emplacement drifts. Access to the emplacement drifts to perform the observations is a key to these concepts. Observation via borehole will provide a limited amount of access. Also, a limited amount of information can be obtained via indirect observations, such as drift ventilation monitoring. But the primary access concept is the general purpose use of remotely operated vehicles, which will serve as mobile platforms for carrying several types of inspection packages into the emplacement drifts for observation and data collection. The instruments will provide real-time and highly detailed visual, thermal and radiological feedback on waste package and emplacement drift conditions. The vehicles will also be equipped with telerobotic manipulators that will emplace and retrieve small test coupons or specimens.

The remotely operated inspection systems will provide human operators, located in a control room, with specific, detailed, real-time feedback about the performance of waste packages, drift excavations, ground support systems, and thermal and radiological environments in the emplacement drifts. These teleoperated inspection systems will be deployed periodically within the emplacement drifts to document and detect any changes and compare them with previous expectations. Should anomalies arise or unexpected changes occur, the remote inspection systems will be an important means for obtaining additional information.

Alternatives for designing these systems are described in Section 3.3.4.7. The selection of specific remotely-operated vehicle designs, including associated instrumentation, will be addressed in separate design specifications and activity plans.

3.3.2.5.1 Remote Visual Inspection

A remotely-operated visual inspection system will be used to obtain visual records of the waste package surface, drift inverts and ground support systems in the waste emplacement drifts following emplacement. In off-normal events such as drift collapse or rock fall, the remotely-operated vehicle systems will be used to assess the situation. This process will require the development of the vision

and delivery system by adapting well-established technology for the parameters to be monitored in the expected emplacement drift environments. Being able to remotely view objects and conditions within the emplacement drifts will be a fundamental capability needed for performance confirmation observations to satisfy regulatory requirements and support long-term repository operations. The key repository excavation parameters requiring remote visual inspection include rockfall/collapse, including size, and ground-water inflow rates. For the waste package, remote visual inspection will monitor corrosion and mechanical effects on barrier thickness and shape.

Following emplacement of waste packages, remote vision systems will be used to record the conditions of the emplaced waste packages, the drift excavation, and the surrounding rock walls. Initially, these video records will establish baseline data of the initial emplacement conditions and future scans will provide the data for evaluating potential planned, as well as unplanned events and conditions. It will be used to inspect areas of concern, such as the performance of the invert floor material, possibly checking for thermally induced cracks or premature deterioration. This inspection system will also check and monitor the integrity of the drift walls, and possible rock falls, and unstable areas. It will check for signs of cracking or deterioration of ground supports. It will check for signs of water, moisture, and waste package corrosion. It will be used to enhance or substantiate off-line photogrammetry and geologic mapping databases. See sections 3.3.4.7 and 3.3.1.1. Besides providing data for confirming postclosure performance, the in-drift inspection capability will be used to verify engineering methods, approaches and techniques as the repository construction and waste emplacement progress.

3.3.2.5.2 Remote Thermal Inspection

A remotely-operated thermal inspection system will be used to measure waste package wall temperature, rock temperature on the emplacement drift wall, and drift air temperature following waste emplacement. While in situ exhaust air monitoring will provide good bulk or average temperature information about the emplacement drifts, it will not provide direct, detailed, thermal data about specific waste packages or specific areas within the drift. Using only exhaust air monitoring, localized areas of heat concentration such as hot spots, which may exceed the 200°C assumed thermal limit could go undetected (CRWMS M&O 1997a). In addition, information about thermal variation and distribution across the emplacement drifts would not be provided.

Remotely-operated thermal inspection systems can be used to observe thermal response parameters close-up and correlate this information over a long period. While the heated drift tests will provide some level of understanding and confidence about the thermal models being developed, they will not replace the need to observe the thermal performance directly until repository closure.

A mobile remote means for obtaining thermal data will be preferred over in situ monitoring because it permits the periodic calibration of instruments. The remotely-operated thermal inspection system will be equipped to monitor both air and surface temperatures. The inspection system may consist of technologies as simple as thermocouple temperature probes, or as advanced as a real-time thermal imaging infrared camera that can provide color-coded images and thermally map entire surfaces of a waste package and the surrounding drift wall.

3.3.2.5.3 Remote Radiological Inspection

A remotely operated radiological inspection system will be used to monitor radiation levels in the emplacement drifts following waste emplacement, to establish initial radiological conditions, and to detect potential waste package failure and radionuclide release. The exhaust air from each emplacement drift will be continually monitored for radioactive gases. If radioactive particles or gases are detected, it will indicate that a waste package has developed a leak. Detection of radionuclides in the exhaust air, however, only provides the first alert that there is a problem. A mobile remote radiological inspection system will then be deployed to enter the affected drift and identify which specific waste package is leaking and the extent of contamination.

Remote radiological inspection systems can range in sophistication from simple passive dosimeter monitoring sensors to teleoperated radiation imaging systems that provide remote, real-time, color coded radiological images over an entire field of view. The latter would permit radiation mapping of individual waste packages, and thus detect the exact location of the leak on a waste package.

3.3.2.5.4 Remote Manipulation

Remote manipulation will be employed to recover sample waste package materials specimens and test coupons placed at key points of interest within the emplacement drifts. Remote manipulation will also be used to collect dust samples and check for particulate contamination by obtaining wiped swatch samples from surfaces of interest. In the event of a rock fall or other anomaly, remote manipulation will be able to remove small rocks or debris that could otherwise impair the complete inspection of an emplacement drift. Telerobotic arms will be used to hold and position other sensor systems, such as cameras or probes, which will allow operators to inspect around or behind objects.

3.3.3 Waste Package Monitoring and Testing

Waste package monitoring and testing concepts consist of off-site testing and experiments, in situ monitoring, and recovery of various types of waste package samples. The recovery of waste package samples includes the option to recover emplaced waste packages, dummy waste packages, which are full size but do not contain actual waste, and waste package specimens or coupons. Each of these concepts is described.

3.3.3.1 Offsite Laboratory Waste Package Testing

This concept mostly entails the continuation into the performance confirmation period of long-term laboratory studies of the waste form and waste package materials that will have supported the viability assessment and License Application. It is desirable in several instances to continue obtaining data for various waste package degradation phenomena that will affect the long-term performance of the disposal container, the waste form, and internal elements of the waste package. The major advantage of laboratory testing compared to in situ repository testing is the economy of testing and the great range of conditions that can be studied. Also, environmental conditions can be maintained in the laboratory that simulate repository conditions at some future time, so that the laboratory testing complements the in situ repository testing, which will occur under environmental conditions representative of the initial stages of repository operations. Another great advantage of

laboratory testing for performance confirmation is that test conditions can be maintained to accelerate the degradation. Because laboratory testing is oriented toward making hypotheses and understanding fundamental mechanisms, it provides a framework for observations made in the in situ performance confirmation concepts.

The key parameters affecting waste package container performance that will be measured in laboratory testing include all of those associated with oxidation and aqueous corrosion. All of the corrosion degradation modes that have been identified as important to either the outer barrier or the inner barrier will be measured in long-term corrosion tests. This testing will include those under immersed conditions and in humid atmospheres. The interactions between barriers, such as the degree of galvanic protection, are readily measurable in a laboratory setting. Several corrosion degradation phenomena, such as pitting corrosion, crevice corrosion, stress corrosion cracking, and hydrogen embrittlement, often exhibit long incubation times before discernible initiation occurs. Another aspect in characterizing corrosion degradation is that a pit or crack may initiate, but the propagation rate may increase, decrease, or remain steady with time. Only by doing the long-term testing will a high degree of confidence be obtained in predicting performance. Characterization of oxidation and corrosion products will be performed. Also, parameters associated with phase stability in the metal and weld integrity will be measured in laboratory investigations.

Some of the long-term testing is already underway, in 1996 and 1997, and several more tests will be initiated during the next 2 to 3 years. Depending on the outcome of the License Application waste package design and results of the material testing work, a limited number of laboratory based tests is planned to continue for perhaps 10 to 20 or more years to provide greater confidence in the selected design, the selected container materials, and the performance models. The degree of confidence will increase with the longevity of the test. Continuation of the testing will provide continuing confirmation of performance prediction models and allow for any needed model modifications. Similarly, degradation concerns with waste package internals, criticality control materials such as basket materials, neutron flux traps, and others, will be resolved by the long-term laboratory testing.

Waste form testing and characterization is best served in continuation of testing, now underway, well past the License Application period. Key parameters characterizing spent fuel, such as overall geometry/dimension, geometry/surface area of UO_2 pellets, as well as the starting inventory of radionuclides, are being measured. In this instance, laboratory testing is in a hot cell. Study of the kinetics and mechanism of dry oxidation of spent fuel is important to understanding a possible early waste package failure mode, such as a breached container admitting oxygen that rapidly oxidizes the warm UO_2 and ruptures the cladding to expose more fuel. Much of the laboratory testing emphasis is on phenomena that will occur in the later part of the containment period and into the controlled release period, when the temperature has decreased so that aqueous conditions can occur to first breach the container and then degrade the internals. The key parameters in this time frame will be the dissolution kinetics of spent fuel, which species enter the water, and in what form, ions or colloids. Transport phenomena involving these ions and colloids are also studied. Similarly, for glass waste forms, the dissolution rates and specification can be monitored over time, as can any tendency for the glass to devitrify. Another important effect, which can realistically only be measured in a laboratory setting, is the interaction between the corroding disposal container and the

release of radionuclides. Some of the particularly long-lived actinides may preferentially sorb onto metal oxides; the extent of this reaction is amenable to quantification in the laboratory.

Much of the effort in setting up the laboratory testing will have been completed before the License Application, so the testing during the performance confirmation period will mainly consist of continuing the operation and periodically characterizing the spent fuel and glass specimens. Continuation of the hot cell tests into the performance confirmation period adds confidence to the performance models. Except for the characterization of an emplaced waste package that has failed or been damaged in the repository, laboratory testing is about the only way that waste form characterization can continue to increase confidence in performance predictions.

3.3.3.2 In Situ Waste Package Monitoring

This concept involves the monitoring of a variety of parameters in the subsurface excavations and surrounding rocks. It is essential for understanding and interpreting results from all of the other in situ performance confirmation concepts. In situ monitoring also provides a reality check on the continuing laboratory investigations. Some of the parameters that will be monitored are also obvious indicators of operational safety in the repository. Foremost among the parameters to be monitored are gaseous radionuclides whose presence would indicate an early waste package leak, such as the scenario in which a cracked weld breaches the waste package and exposes very warm spent fuel to oxygen. Air samplers will be used to detect krypton-85, tritium, possibly carbon-14 (as CO_2), and perhaps other radionuclides in the exit ventilation air. Specific tracer gases will be used so that the location of the leaking container can be determined. Cameras and closed circuit television will monitor waste package container surfaces for evidence of corrosion or other penetrating attack. See also remote observation and inspection systems described in Section 3.3.2.5.

In situ monitoring of the container surface temperature on radioactive waste packages and on dummy waste packages is planned. The humidity will be measured at many locations in the repository, in the emplacement drifts, in access drifts, and wherever dummy waste packages and test alcoves are located, since an important strategy element in waste containment is maintaining dry conditions. Other chemical sensors may be emplaced in the repository, depending on the outcome of laboratory investigations that will identify the important parameters determining waste package performance. One possibility would be detection of certain sulfur containing species, indicating microbial activity. More equipment for monitoring environmental parameters can be used outside the emplacement drifts, for instance in specially constructed test alcoves where dummy waste packages and specimens are placed, dummy waste packages will be instrumented with strain gages to measure stress at different locations on the container. To capture as much information as possible, many diverse kinds of locations in the repository will be instrumented, for example, in faulted or heavily fractured areas such as alcoves for subsurface fault zone monitoring where waste packages would not be emplaced, but which could provide information about what-if scenarios. Detecting and measuring any ground-water seepage into the emplacement drifts will be particularly appropriate for predicting disposal container and waste form performance in later, postclosure time periods, when the thermal blanket will have collapsed and aqueous conditions will be more probable.

3.3.3.3 Recovered Waste Package Testing

This concept involves the transport of real, radioactive waste packages to the surface for inspection and testing purposes. The waste emplacement system to recover waste packages for testing (see Section 3.3.4.3). Because this concept is the most costly, it will be employed only on a contingency basis; in case a breached, damaged, or malfunctioning waste package is detected, it will be recovered and brought back to the surface facility for re-work and testing. From a performance confirmation standpoint, such an occurrence is regarded as a target of opportunity.

Most of the examination of radioactive waste packages will be performed at the repository surface facilities, with perhaps some specialized kind of analyses, if needed, performed in a laboratory. Several of the analyses that will be performed on the recovered waste package will complement analyses being performed offsite in long-term laboratory investigations on the waste form, basket material for criticality control, spent fuel cladding, and any other internal waste package structure, such as glass pour canister or spent fuel interim storage container, even if that item is not intended to be one of the engineered barriers.

The key parameters that will be examined in this concept include many of the waste form characterization parameters. For spent fuel, changes in the geometry and surface area of the UO_2 pellets plus evidence of oxidation will be noted. For the glass waste form, evidence of devitrification will be noted. For all of the waste forms, analyses of the radionuclides will indicate whether predictions of the inventory are accurate. The condition of the spent fuel criticality control structure and the condition of the spent fuel cladding and any other internal elements in the package will be assessed, in addition to the condition of the fill gas in spent fuel packages. Because the expected conditions will be hot and dry during the operational period, none of the aqueous processes such as dissolution are expected to be observed, so that only the continuing laboratory work will provide performance confirmation for these parameters.

3.3.3.4 Recovered Dummy Waste Package Testing

This concept for performance confirmation entails manufacture of a dummy waste package of the same dimensions and configuration as the real waste package, but not containing any radioactive waste. Instead of the waste, the package will house an electrical heater. The dummy package will be used to study thermally induced changes in the container material and in the surrounding environment. The full scale dummy waste package will also permit the same fit between the inner and outer barrier material as the real waste package, which will reflect accurately the state of stress existing in the real package. The dummy waste package will also be fabricated and welded just like the radioactive waste packages, so that examination of the exposed surfaces and welds will be very much like examining the real thing.

The cost of recovering and testing dummy packages is less than that of recovering and testing radioactive waste packages due to not handling radioactive waste. However, the measurements are largely confined to those affecting the disposal container, while pulling radioactive waste packages yields information about the waste form and other internal elements of the waste package. The dummy waste packages would be emplaced in a specially designed alcove where recovery would not present as many obstacles. However, to keep the dummy packages powered will require installation

and maintenance of an infrastructure, with frequent access to the location of this test alcove. Because the repository design is one of close emplacement of radioactive waste packages to achieve a high thermal output, considerable effort and expense will be required in the design and operation of a repository wing to achieve thermal results similar to the emplacement drift. An additional variation in using dummy waste packages will be to reduce electrical power to some of them in order to simulate later time periods in the repository, when the surface temperature will have decreased so that aqueous conditions may occur around the waste package.

While some measurements can be made by observation of the dummy waste package surface during exposure in the repository, most measurements will be made by withdrawing the dummy waste package and examining it destructively either in the surface facility, depending on the kinds of available equipment and instrumentation, or at an offsite laboratory.

Key parameters to be determined by this concept include the dry oxidation rate, corrosion rate in humid atmospheres, and aqueous general corrosion rate, as well as the threshold humidity level for transition from dry oxidation to aqueous corrosion. Evidence of pitting or other localized attack, including any microbially influenced corrosion on the container surface, will be examined. Penetration of the container section by general corrosion, pitting, stress corrosion cracking, or other localized attack will be quantified. The nature and composition of oxidation and corrosion products will be determined during examination of the exposed surfaces of the container. Instrumenting the dummy containers with strain gauges will allow monitoring the stresses at various locations and changes in the stress with the time of exposure in the repository. Non-destructive examination of welds will support investigations of weld integrity while destructive sectioning of the container will support investigation of potentially damaging embrittling phases plus any evidence of penetration by corrosive attack.

3.3.3.5 Recovered Non-Radioactive Specimen Testing

This concept involves placing non-radioactive waste container material specimens at different locations in the repository where they are expected to experience different environmental conditions and then pulling them for laboratory examination at surface facilities. It complements the laboratory testing concept by providing exposure to the more realistic environment instead of a simulated one and acts as an oversight in case some factor has been neglected or cannot be reproduced in laboratory test environments. Specimens will be placed in a variety of exposure locations to cover a reasonable range of the geological and geochemical variations expected to occur in the repository. Some specimens will be placed in the hotter and drier locations, alongside the waste packages in the emplacement drifts or alongside the electrically heated dummy waste packages in test alcoves. These specimens will thus witness the same thermal and humidity conditions that the real, radioactive waste package containers are experiencing during the operational period. Other specimens will be placed in test alcoves located away from the emplacement drifts in the cooler and moister locations in the repository to simulate the conditions that would be representative at a future time when the heat source inside the waste package will have decayed.

Specimen testing will be largely restricted to the container and cladding materials because the exposure conditions in the repository represents the external environment of the waste package, but do not represent the internal environment at the waste package. The specimens will range from

small coupon-size pieces like those used in laboratory testing to panel-size pieces approaching the dimensions of a waste package. Some of the test specimens will contain welds, because the integrity of the welds on the waste package is an important technical issue during the repository operational period. Depending on the nature of the measurement or characterization, the specimens may be analyzed on site at the underground exposure location or at the repository surface facility, or at an off site laboratory. Compared to testing the dummy waste packages and destructive examination of sacrificial waste packages, these specimens are relatively inexpensive. The major expense will be in accessing the specimens located in the emplacement drifts, but several measurements can be taken by remotely controlled cameras and instrumentation to minimize the need for physical withdrawal of the specimens. See Section 3.3.2.5.

The key parameters to be determined by the specimen tests will be corrosion and other degradation characteristics of each waste package barrier. These include the dry oxidation rate and the different phenomena occurring in humid atmospheres and under aqueous conditions such as threshold humidity level, humid air general corrosion rate, aqueous general corrosion rate, pitting corrosion characteristics in humid air and in aqueous conditions, and microbial corrosion characteristics. Evidence of galvanic effects, such as galvanic protection, between the two metals comprising the waste package will be noted. The nature and characteristics of oxidation and corrosion products will be determined by examining the surfaces of the pull specimens. Embrittlement in the container materials and the integrity of the welds will also be determined by analyses of pull specimens.

3.3.4 Subsurface Test Facilities and Support

Several test facilities and support concepts will be utilized to gather the information needed to execute the Performance Confirmation Program. One such concept involves monitoring certain localized, representative areas of the repository extensively and continuously in observation drifts with instrumented boreholes. Other data will be gathered continuously over the entire repository by monitoring a small airflow volume passing through each emplacement drift. The recovery of emplaced waste packages for performance confirmation will be possible. Alcoves for monitoring or testing in non-emplacement areas will be provided. Concerns regarding the subsurface geologic mapping interface with construction will be discussed. Sample collection and handling during repository construction is a fundamental part of the concept. Another method will be intermittent remote excursions into the emplacement drifts, which could involve physical recovery of dummy waste packages and/or samples, such as waste package material coupons, left in the emplacement drifts. Each of these potential concepts is discussed in more detail in the following paragraphs. Much of this information is taken from the *Performance Confirmation Concepts Study Report* (CRWMS M&O 1996f), but information from design analyses (CRWMS M&O 1997c & e) on subsurface test facilities and support elements is also used.

3.3.4.1 Permanent Observation Drifts

In the repository subsurface layout configuration analysis (CRWMS M&O 1997h), drifts are excavated off the ramps to an elevation over the repository emplacement areas and provide a permanent monitoring facility which will remain accessible throughout the preclosure period. Figure 3-2 shows the current design for these observation drifts. Figures 3-3 and 3-4 show alternative, but typical, configurations for the observation drift. In Figure 3-3, a configuration of the

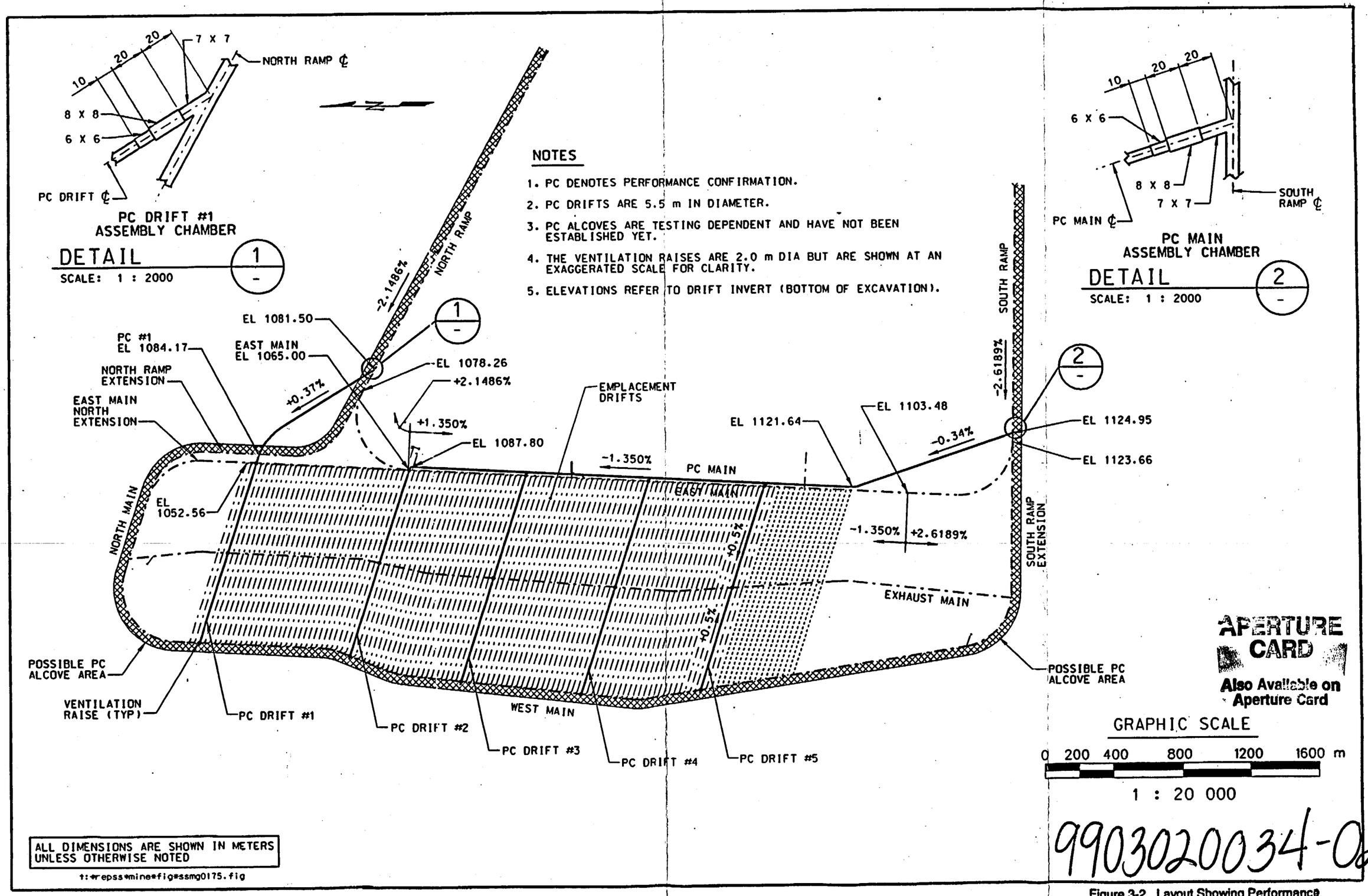

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Figure 3-2. Layout Showing Performance Confirmation Facilities (CRWMS M&O 1997h, Figure 7-11)

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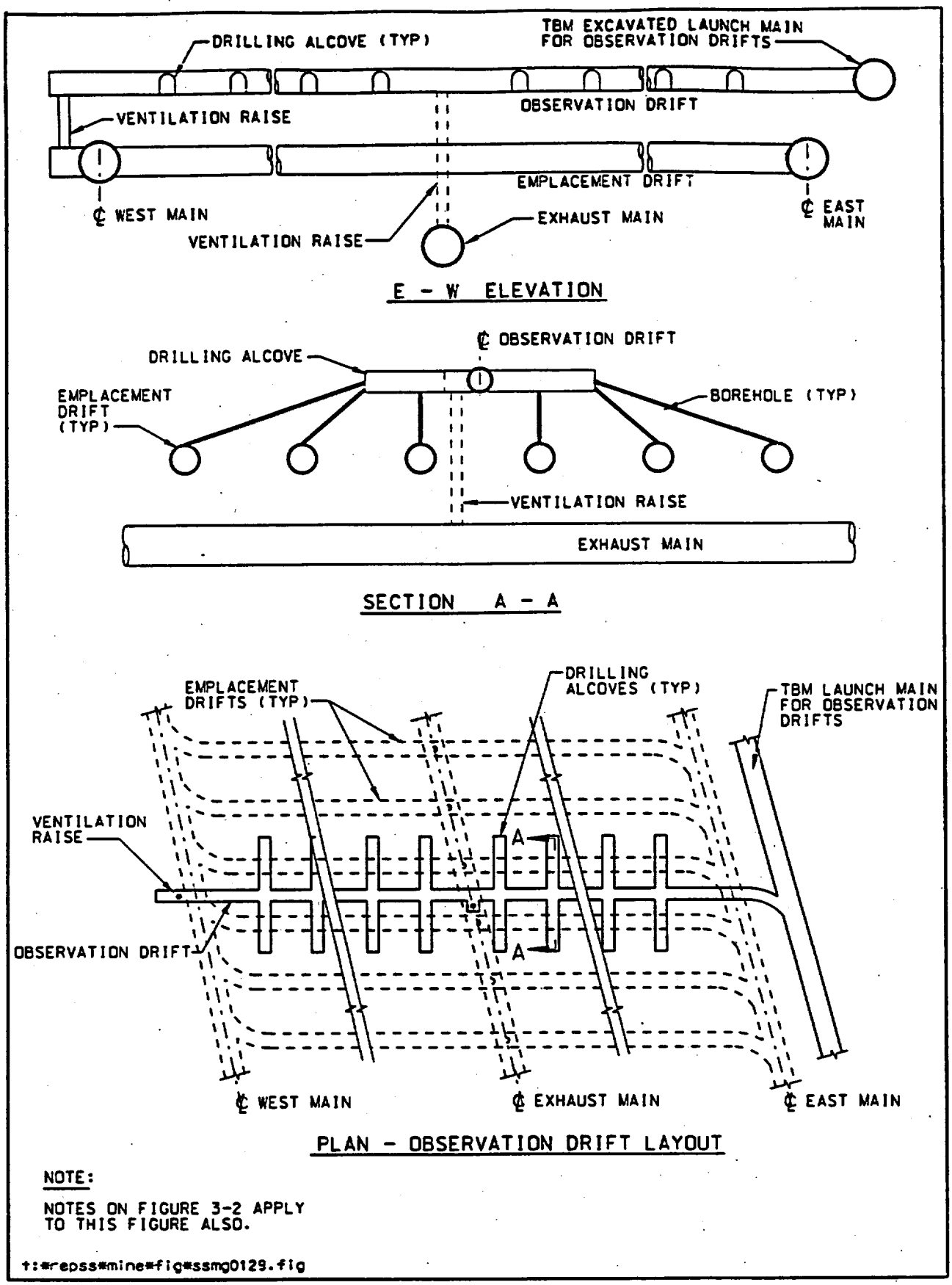
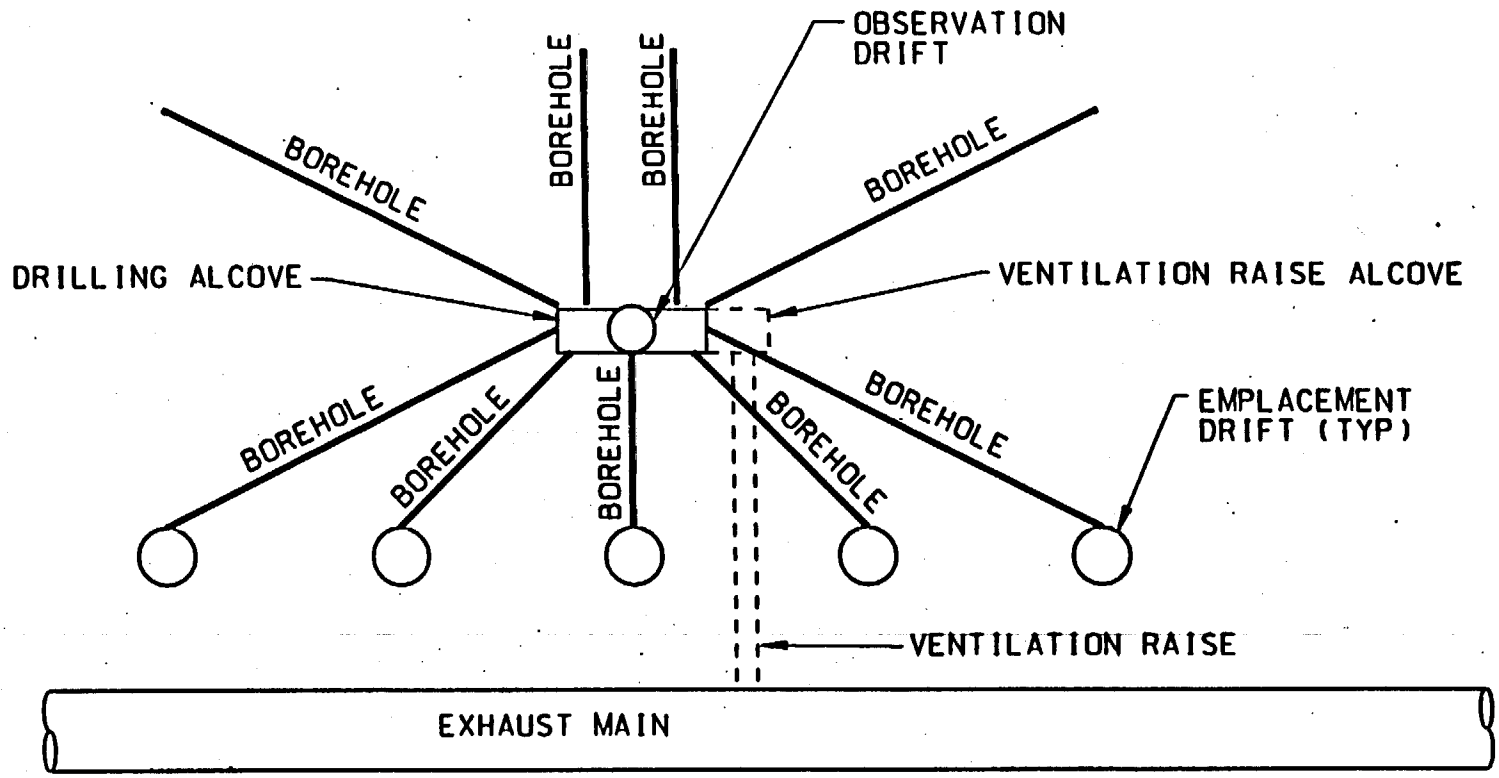


Figure 3-3. Typical Observation Drift Layout for Six Drifts (CRWMS M&O 1997e, Figure 3)



NOTES:

1. ORIENTATION AND NUMBER OF BOREHOLES AROUND EACH EMPLACEMENT DRIFT MAY VARY.
2. NOTES ON FIGURE 3-2 APPLY TO THIS FIGURE ALSO.

Figure 3-4. Typical Observation Drift Layout for Five Drifts (CRWMS M&O 1997e, Figure 4)

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observation drifts is shown which could monitor six emplacement drifts. The observation drift is parallel to the emplacement drift and is located above the pillar between two emplacement drifts. Alcoves are developed off the observation drift to allow drilling to access a larger coverage of the altered zone. In Figure 3-4, the observation drift is located directly above one emplacement drift and the four neighboring drifts are accessed from shorter alcoves and boreholes. Drill holes from the observation drift toward the adjacent emplacement drifts will contain instrumentation for long-term, in situ data collection. Such a concept would likely resemble the current plans for the Exploratory Studies Facility thermal test where the heated drift is not accessible, but is monitored via borehole instruments. Selected drill holes could penetrate the emplacement drift wall, allowing instrumentation to be inserted directly into the emplacement drift, and then withdrawn. Instrumentation would be installed in the drill holes from the observation drifts, and if repair or re-calibration is needed, would be removed and reinserted from the observation drift. In the case of instruments which must be grouted in place, additional holes may have to be drilled in the event of an instrument failure.

A variety of observation drift arrangements could be used to provide access for monitoring above, below, at the same level parallel, perpendicular, or at an angle to an emplacement drift. In the current design, a drift is driven across the repository block approximately 15 m above the repository block, following the orientation and slope of the emplacement drifts.

The current design, in which the observation drifts are located above and parallel to the emplacement drifts, was chosen for a number of reasons. With the observation drift in a plane above the emplacement drifts, boreholes can be drilled down to the emplacement drifts for monitoring ground movement at the tunnel crown (CRWMS M&O 1997e). Monitoring for ground movement may be possible from below, but it is not the preferred configuration. Also, cross-block observation drifts below the emplacement horizon could interfere with the Exhaust Main unless located at a different elevation (CRWMS M&O 1997e). The observation drift located parallel to the emplacement drifts provides the ability to have complete coverage of the volume of the altered zone influenced by the drifts below the neighboring emplacement drifts. This capability is needed for the first emplacement drifts emplaced so that early and complete information about the behavior of the repository is acquired. The needs for altered zone monitoring at other locations are less specific. The current concept provides the capability of complete coverage at four other locations spaced uniformly throughout the repository in a configuration like the one needed for the first emplacement drifts. Other information that is associated with the altered zone behavior (e.g., waste package temperatures, emplacement drift air temperature, emplacement relative humidity) are acquired throughout the repository via other methods like ventilation monitoring or remote observation of the emplacement drifts. The combination of complete coverage at a number of locations and broad coverage for a limited number of associated parameters is expected to provide a reasonable testing program for the altered zone behavior. But, additional analysis and detailed planning is necessary to provide specifications for the final observation drift configuration.

The Enhanced Characterization of the Repository Block effort recently planned to begin in 1998 may have an influence on the configuration of the observation drifts. The effort consists of constructing a drift across and above the repository block and performing associated site characterization testing. The currently planned configuration for this drift is to take off the north ramp in a generally southwest heading until it reaches the Solitario Canyon fault above the western edge of the

repository. This planned additional drifting has not yet been incorporated into the design of the repository subsurface layout configuration nor the configuration of the observation drifts. This drift is located such that performance confirmation testing may also be conducted from this drift. Monitoring from this drift which crosses a number of emplacement drifts would provide some altered zone information on each drift crossed. As the design and construction of this drift progresses, it will be incorporated into the performance confirmation planning and the repository subsurface layout configuration.

The number of observation drifts will ultimately depend on the amount of coverage which is required. The amount of areal coverage would vary with the number of observation drifts and the spacing of the instrumentation stations. In the current design, five observation drifts are used, and as much as approximately 15 percent coverage could be achieved. Measurements in a few observation drifts and associated boreholes are expected to provide acceptable statistical distributions of the performance confirmation parameters, and to provide adequate coverage of spatial heterogeneity across the repository block. Performance analyses planned in support of the performance confirmation program design will establish the actual number and location of the observation drifts.

The observation drift can be relatively small. The size will be determined by required equipment operating envelopes. The current design (CRWMS M&O 1997h) uses tunnel boring machine excavation at a 5.5. m diameter. This size is the same as the emplacement drifts and one of those TBMs could be used to excavate the observation drifts. Ventilation raises will be excavated between the observation drifts and the East Main, West Main, and Exhaust Main. Actual location and configuration of the observation drift ventilation raises or their connections to the mains has yet to be determined.

The configuration of alcoves and boreholes off the observation drifts has yet to be determined. Figures 3-3 and 3-4 provide some alternatives for the alcove and borehole configuration. Performance analyses planned in support of the performance confirmation design will establish the actual number and location of the alcoves and boreholes (see Section 3.2.1.1).

The first observation drift will be excavated during the pre-emplacement development construction period to obtain baseline data prior to the emplacement of the first waste packages. Subsequent observation drifts would be constructed during the normal development operations but prior to waste emplacement in the waste emplacement drifts over which they will be located.

Boreholes drilled from the exhaust main, ventilation drift and perimeter mains and appropriately oriented can be used to monitor parameters in regions above, below, and between emplacement drifts, at least on the periphery of the emplacement. These boreholes alone cannot provide sufficient coverage of the altered zone for thermal monitoring, but may augment the observation drift instrumentation. Boreholes from the Exhaust Main can monitor conditions in the region below the emplacement horizon. At the emplacement horizon, ventilation drifts can monitor the pillars between the emplacement and ventilation drift. Boreholes from the perimeter main can monitor conditions between emplacement drifts. These various configurations are shown in Figure 3-5.

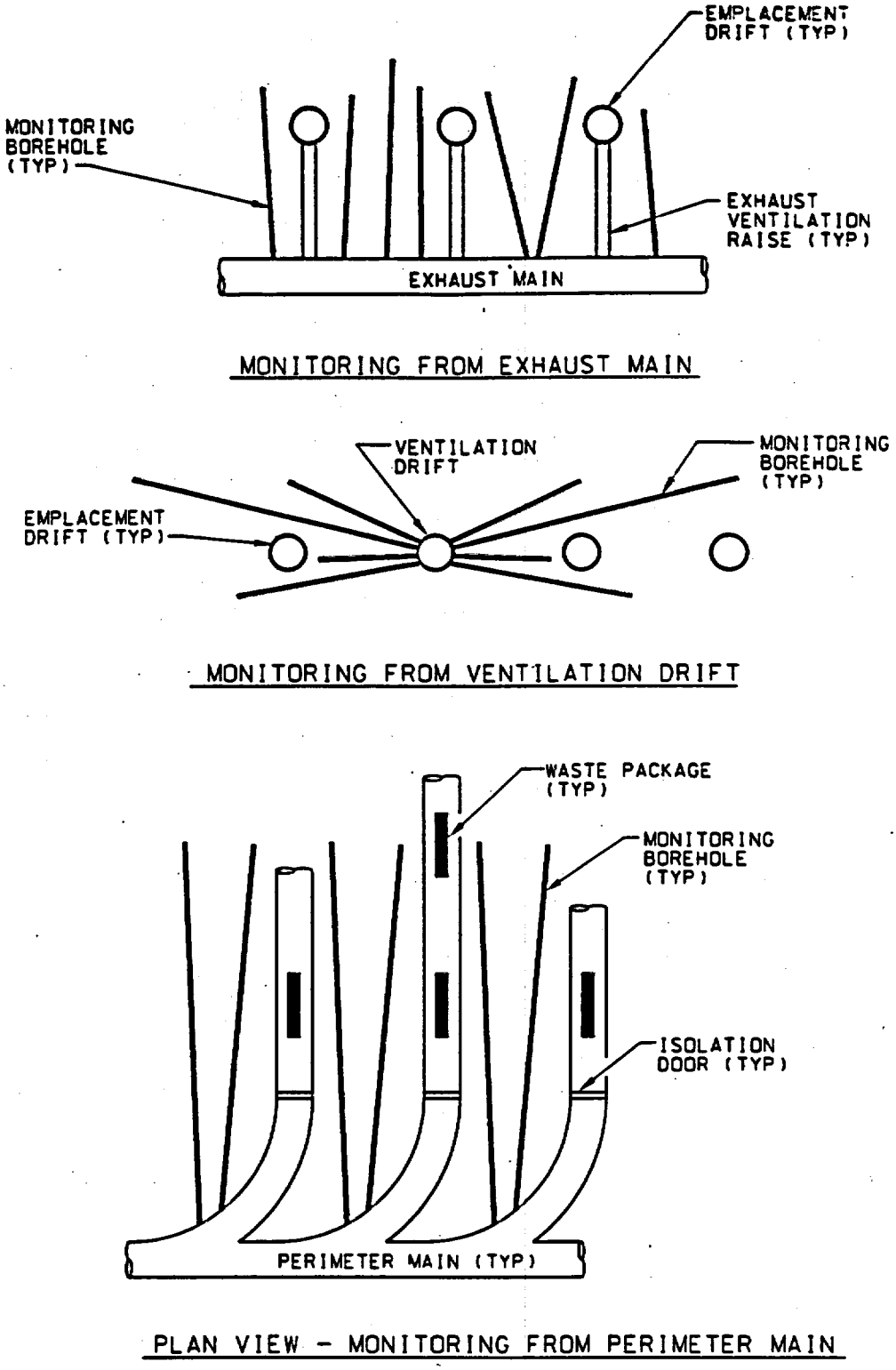

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Figure 3-5. Performance Confirmation Monitoring Alternatives From Non-Emplacement Drifts

3.3.4.2 Emplacement Drift Ventilation Monitoring

The Viability Assessment design concepts include ventilation of emplacement drifts after waste emplacement is completed in the drift (CRWMS M&O 1997c and e). It is assumed that emplacement drift ventilation will be maintained at a low, controlled volume for monitoring purposes (CRWMS M&O 1997a). Ventilation at this level will not lower the peak temperature significantly, but monitoring at the exhaust end of the emplacement drifts will allow measurement of:

- Gases indicative of a waste package leak (krypton-85, etc.)
- Dry bulb temperature
- Wet bulb temperature
- Relative humidity, using the dry bulb and wet bulb temperatures or by direct measurement.

Coupled with monitoring at the intake end of the drifts, this information will yield the amount of moisture being removed from the drifts, an approximation of the rock wall temperature in the drift, and rapid indication of leakage of gaseous radionuclides due to a waste package breach. It will also distribute the heat in the drifts, reducing the magnitude of the disparity in temperature between hotter and cooler zones along the drifts. Additional design description of emplacement drift ventilation monitoring is provided in the following analyses: *Subsurface Repository Performance Confirmation Facilities* (CRWMS M&O 1997e), *Performance Confirmation Data Acquisition System* (CRWMS M&O 1997c) and *Emplacement Drift Air Control System Analysis* (CRWMS M&O 1997o).

3.3.4.3 Recovery of Waste Packages for Performance Confirmation

This concept involves the transport of a previously emplaced waste package to the surface for testing and measurements in support of performance confirmation. This concept will not be implemented for the reasons listed, except as a contingency. Instead, waste package performance will be confirmed with other waste package testing. See Section 3.3.3.

The ability to remove any or all of the waste packages after emplacement is a basic requirement of the repository program. This capability will be maintained throughout the preclosure retrievability period. Such activity could yield information on corrosion, behavior of welds, or early changes in the basket or the fuel itself; however, the activities required to recover one or more waste packages are not trivial. While the exact impacts of this activity are not well defined, it will not be desirable to perform this action repeatedly for the following reasons:

- Cooling of an emplacement drift from a temperature in the range of 140 to 160°C to less than 50°C will cause large changes in the mechanical stresses around the opening, both in the rock and in the installed ground support components. The heating/cooling/reheating will induce strain cycles in the emplacement drift rock and ground support components which would otherwise not occur. Further discussion of the effects of rapid cooling along with modeling results for the unsupported drift openings and the concrete liner is provided in *Repository Ground Support Analysis for Viability Assessment* (CRWMS M&O 1997t).

- The air mass which is pushed out of the emplacement drift and into the main exhaust drift at the onset of drift cooling will make the main exhaust drift temporarily inaccessible. The temperature surge may also adversely affect monitoring equipment likely to be located in the main exhaust drift.

- During the caretaker phase after emplacement is complete, the surface facility will be mothballed. If any activity is required in the surface facility in conjunction with waste package recovery and handling during the caretaker period, the facility would have to be re-activated at some cost. Based on the *Retrievability Strategy Report* (CRWMS M&O 1997s), there is a potential for waste package movement and recovery from accidents during operations that may drive the multipurpose hot cell to remain activated.

3.3.4.4 Alcove Testing in Non-Emplacement Areas

As described in Section 3.3.2, 10 CFR Part 60 describes several testing programs which are to be initiated "during the early or developmental stages of construction...." Included in this suite of testing are tests of potential sealing systems for boreholes and shafts, backfill testing, and heater testing. In addition, subsurface seismic monitoring has been identified as a performance confirmation activity which will be carried during repository operations. Specific subsurface locations and support of these testing activities will be established in the design and accommodated in the operational concept.

As many of these activities as possible will be carried out in an area of the subsurface layout which is removed from the high temperature and radiation environment of the emplacement areas. Personnel access to the emplacement side of the repository will be limited because administrative controls, including strict access limitations, will be enforced to keep radiation doses as low as reasonably achievable. The development side of the repository will provide the best accessibility for testing, and it is assumed for this activity that the early backfill, seal, and thermal testing will be carried out in the development side ventilation system. While access for testing will be not be unlimited even on the development side, it should be sufficient to construct, install, and monitor the tests. Figure 3-2 shows (crosshatched) a continuous length, approximately 12 km, suitable for performance confirmation alcove testing in non-emplacement areas. The continuous length includes the north and south ramps and their extensions, north main, and west main.

3.3.4.4.1 In Situ Seal Testing Alcove

Plans for seal testing will be formulated in the next few years. Following is a preliminary concept.

In situ testing of seal designs and materials may require multiple test locations. Each hydrogeologic unit expected to contain seals at repository closure would be tested. Access to all units from the surface to the repository horizon would be provided in the south ramp. Alcoves could be developed off the south ramp in each unit of interest.

Three test areas, one in the Tiva Canyon welded tuff hydrogeologic unit, one in the Paintbrush nonwelded hydrogeologic unit, and one location in Topopah Spring welded tuff hydrogeologic unit at the repository horizon, are assumed. A description of the seal testing plan is contained in the

Preliminary Test Planning Package for support of Pre-Title Design Studies--Planned Exploratory Studies Facility Tests (YMP 1992). Each of these test areas is estimated to require approximately 300 m of drifting. The test locations would include one near the south portal for the Tiva Canyon unit, one about halfway down the south ramp in the bedded tuff, and one along the South Ramp Extension in the repository horizon.

3.3.4.4.2 Alcoves or Drifts for Backfill Testing

Plans for backfill testing will be formulated after decisions have been made regarding the need and timing of backfilling. Following are preliminary concepts for backfill performance testing and backfill constructability testing.

Backfill Performance Testing–The initial heated backfill test, if required, could be conducted in an alcove along the south ramp extension. It is assumed that an arrangement similar to that being used for the Exploratory Studies Facility heated drift would suffice for this testing activity. A U-shaped alcove layout with one leg of the U serving as the backfilled drift and the other leg as the observation area should be adequate for the test. Heaters to simulate emplaced waste would be covered with backfill material. Instrumentation for data acquisition would be placed in the backfill and in boreholes drilled from the observation drift.

Approximately 100 to 130 meters of drift would need to be excavated. The backfill test area will likely be driven to resemble the emplacement drift size and shape, while the balance of the drifting could be very similar to the Exploratory Studies Facility heated drift test access. Data acquisition could be handled by either a local data logger that is downloaded on a regular basis or by a permanently installed data acquisition, transfer and storage system. In either case, the information would be acquired and stored on-site and subsequently retrieved and transferred to the appropriate scientific personnel located off-site. Onsite scientific presence would be required to monitor the test, and construction support would be required to install the test equipment and to assist with maintenance over the test duration.

Backfill Constructability Test–If the decision is made to backfill the emplacement drifts, the backfill would not be emplaced until just prior to closure. Consequently, this test is not needed until that decision has been made, which would be just prior to backfill placement. This test would likely involve filling all or part of an empty emplacement drift, or one with mock waste packages, to test the viability of the backfill process and equipment, and to gather information on productivity, availability, and the condition and uniformity of the emplaced backfill.

Depending upon the backfill performance requirements developed, there may be a need to conduct a backfill constructability test along with the backfill performance test. This test could reduce the risk of design of the engineered barriers system that includes backfill as a performance barrier, once the construction would be demonstrated along with the backfill performance test. A constructability test just prior to closure may also be needed. If technologies change significantly, then it may warrant a different backfill emplacement system design and constructability test.

3.3.4.4.3 Follow-on Drift Heater Test Arrangement

The heater test arrangement will resemble the Large-Scale, Long-Duration Test described in the *Updated In Situ Thermal Testing Program Strategy* (CRWMS M&O 1997f). The test arrangement will require a relatively intricate, lengthy drifting arrangement with drifts on three distinct levels. A simpler arrangement may be possible. Details will be formulated in implementation plans and specifications after the need for the follow-on tests is established. **TBD - Need for follow-on drift heater test**

3.3.4.4.4 Seismic Monitoring Alcove

Seismic monitoring will occur in a small alcove located along the south ramp extension in the same general area as the backfill test described earlier. Equipment vibration and dust will be accounted for in the selection and installation of the equipment. Data acquisition, as noted, will be handled by a local data logger or by connection into a subsurface-wide data transmission network and storage system. This alcove will be an L shape with a total length of 20 to 30 m.

3.3.4.5 Subsurface Geologic Mapping during Drift Construction

10 CFR Parts 60.72(b)(3) and 60.141(a) require a program of geologic mapping during the construction of the repository. Section 3.3.1.1 provides a strategy for mapping and it is further discussed in Appendix G.

The Exploratory Studies Facility (ESF) tunnel was mapped continuously by personnel stationed on a gantry which is an integral part of the tunnel boring machine trailing gear. The ESF ground support system varies according to the ground conditions as they are seen at the working face. Robust, segmented precast concrete linings are being considered in emplacement drifts in order to reduce the inherent uncertainty of maintaining access for monitoring and retrieval for the extended preclosure period. The use of such lining systems, especially if installed in a close-coupled process with excavation, will complicate continuous and detailed geologic mapping and may prevent continuous full periphery geologic mapping. For a discussion on methods to accomplish this, please see Appendix G. Mapping of non-emplacement drifts is also planned. Visual observation from the tunnel boring machine will be used to detect any geologic anomalies. If detected, such as a fracture zone or ground-water inflow, an immediate decision will be made by the observer if the anomaly needs to be surveyed in detail.

Scheduling will be critical to the successful collection of an unexpected fault zone hydrologic information without adverse impact to repository construction. Because of the large number of emplacement drifts to be excavated, an anomaly encountered in one may be encountered in several drifts. This implies that, once an anomaly is discovered, a contingency plan will be implemented to change ground support systems that would allow investigations to gather geological, hydrological, geomechanical, and geochemical data, as needed, in conjunction with a subsequent intercept of the same anomaly. Also, if the anomaly is of sufficient size, it could be examined from the closest observation drift.

3.3.4.6 Rock Sample Collection during Drift Construction

Rock samples will be collected on a regular basis during the development of the repository. Emplacement drifts need some consideration due to the limitations imposed by the installation of precast concrete linings with the tunnel boring machine excavation. The objectives of the sampling program are to maintain representative geologic specimens of the host rock, to allow laboratory hydrologic testing (e.g., moisture content and matrix water potential), and to allow laboratory compression testing for design verification. Samples will consist of short core, 2 to 5 feet deep, and hand samples obtained by mechanical breaking or chipping. In an emplacement drift with precast concrete liners, short core samples can be taken by drilling through the lining and, if necessary, the borehole can later be grouted or sealed.

A total of 200 to 1000 sampling locations throughout the repository are currently being considered. The actual number of sampling sites will be influenced by the observer on the tunnel boring machine, depending on the variability of geologic conditions. Additional samples will be taken at anomalies that justify stoppage of the tunnel boring machine. See Section 3.3.4.5.

The handling of the samples will depend on any special requirements placed on the sampling by the nature of the testing to be done on the particular sample. Samples will be bagged, boxed, or sealed, and then transported to the surface by the normal personnel and supply transportation system. At the south portal surface facility, the samples will be off-loaded and either stored onsite or transported to an offsite sample management facility.

3.3.4.7 Remotely Operated Systems for Emplacement Drift Monitoring

Several performance confirmation data collection activities will be utilizing telerobotic or remotely operated systems, which will be designed to withstand limited exposure to the elevated temperatures and radiation levels expected within the post-emplacement drift environment. The systems will be general purpose mobile platforms that will be outfitted with instrument packages providing visual, thermal, and radiological inspection capabilities. The vehicles will also be equipped with tell-robotic manipulators with end-of-arm tooling attachments like grippers, cameras and lighting for recovery of waste package test specimens or coupons. These remote systems will be observed and controlled continuously by human operators at a control station located above ground.

Controlled design assumptions specify that maximum temperatures inside the post-emplacement drifts will be limited to 200°C (CRWMS M&O 1997a). Based on current design concepts, preliminary calculations indicate that temperatures inside the post-emplacement drifts may only reach the 146-163°C range (CRWMS M&O 1997i). Other calculations indicate that radiological conditions inside the emplacement drifts may have dose equivalents of 35.30 rem/hr at the surface of some waste packages (CRWMS M&O 1997j). These radiation levels are much too high to realistically permit human entry, but are manageable for remote equipment.

3.3.4.7.1 Design Strategies and Technologies for Elevated Thermal and Radiation Environments

The technical details for the remote data acquisition system in waste emplacement drifts have not yet been finalized. General concepts and considerations that need to be addressed in the design of such a system can be presented, however, based on existing technology.

From the nuclear industry, technologies and effective design techniques exist that will permit remotely operated equipment to be used in radiation environments many times higher than expected inside the emplacement drifts. For the dose rates expected, the principal strategies for minimizing the effects of radiation will be the judicious use of radiation shielding materials, the use of rad-hardened electronic components, and the monitoring of the total accumulated dose and replacing sensitive components at periodic intervals. The latter will be possible because each employment of a remotely-operated vehicle inside the emplacement drifts will be for short periods only.

The major challenge facing designers will be to build systems that can tolerate the elevated temperatures. A review of design strategies and heat compatible technologies indicates that it may be feasible to develop heat tolerant vehicles that can operate for limited periods of time within the emplacement drifts. For much of the design, it will not be difficult to select appropriate mechanical components, such as gears and bearings, and structural materials that are suitable for use at elevated temperatures. A key concern, however, will be the use of heat-sensitive on-board electronics and actuators. Typically, commercial grade electronics and components have maximum operating temperatures in the range of 50°C to 85°C. If available, military grade components may allow operation of some components up to 100°C (CRWMS M&O 1997l). Recent calculations have demonstrated that the equipment and instrumentation within the insulated remotely operated vehicle will not exceed 50°C during the preclosure period if they do not remain in an emplacement drift longer than 58 min without on-board active cooling and up to 180 minutes with active cooling systems (CRWMS M&O 1997c, Table 7.6-10). This period will be sufficient for performing the planned measurements and sample collection.

Beyond selecting the most suitable electronic components, there are several design strategies and technologies that may enable the use of remotely operated vehicle technologies inside the emplacement drifts. These include:

- Limited time of exposure
- Thermal insulation/heat rejection technologies and strategies
- Active and passive cooling systems for internally generated heat
- Thermally robust power and communication technologies
- Limited, or alternated, duty cycle of power intensive components
- Low power electronics and components
- High temperature tolerant electronics and hardware
- Prudent layout of thermal conduction paths for high heat components.

Heat from external sources can be rejected by use of appropriate shielding and insulating materials. The primary concern is removing or dissipating heat internally generated by the remotely operated vehicle. The principal source of internal heat generation is the consumption and conversion of electric power. Two subsystems that are critical to the successful design of heat tolerant vehicles are power and communications technologies.

Electric Power Alternatives–An analysis was completed recently that reviewed several alternative power system design concepts (CRWMS M&O 1997k). Electric batteries are typically used to power conventional remotely operated vehicle designs; standard battery designs, however, generate considerable heat and do not operate well at temperatures above 50°C. One promising concept, which appears to be fairly immune to elevated temperatures, is the use of conductor bar technology. This technology is well proven and used in the transit industry to power trains and trolleys. It involves mounting an electrically conductive bar along side the rail system to which a small riding unit, or shoe, is attached providing electrical power across a sliding brush contact.

A conductor bar installed in the emplacement drifts would be durable, robust and essentially maintenance free. It is a totally passive system and housed in a protective insulator cover. One advantage of this technology is that the primary power source would be external to the remotely operated vehicle and thereby significantly reduce internally generated heat. If a segment of conductor bar becomes unusable, it could be replaced with a new segment using remotely operated vehicles.

Remote Communication Alternatives–Another recent analysis describes existing communications technologies for remotely operated vehicle operation within the emplacement drifts (CRWMS M&O 1997c; CRWMS M&O 1997n). Radio control is used extensively in underground remote mining applications; in underground applications, however, care must be taken when designing the system to avoid a phenomenon called multipathing, where radio signals reflecting off rock walls can be distorted and interfere with clear radio communication.

Another remotely-operated vehicle communications technology that looks promising that also appears to be fairly immune to elevated temperature environments, is the use of wave guide technology, similar to that used in the rail transit industry. This technology entails the use of a small slotted wave guide, a hollow metallic conduit installed along the length of each drift. A small microwave transceiver antenna rides along the slot in the wave guide and provides very high bandwidth communication between the vehicle and the transmitting/receiving station located near the entrance to the emplacement drift. It is a well proven existing technology and requires essentially no maintenance.

Electronic Component Technology–In the past several years, there have been many advances in the area of low-power, high-capacity, electronic components for the portable computer industry. Special 3-volt logic components, hardware sleep modes, and other techniques have been developed that considerably reduce the amount of energy required. The advantage of these components is that they consume much less power and therefore generate much less heat internal to the system.

The automotive, aerospace, and oil and gas industries are currently developing a new breed of electronic components that operate un-cooled, without active cooling, in ambient temperatures above

200°C. Using new silicon carbide and other technologies, whole new families of heat-tolerant integrated circuits are being developed.

3.3.4.7.2 Rail-Based Gantry Remotely-Operated Vehicle Inspection System

The current waste package emplacement concept calls for the use of a rail-based gantry system to emplace waste packages on pedestals along the center of the emplacement drifts (CRWMS M&O 1997m). A gantry-style remotely-operated vehicle inspection system has been designed, which rides the same rail system used for emplacement (CRWMS M&O 1997c). This gantry vehicle could serve as a general purpose instrumentation platform and would provide ample support for remote visual, thermal, and radiological inspection activities. It would also provide an excellent platform on to which remote manipulators could be mounted for sample/coupon recovery activities. The inspection gantry would be controlled from a control station located at the surface.

A remotely operated gantry system arches over and straddles the emplaced waste packages in a kind of horseshoe-shaped configuration. A radial three-axis carriage riding on the arched structure permits instrumentation packages to be driven around the waste packages providing visibility to either side and on top. The gantry vehicle also provides close-up and detailed inspection coverage of surrounding drift walls and infrastructure. See Figure 3-6.

Features of a gantry-style remotely operated vehicle include the following:

- Large payload, capable of carrying multiple, larger instruments, manipulators, and fully redundant backup systems
- Accommodation for heat tolerant power and communication technologies
- Accommodation for alternative power sources such as batteries
- Benefits from existing rail infrastructure
- Provision for overall coverage and close-up detailed inspection
- Ease in insulation from external heat and dissipation of internally generated heat
- Sturdiness and ruggedness of construction suitable for some infrastructure maintenance
- Flexibility in system configuration for varied task assignments and off-normal applications.

Some concerns and limitations related to the use of a gantry-style remotely operated vehicle are the difficulty in extrication should the system and backup systems fail and difficulty or impossibility of the gantry traversing around or over even small obstacles. Some of these concerns have been further addressed in CRWMS M&O 1997c.

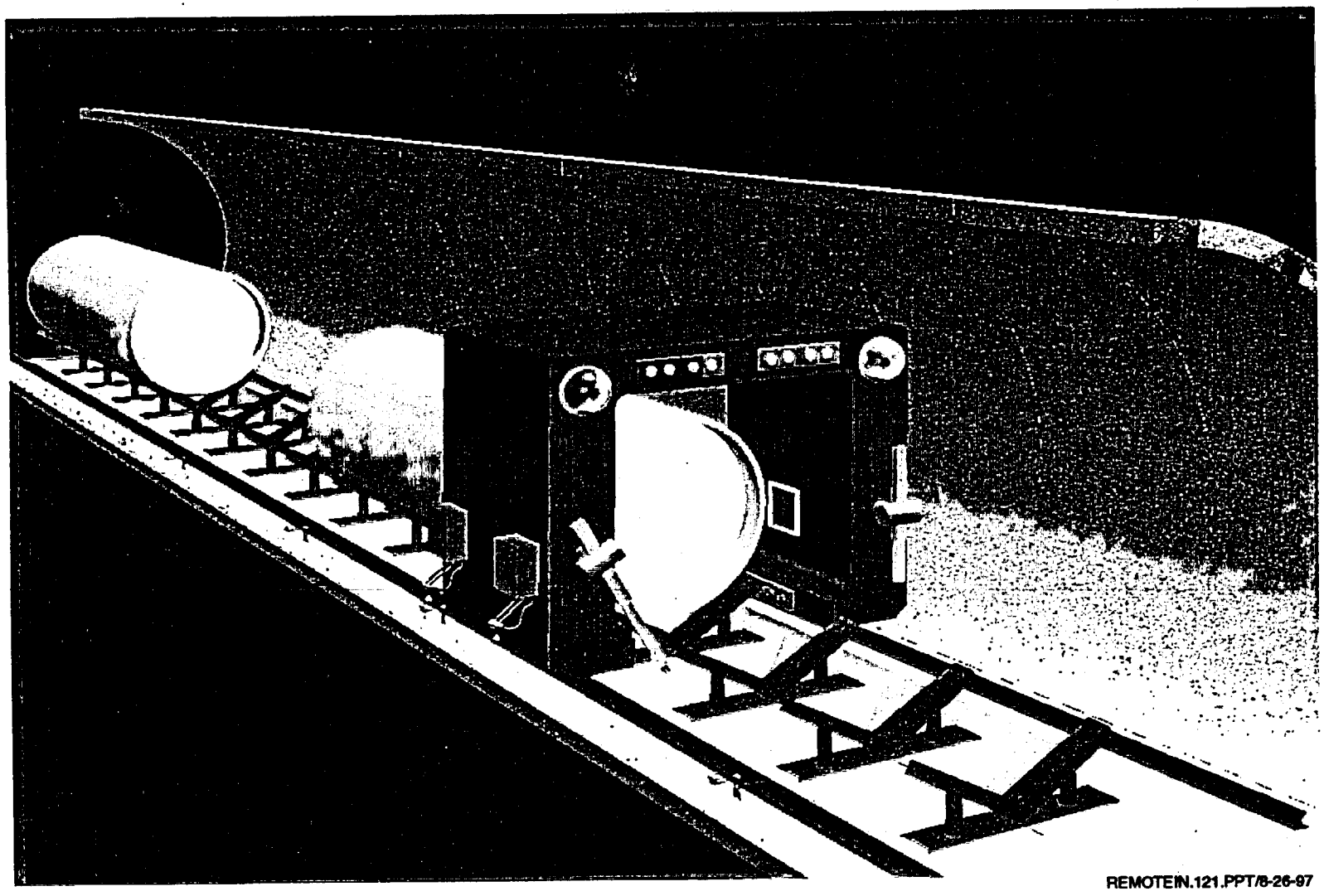

Figure 3-6. Remote Inspection Gantry

3.3.5 Surface Test Facilities and Support

The surface test facilities and support concepts consist of a performance confirmation and multi-purpose hot cell, located in the waste handling building, and a performance confirmation support area. Surface-based handling of samples and data is also considered and includes interfacing with the subsurface test facilities and support concepts, surface-based monitoring and testing concepts, offsite testing, and offsite analysis work.

3.3.5.1 Performance Confirmation and Multi-Purpose Hot Cell

A standard general purpose hot cell will be provided in the waste handling building for performing performance confirmation activities, other non-routine activities (like off-normal or accident scenarios for repository operations), and scientific studies that might become necessary during the operational period of the repository. The cell will be large enough to handle a waste package and versatile enough to be able to perform a large variety of measurements and investigations. It will be possible to change the configuration and use of the cell in fairly rapid order to accommodate equipment that would be used for a variety of purposes. This capability will be based on the use of jumpers, spare lines, and removable plugs, which are standard methods used in multi-purpose hot cells.

The performance confirmation/filler cell provided in the advanced conceptual design closely resembles the cell that is the focus of this concept. The performance confirmation cell would differ from that in the advanced conceptual design only as follows:

- The cell would have increased versatility and be able to accommodate a greater variety of operations.
- The addition of filler material would not necessarily be a major use of the cell.
- An effort would be made to provide a connection, such as a rabbit or conveyor, to the analytical cells.
- Manipulator and viewing access to more than one cell face would be provided; with the size of equipment and objects that are to be placed in the cell, not much can be done from only one side.
- The cell will have the capabilities to open the robust waste packages, perform examinations that may be required, perform non-destructive testing of weld and possibly contents, and other studies.
- The use of this cell for performance confirmation purposes would be a fairly modest part of the cell use.

Table 3-3 summarizes the key features of such a cell.

Table 3-3. Performance Confirmation and Multi-Purpose Hot Cell Concept

Cell dimensions, interior	15 ft wide x 15 ft long x 30 ft high
Cell walls	5 ft ordinary concrete stainless steel lined
Cell access	Cell roof hatch 10 ft sliding shielding door
Viewing	Shielding windows (3)
Handling	Master slave manipulators (3 sets) Electromechanical manipulator Heavy duty dolly (150 ton capacity) 5-ton in-cell crane
Power	Overhead and recessed wall lighting Power jumpers with spares Removable electrical plugs
Instrumentation	Built-in instrumentation jumpers Removable instrumentation plugs
Utilities	Built-in jumpers for air, steam, vacuum, etc. Decontamination wands Cell floor drains in water decon termination system
Other features	Top to bottom ventilation Dedicated radiation monitoring system Ports for sample, tool, etc. removal Storage racks for samples/specimens

This plan does not consider the routine recovery of waste packages at fixed intervals. A waste package or waste packages would be recovered to the surface only if other performance confirmation activities such as corrosion coupons indicate the need for surface inspection of a previously emplaced waste package.

3.3.5.2 Performance Confirmation Support Area

A performance confirmation support area will be located outside the radiologically controlled area of the MGDS. This area will house the administration of performance confirmation programs and other related programs that would require similar capabilities. Its main purpose will be to act as the hub for the acquisition, storage, distribution, and monitoring of all scientific data and samples required for the various scientific programs, including performance confirmation. Table 3-4 lists features of this area.

3.3.6 Operations and Management

This section describes the activities that will be performed in operation and management of the Performance Confirmation Program. Revisions to this Plan, detailed test plans and procedures will be performed, as required. In implementation of the Performance Confirmation Plan, management of the data, results, and samples will performed. For data acquired during performance confirmation,

Table 3-4. Performance Confirmation Support Area Concept

Type of Structure	Either Metal Frame or Block
Size	Approximately 10,000 sq. ft.
Contents, functional areas	Offices (operations and management, procurement, logistics, maintenance, safety, etc.) Data collection Storage Sample packaging, preparation, shipping Instrumentation laboratory Site monitoring central control Records management Limited laboratory (hoods, benches, etc.)

these activities include collection, storage, communication of data. Sample collection, handling, storage, and if necessary, procurement of offsite laboratory services, packaging and transporting samples are the related management activities. Instrument maintenance and calibration operations are necessary to implement the Performance Confirmation Program. After the evaluation of the data and test results, information management is needed with development of performance confirmation records, baseline change control, and administrative support activities.

3.4 EVALUATIONS AND CORRECTIVE ACTIONS

This section describes the approach and activities for comparing the Performance Confirmation Baseline established before the submittal of the License Application with the results of the performance confirmation measurements, testing, and predictions. The planned activities will include evaluations of changes regarding regulatory compliance with NRC postclosure performance requirements since the new data may result in changes in the expected postclosure performance of the natural and engineered barrier systems and the overall MGDS compared to the predictions included in the License Application. The results of these comparisons may require corrective actions in terms of model improvements, changes in the performance confirmation program, and changes to the MGDS design, construction, and operation.

A variety of techniques are planned for evaluating the results of performance confirmation site monitoring and testing. These techniques include statistical tests, natural and engineered barrier process modeling, and total system performance assessment. The planned process modeling and total system performance assessments are described in sections 2.4 and 3.2. The specific statistical tests to be used will be selected when the analyses are needed. Examples of common tests are null-hypothesis testing, the signed-rank test, the paired t- test, the rank-sum test, and the two-sample t-test (MHI 1993). The choice of tests will depend on the nature of the parameter comparison, such as comparing pairs of single-value distributions of parameters, and on the statistical distributions of the parameter values, such as normal or log-normal). The statistical tests will determine the statistical significance of any differences. These tests are planned for comparing:

- Site characterization data with performance confirmation data
- Successive stages of performance confirmation data

- Model predictions of each performance confirmation parameter with the baseline values
- Pre- and post-License Application performance predictions.

The planned comparisons are described in the following sections.

3.4.1 Data Comparisons

Evaluations of the collected performance confirmation data are planned to confirm that the measured values, observed features, and natural and engineered barrier processes are as expected. These evaluations will involve comparisons of the site characterization data themselves with performance confirmation data that do not involve process modeling. It will include mathematical analyses, however, for raw data reduction, numerical interpolations, numerical extrapolations, and statistical interpretations. The interpolations and extrapolations may be accomplished by simple arithmetic calculations, by calibration of mathematical process models, and by inverse process modeling, which could involve some process modeling. See Section 3.2.2. Not all performance confirmation needs involve modeling. For instance, the confirmation that subsurface geologic conditions are as expected is based on comparing observations without the need of modeling other than the interpolations and extrapolations.

The data evaluations will be performed in two phases:

- Before the submittal of the License Application, a comparison of site characterization data with performance confirmation data collected before the submittal of the License Application

- After the submittal of the License Application, a comparison of site data characterization and performance confirmation data collected before the submittal of the License Application with performance confirmation data collected after the submittal of the License Application. The latter will include comparisons with the data baseline used for the License Application.

Only one evaluation seems necessary before the submittal of the License Application. The intervals between iterations after the submittal of the License Application will be determined on the basis of the results of each previous iteration, including the evaluations described in the remainder of Section 3.4. These data comparisons overlap both the pre- and post-License Application model predictions described in Section 3.2 and the evaluations described in sections 3.4.2 and 3.4.3.

Some parameters can be measured directly, for instance, air temperature using a thermometer, but many measurements, especially if through remote means, require the conversion of the measured parameters into the parameters of interest. For some parameters, the conversion of electrical currents or voltages into the physical values of interest, like mechanical stress is involved. For others, analyses are necessary to convert measured parameter values into the parameters of interest. An example is the derivation of saturated hydraulic conductivity from ground-water pumping rates and well drawdown measurements as a function of time. This involves the assumption of a mathematical model for the relationship between these parameters. The hydraulic conductivity is then calculated from the other measurements using that mathematical model.

Other analyses involve the interpolation and extrapolation of point values in space and time to obtain spatial distributions and functions of time and the calculation of statistical distributions of uncertainty for the direct data comparisons and for input to the performance assessment models. This could include, for instance, the derivation of a normal distribution for rock matrix porosity and a log-normal distribution for saturated hydraulic conductivity from spatially distributed measurements of a given hydrogeologic unit. Because differences can be expected, statistical analyses will be performed to evaluate the statistical significance of the differences. Because these comparisons use the site properties defined by the various conceptual site models, this aspect of the performance confirmation constitutes the confirmation of these conceptual models. At present, these models include the geologic framework model (CRWMS M&O 1996a), the unsaturated zone hydrological model (LBNL 1997b), the unsaturated zone flow and transport model (LANL 1995a), the mineralogical model (LANL 1997a), the unsaturated zone/perched water hydrochemical/geochemical model (USGS 1997a), the ground water chemistry model (LANL 1997b) and the saturated zone flow model (USGS 1996b; USGS 1997c; LBNL 1997a).

The direct comparisons between parameter values measured before and after the submittal of the License Application will indicate the statistical significance of any data differences. Because of the interrelationships of parameters, including associated nonlinearities, intuition with respect to the effects of data differences on predicted postclosure performance may be misleading. Consequently, only postclosure performance predictions can demonstrate the significance of data differences with respect to effects on compliance with NRC postclosure performance requirements. These aspects are addressed in Section 3.4.5.

3.4.2 Comparisons of Measured Data with Model Predictions

The statistical tests evaluating the differences between the License Application baseline values and the values measured following the submittal of the License Application provide only a partial picture of the differences. Although the tests determine the statistical significance of the differences, they do not define the technical/scientific significance of the differences with respect to the natural and engineered barrier processes and the overall system performance. Each data comparison looks at only one or two parameters for a given analysis; independent of other parameters, it will neglect the combined, often nonlinear, effects of all parameters determining the performance of a system or component. Consequently, the modeling of the important natural and engineered barrier processes and of the overall system will reveal the technical/scientific significance of the data differences with respect to performance predictions.

The results of the preclosure performance predictions made prior to the submittal of the License Application will be compared with the performance confirmation data (see Section 3.2.1.1). Comparisons will also be made between iterations of post-license application preclosure performance predictions. This includes tests evaluating statistical significance of differences.

3.4.3 Comparisons of Model Predictions

The results of the preclosure performance predictions to be made prior to submittal of the License Application (see Section 3.2.1.1) will be compared with the results of the predictions scheduled after the submittal of the License Application (see Section 3.2.1.2). Comparisons will also be made

between iterations of the post-License Application performance predictions. Statistical tests will be performed to evaluate the statistical significance of differences. More important however will be interpretations of the technical/scientific significance of differences regarding the fundamental concepts of natural and engineered barrier system processes and the overall MGDS performance (see Section 3.4.4).

3.4.4 Accuracy and Validity of Performance Assessment Models

The comparisons identified in Sections 3.4.2 and 3.4.3 provide insights into the validity of the conceptual models and the accuracy of the mathematical models for predicting preclosure performance of the natural and engineered barrier systems and of the overall MGDS. These insights can be used to infer the validity and accuracy of the models predicting the postclosure performance of the natural and engineered barrier systems and of overall MGDS, which will be key results of the performance confirmation program.

3.4.5 Evaluation of Compliance with NRC Postclosure Performance Requirements

The ultimate test of the results of performance confirmation, however, will be to evaluate whether the postclosure performance predicted in support of the License Application **TBD - LA TSPA** will change as a result of changes in parameter values, conceptual and mathematical models, repository layout and waste inventory, and unforeseen events during the preclosure phase. The critical performance confirmation issue will be to demonstrate compliance with the NRC postclosure performance requirements considering these changes.

Consequently, postclosure performance assessments after the submittal of the License Application will form the basis for demonstrating compliance with NRC postclosure performance requirements. See Section 3.2.1.3. The timing of these assessments will depend on the results of the performance confirmation site monitoring and testing, including the data and model comparisons. See sections 3.4.1 through 3.4.4. The postclosure performance assessments described in Section 3.2.1.3 will be performed whenever the statistical comparisons of parameter values and preclosure performance predictions show significant differences or if other observations allude to potential problems or significant changes regarding expected repository performance.

Evaluations of regulatory compliance include analyzing not only the overall MGDS regarding postclosure system performance standards, but also analyzing subsystems regarding the applicable subsystem standards. Currently, 10 CFR Part 60 and expected postclosure system performance standards include:

- 10,000-year cumulative radionuclide release to the accessible environment
- Radionuclide concentrations in ground water
- Radiation doses to a representative member of the public.

Current subsystem postclosure performance standards include:

- Preclosure ground-water travel time
- Waste package life
- Radionuclide release from the engineered barrier system.

These standards may change because of a court remand of 40 CFR Part 191 and the recent recommendations by the National Academy of Sciences for revised standards (NAS 1995).

3.4.6 Trend Detection

The described comparisons and evaluations will be analyzed to identify any trends between the measured and predicted performance of the natural and engineered barrier systems and the overall MGDS regarding the License Application baseline. If trends are significant, based on both statistical analyses and expert interpretations, then corrective actions will be recommended as identified in the following section.

3.4.7 Recommended Corrective Actions

A process for assessing the trends and recommendating corrective actions will be developed but depending on the nature and significance of the deviations and their trends, the following corrective actions may be recommended:

- Revisions and additions to the YMP technical database
- Revisions or improvements of the conceptual models of natural and engineered barrier processes
- Revisions or improvements of the mathematical models and associated computer codes of these processes
- Revisions or improvements in the total system performance assessment software
- Changes in the performance confirmation site monitoring and testing program
- Changes in the performance confirmation test facilities and support systems
- Changes in the design, construction, and operation of the MGDS
- Selective waste retrieval
- MGDS closure including application or license amendment
- Complete waste retrieval and site abandonment
- Interactions with the NRC and stakeholder organizations.

3.4.8 Corrective Action Implementation

The implementation of the corrective actions will be the responsibility of the following organizations:

- YMP Technical database:
  - Technical Data Management Department

- Conceptual and mathematical process models and associated computer codes, depending on process:
  - Site Evaluation Program Operations
  - Repository Design Department
  - Waste Package Development Department
  - Waste Package Materials Department
  - Engineered Barrier System Department

- Total system performance assessment mathematical model and computer software:
  - Performance Assessment Department

- Performance confirmation site monitoring and testing program:
  - System Engineering/Integration
  - Site Evaluation Program Operations

- Performance confirmation test facilities and support system design:
  - System Engineering/Integration
  - Repository Design Department
  - Engineered Barrier System Department

- MGDS design:
  - Repository Design Department
  - Waste Package Development Department
  - Waste Package Materials Department
  - Engineered Barrier System Department

- Performance confirmation test facilities, support system, and repository construction and operation, including waste emplacement and retrieval:
  - Site Construction and Operations

- Interactions with the NRC and stakeholder organizations:
  - Licensing Department

- File abandonment or MGDS closure
  - Site Construction and Operations
  - Licensing Department.

In addition, the System Engineering/Integration will have the responsibility to monitor the implementation of these changes and to revise the *Performance Confirmation Plan* accordingly.

3.4.9 Baseline Change Control

Baseline change control will assure that the above changes are baselined and controlled in accordance with quality assurance procedures to ensure that the same up-to-date data and information will be used by all personnel for all activities described in Section 3.4, including in the implementation of the corrective actions. Baseline and change control will cover:

- Performance confirmation data
- Technical, process and total system performance assessment, computer codes
- Monitoring and testing plans and specifications
- Test facilities and support plans and specifications
- Monitoring and testing reports
- Performance assessment reports
- MGDS design drawings and specifications
- MGDS as-built reporting
- *Performance Confirmation Plan.*

Responsibilities for baseline change and control for each of the above items are spelled out in quality assurance procedures.

3.5 REPORTING

This section identifies the reports to be generated by the performance confirmation activities. Report preparation, review and approval will be conducted in accordance with applicable quality assurance procedures. Each report will include a list of cited references, a glossary of important terms, and a list of acronyms and abbreviations. Most documents listed may be revised periodically to reflect corrective actions resulting from the performance confirmation evaluations. See Section 3.4.7. The reports described in the following subsections are planned.

3.5.1 Monitoring and Testing Plans and Specifications

These documents will identify the planned activities in sufficient detail to execute the activities, including:

- Specifications for the instrumentation, equipment, materials, and supplies
- Identification of the facilities and support systems needed (reports in Section 3.5.2)
- Planned locations and duration
- Frequency of measurements
- Technical testing procedures
- Data acquisition system(s) to be used
- Determination of importance
- Quality assurance requirements

- Names of responsible organization, principal investigator, and key staff
- Testing and evaluation reports to be generated.

3.5.2 Test Facilities and Support Requirements

These documents will identify the Performance Confirmation requirements for the facilities and support systems in sufficient detail to construct and operate them, including:

- Specifications for the testing facilities and support systems
- Planned locations

3.5.3 Monitoring and Testing Reports

These reports will document the design of each site monitoring and testing activity, the conduct of the activity, and the results of the activity, which will include:

- Description of the activity
- Identification of the test facilities and support systems used
- Identification of the location, time and duration of the activity
- Instrumentation used
- Measured data
- Calculated data (from raw data conversions, interpolations, and extrapolations)
- Problems encountered and actions taken to resolve the problem.

3.5.4 Technical Database Reports

Periodic reports on the status of the Project technical database and changes during the reporting period, since the last periodic report, will be prepared, which will include:

- List of site monitoring and testing reports data that have been added
- List of parameter names that have been added and reasons for addition
- List of parameter names that have been removed and reasons for removal
- List of parameter names that had values added
- List of parameter names that had values deleted
- List of parameter names whose values were revised.

3.5.5 Data Comparison Reports

These reports will be prepared for each iteration of the data comparisons described in Section 3.4.1. They will include:

- Comparisons of the measured performance confirmation parameter values with the site characterization and License Application baseline

- Statistical analyses to determine the statistical significance of any differences

- Technical/scientific significance of the differences
- Trends and trend analysis (see Section 3.4.6)
- Recommendations for corrective actions (see Section 3.4.7 for list of potential actions).

Evaluations of postclosure performance and regulatory implications will be included in separate reports. See Section 3.5.3.

3.5.6 Data/Model Comparison Reports

These reports will be prepared for each iteration of the comparisons of performance confirmation data with pre-License Application preclosure performance predictions described in Section 3.2.1. They will include:

- Comparisons of the measured performance confirmation parameter values with the pre-License Application preclosure performance predictions
- Comparisons of the measured performance confirmation parameter values with post-License Application preclosure performance predictions of a previous iteration
- Statistical analyses to determine the statistical significance of differences
- Technical/scientific significance of the differences
- Conclusions with respect to the validity of the conceptual models and accuracy of the mathematical models (see Section 3.4)
- Identification of any trends with respect to previous evaluations (see Section 3.4.6)
- Recommendations for corrective actions (see Section 3.4.7 for list of potential actions).

Evaluations of postclosure performance and regulatory implications will be included in separate reports. See Section 3.5.7.3.

3.5.7 Performance Assessment Reports

Separate reports will be prepared for each iteration of the three types of performance predictions. See Section 3.2.1.

- Pre-License Application predictions of the preclosure performance of the natural and engineered barrier systems
- Post-License Application predictions of the preclosure performance of the natural and engineered barrier systems

- Post-License Application predictions of the postclosure performance of the natural and engineered barrier systems.

A single report may be prepared for each performance assessment iteration or separate topical reports may prepared for specific aspects of process modeling or total system performance assessments.

Following is the planned report content for each of these three types of predictions.

3.5.7.1 Pre-License Application Predictions of Preclosure Performance

These reports will include:

- Summary descriptions of the conceptual and mathematical models and computer codes used
- Descriptions and listings or references to the data to be used for the predictions, which will include site-characterization data, pre-License Application performance confirmation data, and the License Application MGDS design
- Predictions of parameter values for the locations and times of planned in situ and field measurements of natural and engineered barrier performance
- Predictions of expected results of laboratory testing and experiments.

3.5.7.2 Post-License Application Predictions of Preclosure Performance

These reports will include:

- Descriptions and listings or references to the data to be used for the predictions, which will include site-characterization data, pre- and post-License Application performance confirmation data, and as-built MGDS conditions
- Predictions of parameter values for the locations and times of planned in situ and field measurements of natural and engineered barrier performance
- Predictions of expected results of laboratory testing and experiments
- Comparisons with the pre-License Application predictions of preclosure performance
- Comparisons with previous iterations of post-License Application predictions of preclosure performance
- Statistical analyses to evaluate the statistical significance of differences
- Interpretations of the technical/scientific significance of differences
- Conclusions with respect to the validity of the conceptual models and accuracy of the mathematical models (see Section 3.4.4)

- Identification of trends with respect to previous evaluations (see Section 3.4.6)
- Recommendations for corrective actions (see Section 3.4.7 for list of potential actions).

3.5.7.3 Post-License Application Predictions of Postclosure Performance

These reports will include:

- Descriptions and listings or references to the data to be used for the predictions, which will include site-characterization data, pre- and post-License Application performance confirmation data, and as-built MGDS conditions
- Predictions of postclosure natural and engineered barrier system and overall MGDS performance
- Comparisons with the License Application predictions of postclosure performance
- Comparisons with previous iterations of post-License Application predictions of preclosure performance
- Statistical analyses to evaluate the statistical significance of differences
- Interpretations of the technical/scientific significance of differences
- Conclusions regarding the validity of the conceptual models and accuracy of the mathematical models (see Section 3.4.4)
- Identification of trends with respect to previous evaluations (see Section 3.4.6)
- Recommendations for corrective actions (see Section 3.4.7 for list of potential actions).

3.5.8 Performance Confirmation Plan

This *Performance Confirmation Plan* will be revised as needed to reflect the previously listed evaluations and reporting.

3.5.9 Other Documentation

As identified in various places of this Plan, other activities will interface with and will be affected by the Performance Confirmation Program. Documentation of these activities is outside the scope of this Plan. This documentation will include:

- MGDS design, construction, and operation, including waste emplacement and potential retrieval

- Conceptual models of natural and engineered barrier processes, their mathematical models and computer codes, and total system performance assessment software, including software qualification

- Interactions with the NRC and stakeholder organizations

- Documentation in compliance with specific steps of the many relevant quality assurance procedures including mathematical model validation and computer software verification

- Documentation in support of the License Application amendment for repository closure and other regulatory compliance documentation.

3.6 TRAINING

Currently, the CRWMS M&O Quality Administrative Procedure QAP-2-1, *Indoctrination and Training*, establishes responsibilities and processes for indoctrination and training of CRWMS M&O Contractor personnel conducting work subject to *Quality Assurance Requirements and Description* requirements. The responsible manager is required to determine the employee's training needs and to identify quality-affecting activities or task requirements based on a review of activity evaluations and the employee's position description. Each employee is required to attend quality assurance indoctrination and complete training through reading/self-study or classroom training prior to performing work subject to quality assurance requirements. Finally, the manager is required to monitor employee's performance and work scope to determine the need for additional training, retraining, or deletion of training.

3.7 QUALITY CONTROL

Currently, the CRWMS M&O Quality Administrative Procedure QAP-2-0, *Conduct of Activities*, provides the methodology for evaluating activities, identifying those subject to *Quality Assurance Requirements and Description* requirements, and to determine if appropriate controls are in place prior to the performance of work. The responsible manager for each activity is required to evaluate whether the activity is subject to *Quality Assurance Requirements and Description* requirements; select personnel with appropriate qualifications for the conduct of those activities; ensure that personnel have completed Quality Assurance indoctrination and training (see Section 3.6); ensure that personnel conduct the activities in accordance with the procedures necessary to control their work; and when sufficient procedures do not exist for controlling the work, ensure that new procedures, or revisions to existing procedures, are prepared.

When evaluating whether an activity is subject to *Quality Assurance Requirement and Description* requirements, the responsible manager will determine if the permanent item(s) with which the activity is associated is on the *Q-List* (DOE 1997c) and determine the extent to which the activity will impact any permanent items that are subject to *Quality Assurance Requirements and Description* requirements. Since performance confirmation related activities are conducted to determine if the items important to waste isolation are functioning properly, it is anticipated that most activities will be evaluated to be subject to *Quality Assurance Requirements and Description* requirements. Each activity defined in the plan will be individually evaluated when the activity is directed to be

conducted by the DOE. This direction or guidance may be in the form of the Work Breakdown Structure, Work Authorization Directives, the Yucca Mountain Project Office Participant Planning Sheets or other technical direction.

Evaluations of items and activities are required to be performed by the MGDS Safety Assurance department to assess relevance to potential waste isolation impacts (due to construction and/or PC activities), potential interactions between independent PC activities, and/or potential interactions between construction activities and PC activities.

The Performance Confirmation Plan will adhere to the quality assurance, management, and technical controls described in the *Quality Assurance Requirements and Description*, Section 11. Applying these controls will ensure the validity of the information required to support the licensing process.

3.8 INTERIM PERIOD TEST AND EVALUATION

The interim period test and evaluation activities will be those that must occur between the time of the submittal of the License Application for repository construction and the time of construction authorization. These activities will include a selected number of site monitoring and testing activities that are planned to continue through the end of site characterization. Activities that will continue monitoring changes of baseline conditions due to site characterization will be included in this period. Other selected long-term testing activities begun in site characterization will be included. Updated planning as required by the licensing process will be conducted.

The specific site monitoring and testing activities to be continued in this time period are **TBD - Interim period site monitoring and testing activities**. The Site Characterization Plan identified a set of activities that were expected to continue in this time period. Tables that describe these activities were provided in the *Performance Confirmation Concepts Study Report* (CRWMS M&O 1996f), Appendix I. The specific tests recommended will consider those recommended in the Site Characterization Plan, but will be a subset of all performance confirmation site monitoring and testing activities discussed in this Plan.

3.9 RELATIONSHIP, COORDINATION, AND INTEGRATION WITH MGDS TEST AND EVALUATION ACTIVITIES

The MGDS Test and Evaluation Program includes all development, operations, and performance confirmation testing and evaluation activities. The Performance Confirmation Program is a subset; however, since it is specifically identified in 10 CFR Part 60, Subpart F, it has important regulatory significance. The Project Test and Evaluation Plan will be the document that governs the MGDS Test and Evaluation Program. A draft MGDS *Viability Assessment Test and Evaluation Plan* (CRWMS M&O 1997b) is currently in preparation. This document will consist of an integrated test plan that, when implemented, will validate the MGDS for receipt, handling, disposal, and isolation of waste. A portion of the MGDS test section refers to performance confirmation tests as defined in the *Performance Confirmation Plan*. The Viability Assessment Test and Evaluation Plan will identify a list of key project characteristics and measures, the methodology for implementing tests and evaluations on the Project, organizational structure and responsibilities, an integrated schedule, an outline of each phase and a summary of test and evaluation resources.

The development of the *Performance Confirmation Plan* will use information developed for and specified in the Viability Assessment Test and Evaluation Plan, as it becomes available. Also, information developed for the *Performance Confirmation Plan* will also be used. The activities planned for performance confirmation will be compared with developmental and operations testing activities to assess the benefits of combined tests and to form the integrated test schedule. Estimates of the performance confirmation program resources will be summarized to show the overall testing and evaluation resources required. Formal reviews of both plans will be performed to ensure proper coordination and integration of the plans as they are developed or revised.

3.10 DETAILED PERFORMANCE CONFIRMATION PLANNING

This section identifies the requirements for detailed planning of performance confirmation tests. These requirements are established to ensure that sufficient information included in the planning and the work is properly controlled. These requirements are based on the *Quality Assurance Requirements and Description* document, Section 11.2.1 (DOE 1997a). A portion of these requirements will be addressed in the scope sheets which follow in Section 4. The other requirements must be addressed throughout detailed performance confirmation test planning. The Viability Assessment Test and Evaluation Plan will provide the methodology for implementing tests and evaluation on the Project and this methodology will be followed for detailed test planning.

Detailed performance confirmation test planning must include identification of test procedures to be developed to control and perform tests. Applicable existing procedures will be modified, as appropriate to conduct performance confirmation activities. The detailed test planning will use the Performance Confirmation Baseline information to identify test requirements and acceptance limits, including required levels of precision and accuracy. The detailed test planning will identify test methods to be employed and instructions for performing the test. The scope sheets will identify test prerequisites that address calibrated instrumentation, appropriate and adequate test equipment and instrumentation, trained personnel, condition of test equipment and the item to be tested, suitably controlled environmental conditions, and provisions for data acquisition. The detailed test planning will identify mandatory hold points. Scope sheets will identify reporting requirements. Detailed test planning will identify methods to record data and results. Provisions for ensuring that prerequisites for the given test have been met will be identified in the detailed test planning. Selection and identification of the measuring and test equipment to be used to perform the test to ensure that the equipment is of the proper type, range, accuracy, and tolerance to accomplish the intended function will be done during detailed planning. Detailed test planning will identify the functional qualification level of personnel performing tests.

The Performance Confirmation Program Testing Schedule is shown in Figure 3-7. The schedules for the three high-level monitoring and testing concepts (site monitoring and testing, repository monitoring and testing, and waste package monitoring and testing) are shown in the figure. Also, for each high-level concept, the figure also shows lower-level testing packages for each high-level concept (see Section 3.3).

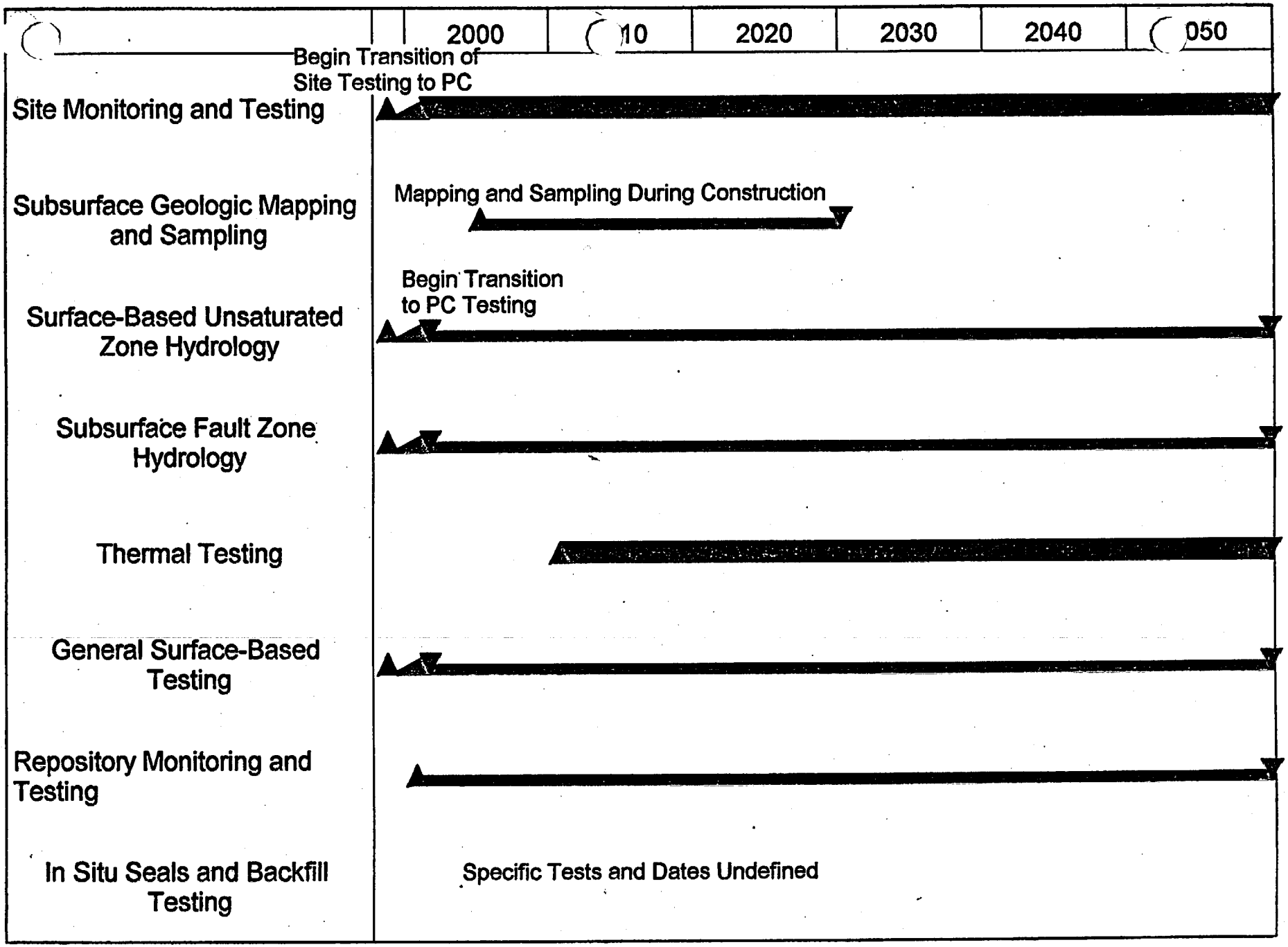

Figure 3-7. Performance Confirmation Program Testing Schedule

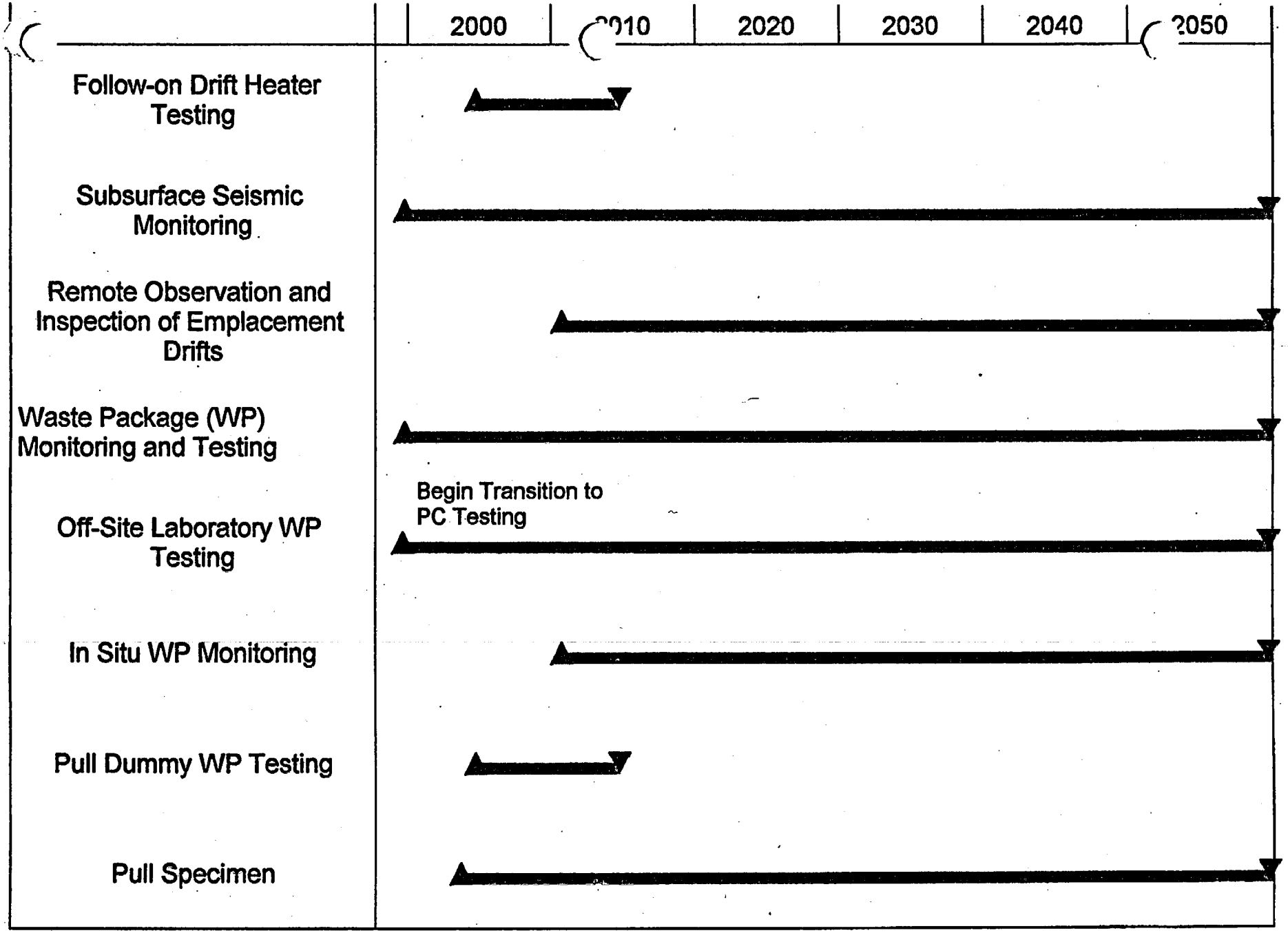

Figure 3-7. Performance Confirmation Program Testing Schedule (Continued)

The site monitoring and testing concepts are composed of a number of testing packages including: subsurface geologic mapping and sampling; surface-based unsaturated zone hydrology; underground fault zone hydrology; thermal testing; and general surface-based testing. The subsurface geologic mapping and sampling will be conduct during the construction and is planned to continue through the development period until all the subsurface facilities are completed. The surface-based unsaturated zone hydrology and underground fault zone hydrology packages will be transitioned from site characterization to performance confirmation testing prior to the license application. These packages are currently planned to continue throughout the program, until specific stopping criteria for the testing is developed. The thermal testing package is a major element of the site monitoring and testing concept. It is planned to begin prior to the emplacement of the waste in the repository and to continue throughout the program. The general surface-based testing package encompasses a number of activities some of which will be transitioned from site characterization to performance confirmation testing prior to the license application. Other elements of the general surface-based testing package are planned to continue throughout the program, until specific stopping criteria for the testing is developed.

The repository monitoring and testing concepts include: in situ seal testing; in situ backfill testing; follow-on drift heater testing; subsurface seismic monitoring; and remote observation and inspection of emplacement drifts. The remote observation and inspection include (a) visual, thermal, and radiological monitoring, (b) waste package coupon and rock sample retrieval, and (c) small rock debris removal. The specific tests and dates for in situ seal testing and in situ backfill testing are not yet defined. The follow-on drift heater test is planned to begin detailed planning and construction in 2004 and complete in 2014 with at least six years of testing. Subsurface seismic monitoring will be transitioned from site characterization to performance confirmation testing prior to the license application and will continue throughout the program, until specific stopping criteria for the testing is developed. The remote observation and inspection of emplacement drifts are planned to begin soon after the first waste is emplaced and continue throughout the program.

The waste package monitoring and testing concepts include off-site laboratory testing, in situ waste package monitoring, recovered dummy waste package testing, and recovered non-radioactive specimen testing. Offsite laboratory testing will be transitioned from site characterization to performance confirmation testing prior to the license application and will continue throughout the program. In situ waste package monitoring is planned to begin soon after waste is emplaced and continue throughout the program. Recovered dummy waste package testing is planned to occur concurrently with the follow-on heater testing. Recovered non-radioactive specimen testing will begin in 2004 and continue throughout the program, until specific stopping criteria for the testing is developed.

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4. TEST AND EVALUATION SCOPE AND REQUIREMENTS

This section of the plan compiles scope sheets for the activities necessary for performance confirmation as described in Section 3. The scope sheets are organized in sections related to site monitoring and testing, repository monitoring and testing, waste package monitoring and testing, evaluations, and operations and management. Each scope sheet provides information related to the activity including an identification number and activity title, the organizations responsible, performing, and supporting the activity, and the location of where the activity is to take place. The responsible organization, based on the current organizational structure, develops the scope sheet and ensures that the activity is sufficiently developed based on the current level of characterization and design. As the characterization and design evolves toward the License Application, further development of the scope sheets will follow. The performing organization may be different than the responsible organization, but often times are the same. The supporting organization, as a minimum, will be a coordinator on the activity. The scope sheet also includes a description of the activity, objectives, constraints, and requirements related to pretest and schedule, hardware and software, and facilities, data acquisition and reporting.

The scope sheets are to be used to establish requirements on the test and evaluation activities necessary to conduct the Performance Confirmation Program. The definition of these activities and requirements will be used to:

- Ensure integration with mined geologic disposal system (MGDS) design and with development test and evaluation and operations test and evaluation planning
- Provide a basis for detailed test and evaluation planning.
- Develop an integrated test schedule and develop an estimate of resources needed for to conduct the Performance Confirmation Program.

The test scope reflected in this section represents best thinking by discipline experts at this time regarding the testing needed to support effective and efficient performance confirmation. This scope, the types of tests and the approaches used may be changed appropriately as discipline experts and others involved in performance confirmation develop increased insights. This careful process of refining the monitoring, testing, and analysis requirements will be pursued in order to assure achieving the program goal of optimizing the information used for License Application. As such, this document should be considered a living document.

The constraints and requirements in the following sections are based on engineering and scientific judgement. The expertise of investigators was consulted in developing the constraints and requirements. Also, investigators were key contributors to the plan and part of the integrated product team that supported development of this plan. These investigators are currently conducting similar types of activities during site characterization or have conducted similar types of activities in the past. At this time, some of the requirements imposed design solutions. As the performance confirmation baseline becomes further defined and as part of the detailed test planning process, the methods which are currently specified will be reassessed.

4.1 SITE MONITORING AND TESTING SCOPE SHEETS

This section presents scope sheets for the site monitoring and testing for performance confirmation. A testing activity scope sheet is included for each parameter identified in the general site, unsaturated zone, saturated zone parameter sections of Appendix D. These site related parameters have been further grouped into their associated testing concept. The concepts are underground mapping and sampling, surface based hydrology, underground fault zone hydrology, underground thermal testing, and general surface-base site testing.

In this section, scope sheets are provided for each parameter listed in Appendix D and for each testing concept listed in the last column of the Performance Confirmation Parameter table. Therefore, test scope sheets for a parameter may exist in several testing concepts. Also, the individual testing scope sheet may not entail a completely different test. The parameters related to mapping and sampling were grouped together in the following pages and these activities should be looked at as a whole to develop an efficient mapping and sampling testing package, similarly for the other testing concepts.

Several scope sheets have notes indicating that the activity is recommended for deletion. After further consideration, the activity is no longer needed in the concept listed. These scope sheets were included to show the relationship to the parameters and preliminary concept listed in Appendix D. As an example, Test Scope Sheet ID# 4.1.26, Thermal Characteristics of the Rock Matrix: Altered Zone Rock Temperature, is a performance confirmation parameter that had been considered for collection as part of the surfaced-based borehole hydrology concept. Sufficient data on the parameter will be collected in the thermal testing concept, and based on this, it was recommended for deletion in the surface based testing concepts. The input on parameters and concepts from Appendix D is planned to be updated in the near future and these type of changes will be considered and incorporated at that time.

TEST SCOPE SHEET

ID# and Title: 4.1.1 Human Interference: Hydrocarbon and Mineral Resources - Location (11-MS1)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Observations of rock mass conditions at the heading and geologic mapping during underground excavation and offsite lab analysis of samples are recommended if any indications of hydrocarbons and/or any metallic/non metallic mineral resources are found during the subsurface excavation process.

B. OBJECTIVES:

- Determine economic significance of mineral deposits
- Evaluate potentially adverse conditions in accordance with 10 CFR Part 60.122(c).

C. CONSTRAINTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Map and sample with minimum obstruction of ribs and crown, prior to installation of utilities and vent line.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Tunnel support design compatible with mapping requirements.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. Samples, 2 to 5 ft. holes if needed
- Hand sampling
- Personnel access
- Survey the location of sampling.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling. including daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.2 Human Interference: Hydrocarbon and Mineral Resources - Quantity (12-MS2)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Observations of rock mass conditions at the heading and geologic mapping during underground excavation and offsite lab analysis of samples are recommended if any indications of hydrocarbons and mineral resources are found during the subsurface excavation process
- If any natural resources are found the type of hydrocarbon, gas, or mineral has to be determined and the potential recoverable quantity estimated.

B. OBJECTIVES:

- Determine economic significance of mineral deposits
- Evaluate potentially adverse conditions in accordance with 10 CFR Part 60.122(c).

C. CONSTRAINTS:

- Clean tunnel perimeter prior to mapping to allow required detail.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Tunnel support design compatible with mapping requirements.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. samples, 2 to 5 ft. holes
- Hand sampling
- If any hydrocarbons are found, estimate the potential recoverable quantity. This may require drilling and pump testing a well. If metallic or other resources are found, some additional excavations may be required to delineate the size and grade of a potential ore body.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling. including daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.3 Rock Matrix: Stratigraphy - Lateral Extent (14-MS3)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Observation of rock mass conditions at the heading
- Geologic mapping during underground excavation

B. OBJECTIVES:

- Confirmation of rock types will confirm design and performance assessment assumptions and update geologic models
- Rock types and mineralogy are basic information for rock characteristic spatial extrapolations of point measurements
- Document as-built condition.

C. CONSTRAINTS:

- Tag and store **TBD - Core samples**
- Tunnel support design compatible with mapping requirements
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions at each excavation heading for general geological and geotechnical characteristics, identification of reportable geologic conditions, and development of construction records

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems
- Mapping should follow tunnel boring machine to provide updated geology for evaluation.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. samples, 2 to 5 ft. holes and hand sampling
- Personnel access
- Thickness greater than 2 m for features to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.4 Rock Matrix: Stratigraphy - Depth (15-MS4)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Observations of rock mass conditions at the heading
- Geologic mapping during underground excavation

B. OBJECTIVES:

- Confirmation of rock types will confirm design and performance assessment assumptions and update geologic models
- Rock types and mineralogy are basic information for rock characteristic spatial extrapolations of point measurements
- Document as-built condition.

C. CONSTRAINTS:

- Tag and store **TBD - Core samples**
- Tunnel support design compatible with mapping requirements
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions at each excavation heading for general geological and geotechnical characteristics, identification of reportable geologic conditions, and development of construction records

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems
- Mapping should follow tunnel boring machine to provide updated geology for evaluation.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. samples, 2 to 5 ft. holes and hand sampling
- Personnel access.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.5 Rock Matrix: Stratigraphy - Thickness (16-MS5)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Observations of rock mass conditions at the heading
- Geologic mapping during underground excavation

B. OBJECTIVES:

- Confirmation of rock types will confirm design and performance assessment assumptions and update geologic models
- Rock types and mineralogy are basic information for rock characteristic spatial extrapolations of point measurements
- Confirm predictive data
- Document as-built condition.

C. CONSTRAINTS:

- Tag and store **TBD - Core samples**
- Tunnel support design compatible with mapping requirements
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions at each excavation heading for general geological and geotechnical characteristics, identification of reportable geologic conditions, and development of construction records

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems
- Mapping should follow tunnel boring machine to provide updated geology for evaluation.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. samples, 2 to 5 ft. holes and hand sampling
- Personnel access
- Thickness greater than 0.2 m for features to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.6 Rock Matrix: Stratigraphy - Rock Types (17-MS6)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Observations of rock mass conditions at the heading
- Geologic mapping during underground excavation

B. OBJECTIVES:

- Confirmation of rock types will confirm design and performance assessment assumptions and update geologic models
- Rock types and mineralogy are basic information for rock characteristic spatial extrapolations of point measurements
- Confirm predictive data
- Document as-built condition.

C. CONSTRAINTS:

- Tag and store **TBD - Core samples**
- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions at each excavation heading for general geological and geotechnical characteristics, identification of reportable geologic conditions, and development of construction records

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems
- Mapping should follow tunnel boring machine to provide updated geology for evaluation

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. samples, 2 to 5 ft. holes and hand sampling
- Personnel access
- Average dimension greater than 0.2 m for stratigraphic features to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.7 Rock Matrix: Stratigraphy - Mineralogy (18-MS7)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Observations of rock mass conditions at the headings
- Geologic mapping during underground excavation
- Laboratory testing to identify/quantity minerals present.

B. OBJECTIVES:

- Confirmation of rock types will confirm design and performance assessment assumptions and update geologic models
- Rock types and mineralogy are basic information for rock characteristic spatial extrapolations of point measurements
- Confirm predictive data.

C. CONSTRAINTS:

- Tag and store **TBD - Core samples**
- Tunnel support design compatible with mapping requirements
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions at each excavation heading for general geological and geotechnical characteristics, identification of reportable geologic conditions, and development of construction records

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Should follow tunnel boring machine - to provide updated geology for evaluation
- Core drill 2" to 3" diam. samples, 2 to 5 ft. holes and hand sampling
- Personnel access
- Average dimension greater than 2 m for features to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.8 Hydraulic Characteristics of Rock Matrix of Altered Zone: Saturated Hydraulic Conductivity/Permeability (19-MS8)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:
- Confirm and/or update altered zone rock hydrologic properties by underground testing/sampling and offsite laboratory analysis.

B. OBJECTIVES:
- Confirm and/or update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:
- Tunnel support design compatible with mapping/sampling requirements
- Samples must be preserved.

D. PRETEST AND SCHEDULE REQUIREMENTS:
- Clean tunnel perimeter prior to mapping/sampling to allow required detail
- Sampling during repository construction coordinated with proposed liner systems
- Minimize exposure of tunnel wall to construction water and ventilation air prior to sampling.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:
- Offsite laboratory for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:
- Core drill 2" to 3" diam. Intact, undisturbed samples, 2 to 5 ft. holes
- Personnel access
- **TBD - Sample locations and frequency requirements.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.9 Hydraulic Characteristics of Rock Matrix of Altered Zone: Effective Porosity (20-MS9)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Confirm and/or update altered zone rock hydrologic and transport properties by underground testing/sampling and offsite laboratory analyses.

B. OBJECTIVES:

- Confirm and/or update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- Tunnel support design compatible with mapping/sampling requirements
- Samples must be preserved.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping/sampling to allow required detail
- Sampling during repository construction coordinated with proposed liner systems
- Minimize exposure to construction water and ventilation air prior to sampling.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratory for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. intact, undisturbed samples, 2 to 5 ft. holes
- Personnel access
- **TBD - Sample locations and frequency requirements**
- **TBD - Sampling criteria important.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.10 Hydraulic Characteristics of Rock Matrix of Altered Zone: Dispersivity/Dispersion Coefficient (21-MS10)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Confirm and/or update altered zone rock hydrologic and transport properties by underground testing/sampling and offsite laboratory analyses.

B. OBJECTIVES:

- Confirm and/or update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- **TBD - Sample size is important for adequate representation of this parameter to each stratigraphic unit if using offsite analysis**
- Tunnel support design compatible with mapping/sampling requirements
- Samples must be preserved.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping/sampling to allow required detail
- Sampling during repository construction coordinated with proposed liner systems
- Minimize exposure to construction water and ventilation air prior to sampling.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratory for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- **TBD - Sample locations and frequency requirements**
- **TBD - Sample size specific to this parameter.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.11 Hydraulic Characteristics of Rock Matrix of Altered Zone: Hydraulic Potential/Moisture Cont. Relationship (22-MS11)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Hydraulic characteristic relationship based on experimental evidence, with individual parameters obtained from sample lab analyses and/or borehole monitoring.

B. OBJECTIVES:

- Confirm and/or update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- Dependent on individual relationship parameters obtained from underground sampling and/or borehole monitoring
- Samples must be preserved in air tight container.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Must be coordinated with obtaining individual parameters
- Samples must be collected in a timely manner
- Minimize exposure to construction water and ventilation air prior to sampling.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratory if obtaining parameters through underground sampling.

F. DATA ACQUISITION REQUIREMENTS:

- Individual parameters making up this relationship obtained from underground sampling and offsite lab analyses and/or borehole monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.12 Hydraulic Characteristics of Rock Matrix of Altered Zone: Moisture Cont./Hydraulic Conductivity Relationship (23-MS12)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Hydraulic characteristic relationship based on experimental evidence, with individual parameters obtained from sample lab analyses and/or borehole monitoring
- Document sample/test locations.

B. OBJECTIVES:

- Confirm and/or update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- Dependent on individual relationship parameters obtained from underground sampling and/or borehole monitoring
- Samples must be preserved in air tight container
- Mapping after construction and prior to drilling/sampling.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Must be coordinated with obtaining individual parameters
- Samples must be collected in a timely manner
- Minimize exposure to construction water and ventilation air prior to sampling.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Individual parameters making up this relationship obtained from underground sampling and offsite lab analyses and/or borehole monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.13 Pneumatic Characteristics of Rock Matrix: Altered Zone Air Permeability (24-MS13)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Confirm and/or update altered zone rock pneumatic properties by underground testing/sampling and offsite laboratory analyses
- Document sample/test locations.

B. OBJECTIVES:

- Confirm and/or update two-phase groundwater and radionculide transport flow model.

C. CONSTRAINTS:

- Also obtained through borehole air permeability tests
- Mapping after construction and prior to drilling/sampling.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping/sampling to allow required detail
- Sampling during repository construction coordinated with proposed liner systems
- Minimize exposure to construction water and ventilation air prior to sampling.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratory for sample analyses.

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. intact, undisturbed samples, 2 to 5 ft. holes
- Personnel access
- **TBD- Sample locations and frequency requirements.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.14 Rock Fracture Zones - Geometry: Location (30-MS14)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Mapping fracture characteristics during underground excavation.

B. OBJECTIVES:

- Confirm baseline fracture characterization
- Update hydrologic and thermo-mechanical models
- Infer connectivity between individual fractures
- Document as-built conditions.

C. CONSTRAINTS:

- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Mapping immediately behind tunnel boring machine if results of rock mass classification is used to optimize tunnel support requirements
- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- Fracture zones greater than 0.2 m in width to be mapped
- Individual fractures greater than 5m in length to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Map at scale useful as model input
- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.15 Rock Fracture Zones - Geometry: Width (31-MS15)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Mapping fracture characteristics during underground excavation.

B. OBJECTIVES:

- Confirm baseline fracture characterization
- Update hydrologic and thermo-mechanical models
- Infer fracture connectivity
- Document as-built conditions.

C. CONSTRAINTS:

- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Mapping immediately behind tunnel boring machine if results of rock mass classification is used to optimize tunnel support requirements
- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- Fracture zones greater than 0.2 m in width to be mapped
- Individual fractures greater than 5m in length to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.
- Map at scale useful as model input.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.16 Rock Fracture Zones - Geometry: Length (32-MS16)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Mapping fracture characteristics during underground excavation.

B. OBJECTIVES:

- Confirm baseline fracture characterization
- Update hydrologic and thermo-mechanical models
- Infer fracture connectivity
- Document as-built conditions.

C. CONSTRAINTS:

- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings.
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Mapping immediately behind tunnel boring machine if results of rock mass classification is used to optimize tunnel support requirements
- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Test alcoves, observation and emplacement drifts for mapping during underground excavation.

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- Fracture zones greater than 0.2 m in width to be mapped
- Individual fractures greater than 5m in length to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.
- Map at scale useful as model input.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.17 Rock Fractures - Geometry: Orientation (32-MS17)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Mapping fracture characteristics during underground excavation.

B. OBJECTIVES:

- Confirm baseline fracture characterization
- Update hydrologic and thermo-mechanical models
- Infer fracture connectivity
- Document as-built conditions.

C. CONSTRAINTS:

- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Mapping immediately behind tunnel boring machine if results of rock mass classification is used to optimize tunnel support requirements
- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Test alcoves, observation and emplacement drifts for mapping during underground excavation.

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- Fracture zones greater than 0.2 m in width to be mapped
- Individual fractures greater than 5m in length to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.
- Map at scale useful as model input.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.18 Rock Fractures - Geometry: Displacement (34-MS18)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Mapping fracture/fault displacement characteristics during underground excavation.

B. OBJECTIVES:

- Confirm baseline fracture characterization
- Update hydrologic and thermo-mechanical models
- Document as-built conditions.

C. CONSTRAINTS:

- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Mapping immediately behind tunnel boring machine if results of rock mass classification is used to optimize tunnel support requirements
- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- Fracture zones greater than 0.2 m in width to be mapped
- Individual fractures greater than 5m in length to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.
- Map at scale useful as model input.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.19 Rock Fracture Zones - Geometry: Fracture Aperture (35-MS19)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Mapping fracture zone characteristics during underground excavation.

B. OBJECTIVES:

- Confirm baseline fracture zone characterization
- Update hydrologic and thermo-mechanical models
- Document as-built conditions.

C. CONSTRAINTS:

- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Mapping immediately behind tunnel boring machine if results of rock mass classification is used to optimize tunnel support requirements
- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- Fracture zones greater than 0.2 m in width to be mapped
- Individual fractures greater than 5m in length to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.
- Map at scale useful as model input.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.20 Rock Fracture Zones - Geometry: Fracture Density (36-MS20)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavations

A. DESCRIPTION:

- Mapping fracture zone characteristics during underground excavation.

B. OBJECTIVES:

- Confirm baseline fracture zone characterization
- Update hydrologic and thermo-mechanical models
- Infer fracture connectivity
- Document as-built conditions.

C. CONSTRAINTS:

- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Mapping immediately behind tunnel boring machine if results of rock mass classification are used to optimize tunnel support requirements
- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Possible alternative mapping using photogrammetry is a consideration.

F. DATA ACQUISITION REQUIREMENTS:

- Personnel access
- Fracture zones greater than 0.2 m in width to be mapped
- Individual fractures greater than 5m in length to be mapped.

G. TEST/ASSESSMENTS REPORTS:

- Monitoring and Testing Report (Section 3.5.3) on Mapping and Sampling, including the following:
  - full perimeter (developed plan) geologic maps
  - scanline maps
  - daily or shift reports on conditions observed at the heading.
- Statistical analysis of fracture density, location and orientation
- Map at scale useful as model input.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.21 Biological Characteristics of Rock Fracture Zones: List of Microbes (37-MS21)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Fracture zone mapping, sampling, and offsite lab biological analysis.

B. OBJECTIVES:

- Confirm baseline biological activity characterization potentially affecting groundwater chemistry and thus waste package corrosion, waste dissolution, and radionuclide transport.

C. CONSTRAINTS:

- Samples must be carefully selected by properly trained personnel.
- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Collect biological samples before and after tunnel cleaning
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratories for biological analysis.

F. DATA ACQUISITION REQUIREMENTS:

- Hand sampling
- 2" to 3" diam. samples, core drill 2 to 5 ft. holes.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.22 Biological Characteristics of Rock Fracture Zones: Microbial Activity (38-MS22)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Fracture zone mapping, sampling and offsite lab biological analysis.

B. OBJECTIVES:

- Baseline biological activity characterization potentially affecting groundwater chemistry and thus waste package corrosion, waste dissolution, and radionuclide transport.

C. CONSTRAINTS:

- Samples must be carefully selected by properly trained personnel.
- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratories for biological analysis.

F. DATA ACQUISITION REQUIREMENTS:

- Hand sampling
- 2" to 3" diam. samples, core drill 2 to 5 ft. holes.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.23 Chemical/Mineralogical Characteristics of Infillings of Rock Fracture Zones: Apparent Age of Minerals (39-MS23)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Fracture mapping, sampling, and offsite lab mineralogical analyses.

B. OBJECTIVES:

- Mineralogical characteristics of infillings provide information on evolution of the fractures, including their hydraulic characteristics, which can then be used to predict any future changes that may affect water, water vapor, air and gas flow, and aqueous and gaseous radionuclide transport through the fracture zones
- Update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- Samples must be carefully selected by properly trained personnel.
- Tunnel support design compatible with mapped conditions
- Full perimeter and scanline mapping of non-emplacement drift openings
- Full perimeter and scanline mapping of approximately every tenth emplacement drift
- Observe rock mass conditions, identification of reportable geologic conditions, and development of construction records.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Clean tunnel perimeter prior to mapping to allow required detail
- Mapping during repository construction coordinated with proposed liner systems.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratories for mineralogical analysis.

F. DATA ACQUISITION REQUIREMENTS:

- Hand sampling
- 2" to 3" diam. Samples, core drill 2 to 5 ft. holes.

G. TEST/ASSESSMENTS REPORTS:

- Map at scale useful as model input.

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.24 Chemical Composition of Groundwater (UZ): Altered Zone Chemical Composition (Eh & pH) (49-MS24)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Offsite Lab(s)
Location: Repository Excavations

A. DESCRIPTION:

- Underground sampling and offsite laboratory analyses of unsaturated zone groundwater.

B. OBJECTIVES:

- Monitor groundwater chemical composition which can affect waste package performance
- Confirm baseline data.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Sampling performed during repository construction.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratory.

F. DATA ACQUISITION REQUIREMENTS:

- Possible sampling methods:
  - collection of perched water samples during drilling
  - extraction of pore water from drill core or hand samples
  - flexible borehole liner instrumentation package including periodic sampling capability (included in other Test Scope Sheets)
- **TBD - Number of samples and sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.25 Chemical Characteristics of Groundwater (UZ): Age (H-3, C-14, CL-36) (51-MS25)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavations and Underground Boreholes

A. DESCRIPTION:

- Unsaturated zone groundwater sampling and offsite lab analyses.

B. OBJECTIVES:

- Confirm baseline age data acquisition
- Confirm chemical changes resulting from waste heat generation
- Update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable for continuous long term monitoring and sampling
- New boreholes drilled near existing to avoid re-characterization costs
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- **TBD - Number boreholes installed for monitoring in the early stages of repository construction and up to facility closure.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Offsite laboratories for sample analysis
- **TBD - Number of boreholes.**
- Possible sampling methods:
  - collection of perched water samples during drilling
  - extraction of pore water from core samples
  - flexible borehole liner instrumentation package including periodic sampling capability (included in other Test Scope Sheets)
- Target interval = PTn

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.26 Thermal Characteristics of Rock Matrix: Altered Zone Rock Temperature (28-SB1)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Recommend Deletion of this activity 2/17/97 TRS*
Performing Organization:
Supporting Organization:
Location: Surface Based Boreholes in Altered Zone Rock Matrix

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.27 Thermal Characteristics of & Rock Matrix (UZ & SZ): Far-Field Rock Temperature (29-SB2)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes in Far-Field Rock Matrix

A. DESCRIPTION:

- Far-field rock matrix temperature monitoring using new surface based boreholes.

B. OBJECTIVES:

- Validate and/or update thermal mechanical rock mass behavior model
- Confirm far-field baseline data acquisition
- Update hydrologic models.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable for long-term monitoring, sampling and calibration
- New boreholes placed near existing to avoid re-characterization
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Installed for monitoring in the early stages of repository construction and up to facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Depth of boreholes: just above water table, within PTn, just below PTn
- Westbay borehole instrumentation packages
- Borehole thermocouple psychrometers or thermistors
- Possible geophysical logging
- Minimum number of boreholes: 6
- Location: topographic and geologic settings that most affect shallow infiltration and deep percolation: ridgetops, sideslopes, terraces, active channels, sites with PTn bedrock, and fault zones.
- UZ and SZ instrumentation in the same borehole.

F. DATA ACQUISITION REQUIREMENTS:

- Borehole data acquisition system for continuous monitoring

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.28 Thermal Characteristics of Rock Fracture Zones: Altered Zone Rock Temperature (47-SB3)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Recommend deletion of this activity TRS 2/17/97*
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.29 Thermal Characteristics of Rock Fracture Zones: Far Field Rock Temperature (48-SB4)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Recommend deletion of this activity TRS 2/17/97*
Performing Organization:
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.30 Chemical Composition of Ground Water (UZ): Altered Zone Chemical Composition (Eh & pH) (49-SB5)
Responsible Organization. Site Evaluation Program Operations
NOTE: *Recommend deletion of this activity TRS 2/17/97*
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes in Unsaturated Altered Zone

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.31 Chemical Composition of Ground Water (UZ): Far-Field Chemical Composition (Eh & pH) (50-SB6)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes in UZ

A. DESCRIPTION:

- Far-field, unsaturated zone groundwater monitoring and sampling of surface-based boreholes and offsite lab analysis.

B. OBJECTIVES:

- Confirm far-field baseline data acquisition and allow design adjustments
- Monitor chem. changes resulting from waste heat and associated ground water flow effects
- Update waste package degradation model.

C. CONSTRAINTS:

- Boreholes need to be in far field unsaturated zone
- Instrumentation needs to be retrievable and/or replaceable for long-term monitoring, sampling, and calibration
- New boreholes drilled near existing to avoid re-characterization costs
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Installed prior to repository construction for monitoring up to facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Groundwater monitoring and sampling capabilities in UZ
- Possible sampling methods:
  - election of perched water during drilling
  - extraction of pore water from core samples
  - flexible borehole liner instrumentation package, including water chemistry sensors and/or periodic sampling capabilities
- Target interval = PTn
- **TBD - Location, number, depth and monitoring interval for boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Test concepts need to be reviewed

TEST SCOPE SHEET

ID# and Title: 4.1.32 Chemical Characteristics of Ground Water (UZ): Age (H-3. C-14. CL-36) (51-SB7)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes in UZ

A. DESCRIPTION:

- Unsaturated zone groundwater sampling of surface-based boreholes and offsite lab analysis.

B. OBJECTIVES:

- Confirm baseline age data acquisition
- Update fluid flow models
- Update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable for long-term monitoring, sampling, and calibration
- New boreholes drilled near existing to avoid re-characterization costs
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- **TBD - Number boreholes installed for monitoring in the early stages of repository construction and up to facility closure.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- offsite laboratories for sample analysis
- flexible borehole liner instrumentation package including periodic sampling capabilities
- **TBD - Location, number, depth and monitoring interval for boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Test concepts to be reviewed.

TEST SCOPE SHEET

ID# and Title: 4.1.33 Hydraulic Characteristics of Ground Water (UZ): Surface Water Infiltration (52-SB8)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Shallow Zones of Surface Based Boreholes

A. DESCRIPTION:

- Soil/rock moisture measurements obtained in shallow zones of surface-based boreholes. Soil moisture meter readings calibrated/verified by periodic sampling and lab analysis.

B. OBJECTIVES:

- Update ground water flow and radionuclide transport models.

C. CONSTRAINTS:

- Borehole locations at topographic and geologic settings with significant infiltration effects (ridge tops, sideslopes, terraces, active channels, sites with PTn bedrock, fault zones).

D. PRETEST AND SCHEDULE REQUIREMENTS:

- **TBD - Number of boreholes installed for monitoring prior to repository construction**
- Monitoring through facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- **TBD - Number of boreholes and number of weather stations**
- Location of boreholes = Pagany and Drillhole Washes; Diabolus and Dead Yucca Ridges; Yucca Crest, Split Wash.
- Minimum depth of monitoring = alluvium/bedrock contact.
- Critical depth: Alluvium/bedrock contact

F. DATA ACQUISITION REQUIREMENTS:

- Westbay or other borehole instrumentation packages
- Continuous monitoring
- **TBD - Download frequency**
- Borehole and weather station data acquisition system.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Neutron moisture logging may be required at some sites.

TEST SCOPE SHEET

ID# and Title: 4.1.34 Hydraulic Characteristic of Groundwater (UZ): In-situ Fluid Potential (53-SB9)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Suggest combining this sheet with 4.1.35 D.G./TRS 9/3/97*
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Packed Off Zones of Surface-based Boreholes

A. DESCRIPTION:

- Soil/rock moisture measurements in surface-based boreholes.

B. OBJECTIVES:

- Update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

- Borehole locations at topographic and geologic settings with significant infiltration effects.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Boreholes installed for monitoring during repository design and early stages of construction for design input
- Monitoring through facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Minimum number of boreholes: 6
- Location of boreholes: ridgetops, sideslopes, terraces, active channels, sites with Ptn bedrock, and fault zones. Specific geographic locations: Pagany and Drillhole Washes, Diabolus and Dead Yucca Ridges, Yucca Crest, and Split Wash.
- Depth of boreholes: with PTn, just below PTn
- Monitoring depth: water table and above
- Borehole instrumentation (typical): thermoucouple psychrometers for deep holes; tensiometers, neutron probes, or heat dissipation probes for shallow holes.

F. DATA ACQUISITION REQUIREMENTS:

- Continuous monitoring
- **TBD - Download frequency**
- Borehole data acquisition system.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Equilibration capability of currently available instrumentation is questionable.

TEST SCOPE SHEET

ID# and Title: 4.1.35 Hydraulic Characteristics of Ground Water (UZ): Far Field Moisture Content (55-SB10)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Suggest combining this sheet with 4.1.34 D.G./TRS 9/3/97*
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes

A. DESCRIPTION:

- Far field, unsaturated zone groundwater monitoring using surface-based boreholes.

B. OBJECTIVES:

- Update groundwater flow, radionuclide transport, and waste package degradation models
- To provide far field baseline data acquisition and to allow design adjustments.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable
- New boreholes drilled near existing to avoid re-characterization
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Installed prior to repository construction.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Flexible borehole liner instrumentation package
- Borehole geophysical logging and/or electric resistivity tomography as a consideration
- **TBD - Number of boreholes**
- **TBD - Location of boreholes**
- **TBD - Depth of boreholes**
- **TBD - Monitoring interval.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.36 Hydraulic Characteristics of Ground Water (UZ): Far Field Liquid Water Flux (57-SB11)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Suggest changing this activity to an evaluation based on surface based borehole test results (e.g., infiltration, temperature, and fluid potential) D.G./TRS 8/8/97*
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculations from Soil/rock Moisture Measurements

A. DESCRIPTION:

- Iteratively re-run the site-scale analytical or numerical models or submodels that calculate the flux based on updated information about the site.

B. OBJECTIVES:

- Used for groundwater flow modeling, design aid and updating as waste heat affects the thermally altered zone
- Important to groundwater flow, waste package performance and radionuclide transport
- To provide far field baseline data acquisition and to allow design adjustments
- Comparison monitoring for changes resulting from waste heat and associated altered zone groundwater flow effects.

C. CONSTRAINTS:

- Determination of rock mass permeability subject to inaccuracy.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Data obtained prior to or during early stages of repository construction
- Parameter measurements monitored through facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

N/A

F. DATA ACQUISITION REQUIREMENTS:

N/A

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Test concepts need to be reviewed. These calculations should be combined with rock/water temperature, infiltration, and fluid potential.

TEST SCOPE SHEET

ID# and Title: 4.1.37 Hydraulic Characteristics of Ground Water: Altered Zone Water Vapor Content/Humidity (58-SB12)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Recommend deletion of this activity TRS 2/17/97*
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface-based Boreholes in Unsaturated Altered Zone

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# & Title: 4.1.38 Hydraulic Characteristics of Ground Water (UZ): Far Field Water Vapor Content/humidity (59-SB13)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface-based Boreholes in Far-field Unsaturated Zone

A. DESCRIPTION:

- Measured in surface-based boreholes as part of unsaturated zone ground water monitoring.

B. OBJECTIVES:

- Provide far field baseline data acquisition and to allow design adjustments.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable for long-term monitoring, sampling, and calibration
- **TBD - Number of boreholes based on repository configuration, thermal load and others**
- New boreholes should be drilled near existing to avoid re-characterization costs
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation.

D. PRETEST & SCHEDULE REQUIREMENTS:

- Boreholes drilled and instrumentation installed prior to repository construction and monitored through repository closure.

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- Flexible borehole liner
- Borehole humicaps and/or psychrometers.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Number of boreholes**
- **TBD - Location of boreholes**
- **TBD - Depth of boreholes**
- Borehole data acquisition system
- **TBD - Borehole monitoring interval.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.39 Hydraulic Characteristics of Ground Water (UZ): Far Field Water Vapor Flux (61-SB14)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculated from Soil/Rock Moisture Measurements

A. DESCRIPTION:

- Calculated from moisture content and pneumatic pressure measurements using surface-based boreholes.

B. OBJECTIVES:

- Confirm far field baseline data acquisition and allow design adjustments
- Update ground water flow, radionuclide transport and waste package degradation models.

C. CONSTRAINTS:

- Neutron moisture logging depth is limited

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Data obtained prior to or during early stages of repository construction for design adjustments
- Parameter measurements monitored through facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Surface-based boreholes for obtaining moisture measurements
- **TBD - Number of boreholes**
- **TBD - Location of boreholes**
- **TBD - Depth of boreholes**
- **TBD - Monitoring interval.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Download frequency**
- Borehole data acquisition system using neutron logging at shallow depths
- Continuous monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.40 Hydraulic Characteristics of Ground Water (UZ): Pre-waste Emplacement Ground Water Travel Time Disturbed Zone to Water Table (62-SB15)

Responsible Organization: Site Evaluation Program Operations

NOTE: *Suggest changing this activity to an evaluation based on site-scale transport modeling results. DG/TRS 8/8/97*

Performing Organization: Site Evaluation Program Operations

Supporting Organization:

Location: Calculated from Other Hydrogeologic Measurements

A. DESCRIPTION:

- Ground water travel time based on core analysis, geophysics, tracer tests, and gas injection tests.

B. OBJECTIVES:

- Estimate travel time of radionuclides to water table
- Refine UZ fluid flow model
- Sorption properties, rock mass permeability UZ.

C. CONSTRAINTS:

- Need tracer tests for field calibration.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Obtain baseline data prior to waste emplacement.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Borehole data acquisition system.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Test concepts need to be reviewed

TEST SCOPE SHEET

ID# and Title: 4.1.41 Hydraulic Characteristics of Ground Water (UZ): Post-waste Emplacement Ground Water Travel Time from Disturbed Zone to Water Table (63-SB16)

Responsible Organization: Site Evaluation Program Operations

NOTE: *Suggest changing this activity to an evaluation based on site-scale transport modeling results. DG/TRS 8/8/97*

Performing Organization: Site Evaluation Program Operations

Supporting Organization:

Location: Calculated from Other Hydrogeologic Measurements

A. DESCRIPTION:

- Hydraulic characteristic based on other hydrogeologic measurements as part of modeling.

B. OBJECTIVES:

- Update site-scale transport model.

C. CONSTRAINTS:

- Need tracer tests for meaningful calculation and for field calibration.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Data obtained post-waste emplacement as part of repository monitoring.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

N/A

F. DATA ACQUISITION REQUIREMENTS:

N/A

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.42 Thermal Characteristics of Ground Water (UZ): Altered Zone Fluid Temperature (64-SB17)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Recommend deletion of this activity TRS 2/17/97*
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, D.M.O
Location: Surface-based Boreholes in Altered, Unsat. Zone

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.43 Thermal Characteristics of Groundwater (UZ): Far-field Fluid Temperature (65-SB18)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes

A. DESCRIPTION:

- Far-field UZ fluid temperature monitoring using new surface based boreholes.

B. OBJECTIVES:

- Confirm baseline and comparison data acquisition and to allow design adjustments
- Update UZ flow model.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable for long term monitoring, sampling, and calibration
- **TBD - Number of boreholes based on repository configuration, thermal load and others**
- New boreholes drilled near existing to avoid re-characterization costs
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Installed for monitoring in the early stages of repository construction and up to closure of facility.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Borehole instrumentation packages
- Monitored using borehole thermocouple psychrometers, two per interval.

F. DATA ACQUISITION REQUIREMENTS:

- Borehole data acquisition system, continuous monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

These test concepts could be combined with far-field rock temperature

TEST SCOPE SHEET

ID# and Title: 4.1.44 Pneumatic Characteristics of Subsurface Air and Gases (UZ): Air Pressure (66-SB19)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes

A. DESCRIPTION:

- Unsaturated Zone pneumatic pressure monitoring using surface-based boreholes.

B. OBJECTIVES:

- Update ground water flow model
- Update radionuclide transport model.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable for long-term monitoring, sampling and calibration
- **TBD - Number of boreholes based on repository configuration, thermal load, and others**
- New boreholes drilled near existing to avoid re-characterization costs
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation
- If new boreholes located away from existing, characterization data could be obtained by geophysical logging.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Installed prior to repository construction for monitoring through closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Borehole instrumentation packages
- Monitored using borehole transducers
- Minimum number of boreholes: 6
- Depth of boreholes: just above water table.

F. DATA ACQUISITION REQUIREMENTS:

- Borehole data acquisition system, continuous monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.45 Pneumatic Characteristics of Subsurface Air and Gases (UZ): Air Flow (67-SB20)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculated from Air Pressure and Permeability

A. DESCRIPTION:
- Calculating UZ air flow from air pressure and permeability obtained from surface-based boreholes.

B. OBJECTIVES:
- Update UZ flow model
- Update RN transport model.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:
- Confirm baseline data in the early stages of repository operation and up to closure of facility.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:
- Need surface-based boreholes and associated data acquisition system.

F. DATA ACQUISITION REQUIREMENTS:
- Model updated at TBD - Frequency
- Permeability obtained from sampling and offsite lab analysis.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This calculation should be combined with pneumatic pressure monitoring and rock/water temperature monitoring.

TEST SCOPE SHEET

ID# and Title: 4.1.46 Hydraulic Characteristics of Ground Water (Saturated Zone): Water Table Elevation (68-SB21)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Drilling Contractor, DMO
Location: Surface Based Boreholes to Saturated Zone

A. DESCRIPTION:

- Monitoring ground water table elevations using surface-based boreholes.

B. OBJECTIVES:

- Confirm baseline data acquisition and continuous monitoring
- Update saturated zone flow model.

C. CONSTRAINTS:

- **TBD - Number of boreholes based on repository configuration, thermal load and others**
- **TBD - Minimum number of downgradient boreholes to saturated zone**
- Instrumentation needs to be retrievable and/or replaceable
- New boreholes drilled near existing to avoid re-characterization
- Existing boreholes in the area of new boreholes need to be sealed to ensure undisturbed rock mass representation
- If new boreholes located away from existing, characterization data could be obtained by geophysical logging.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Wells installed for baseline monitoring prior to repository operation and up to closure of facility
- Survey of elevation of casing tops.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Groundwater sampling capability in surface-based Boreholes
- **TBD - Number of boreholes**
- **TBD - Location of borehole**
- Water level logs or monitoring system
- UZ and SZ instrumentation in same borehole.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Borehole data acquisition system, continuous monitoring periodic downloading**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.47 Hydraulic Characteristics of Ground Water (Sat. Zone): Ground Water Flux (69-SB22)
Responsible Organization: Site Evaluation Program Operations
NOTE: *Suggest changing this activity to an evaluation D.G./TRS 8/22/97.*
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculated from Soil/rock Moisture Measurements

A. DESCRIPTION:

- Hydraulic characteristics calculated from rock moisture measurements.

B. OBJECTIVES:

- Update ground water (SZ) flow model.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Moisture measurement data obtained prior to repository construction for baseline analysis
- Wells installed for baseline monitoring prior to repository operation and up to closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Ground water sampling capability in surface-based boreholes

F. DATA ACQUISITION REQUIREMENTS:

N/A

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.48 Hydraulic Characteristics of Ground Water (Saturated Zone): Pre-waste Emplacement Ground Water Travel Time from Beneath Repository to Accessible Environment (70-SB23)

Responsible Organization: Site Evaluation Program Operations

NOTE: *Suggest changing this activity to an evaluation D.G./TRS 8/22/97.*

Performing Organization: Site Evaluation Program Operations

Supporting Organization:

Location: Calculated from Other Hydrogeologic Measurements

A. DESCRIPTION:

- Hydraulic characteristic based on other hydrogeologic measurements as part of modeling.

B. OBJECTIVES:

- Update ground water flow model
- Estimate sorption properties, transmissivity, storativity, dispersivity of aquifers
- Hydraulic gradient.

C. CONSTRAINTS:

- Need tracer tests for field calibration

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Data obtained prior to repository construction for baseline analysis.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

N/A

F. DATA ACQUISITION REQUIREMENTS:

N/A

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.49 Hydraulic Characteristics of Ground Water (Saturated Zone): Post-waste Emplacement Ground Water Travel Time from Beneath Repository to Accessible Environment (71-SB24)

Responsible Organization: Site Evaluation Program Operations

NOTE: *Suggest changing this activity to an evaluation D.G./TRS 8/22/97*

Performing Organization: Site Evaluation Program Operations

Supporting Organization:

Location: Calculated from Other Hydrogeologic Measurements

A. DESCRIPTION:

- Hydraulic characteristic based on in situ monitoring at downgradient wells and tracer tests
- Based on pre-waste emplacement testing and observation in monitoring boreholes.

B. OBJECTIVES:

- Estimate potential travel time of radionuclides to water table
- Update ground water flow and transport models model
- Form and concentration of radionuclides.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Borehole to be installed and instrumented prior to waste emplacement
- Data collection to begin with waste emplacement.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

N/A

F. DATA ACQUISITION REQUIREMENTS:

N/A

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.50 Aqueous Radionuclide Transport of Each Important Radionuclide: Radionuclide Concentration (72-SB25)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Surface Based Boreholes to Saturated Zone

A. DESCRIPTION:

- Ground water sampling at surface-based boreholes as part of Repository monitoring for radionuclide release.

B. OBJECTIVES:

- Repository monitoring for radionuclide release
- Update/confirm transport model.

C. CONSTRAINTS:

- **TBD - Number and location of boreholes should provide adequate representation of upgradient and downgradient conditions.**

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Ground water sampling prior to waste emplacement for baseline data
- Annual post-emplacement sampling, monthly or more frequently if detected.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Ground water sampling capabilities in surface-based boreholes to saturated zone
- **TBD - Number of boreholes**
- **TBD - Location of boreholes**
- Depth of boreholes: water table and below

F. DATA ACQUISITION REQUIREMENTS:

- Ground water sampling at surface-based boreholes and offsite lab analysis

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Testing should be coordinated/integrated with any similar monitoring required for the Environmental Program.

TEST SCOPE SHEET

ID# and Title: 4.1.51 Aqueous Radionuclide Transport of Each Important Radionuclide: Radionuclide Release Rate to Accessible Environment (73-SB26)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculated from Saturated Zone Water Flux and Radionuclide Concentration

A. DESCRIPTION:

- Radionuclide release rate to accessible environment calculated from saturated zone water flux and radionuclide concentration.

B. OBJECTIVES:

- Repository monitoring for radionuclide release
- Update/confirm transport models.

C. CONSTRAINTS:

- Need contingency plan for remedial action
- **TBD - Number and location of boreholes should provide adequate representation of upgradient and downgradient conditions.**

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Calculated prior to waste emplacement for baseline data
- Annual post emplacement monitoring, continuously or more frequently if significant.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Ground water sampling capability in surface-based boreholes to saturated zone
- **TBD - Number of boreholes**
- **TBD - Location of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- Saturated zone water flux characteristic calculated from rock moisture measurements, and field pumping tests
- Radionuclide concentration obtained from ground water sampling of surface-based boreholes.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Testing should be coordinated/integrated with any similar monitoring required for the Environmental Program.

TEST SCOPE SHEET

ID# and Title: 4.1.52 Hydraulic Characteristics of Rock Fracture Zones: Saturated Hydraulic Conductivity/Permeability (40-FZ1)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- Mapping, sampling and offsite lab work, supplemented with selected liquid flow tests.

B. OBJECTIVES:

- Characterize untested fracture zones encountered during repository excavation
- Update groundwater flow and radionuclide transportation models
- Evaluate fracture zone hydrologic characteristics.

C. CONSTRAINTS:

- Develop testing, monitoring, and experiment concepts which minimize interference with repository construction and emplacement operations, but still supply adequate information
- Representative sample size is important consideration for adequate representation.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Performed during repository construction after full perimeter geologic mapping in test alcoves
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Test alcoves and underground boreholes
- Offsite laboratories for testing core samples
- **TBD- Location of test alcoves, number and length of boreholes**
- **TBD - Depth of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization**
- Data acquisition system for flow testing.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This activity applies to major fault and fracture zones. Activities are planned in FY 97 Change Report for Risk Mitigation.

TEST SCOPE SHEET

ID# and Title: 4.1.53 Hydraulic Characteristics of Rock Fracture Zones: Effective Porosity (41-FZ2)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- In-hole and/or cross-hole air permeability and tracer testing, coring/sampling, offsite lab work, and scientific extrapolation.

B. OBJECTIVES:

- Characterize untested fracture zones encountered during repository excavation
- Update groundwater flow and radionuclide transportation models
- Evaluate fracture zone hydrologic characteristics.

C. CONSTRAINTS:

- Develop testing, monitoring, and experiment concepts which minimize interference with repository construction and emplacement operations, but still supply adequate information.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Performed during repository construction after full perimeter geologic mapping in test alcoves
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Test alcoves, observation drifts and underground boreholes
- In-hole and/or cross-hole air permeability testing equipment (including tracer testing)
- Offsite laboratories for testing core samples
- **TBD - Location of test alcoves, number and length of boreholes**
- **TBD - Depth of holes.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization**
- Data acquisition system for flow and tracer testing.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This activity applies to major fault and fracture zones.

TEST SCOPE SHEET

ID# and Title: 4.1.54 Hydraulic Characteristics of Rock Fracture Zones: Dispersivity/dispersion Coefficient (42-FZ3)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- In-hole and/or cross-hole flow and tracer tests to determine fracture zone hydrologic and radionuclide transport characteristics.

B. OBJECTIVES:

- Characterize untested fracture zones encountered during repository excavation
- Update groundwater flow and radionuclide transport models
- Evaluate fracture zone hydrologic characteristics.

C. TEST CONSTRAINTS:

- Develop testing, monitoring, and experiment concepts which minimize interference with repository construction and emplacement operations, but still supply adequate information.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Performed during repository construction
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- In-hole and/or cross-hole flow and tracer testing equipment
- Test alcoves and underground boreholes
- **TBD - Location of test alcoves, number and length of boreholes**
- **TBD - Depth of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Extent of coring and geophysical borehole logging**
- Data acquisition system for long term monitoring, flow and tracer testing.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This activity applies to major fault and fracture zones.

TEST SCOPE SHEET

ID# and Title: 4.1.55 Hydraulic Characteristics of Rock Fracture Zones: Hydraulic Potential-Moisture Content Relationship (43-FZ3)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- Hydraulic characteristic relationship based on experimental evidence, with individual parameters obtained through borehole monitoring and/or subsequent derivation and laboratory measurements.

B. OBJECTIVES:

- Characterize untested fracture zones encountered during repository excavation
- Update groundwater flow and radionuclide transport models
- Evaluate fracture zone hydrologic characteristics.

C. CONSTRAINTS:

- Borehole instrumentation needs to be retrievable and/or replaceable since monitoring may take place up to repository closure
- Develop testing, monitoring, and experiment concepts which minimize interference with repository construction and emplacement operations, but still supply adequate information.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Performed during repository construction with monitoring possibly through closure
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Borehole instrumentation packages for moisture content including neutron logging and/or electrical resistivity tomography **(TBD - Feasibility)**
- Test alcoves, observation drifts and underground boreholes
- **TBD - Location of test alcoves, number and length of boreholes**
- Thermocouple psychrometer measurements of temperature and relative humidity for deriving hydraulic potential
- Offsite laboratory.

F. DATA ACQUISITION REQUIREMENTS:

- Data acquisition system for long term monitoring
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

- Data acquisition system for long term monitoring.

COMMENTS:

This activity applies to major fault and fracture zones.

TEST SCOPE SHEET

ID# and Title: 4.1.56 Hydraulic Characteristics of Rock Fracture Zones: Moisture Content-Hydraulic Conductivity Relationship (44-FZ4)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- Hydraulic characteristic relationship based on experimental evidence, with individual parameters obtained through borehole monitoring, fracture zone testing and laboratory measurements.

B. OBJECTIVES:

- Characterize untested fracture zones encountered during repository excavation
- Update ground water flow and radionuclide transp. models
- Evaluate fracture zone hydrologic characteristics.

C. CONSTRAINTS:

- Borehole instrumentation needs to be retrievable and/or replaceable since monitoring may take place up to repository closure
- Develop testing, monitoring, and experiment concepts which minimize interference with repository construction and emplacement operations, but still supply adequate information.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Performed during repository construction with monitoring possibly through closure
- After full perimeter geologic mapping in test alcoves
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Test alcoves, observation drifts, and underground boreholes for study during underground excavation and continued monitoring
- In-hole and/or cross-hole air permeability testing
- Flexible borehole liner instrumentation packages for moisture content including neutron logging and/or electrical resistivity tomography **TBD - Feasibility**
- **TBD - Location of test alcoves, number and length of boreholes**
- Offsite laboratory.

F. DATA ACQUISITION REQUIREMENTS:

- Data acquisition system for long term monitoring
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This activity applies to major fault and fracture zones.

TEST SCOPE SHEET

ID# and Title: 4.1.57 Pneumatic Characteristics of Rock Fracture Zones: Altered Zone Air Permeability (45-FZ6)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- In-hole and/or cross-hole air permeability, coring/sampling, offsite lab work to determine fracture zone pneumatic characteristic

B. OBJECTIVES:

- Characterize untested fracture zones encountered during repository excavation
- Update groundwater flow and radionuclide transport models
- Evaluate fracture zone hydrol. characteristics

C. CONSTRAINTS:

- Develop testing, monitoring, and experiment concepts which minimize interference with repository construction and emplacement operations, but still supply adequate information

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Performed during repository construction
- After full perimeter geologic mapping of test alcove
- Rock mass characterization of underground boreholes

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Test alcoves, observation drifts, and underground boreholes for study during underground excavation
- Offsite laboratories for testing core samples
- In-hole and/or cross-hole air permeability testing
- **TBD - Location of test alcoves, number and length of boreholes**

F. DATA ACQUISITION REQUIREMENTS:

- Core drill 2" to 3" diam. intact, undisturbed samples
- Data acquisition system for long term monitoring
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This activity applies to major fault and fracture zones.

TEST SCOPE SHEET

ID# and Title: 4.1.58 Pneumatic Characteristics of Rock Fracture Zones: Altered Zone Gaseous Dispersion Coefficient (46-FZ7)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- In-hole and/or cross-hole gas flow and tracer tests to determine fracture zone hydrologic and radionuclide transport characteristics.

B. OBJECTIVES:

- Characterize untested fracture zones encountered during repository excavation
- Update groundwater flow and radionuclide transport models
- Evaluate fracture zone hydrol. characteristics.

C. CONSTRAINTS:

- Develop testing, monitoring, and experiment concepts which minimize interference with repository construction and emplacement operations, but still supply adequate information.
- Penetrated rock mass characterization of underground boreholes.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Performed during repository construction
- After full perimeter geologic mapping in test alcoves.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Test alcoves, observation drifts, and underground boreholes for study during underground excavation
- In-hole and/or cross-hole gas flow and tracer tests
- **TBD - Location of test alcoves, number and length of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- Data acquisition system for long term testing.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This activity applies to major fault and fracture zones.

TEST SCOPE SHEET

ID# and Title: 4.1.59 Thermal Characteristics of Rock Fracture Zones: Altered Zone Rock Temperature (47-FZ8)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Test Alcoves, Observation Drifts

A. DESCRIPTION:

- Altered zone, fracture zone rock temperature monitoring using boreholes based in test alcoves and observation drifts.

B. OBJECTIVES:

- Validate and/or update thermalmechanical rock mass behavior model
- Confirm baseline data acquisition and allow design adjustments
- Investigate how changing rock temperature affects groundwater flow and thus potentially affects waste package performance.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Conducted primarily in the early stages of repository operations and then monitoring possibly up to closure
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Boreholes required for instrumentation installation
- Borehole thermocouples and/or resistance temperature detectors
- Infrared thermal imaging of rock surface a consideration.

F. DATA ACQUISITION REQUIREMENTS:

- Observation drift and alcove data acquisition system for continuous monitoring
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

This activity applies to major fault and fracture zones.

TEST SCOPE SHEET

ID# and Title: 4.1.60 Hydraulic Characteristics of Rock Matrix of Altered Zone: Saturated Hydraulic Conductivity/permeability (19-UT1)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavation, Observation Drifts

A. DESCRIPTION:

- Confirm and/or update altered zone rock hydrologic properties by underground testing/ sampling and offsite laboratory analyses
- In UZ, obtained by sampling and offsite lab analyses.

B. OBJECTIVES:

- Confirm and/or update groundwater flow models
- Provide input data for thermal-hydrologic-chemical model calculations.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.61 Hydraulic Characteristics of Rock Matrix of Altered Zone: Effective Porosity (20-UT2)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavation, Observation Drifts

A. DESCRIPTION:

- In-hole and cross-hole air permeability testing in observation drift based boreholes together with scientific extrapolation to determine altered zone rock matrix hydrological properties
- Also obtained using offsite laboratory tests on disturbed core samples.

B. OBJECTIVES:

- Confirm and/or update groundwater flow and radionuclide transport models
- Provide input data for thermal-hydrologic-chemical model calculations.

C. CONSTRAINTS:

- Sampling and offsite laboratory analyses should also be incorporated
- Rock mass characterization of underground boreholes.

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Observation drift layout based on rock mass volume to be monitored
- **TBD - Rock mass volume to be monitored**
- **TBD - Number, location and depth of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.62 Hydraulic Characteristics of Rock Matrix of Altered Zone: Dispersivity/dispersion Coefficient (21-UT3)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavation, Observation Drifts

A. DESCRIPTION:
- In- hole and cross-hole tracer tests to determine rock matrix zone radionuclide transport characteristics.

B. OBJECTIVES:
- Confirm and/or update transport models.

C. CONSTRAINTS:
- **TBD - Test area and important for adequate representation of this parameter to each stratigraphic unit.**

D. PRETEST AND SCHEDULE REQUIREMENTS:
- Preheat data are required
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:
- Observation drift layout based on rock mass volume to be monitored
- **TBD - Rock mass volume to be monitored**

F. DATA ACQUISITION REQUIREMENTS:
- **TBD - Number of boreholes per drift and borehole lengths**
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.63 Hydraulic Characteristics of Rock Matrix of Altered Zone: Hydraulic Potential/moisture Cont. Relationship (22-UT4)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavation, Observation Drifts

A. DESCRIPTION:

- Hydraulic characteristic relationship based on experimental evidence, with individual parameters obtained from sample lab analysis and/or borehole monitoring
- Individual parameters making up this relationship obtained from underground sampling and offsite lab analysis and/or borehole monitoring
- Required parameters are hydraulic potential (fluid temperature and humidity) and moisture content.

B. OBJECTIVES:

- Confirm and/or update groundwater flow models.

C. CONSTRAINTS:

- Dependent on individual relationship parameters obtained from underground sampling and/or borehole monitoring.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Must be coordinated with obtaining individual parameters
- Parameters obtained during repository construction
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Observation drift based boreholes with needed parameter monitoring capabilities if obtaining make-up parameters during thermal testing.

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.64 Hydraulic Characteristics of Rock Matrix of Altered Zone: Moisture Cont./hydraulic Conductivity Relationship (23-UT5)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavation, Observation Drifts

A. DESCRIPTION:

- Hydraulic characteristic relationship based on experimental Evidence, with individual parameters obtained from sample lab analysis and/or borehole monitoring
- Individual parameters making up this relationship obtained from underground sampling and offsite lab analysis and/or borehole testing and monitoring
- Required parameters are moisture content and hydraulic conductivity.

B. OBJECTIVES:

- Confirm and/or update groundwater flow models.

C. CONSTRAINTS:

- Dependent on individual relationship parameters obtained from underground sampling and/or borehole monitoring
- Rock mass characterization of underground boreholes.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Must be coordinated with obtaining individual parameters
- Parameters obtained during repository construction.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Observation drift based boreholes with needed parameter monitoring capabilities (moisture content) if obtaining parameters during thermal testing.

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.65 Pneumatic Characteristics of Rock Matrix: Altered Zone Air Permeability (24-UT6)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization: Construction Contractor, CMO
Location: Repository Excavation, Observation Drifts

A. DESCRIPTION:

- In-hole and cross-hole air permeability testing in observation drift boreholes to determine altered zone rock matrix pneumatic properties.

B. OBJECTIVES:

- Confirm and/or update two-phase groundwater flow model
- Provide information for assisting analysis of field test results.

C. CONSTRAINTS:

- Air permeability testing performed before and during emplacement drift monitoring with boreholes left available
- Also performed in conjunction with alcove thermal testing

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Rock mass characterization prior to testing
- Performed during repository construction
- Performed before and after alcove thermal test
- Performed before and during emplacement drift monitoring.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Observation drift based boreholes with instrumentation capabilities for parameter monitoring
- Observation drift and borehole layout based on monitoring a predetermined rock mass volume
- **TBD - Number, location and depth of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Number and frequency of tests.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.66 Mechanical Characteristics of Rock Matrix: Altered Zone In-situ Stress (25-UT7)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Observation and Emplacement Drift(s)

A. DESCRIPTION:

- Altered zone stress monitoring in rock mass and support elements around emplacement drifts.

B. OBJECTIVES:

- Validate and/or update thermomechanical rock mass behavior model
- Provide early data acquisition and allow design adjustments.

C. CONSTRAINTS:

- Permanent instrumentation installed in emplacement drifts subject to waste isolation analysis
- Emplacement drift instrumentation may need to be abandoned due to lack of accessibility after emplacement.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Conducted primarily in the early stages of repository operations
- Baseline data required prior to emplacement
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Stressmeters or load cells embedded in drift linings
- Boreholes required for instrumentation installation
- **TBD - Number of stations and number of instruments per station.**

F. DATA ACQUISITION REQUIREMENTS:

- Observation drift data acquisition system for continuous monitoring
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.67 Mechanical Characteristics of Rock Matrix: Altered Zone Strain (26-UT8)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Observation and Emplacement Drift(s)

A. DESCRIPTION:

- Altered zone strain monitoring.

B. OBJECTIVES:

- Validate and/or update thermomechanical rock mass behavior model
- Provide early data acquisition and to allow design adjustments.

C. CONSTRAINTS:

- Permanent instrumentation installed in emplacement drifts subject to waste isolation analysis
- Emplacement drift instrumentation may need to be abandoned due to lack of accessibility after emplacement.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Conducted primarily in the early stages of repository operations
- Baseline data required prior to emplacement.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Strain gauges mounted on tunnel support/stabilization elements (lining, rock bolts etc.) in emplacement drifts
- **TBD - Number of stations and number of instruments per station.**

F. DATA ACQUISITION REQUIREMENTS:

- Observation drift data acquisition system, for continuous monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.68 Mechanical Characteristics of Rock Matrix: Altered Zone Rock Deformation & Displacement (27-UT9)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Observation Drift(s), Emplacement Drifts

A. DESCRIPTION:

- Altered zone, deformation and displacement monitoring.

B. OBJECTIVES:

- Validate and/or update thermomechanical rock mass behavior model
- Provide early data acquisition and allow design adjustments.

C. CONSTRAINTS:

- Permanent instrumentation installed in emplacement drifts subject to waste isolation analysis
- Boreholes required for instrumentation installation
- Emplacement drift instrumentation may need to be abandoned due to lack of accessibility after emplacement
- Penetrated rock mass characterization of underground boreholes
- Trial testing and correlation of microseismic with displacement for microseismic monitoring.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Conducted primarily in the early stages of repository operations
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Multiple point borehole extensometers (MPBX), laser extensometers and inclinometers around emplacement drifts
- **TBD - Number of stations and number of instrumentation per station**
- Seismographs for microseismic monitoring.

F. DATA ACQUISITION REQUIREMENTS:

- Observation drift data acquisition system for continuous monitoring
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.69 Thermal Characteristics of Rock Matrix: Altered Zone & Rock Temperature (28-UT10)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Underground Boreholes

A. DESCRIPTION:

- Altered zone temperature monitoring.

B. OBJECTIVES:

- Validate and/or update thermomechanical rock mass behavior model
- Provide early data acquisition and allow design adjustments
- Changing rock temperature may affect groundwater flow and thus potentially affects waste package performance.

C. CONSTRAINTS:

- Boreholes required for instrumentation installation
- Thermal modeling implies temperature measurements above and below repository with more closely spaced measurements near repository level
- Penetrated rock mass characterization of underground boreholes.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Conducted initially in the early stages of repository operation for model confirmation and then through repository closure
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- **TBD - Number of stations based on number of observation drifts and number of stations in each drift**
- Borehole thermocouples and/or resistance temperature detectors
- Infrared thermal imaging of rock surface a consideration.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Borehole observation drift data acquisition system; continuous monitoring**
- **TBD - Download frequency**
- **TBD - Measurement frequency**
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.70 Chemical Composition of Groundwater (UZ): Age (H-3, C-14, Cl-36) (51-UT11)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Underground Boreholes

A. DESCRIPTION:

- Unsaturated zone groundwater sampling of underground boreholes and offsite lab analysis.

B. OBJECTIVES:

- Confirm baseline age data acquisition for design confirmation
- Confirm chemical changes resulting from waste heat generation.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Boreholes installed in the early stages of repository construction and sampled at **TBD - Frequency up to facility closure**
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Groundwater monitoring and sampling capabilities in underground based boreholes in unsaturated altered zone
- Off-site laboratories for sample analysis
- SEAMIST borehole instrumentation package, including periodic sampling capabilities
- **TBD - Number, location and depth of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- Borehole data acquisition system
- **TBD - Sampling frequency**
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**
- Possible sampling methods:
  - Collection of perched water samples during drilling
  - Extraction of pore water core samples
  - SEAMIST System.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.71 Hydraulic Characteristic of Groundwater (UZ): In-situ Fluid Potential (53-UT12)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Underground Boreholes

A. DESCRIPTION:

- Measurements of temperature and relative humidity in underground boreholes.

B. OBJECTIVES:

- Update thermal-hydrological and radionuclide transport models.

C. CONSTRAINTS:

- Penetrated rock mass characterization of underground boreholes.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Boreholes drilled and instrumentation installed for monitoring during early stages of repository construction
- Monitoring through facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- SEAMIST borehole instrumentation packages
- Borehole thermocouples and/or resistance temperature detectors for temperature
- Humicaps and/or psychrometers for relative humidity
- **TBD - Number of observation drifts**
- **TBD - Number of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- Borehole and observation drift data acquisition system for continuous monitoring
- **TBD - Continuous monitoring with download frequency.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Recent activities have successfully measured water potential in short horizontal boreholes off the ESF using heat dissimitation probes and tensiometers. These are "contact" sensors so they do not measure relative humidity as an intermediate parameter to set water potential.

TEST SCOPE SHEET

ID# and Title: 4.1.72 Hydraulic Characteristics of Groundwater (UZ): Altered Zone Moisture Content (54-UT13)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Underground Boreholes

A. DESCRIPTION:

- UZ zone groundwater moisture parameter obtained from soil/rock moisture measurements in boreholes.

B. OBJECTIVES:

- Update thermomechanical, groundwater flow, and radionuclide transport models.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Boreholes drilling and instrumentation installed during early stages of repository construction
- Monitoring through facility closure
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- **TBD - Number of observation drifts**
- **TBD - Number of boreholes per drift, location and depth**
- SEAMIST borehole instrumentation packages including neutron log and/or electrical resistivity tomography **TBD - Feasibility.**

F. DATA ACQUISITION REQUIREMENTS:

- Borehole and observation drift data acquisition system for continuous monitoring
- Periodic borehole geophysical logging and/or electric resistivity tomography
- Continuous monitoring with **TBD - Download frequency**
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

For direct measurement of volumetric water content in the ESF, recent activities are using a time domain reflectometry (TDR) system with a packer string, along with initial and periodic neutron logging.

TEST SCOPE SHEET

ID# and Title: 4.1.73 Hydraulic Characteristics of Groundwater: Altered Zone Liquid Water Flux (56-UT14)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculations from Soil/Rock Moisture Measurements

A. DESCRIPTION:

- Calculated from soil/rock moisture measurements using underground borehole instrumentation data.

B. OBJECTIVES:

- Update groundwater flow and radionuclide transport models.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Boreholes drilling and instrum. installed for monitoring in the early stages of repository construction and through to facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Observation drift based boreholes for obtaining required parameters
- **TBD - Number of observation drifts**
- **TBD - Number, location and depths of boreholes**
- Flexible borehole liner instrumentation package.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Download frequency**
- Borehole and observation drift data acquisition system for continuous monitoring
- Continuous monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.74 Hydraulic Characteristics of Groundwater: Altered Zone Water Vapor Content/Humidity (58-UT15)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Underground Boreholes

A. DESCRIPTION:

- Measured in underground boreholes as part of unsaturated zone groundwater monitoring.

B. OBJECTIVES:

- Update groundwater flow, radionuclide transport and waste package degradation models.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Boreholes drilled and instrumentation installed for monitoring in the early stages of repository construction and up to facility closure
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- SEAMIST borehole instrumentation package
- Borehole humicaps and/or psychrometers **(TBD - Feasibility with SEAMIST)**
- **TBD - Number, location, and depth of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- Borehole and observation drift data acquisition system with continuous monitoring
- **TBD - Number, location, and depth of boreholes**
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.75 Hydraulic Characteristics of Groundwater: Altered Zone Water Vapor Flux (60-UT16)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculations from Soil/Rock Moisture Measurements

A. DESCRIPTION:

- Calculated from soil/rock moisture measurements using observation drift based boreholes.

B. OBJECTIVES:

- Update groundwater flow, waste package performance and radionuclide transport models.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Observation drift based boreholes for obtaining required parameters
- Data obtained during early stages of repository construction for design updating
- Parameter measurements monitored through facility closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- **TBD - Number, location, and depth of boreholes.**

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Download frequency**
- Continuous moisture measurement monitoring
- Borehole and observation drift data acquisition system for continuous monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.76 Hydraulic Characteristics of Groundwater: Pre-waste Emplacement Ground Water Travel Time Disturbed (Altered) Zone to Water Table (62-UT17)
Responsible Organization: Site Evaluation Program Operations
Performing Organization:
Supporting Organization:
Location: Calculated from other Hydrogeologic Measurements

A. TEST DESCRIPTION:

- Calculated from other hydrogeologic measurements as part of modeling.

B. TEST OBJECTIVES:

- Characterize rock mass hydraulic characteristics prior to waste emplacement
- Update groundwater flow and radionuclide transport models.

C. TEST CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Necessary parameter measurements made prior to waste emplacement.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.77 Hydraulic Characteristics of Groundwater: Post-waste Emplacement Ground Water Travel Time from (Altered) Zone to Water Table (63-UT18)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculated from other Hydrogeologic Measurements

A. TEST DESCRIPTION:

- Calculated from other hydrogeologic measurements as part of model updates post-waste emplacement

B. TEST OBJECTIVES:

- Characterize rock mass hydraulic characteristics prior to waste emplacement
- Update groundwater flow and radionuclide transport models.

C. TEST CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.78 Thermal Characteristics of Groundwater (UZ): Altered Zone Fluid Temperature (64-UT19)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Underground Boreholes

A. DESCRIPTION:

- Altered zone fluid temperature monitoring in observation drift based boreholes.

B. OBJECTIVES:

- Update groundwater flow, radionuclide transport, and waste package degradation models.

C. CONSTRAINTS:

- Instrumentation needs to be retrievable and/or replaceable.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Conducted primarily in the early stages of repository operations and then monitoring up to closure
- Rock mass characterization of underground boreholes.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- SEAMIST or Westbay borehole instrumentation packages
- Borehole thermocouples and/or resistance temperature detectors
- **TBD - Extent of coring and geophysical borehole logging for rock mass characterization.**

F. DATA ACQUISITION REQUIREMENTS:

- Observation drift and borehole data acquisition system for continuous monitoring
- **TBD - Number, location, and depth of boreholes.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.79 Pneumatic Characteristics of Subsurface Air and Gases: Air Pressure (66-UT20)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Underground Boreholes

A. DESCRIPTION:
- Monitoring UZ air and gases (pressure) using underground boreholes.

B. OBJECTIVES:
- Update groundwater flow model.

C. CONSTRAINTS:
- Instrumentation needs to be retrievable and/or replaceable
- Penetrated rock mass characterization of underground boreholes.

D. PRETEST AND SCHEDULE REQUIREMENTS:
- Conducted primarily in the early stages of repository operations and then monitoring up to closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:
- Flexible borehole liner or Westbay borehole instrumentation packages
- Monitored using borehole gas pressure transducers.

F. DATA ACQUISITION REQUIREMENTS:
- Observation drift and borehole data acquisition system
- **TBD - Number, location, and depth of boreholes**
- Continuous monitoring.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.80 Pneumatic Characteristics of Subsurface Air and Gases: Air Flow (67-UT21)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Calculated from Air Pressure and Permeability

A. DESCRIPTION:

- Calculating UZ air flow from air pressure and permeability obtained from observation drift based boreholes.

B. OBJECTIVES:

- Update groundwater flow model.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Obtain baseline data in the early stages of repository operation and up to closure of facility.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Observation drift and boreholes data acquisition system
- **TBD - Download frequency**
- Continuous monitoring.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Model updated at frequency.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.81 Physiography: Topography - Ground Surface Elevation (1-GS1)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization.
Location: Repository Area Ground Surface

A. DESCRIPTION:

- Geodetic surveys - prior to and after events.

B. OBJECTIVES:

- Obtain baseline data
- Monitor potential uplift or subsidence, future erosion and future deposition and future seismicity.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Survey for baseline readings prior to repository construction
- Survey during and after geologic events.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Number of surveys per year and through repository closure.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# & Title: 4.1.82 Physiography: Vegetation - Plant Type (2-GS2)
Responsible Organization: Environment, Safety and Regional Programs
Performing Organization: Environmental Sciences Department
Supporting Organization:
Location: Repository Area Ground Surface

A. TEST DESCRIPTION:

- Seasonal surveys of plant species composition
- Seasonal and diurnal measurements of transpiration rates by dominant plant species.
- Timing of activity by dominant plant species.
- Effects of soil temperatures on transpiration and growth of dominant shrub species and the consequences to surface and subsurface infiltration.

B. OBJECTIVES:

- Provide information on plant species distributions and species specific variations in water-use under different thermal regimes.
- Provide information on the effects of soil temperature on root growth and water-use of dominant shrub species for use in infiltration models.
- Provide information on plant growth relative to timing of precipitation events.

C. CONSTRAINTS:

- Sample vegetation with minimum amount of disturbance.
- Transplant dominant shrub species into area where soil temperature can be manipulated.

D. PRETEST & SCHEDULE REQUIREMENTS:

- Baseline surveys at TBD - Areas.
- Continuous seasonal surveys through repository closure.

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- **TBD - soil temperature manipulation areas**
- Porometers and pressure chambers for measuring water relations.

F. DATA ACQUISITION REQUIREMENTS:

- Seasonal and diurnal surveys
- **TBD - soil temperature manipulation areas**

G. TEST/ASSESSMENTS REPORTS:

- Extent of soil temperature control on species survival, root growth and plant water-use and the consequences for infiltration.

COMMENTS:

- Increased soil temperatures from repository waste heat are likely to affect plant water use and therefore infiltration rates. Soil temperature manipulations can be achieved in the field or in a greenhouse.
- The timing of plant growth relative to the timing of major precipitation events will determine how effective plant communities are in preventing infiltration and ultimately percolation flux.
- Some equipment has already been acquired and is currently being used.

TEST SCOPE SHEET

ID# & Title: 4.1.83 Physiography: Vegetation - Areal Distribution (3-GS3)
Responsible Organization: Environmental, Safety and Regional Programs
Performing Organization: Environmental Sciences Department
Supporting Organization:
Location: Repository Area Ground Surface

A. DESCRIPTION:

- Seasonal surveys of vegetation cover and leaf area index in communities that differ in water availability and soil temperatures.
- Monitor soil temperature and moisture.
- Use leaf area index and cover in conjunction with leaf level transpiration rates to assess community level plant water use under different temperature and moisture regimes.

B. OBJECTIVES:

- Provide information on plant community composition, production and water-use across the ranges of soil temperatures and moisture availability that occur within the repository area ground surface.
- Provide information about the effects of seasonal plant water-use on infiltration in a variety of communities.

C. CONSTRAINTS:

- Sample communities with minimum amount of disturbance.
- Limited to current diurnal and seasonal soil temperatures and moisture patterns.

D. PRETEST & SCHEDULE REQUIREMENTS:

- Baseline surveys at **TBD - Areas.**
- Continuous seasonal surveys through repository closure.

E. TEST HW/SW FACILITIES REQUIREMENTS:

- Statistical, database and graphing software for data analyses. Porometers and pressure chambers for measuring water relations. Weather stations and soil probes for monitoring microclimate conditions.

F. DATA ACQUISITION REQUIREMENTS:

- Seasonal surveys of vegetation cover, leaf area index and leaf level transpiration rates.
- Monitor climate, soil moisture, soil temperature.
- **TBD - Survey areas**

G. TEST/ASSESSMENTS REPORTS:

- Extent of plant water-use in representative subset of communities within the repository area ground surface.
- Extent to which soil temperature and moisture control plant related processes.
- Extent to which plant water-use controls surface water infiltration.

COMMENTS

- Baseline surveys of biotic and abiotic community characteristics and plant water-use were initiated in May 1997 in eight communities within the repository footprint.
- Some equipment has already been acquired and is currently being used.

TEST SCOPE SHEET

ID# & Title: 4.1.84 Physiography: Climate and Meteorology - Precipitation (4-GS4)
Responsible Organization: Environmental, Safety and Regional Programs
Performing Organization: E.F.P.D. (Environmental Field Programs Div.)
Supporting Organization:
Location: Repository Area Ground Surface

A. DESCRIPTION:

- Site precipitation continuous monitoring at YMP EFPD meteorological stations for meteorological and hydrologic input.

B. OBJECTIVES:

- Important to calculate infiltration rate for hydrologic modeling
- Needed for present climate portion of Future climate modeling
- Important input for certain site models
- Input for atmospheric deposition models.

C. CONSTRAINTS:

D. PRETEST & SCHEDULE REQUIREMENTS:

- YMP EFPD meteorology stations include 9 full meteorological stations and 17 continuous precipitation sites established prior to repository construction during site characterization
- Continuous monitoring through facility closure.

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- YMP meteorology stations at existing and **TBD - Location.**

F. DATA ACQUISITION REQUIREMENTS:

- Centralized data acquisition system continued by EFPD to supply data as needed.
- Continuous monitoring to be continued by EFPD to supply data as needed.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# & Title: 4.1.85 Physiography: Climate and Meteorology - Dry Bulb Temperature (5-GS5)
Responsible Organization: Environmental, Safety and Regional Programs
Performing Organization: S.P.O. - E.F.P.D. (Environmental Field Programs Div.)
Supporting Organization:
Location: Repository Area Ground Surface

A. DESCRIPTION:

- Ambient air temperature continuous monitoring at YMP EFPD meteorological stations for meteorological input.

B. OBJECTIVES:

- Needed for present climate portion of Future climate modeling
- Important input for certain site models
- Input for atmospheric deposition models.

C. CONSTRAINTS:

D. PRETEST & SCHEDULE REQUIREMENTS:

- YMP EFPD meteorology stations include 9 full meteorological stations established prior to repository construction during site characterization
- Continuous monitoring through facility closure.

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- YMP meteorology stations at existing and TBD - Location.

F. DATA ACQUISITION REQUIREMENTS:

- Centralized data acquisition system continued by EFPD to supply data as needed.
- Continuous monitoring to be continued by EFPD to supply data as needed.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# & Title: 4.1.86 Physiography: Climate and Meteorology - Atmospheric Pressure (6-GS6)
Responsible Organization: Environmental, Safety and Regional Programs
Performing Organization: E.F.P.D. (Environmental Field Programs Div.)
Supporting Organization:
Location: Repository Area Ground Surface

A. DESCRIPTION:

- Atmospheric pressure continuous monitoring at YMP EFPD meteorological stations for meteorological input.

B. OBJECTIVES:

- Important input for certain site models
- Input for radon emanation calculations.

C. CONSTRAINTS:

D. PRETEST & SCHEDULE REQUIREMENTS:

- YMP EFPD meteorology stations include 9 full meteorological stations established prior to repository construction during site characterization
- Continuous monitoring through facility closure.

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- YMP meteorology stations at existing and **TBD - Location.**

F. DATA ACQUISITION REQUIREMENTS:

- Centralized data acquisition system continued by EFPD to supply data as needed.
- Continuous monitoring to be continued by EFPD to supply data as needed.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# & Title: 4.1.87 Physiography: Climate and Meteorology - Relative Humidity (7-GS7)
Responsible Organization: Environmental, Safety and Regional Programs
Performing Organization: E.F.P.D. (Environmental Field Programs Div.)
Supporting Organization:
Location: Repository Area Ground Surface

A. DESCRIPTION:

- Relative humidity continuous monitoring at YMP EFPD meteorological stations for meteorological input.

B. OBJECTIVES:

- Important to calculate evaporation for infiltration rate for hydrologic modeling
- Important input for certain site models

C. CONSTRAINTS:

D. PRETEST & SCHEDULE REQUIREMENTS:

- YMP EFPD meteorology stations include 9 full meteorological stations established prior to repository construction during site characterization
- Continuous monitoring through facility closure.

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- YMP meteorology stations at existing and **TBD - Location.**

F. DATA ACQUISITION REQUIREMENTS:

- Centralized data acquisition system continued by EFPD to supply data as needed.
- Continuous monitoring to be continued by EFPD to supply data as needed.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.88 Geologic Events and Processes: Seismicity - Location (8-GS8)
Responsible Organization: Site Evaluation Program Operations
Performing Organization : Site Evaluation Program Operations
Supporting Organization:
Location: Repository Area Ground Surface

A. DESCRIPTION:

- Surface based seismic monitoring
- Alcove based seismic stations.

B. OBJECTIVES:

- Record seismic activity at the site and surrounding areas
- Subsurface based stations recommended: to confirm facility design assumptions; record earthquakes should any damage occur; basis for evaluating subsurface movement: as a basis for above ground changes; confirm damping of acceleration/ground motion with depth obtain confirmatory data to support seismic hazard assessment
- Monitor for potential evidence of deep magmatic intrusion and future volcanic activity.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Surface stations completed prior to construction
- Establish alcove based seismic stations
- Continuous monitoring.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Surface and subsurface based seismic stations with remote data transmission.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Threshold recording limit for significant events**
- Avoid noise from construction activities.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.89 Geologic Events and Processes: Seismicity - Seismic Magnitude (9-GS9)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Surface Based and Underground Alcove Seismic Stations

A. DESCRIPTION:

- Surface based seismic monitoring
- Alcove based seismic stations.

B. OBJECTIVES:

- Record seismic activity at the site and surrounding areas
- Subsurface based stations recommended: to confirm facility design assumptions: record earthquakes should any damage occur; basis for evaluating subsurface movement: as a basis for above ground changes; confirm damping of acceleration/ground motion with depth
- Monitor for potential evidence of deep magmatic instruction and assess potential of future volcanic activity.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Surface stations completed prior to construction
- Establish alcove based seismic stations
- Continuous monitoring.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Surface and subsurface based seismic stations with remote data transmission.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Threshold recording limit for significant events.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.1.90 Geologic Events and Processes: Seismicity - Acceleration/Ground Motion (10-GS10)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Surface Based and Underground Alcove Seismic Stations

A. DESCRIPTION:

- Surface based seismic monitoring
- Alcove based seismic stations.

B. OBJECTIVES:

- Record seismic activity at the site and surrounding areas
- Verify maximum ground surface acceleration not exceeded for surface structures
- Subsurface based stations recommended: to confirm facility design assumptions; record earthquakes should any damage occur; basis for evaluating subsurface movement; as a basis for above ground changes; confirm damping of acceleration/ground motion with depth
- Monitor for potential evidence of deep magmatic intrusion and assessment potential of future volcanic activity.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Surface stations completed prior to construction
- Establish alcove based seismic stations
- Continuous monitoring.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Surface and subsurface based seismic stations with remote data transmission.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Threshold recording limit for significant events.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# & Title: 4.1.91 Public Radiological Health Risk: Background Radiation Level (13-GS11)
Responsible Organization: Environmental, Safety and Regional Programs
Performing Organization: Rad/Environmental Field Programs
Supporting Organization:
Location: General Site

A. DESCRIPTION:

- Surface based radiological environmental monitoring.

B. OBJECTIVES:

- Develop baseline background radiation levels for use as input data to postclosure performance assessments and comply with health and safety regulations.

C. CONSTRAINTS:

- Health and safety plan for guidelines and corrective actions during intrusive activity before health and safety administrative limits are exceeded.

D. PRETEST & SCHEDULE REQUIREMENTS:

- Continuous ongoing through closure (start-up, operations).

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- Existing site monitoring stations, which increase or decrease in concert with the increase or decrease of intrusive activities.

F. DATA ACQUISITION REQUIREMENTS:

- Existing monitoring equipment and personnel, which increase or decrease in concert with the increase or decrease of intrusive activities. Additionally, equipment supplies and repairs as need to maintain readiness.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

Other environmental regulatory requirements may be drivers of this program.

Provisions will need to be made for postclosure radiological environmental monitoring program.

4.2 REPOSITORY MONITORING AND TESTING SCOPE SHEETS

This section presents scope sheets for the repository monitoring and testing for performance confirmation. A testing activity scope sheet is included for each parameter identified in the repository excavation and borehole parameter section of Appendix D.

In this section, scope sheets are provided for each parameter listed in Appendix D of the Performance Confirmation Parameter table. The individual testing scope sheet may not entail a completely different test. The activities should be looked at as a whole to develop an efficient testing package for the collection of these parameters.

TEST SCOPE SHEET

ID# and Title: 4.2.1 Excavation Geometry: Geometry of Waste Emplacement Drifts - Deformation/Convergence (74-GR1)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:
- Continuous underground deformation monitoring of waste emplacement drift.

B. OBJECTIVES:
- Continuous deformation monitoring of emplacement drifts for verification and/or updating of thermal-mechanical models
- Drift changes resulting after excavation need to be monitored because of the potential impacts of drift deformation and convergence on waste package performance.

C. CONSTRAINTS:
- Permanent instrumentation installed in emplacement drifts subject to waste isolation analysis
- Instrumentation needs to be serviceable or must be abandoned in place.

D. PRETEST AND SCHEDULE REQUIREMENTS:
- Instrumentation to be installed during emplacement drift construction and monitored until permanent closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:
- **TBD - Number of stations/instruments within emplacement drifts.**
- Remote observation capabilities for servicing and monitoring instrumentation.

F. DATA ACQUISITION REQUIREMENTS:
- **TBD - Emplacement drift inspection frequency, robotics, cameras, lasers.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.2 Excavation Geometry: Geometry of Waste Emplacement Drifts -- Rockfall/ Collapse Size (75-GR2)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:
- Periodic emplacement drift inspection for rockfalls and ground support collapse.

B. OBJECTIVES:
- Drift changes resulting after excavation need to be monitored because of the potential impacts on waste package performance.

C. CONSTRAINTS:
- Remote observation required after waste emplacement.

D. PRETEST AND SCHEDULE REQUIREMENTS:
- Periodic inspections from initial excavation until permanent closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:
- Remote observation capabilities required for inspections.

F. DATA ACQUISITION REQUIREMENTS:
- **TBD - Emplacement drift inspection frequency, robotics, cameras, lasers.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.3 Subsurface Excavation Environment: Physical Characteristics of Excav. Environment - Dry Bulb Air Temp (76-GR3)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Subsurface excavation temperature monitoring at portals and selected underground locations.

B. OBJECTIVES:

- Air temperature potentially affects waste package performance
- Confirm model predictions
- Monitor potential random effects caused by groundwater inflows and other natural barrier heterogeneities.

C. CONSTRAINTS:

- Instrumentation needs to be serviceable if within emplacement drifts.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Continuous monitoring from initial excavation through repository closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Parameter data acquisition system for continuous remote monitoring possibly coupled with that of other parameters.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.4 Subsurface Excavation Environment: Physical Characteristics of Excav. Environment - Relative Humidity (77-GR4)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Subsurface excavation relative humidity monitoring at portals and selected underground locations.

B. OBJECTIVES:

- Monitoring relative humidity which potentially affects waste package performance
- Confirm model predictions
- Monitor potential random effects caused by groundwater inflows and other natural barrier heterogeneities.

C. CONSTRAINTS:

- Instrumentation needs to be serviceable within emplacement drifts.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Continuous monitoring from initial excavation through Repository closure.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

- Parameter data acquisition system for continuous remote monitoring possibly coupled with that of other parameters.

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.5 Subsurface Excavation Environment: Physical Characteristics of Excav. Environment - Groundwater Inflow Rate into Excavation (78-GR5)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Monitoring groundwater inflow rate according to perched water procedure.

B. OBJECTIVES:

- Detect and monitor any inflows encountered during repository excavation and following waste emplacement
- Evaluate waste package performance
- Update other parameter monitoring requirements (ex. Temperature and relative humidity).

C. CONSTRAINTS:

- Difficult to be predicted and measured
- Need personnel access during construction and possible remote monitoring after waste emplacement.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Monitoring from initial excavation until end of seepage.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.6 Subsurface Excavation Environment: Physical Characteristics of Excav. Environment - Groundwater Inflow Temperature (79-GR6)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Monitoring groundwater inflow temperature according to perched water procedure.

B. OBJECTIVES:

- Detect and monitor any inflows (rate and temp.) encountered during repository excavation and following waste emplacement
- Evaluate waste package performance
- Update other parameter monitoring requirements (ex. air temperature and relative humidity).

C. CONSTRAINTS:

- Difficult to be predicted and measured
- Need personnel access during construction and possible remote monitoring after waste emplacement.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Monitoring from initial excavation until end of seepage.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.7 Subsurface Excavation Environment: Chemical Characteristics of Excavation Environment -- Eh and Ph of Groundwater Inflow (80-GR7)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Monitoring groundwater inflow chemical characteristics (Eh and pH) according to perched water procedure.

B. OBJECTIVES:

- Evaluate waste package performance.

C. CONSTRAINTS:

- Need personnel access during construction and possible remote monitoring after waste emplacement.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Monitoring from initial excavation until end of seepage.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.8 Subsurface Excavation Environment: Chemical Characteristics of Excavation Environment -- Eh & Ph of Groundwater Outflow (8-GR8)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Estimating changes of groundwater chemical characteristics with seepage through emplacement drift inverts (Eh and pH) from geochemical modeling.

B. OBJECTIVES:

- Affects waste package performance.

C. CONSTRAINTS:

- Not practical to monitor, needs to be estimated from models.

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.9 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Construction and Fire Water - Quantity Remaining in Rock (82-GR9)
Responsible Organization: Site Evaluation Program Operations
Performing Organization : Site Evaluation Program Operations
Supporting Organization :
Location: Repository Excavation

A. TEST DESCRIPTION:

- Periodic repository rock sampling and offsite lab analyses for tracers, fluids, and materials introduced by the Exploratory Studies Facility and repository construction expected to remain after closure.

B. TEST OBJECTIVES:

- Evaluate postclosure performance of the natural and engineered barrier systems. (The water remaining in the rock could affect groundwater flow and associated waste package performance and radionuclide transport.)

C. TEST CONSTRAINTS:

- It is assumed that record keeping of tracers, fluids, and materials used in the subsurface excavations is part of the construction and operation activities.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Record keeping during construction and operation activities
- **TBD - Sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Off-site laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency and underground sampling locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.10 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Construction and Fire Water - Chemical Composition, Including Eh & ph (83-GR10)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Periodic repository rock sampling and offsite lab analyses for chemical composition of tracer, fluids, and materials introduced by the Exploratory Studies Facility and repository construction expected to remain after closure.

B. OBJECTIVES:

- Evaluate postclosure performance of the natural and engineered barrier systems. (The water remaining in the rock could affect groundwater flow and associated waste package performance and radionuclide transport.)

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Record keeping during construction and operation activities
- **TBD - Sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Off-site laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency and underground sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.11 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Hydrocarbons -- Quantity Remaining in Rock (84-GR11)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Periodic repository rock sampling and offsite lab analyses for hydrocarbons introduced by the Exploratory Studies Facility and repository construction expected to remain after closure.

B. OBJECTIVES:

- Evaluate postclosure performance of the natural and engineered barrier systems.

C. CONSTRAINTS:

- It is assumed that record keeping of tracers, fluids, and materials used in the subsurface excavations is part of the construction and operation activities.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Record keeping during construction and operation activities
- **TBD - Sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Off-site laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency and underground sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.12 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Hydrocarbons -- Chemical Composition, Including Eh & Ph (85-GR12)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Periodic repository rock sampling and offsite lab analyses for chemical composition of hydrocarbons introduced by the Exploratory Studies Facility and repository construction expected to remain after closure.

B. OBJECTIVES:

- Evaluate postclosure performance of the natural and engineered barrier systems.

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Record keeping of tracers, fluids, and materials during construction and operation activities
- **TBD - Sampling frequency**
- It is assumed that record keeping of tracers, fluids, and materials used in the subsurface excavations is part of the construction and operation activities.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Offsite laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Sampling frequency and underground sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.13 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Concrete - Chemical Composition/Alteration (86-GR13)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Periodic inspection and offsite lab analysis of repository Construction concrete for chemical composition and alteration as a function of time.

B. OBJECTIVES:

- Evaluate long term performance.

C. CONSTRAINTS:

- The amount, chemical composition and locations of concrete used will be part of the design and construction record.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- **TBD - Inspection and sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Off-site laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD- Inspection and sampling frequency and underground sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.14 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Steel -- Chemical Composition/Alteration (87-GR14)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Periodic inspection and offsite lab analysis of repository construction steel for chemical composition and alteration as a function of time.

B. OBJECTIVES:

- Evaluate long term performance.

C. CONSTRAINTS:

- The amount, chemical composition and locations of steel used will be part of the design and construction record.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- **TBD - Inspection and sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Off-site laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Inspection and sampling frequency and underground sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.15 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Ground Support -- Chemical Composition/Alteration (88-GR5)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Periodic inspection and offsite lab analyses of repository construction materials for chemical composition and alteration as a function of time
- Includes concrete, steel, and plastics used for safety purpose following excavation and during waste emplacement.

B. OBJECTIVES:

- Evaluate long-term performance.

C. CONSTRAINTS:

- The amount, chemical composition and locations of ground support material used will be part of the design and construction record.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- **TBD - Inspection and sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Offsite laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Inspection and sampling frequency and underground sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.16 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Pedestals - Chemical Composition/Alteration (89-GR16)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:
- Periodic inspection and offsite lab analyses of railcars for chemical composition and alteration as a function of time.

B. OBJECTIVES:
- Evaluate long-term performance.

C. CONSTRAINTS:
- Design and emplacement records will be the basis for the number, chemical compositions of constituent materials and locations of those to remain in place.

D. PRETEST AND SCHEDULE REQUIREMENTS:
- **TBD - Inspection and sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:
- Remote sampling capabilities after waste emplacement
- Off-site laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:
- **TBD - Inspection, sampling frequency and underground sample locations.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.17 Exploratory Studies Facility and Repository Construction Fluids and Materials Remaining after Repository Closure: Other Fluids and Materials Remaining in Repository after Closure -- Chemical Composition/Alteration (90-GR17)

Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization:
Location: Repository Excavation

A. DESCRIPTION:

- Periodic inspection and offsite lab analysis of specimens or rock samples as applicable for chemical composition and alteration as a function of time.

B. OBJECTIVES:

- Evaluate long-term performance.

C. CONSTRAINTS:

- The determination of importance evaluation for subsurface Exploratory Studies Facility can be used as an initial indication of the types of fluids and materials and their potential impact on waste isolation
- Design, construction and emplacement records will keep track of those that may have a waste isolation impact.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- **TBD - Inspection and sampling frequency.**

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Remote sampling capabilities after waste emplacement
- Off-site laboratories for sample analysis.

F. DATA ACQUISITION REQUIREMENTS:

- **TBD - Inspection, sampling frequency and underground sample locations**
- **TBD - Materials to be tested.**

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.18 Engineered Barrier System Release of Each Important Radionuclide - Fractional Radionuclide Release Relative to 1,000 Year Inventory (91-GR18)
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations
Supporting Organization.
Location: Calculation Based on Data from Repository

A. DESCRIPTION:

B. OBJECTIVES:

C. CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

F. DATA ACQUISITION REQUIREMENTS:

G. TEST/ASSESSMENTS REPORTS:

COMMENTS:

TEST SCOPE SHEET

ID# and Title: 4.2.19 Performance Confirmation Test for Repository Seals
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations, Repository Design
Supporting Organization:
Location: Dedicated alcove

A. DESCRIPTION:

- Large scale seal test, including treatment of surrounding modified permeability zone

B. OBJECTIVES:

- Compliance of the large scale seal design with hydrologic design goals for the repository.

C. TEST/ANALYSIS CONSTRAINTS:

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Characterization of modified permeability zone
- Design of seal systems, including primary grouting pattern, selection of final design mix for cementitious seals, structural analysis of the plug, and preparation of engineering work packages
- Schedule to allow testing during the early or developmental stages of construction

E. TEST HW/SW/FACILITIES REQUIREMENTS:

- Dedicated drift for construction of the repository seal
- Instrumented boreholes

F. DATA ACQUISITION REQUIREMENTS:

- Data acquisition system providing automated stress, strain, and temperature measurements.

G. TEST/ASSESSMENTS REPORTS:

- Pretest predictive analyses
- Report on test results

COMMENTS:

4.3 WASTE PACKAGE MONITORING AND TESTING SCOPE SHEETS

This section presents scope sheets for the waste package monitoring and testing for performance confirmation. A testing activity scope sheet is include for each of the four major testing areas described in Section 3.3.2.

TEST SCOPE SHEET

ID# and Title: 4.3.1 Laboratory Measurements Performed "Off Site"
Responsible Organization: Waste Package Materials
Performing Organization: Waste Package Materials
Supporting Organization: Performance Assessment, Waste Package Design
Location: The actual laboratory/test facility where these tests will be performed is to be determined. However, continuity will be maintained between laboratory testing that is currently going on in support of the Viability Assessment and the License Application and the laboratory work planned to support performance confirmation.

A. DESCRIPTION:

- Laboratory testing will be conducted at a site away from the repository as an important element in performance confirmation for waste package container materials. Measurements made from the "off site" laboratory investigations complement those obtained from exposure of "pull" test specimens in the repository environment itself. It is expected that the current laboratory testing supporting the License Application will narrow the broad range of environmental parameters now being considered and identify those key parameters needing further evaluation for confidently predicting the waste package performance. It is further expected that the current testing for evaluating several candidate materials will become more focused once the materials are selected for the License Application design. Similarly, it is expected that the current laboratory testing on the waste form performance, mostly in "hot cells" will become more narrowly focused on the key parameters affecting performance. In the case of waste form testing, no equivalent in situ kind of testing in the repository environment is feasible, so that continuation of the laboratory effort for longer time periods is important in increasing the confidence of performance predictions. A fuller description of the testing is given in the *Performance Confirmation Concepts Study Report*, Section 3.2.1.3.

B. OBJECTIVES:

- The main objective is to obtain longer term test data, which should reduce some performance uncertainty and therefore lead to greater confidence in predicting performance. Some degradation phenomena require a long incubation time before they are discernible. Laboratory testing can be conducted over a much wider range of conditions than the conditions available for repository testing in the near-term when the repository is in the "thermal spike" time period shortly after waste emplacement. Much of the laboratory testing is aimed at simulating repository conditions when the waste has cooled, when more moist conditions are possible.

C. CONSTRAINTS:

- The major constraint is that the environments are simulated, and there is always some uncertainty in selecting those environments for these long term tests. Since the choice of environments and other test conditions represents a large investment in time and money, it is prudent to obtain a broad range of expert opinion and review on test conditions and test procedures before these tests are begun.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Because the performance confirmation laboratory testing is a continuing operation from the testing now going on, there are no special pretest requirements. The schedule requirements are mostly to be determined.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Requirements are those applicable to the usual laboratory settings. Because of the long duration of the testing, temperatures, water chemistries, and other test conditions will be monitored and controlled automatically so this may entail some software and control systems technology. Maintenance personnel and trained technicians will be needed. "Hot cell" facilities for the waste form testing require a high degree of maintenance and monitoring.

F. DATA ACQUISITION REQUIREMENTS:

- Depending on the particular test, some data acquisition will be continuous and lend itself to automated recording. Other tests will yield results as a batch process, as specimens are removed from the test medium for periodic analysis and characterization. There will always be a need for some skilled technicians and analysts to perform the characterization throughout the performance confirmation period.

G. TEST/ANALYSIS/ASSESSMENTS REPORTS:

- These reports will be prepared periodically to support the different phases of the performance confirmation evaluation concept discussed in the *Performance Confirmation Concepts Study Report*, Section 3.2.3. The frequency of reporting is to be determined.

TEST SCOPE SHEET

ID# and Title: 4.3.2 In Situ Monitoring
Responsible Organization: Waste Package Materials
Performing Organization: Repository Operations
Supporting Organization: Performance Assessment (possibly others)
Location: Different locations within the repository subsurface facilities.

A. DESCRIPTION:

- This activity is concerned with measurements of environmental features and other parameters in the repository. It is expected that temperature and humidity are two important parameters that will be measured at many locations in the repository subsurface facilities, including locations in the emplacement drifts, such as on the container surface, on the drift wall, on the invert, as well as locations in the access drifts, in test alcoves, and other places. Some of the in situ measurements, such as detection of a gaseous radionuclide, relate directly to safety issues and would signal a pre-mature containment failure. Other measurements relate to more gradual environmental changes that would consequently influence the waste package performance. Examples are changes in the atmospheric gases, such as loss of carbon dioxide, or detection of a sulfur-bearing species signaling microbiological activity. Exactly which parameters/chemical species to be monitored depends on which of these are identified as key parameter to performance and which of these are measurable. Again, depending on the specifics, the monitoring may be continuous or performed on a periodic basis.

B. OBJECTIVES:

- The objective is to make real time measurements and to establish credibility of models that predict changes of important physical and chemical parameters. Many estimates of temperatures and humidities and their changes with time have been made from models of the repository. In situ monitoring permits evaluation of those models.

C. CONSTRAINTS:

- A major constraint would be technological 'state of the art' limitations on what parameters are measurable. The instrumentation, and in some instances cabling or transmitters, would also have to function in the thermal/ radiation/ geochemical environment in Yucca Mountain. A means for replacing broken or damaged equipment or instruments would need to be available, and this may impose some major constraints for any instruments in the emplacement drifts.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Installation of monitors and sensors would depend on the repository construction and waste emplacement schedule. Once the repository is operational, most of the in situ monitoring would be continuous. Scheduling for some of the periodic measurements would need to be determined.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- The "infrastructure" to maintain and monitor the various sensor devices may be considerable. The widespread locations of the monitor sites across the repository imprint may require a considerable network of cables or other transmitting devices.

F. **DATA ACQUISITION REQUIREMENTS:**

- Computer workstations for data acquisition and recording would be needed at the surface facility or underground.

G. **TEST/ANALYSIS/ASSESSMENTS REPORTS:**

- These reports will be prepared periodically to support the different phases of the performance confirmation evaluation concept discussed in the *Performance Confirmation Concepts Study Report,* Section 3.2.3. The frequency of reporting is to be determined.

TEST SCOPE SHEET

ID# and Title: 4.3.3 Pull Radioactive Waste Package
Responsible Organization: Waste Package Materials
Performing Organization: Repository Operations
Supporting Organization: Performance Assessment
Location: Emplacement Drifts

A. DESCRIPTION:

- This type of testing involves removal of a real, radioactive waste package from the emplacement drift and characterization of the waste package and its contents. Depending on the design of the surface handling facility, the characterization may be performed at the repository surface facilities or at a location equipped to handle nuclear materials. Because of high costs, this type of analysis is to be performed only as a contingency if a waste package has breached or been severely damaged. It is viewed as a "target of opportunity" should such an event occur. Depending on the nature of the waste package malfunction, the characterization may cover the container, the waste form, and the other internal components.

B. OBJECTIVES:

- The main objective would be to determine the cause of the malfunction (if not obvious) and to assess the damage of the various waste package components. It would present an opportunity to observe what would happen to the waste in the event of an early failure.

C. CONSTRAINTS:

- There are major constraints in retrieving the waste package and moving it to the surface facility (or elsewhere to an offsite hot cell).

D. PRETEST AND SCHEDULE REQUIREMENTS:

- This is not a scheduled test or analysis.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Since this type of test/analysis is not a planned event, construction of facilities appropriate for an "involved" type of analysis would likely not be built at the repository. However, the nature of the malfunction would determine the extent of analyses needed and where these would be performed.

F. DATA ACQUISITION REQUIREMENTS:

- This is not a scheduled test or analysis.

G. TEST/ANALYSIS/ASSESSMENTS REPORTS:

- This is not a scheduled test or analysis.

TEST SCOPE SHEET

ID# and Title: 4.3.4 Pull Dummy Waste Package
Responsible Organization: Waste Package Materials
Performing Organization: Repository Operations with Waste Package Materials
Supporting Organization: Performance Assessment, Waste Package Design
Location: At different locations in the repository subsurface facilities, in test alcoves, and perhaps at the end of the emplacement drifts where they are more accessible for removal.

A. DESCRIPTION:

- This type of test/analysis is the fabrication of a dummy waste package, of the same configuration and dimensions as the real waste package, but without the waste contents. Instead, the dummy would contain internal heating elements to provide the same thermal output as the real package. The full scale dummy waste package permits the same fit of the two-barrier container, reflecting accurately the same state of stress existing in the real package and exposure of the waste package surface to the actual repository environment.

B. OBJECTIVES:

- To obtain test information on as close to the "real thing" as possible without the radioactive component in the real repository environment.

C. CONSTRAINTS:

- Compared to the laboratory testing and pull specimen testing, this is an expensive test. Also, the size of the dummy limits where it can be emplaced.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Placement of the dummy waste packages would depend on the repository construction and waste emplacement schedules. The schedule for retrieving dummy waste packages for analyses is to be determined.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- An underground "infrastructure" is needed to provide power to the dummy waste package, as well as the means to retrieve any dummy waste package from the emplacement drift (if located there) and from other locations, such as in test alcoves in the repository. Depending on the nature of the surface facilities constructed at Yucca Mountain, the analysis of the dummy waste package may be performed there or it could be sent elsewhere to a more fully equipped laboratory. The requirements made for the "pull specimens" also apply to the dummy waste package.

F. DATA ACQUISITION REQUIREMENTS:

- Many of the requirements made for the laboratory offsite testing apply.

G. TEST/ANALYSIS/ASSESSMENTS REPORTS:

- These reports will be prepared periodically to support the different phases of the performance confirmation evaluation concept discussed in the *Performance Confirmation Concepts Study Report*, Section 3.2.3. The frequency of reporting is to be determined.

TEST/ANALYSIS SCOPE SHEET

ID# and Title: 4.3.5 Pull Specimens
Responsible Organization: Waste Package Materials
Performing Organization: Repository Operations with Waste Package Materials
Supporting Organization: Performance Assessment, Waste Package Design
Location: The tests will be performed in the repository, including the emplacement drifts, test alcoves, and other locations in order to expose specimens to as wide a range of temperature/environmental conditions as possible. Depending on the kinds of facilities at the repository site, pull specimens may be analyzed on site or sent off to another location for analyses, particularly if more specialized types of analyses are required. It will be beneficial to coordinate the analyses of laboratory test specimens with those for the pull specimen analyses.

A. DESCRIPTION:

- This work involves placement of test specimens at various locations in the repository subsurface facilities in Yucca Mountain. Some specimens will act as "witness specimens" to be placed near the waste packages and thus experience (or witness) the same temperatures and environmental conditions as the waste package container surface. (This same scheme of emplacing witness specimens is often used along buried pipelines and on off-shore drilling platforms.) The specimens are then "pulled" at various planned intervals and analyzed for evidence of corrosion and other degradation. Some specimens will be emplaced at other locations, such as in test alcoves, so that the array of "pull specimens" will experience a wide range of different temperatures and humidities. It is even desirable to place some specimens in highly fractured areas, where waste packages would not be intentionally emplaced, in order to obtain results from a location that may be subject to water intrusion. Specimen sizes will range from laboratory "coupon size" to much larger panel sizes that approach some of the dimensions of the actual waste package. Some pull specimens will contain welds and will be fabricated much like parts of the waste package.

B. OBJECTIVES:

- The test objectives are very similar to those for the laboratory tests, and the two types of tests are viewed as complementary since the laboratory tests utilize simulated environments while the pull specimen tests are under actual repository conditions.

C. CONSTRAINTS:

- From an operational point of view, retrieval of the pull specimens from the emplacement drifts involves the expense of using remote equipment. This may constrain the actual locations for placing the specimens in the emplacement drifts (such as near the ends of the drift) so that the specimens are more readily retrievable. Pull specimens placed in the personnel accessible parts of the repository should not present any particular problems in retrieval. From an environmental point of view, a major constraint is that the range of environmental exposure conditions is limited to those present in the repository during the early stages of emplacement when the repository is in the "thermal spike" phase.

D. PRETEST AND SCHEDULE REQUIREMENTS:

- Placement of pull test specimens depend on the repository construction and waste emplacement schedules. The schedule for retrieval of pull specimens is to be determined.

E. TEST HARDWARE/SOFTWARE FACILITIES REQUIREMENTS:

- Depending on the surface facilities constructed at Yucca Mountain, some (or all) of the pull specimen characterization may be conducted on site. Some special kinds of analyses may need to be performed off site. If no laboratory analytical facilities are built at Yucca Mountain, then the characterization work could be conducted at the same location/facility used for the offsite laboratory testing.

F. DATA ACQUISITION REQUIREMENTS:

- Many of the requirements made for the laboratory testing performed off site also apply here.

G. TEST/ANALYSIS/ASSESSMENTS REPORTS:

- These reports will be prepared periodically to support the different phases of the performance confirmation evaluation concept discussed in the *Performance Confirmation Concepts Study Report*, Section 3.2.3. The frequency of reporting is to be determined.

4.4 EVALUATION SCOPE SHEETS

This section presents scope sheets for the performance confirmation evaluations. The evaluations include the three categories of performance assessment predictions (Section 3.2.1). the specific process modeling for each of these categories (Section 3.2.2), and the performance confirmation evaluations (sections 3.4.1 through 3.4.6), and the recommendation of corrective actions (Section 3.4.7). A performance confirmation evaluation is not prepared for the implementation of corrective actions (Section 3.4.8), because this is not within the scope of the Performance Confirmation Program. A performance confirmation evaluation is not prepared for baseline change control (Section 3.4.9), since this is an integral component of most other evaluation activities. rather than a separate activity or evaluation.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.1 Pre-License Application Predictions of Preclosure Performance[1]
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Licensing, Technical Data Management, Repository Design, Waste Package Development, Waste Package Materials
Location: Offsite offices of performing and supporting organizations

A. DESCRIPTION:

- Before the submittal of the License Application, predict the preclosure performance of the natural and engineered barrier systems (Section 3.2.1.1).

B. OBJECTIVES:

- Provide input to comparing measured performance confirmation data with Modeling results (Section 3.4.2), evaluating the accuracy and validity of postclosure performance assessment models (sections 3.4.3 and 3.4.4), and determining the need for corrective actions (Section 3.4.6 through 3.4.8).

C. CONSTRAINTS:

- The evolution of (a) the MGDS design, (b) understanding of natural and engineered barrier processes, (c) computer hardware, and (d) associated improvements in performance assessment models and computer codes may require more iterations for some processes than indicated in D.

D. SCHEDULE:

- Perform two (or more) iterations: (1) as soon as possible to provide initial guidance for performance confirmation testing and measurement specifications, and (2) shortly before the submittal of the License Application.

E. TEST HARDWARE/SOFTWARE FACILITIES

- Computers at the offices of the performing and contributing organizations; Performance assessment computer codes (see performance confirmation evaluations 4.4.4 through 4.4.9 for codes used at present for specific processes).

F. INPUT:

- Results of site characterization and MGDS design; Exploratory Studies Facility configuration; results of pre-License Application performance confirmation site monitoring and testing (see performance confirmation evaluations 4.4.4 through 4.4.9 for specific parameters and locations).

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[1]Pre-License Application predictions of both preclosure and postclosure performance will be conducted as part of the total system performance assessment for the License Application. These analyses are expected to include all of the evaluations described in this Scope Sheet and are included in the Performance Confirmation Plan for completeness and to ensure the proper scope of activities to support Performance Confirmation are conducted.

G. OUTPUT:

- Predicted PC parameter values at locations and times of PC testing and measurements of the parameters, including predicted results of laboratory experiments; will provide input to evaluations and corrective actions (Section 3.4).

H. REPORTS:

- Pre-License Application preclosure performance assessment reports (Section 3.5.7.1) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.2 Post-License Application Predictions of Preclosure Performance
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Licensing, Technical Data Management, Repository Design, Waste Package Development, Waste Package Materials , Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- After the submittal of the License Application, predict the preclosure performance of the natural and engineered barrier systems (Section 3.2.1.2).

B. OBJECTIVES:

- Provide input to comparing measured performance confirmation data with Modeling results (Section 3.4.2), evaluating the accuracy and validity of postclosure performance assessment models (sections 3.4.3 and 3.4.4), and determining the need for corrective actions (sections 3.4.6 through 3.4.8).

C. CONSTRAINTS:

- The evolution of (a) the MGDS construction and waste emplacement, (b) understanding of natural and engineered barrier processes, (c) computer hardware, and (d) associated improvements in performance assessment models and computer codes will determine the frequency of iterations, which may vary for different processes.

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Performance assessment computer codes (see performance confirmation evaluations 4.4.4 through 4.4.9 for codes used at present for specific processes).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of pre- and post-License Application performance confirmation site monitoring and testing (see performance confirmation evaluations 4.4.4 through 4.4.9 for specific parameters and locations).

G. OUTPUT:

- Performance confirmation parameter values at locations and times of PC testing and measurements of the parameters, including results of laboratory experiments: will provide input to evaluations and corrective actions (Section 3.4).

H. REPORTS:

- Post-License Application preclosure performance assessment reports (Section 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.3 Post-License Application Predictions of Postclosure Performance
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Licensing, Technical Data Management, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- After the submittal of the License Application, predict the postclosure performance of the natural and engineered barrier systems and the overall MGDS (Section 3.2.1.3).

B. OBJECTIVES:

- Provide input for evaluating compliance with postclosure performance standards (Section 3.4.5), determining the need for corrective actions (Section 3.4.6 through 3.4.8), and to license amendment for repository closure (Section 3.5.9).

C. CONSTRAINTS:

- The evolution of (a) the MGDS construction and waste emplacement, (b) understanding of natural and engineered barrier processes, (c) computer hardware, and (d) associated improvements in performance assessment models and computer codes will determine the frequency of iterations, which may vary for different processes.

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Performance assessment computer codes (see performance confirmation evaluation 4.4.10 for codes used at present for specific processes).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of pre- and post-License Application performance confirmation site monitoring and testing (see performance confirmation evaluations 4.4.4 through 4.4.9 for specific parameters and locations).

G. OUTPUT:

- Parameter values and distributions of postclosure performance standards; compliance with postclosure performance standards; will provide input to postclosure performance evaluations, corrective actions and to license amendment for repository closure (Section 3.4.3 through 3.4.7 /performance confirmation evaluations 4.4.13 through 4.4.17).

H. REPORTS:

- Post-License Application postclosure performance assessment reports (Section 3.5.7.3) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.4 Coupled Thermal-Hydrological and Ventilation Modeling
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluations Program Operations, Repository Design, Technical Data Management, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Predict excavation and adjacent rock thermal, hydrological, and pneumatic parameter values at performance confirmation locations (Section 3.2.2.1).

B. OBJECTIVES:

- Provide input to pre-license and post-License Application predictions of preclosure performance (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two or more iterations before the submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Coupled thermal-hydrological-ventilation computer codes (computer codes used at present include A-TOUGH, CLIMATE, CLIMSIM, FEHMN, ITOUGH2, MPSalsa, NUFT, TOUGH2, VNETPC, and V-TOUGH -- see Appendix C for brief descriptions and references).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of performance confirmation monitoring of excavation air temperature and relative humidity; rock, water and air temperature; moisture content, in situ fluid potential, and air pressure in rock adjacent to excavations; for locations of subsurface geologic mapping, underground fault zone hydrology package, thermal testing package, waste package testing, selected emplacement drifts, selected other excavation drifts, and observations drifts.

G. OUTPUT:

- Predicted values of parameters listed above at locations listed above; will provide input to pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

H. REPORTS:

- Separate process modeling topical reports (Section 3.5.9) or sections in pre- and post-License Application preclosure performance assessment reports (sections 3.5.7.1 and 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.5 Geomechanical and Coupled Thermal-Mechanical Modeling
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Repository Design, Waste Package Development, Technical Data Management, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Predict rock (adjacent to excavations) and waste package surface thermal and mechanical parameter values at performance confirmation locations (Section 3.2.2.2).

B. OBJECTIVES:

- Provide input to pre-license and post-License Application predictions of preclosure performance (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two or more iterations before the submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Geomechanical and coupled thermal-mechanical computer codes (computer codes used at present include 3DEC, ABAQUS, ANSYS, JAC / JAC2D / JAC3D, UDEC, and UNWEDGE -- see Appendix C for brief descriptions and references).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of performance confirmation monitoring of rock stress, strain, deformation / displacement adjacent to excavations, size and location of rockfalls; temperatures, stress and strain on surfaces of actual and dummy waste packages; for locations of thermal testing package, waste package testing, selected emplacement drifts, and observations drifts.

G. OUTPUT:

- Predicted values of parameters listed above at locations listed above; will provide input to pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

H. REPORTS:

- Separate process modeling topical reports (Section 3.5.9) or sections in pre- and post-License Application preclosure performance assessment reports (sections 3.5.7.1 and 3.5.7.2) for each iteration; will provide input to pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

EVALUATION SCOPE SHEET

ID# and Title: 4.4.6 Geochemical Modeling
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluations Program Operations, Repository Design, Waste Package Materials Development, Technical Data Management, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Predict ground-water chemistry adjacent to excavations, chemical alteration products of waste packages and waste package coupons in emplacement drifts and at subsurface waste package test locations, and chemical alteration of introduced tracers, fluids and materials remaining in the repository (Section 3.2.2.3).

B. OBJECTIVES:

- Provide input to pre-license and post-License Application predictions of preclosure performance (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two or more iterations before the submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/ operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Geochemical computer codes (the principal computer code used at present is EQ3/6 -- see Appendix C for brief description and references).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of performance confirmation monitoring of ground-water chemistry adjacent to excavations, chemical alteration products of waste packages and waste package coupons in emplacement drifts and at subsurface waste package test locations, and chemical alteration of introduced tracers, fluids and materials.

G. **OUTPUT:**

- Predicted values of parameters listed above at locations listed above; will provide input to pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

H. **REPORTS:**

- Separate process modeling topical reports (Section 3.5.9) or sections in pre- and post-License Application preclosure performance assessment reports (sections 3.5.7.1 and 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.7 Coupled Waste Package and Near-Field Thermal Modeling
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluations Program Operations, Repository Design, Waste Package Development, Technical Data Management, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Predict temperatures of excavation walls, on surfaces of waste packages, and of waste package coupons, in emplacement drifts and at subsurface waste package test locations (Section 3.2.2.4).

B. OBJECTIVES:

- Provide input to pre-license and post-License Application predictions of preclosure performance (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two or more iterations before the submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Thermal computer codes (a computer code used at present is COYOTE -- see Appendix C for brief description and references).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of performance confirmation monitoring of temperatures of excavation walls, on surfaces of waste packages, and of waste package coupons, in emplacement drifts and at subsurface waste package test locations.

G. OUTPUT:

- Predicted values of parameters listed above at locations listed above; will provide input to pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

H. REPORTS:

- Separate process modeling topical reports (Section 3.5.9) or sections in pre- and post-License Application preclosure performance assessment reports (sections 3.5.7.1 and 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.8 Waste Package Degradation Modeling
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Waste Package Materials, Technical Data Management, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Predict thickness changes of waste package barriers and coupons at subsurface waste package test locations and in the laboratory (Section 3.2.2.5).

B. OBJECTIVES:

- Provide input to pre-license and post-License Application predictions of preclosure performance (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two or more iterations before the submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Corrosion and waste package performance computer codes (computer codes used at present include AREST, AREST-CT, PIGS, WAPDEG and YMIM -- see Appendix C for brief descriptions and references).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of performance confirmation monitoring of temperatures of excavation walls, on surfaces of waste packages, and of waste package coupons, in emplacement drifts and at subsurface waste package test locations.

G. OUTPUT:

- Predicted values of parameters listed above at locations listed above; will provide input to pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

H. REPORTS:

- Separate process modeling topical reports (Section 3.5.9) or sections in pre- and post-License Application preclosure performance assessment reports (sections 3.5.7.1 and 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.9 Nuclear Criticality Modeling
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials, Technical Data Management, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Predict potential internal and external waste package criticality for waste forms and packages of concern at selected emplacement drift locations (Section 3.2.2.6).

B. OBJECTIVES:

- Provide input to pre-license and post-License Application predictions of preclosure performance (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two or more iterations before the submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Nuclear criticality computer codes (computer codes used at present include MCNP and SCALE -- see Appendix C for brief descriptions and references).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results of near-field performance confirmation monitoring and performance assessment modeling.

G. OUTPUT:

- Predicted potential internal and external criticality for selected emplacement drift locations and all relevant waste types and packages; will provide input to pre- and post-License Application pre- and postclosure performance predictions (sections 3.2.1.1 through 3.2.1.3 /performance confirmation evaluations 4.4.1 and 4.4.3).

H. REPORTS:

- Separate process modeling topical reports (Section 3.5.9) or sections in pre- and post-License Application preclosure performance assessment reports (sections 3.5.7.1 and 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.10 Saturated-Zone Ground-Water Flow Modeling
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Technical Data Management
Location: Offsite offices of performing and supporting organizations

A. DESCRIPTION:

- Predict saturated zone ground-water table elevations at ground-water table borehole monitoring locations, and ground-water flux and tracer dispersion at ground-water pump and tracer test borehole locations (Section 3.2.2.6).

B. OBJECTIVES:

- Provide input to pre-license and post-License Application predictions of preclosure performance (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two or more iterations before the submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; Coupled thermal-hydrological-ventilation computer codes (computer codes used at present include FEHMN, MODFLOWP, NUFT, TOUGH2, and V-TOUGH -- see Appendix C for brief descriptions and references).

F. INPUT:

- Results of site characterization; results of performance confirmation monitoring of water tables from surface-based boreholes; results of pump and tracer tests at pump and tracer test borehole locations.

G. OUTPUT:

- Predicted values of parameters listed above at locations listed above; will provide input to pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

H. REPORTS:

- Separate process modeling topical reports (Section 3.5.9) or sections in pre- and post-License Application preclosure performance assessment reports (sections 3.5.7.1 and 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.11 Total System Performance Assessment
Responsible Organization: Performance Assessment
Performing Organization: Performance Assessment
Supporting Organization: Site Evaluation Program Operations, Licensing, Repository Design, Waste Package Development, Waste Package Materials, Technical Data Management, Site Construction and Operations, Radiation Field Programs Department (Biosphere Working Group
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Predict overall MGDS postclosure performance, including relevant natural and engineered barrier processes (Section 3.2.2.7).

B. OBJECTIVES:

- Provide input to comparisons of postclosure performance predictions (Section 3.4.3) and to evaluations of compliance with postclosure performance standards (Section 3.4.5).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Computers at the offices of the performing and contributing organizations; TSPA software and supporting natural and engineered barrier process computer codes (TSPA software used at present includes RIP and TSA; examples of supporting process codes used at present are GENESIS and RegCM2 for climate modeling; FEHMN, MODFLOW, NUFT, TOUGH2 and V-TOUGH for ground-water flow analyses; ORIGEN2 for computing radionuclide inventory and heat generation of nuclear wastes; EQ3/6 for geochemical analyses; AREST, AREST-CT, PIGS, WAPDEG and YMIM for analyses of waste package degradation and radionuclide release from the waste packages; FEHMN, NUFT and TRACR3D for analyses of geosphere radionuclide transport; and GENII and MACCS for analyses of biosphere radionuclide transport and radiation dose exposures of humans; PGEMs, MATHEW, PAVAN and HOTMAC are being used or evaluated for Biosphere dispersion assessments -- see Appendix C for brief descriptions and references).

F. INPUT:

- Results of site characterization and MGDS design; as-built MGDS configuration, including waste inventory; results performance confirmation site monitoring and testing.

G. **OUTPUT:**

- Predicted values and distributions of postclosure performance measures: will provide input to post-License Application evaluations of postclosure performance and regulatory compliance (sections 3.4.3 and 3.4.5 /performance confirmation evaluations 4.4.13 and 4.4.15).

H. **REPORTS:**

- Post-License Application postclosure performance assessment reports (Section 3.5.7.3) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.12 Data Comparisons
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials
Supporting Organization: Performance Assessment, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Compare site characterization parameter values with performance confirmation parameter values and successive stages of performance confirmation parameter values with each other (Section 3.4.1). This includes comparing site properties defined by the various conceptual site models with the performance confirmation measurements, and thus constitutes a test of the validity and accuracy of these conceptual models.

B. OBJECTIVES:

- Evaluate statistical significance of differences between site characterization and performance confirmation parameter values and implications with respect to postclosure performance; provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two (or more) iterations before submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Standard computers at the offices of the performing and contributing organizations; standard data conversion, interpolation, extrapolation, and statistical analysis software.

F. INPUT:

- Results performance confirmation site monitoring and testing.

G. OUTPUT:

- Interpreted values of raw data, interpolated and extrapolated parameter values, statistical measures of data differences, implications with respect to postclosure performance; will provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

H. REPORTS:

- Data comparison reports (Section 3.5.5) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.13 Comparisons of Measured Data with Model Predictions
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Performance Assessment, Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials
Supporting Organization: Site Construction and Operations
Location: Offsite offices of performing organizations and onsite office of Site Construction and Operations

A. DESCRIPTION:

- Compare performance confirmation parameter values with pre- and post-License Application preclosure performance predictions (Section 3.4.2).

B. OBJECTIVES:

- Evaluate statistical significance of differences between measured performance confirmation parameter values and model predictions (Section 3.4.2), implications with respect to model accuracy and validity (Section 3.4.4) and postclosure performance (Section 3.4.5), and provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform two (or more) iterations before submittal of the License Application and several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Standard computers at the offices of the performing and contributing organizations; standard interpolation, extrapolation, and statistical analysis software.

F. INPUT:

- Results performance confirmation site monitoring and testing; results of pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2/performance confirmation evaluations 4.4.1 and 4.4.2).

G. OUTPUT:

- Interpolated and extrapolated measured and predicted parameter values, statistical measures of differences between measured and predicted values; implications with respect to model accuracy and validity and postclosure performance; will provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

H. REPORTS:

- Data/model comparison reports (Section 3.5.6) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.14 Comparisons of Model Predictions
Responsible Organization: Systems Engineering/Integration
Performing Organization: Performance Assessment, Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials
Supporting Organization: Site Construction and Operations
Location: Offsite offices of performing organizations and onsite office of Site Construction and Operations

A. DESCRIPTION:

- Compare pre- and post-License Application preclosure performance predictions and successive post-License Application preclosure performance predictions with each other (Section 3.4.3).

B. OBJECTIVES:

- Evaluate statistical significance of differences between model predictions (Section 3.4.3), implications with respect to model accuracy and validity (Section 3.4.4) and postclosure performance (Section 3.4.5), and provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Standard computers at the offices of the performing and contributing organizations; standard interpolation, extrapolation, and statistical analysis software.

F. INPUT:

- Results of pre- and post-License Application preclosure performance predictions (sections 3.2.1.1 and 3.2.1.2 /performance confirmation evaluations 4.4.1 and 4.4.2).

G. OUTPUT:

- Interpolated and extrapolated measured and predicted parameter values, statistical measures of differences between measured and predicted values; implications with respect to model accuracy and validity and postclosure performance; will provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

H. REPORTS:

- Post-License Application preclosure performance assessment reports (Section 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.15 Accuracy and Validity of Performance Assessment Models
Responsible Organization: Systems Engineering/Integration
Performing Organization: Performance Assessment, Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials
Supporting Organization: Site Construction and Operations
Location: Offsite offices of performing organizations and onsite office of Site Construction and Operations

A. DESCRIPTION:

- Evaluate the accuracy and validity of performance assessment models for postclosure performance predictions on the basis of the results of performance confirmation site monitoring and testing, associated data evaluations, and preclosure performance predictions (Section 3.4.4).

B. OBJECTIVES:

- Provide a basis for the adequacy and defensibility of evaluations of compliance with postclosure performance standards (Section 3.4.5); provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Standard computers at the offices of the performing and contributing organizations; standard interpolation, extrapolation, and statistical analysis software.

F. INPUT:

- Results of comparisons performance confirmation data and preclosure performance predictions (sections 3.4.1 through 3.4.3 /performance confirmation evaluations 4.4.11 through 4.4.13).

G. OUTPUT:

- Quantitative statistics and qualitative interpretation of performance assessment model accuracy and validity for postclosure performance predictions; will provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

H. REPORTS:

- Separate computer code verification and mathematical model validation reports (Section 3.5.9) or sections in post-License Application preclosure performance assessment reports (Section 3.5.7.2) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.16 Evaluation of Regulatory Compliance
Responsible Organization: Systems Engineering/Integration
Performing Organization: Performance Assessment, Licensing
Supporting Organization: Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials
Location: Offsite offices of performing and supporting organizations

A. DESCRIPTION:

- Evaluate changes (from License Application) in level of regulatory compliance with postclosure performance standards as a result of performance confirmation site monitoring and testing results, conceptual and mathematical model and computer code changes, as-built MGDS, and any unforeseen events during preclosure phase (Section 3.4.5).

B. OBJECTIVES:

- Provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Standard computers at offices of the performing and supporting organizations; standard statistical software.

F. INPUT:

- License Application postclosure performance predictions and regulatory compliance evaluations (not within scope of Performance Confirmation Program) and results of postclosure performance predictions (Section 3.2.1.3 /performance confirmation evaluation 4.4.3).

G. OUTPUT:

- Quantitative statistics and qualitative interpretation of regulatory compliance with postclosure performance standards; will provide input to determining the need for corrective actions (sections 3.4.6 through 3.4.7).

H. REPORTS:

- Separate regulatory compliance reports (Section 3.5.9) or sections in post-License Application postclosure performance assessment reports (Section 3.5.7.3) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.17 Trend Detection
Responsible Organization: Systems Engineering/Integration
Performing Organization: Performance Assessment, Licensing
Supporting Organization: Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Evaluate any trends in the results of performance confirmation site monitoring and testing, data evaluations and comparisons, and pre- and post-License Applications pre- and postclosure performance predictions and comparisons (Section 3.4.6).

B. OBJECTIVES:

- Provide input to determining the need for corrective actions (Section 3.4.7 through 3.4.8).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Standard computers at offices of the performing and supporting organizations; standard statistical software.

F. INPUT:

- Data comparisons (Section 3.4.1 / performance confirmation evaluation 4.4.11), data / modeling comparisons (Section 3.4.2 / performance confirmation evaluation 4.4.12), model prediction comparisons (Section 3.4.3 /performance confirmation evaluation 4.4.13, model accuracy and validation evaluations (Section 3.4.4 / performance confirmation evaluation 4.4.14), and regulatory compliance evaluations (Section 3.2.5 / performance confirmation evaluation 4.4.15).

G. OUTPUT:

- Quantitative statistics and qualitative interpretation of trends in results of performance confirmation site monitoring and testing, pre- and post-closure performance predictions, and levels of regulatory compliance; will provide input to recommending corrective actions (Section 3.4.7 /performance confirmation evaluation 4.4.17).

H. REPORTS:

- Separate trend detection reports or sections in data comparisons reports (Section 3.5.5), data/model comparison reports (Section 3.5.6), post-License Application performance assessment reports (sections 3.5.7.2 and 3.5.7.3), and regulatory compliance evaluation reports (Section 3.5.9) for each iteration.

EVALUATION SCOPE SHEET

ID# and Title: 4.4.18 Recommended Corrective Actions
Responsible Organization: Systems Engineering/Integration
Performing Organization: Performance Assessment, Licensing
Supporting Organization: Site Evaluation Program Operations, Repository Design, Waste Package Development, Waste Package Materials, Site Construction and Operations
Location: Offsite offices of performing and supporting organizations (except onsite office of Site Construction and Operations)

A. DESCRIPTION:

- Recommend corrective actions, if necessary, in terms of changes in the Yucca Mountain Project technical database, Performance Confirmation Program, conceptual and mathematical models and computer codes, MGDS design/construction /operation; recommend interactions with the NRC and stakeholders, repository closure, and/or if necessary, waste retrieval, site abandonment (Section 3.4.7).

B. OBJECTIVES:

- Provide input to the implementation of corrective actions (Section 3.4.8).

C. CONSTRAINTS:

D. SCHEDULE:

- Perform several iterations after the submittal of the License Application, as determined on the basis of the results of performance confirmation site monitoring and testing, the associated evaluations, performance assessment model and computer code changes, MGDS design/construction/operation changes, and other corrective actions.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Offices of the performing and supporting organizations.

F. INPUT:

- Trend detection (Section 3.4.6 /performance confirmation evaluation 4.4.16).

G. OUTPUT:

- Recommended corrective actions as input to their implementation (Section 3.4.8).

H. REPORTS:

- Separate recommended corrective action reports or sections in data comparisons reports (Section 3.5.5), data / model comparison reports (Section 3.5.6), post-License Application performance assessment reports (sections 3.5.7.2 and 3.5.7.3), regulatory compliance evaluation reports (Section 3.5.9), or trend detection reports for each iteration.

4.5 OPERATIONS AND MANAGEMENT SCOPE SHEETS

This section presents scope sheets for the performance confirmation operations and management activities. These activities include updates to the *Performance Confirmation Plan*, detailed test planning, data management, sample management, and information management. Each activity is described in more detail in the following activity scope sheets.

ACTIVITY SCOPE SHEET

ID# and Title: 4.5.1 *Performance Confirmation Plan* Updates
Responsible Organization: Systems Engineering/Integration
Performing Organization: Systems Engineering/Integration
Supporting Organization: Site Evaluation Program Operations, Licensing, Technical Data Management, Repository Design, Waste Package Development, Waste Package Materials, Performance Assessment
Location: Offsite offices of performing and supporting organizations

A. DESCRIPTION:

- Update the *Performance Confirmation Plan* before the submittal of the License Application for construction authorization to be consistent with the License Application design, site characterization data and performance assessment information. Updates will be performed as required based on changes to the design, testing, or corrective actions, throughout the life of the Performance Confirmation Program.

B. OBJECTIVES:

- Develop a *Performance Confirmation Plan* consistent with the License Application design, site characterization information, and performance assessment for the License Application for construction authorization. Retain flexibility to respond to changes in the design, testing, or corrective action throughout the life of the Performance Conformation Program.

C. CONSTRAINTS:

- The evolution of (a) the MGDS design, (b) understanding of natural and engineered barrier processes, (c) computer hardware, and (d) associated improvements in performance assessment models and computer codes may require updates to the *Performance Confirmation Plan.*

- The Performance Confirmation Program should be planned as an integral part of the repository design (developmental test and evaluation) and operation (operational test and evaluation).

- The Performance Confirmation Program should develop a plan for scenarios, criteria, and recommended corrective actions for statistically significant deviations from the performance confirmation technical baseline.

D. SCHEDULE:

- Perform shortly before the submittal of the License Application and after the completion of the performance assessment for the License Application for construction authorization. Update the *Performance Confirmation Plan* as required to respond to changes in the design, testing, or corrective action.

E. **TEST HARDWARE/SOFTWARE FACILITIES:**

- Provide facilities or offices of the performing and contributing organizations.

F. **INPUT:**

- Results of site characterization information for items important to waste isolation. MGDS design of items important to waste isolation, and performance assessments supporting the License Application for construction authorization; results of pre-License Application performance confirmation site monitoring and testing; information on the changes to the MGDS design important to waste isolation, understanding of the natural and engineered barrier processes, computer hardware, and associated improvements in the performance assessment model and computer codes.

G. **OUTPUT:**

- *Performance Confirmation Plan* for the License Application for construction authorization and subsequent revisions, as required.

ACTIVITY SCOPE SHEET

ID# and Title: 4.5.2 *Performance Confirmation Plan* Detailed Test Planning
Responsible Organization: See Scope Sheet for each test
Performing Organization: See Scope Sheet for each test
Supporting Organization: Site Evaluation Program Operations, Licensing, Technical Data Management, Repository Design, Waste Package Development, Waste Package Materials, Performance Assessment
Location: Offsite offices of performing and supporting organizations

A. DESCRIPTION:

- Perform detailed test planning of the testing activities prior to implementation. These activities include identification of test procedures to be developed to control and perform tests, identify test methods to be employed and instructions for performing the test, identify mandatory hold points, and provisions for ensuring that prerequisites for the given test have been met will be identified. Selection and identification of the measuring and test equipment to be used to perform the test to ensure that the equipment is of the proper type, range, accuracy, and tolerance to accomplish the intended function will be done during detailed planning. Detailed test planning will also identify the functional qualification level of personnel performing tests.

B. OBJECTIVES:

- Provide sufficient test planning detail so that implementation and performance of the identified testing can be completed.

C. CONSTRAINTS:

D. SCHEDULE:

- Perform prior to implementation of each performance confirmation test and after initial approval and revision of the *Performance Confirmation Plan*. The identified start of each performance confirmation test will define the need for completion of the detailed planning.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- Provide facilities or offices of the performing and contributing organizations.

F. INPUT:

- *Performance Confirmation Plan* scope sheets.

G. OUTPUT:

- Procedures delineating the detailed test planning.

H. REPORTS:

- Reports to inform management of the status of test planning and preparation.

ACTIVITY SCOPE SHEET

ID# and Title: 4.5.3 Performance Confirmation Data Management
Responsible Organization: Technical Data Management
Performing Organization: Technical Data Management
Supporting Organization: Site Evaluation Program Operations, Licensing, Systems Engineering/Integration, Repository Design, Waste Package Development, Waste Package Materials, Performance Assessment
Location: Onsite and offsite offices of performing and supporting organizations.

A. DESCRIPTION:

- The performance confirmation data management activity will provide sufficient information such that performance confirmation parameters which are measured, are retained and communicated to the appropriate analyst for comparison to expected values.

B. OBJECTIVES:

- To capture, communicate and retain specified parameters for inclusion in the Performance Confirmation Program data base.

C. CONSTRAINTS:

- The Performance Confirmation Program should develop, define, document, and control a Performance Confirmation Technical Baseline for the parameters identified in Appendix D consisting of reference site characterization data; process, abstraction and assessment models and computer codes; expected values and associated uncertainties; limits of statistically significant deviations.
- Measured accuracy and frequency requirements should be based on analyses considering expected values, associated uncertainties and limits of statistically significant deviations and deviation limits.
- Statistically significant deviations from the performance confirmation technical baseline should be reported as soon as possible and assessed within **TBD - Timing for assessing waste isolation implications of data deviations.**

D. SCHEDULE:

- The technical data required for performance confirmation should be defined before License Application for construction.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- The Performance Confirmation Program should document variations in site characterization parameters, values, or conditions defined in Appendix D, based on site characterization data. The variations should be tracked and reported as required to monitor the effects of excavation and waste emplacement during the repository operation and caretaker periods.
- Performance confirmation staff, measurement and monitoring hardware and software, shall be available to support the variable demand for analysis, assessment, and periodic reporting throughout the Performance Confirmation Program.

- The Repository Surface Facilities shall have the capability to support Performance Confirmation surface operations equipment and tests including, the facilities and equipment to support Performance Confirmation operations such as test monitoring and control, data processing, record management and communication, limited laboratory tests, analysis and evaluations.

F. **INPUT:**

- The parameters needed for performance confirmation and the instrumentation output as data.

G. **OUTPUT:**

- Data providing results of parameter measurements.

H. **REPORTS:**

- Compiled data in recoverable format.

ACTIVITY SCOPE SHEET

ID# and Title: 4.5.4 Performance Confirmation Sample Management
Responsible Organization: Site Evaluation Program Operations
Performing Organization: Site Construction and Operations
Supporting Organization: Site Evaluation Program Operations, Waste Package Materials
Location: Onsite offices of performing and supporting organizations.

A. DESCRIPTION:

- The performance confirmation sample management activity will provide control over all samples related to performance confirmation.

B. OBJECTIVES:

- Positive control will be maintained from sample collection to transmittal of test data.

C. CONSTRAINTS:

- Test locations/environments, samples, and specimens, onsite and offsite, shall be representative of the repository environments and design elements.

D. SCHEDULE:

- Performance confirmation sample management activities will be ready before samples are to be obtained in support of performance confirmation testing.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- The capability to receive, manage, temporarily store, and ship Rock samples for offsite testing.

F. INPUT:

- Sample identification and control information with appropriate tracking.

G. OUTPUT:

- Sample to appropriate test organization.

H. REPORTS:

- As required to keep track of all samples and inform the appropriate personnel of the sample status.

ACTIVITY SCOPE SHEET

ID# and Title: 4.5.5 Performance Confirmation Information Management
Responsible Organization: Support Operations/Information Management
Performing Organization: Support Operations/Information Management
Supporting Organization: Site Evaluation Program Operations, Licensing, Systems Engineering/Integration, Repository Design, Waste Package Development, Waste Package Materials, Performance Assessment
Location: Offsite offices of performing and supporting organizations.

A. DESCRIPTION:

- Performance confirmation information management should provide sufficient control that baseline information concerning confirmation parameters, changes in the baseline information are retained.

B. OBJECTIVES:

- Perform management of information develop in support of the Performance Confirmation Program. Retain in the flexibility to respond to changes, testing, or needed corrective action throughout the life of the Performance Conformation Program.

C. CONSTRAINTS:

- Initial data on natural events, such as seismic events, and operational accidents involving structures, systems, and components that are important to waste isolation should be reported as soon as possible and their impact assessed within **(TBD) Timing for assessing waste isolation implications of natural events and operational accidents.**

D. SCHEDULE:

- Information management activities will be ready before samples are to be obtained in support of performance confirmation testing.

E. TEST HARDWARE/SOFTWARE FACILITIES:

- The Performance Confirmation Program should define expected values, distributions and uncertainties, and statistical significance levels for each parameter identified in Appendix D and assess all statistically significant deviations from expected values.
- The capability to transfer, automatically acquire, record, process, and communicate instrumentation data from surface and subsurface monitoring equipment and tests.

F. INPUT:

- Information for the site characterization and MGDS design; as-built MGDS configuration; performance confirmation baseline content description; results of performance confirmation site monitoring and testing

G. OUTPUT:

- Information on predicted Performance Confirmation parameter values showing locations and times of Performance Confirmation testing and measurements of the parameters. including predicted results of laboratory experiments.

H. REPORTS:

- Reports as required to ensure the information management is performing as expected and managers are receiving needed information.