SELECTION OF SITE-CHARACTERIZATION TESTS IN THE EXPLORATORY-SHAFT FACILITY AT THREE CANDIDATE REPOSITORY SITES

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ABSTRACT

Various in-situ tests will be conducted in the exploratory-shaft facilities at each of the candidate repository sites. This paper compares preliminary test plans for the Nevada, Washington, and Texas sites, identifying differences and similarities among them. The final test plans will reflect an approach recently adopted by the Department of Energy (DOE) to address each of the siting and licensing requirements in Federal regulations for geologic repositories. This approach is discussed, and the rationale for determining parameter needs and linking those needs to the test plans is presented. An example of how this rationale is used to identify specific tests is provided.

INTRODUCTION

The Nuclear Waste Policy Act of 1982 and 10 CFR Part 60 require that, as part of the process of selecting and developing the first geologic repository, the DOE conduct a program of site characterization. A site-characterization plan (SCP) is being developed for each of the three candidate sites for the first geologic repository: the Deaf Smith County site in salt in the State of Texas, the Hanford site in basalt in the State of Washington, and the Yucca Mountain site in tuff in the State of Nevada. Site characterization involves research in both the laboratory and the field to establish the geologic conditions and ranges of parameters at a candidate site. The site-characterization program should meet two basic objectives: (1) to characterize the host rock and to measure, in situ, its properties before construction and waste emplacement; and (2) to provide a basis for predicting how the host rock and engineered components will respond to construction and waste emplacement.

The in situ tests will include a number of tests performed in an exploratory-shaft facility (ESF) during site characterization. The ESF will consist of (1) two exploratory shafts, (2) underground testing areas, and (3) surface facilities needed to support construction and testing. Preliminary test plans for testing from the exploratory shafts and the underground facility have been prepared for each of the sites. The test plans established a basis for designing the shafts and the underground facility, developing schedules for construction activities and testing, and estimating costs for budget requirements. The identification of specific tests to be included in these preliminary test plans was based largely on judgment as to what tests would be necessary and sufficient. A more specific rationale, relating the tests to regulatory requirements and related information needs, was needed.

To provide a comprehensive and systematic rationale for planning the tests and meeting the site-characterization objectives, the DOE established a general approach for identifying the parameters that must be studied. The approach, referred to as the issue-resolution strategy, provides the basis for developing the test and analytical programs that will support site selection and submittal of the license application. The issue-resolution strategy is being used to produce the detailed plans for (ESF) testing and may result in a testing program that is different from the preliminary test plans discussed in this paper.

This paper discusses the in-situ tests that comprise the preliminary test plan for the ESF at each of the three candidate sites for the first repository. Surface-based field tests and laboratory tests are not addressed. Similarities and differences between the test plans at the three sites are discussed. Next, the issue-resolution strategy is described to demonstrate how this process identifies the parameters that must be evaluated during site characterization. Finally, an example of the issue-resolution strategy is presented, starting with a regulatory requirement and ending with the identification of specific tests that will be performed to evaluate specific parameters needed to resolve the issue and demonstrate compliance with the regulations.

PRELIMINARY IN-SITU TEST PLANS

Preliminary in-situ test plans for the ESF have been developed for each of the sites and include geologic-geophysical, hydrologic, geomechanical, geochemical, and thermal tests. The preparation of the test plans began several years ago to provide a basis for designing the exploratory shafts and the underground facility. The layout of the underground facility, the construction and testing schedule, and manpower and cost estimates were based on these early test plans.

As mentioned above and explained further below, the final test plans will reflect the issue-resolution strategies that will provide the rationale for ESF testing. The preliminary test plans are presented to indicate the kinds of testing that are being considered at the candidate sites. Undoubtedly, many of the tests from the preliminary plans will be retained in the final plans.

Comparison of Test Plans

The preliminary in-situ ESF testing programs for the Deaf Smith County, Hanford, and Yucca Mountain sites are listed in the appendix. An "x" in a column adjacent to a test indicates that the test is planned for that site. The tests have been grouped into three general categories: (1) basic geologic characterization tests; (2) hydrologic tests; and (3) tests to examine near-field and thermally induced effects.

The ESF at each of the sites will consist of two shafts and a series of underground drifts. The shafts have design requirements to provide ventilation and access to the underground test facility but will also be used to access the rock mass above the candidate horizon for characterization. The extent of the drifting at each of the sites may vary from 500 to 3000 m, depending on the expected variability of geologic conditions and the scale of the access considered necessary to characterize the features encountered. For example, long horizontal boreholes may be sufficient to estimate the frequency of vertical discontinuities some distance away from the underground test facility, but drifts may be required to identify the characteristics of a fault zone.

The tests listed in the appendix comprise a fairly comprehensive set of testing methods that have been developed to characterize a host rock. Of the 44 tests listed in the appendix, more than half (27) are common to all three sites. Of the 17 remaining tests, most (10) are common to two of the three sites, and only a few (7) of the tests are planned at only one site.

Most of the differences in the geologic characterization test plans reflect variations in *the* test method for estimating a parameter, not in the need for the parameter. For example, each of the sites will be conducting tests to estimate the in situ stresses, excavation-induced stresses, and the deformation modulus of the rock mass. The test methods chosen were judged to be the most likely to provide the required information given the geologic conditions expected at each site.

One of the exceptions to this is shaft mapping at the Hanford site, because it is precluded by the shaft construction method. The current design for the shafts at the Hanford site is that they will be blind-bored with a large rotary drill. The shaft liner will be lowered into the shaft opening filled with drilling fluid. After the liner has been lowered into the shaft opening, the annular region between the liner and the shaft wall will be injected with grout, displacing the drilling fluid. At no time during the construction will access to the shaft wall be possible. However, some shaft-mapping information --such as fracture frequency, geometry, and infilling-- will be obtained from lateral exploratory coreholes drilled through portholes in the casing of the shaft.

Some variances in the test plans are the result of differences in the location of a test or in the timing of the test. Currently, the room-backfill test at the Hanford site is planned in the Near-Surface Test Facility in Gable Mountain rather than the ESF. At the Yucca Mountain site, the need for backfilling the underground openings in the repository is being evaluated. If these evaluations show that backfill is needed and a need for such tests is determined, the tests will be performed after site characterization, during the construction of the repository.

Differences in the planned hydrologic tests are the result of site-specific conditions. The possibility of encountering perched water and brine conditions is specific to the Yucca Mountain and Deaf Smith sites, respectively. The hydrologic test program for Yucca Mountain does not include the seals tests because of the fractured and unsaturated conditions of the host rock and its position above the water table. The current design concept is that it is advantageous to have shafts and drifts that are pervious. These areas would act as sinks for ground water, minimizing the amount of water that would reach the waste emplaced in the repository.

Variations in the tests used to estimate the effect of the thermal perturbation from waste emplacement are due largely to differences in data needs test scale and testing approach. At the Hanford and the Yucca Mountain sites, the need for a large-scale test will be evaluated from the results of small-scale tests. If large-scale tests are determined to be necessary, the tests will be conducted after site characterization.

THE ISSUES HIERARCHY AND THE ISSUE-RESOLUTION STRATEGY

The DOE's plans for the site-characterization program at each site will be presented in Chapter 8 of the SCP. The SCP is being developed on the basis of two organizing principles: the issues hierarchy and the issue-resolution strategy. The issues hierarchy, described in a recent DOE report (Issues Hierarchy for a Mined Geologic Disposal System, DOE/RW-0101, September 1986), states the questions that must be answered about the performance of the disposal system and identifies the information that must be known before a site can be selected and licensed . The issue-resolution strategy is the general procedure or rationale for determining how the issues of the issues hierarchy are to be resolved.

Issues Hierarchy

The issues hierarchy is a three-tiered framework consisting of key issues, issues, and information needs. Collectively, the issues hierarchy embodies the principal regulations governing geologic disposal. The level of detail addressed by the issues hierarchy increases from the key issues to the issues and finally the information needs. The key issues and the issues are common to all candidate sites. The information needs, though generally similar for all sites, are based on the characteristics of the site and the host rock as well as the data collected to date.

The issues hierarchy defines the performance-related issues that must be resolved to demonstrate compliance with the key regulatory requirements. It does not address other requirements that the disposal system must satisfy, such as functional and operating requirements as well as design specifications. These system requirements are linked to the issues hierarchy by the issue-resolution strategy.

Issue Resolution

To resolve the issues in the issues hierarchy, the DOE has adopted a general "issue-resolution strategy" that guides the development of specific plans for resolving each issue. This general strategy is a procedure consisting of as many as 12 steps as shown in Fig. 1.

The first section of the strategy, labeled "issue identification", includes the development of the issues hierarchy itself. The second section, called "performance allocation," consists of the steps that provide the rationale for the establishment of site-specific site-characterization activities. Applied separately to each issue in the hierarchy, this section produces the principal guidance for planning the activities needed to resolve the issue.

The first step in performance allocation, setting the licensing strategy, is a statement of the disposal-system components on which the DOE currently intends to rely in resolving an issue. The licensing strategy may also identify specific features or characteristics of the components that the DOE expects will contribute to the performance and hence to the resolution of the issue. The next step, the identification of the performance measures and goals, establishes the physical quantities that describe the performance of the component in meeting the licensing strategy. The "goal" of a performance measure can be considered a guide for the development of the testing program and establishing the basis for the information that must be provided by the testing program.

After identification of the performance measures, the "information needs" are identified. The information needs specify the categories or types of information needs

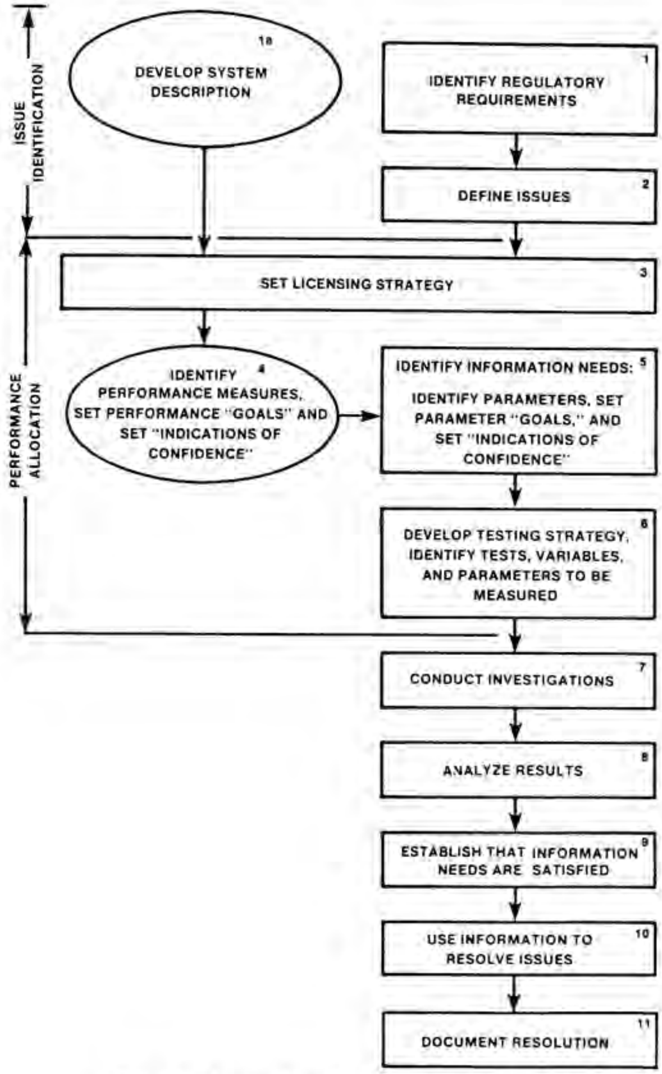

Fig. 1. Issue Resolution Strategy.

necessary to resolve an issue. A part of this step is the specification of parameters that are required to evaluate the performance measures. Because many of the performance measures cannot be measured directly (e.g., the time of ground-water travel through a geohydrologic unit), they must be expressed by an equation in which the quantities that can be measured more directly (e.g., hydraulic conductivity) appear as parameters. Therefore, the information-needs step defines the activities that will produce the list of parameters or performance measures needed. The activities can be either tests or analyses.

AN EXAMPLE OF ISSUE RESOLUTION

To illustrate how the issue-resolution strategy and performance allocation relate to, and provide the rationale for, specific site-characterization tests, a simplified example is presented. The example begins with a performance issue and ends with the identification of a site parameter and related test. The level of detail for issue resolution employed in the SCPs will be much greater than what is presented here. For the sake of brevity, the issue-resolution strategy in the example identifies only a subset of the performance measures and parameters that may be required.

Issue 1.4 of the issues hierarchy will be used to illustrate the issue-resolution strategy. Issue 1.4 is a performance issue that addresses the performance objective from 10 CFR Part 60 concerning containment by the waste package. Compliance with the performance objective (and therefore the resolution of the issue) requires a demonstration that the waste package will provide substantially complete containment for a period of 300 to 1000 years after emplacement.

For this example, it is assumed that the strategy for resolving this issue includes reliance on the emplacement borehole to remain unsupported and structurally stable for a period of 1000 years. This step is part of step 3 in Figure 1 (set licensing strategy). The performance measure for this strategy might be the "factor of safety" for failure of the rock around the emplacement borehole with a goal of a factor of safety greater than 2.0 (step 4).

In order to provide an estimate of the factor of safety, several pieces of information must be obtained. Some of the information is related to the design of the repository and the emplacement boreholes (e.g., size, orientation, spacing, length, construction method). Other information relates to specific characteristics of the site, such as the in-situ stress state, rock-mass strength, deformability, and thermal properties. The identification of these parameters is step 5.

For this example, only one of the site parameters identified above, the in-situ stress state, is developed further. Obviously, all the information needs would have to be evaluated during site characterization. Similarly, the licensing strategy in step 3 would identify other performance measures that would have to be developed.

Step 5 also requires that parameter goals be identified with related indications of confidence. The parameter goal should be set in consideration of the range of values indicated by existing data, should be conservative, and should be reasonably achievable (i.e., it should be likely that the goal will be met). In this example, it is assumed that measurements of in-situ stress have not been made at the site and that likely values for the site must be estimated. The parameter goal is based on the hypothesis that the in-situ stress state is a result of lithostatic stresses only and that no tectonic stresses are present. This hypothesis is based on structural geologic and seismic data that indicate minimal tectonic activity in the area. Therefore, the parameter goal for in-situ stresses can be calculated from the design depth of the repository and the range of rock densities in the overlying rock. The parameter goal is based on the mean values of the densities and thicknesses of the overlying rock units plus the mean Poisson's ratio and an assumed elastic behavior of the rock mass.

The last step that will be discussed here, step 6, is the development of the test program for obtaining in-situ stress data. Several test methods are available for estimating the in-situ stress state (e.g., hydraulic fracturing, overcoring, Keisser effect, etc.), and the program may consist of more than one method for estimating the parameter, depending on the sensitivity of the performance measure to the parameter. The factor of safety is very sensitive to the in-situ stress state, and therefore several different methods for estimating in-situ stress may be justified. The design of the testing program should consider the parameter goal, as well as the hypothesis being tested (i.e., lithostatic stress state) in order to provide the appropriate data for the test statistic being used.

The above example could be developed further, identifying the number and locations of the test, procedures for testing and data reduction, etc. However, the intent is to demonstrate how the issue-resolution strategy is used to develop the testing programs, providing the link between the individual tests and the issues (from the issues hierarchy) they support. It is likely that several of the issues may require similar information needs. In this case, the performance measure requiring the greatest level of confidence will govern the scope of the testing program. Such a comparison will prevent duplication of effort while at the same time providing all the needed information.

SUMMARY

Preliminary in-situ test plans have been developed for the exploratory-shaft facilities at each of the candidate repository sites. The tests plans provide a basis for designing the underground facility and estimating related costs and schedules. Most of the tests in the preliminary in-situ test plans are common for the three candidate sites. Differences in the test plans reflect variations in the test methods chosen for estimating a parameter or conditions that are specific for a site.

The DOE has adopted an issues hierarchy approach for developing the ESF test program. The issues hierarchy and an issue-resolution strategy are being used to establish the parameters that need to be estimated during site characterization in order to demonstrate site compliance with Federal regulations. This approach provides a easily identifiable link between the individual tests that will be performed with the issues (regulations) they support. While many of the tests from the preliminary in-situ test plans will be the same as those identified by the issues-resolution strategy, the plans may be revised as a result of this approach.

APPENDIX

Comparison of the In Situ Tests in the

Exploratory Shaft Facilities

BASIC GEOLOGIC CHARACTERIZATION TESTS	Yucca Mountain	Hanford	Deaf Smith
Drift-mass mapping and photography	(x)	(x)	(x)
Lateral coring from drifts	(x)	(x)	(x)
Borehole condition/convergence monitoring	(x)	(x)	(x)
Demonstration breakout room test	(x)	(x)	(x)
Sequential drift-mining test	(x)	(x)	(x)
Crosshole seismic	(x)	(x)	(x)
Seismic surveys	(x)	(x)	(x)
Electrical survey	(x)	(x)	(x)
Seismic monitoring	(x)	(x)	(x)
Caliper log	(x)	(x)	(x)
Gamma-gamma density log	(x)	(x)	(x)
Sonic log	(x)	(x)	(x)
Neutron-epithermal neutron log	(x)	(x)	(x)
Fluid temperature log	(x)	(x)	(x)
Lateral exploratory coring from the exploratory shaft	(x)	(x)	(x)
Overcore stress tests	(x)	(x)	(x)
Hydraulic fracturing stress test	( )	(x)	(x)
Plate-loading test	(x)	(x)	( )
Borehole jacking test	( )	(x)	(x)
Slot-strength/flat jack tests	(x)	(x)	( )
Shaft convergence test	(x)	( )	(x)
Shaft-wall mapping, photography, and specimen sampling	(x)	( )	(x)
Vertical exploratory coring at shaft locations	( )	( )	(x)
Room backfill performance test	( )	( )	(x)

Underground gravity survey	( )	( )	(x)
Demonstration of boring technology (horizontal)	(x)	( )	( )
HYDROLOGIC TESTS			
Matrix properties test	(x)	(x)	(x)
Intact-fracture test	(x)	(x)	(x)
Inflitration test	(x)	(x)	(x)
Bulk-permeability test	(x)	(x)	(x)
Radial-borehole test	(x)	(x)	(x)
Excavation effect test	(x)	(x)	(x)
Hydrochemistry test	(x)	(x)	(x)
Tracer test	(x)	(x)	(x)
Borehole-seal test	( )	(x)	(x)
Hydraulic conductivity of shaft seal interval	( )	(x)	(x)
Room seal test	( )	(x)	(x)
Brine migration test	( )	( )	(x)
Perched-water test	(x)	( )	( )
NEAR FIELD AND THERMALLY PERTURBED			
Waste-package environment test	(x)	(x)	(x)
Canister-scale heater test	(x)	(x)	(x)
Small-scale heater test	(x)	(x)	(x)
Heated block test	(x)	(x)	( )
Room-scale heater test	( )	( )	(x)