SITE CHARACTERIZATION INFORMATION NEEDS

FOR A HIGH-LEVEL WASTE GEOLOGIC REPOSITORY

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ABSTRACT

At each of the three candidate sites recommended for site characterization for High-Level Waste Geologic Repository development, the DOE has proposed to conduct both surface-based testing and in situ exploration and testing at the depths that wastes would be emplaced. The basic information needs and consequently the planned surface-based and in situ testing program will be governed to a large extent by the amount of credit taken for individual components of the geologic repository in meeting the performance objectives and siting criteria. Therefore, identified information to be acquired from site characterization activities should be commensurate with DOE's assigned performance goals for the repository system components on a site-specific basis. Because of the uncertainties that are likely to be associated with initial assignment of performance goals, the information needs should be both reasonably and conservatively identified.

INTRODUCTION

The Nuclear Waste Policy Act of 1982 (1) requires the Department of Energy (DOE) to carry out appropriate site characterization programs at the three candidate sites approved by the President in May 1986 (2). The Act authorizes the DOE to conduct such site characterization activities that are considered necessary to provide the data required for evaluation of the site suitability for submitting an application for construction authorization and for compliance with the National Environmental Policy Act of 1969 (3). Also, the site characterization activities must be conducted in a manner that minimizes any significant adverse environmental impacts and any adverse safety-related impacts on the isolation capability of the host rock.

The site characterization program would consist of surface-based and in situ testing. The program would also include exploration and research, both in the laboratory and in the field. Major activities during site characterization would include borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing at depth.

The Nuclear Regulatory Commission (NRC) regulation 10 CFR 60 (4) requires that before proceeding to sink shafts at any site, the DOE shall submit to the NRC a site characterization plan (SCP) for the sites and solicit comments thereon. The SCP must cover a description of site characterization activities, including the following: (i) The extent of planned excavations; (ii) Plans for any onsite testing with radioactive material, including radioactive tracers, or nonradioactive material; (iii) Plans for any investigation activities that may affect the capability of such area to isolate high-level radioactive waste; (iv) Plans to control any adverse impacts from such site characterization activities that are important to safety or that are important to waste isolation; and (v) Plans to apply quality assurance to data collection, recording, and retention.

The main purpose of the site characterization activities would be to determine the suitability of the site for geologic repository development. The activities would also be intended to evaluate representative parameters associated with the design of the geologic repository operations area. The essential elements of the site characterization program would address the requirements and performance objectives of the NRC regulation 10 CFR 60.

The NRC interacts with the DOE on a continuous basis to provide timely guidance on the resolution of licensing issues concerning the disposal of high-level nuclear waste in the deep geologic repositories (5). Generic and site-specific technical positions are prepared on a number of topics to provide guidance to the DOE as a part of early and ongoing prelicensing consultations. For example, the NRC staff Generic Technical Position on 'In Situ Testing During Site Characterization for High-Level Nuclear Waste Repositories' provides guidance to the DOE on in situ testing during site characterization (6). The NRC staff's Generic Technical Position on 'Design Information Needs in the Site Characterization Plan' provides guidance on the type and the level of detail of design information that should be included in the SCP (7). These and other NRC Technical Positions stress that the site characterization testing program should address the requirements and performance objectives of the NRC regulation (10 CFR 60). For example, it is emphasized that the rationale for the DOE's planned testing program should be based on the need for evaluating the geologic repository performance objectives (10 CFR 60.111-113).

INFORMATION NEEDS

The NRC Regulation outlines the required contents of the DOE's site characterization plan. As a minimum, the plan shall include (a) a general plan for site characterization activities; (b) a description of the high-level waste to be emplaced; and (c) a conceptual design for the geologic repository operations area.

The information needs and consequently the planned surface-based and in situ testing program will be governed to a large extent by the licensing issues that need to be resolved and the amount of credit taken for individual components of the multiple-barriers of the geologic repository in meeting the performance objectives, siting criteria and design criteria. The site-specific information needs are likely to depend upon (i) local geologic, hydrologic and geochemical conditions, (ii) selected repository design, (iii) analytical methods and models selected for use, (iv) the key issues found relevant to performance of the selected repository design and (v) other compliance to siting critiera and design criteria to be reviewed by the NRC that are not performance objectives (e.g., 10 CFR 60.122).

Although the details of information needs must be determined on a site-specific basis, a major portion of the rationale to derive the information needs would be common to all sites (8). Basically the information needed from site characterization should be related to addressing the EPA standards (40 CFR 191) and the performance, siting and design issues identified in 10 CFR 60.

The EPA standards specify certain limits on radiation exposures and releases of radiactive material during two principal phases, viz., (i) the period of management and storage operation at a repository, and (ii) the long-term period after waste disposal has been completed (9). The limits on exposures and releases applicable to the period after disposal include containment requirements, individual protection requirements, and groundwater protection requirements. Information is needed to address the requirements of 40 CFR 191, regarding special sources of groundwater individual radiation protection and cumulative radionuclide releases at the accessible environment. The NRC Regulation 10 CFR 60.112 for the overall system performance objective incorporates requirements for applicable environmental standards for radioactivity established by EPA.

To identify information needs for each performance, siting and design criterion, the corresponding issues must be identified for various technical and system criteria of 10 CFR 60 and corresponding information needs should then be developed. For example, to demonstrate a specific waste package lifetime the geochemical conditions impinging on the canisters must be understood sufficiently well to allow for the uncertainty surrounding the chemical component of the failure model used.

The site characterization information needs include data to evaluate the siting criteria of 10 CFR 60.122. This information should include data to assess whether favorable conditions of 10 CFR 60.122(b) or potentially adverse conditions of 10 CFR 60.122(c) are present that affect the isolation capability of the geologic repository. In case any one of the potentially adverse conditions is found to be present, information must be obtained to demonstrate that the potentially adverse condition has been adequately investigated, and that it does not compromise meeting the performance objectives.

Having established an acceptable conceptual design for the surface and subsurface structures, systems and components of the Geologic Repository, the following steps would enable an identification of design information needs: (i) identify structures, systems and components whose design could require site characterization, and (ii) establish the site-specific parameters needed for the design and analyses of each of these features.

In addition to considering the general design criteria related to radiological protection, the information needs should include consideration of flexibility of design, retrieval of waste, engineered barrier design and the effect of thermal loads on the design. Design of seals for shafts, ramps and boreholes should also be considered in developing the list of information needs.

TESTING NEEDS

A geologic repository is a multiple-barrier system. The amount of testing required for individual components of the barrier system will depend in part on the amount of credit taken for individual components in meeting the performance requirements. This implies that in developing its plans for testing during the site characterization and engineered component design phases, DOE will identify performance goals for repository system components on a design and site-specific basis. Both the tentative level of performance needed from a component and the desired level of confidence should be identified.

Identification of performance goals and confidence levels is a prerequisite to establishing what is a necessary and sufficient level of testing. Thus, tentative goals are needed at the time that the Site Characterization Plans are issued. Because of the large uncertainties that would be associated with DOE's understanding of a candidate site at that time, these tentative performance goals should be reasonably and conservatively chosen. As site characterization proceeds and a more complete understanding of the site is developed, the initial choice of performance goals may have to be revised and commensurate changes in scope and level-of-detail made to site characterization activities. By early identification of the desired confidence level, an indication of acceptable uncertainty can be incorporated into test planning directly so that a rationale for proposed tests would have a documented basis.

The information needs related to rock characteristics and performance would have to be addressed by the DOE through the development and implementation of a surface-based and in situ test plan because, in the absence of in situ test results, confidence in the predictions based only on surface-based (such as borehole tests) and laboratory testing may be limited. The following unique features make in situ tests an essential element of site characterization and the rational design of the geologic repository operations area.

(i) Numerous laboratory and in situ tests have shown that many of the measured rock properties (for example, compressive strength and permeability) are influenced by the size of the rock specimen tested. In highly jointed rocks, this dependence on size could be more pronounced.

(ii) The natural conditions of the rock mass cannot be exactly duplicated in the laboratory. Examples are (a) geologic discontinuities such as joints and shear planes, (b) hydrologic conditions such as hydraulic head and pore pressure, (c) loading conditions such as the in situ stress field, and (d) redox conditons. The in situ tests more closely encompass the natural rock conditions when the rock is tested in its natural state.

(iii) Many coupled/interactive processes (for example, hydrothermal, thermomechanical, hydromechanical, and thermochemical) are likely to occur in the host rock in which the nuclear waste will be disposed. In situ tests offer greater promise for predicting the effects of coupled/interactive processes on rock in a near natural state than most small-scale laboratory tests.

(iv) Variability in geology (for example, joint patterns and spacing), hydrology, and geochemistry can only be directly assessed through in situ testing. Estimation of variability in different parts of the geologic repository are necessary for satisfactory design of underground facility and seals.

In spite of being the most effective and direct approach to the characterization of the site, any in situ testing program will be, of necessity, limited by practical considerations. For example, the extent of underground excavation for in situ testing purposes may be limited in comparison to the total volume of rock being characterized. Also, the duration of tests may also be limited by practical considerations because the in situ tests can only be conducted for a limited duration compared with the long time-span (10,000 years) during which the geologic repository must function to isolate the waste.

To predict the long-term behavior of the geologic repository, analytical, experimental, and numerical models must be used to make predictions far into the future. Predictive models have their own limitations on applicability and are sensitive to the quality of data used as input. Uncertainties in the prediction process can be reduced by (i) conducting appropriate in situ tests on a representative volume of rock and (ii) using appropriate parametric studies to account for possible inherent spatial variations of physical, hydraulic, and chemical properties within the rock formation.

Although in situ testing is necessary, it is not sufficient by itself and requires integration with all other testing (e.g., surface based and laboratory testing). Types of in situ tests include: geological, geophysical, hydrological, geomechanical, geochemical, and thermal tests. Some of these tests are to be performed from the exploratory shaft(s) and underground openings on surrounding rock and on other materials and components such as the waste package, engineered backfill, linings, and seals. The conditions under which these in situ tests are to be run should represent, as closely as possible, the realistic repository environment (for example, cover a range of temperatures and stresses). The tests performed under such conditions would provide data to assess the suitability of a particular site and a particular geologic medium to host high-level nuclear waste in addition to providing realistic input parameters for the design of a geologic repository.

The information obtained from the in situ testing is likely to be used for site selection as well as for substantiating the site data to be provided in the construction authorization application. Because of the long lead-time of some tests, the schedule of testing will be crucial to the licensing activity. When a construction authorization application is submitted for a particular site, that application must be complete and fully supported by the data and analyses necessary for NRC to make a decision on construction authorization findings (10 CFR Part 60.31). DOE should identify in the SCP which tests will be completed at the time of construction authorization application, and which tests and long-term performance confirmation activities will continue after that.

UNCERTAINTIES

Decisions related to establishing the amount and variety of testing needed should be made on a site- and design-specific basis. This can vary significantly depending on the objective, nature, and scope of the tests and the degree of certainty sought. Several different tests can be used to obtain the same rock parameters. For example, the plate test, pillar test, and block test can each provide sufficient information to estimate the material modulus. Some of these tests or types of tests can be repeated a number of times depending on the required level of confidence. The same test may be repeated at a number of different locations to assess the inherent variability of the measured parameter. Also, it may be desirable to conduct tests under a range of conditions to represent the extremes of the anticipated processes and events. For example, a range of temperatures and confining pressures can be applied to cover the anticipated repository conditions.

Because of the complexities of designing and constructing an underground repository, testing will likely have to be performed at different scales. Laboratory testing on small specimens will provide useful information for preliminary designs and analyses. However, in many cases, large-scale testing (also called full-scale testing) will be required to yield a realistic and convincing data base. The need for large-scale testing will have to be established on a site- and design-specific basis. The SCP should address the scale of testing and its implications for site characterization. Moreover, the underground openings should be of sufficient extent so that the variability in the host rock and adjacent strata can be properly assessed.

When the processes being observed are complex, or time effects are important (or predominant), it is extremely important that tests be of sufficiently long duration so that meaningful and representative data can be obtained. There is particular uncertainty in the testing required to analyze coupled/interactive thermal effects of waste emplacement on the host rock and groundwater. Because of the significant effects on schedules, such long-duration tests need careful planning. Any uncertainty associated with the extrapolation of data in time and space should be identified. Testing should be directed at reducing uncertainties in the performance of key components of the multiple-barrier system.

CONCLUDING REMARKS

The paper has identified a process to develop key design and testing information needs for the surface and subsurface structures, systems and components of the Geologic Repository. It is emphasized that although the details of information needs must be determined on a site-specific basis, a large portion of the rationale would be identical for all sites. The basic approach would involve identifying the amount of credit to be taken for individual components of the multiple-barrier system. Potentially large uncertainties in implementing the process should be anticipated and dealt with.

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