PERFORMANCE-ASSESSMENT SUPPORT FOR THE DESIGN OF THE YUCCA MOUNTAIN EXPLORATORY-SHAFT FACILITY*

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ABSTRACT

The Yucca Mountain Project, part of the waste-management program of the U.S. Department of Energy, is using performance assessment in support of the design of an exploratory-shaft facility (ESF). A summary of this support offers (1) a view of performance assessment in actual practice and (2) a preview of the methods that may be useful in future support for the development of a complete repository.

The support for the ESF design began with a thorough review of the requirements that the properly designed facility must meet. This review produced a list of eleven performance-assessment analyses needed for supporting the design. These analyses will support the design by providing specific numerical constraints on the design and by evaluating proposed designs to determine whether they comply with the requirements. The analyses are exercising not only the computational capabilities of the performance-assessment effort but also many of the complex interfaces and procedures required for developing a repository. The insights gained from this effort will be valuable in future support of a full repository.

INTRODUCTION

Assessing the performance of a repository for the disposal of highly radioactive waste is an important part of the complex process of obtaining a license for such a repository. Formal definitions of performance assessment usually suggest that it will contribute to two broad activities: the evaluation of compliance with regulations and support for the development of the repository system. The first of these two purposes has received much attention through the development of strategies and technical methods for evaluating compliance. The second purpose, however, has not been developed so fully; although the tools it will use are similar to those developed for the first purpose, few reports have described their use in support of design. This paper reports a specific use of performance assessment in its design-support role.

The Yucca Mountain Project, an activity of the U.S. Department of Energy (DOE), is examining a site in Nevada to assess its suitability for a repository. The project is developing a detailed design for an exploratory-shaft facility (ESF), in which underground site features can be directly observed and extensive in situ testing can be performed (1). The project is using its performance-assessment capabilities to support the development of the ESF. Because the process of designing the ESF is in many respects similar to the process that will eventually produce a design for a repository, this support effort is useful not only for its contribution to the ESF design but also for the insights it can offer into future support for repository design.

THE BASIS FOR DESIGN SUPPORT: THE ESF REQUIREMENTS

The requirements placed on the design, construction, and operation of the ESF are numerous. The requirements stem not only from ordinary construction constraints but also from the need to avoid altering the waste-isolation characteristics of the formations in which observations and testing will take place. Moreover, the DOE, according to the current plans, would use the ESF eventually as part of the repository (if the site proves suitable), even though waste will not be emplaced in the part of the repository that was originally the ESF. The shafts leading to the ESF, for example, would be used in the repository for ventilation. For this reason, the ESF must meet a number of requirements that are not derived directly from its role as a place for observation and testing. These additional requirements are derived from the regulations that a repository must meet (e.g., 10 CFR 60 and 40 CFR 191).

The development of the ESF, like the development of a repository, must begin from a compilation of all the requirements. The Yucca Mountain Project has compiled an extensive set of requirements drawn from construction and safety rules, the need to provide a valid test facility, and the regulations governing a repository (2). As examples of the hundreds of requirements in the compilation, the following two are useful in this paper's description of performance-assessment support:

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"The amount of water used in the construction and operation of the shaft shall be limited to preclude interference with tests."

"ESF items and activities shall not affect overall site integrity ..."

Both of these requirements (in addition to many others) must be met by the methods used in constructing a shaft for the ESF. Such broadly phrased requirements are, however, difficult for a designer to implement without further specification. Such requirements can be made more quantitative by analyses that use performance-assessment methods. The Yucca Mountain Project is finding two types of performance analyses useful in this contribution.

The first of these types is a calculation that helps to translate a qualitatively worded requirement into quantitatively expressed limits that the ESF must be designed to meet. An example of such a calculation, directed at the first of the two example requirements quoted above, is an estimate of the distance water used in the construction of a shaft will move. If this calculation is performed as a function of the amount of water used, its results will provide to a designer an estimate of the amount of water that the construction may use without violating the requirement for avoiding interfering with tests.

The second type of analysis is a calculation that evaluates a proposed design to determine quantitatively the ability of the design to meet a requirement. An example of such a calculation is an estimate, based on a proposed design, of the effect of water used in shaft construction on the ability of the site to retain radioactive material. This estimate could show whether the proposed design will achieve compliance with the second requirement quoted above. An actual calculation of this kind might well be similar to the calculation of water movement suggested above: if the water proposed for use in shaft construction can be shown to move only a short distance into the rock around the shaft, the water may not compromise the overall integrity of the site for isolating waste.

The basis, then, for the use of performance assessment in support of the ESF design is the set of design requirements. Carefully defined performance analyses can be useful in refining these requirements and in evaluating the ability of a design to meet them.

THE IDENTIFICATION OF ANALYSES

To decide what analyses would be useful, the performance-assessment support for the ESF began with a thorough review of the compiled requirements to be placed on the design. The review identified requirements that should be made more quantitative before a detailed design is begun, and it identified requirements that should be checked after a design is proposed.

After this review, it was possible to describe analyses that could contribute to these two needs. Because many of the identified requirements address similar physical phenomena, it was possible to define calculations that could be used in addressing more than one requirement. For example, twelve separate requirements affect the amount of water that may be used during the construction of a shaft. One set of calculations dealing with the water to be used in shaft construction was therefore defined in such a way that its results would be useful in dealing with all twelve requirements. The set includes both types of performance analyses: calculations that quantify requirements and calculations that evaluate the compliance of proposed designs.

This process identified and defined eleven sets of analyses:

1. The movement of water used in constructing roads and surface pads. Computer calculations will predict changes in saturation resulting from the movement of such water and will examine the effects on experiments and on system performance.
2. The movement of water used in constructing shafts. Calculations of saturation changes will be used to determine the potential for this water to affect experiments and system performance.
3. The movement of water from ESF sewage systems and settling ponds. Calculations similar to those in sets 1 and 2 will determine the potential for this water to affect experiments and repository performance.
4. The entry of flood water into shafts through fractures in the rock surrounding the shaft collar and liner. These calculations will determine whether the amount of such water is greater than the drainage and storage capacity of the shafts.
5. The effects of blasting in building the shaft and the main surface pads. Calculations of the extent of fracturing will estimate the blast damage and will suggest design modifications to reduce blast effects.
6. The creep of rock around the shaft and its collar. Calculations will determine whether significant creep is likely to occur and whether proposed designs impose adequate limits on the loads exerted on the shaft and collar.
7. Thermal stress on the shaft and its collar resulting from the eventual emplacement of waste in the repository. These calculations will use the temperatures predicted by set 8 to determine the effect of heating on the shaft and its collar.
8. Far-field thermal effects resulting from the eventual emplacement of waste in the repository. These calculations will predict temperatures over 10,000 years in the repository, including temperatures at the ESF.

9. Technical review of three formal lists prepared for the ESF: items important to safety, items important to waste isolation, and quality activities.
10. The hydrologic and geochemical effects of tracers used in construction water. These calculations will evaluate the potential for tracer compounds to affect experiments and repository performance.
11. The hydrologic and geochemical effects of chemicals deposited at the ESF during surface and underground construction. These calculations will determine the effects of chemicals and microbial activity on fluid movement and radionuclide transport.

Each of these analyses is to be performed in several phases: literature search, scoping activities to define the calculations in detail, performance of calculations, derivation of quantitative design requirements from the calculations, and evaluation of proposed designs and construction methods.

Defining these analyses and making preparations for performing them have required further efforts that should be described briefly. Although these efforts may, in a narrow sense, be considered routine, they have in themselves been beneficial to the Yucca Mountain Project, for reasons to be explained shortly. The entire support effort has had to be planned in detail and coordinated among numerous project participants who work in different disciplines and organizations: for example, performance-assessment analysts, architect-engineer groups, site-characterization experts, and quality-assurance engineers. Interactions with DOE advisory groups, such as the Nuclear Waste Technical Review Board, and with staff from the U.S. Nuclear Regulatory Commission (NRC) are taking place. To ensure that the analyses uniformly use the best available values for site characteristics, reference data describing those characteristics have been identified and approved. Necessary quality-assurance procedures have been identified, and the participants in the effort have been trained in them.

After these prefatory, but indispensable, efforts, the analyses could begin. Because the priorities within the Yucca Mountain Project have changed since the performance-assessment support effort was begun, the analyses have been delayed and have not yet produced results that can be reported at this conference.

USEFUL EXPERIENCE GAINED FROM THE SUPPORT EFFORT

In the absence of specific results to report, I can list several benefits to be expected from doing the analyses. These benefits stem partly from the experience already gained in the prefatory efforts described above; they also stem from the experience that the Yucca Mountain Project will gain as the analyses are actually carried out.

The most obvious benefit is, of course, the quantitative contribution to the ESF design. Other benefits, however, will ultimately be of great value to the repository program. These benefits arise because carrying out the analyses requires the development and, in fact, the actual exercise of such things as the following:

1. Practical methods for integrating the work of the large, multidisciplinary repository-development staff.
2. Practical mechanisms for producing genuinely technical interactions between the NRC and DOE staffs.
3. Practical methods for defining and approving reference data.
4. Practical procedures for implementing a fully qualified quality-assurance program.

The insights gained from these developments and exercises should help to make future steps in licensing more efficient.

Furthermore, developing this support effort has furnished a framework that future support work may be built upon: definitions of performance analyses derived specifically from requirements. The effort therefore serves as a preview of the ways in which performance assessment may be expected to contribute in the future to the second of its fundamental roles--support for the development of a repository.

REFERENCE

1. U.S. DEPARTMENT OF ENERGY, "Site Characterization Plan Overview, Yucca Mountain Site, Nevada Research and Development Area, Nevada," DOE/RW-0198, Office of Civilian Radioactive Waste Management (1988).
2. U.S. DEPARTMENT OF ENERGY, "Exploratory Shaft Facility Subsystem Design Requirements Document," YMP/CC-0003, Rev. 0, Yucca Mountain Project Office (1989).