ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439

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**RADIOACTIVE WASTE ISOLATION IN SALT:
RATIONALE AND METHODOLOGY FOR ARGONNE-CONDUCTED
REVIEWS OF SITE CHARACTERIZATION PROGRAMS**

by

W. Harrison, J.D. Ditmars, M.W. Tisue,
D.F. Hambley, D.F. Fenster, and D.M. Rote

Energy and Environmental Systems Division
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FOREWORD

Documents are being submitted to the Salt Repository Project Office (SRPO) of the U.S. Department of Energy (DOE) by Battelle Memorial Institute's Office of Nuclear Waste Isolation (ONWI) to satisfy milestones of the Salt Repository Project of the Civilian Radioactive Waste Management Program. Some of these documents are being reviewed by multidisciplinary groups of peers to ensure DOE of their adequacy and credibility. Adequacy of documents refers to their ability to meet the requirements of the U.S. Environmental Protection Agency and the U.S. Nuclear Regulatory Commission, as enunciated in 40 CFR Part 191 and 10 CFR Part 60, respectively, as well as those of the Nuclear Waste Policy Act of 1982. Credibility of documents refers to the validity of the assumptions, methods, and conclusions, as well as to the completeness of coverage.

Since late 1982, Argonne National Laboratory has been under contract to DOE to conduct multidisciplinary peer reviews of program plans and reports covering research and development activities related to siting and constructing a high-level nuclear waste repository in salt. Site characterization plans (SCPs) being prepared by ONWI are to be reviewed by the Argonne peer review panel. Particular emphasis is to be placed on Sec. 8 of the SCP, which will cover the site characterization program. Because Sec. 8 is the essence of an SCP, it will require a comprehensive, carefully structured review. This report provides background and guidance to panelists to help ensure the success of the peer review process.

A draft of this report was sent to SRPO for comment on December 14, 1984, and to 28 peer review panelists on March 19, 1985. This revised version of the report has considered the critiques of the aforementioned parties.

PREVIOUSLY PUBLISHED REPORTS IN THE SERIES

"RADIOACTIVE WASTE ISOLATION IN SALT"

- ANL/EES-TM-242** Peer Review of the Office of Nuclear Waste Isolation's Geochemical Program Plan (Feb. 1984)
- ANL/EES-TM-243** Peer Review of the Office of Nuclear Waste Isolation's Socioeconomic Program Plan (Feb. 1984) (revised July 1984)
- ANL/EES-TM-246** Peer Review of the Office of Nuclear Waste Isolation's Plans for Repository Performance Assessment (May 1984)
- ANL/EES-TM-254** Peer Review of the Office of Nuclear Waste Isolation's Reports on Preferred Repository Sites within the Palo Duro Basin, Texas (June 1984)
- ANL/EES-TM-256** Special Advisory Report on the Status of the Office of Nuclear Waste Isolation's Plans for Repository Performance Assessment (Oct. 1983)
- ANL/EES-TM-258** Peer Review of the Office of Nuclear Waste Isolation's Plan to Decommission and Reclaim Exploratory Shafts and Related Facilities (July 1984)
- ANL/EES-TM-259** Peer Review of the Office of Nuclear Waste Isolation's Final Report on the Organic Geochemistry of Deep Groundwaters from the Palo Duro Basin, Texas (Aug. 1984)
- ANL/EES-TM-260** Peer Review of the Texas Bureau of Economic Geology's Report on the Petrographic, Stratigraphic, and Structural Evidence for Dissolution of Upper Permian Bedded Salt, Texas Panhandle (Aug. 1984)
- ANL/EES-TM-261** Peer Review of the Office of Nuclear Waste Isolation's Report on Functional Design Criteria for a Repository for High-Level Radioactive Waste (Aug. 1984)
- ANL/EES-TM-262** Peer Review of the D'Appolonia Report on Schematic Designs for Penetration Seals for a Repository in the Permian Basin, Texas (Sept. 1984)
- ANL/EES-TM-263** Peer Review of the Office of Nuclear Waste Isolation's Reports on Multifactor Life Testing of Waste Package Materials

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ABSTRACT

Both regulatory and technical concerns must be addressed in Argonne-conducted peer reviews of site characterization programs for individual sites for a high-level radioactive waste repository in salt. This report describes the regulatory framework within which reviews must be conducted and presents background information on the structure and purpose of site characterization programs as found in U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 4.17 and Title 10, Part 60, of the Code of Federal Regulations. It also presents a methodology to assist reviewers in addressing technical concerns relating to their respective areas of expertise. The methodology concentrates on elements of prime importance to the U.S. Department of Energy's advocacy of a given salt repository system during the NRC licensing process. Instructions are given for reviewing 12 site characterization program elements, starting with performance objectives, performance issues, and levels of performance of repository subsystem components; progressing through performance assessment; and ending with plans for data acquisition and evaluation. The success of a site characterization program in resolving repository performance issues will be determined by judging the likelihood that the proposed data acquisition activities will reduce uncertainties in the performance predictions.

1 INTRODUCTION

Regulations mandate that a site characterization program be part of the U.S. Department of Energy's (DOE's) site characterization plan (SCP) for each potential site for a repository in salt for high-level radioactive waste. The section of the SCP that covers the site characterization program is to describe and justify the exploration and testing to be conducted during site characterization. The SCP is a comprehensive document that also includes a geologic description of the site, a conceptual design of the repository, and information on the waste package.

1.1 OBJECTIVE

This report presents the rationale behind and methodology for Argonne-conducted peer reviews of site characterization programs proposed by DOE contractors for high-level waste repositories in domed or bedded salt. The success of the peer review effort requires using panelists who are experts in numerous disciplines and who have a common basis of understanding as they undertake their reviews. The objective of this report is to provide such a common basis by summarizing the regulatory framework that will have governed the drafting of the SCPs and by highlighting the essential elements of reviews of site characterization programs.

1.2 REGULATORY REQUIREMENTS AFFECTING SITE CHARACTERIZATION PLANS

The U.S. Nuclear Regulatory Commission (NRC) is responsible for licensing repositories for high-level radioactive waste and in 1981 issued licensing procedures in the form of a proposed rule, Title 10, Part 60, of the Code of Federal Regulations (10 CFR Part 60). This preliminary rule was subsequently revised, primarily with respect to Subpart E (Technical Criteria), and reissued in June 1983 as a final rule entitled *Disposal of High-Level Radioactive Wastes in Geologic Repositories; Licensing Procedures*.¹ The precicensing procedures set forth in the final rule require that DOE submit an SCP* to NRC prior to starting detailed characterization at any potential repository site.

In July 1982, NRC published Regulatory Guide 4.17,² which details the many technical and institutional issues involved in licensing a high-level radioactive waste repository. It also suggests both the format and content of an SCP in accordance with 10 CFR 60, including a format for presenting site-specific information. A revised draft of Regulatory Guide 4.17 was issued for comment in late 1984, and this report follows the revised version.

In addition to these formal documents, NRC has issued less formal documents that state current plans and positions concerning its role in licensing in general and in the drafting of SCPs in particular. Two such documents bear on Argonne-conducted reviews of site characterization programs.

In August 1983, NRC prepared a revised version of the *Standard Review Plan for Site Characterization Plans* (SRP).³ It states NRC's position with respect to SCPs and the general approach to be taken by NRC staff members in their reviews. In addition to detailing the mechanics of the NRC review process, the SRP summarizes the problems and issues associated with evaluating an exploration and testing program. The general approach taken can be capsulized as follows (Ref. 3, p. 10):

In establishing licensing information requirements, the most immediate problem with respect to site characterization activities is "specifically, how much of what types of information is needed and enough?" or "how

*Referred to in 10 CFR 60 as an SCR (site characterization report). This usage was superseded by SCP in the Nuclear Waste Policy Act (NWPA) of 1982.

much testing and analysis is needed and enough?" ... [The NRC] approach is a systematic, iterative review process that uses preliminary performance assessments and sensitivity studies to establish when enough is known and thereby achieve closure. In this way all investigations are, in some fashion, related to quantitative performance assessments and their relative importance established. The process puts the burden on DOE to take the lead in identifying the specific information that will be required to assess performance of the repository system.

In July 1984, NRC completed the *Draft Generic Technical Position on Licensing Assessment Methodology for HLW [high-level waste] Repositories (DGTP)*.⁴ It documents what NRC "...considers to be the necessary elements of an acceptable licensing assessment and performance assessment methodology that addresses safety assessments" (Ref. 4, p. 3). The NRC also requires that "DOE...demonstrate that it has a performance assessment program...that can be used to guide the ongoing repository siting and design programs and that will ultimately lead to a complete and defensible demonstration of compliance with the requirements of 10 CFR Part 60" (Ref. 4, p. 25). The performance assessment program referred to above is to be used in formulating the site characterization program, which is to be described in Sec. 8 of a given site characterization plan. Figure 1 is a schematic of the iterative process that NRC assumes will take place with regard to resolving licensing issues. This process must be reflected in the SCP. The relationships between the portions of the process described here and the various parts of an SCP are described in more detail in Sec. 3 of this report.

First, specific performance issues are identified in terms of known site characteristics. (An example of a specific performance issue is containment of radionuclides within the waste packages.) The next few steps in the process are carried out concurrently. (1) Assessment methods (analyses and mathematical models) are developed to address each of the performance issues. (2) The design requirements for repository components are established as the result of iterations among known site characteristics, preliminary designs, and assessment results. (3) System sensitivity studies related to performance assessment predictions are carried out to determine critical information and data needs for reducing the uncertainties in predictions. Repository component designs may also drive information needs.

As shown in Fig. 1, sensitivity studies are the basis for identifying information needs. Test plans and procedures are then established to acquire the information needed to reduce uncertainty in the performance assessment predictions. The iteration loop is closed after the data generation step if reduced levels of uncertainty in the prediction have been established. In summary, if newly obtained data provide updated assessments with acceptable levels of uncertainty, the process is finished with regard to a particular issue. Performance assessment, or the assessment of repository performance against prescribed performance objectives, is an essential part of the overall licensing process.

1.3 PEER REVIEW OBJECTIVES WITH RESPECT TO THE REGULATORY FRAMEWORK

Of the documents described in Sec. 1.2, only 10 CFR 60 has been codified as a federal regulation. Regulatory Guide 4.17, SRP, and DGTP are intended as guidance

FIGURE 1 Iterative Review Process Assumed by NRC to Take Place in Resolving Licensing Issues

documents for DOE. They will also be used by NRC staff to establish and document the information needed in a licensing application and to perform licensing assessments. Therefore, these documents constitute the regulatory environment within which SCPs will be reviewed by NRC staff. If the Argonne-conducted peer reviews are to be effective, they must respond to the major points developed in NWPA, 10 CFR 60, and NRC guidance documents.

The peer review process requires that Argonne integrate the responses of the reviewers into a coherent report that addresses broad regulatory concerns as well as more detailed technical concerns. Simple evaluation of the components of individual planned tests and exploration procedures to see whether they are technically sound and feasible is not sufficient, although such evaluation is necessary. Reviewers must also consider whether the test plans and procedures have their origins in performance assessments and sensitivity studies and whether they thereby provide a rational basis for reducing uncertainties in performance predictions.

2 PURPOSE AND FORM OF SITE CHARACTERIZATION PROGRAMS

During the licensing process, DOE will have to demonstrate that the waste package, the site-specific repository design, and the natural and engineered barriers at the chosen site comply fully with all regulatory requirements, but in particular with the performance objectives in 10 CFR 60. The purpose of site characterization, then, is to identify and resolve all of the technical issues bearing on demonstrating such compliance.

Section 8 of the SCP should, according to Regulatory Guide 4.17 (Ref. 2, p. 52):

provide the rationale behind the proposed site characterization program and should describe in detail the program of exploration and testing to be conducted during site characterization. The description of the site characterization program at the named site should include (1) the issues to be resolved and information to be acquired during site characterization; (2) the tests and experiments to be performed; (3) [the] schedule, sequence, and duration of testing and data analyses; (4) the extent of planned excavation and in situ testing at depth; (5) elements of the conceptual design of a repository appropriate to the site relevant to data acquisition, analyses, and scheduling; (6) key milestones against which the progress of site characterization can be measured; (7) provisions to control any adverse safety-related effects that may result from site characterization; and (8) the quality assurance methods to be used in data acquisition and analysis. Also to be noted should be the decision points at which the direction of the site characterization program might be changed if warranted by the results obtained.

This chapter [section] should provide information about the planned tests at a level of detail sufficient to enable determination of whether adequate information for licensing will be produced. It should present definitive descriptions of the parameters to be controlled and measured in planned tests, or analyses that *show how the tests adequately bound the range of potential limiting conditions that are important to performance of that [sic] aspects of the repository being investigated* [italics added].

In addition to questioning the relevance and completeness of data supplied in the license application, the licensing process must explicitly address the question of whether or not data are of adequate quality so that licensing determinations can be made with reasonable confidence. The quality of data is virtually determined by the specific data gathering methods and procedures that are used. It is important, therefore, that specific methods to be used in data gathering and in the site characterization program be the subject of prelicensing consultation between DOE and NRC.

The quality of the data can be addressed by reviewers according to their expertise and without detailed attention to performance issues. However, in considering the relevance and completeness of the data with respect to performance issues, reviewers will need to relate their areas of expertise to the specific performance issues raised or not raised in the SCP.

The issues identified by a DOE contractor preparing an SCP, and the predicted performance of the repository system with regard to the issues, will drive the site characterization program. As discussed in App. A, descriptions of the present understanding of the site (Secs. 1-5 of the SCP), the repository conceptual design (Sec. 6), and the discussion of the waste package (Sec. 7) refer directly to specific issues. For its review, NRC will prepare a similar, but not necessarily identical, list of issues.

A hierarchy of issues is being formulated,⁵ which starts with key issues that are based on the need for compliance with general regulations, and progresses to issues and subissues that are responsive to the specifics of 10 CFR 60. Associated with each of the subissues are information and data needs. These needs address not only site characteristics, such as the thicknesses of geologic units and aquifer hydraulic conductivities, but also predictions of the effects of expected postclosure processes and events, such as estimates of fluxes of radionuclides in the groundwater system. In other words, performance assessments are required as well as data acquisition.

The lists of issues, subissues, and related information and data needs to resolve those subissues are comprehensive⁵ and will drive testing and exploration programs of considerable magnitude. However, site characterization programs have to be implemented in a reasonable time and with limited resources, as indicated in App. B. The reality of the work schedule and the broad range of issues mandate that site characterization programs focus on the tasks that will reduce uncertainties in performance predictions to acceptable levels.

Site characterization programs can take various forms. Two generic programs are being developed by DOE's Salt Repository Project Office. A surface-based program and a subsurface-based program will describe the "how to" of site characterization and will be updated periodically as results are obtained from field, laboratory, and modeling activities. The SCPs, on the other hand, will provide the "what" of site characterization and will not be revised as results are obtained. Instead, periodic progress reports will be written to indicate how the plan is being executed.

3 REVIEW OF SITE CHARACTERIZATION PROGRAMS

3.1 ARGONNE APPROACH

An Argonne-conducted peer review of a site characterization program will not duplicate the exhaustive type of review that will be carried out by NRC. Argonne will concentrate on elements of prime importance to DOE's advocacy of the salt repository system and its components during the NRC licensing process. Since the resources allocated for review are relatively small, which will prevent meticulous checking of calculations, verification of numerical values and reproduction of performance assessment simulations, Argonne-conducted reviews will have to focus on the correctness and applicability of procedures and chosen scenarios.

The Argonne-managed peer review panel will be responsible for considering all of the many program components. However, individual panelists will be asked to concentrate on components related to their areas of expertise. Panelists will need to consider not only the issues, but also the specific tests proposed. Typical questions that a reviewer might respond to are supplied, along with general guidelines concerning the review process. Because the suggested questions may not always be exactly appropriate or cover all of the relevant areas, reviewers may pose and respond to additional questions.

Section 8 (Site Characterization Program) of the SCP is expected to be organized along the lines suggested in Regulatory Guide 4.17 (see Table 1).^{*} Panelists should begin their reviews by reading and commenting on the understandability and logic of Sec. 8.1 (Rationale for Planned Site Characterization Program). They should then follow the sequence of steps presented in Fig. 2 as they review those portions of Sec. 8 that relate to their areas of expertise. At several points in the review process, it will probably be necessary to consider material in Part A (Secs. 1-7 of the SCP), which includes available site-specific information. Guidelines for such review are given in App. A.

The central concern is that the proposed data acquisition program be formulated to respond to all issues identified in the SCP, plus any that the reviewer may believe to have been omitted. The degree of responsiveness is to be measured by considering the known information, the results of earlier performance assessment and sensitivity studies, and the data acquisition programs proposed to reduce uncertainties in the performance predictions. Refer to Table 2 for NRC definitions concerning licensing assessments.

3.2 PERFORMANCE BASIS FOR LICENSING ASSESSMENTS

A group of performance objectives for a repository system can be considered the basis for licensing assessments. From these performance objectives are developed a

^{*}The outline as given in Table 1 and the format for Sec. 8, as it is expected to be developed by ONWI/DOE, may prove to be different.

TABLE 1 Proposed Outline for Site Characterization Programs

Section 8 - Site Characterization Program^a

- 8.0 Introduction**
- 8.1 Rationale for Planned Site Characterization Program**
 - 8.1.1 Identification of Information Needs
 - 8.1.2 Prioritization of Information Needs
 - 8.1.3 Approach to Obtaining Information
 - 8.1.4 Utilization of Information
- 8.2 Issues to Be Resolved and Information Required during Site Characterization**
 - 8.2.1 Issues to Be Resolved
 - 8.2.2 Approach to Issue Resolution
- 8.3 Planned Tests, Analyses, and Studies**
 - 8.3.1 Site Program
 - 8.3.2 Repository Program
 - 8.3.3 Seal System Program
 - 8.3.4 Waste Package Program
 - 8.3.5 Performance Assessment Program Plan
- 8.4 Planned Site Preparation Activities**
 - 8.4.1 Surface Site Preparation Activities
 - 8.4.2 Underground Test Facility
- 8.5 Milestones, Decision Points, and Schedule**
 - 8.5.1 Site Characterization Activities and Milestones
 - 8.5.2 Performance Assessment Activities and Milestones
 - 8.5.3 Repository Design Activities and Milestones
 - 8.5.4 Waste Package Design Activities and Milestones
 - 8.5.5 Project Major Decision Points
 - 8.5.6 Schedules
- 8.6 Quality Assurance Program**
 - 8.6.1 Quality Assurance Plan Summary
 - 8.6.2 Regulatory Requirements for Quality Assurance
 - 8.6.3 Organization of the Project with Respect to Quality Assurance
 - 8.6.4 Application of Quality Assurance
 - 8.6.5 Administrative Quality Assurance Procedures
 - 8.6.6 Quality Assurance Plans and Procedures for Specific Program Areas

TABLE 1 (Cont'd)

8.7	Decontamination and Decommissioning
8.7.1	Decontamination
8.7.2	Decommissioning
8.7.3	Plans for Mitigation of Any Significant Adverse Environmental Impacts Caused by Site Characterization Activities

^aSee Table A.1 of App. A of this report for a more detailed outline of this and other sections in the SCP.

Source: Ref. 2, as modified in Ref. 6.

hierarchy of performance issues, that is, issues that must be addressed and resolved to satisfy the performance objectives. The performance levels of the components of repository subsystems must be specified by DOE such that overall system performance is maintained. The above elements provide the foundation for peer review assessment of the appropriateness and probable success of any site characterization program.

3.2.1 Performance Objectives

Background. This rationale and methodology report concerns safety assessments. The safety of the repository system is to be assessed for two time periods: the time through permanent closure and the time after permanent closure. Table 3 indicates the principal performance objectives given in 10 CFR 60 for preclosure and postclosure assessments.

The concepts of performance objectives for salt repositories have been developed by NRC over time. During this process, specific approaches to assess compliance with quantitative objectives have been suggested. Because the U.S. Environmental Protection Agency (EPA) has its standards for release of radiation to the accessible environment only in draft form at this time, some uncertainty exists with regard to the specifics of some objectives and approaches.

Despite the specific performance objectives cited in Table 3, NRC may approve or specify, on a case-by-case basis, different values for the radionuclide release rate, design containment period, or pre-waste-emplacement groundwater travel time, but only if the overall system performance objective is satisfied. As a result, DOE and its contractors might deviate somewhat from the specific performance objectives for particular barriers (see Table 3), arguing that the total system will still meet the overall system performance objectives.

FIGURE 2 Sequence of Steps to Be Followed by Reviewers of a Site Characterization Program (numbers within boxes refer to subsections of this report)

TABLE 2 Definitions Concerning Licensing Assessments

Licensing assessment is the process of evaluating whether a license application complies with all the requirements that it purports to meet. For the geologic program, it is the assessment of the individual findings for each of the requirements of 10 CFR 60. Licensing assessment also includes semiquantitative and qualitative assessments that will address the nonnumerical requirements and criteria [of performance assessment] and will provide input to quantitative assessments.

Licensing issues are technical questions that NRC will address in order to (1) complete the licensing assessment of site suitability and/or design suitability in terms of 10 CFR 60, Subpart E and (2) adopt the environmental impact statement prepared by DOE.

Licensing issues include both performance issues and site issues [italics added].

Performance issues are broad questions common to all sites concerning both the operational and long-term performance of the various components of the overall geologic repository system. These issues are derived directly from the performance objectives of 10 CFR 60, Subpart E.

Site issues include site-specific technical questions about those significant conditions and processes needed to address the performance issues.

Accessible environment means the atmosphere, land surfaces, surface waters, oceans, and portions of the lithosphere that are beyond the controlled area.

Controlled area means a surface location to be identified by passive institutional controls that prohibit incompatible activities. It extends horizontally no more than 2 km in any direction from the outer boundary of the original location of the radioactive wastes in a disposal system and includes the subsurface underlying the surface location.

Source: The definition for "licensing assessment" is from Refs. 4 and 6; the definitions for "licensing issues," "performance issues," and "site issues" are from Ref. 7; and the definitions for "accessible environment" and "controlled area" are from Ref. 8.

TABLE 3 Performance Objectives

10 CFR 60.111, Performance of the Geologic Repository Operations Area through Permanent Closure

- 10 CFR 60.111(a) Protection against radiation exposures and releases of radioactive material. ...[R]adiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will...be maintained within the limits specified in Part 20 of this chapter [10 CFR 20, Standard for Protection against Radiation] and such generally applicable standards for radioactivity as may have been established by EPA [40 CFR 191, which includes protection of groundwater aquifers and calculations of probabilities associated with releases of certain radionuclides].
- 10 CFR 60.111(b)(1) Retrieval of waste. ...[T]he geologic repository operations areas shall be designed so that any or all of the emplaced waste could be retrieved...starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by [NRC].

10 CFR 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 [EPA] with respect to both anticipated processes and events and unanticipated processes and events.

10 CFR 60.113, Performance of Particular Barriers after Permanent Closure

- 10 CFR 60.113(a)(1)(ii)(A) [Containment by the engineered barrier system]. Containment of HLW [high-level waste] within the waste packages will be substantially complete for a period...not less than 300 years nor more than 1000 years after permanent closure of the geologic repository.

TABLE 3 (Cont'd)

-
- 10 CFR 60.113(a)(1)(ii)(B) [Isolation by the engineered barrier system]. 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 1000 years following permanent closure. ... 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 1000 years of radioactive decay.
 - 10 CFR 60.113(a)(2) [Preemplacement groundwater travel time in geologic setting]. The geologic repository shall be located so that pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1000 years.
-

Source: Ref. 1.

Reviewer Questions. In evaluating discussions of performance objectives and licensing found in a site characterization program, reviewers should ask at least the following questions:

- Are the performance objectives stated clearly and understandably?
- Are the performance objectives consistent with those given in 10 CFR 60, as summarized in Table 3?
- If the performance objectives are different from those in 10 CFR 60 with regard to particular barriers, is a logical case made that overall system performance objectives will be met, despite differences in the performance objectives of system components?

3.2.2 Performance Issues

Background. Site characterization programs must logically present the relationships between the performance objectives of 10 CFR 60 and issues or questions

developed from the objectives. The DGTP report advises that "issues should be broken down logically from general, performance-related questions to increasingly detailed, specific-information-related questions that must be answered to address the major performance issues."⁴

A portion of a hierarchy of performance issues that could be developed from the performance objectives is given in Table 4. Such hierarchies can be expanded to even greater levels of detail, with the lowest levels including questions related to specific information and data needs. Site characterization activities, including performance assessments and data acquisition, must be judged on how well they address overall performance objectives. Therefore, the paths linking performance objectives with site characterization activities within an issues hierarchy require careful scrutiny.

Reviewer Questions. In reviewing performance issues, panelists should ask at least the following questions for their areas of expertise:

- Is the rationale logical and clear for identifying each issue and subissue?
- Is each issue linked to a performance objective?
- Are issues raised that do not address a performance objective?
- Are the performance issue hierarchies complete?

3.2.3 Levels of Performance for Components of Repository Subsystems

Background. Substantial flexibility will be permitted by NRC in repository subsystem performance so long as overall system performance meets EPA standards (10 CFR 60.113; Ref. 4, p. 11). Repository subsystems include the waste package, repository system, and natural and engineered barriers. Examples of components of each of these subsystems are the container for the waste form, a seal for a repository shaft, and an individual aquifer, respectively. The performance of individual components will need to be demonstrated. An example performance objective would be the essentially complete containment of high-level waste within the waste container for a period not less than 300 years after permanent closure.

At the outset of the site characterization process, DOE will establish what it expects to demonstrate with respect to the performance of each subsystem. Section 6 (Conceptual Design of a Repository) and Sec. 7 (Waste Form and Package) of the SCP will deal with subsystem performance. In particular, Regulatory Guide 4.17 requires that Sec. 6.3.8 contain predictions of system performance as a means of setting performance levels. Further review instructions are given in Secs. A.2 and A.3 of App. A. Section 7.1, which requires a description of the type of environment into which the waste package will be emplaced, will also be important in setting levels of performance because bounding conditions are to be specified.

TABLE 4 A Hierarchy of Performance Issues

Key Issue 1. Will the geologic repository, consisting of multiple natural and engineered barriers, isolate the radioactive waste from the accessible environment after closure in accordance with applicable requirements set forth by EPA and NRC?

Issue 1.1. Under expected conditions, will the geologic setting of the repository (a) meet the performance objective of 1000-year pre-waste-emplacement groundwater travel time from the disturbed zone to the accessible environment and (b) support the overall repository system performance objective for releases to the accessible environment?

Subissue 1.1.1. What is the extent of the disturbed zone?

Subissue 1.1.2. What is the boundary of the accessible environment?

Subissue 1.1.3. How stable is the position of the waste within the salt?

Subissue 1.1.4. What are the predicted groundwater travel paths (pre- and post-emplacement)?

Subissue 1.1.5. What are the predicted groundwater fluxes and velocities along each projected travel path under (a) pre-waste-emplacement and (b) post-waste-emplacement conditions?

Subissue 1.1.6. What is the predicted release rate from the engineered barrier system?

Subissue 1.1.7. What is the radionuclide flux into and through the host formation under expected conditions?

Issue 1.2. Under expected conditions will the waste packages contain the waste form 300 to 1000 years after closure?

Issue 1.3. Under expected conditions will the engineered barrier system limit its post-containment release of radionuclides to no more than one part in 100,000 per year of the 1000-year inventory or such other fraction as may be approved by NRC?

Issue 1.4. Under disruptive conditions resulting from the drilling scenario will the engineered barrier system and the geologic setting of the site continue to provide the required containment and isolation of the emplaced waste?

Reviewer Questions. When reviewing contractor performance specifications for repository subsystem components, panelists should ask at least the following questions.

- Is it clear why the proposed performance level for a particular subsystem is necessary and sufficient relative to overall system performance objectives?
- What reliability is to be associated with the proposed performance level, so that a measure of overall system reliability can be gained?
- What rationale for the decision-making process led to the proposed performance level?

3.3 PERFORMANCE ASSESSMENTS

Performance assessment is the chief means for evaluating the performance of repository subsystems against performance objectives. Performance assessment may involve using simple bounding analyses or, at the other extreme, very complex computer codes. It also entails more than the prediction mechanism itself; it includes scenarios, conceptual models, mathematical models, and sensitivity studies. Each of these components requires review.

"In order to guide site characterization activities, it is critical that the methodology be developed and applied in the planning of site characterization, starting with preliminary scenarios, models, and data that will be refined iteratively throughout the site investigation process" (Ref. 4, p. 8). As indicated in Fig. 1, this methodology requires significant interaction between existing data and interpretations, performance objectives, and repository component designs. This interaction should be documented in Sec. 8.1 (Rationale for Planned Characterization Program) and in Sec. 6.3.8 (Repository System Component Performance Requirements) of the SCP. In reviewing various parts of a performance assessment, panelists may have to refer to material in Part A of an SCP to establish the overall basis for assessment.

3.3.1 Performance Assessment Scenarios

Background. Scenarios describing anticipated and, to the extent possible, low-probability ("unanticipated") events and processes affecting system performance should be identified, screened, and quantified in an SCP. In identifying a scenario, as much site-specific information as possible should have been included. Screening of scenarios involves testing identified scenarios against performance objectives to determine whether the scenarios are likely to affect meeting system or component performance objectives. Quantification of scenarios refers not only to quantitatively describing the scenario but also to assigning the likelihood of its occurrence.

For example, a scenario concerning groundwater transport of radionuclides away from a repository in salt that had been breached by dissolution should include information regarding (1) locations of possible dissolution breaches; (2) identification of geohydrologic units involved in transport; (3) estimates of pathways to the accessible environment; and (4) approximate time of breach, which would determine the inventory of radionuclides available for transport.

Reviewer Questions. After examining the various scenarios proposed in an SCP, reviewers should respond to at least the following questions:

- Have all likely scenarios been identified?
- Are the identified scenarios described clearly?
- Are the described scenarios credible in terms of events and processes?
- Does it appear that each scenario has been screened with regard to its importance relative to performance objectives?
- If a likelihood of occurrence (probability) has been assigned to a scenario, is it realistic and defensible?

3.3.2 Conceptual Models

Background. A conceptual model is "a pictorial and/or narrative description...[that] represents all relevant components and structures contained within the system or subsystem, the interactions between the components and structures, and any internal or external processes which affect the overall performance of the subsystem (Ref. 4, Appendix, p. 1). Conceptual models form the link between scenarios and mathematical models, thereby serving as a foundation for performance assessment of repository subsystems. Conceptual models of the performance of engineered barriers must combine design-specific data with scenario conditions. Conceptual models of the performance of natural barriers must integrate available site-specific data and interpretations of the natural environment. Before the consequences of radionuclide release and transport scenarios can be estimated numerically, alternative conceptual models of the repository subsystem must be developed for both anticipated and unanticipated conditions.

In the case of radionuclide transport, NRC believes that an SCP "should consider alternative conceptual models of transport phenomena that include, at a minimum, (1) advection; (2) dispersion; (3) geochemical retardation (e.g., sorption, solubility control, [and] diffusion); and (4) branching decay" (Ref. 4, p. 24). However, different processes may predominate in different conceptual models.

Proper review of a conceptual model will usually require referring to the site-specific data upon which the model is based. These data are located in Secs. 1-5 of an SCP. Review instructions are given in Sec. A.1 of App. A.

Reviewer Questions. Reviewers should ensure that at least the following questions are answered regarding conceptual models.

- Have alternative conceptual models been considered for each relevant scenario?
- Do the alternative conceptual models cover both "anticipated" and "unanticipated" events? Unanticipated events are those that could affect the geological setting but are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved. Nonetheless, they are sufficiently credible to warrant consideration.
- For repository subsystems with which the reviewer is familiar, do the conceptual models integrate available site-specific data and interpretations of relevant natural phenomena?
- Are the conceptual models supported by design-specific and site-specific data?

3.3.3 Mathematical Models

Background. Mathematical models provide the quantitative framework for the conceptual models discussed above and must adequately represent the processes inherent in the conceptual models. Developing suitable mathematical models may require that the underlying conceptual models be simplified in their mathematical representations because of limited knowledge concerning the processes modeled. In those instances, the simplifications needed in going from the conceptual to the mathematical model should be stated clearly, and the implications of the simplifications (e.g., more conservative results) should be noted.

The analytical or numerical solution techniques should be documented for the mathematical models used for performance assessment. The documentation should not only describe the solution procedures but also, in the case of computer codes, results of verification activities. To the extent possible, evidence of model validation should be cited to support model applications. Because many predictive models will require predictions over very long periods of time, formal validation cannot always be expected.

At the time an SCP is prepared, some of the performance assessment tools (models) will not have been developed. This lack should not be of undue concern because

such development is an iterative part of the site characterization program. The guidance developed by NRC for Sec. 8 suggests that model development plans, as they are related to site characterization, should be discussed in the SCP. Thus, reviewers may need to examine plans for further model development in addition to existing models.

Checking the results of mathematical model predictions may be difficult because reviewers will not know for certain if the results are correct without replicating the calculations. Simple bounding computations can perhaps be checked quickly, but the results of numerical model computations will generally be unreplicated. To assess the results of modeling, reviewers will have to rely on their familiarity with the model or the processes modeled, or their own bounding calculations. Reviewers may need to assess the results of sensitivity studies and data acquisition plans before determining whether additional modeling is required and deciding on what type of modeling is best.

Reviewer Questions. Reviewers of mathematical models and their solutions will want to answer at least the following questions:

- To what degree do the mathematical models represent the conceptual models?
- Have the effects of simplifying conceptual models for mathematical modeling been assessed, and have the implications for performance prediction for the relevant subsystem and site been noted?
- Are the solution techniques (analytical and numerical) adequately documented?
- Are the solution techniques acceptable for the types of predictions undertaken?
- Do the models include site-specific and design-specific input and parameters embodying the most current and accepted concepts and data appropriate to the application?
- Do the results of model application appear reasonable?
- Do the models include "long-term" mechanisms appropriate to the time scale of prediction?
- Are the plans for further modeling consistent with the performance issues, conceptual modeling, and data acquisition plans?

3.3.4 Sensitivity Studies

Background. Sensitivity studies provide the link between the predictions of models under a specific set of input conditions and requirements for additional data.

Changes in model predictions are examined as a function of variations in model input, model parameters, and, in some cases, model structure. Determining the sensitivity of model predictions to these quantities permits investigating potential reductions in uncertainties with respect to uncertainties (or variabilities) in the quantities.

Sensitivity studies range in sophistication from parameter variation analyses for relatively simple bounding calculations to formal techniques (e.g., adjoint analysis) for complex numerical models. The most important characteristic of any sensitivity study is that variations in performance-related predictions are linked to critical site- or design-related parameters.

For example, a sensitivity study of groundwater travel time might investigate the sensitivity of groundwater velocities along the expected travel path to the distribution of hydraulic conductivity values in the region modeled. Knowing the sensitivity of the travel-time computation to such a distribution would provide guidance for the site characterization program as to whether increased information about hydraulic conductivity distributions would likely reduce uncertainties in predictions of travel time.

Reviewer Questions. Reviewers should examine the sensitivity studies and then ask:

- Have sensitivity studies been performed with regard to the critical information needs surrounding the performance issues? If not, in what areas are sensitivity studies required?
- Were the sensitivity studies carried out correctly?
- Were the important parameters and parameter ranges tested in the sensitivity studies?
- Are the results of sensitivity studies clearly linked to expected uncertainties in performance predictions?

3.3.5 Unresolved Issues

Background. The format proposed by NRC for site characterization programs suggests that Sec. 8.2 identify issues to be resolved and information required during site characterization (see Table 1). The performance issues and the performance assessments are the basis for determining which issues are unresolved. To be identified as resolved, the issue must have been convincingly resolved during performance assessment. Unresolved issues must be traceable to particular performance objectives and must be so classified because of a lack of information or unacceptable levels of performance.

Reviewer Questions. Reviewers should answer at least the following questions.

- Are the resolved issues convincingly resolved?
- Do the unresolved issues represent issues essential for meeting performance objectives?
- How should the list of unresolved issues be modified?

3.4 DATA ACQUISITION PLANS

The results of performance assessments, including sensitivity studies, lead to identification of unresolved performance issues, that is, issues for which prediction of performance has been impossible because of missing information or issues for which predicted performance has unacceptably large uncertainties. In either case, site characterization programs should focus on resolving these "unresolved issues" through acquisition of data and continued iteration through the performance assessment loop.

Review of site characterization programs must be conducted on at least two levels -- the technically detailed level at which the appropriateness of test plans and experimental procedures are assessed and a broader level at which proposals are advanced for addressing unresolved issues.

3.4.1 Information and Data Needs

Background. Identifying the information and data needs to be addressed by site characterization programs must be based on previously reviewed performance assessments. Information may be needed to complete scenario or conceptual model definitions, and data may be needed to reduce uncertainties in performance predictions. It is not sufficient to simply argue that additional data should be acquired to reduce uncertainties. A clear rationale must be provided to link the data needs to uncertainty reduction. If it is claimed, for example, that additional data on hydraulic conductivity are required to reduce uncertainties associated with prediction of groundwater travel time, that claim should be substantiated with sensitivity studies that demonstrate that increased knowledge of hydraulic conductivity values will indeed reduce the uncertainty in the predictions of travel time.

Reviewers should also be satisfied that additional data are required because the existing data base for individual repository subsystems is insufficient to satisfy declared needs. Before recommending that additional information or data will be required, reviewers should put their suggestions for data acquisition to the same test. This determination may require review of the available information for the relevant repository subsystem (see Fig. 2).

Reviewer Questions. Reviewers should carefully scrutinize information and data needs and answer at least the following questions.

- Do the plans for data acquisition address data that are not presently available but that are required to provide needed information?
- Do performance predictions and sensitivity studies support the idea that acquisition of these data will reduce uncertainties in system performance to acceptable levels?
- If the specified data are not acquired, can performance issues still be addressed?
- Have the costs of the data acquisition program been considered?

3.4.2 Conceptual Framework of Tests Planned to Satisfy Data Acquisition Needs

Background. Once data acquisition needs have been identified, the conceptual framework for the tests and experiments must be established. In other words, the planned tests should provide the needed data. For example, if hydraulic conductivity data are required to reduce uncertainty in predictions of groundwater travel time, large-scale aquifer pumping tests might be more appropriate than permeability tests on extracted core samples. Also, because the spatial and temporal scales of tests and experiments are often reflected in the data obtained, care should be taken to ensure a reasonable match between model input or parameter scales and those of the data. Spatial- and time-scale similitude should be considered in prototype testing, as well as in small-scale and accelerated testing.

Reviewer Questions. Reviewers should carefully consider the relationship between data needs and planned data acquisition activities in answering the following questions.

- Will the prescribed tests and experiments yield the needed data?
- Are the spatial and temporal scales associated with the planned tests properly matched with the data requirements?
- Are the tests likely to introduce uncertainty sufficient to offset any reduction in performance uncertainty?
- Will the proposed tests and methods provide the needed amount of relevant data given scheduling constraints (see App. B)?
- Has sufficient quantitative justification been provided to demonstrate the validity of the data acquisition program?

3.4.3 Test Plans and Experimental Procedures

Background. Proper test procedures and experimental methodologies are required if the planned data acquisition activities are to produce the desired data. Of particular concern are the uncertainties associated with the tests and experiments, and the impact of those uncertainties on performance predictions requiring the data.

Reviewer Questions. Upon reviewing the test plans and experimental procedures in their areas of expertise, reviewers should respond to at least the following questions:

- Are the proposed test and experimental methodologies and procedures correct for the proposed applications?
- Will the tests provide data with acceptable levels of uncertainty, that is, levels that permit reductions in prediction uncertainty.
- Are the uncertainties associated with data collected in the prescribed method likely to be so large as to diminish the value of the data?
- Are there better ways to conduct such tests?

3.4.4 Evaluation of the Acquired Data

Background. Acquiring data through testing and experimentation is not an end in itself but rather the beginning of an iteration back through the issue-handling process indicated in Fig. 1. Data acquired during site characterization should be used to update performance assessment activities from scenario identification through sensitivity studies. Effective and timely use of new data requires that their effects on unresolved issues are evaluated and that data acquisition plans are adjusted accordingly.

Reviewer Questions. In concerning themselves mainly with the disposition of new data, reviewers of data acquisition programs should respond to at least to the following questions.

- Are plans presented for evaluating the new data to determine if they have reduced uncertainty in performance predictions or if more data are required?
- Do the plans for data evaluation make use of the assessment and sensitivity study techniques presented in the SCP?
- Are plans for data analyses and possible test modifications consistent with DOE site characterization timetables?

REFERENCES

1. *Disposal of High-Level Radioactive Wastes in Geologic Repositories; Licensing Procedures*, U.S. Nuclear Regulatory Commission, Code of Federal Regulations, 10 CFR Part 60 (Jan. 1, 1985).
2. *Standard Format and Content of Site Characterization Reports for High-Level-Waste Geologic Repositories*, U.S. Nuclear Regulatory Commission, Regulatory Guide 4.17 (July 1982). A revised version was issued in late 1984.
3. *Standard Review Plan for Site Characterization Plans*, U.S. Nuclear Regulatory Commission (Aug. 1983).
4. *Draft Generic Technical Position on Licensing Assessment Methodology for High-Level Waste Geologic Repositories*, U.S. Nuclear Regulatory Commission (July 1984).
5. *Salt Repository Project Issues Hierarchy and Data Needs for Site Characterization*, prepared by the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio, for the U.S. Department of Energy, preliminary draft (Feb. 1985).
6. *Annotated Outline for Site Characterization Plans*, U.S. Department of Energy, Office of Civilian Radioactive Waste Management (Feb. 1985).
7. *Draft Issue-Oriented Site Technical Position (ISTP) for Salt Repository Project (SRP): Gulf Coast Salt Dome Sites*, U.S. Nuclear Regulatory Commission (Sept. 1984).
8. *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*, U.S. Environmental Protection Agency, Working Draft No. 5, Final 40 CFR 191 (April 17, 1985).

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APPENDIX A

REVIEW OF PART A (SECTIONS 1-7) OF A SITE CHARACTERIZATION PLAN

APPENDIX A

REVIEW OF PART A (SECTIONS 1-7) OF A SITE CHARACTERIZATION PLAN

The U.S. Department of Energy, in response to a suggestion by NRC, has developed the table of contents for an SCP given in Table A.1. Part A covers the current level of understanding concerning the site, the waste package, and the conceptual repository design. Passage of NWPA, which requires that comprehensive environmental assessments precede the drafting of an SCP for each candidate repository site, may have had the effect of reducing the amount of background information needed in Secs. 1-5 of Part A. Part B consists solely of Sec. 8 (Site Characterization Program), which primarily describes unresolved issues and details plans to acquire the data and models needed to resolve those issues. Site decontamination and decommissioning are covered at the end of Sec. 8.

Comprehensive review of site characterization programs, the subject of this report, requires that panelists consider applicable sections of Part A as necessary. The Part A topics covered in this report are discussed in three groups: site geology, conceptual design of a repository, and waste package.

A.1 SITE GEOLOGY (SECTIONS 1-5)

Sections 1-5 of an SCP describe the current level of understanding of the geologic setting. As defined in 10 CFR 60, the geologic setting consists of the geologic, hydrologic, and geochemical systems of the repository site and the surrounding region. Although the information presented in Secs. 1-5 does not directly address the performance objectives or performance issues detailed in 10 CFR 60, such information provides a basis for their evaluation.

An example of an important issue requiring reference to material presented in Secs. 1-5 is whether, under expected conditions, the geologic setting of the repository is such that the overall repository system performance objective for releases to the accessible environment can be met. Or, more specifically, is the geologic setting such that the performance objective of a pre-waste-emplacement groundwater travel time from the disturbed zone to the accessible environment of 1000 years can be met?

Unresolved issues concerning geomorphology, for example, might require answers to the following questions: (1) what are the characteristics of the physiographic province, physiographic/geomorphic units, and geomorphic features of the geologic system? (2) what are the erosional rates and mechanisms operating in the geologic system? (3) what are the present dissolution rates? and (4) what is the nature of the unconformities present in the geologic record, and how might these alter calculations of geomorphic processes? Whether such questions can be adequately answered will depend on site-specific data. Such data, if available, should be presented in the relevant sections of Part A. If such data are not available, plans to acquire them should be part of the site characterization program described in Part B.

TABLE A.1 DOE's Proposed Table of Contents for a Site Characterization Plan

Part A -- Description of Site, Waste Package, and Repository Design**Section 1 -- Geology**

- 1.0 Introduction**
- 1.1 Geomorphology**
 - 1.1.1 Physiography
 - 1.1.2 Geomorphic Units
 - 1.1.3 Geomorphic Processes
- 1.2 Stratigraphy and Lithology**
 - 1.2.1 Stratigraphic Framework of the Candidate Area
 - 1.2.2 Stratigraphic Framework of the Site
- 1.3 Structural Geology and Tectonics of Candidate Area and Site**
 - 1.3.1 Tectonic Framework
 - 1.3.2 Tectonic History
 - 1.3.2.1 Volcanic History
 - 1.3.2.2 Structural History
 - 1.3.2.3 Existing Stress Regime
 - 1.3.2.4 Vertical and Lateral Crustal Movement
 - 1.3.2.5 Geothermal Regime
- 1.4 Seismology of Candidate Area and Site**
 - 1.4.1 Seismology of Candidate Area
 - 1.4.1.1 Seismicity of Candidate Area
 - 1.4.1.2 Relationship of Seismicity to Geologic or Tectonic Characteristics of Candidate Area
 - 1.4.1.3 Determination of Earthquake-Generating Potential of Geologic Structures and Seismo-Tectonic Zones within Candidate Area
 - 1.4.1.4 Earthquake-Induced Phenomena within Candidate Area that May Affect Site
 - 1.4.1.5 Seismic Hazard in the Candidate Area
 - 1.4.2 Seismology of the Site
 - 1.4.2.1 Vibratory Ground Motion at Site Resulting from Potential Earthquakes in Area
 - 1.4.2.2 Characteristics of Seismic Wave Transmission at Site
 - 1.4.2.3 Potential for Induced Seismicity Affecting Site
- 1.5 Long-Term Regional Stability with Respect to Tectonic and Geologic Processes**
- 1.6 Subsurface Drilling and Mining**
- 1.7 Mineral and Hydrocarbon Resources**
 - 1.7.1 Mineral Resources
 - 1.7.2 Hydrocarbon Resources

TABLE A.1 (Cont'd)

-
- 1.8 Summary and Conclusions
 - 1.8.1 Summary of Significant Results
 - 1.8.2 Relation to Design
 - 1.8.3 Identification of Information Needs
 - 1.8.4 Relation to Regulatory Guide 4.17

References

Section 2 -- Geoengineering

- 2.0 Introduction
- 2.1 Mechanical Properties of Rock Units -- Intact Rock
 - 2.1.1 Mechanical Properties of Other Rocks
 - 2.1.2 Mechanical Properties of Rocks at the Site
- 2.2 Mechanical Properties of Rock Units -- Discontinuities
 - 2.2.1 Mechanical Properties of Discontinuities in Other Rocks
 - 2.2.2 Mechanical Properties of Discontinuities in Rocks at the Site
- 2.3 Mechanical Properties of Rock Units -- Large-Scale
 - 2.3.1 Mechanical Properties of Other Rocks
 - 2.3.2 Mechanical Properties of Rocks at the Site
 - 2.3.3 Relationship between Intact Rock, Discontinuities, and Large-Scale Rock Properties
- 2.4 Thermal and Thermomechanical Properties -- Intact Rock
 - 2.4.1 Thermal and Thermomechanical Properties of Other Rocks
 - 2.4.2 Thermal and Thermomechanical Properties of Rock at the Site
- 2.5 Thermal and Thermomechanical Properties -- Large-Scale
 - 2.5.1 Thermal and Thermomechanical Properties of Other Rocks
 - 2.5.2 Thermal and Thermomechanical Properties of Rock at the Site
 - 2.5.3 Relationship between Intact Rock and Large-Scale Properties
- 2.6 Stress Field
 - 2.6.1 Stress Field in Region of the Site
 - 2.6.2 Stress Field at the Site
- 2.7 Special Geoengineering Properties
- 2.8 Excavation Characteristics of Rock Mass
 - 2.8.1 Excavation Characteristics of Similar Rocks
 - 2.8.2 Excavation Characteristics of Rock at the Site
 - 2.8.3 Changes in Geoengineering Properties due to Excavation

TABLE A.1 (Cont'd)

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- 2.9 Summary and Conclusions
 - 2.9.1 Summary of Significant Results
 - 2.9.2 Relation to Design
 - 2.9.3 Identification of Information Needs
 - 2.9.4 Relation to Regulatory Guide 4.17

References

Section 3 -- Hydrology

- 3.0 Introduction
- 3.1 Description of Surface Hydrology
- 3.2 Floods
 - 3.2.1 Flood History and Potential for Future Flooding
 - 3.2.2 Flood Protection
- 3.3 Locations and Distances to Points of Surface-Water Use
 - 3.3.1 Present Quantity and Quality of Surface Water Extracted
 - 3.3.2 Projected Surface-Water Uses
- 3.4 Chemical Composition of Adjacent Watercourses
- 3.5 Points of Ground-Water Discharge
- 3.6 Regional Hydrologic Reconnaissance of Candidate Area and Site
 - 3.6.1 Hydrogeologic Units
 - 3.6.2 Relationship among Hydrogeologic Units
 - 3.6.3 Potentiometric Levels
 - 3.6.4 Hydraulic Characteristics of Principal Hydrogeologic Units
- 3.7 Regional Ground-Water Flow System
 - 3.7.1 Identification of Recharge and Discharge Areas
 - 3.7.2 Principal Ground-Water Flow Paths
 - 3.7.3 Isotopic and Regional Hydrochemistry
 - 3.7.4 Paleohydrology
- 3.8 Ground-Water Uses
 - 3.8.1 Regional Ground-Water Aquifers Used for Human Activities
 - 3.8.2 Regional Ground-Water Management Plans
- 3.9 Site Hydrogeologic System
 - 3.9.1 Baseline Monitoring
 - 3.9.1.1 Monitoring Networks
 - 3.9.1.2 Potentiometric Levels
 - 3.9.1.3 Hydrochemistry

TABLE A.1 (Cont'd)

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- 3.9.2 Hydraulic Characteristics
 - 3.9.3 Ground-Water Flow System Conceptual Model
 - 3.9.3.1 Accessible Environment and Credible Pathways
 - 3.9.3.2 Potentiometric Levels and Head Relationships
 - 3.9.3.3 Recharge-Discharge and Leakage
 - 3.9.3.4 Unsaturated Zone Relationships
 - 3.9.4 Ground-Water Velocity and Travel Time
 - 3.9.5 Hydrochemical Confirmation of Ground-Water Behavior
 - 3.9.6 Monitoring and Verification
 - 3.9.7 Local Ground-Water Users
 - 3.9.8 Paleohydrology
 - 3.10 Summary and Conclusions
 - 3.10.1 Summary of Significant Results
 - 3.10.2 Relation to Design Identification of Information Needs
 - 3.10.3 Identification of Information Needs
 - 3.10.4 Relation to Regulatory Guide 4.17

References

Section 4 -- Geochemistry

4.0 Introduction

4.1 Geochemistry of the Host Rock and Surrounding Units

- 4.1.1 Mineralogy and Petrology
 - 4.1.1.1 General Description of Host Rock and Surrounding Units
 - 4.1.1.2 Analytical Techniques
 - 4.1.1.3 Mineralogic, Petrologic, and Chemical Composition of the Host Rock and Surrounding Units
 - 4.1.1.4 Mineral Stability
- 4.1.2 Ground-Water Geochemistry
 - 4.1.2.1 General Description of the Hydrochemistry
 - 4.1.2.2 Major Inorganic Content
 - 4.1.2.3 Trace Elements
 - 4.1.2.4 Organic Content
 - 4.1.2.5 Dissolved Gas
 - 4.1.2.6 Background Radioactivity
 - 4.1.2.7 Particulates and Colloids
 - 4.1.2.8 Temperature and Pressure
 - 4.1.2.9 Mineralogical Controls on Water Composition
 - 4.1.2.10 Reference Ground-Water Composition
- 4.1.3 Geochemical Retardation Processes
 - 4.1.3.1 General Description of Geochemical Retardation
 - 4.1.3.2 Analytical Techniques
 - 4.1.3.3 Sorption
 - 4.1.3.4 Processes Affecting Radionuclide Concentrations and Specification in Solution

TABLE A.1 (Cont'd)

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- 4.1.3.5 Matrix Diffusion
 - 4.1.3.6 Radionuclide Transport
 - 4.1.3.7 Geochemical Retardation in the Host Rock and Surrounding Units -- Anticipated Conditions
 - 4.1.3.8 Geochemical Retardation in the Host Rock and Surrounding Units -- Unanticipated Conditions
 - 4.2 Geochemical Effects of Waste Emplacement
 - 4.2.1 Anticipated Thermal Conditions Resulting from Waste Emplacement
 - 4.2.2 Hydrothermal Alteration due to the Thermal Pulse
 - 4.2.3 Changes in Water Chemistry due to the Thermal Pulse
 - 4.2.4 Effects of the Thermal Pulse on Radionuclide Migration
 - 4.3 Natural Analogs and Related Field Tests
 - 4.3.1 Natural Analogs
 - 4.3.2 Related Field Tests
 - 4.4 Geochemical Stability
 - 4.4.1 Potential Man-Induced Effects
 - 4.4.2 Potential Effects of Natural Changes
 - 4.5 Summary and Conclusions
 - 4.5.1 Summary of Significant Results
 - 4.5.2 Relation to Design
 - 4.5.3 Identification of Information Needs
 - 4.5.4 Relation to Regulatory Guide 4.17

References

Section 5 -- Climatology and Meteorology

- 5.0 Introduction
- 5.1 Recent Climate and Meteorology
 - 5.1.1 Climate
 - 5.1.2 Local and Regional Meteorology
 - 5.1.3 Site Meteorological Measurement Program
- 5.2 Long-Term Climatic Assessment
 - 5.2.1 Paleoclimatology
 - 5.2.2 Future Climatic Variation
 - 5.2.3 Site Paleoclimatic Investigation
- 5.3 Summary and Conclusions
 - 5.3.1 Summary of Significant Results
 - 5.3.2 Relation to Design
 - 5.3.3 Identification of Information Needs
 - 5.3.4 Relation to Regulatory Guide 4.17

TABLE A.1 (Cont'd)

References

Section 6 -- Conceptual Design of a Repository

5.0 Introduction

6.1 Design Basis

- 6.1.1 Repository Design Requirements
- 6.1.2 Reference Design Data Base
- 6.1.3 Analytical Tools for Geotechnical Design
- 6.1.4 Structures, Systems, and Components Important to Safety
- 6.1.5 Barriers Important to Waste Isolation

6.2 Current Repository Design Description

- 6.2.1 Background
- 6.2.2 Overall Facility Design
- 6.2.3 Repository Operations
- 6.2.4 Design of Surface Facilities
 - 6.2.4.1 Foundation Considerations
 - 6.2.4.2 Flood Protection
- 6.2.5 Shaft and Ramp Design
- 6.2.6 Subsurface Design
 - 6.2.6.1 Excavation Techniques
 - 6.2.6.2 Ground Support
 - 6.2.6.3 Ground-Water Control
- 6.2.7 Backfill of Underground Opening
- 6.2.8 Shaft and Borehole Seals
 - 6.2.8.1 Shaft Seal Characteristics
 - 6.2.8.2 Shaft Seal Emplacement
 - 6.2.8.3 Borehole Seal Characteristics
 - 6.2.8.4 Borehole Seal Emplacement

6.3 Assessment of Design Information Needs

- 6.3.1 Introduction
- 6.3.2 Design of Underground Openings
- 6.3.3 Backfill
- 6.3.4 Strength of Rock Mass
- 6.3.5 Sealing of Shafts, Boreholes, and Underground Openings
- 6.3.6 Construction
- 6.3.7 Design of Surface Facilities
- 6.3.8 Repository System Component Performance Requirements

6.4 Summary of Design Issues and Data Needs

References

TABLE A.1 (Cont'd)

Section 7 -- Waste Package

- 7.0 Introduction
- 7.1 Emplacement Environment
- 7.2 Design Basis
- 7.3 Design Descriptions
 - 7.3.1 Reference Design
 - 7.3.2 Alternative Designs
- 7.4 Research and Development Status
- 7.5 Summary and Conclusions

References

Part B: Site Characterization Program

Section 8 -- Site Characterization Program

- 8.0 Introduction
- 8.1 Rationale for Planned Site Characterization Program
 - 8.1.1 Identification of Information Needs
 - 8.1.2 Prioritization of Information Needs
 - 8.1.3 Approach to Obtain Information
 - 8.1.4 Utilization of Information
 - 8.1.4.1 Determination of Whether Criteria Developed Pursuant to Paragraph 112(a) of NWPA Are Met
 - 8.1.4.2 Site Suitability
 - 8.1.4.3 Issue Resolution
- 8.2 Issues to Be Resolved and Information Required during Site Characterization
 - 8.2.1 Issues to Be Resolved
 - 8.2.1.1 Mission Plan Issues
 - 8.2.1.2 Site-Specific Issues
 - 8.2.2 Approach to Issue Resolution
- 8.3 Planned Tests, Analyses, and Studies
 - 8.3.1 Site Program
 - 8.3.1.1 Overview
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TABLE A.1 (Cont'd)

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- 8.3.1.5 Geochemistry
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 - 8.3.2 Repository
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TABLE A.1 (Cont'd)

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- 8.6.5 Administrative Quality Assurance Procedures
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 - 8.7.3 Mitigation of Any Significant Adverse Environmental Impacts
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References

Source: *Salt Repository Project, FY 84 Technical Project Plan, ONWI-19 (FY 84)*, Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio (Aug. 1984).

The U.S. Nuclear Regulatory Commission recognizes that certain data requested in some sections of Regulatory Guide 4.17 may not be available or may not be available in the level of detail required at the time an SCP is submitted. However, the goal is for site characterization programs to be formulated such that the level of detail eventually reaches that required for licensing. Therefore, panelists should keep the following questions in mind with regard to data presented in Part A:

- Are the methods of data collection described clearly?
- Have the data been collected using methods considered appropriate by the technical community?
- Is there evidence that the data collection efforts included quality assurance procedures?
- Are the data presented in a manner that permits readers to draw their own conclusions?
- Are the methods of data reduction, analysis, and evaluation described clearly?
- Are the limitations and uncertainties associated with data collection and data interpretation discussed?
- Are inferences clearly differentiated from the data upon which the inferences are based?
- Are the interpretations supported by the available data?

- Are alternative hypotheses discussed wherever appropriate?
- Are conclusions concerning resolved issues supported by the available data?

Reviewers will also need to consider questions closely related to their disciplines. Examples of several geoengineering questions follow:

- Are data provided on relevant mechanical properties?
- Are data on mechanical properties provided for all relevant geologic formations present at the given site?
- Have the index property tests been carried out over a range of temperature and pressure conditions sufficiently large to bound the conditions expected in a repository during operation?
- Have the thermal and thermomechanical property data been obtained from tests whose temperature and pressure conditions bound the conditions expected in a repository?
- Are the reported values for the stress field reasonable?
- Does the discussion of excavation characteristics properly assess the relevance of excavation damage to design of repository openings and shafts?

The most important questions are those related to particular performance objectives in 10 CFR 60 and those that help to demonstrate regulatory compliance. Each reviewer must determine which issues have been satisfactorily resolved and which issues remain to be resolved (see Secs. 3.2.2 and 3.3.5 of this report). This step is a necessary prerequisite to reviewing the site characterization program itself.

A.2 CONCEPTUAL DESIGN OF A REPOSITORY (SECTION 6)

Inclusion of a conceptual design of a repository appropriate for the site in the SCP is required by 10 CFR 60.17(c). The purpose is to help identify where information is lacking so that these needs can be addressed during site characterization. The repository design must be sufficiently detailed to allow NRC to judge the completeness and relevance of planned site characterization activities. In particular, NRC must determine whether the site characterization program provides for the right kinds and amounts of testing to fulfill licensing requirements.

Before reviewing the parts of Sec. 6.3 (Assessment of Design Information Needs) relevant to their specialties, reviewers should read Secs. 6.1 (Design Basis) and 6.2 (Current Repository Design Description). If a major design omission is discovered, it should be mentioned. However, it is inappropriate for panelists to become involved in a

detailed critique of the proposed conceptual design. For the most part, the design is a "given" against which to measure data needs.

A.2.1 Design Basis

Reviewers should satisfy themselves that the design criteria are necessary and sufficient. Whenever ranges of values are given for single parameters, reviewers should consider the relevance of the given range and the level of confidence in the expected value falling within the given range. Reviewers should also consider whether all structures, systems, and components important to safety have been identified.

A.2.2 Current Repository Design Description

Section 6.2 should describe, in considerable detail, the conceptual design of the repository as it stands when the SCP is written. Reviewers should bear in mind that designs may change as better information becomes available.

Especially important are the provisions for waste retrieval, if any, that have been made and the effect of these provisions on repository design. Have all potential scenarios requiring retrieval been considered?

A.2.3 Assessment of Design Information Needs

Design of Underground Openings. Section 6.3 should include the layout and design of proposed storage rooms, main entries, return airways, and any other proposed subsurface openings. These plans should show the relationship of the repository openings to openings used in proposed plans for in situ testing and to known or inferred geologic or hydrologic structures. They should identify the proposed locations of shafts and indicate whether the shaft(s) used for in situ testing are to be incorporated into the repository.

Reviewers should respond to the following questions.

- Has creep been properly considered in specifying the cross sections of openings?
- Are the shafts of sufficient size to perform their stated functions?
- Is the design of the ventilation system(s) adequate?
- Is the refrigeration/cooling capacity sufficient?
- Is there proper separation between the development and emplacement ventilation circuits in the repository?

- Are the dimensions of the storage rooms large enough to allow emplacement and retrieval of waste packages?
- Are the pillars sufficiently large so that they will most probably not yield?

Backfill. The proposed characteristics and functions of the backfill should be described, as should the relationships between the physical, chemical, and mechanical properties of the backfill and the expected conditions of the site (e.g., temperature, stress level, and radiation).

Reviewers should respond to the following questions.

- Is the proposed backfill placement method reasonable and practical?
- Are the anticipated chemical interactions among the waste package, backfill, and host rock realistic?
- Do the properties of the backfill yield an optimum isolation capability?

Strength of Rock Mass. The information provided on the repository conceptual design should include the design values used for the mechanical properties of the rock. For repositories in salt, a clearly identified separation should be made between the properties of the salt and nonsalt rocks. The rock mechanics information should be presented in sufficient detail to show the relationship between the mechanical properties and the design.

Reviewers should respond to the following questions.

- Are the effects of radiation on mechanical properties (if any) adequately considered?
- Are the models used to aid in developing the conceptual design applicable? Have the results of modeling been correctly interpreted? Are alternative interpretations possible? Would alternative modeling methods/codes give better results?
- Are the mechanical properties for which design values have been given appropriate for salt rocks. Are the design values for the mechanical properties of the nonsalt rocks reasonable?

Sealing of Shafts, Boreholes, and Underground Openings. The SCP should present the proposed treatment of the disturbed rock zone surrounding openings and excavated surfaces. The proposed methods for controlling the ingress of groundwater to the facility

should also be provided, as should the proposed method(s) for sealing shafts and boreholes. Available laboratory and field data should be provided, together with a discussion of the inferred site conditions upon which the design is based.

Reviewers should respond to the following questions.

- Are the stated mechanical, chemical, and hydrologic properties of the proposed sealing materials appropriate for salt?
- Will seals composed of the proposed materials satisfy the performance objectives for engineered barriers?
- Are the methods proposed for seal placement practical?

Construction. The construction techniques being considered should be discussed, including proposed excavation techniques, rock reinforcement or support techniques (if any), and groundwater collection and control methods. Although groundwater is of little consequence in the salt, it will be present in the strata overlying the salt. Hence, the shaft design must allow either for groundwater collection or for sealing of water-bearing horizons.

Reviewers should satisfy themselves that proposed construction methods are applicable to the salt medium and that resulting damage to the rock surrounding openings is minimized.

Design of Surface Facilities. The surface materials and the foundation soil and rock being considered in the design of foundations for surface facilities should be described. Although not specifically mentioned in Regulatory Guide 4.17, reviewers should also satisfy themselves that the design of stockpiles of broken rock and holding ponds for process, potable, or seepage water are adequate.

A.2.7 Repository System Component Performance Requirements

Regulatory Guide 4.17 requires that numerical values be provided for the performance requirements for repository system components and for engineered and natural barriers. These values are to be used for determining whether more information is necessary to ensure that performance will be satisfactory. The values are to be found in Sec. 8.3.5. An explicit description of the steps to be taken in obtaining more information and a clear justification of why these particular steps are to be taken in going from Part A to Part B should be provided.

A.3 WASTE PACKAGE (SECTION 7)

According to a draft revision of Regulatory Guide 4.17, the section of an SCP dealing with the waste form and package should:

Evaluate the principal candidate waste forms and packages that may be considered appropriate for the site, and describe how the range of environments anticipated at the site and the resulting design limits would affect these waste forms and packages. *To the extent that the information is available prior to site characterization [emphasis added]*, describe and compare alternative waste forms and packages being considered and their development programs. Provide a basis for evaluating the adequacy of the information to be produced in the site characterization program.

From this guideline, it can be anticipated that the details of the "principal" or "alternative" waste package designs for a particular site will evolve. Thus, even the definitions of terms are somewhat indefinite. Nevertheless, the following definitions from 10 CFR 60 will be used in this discussion:

Underground Facility -- the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals.

Waste Form -- radioactive waste materials and any encapsulating or stabilizing matrix.

Waste Package -- waste form and any containers, shielding, packing, and other absorbent materials immediately surrounding an individual waste container.

Engineered Barrier System -- the waste package and the underground facility.

Containment Period -- period during which wastes are contained within the engineered barrier system. (Following this period, isolation of the wastes from the accessible environment is achieved by virtue of the characteristics of the geologic repository.)

The "waste package" as defined above includes three components: the waste form, which may be a solid vitreous cylinder or a cluster of fuel rods; a metal container, which may consist of one or more metal layers that may be separated by air gaps or insulating material; and the packing material, if any, which may be ground-up host material or clay, that surrounds the metal container and separates it from the host medium.

These three components may vary in design from site to site. The packing material may be excluded or, if included, may not be regarded as contributing to containment of the radioactive waste. In any case, these components should be regarded as a coupled system. In other words, even though one component may not be regarded as contributing significantly to the containment system, the possibility of its having an adverse effect on the performance of the waste package must be evaluated.

A.3.1 Objectives of Waste Package Design

The two main objectives of waste package design are summarized in the following quotes from 10 CFR 60:

Containment of HLW [high-level waste] within the waste packages will be substantially complete for a period to be determined by the Commission, taking into account the factors specified in subsection 60.113(b) [of 10 CFR 60], provided that such period shall be not less than 300 years nor more than 1000 years after permanent closure of the geologic repository; and

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 1000 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 1000 years of radioactive decay.

A third objective of waste package design is to ensure safe retrievability for the first 50 years of operation.

A.3.2 Objective of the Review Process and the Major Issues

The primary objective of reviewing the section in an SCP on the waste form and package (Sec. 7) is to determine if the authors have adequately demonstrated that their proposed design(s) will meet the design objectives stated above. Such demonstration should focus on the following major questions:

- When, how, and at what rate will invading fluids penetrate the packing material around the waste container and come into contact with the container surface?
- When, how, and at what rate will invading fluids penetrate the metal container and come into contact with the waste form?
- When, how, and at what rate will radionuclides be released from the waste form?
- How and at what rates will radionuclides be transported through the failed waste package and come into contact with the host medium?

A.3.3 Contents of Section 7 of an SCP and Review Questions

Section 7 of an SCP will probably consist of five subsections in accordance with Regulatory Guide 4.17. Each of these five subsections is briefly discussed below, together with pertinent review questions.

Description. This subsection should describe the forms and properties of candidate waste packages.

- Does the description clearly define the physical form and mechanical properties, chemical form and chemical properties, radionuclide inventory, thermal output, radiation properties, and expected temperatures of the waste form?
- Similarly, are the pertinent properties of the metal container and packing material, if any, clearly described?
- Are additional information and data needed? If so, are these needs incorporated into future program plans?

Design Concepts. This subsection should describe the waste form and package design concepts considered appropriate for the specific site and conceptual repository design. Individual barriers and estimates of their reliability should be discussed.

- Has it been demonstrated (or is there a well-defined plan to demonstrate) that the design concepts will achieve the design objectives for the waste package?
- What uncertainties are associated with the design concepts?
- What additional information and data are required?

Research and Development. This subsection should describe the status of research and development (including planned activities) related to demonstrating that the proposed waste package design(s) will meet performance objectives.

- Have the pertinent information and data needs been addressed?
- Have the proposed waste package designs been adequately evaluated, and have the four issues noted in Sec. A.3.2 been properly addressed? If not, have such activities been included in the research plans?
- Are the times allocated for planned research and development activities consistent with the program's overall time constraints?
- What alternative directions, if any, should be taken?

Emplacement Environment. Given available information and data, this subsection should describe, to the extent possible, the environment into which the waste packages are to be emplaced. In particular, the conditions and processes that could affect the performance of the waste package should be described, and upper bounds on these effects should be given.

- Have the major chemical conditions and processes within the waste package, and between the waste package and its environment, that could affect the performance of the waste package been identified?
- Have these effects and their uncertainties been adequately evaluated, or are there plans to do so?
- Have the physical conditions and processes within the waste package, and between the waste package and its environment, that could influence the performance of the waste package been identified?
- Have these effects and their uncertainties been adequately evaluated, or are there plans to do so?
- Have the nuclear conditions and processes within the waste package, and between the waste package and its environment, that could influence the performance of the waste package been identified?
- Have these effects and their uncertainties been adequately evaluated, or are there plans to do so?
- Have claims of the dominance of certain failure modes been properly supported?
- Have the additional information needs, if any, been specified and incorporated into the planned research?

Alternative Waste Forms and Waste Packages. This subsection should contain sufficient information about proposed alternative waste forms and packages to show full integration of the criteria and decision processes for site selection with those for waste form and waste package selection.

- Are the advantages and disadvantages of the various alternative designs described?
- Are information and data needs addressed?
- Are the times specified for gathering the needed information and data compatible with the program's overall time constraints.

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APPENDIX B
SCHEDULE FOR SITE CHARACTERIZATION

APPENDIX B**SCHEDULE FOR SITE CHARACTERIZATION**

The adequacy of site characterization programs must be assessed in terms of the requirements of the licensing process. In other words, site characterization activities must provide the information needed to demonstrate, with reasonable assurance, that the site and the repository design meet the performance objectives specified in the regulations. Because of limited time and resources, no more than the necessary minimum of site characterization activities can be justified. With respect to limited time, the following points must be considered:

- In NWPA, a schedule is mandated for siting and constructing a repository for high-level radioactive waste. On December 19, 1984, as required by NWPA, the Secretary of DOE recommended three sites to the President for characterization. Each of the site nominations was accompanied by a draft environmental assessment. The three sites recommended were a basalt site near Hanford, Washington; a tuff site at the Nevada Test Site; and a salt site in the Permian Basin in the Panhandle of Texas. The President may delay for no more than six months his decision to approve or disapprove a candidate site.
- The Act further requires that an SCP be submitted to NRC by the Secretary of DOE before the sinking of a shaft at any site. During the conduct of site characterization activities, progress reports must be submitted at least every six months.
- No later than March 31, 1987, the President must recommend to Congress the site that he considers best qualified for an application for construction authorization. The President may, however, extend the deadline by one year. The Secretary of DOE must submit an application for construction authorization to NRC within 90 days of the date the recommendation is approved. The NRC must issue a decision regarding construction authorization within three years of receipt of the application, or by January 1, 1989, whichever is later.
- The schedule therefore mandates that the site characterization program must take no longer than four years, including time for hearings and approvals. Allowing about three years for mobilization, the sinking of the shaft, and the driving of drifts, the time available for the actual testing is about one year. In other words, test methods proposed in the site characterization program must be capable of generating meaningful data during time intervals of 6-12 months.

Figure B.1 gives the overall project schedule as of July 1984. Site characterization will not be halted as soon as construction authorization is received. Indeed, site characterization, including performance assessment and confirmation, will continue until site decommissioning. However, sufficient information must be available prior to construction authorization to provide reasonable assurance that the performance objectives of 10 CFR 60 will be met.

FIGURE B.1 Salt Repository Project Schedule as of July 1984 (Source: Salt Repository Project, FY 84 Technical Project Plan, ONWI-19 [FY 84], Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, Ohio [Aug. 1984])

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