NUREG-1323
Rev. 1

License Application Review Plan for a Geologic Repository for Spent Nuclear Fuel and High-Level Radioactive Waste

Draft Review Plan

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

DF02 1/0

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LICENSE APPLICATION REVIEW PLAN FOR A GEOLOGIC REPOSITORY FOR SPENT NUCLEAR FUEL AND HIGH LEVEL RADIOACTIVE WASTE

DRAFT REVIEW PLAN

DECEMBER 1995

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Draft NUREG-1323 Revision 1 Summary of Changes

Revision 1 of Draft NUREG-1323 [License Application Review Plan (LARP)] consists of the following changes:

Remove	Replace with
Title Page, unnumbered	Revision 1 Title page, unnumbered
Abstract, page iii	Abstract, page iii
Table of Contents, pages v to ix	Table of Contents, pages v to ix
Foreword, pages xi to xii	No replacement
Part A, all	Part A, pages 1 to 5
Review Plan 3.1.2, all	Review Plan 3.1.2, pages 3.1.2-1 to 3.1.2-9
Review Plan 3.1.3, all	Review Plan 3.1.3, pages 3.1.3-1 to 3.1.3-7
Review Plan 3.1.4, all	Review Plan 3.1.4, pages 3.1.4-1 to 3.1.4-6
Review Plan 3.2.1.2, all	Review Plan 3.2.1.2, pages 3.2.1.2-1 to 3.2.1.2-7
Review Plan 3.2.1.6, all	Review Plan 3.2.1.6, pages 3.2.1.6-1 to 3.2.1.6-7
Review Plan 3.2.1.10, all	Review Plan 3.2.1.10, pages 3.2.1.10-1 to 3.2.1.10-17
Review Plan 3.2.2.5, all	Review Plan 3.2.2.5, pages 3.2.2.5-1 to 3.2.2.5-9
Review Plan 3.2.4.1, all	Review Plan 3.2.4.1, pages 3.2.4.1-1 to 3.2.4.1-9
Review Plan 4.1.1, all	Review Plan 4.1.1, pages 4.1.1-1 to 4.1.1-8
Review Plan 4.1.2, all	Review Plan 4.1.2, pages 4.1.2-1 to 4.1.2-6
Review Plan 4.1.3, all	Review Plan 4.1.3, pages 4.1.3-1 to 4.1.3-6
Review Plan 5.1, all	Review Plan 5.1, pages 5.1-1 to 5.1-6
Review Plan 9.0, all	Review Plan 9.0, pages 9.0-1 to 9.0-7
Appendix A, all	Appendix A, pages A-1 to A-6
Appendix C, all	Appendix C, pages C-1 to C-5
Appendix D, all	Appendix D, pages D-1 to D-4
Appendix E, all	Appendix E, pages E-1 to E-27
Appendix F, all	No replacement

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License Application Review Plan
for a Geologic Repository for Spent Nuclear Fuel and High-Level Radioactive Waste

Draft Review Plan

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Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001

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ABSTRACT

The License Application Review Plan (LARP) provides guidance to the Nuclear Regulatory Commission staff in the Office of Nuclear Material Safety and Safeguards, Division of Waste Management, who will review the U.S. Department of Energy's (DOE's) license application to construct and operate a mined geologic repository for the disposal of spent nuclear fuel and other high-level radioactive waste. The LARP is intended to ensure the quality and uniformity of the staff reviews and establishes the appropriate review priorities, and presents a well-defined base from which to evaluate proposed changes in the scope and requirements of the staff reviews. Because it is a public document, it will also make available to DOE and other interested parties information on the staff's review process by describing the review strategies, methods, and acceptance criteria that the staff will use in its reviews.

The LARP is divided into three parts. Part A contains the License Application Review Strategy, which gives general guidance to the staff in conducting its license application reviews. Part B contains eight individual Review Plans, to be used by the staff to review general information in the license application. Part C contains 89 individual review plans, distributed among ten chapters, which the staff will use to review the Safety Analysis Report, the principal part of the license application in which DOE provides the information needed to demonstrate compliance with the technical requirements of 10 CFR Part 60. The organization of the individual review plans in Parts B and C is consistent with the organization of the license application as specified in the draft regulatory guide "Format and Content for the License Application for the High-Level Waste Repository." Finally, each individual review plan has a standard format consisting of the following seven sections: (1) *Applicable [10 CFR Part 60] Regulatory Requirements*; (2) *Review Strategy;* (3) *Review Methods and Acceptance Criteria*; (4) *Implementation*; (5) *Example Evaluation Findings;* and (6) *References*.

This draft version, designated Revision 1, represents the staff's latest efforts in the development of the LARP. The LARP remains, however, work in progress comprised of both completed and outlined individual review plans. Appendix D provides a status of the development of the individual review plans. This revision has deleted the Appendix F, "Identification of the Relationship between 10 CFR 60.122 and 10 CFR 60.112 and 10 CFR 60.113," which was included in Revision 0. The Commissioners have determined that the guidance provided by the LARP is sufficient so that a rulemaking is not necessary. The Foreword was also deleted. The draft LARP is a preliminary document and, as such, is subject to change.

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APPENDICES

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PART A

LICENSE APPLICATION REVIEW STRATEGY

1 LICENSE APPLICATION REVIEW OBJECTIVES

As noted earlier, NWPA requires that NRC reach a construction authorization decision 3 years after DOE submits a license application unless the Commission extends this deadline (but not by more than 12 months). The staff's current plans call for it to review DOE's license application and prepare its SER during the first 18 months of the NWPA 3-year timeframe from when the license application is docketed. The last 18 months of the NWPA 3-year timeframe will be used to conduct the licensing board hearing and for the Commission to reach the construction decision. The objective of the staff review therefore is to determine the completeness and acceptability of DOE's license application and document its findings in the SER, with respect to compliance with 10 CFR Part 60, within the first 18 months, so that the Commission can make its construction authorization decision within the last 18 months.

2 LICENSE APPLICATION REVIEW STRATEGIES

The following five strategies will be used by the staff in its review of DOE's license application to achieve the aforementioned objective:

(1) Conduct a two-phase review consisting of an initial *Acceptance Review* followed by a *Compliance Review*;

(2) Use *Compliance Reviews* to verify the acceptability of DOE's compliance demonstrations;

(3) Use results of the pre-license application reviews and supporting investigations;

(4) Use a systematic, audit approach for *Compliance Reviews* and prioritize these reviews by focusing on areas most important to repository performance (i.e., compliance with 10 CFR Part 60 performance objectives); and

(5) Select from four types of *Compliance Reviews*, including staff analyses and testing for the systematic, audit approach.

A description and rationale for each strategy is given below.

2.1 Conduct a Two-Phase Review Consisting of an Initial Acceptance Review Followed by a Compliance Review

Upon DOE submittal of the license application, the staff will conduct an *Acceptance Review* to determine if the license application is complete and acceptable for docketing. This review will focus on the inclusion, in the license application, of those procedural elements that are defined in 10 CFR 60.21(a-c) and 60.22(a-e) and the associated 10 CFR Part 60 technical requirements that may affect the issuance or denial of a construction authorization. If the license application is not complete, docketing will be denied, until DOE provides such additional information as may be required for the license application to be docketed. The staff's use of the *Acceptance Review* is required by 10 CFR 2.101(f). In addition, the *Acceptance Review* is expected to contribute significantly to meeting the NWPA-mandated 3-year licensing time period by not starting the 3-year review process until DOE submits the information needed for a complete and acceptable license application.

Once the license application is docketed, the NWPA 3-year timetable will begin, and the staff will conduct *Compliance Reviews* (either *General Information Reviews* or *Safety Reviews*) over the next 18 months to determine the acceptability of DOE's demonstrations of compliance with the regulatory requirements of 10 CFR Part 60. The results of the *Compliance Review* will be documented as staff *Evaluation Findings* in the staff's SER.

2.2 Use Compliance Reviews to Verify the Adequacy of DOE's Compliance Demonstrations

NRC's overall licensing philosophy is that the safe operation of any nuclear facility is the licensee's responsibility. In the case of the geologic repository program, DOE as the licensee will need to demonstrate that it can construct and operate a geologic repository for HLW in the manner defined in 10 CFR Part 60.

It is not the staff's responsibility to demonstrate compliance with the requirements in 10 CFR Part 60; that is DOE's statutory responsibility. This review strategy recognizes that the staff will need to conduct the necessary reviews and supporting activities to gain confidence that the conclusions reached by DOE in its license application lead to an acceptable demonstration of compliance with 10 CFR Part 60. However, the staff will not duplicate all of DOE's demonstrations. Rather in the manner defined by the individual review plans, the staff will undertake compliance reviews to verify and document through *Evaluation Findings*, DOE's compliance demonstrations (see Figure 1). This strategy is consistent with NRC's statutory licensing role.

2.3 Use Results of the Pre-License Application Reviews and Supporting Investigations

Reports prepared by DOE during the pre-licensing phase and referenced by DOE in its license application will include a substantial amount of detailed technical information such as data, methodologies, detailed analyses, and data interpretations. The staff will conduct pre-license application, technical reviews of some of these supporting reports. Therefore, where information in these reports has been previously reviewed, it will ordinarily not need to be reviewed again during the license application *Compliance Review*, unless additional information calls into question the staff's earlier reviews. However, the staff will review how the information is used in demonstrating compliance.

The staff concerns identified by its pre-license application reviews will continue to be documented in letters to DOE and are identified as open items. All staff concerns are important for DOE to resolve; however, the staff might consider some to be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent the staff from conducting a meaningful review, or the Commission from making a decision regarding construction authorization, within the 3-year statutory time period. For this reason, the staff considers this type of concern to be an objection to license application submittal. Concerns regarding lack of adequate information to be able to evaluate *Key Technical Uncertainties* (see Section 3.2 of the "Introduction") or other concerns that would need a long time to resolve, such as new or additional testing or development of new or revised analytical methods, are examples of this type of objection.

The staff will track DOE's resolution of all concerns, in particular objections to license application submittal. In Section 1.6.2 of its FCRG, the staff has asked that DOE provide the status of any unresolved objections in its license application. As part of the *Acceptance Review* of the license application and before a decision on docketing the license application, the staff will evaluate the effect of any unresolved objections, both individually and in combination with others, on the staff's ability to conduct a meaningful compliance review or the commission from making a decision regarding construction authorization within the 3-year statutory time period.

This strategy should streamline the *Acceptance Review* and result in *Compliance Reviews* that focus less on detailed supporting information and methodologies and focus more on how the detailed information was used to demonstrate compliance. Therefore, this strategy will contribute to the effectiveness and efficiency of the license application review and is considered essential for the staff to be able to conduct its license application review in 18 months.

2.4 Use a Systematic, Audit Approach for Compliance Reviews and Prioritize these Reviews by Focusing on Areas Most Important to Repository Performance (i.e., Compliance with 10 CFR Part 60 Performance Objectives)

This review strategy consists of conducting a complete *Compliance Review* of the broad level of information in the license application and more detailed reviews on an audit basis (in selected areas), to determine if the detailed information supports DOE's demonstrations in the license application. This strategy can be envisioned as a "vertical slice" into the detailed levels.

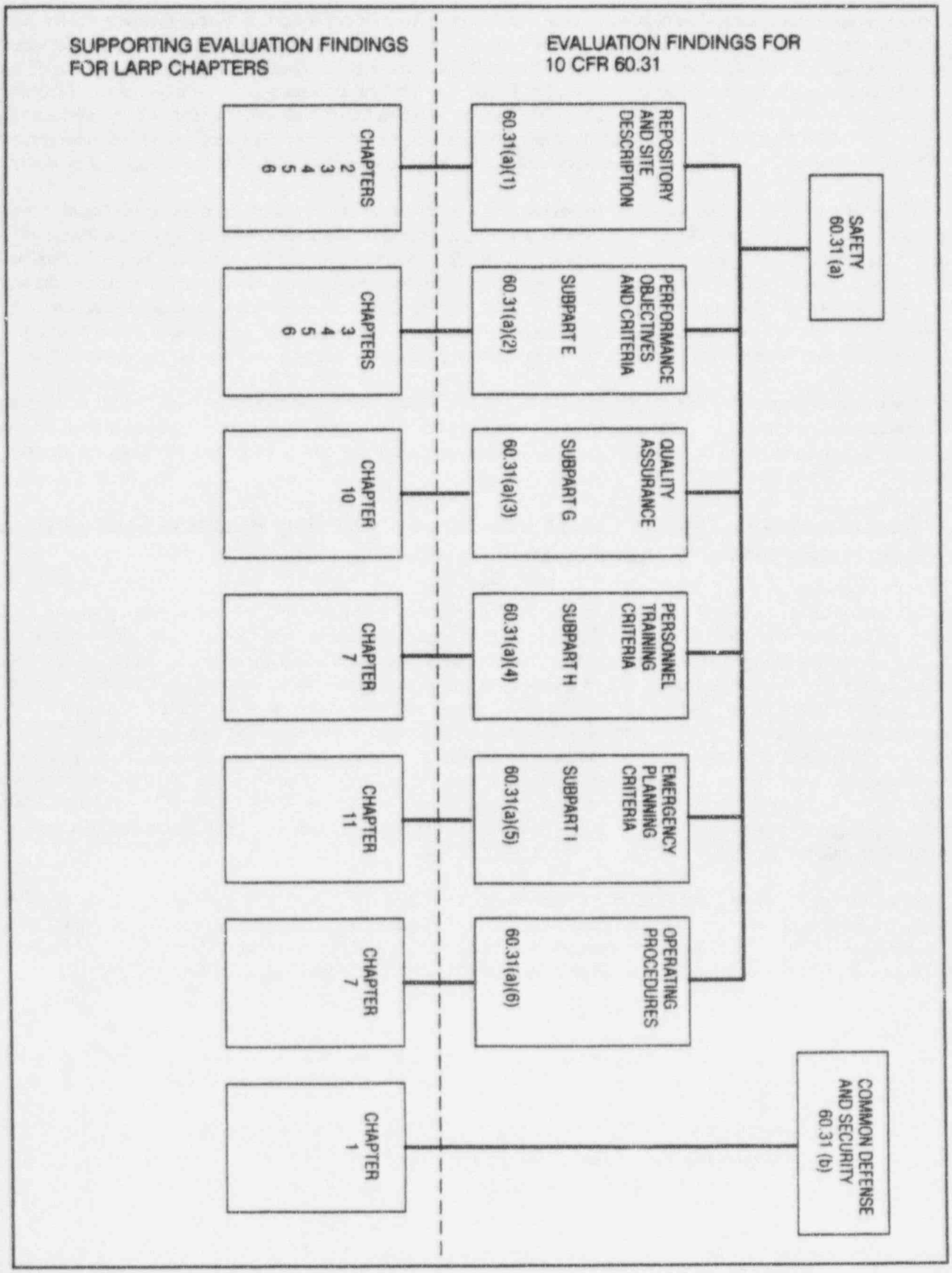

Figure 1. General Logic Structure of Staff Evaluation Findings in the Safety Evaluation Report.

This strategy describes a method to prioritize the review by identifying the higher priority areas that will receive more attention by the staff (see License Application Review Strategy No. 5, below). Areas selected for detailed review will be primarily focused on technical uncertainties judged to be most important to repository performance. The staff has developed and is applying criteria to systematically identify the technical uncertainties most important to repository performance (i.e., technical uncertainties that pose a risk of noncompliance with one or more of the performance objectives of 10 CFR Part 60). The staff's judgment in applying these criteria is supported by insights gained from reviews of DOE's program, staff performance assessments, and the work by other parties, including the concerns they raise.

This strategy also recognizes that, because of the nature and complexities of the repository program, some flexibility must be maintained while conducting the staff's *Compliance Reviews*. Therefore, the staff has flexibility in how it applies the LARP at the time of review; however, the intent is to follow the LARP unless there is a justified change that has been approved by management. Therefore, the types of reviews described in the LARP are the minimum review that the staff would do. Changes to refocus a review might be justified to respond to new information, comments raised by other parties, or to go into more detail in order to adequately review a particular issue. Changes may also be needed to place lesser emphasis on a review if an issue turns out to have less significance to performance than previously envisioned.

This review strategy not only ensures that the staff will conduct a complete review at a broad level, but also directs the staff to focus detailed attention on those areas most important to performance and that will likely be the areas most difficult to consider in licensing. Therefore, this strategy is intended to enhance the effectiveness and efficiency of the staff's review.

2.5 Select from Four Types of Compliance Reviews, Including Results of Staff Analyses and Testing for the Systematic, Audit Approach

The staff will select the type(s) of reviews from four different types of compliance reviews and supporting investigations appropriate for the review priority determined by the systematic, audit approach described above, to determine compliance with 10 CFR Part 60. These review types are described in detail in Appendix B and are shown in Figure 2. Therefore, selected license application information will be reviewed in greater detail and further evaluated and verified, using the results of staff investigations. These investigations might include analyses where the staff uses the results of its own performance assessments by applying either available numerical models or models it has developed independently. It should be emphasized that the burden is completely on DOE to provide the data and assessments to support its performance assessments in the license application. In most cases, the staff will rely on DOE data, independently reviewed by the staff, as input to the staff's performance assessments. In addition, the results of staff field or laboratory testing might also be used to either verify some of DOE's results or simply to gain an independent understanding of a condition or process, to enhance the staff's ability to conduct detailed review.

Finally, the variety of reviews and independent staff investigations described above will provide evaluations of DOE's program from different perspectives and different levels of detail, resulting in complementary lines of evidence regarding the acceptability of DOE's compliance demonstrations in its license application. Therefore, this strategy should improve the effectiveness of the staff's verification and thus increase the staff's confidence in making findings.

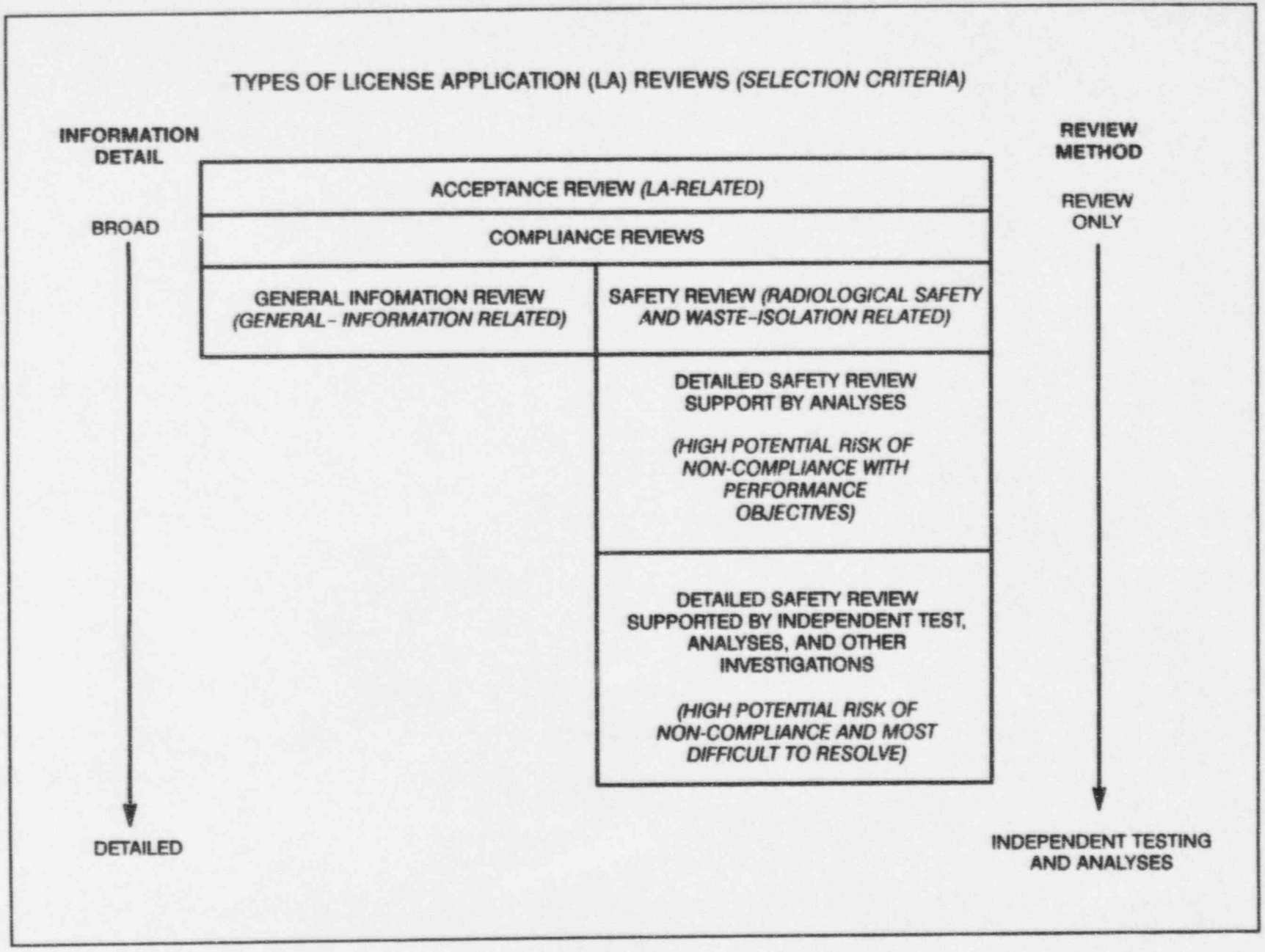

Figure 2. Types of License Application Reviews and Associated Selection Criteria.

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

DESCRIPTION OF INDIVIDUAL SYSTEMS AND CHARACTERISTICS OF THE SITE: HYDROLOGIC SYSTEM

1 APPLICABLE REGULATORY REQUIREMENT(S)

For this review plan, the staff will determine if the regulatory requirement for the description and assessment of the hydrologic system of the site, defined in 10 CFR 60.21(c)(1)(i-ii), as applicable, has been met:

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurf: conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description snall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

* * * * *

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

* * * * *

(13) An identification and evaluation of the natural resources of the geologic setting, including estimates as to undiscovered deposits, the exploitation of which could affect the ability of the geologic repository to isolate radioactive wastes. Undiscovered deposits of resources characteristic of the area shall be estimated by reasonable inference based on geological and geophysical evidence. This evaluation of resources, including undiscovered deposits, shall be conducted for the site and for areas of similar size that are representative of and are within the geologic setting. For natural resources with current markets the resources shall be assessed, with estimates provided of both gross and net value. The estimate of net value shall take into account current development, extraction and marketing costs. For natural resources without current markets, but which would be marketable given credible projected changes in economic or technological factors, the resources shall be described by physical factors such as tonnage or other amount, grade, and quality.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

The descriptive material provided in Section 3.1.2 of the license application will support detailed *Safety Reviews* of information contained elsewhere in the license application. Thus, the information contained in Section 3.1.2 will be reviewed in parallel with the information contained in those sections of the license application concerning siting conditions, design, and performance. Therefore, during the Acceptance Review of Section 3.1.2, the reviewer should determine that the appropriate descriptive information needed to support the *Safety Reviews* has been provided in this section of the license application, and that the information is both internally consistent and consistent from section-to-section.

If it is determined that the descriptive information in Section 3.1.2 of the license application is inadequate to support the *Compliance Reviews* described above, then additional information will be requested from DOE, before these *Compliance Reviews* can begin.

2.2 Compliance Review

2.2.1 Safety Review

As noted above, most of the descriptive material provided in this section of the license application will be initially reviewed and then evaluated as part of the *Compliance Review* of those sections of the license application which use this information. Section 4.2 ("Interfaces") of this review plan describes where the *Compliance Review(s)* of the information in this section of the license application will take place.

For each of the *Compliance Reviews* described in Section 4.2, a portion of the review will therefore focus on whether the descriptive information provides an acceptable basis for the associated assessment. Thus, this portion of the review will result in an *Evaluation Finding* for the specific supporting information in that section of the license application in which it is being used.

Therefore, under this review plan, no additional *Compliance Review* will be done; the staff will make only an "aggregate" *Evaluation Finding* for the whole description of the hydrologic system of the site. Such a finding would collectively reflect the sum of the specific *Evaluation Findings* made in those sections of the license application described in Section 4.2.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare information in the license application concerning the description of the Hydrologic System of the site with the corresponding section of the FCRG and with the resolution status of staff objections to the license application submittal in the Open Item Tracking System (OITS). The staff will then determine whether this information meets the following Acceptance Criteria:

(1) The information presented in the license application is clear, completely documented, consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) DOE has either resolved, at staff level, NRC objections to the license application submittal which apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections. Namely, it should be determined whether DOE has:

- Identified all unresolved objections.
- Explained the differences between NRC and DOE positions which precluded resolution of each objection.
- Described pertinent attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful *Compliance Review* or the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the Acceptance Criteria specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented in the staff's Safety Evaluation Report (SER) to provide the basis for the actual *Evaluation Findings*.

3.2.1 Safety Review of 10 CFR 60.21(c)(1)

The staff's *Compliance Review* will consist of the following two steps. First, the staff will review the descriptive information provided for the hydrologic system. This will provide an overall understanding of how DOE has presented its information on the many individual aspects of the hydrologic system and how this information has been integrated. The types of descriptive information to be provided to other review plans are listed in Section 4.2.2.

Second, after the staff has conducted each of the *Compliance Reviews* for those sections of the license application identified in Section 4.2.2, the individual *Evaluation Findings* from these reviews will be considered on balance to determine whether the following Acceptance Criterion has been met:

(1) The descriptive information for the hydrologic system provides an acceptable basis for all of the associated assessments that rely on this information.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	DWM/PAHB	Hydrologic Transport Section
Support:	None	

4.2 Interfaces

4.2.1 Input Information

Input Information	*Review Plan No.*
None	None

4.2.2 Output Information

Output from activities associated with this review plan will provide specific information important for use in other review plans as the following table indicates.

Output Information	*Review Plan No.*
See FCRG — Section 3.1.2 for examples	3.2.2.1 - FAC: Nature and Rates of Hydrogeologic Processes
See FCRG — Section 3.1.2 for examples	3.2.2.3 - FAC: Groundwater Travel Time Substantially Exceeding 1000 Years
See FCRG — Section 3.1.2 for examples	3.2.2.4 - FAC: Unsaturated Zone Hydrogeologic Conditions
See FCRG — Section 3.1.2 for examples	3.2.3.1 - FAC: Nature and Rates of Geochemical Processes
See FCRG — Section 3.1.2 for examples	3.2.3.2 - FAC: Geochemical Conditions
See FCRG — Section 3.1.2 for examples	3.2.4.1 - FAC: Precipitation that is a Small Percentage of Potential Evapotranspiration (Potentially Adverse Condition)
See FCRG — Section 3.1.2 for examples	3.2.1.4 - PAC: Evidence of Dissolution
See FCRG — Section 3.1.2 for examples	3.2.1.10 - PAC: Evidence of Extreme Erosion
See FCRG — Section 3.1.2 for examples	3.2.1.11 - Presence of Naturally Occurring Materials
See FCRG — Section 3.1.2 for examples	3.2.1.13 - PAC: Evidence of Drilling
See FCRG — Section 3.1.2 for examples	3.2.2.5 - PAC: Flooding
See FCRG — Section 3.1.2 for examples	3.2.2.6 - PAC: Human Activity and Groundwater
See FCRG — Section 3.1.2 for examples	3.2.2.7 - PAC: Natural Phenomena Affecting Groundwater
See FCRG — Section 3.1.2 for examples	3.2.2.8 - PAC: Structural Deformation and Groundwater
See FCRG — Section 3.1.2 for examples	3.2.2.9 - PAC: Changes to Hydrologic Conditions
See FCRG — Section 3.1.2 for examples	3.2.2.10 - PAC: Complex Engineering Measures
See FCRG — Section 3.1.2 for examples	3.2.2.11 - PAC: Potential for Unsaturated Zone Saturation
See FCRG — Section 3.1.2 for examples	3.2.2.12 - PAC: Perched Water Bodies
See FCRG — Section 3.1.2 for examples	3.2.3.4 - PAC: Groundwater Conditions and the Engineered Barrier System
See FCRG — Section 3.1.2 for examples	3.2.3.7 - PAC: Gaseous Radionuclide Movement
See FCRG — Section 3.1.2 for examples	3.2.4.2 - PAC: Changes to Hydrologic System from Climate
See FCRG — Section 3.1.2 for examples	3.3 - Assessment of Compliance with the Groundwater Travel Time Performance Objective
See FCRG — Section 3.1.2 for examples	4.5 - Assessment of Integrated GROA Compliance with the Performance Objectives
See FCRG — Section 3.1.2 for examples	4.5.1 - Protection Against Radiation Exposures and Releases of Radioactive Material to Unrestricted Areas

Output Information	*Review Plan No.*
See FCRG — Section 3.1.2 for examples	4.5.2 - Retrievability of Waste
See FCRG — Section 3.1.2 for examples	5.4 - Assessment of Compliance with the Engineered Barrier System Performance Objectives
See FCRG — Section 3.1.2 for examples	6.1 - Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials
See FCRG — Section 3.1.2 for examples	6.2 - Assessment of Compliance with the Individual Protection Requirements
See FCRG — Section 3.1.2 for examples	6.3 - Assessment of Compliance with the Groundwater Protection Requirements
See FCRG — Section 3.1.2 for examples	8.1.2 - Performance Confirmation Program for the Natural Systems of the Geologic Setting: Hydrologic System
See FCRG — Section 3.1.2 for examples	8.4 - Radiation Protection During Performance Confirmation
See FCRG — Section 3.1.2 for examples	4.1 - Description of the GROA Structures, Systems, and Components
See FCRG — Section 3.1.2 for examples	4.1.1 - Surface Facilities
See FCRG — Section 3.1.2 for examples	4.1.2 - Shafts and Ramps
See FCRG — Section 3.1.2 for examples	4.1.3 - Underground Facility
See FCRG — Section 3.1.2 for examples	4.1.4 - Radiation Protection Systems
See FCRG — Section 3.1.2 for examples	4.2 - Assessment of Compliance with Design Criteria for Surface Facilities
See FCRG — Section 3.1.2 for examples	4.3 - Assessment of Compliance with Design Criteria for Shafts
See FCRG — Section 3.1.2 for examples	4.4 - Assessment of Compliance with Design Criteria for the Underground Facility
See FCRG — Section 3.1.2 for examples	5.2 - Assessment of Compliance with the Design Criteria for the Waste Package and Its Components
See FCRG — Section 3.1.2 for examples	5.3 - Assessment of Compliance with the Design Criteria for the Engineered Barrier System
See FCRG — Section 3.1.2 for examples	5.5 - Radiation Protection

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing, and the subsequent *Compliance Review*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis, should be documented in the staff's SER.

5.1 Finding for Acceptance Review

The NRC staff finds the information presented by DOE, as defined by the applicable 10 CFR Part 60 Regulatory Requirements, is acceptable (not acceptable) for docketing and a subsequent *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)

TBD from ongoing *Example Evaluation Findings Task*.

6 REFERENCES

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

Table 3.1.2-1 Sections of the License Application That Require Input from the "Description of the Individual Systems and Characteristics of the Site: Hydrologic System" Section of the License Application.

License Application Section	*Title*
Siting Criteria	
(Favorable Conditions)	
3.2.2.1	Nature and Rates of Hydrogeologic Processes
3.2.2.3	Groundwater Travel Time Substantially Exceeding 1000 Years
3.2.2.4	Unsaturated Zone Hydrogeologic Conditions
3.2.3.1	Nature and Rates of Geochemical Processes
3.2.3.2	Geochemical Conditions
3.2.4.1	Precipitation that is a Small Percentage of Potential Evapotranspiration
(Potentially Adverse Conditions)	
3.2.1.4	Evidence of Dissolution
3.2.1.10	Evidence of Extreme Erosion
3.2.1.11	Presence of Naturally Occurring Materials
3.2.1.13	Evidence of Drilling
3.2.2.5	Flooding
3.2.2.6	Human Activity and Groundwater
3.2.2.7	Natural Phenomena Affecting Groundwater
3.2.2.8	Structural Deformation and Groundwater
3.2.2.9	Changes to Hydrologic Conditions
3.2.2.10	Complex Engineering Measures
3.2.2.11	Potential for Unsaturated Zone Saturation
3.2.2.12	Perched Water Bodies
3.2.3.4	Groundwater Conditions and the Engineered Barrier System
3.2.3.7	Gaseous Radionuclide Movement
3.2.4.2	Changes to Hydrologic System from Climate
Performance Objectives	
3.3	Assessment of Compliance with the Groundwater Travel Time Performance Objective
4.5	Assessment of Integrated GROA Compliance with the Performance Objectives: 4.5.1 Protection against Radiation Exposures and Releases of Radioactive Material to Unrestricted Areas 4.5.2 Retrievability of Waste
5.4	Assessment of Compliance with the Engineered Barrier System Performance Objectives
6.1	Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials
6.2	Assessment of Compliance with the Individual Protection Requirements
6.3	Assessment of Compliance with the Groundwater Protection Requirements
8.1.2	Performance Confirmation Program for the Natural Systems of the Geologic Setting: Hydrologic System
8.4	Radiation Protection during Performance Confirmation

Table 3.1.2-1 Sections of the License Application That Require Input from the "Description of the Individual Systems and Characteristics of the Site: Hydrologic System" Section of the License Application (Cont'd).

License Application Section	*Title*
Design Criteria	
4.1	Description of the GROA Structures, Systems, and Components: 4.1.1 Surface Facilities 4.1.2 Shafts and Ramps 4.1.3 Underground Facility 4.1.4 Radiation Protection Systems
4.2	Assessment of Compliance with Design Criteria for Surface Facilities
4.3	Assessment of Compliance with Design Criteria for Shafts
4.4	Assessment of Compliance with Design Criteria for the Underground Facility
5.2	Assessment of Compliance with the Design Criteria for the Waste Package and its Components
5.3	Assessment of Compliance with the Design Criteria for the Engineered Barrier System
5.5	Radiation Protection

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

DESCRIPTION OF INDIVIDUAL SYSTEMS AND CHARACTERISTICS OF THE SITE: GEOCHEMICAL SYSTEM

1 APPLICABLE REGULATORY REQUIREMENT(S)

For this review plan, the staff will determine if the regulatory requirement for the description and assessment of the geochemical system of the site, defined in 10 CFR 60.21(c)(1)(i-ii), as applicable, has been met:

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

* * * * *

(E) The geochemical properties;

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

* * *

(13) An identification and evaluation of the natural resources of the geologic setting, including estimates as to undiscovered deposits, the exploitation of which could affect the ability of the geologic repository to isolate radioactive wastes. Undiscovered deposits of resources characteristic of the area shall be estimated by reasonable inference based on geological and geophysical evidence. This evaluation of resources, including undiscovered deposits, shall be conducted for the site and for areas of similar size that are representative of and are within the geologic setting. For natural resources with current markets the resources shall be assessed, with estimates provided of both gross and net value. The estimate of net value shall take into account current development, extraction and marketing costs. For natural resources without current markets, but which would be marketable given credible projected changes in economic or technological factors, the resources shall be described by physical factors such as tonnage or other amount, grade, and quality.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

The descriptive material provided in Section 3.1.3 of the license application will support detailed *Safety Reviews* of information contained elsewhere in the license application. Thus, the information contained in Section 3.1.3 will be reviewed in parallel with the information contained in those sections of the license application concerning siting conditions, design, and performance. Therefore, during the acceptance review of Section 3.1.3, the reviewer should determine that the appropriate descriptive information needed to support the *Safety Reviews* has been provided in this section of the license application, and that the information is both internally consistent and consistent from section-to-section.

If it is determined that the descriptive information in Section 3.1.3 of the license application is inadequate to support the *Compliance Reviews* described above, then additional information will be requested from DOE before these *Compliance Reviews* can begin.

2.2 Compliance Review

2.2.2 Safety Review

As noted above, most of the descriptive material provided in this section of the license application will be initially reviewed and then evaluated as part of the *Compliance Review* of those sections of the license application which use this information. Section 4.2 ("Interfaces") of this review plan describes where the *Compliance Review(s)* of the information in this section of the license application will take place.

For each of the *Compliance Reviews* described in Section 4.2, a portion of the review will therefore focus on whether the descriptive information provides an acceptable basis for the associated assessment. Thus, this portion of the review will result in an *Evaluation Finding* for the specific supporting information in that section of the license application in which it is being used.

Therefore, under this review plan, no additional *Compliance Review* will be done; the staff will make only an "aggregate" *Evaluation Finding* for the whole description of the geochemical system of the site. Such a finding would collectively reflect the sum of the specific *Evaluation Findings* made in those sections of the license application described in Section 4.2.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare information in the license application concerning the description of the Geochemical System of the site with the corresponding section of the FCRG and with the resolution status of staff objections to the license application submittal in the Open Item Tracking System (OITS). The staff will then determine whether this information meets the following Acceptance Criteria:

(1) The information presented in the license application is clear, completely documented, consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) DOE has either resolved, at staff level, NRC objections to the license application submittal which apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections. Namely, it should be determined whether DOE has:

- Identified all unresolved objections.
- Explained the differences between NRC and DOE positions which precluded resolution of each objection.
- Described attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful *Compliance Review* or the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the Acceptance Criteria specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented in the staff's Safety Evaluation Report (SER) to provide the basis for the actual *Evaluation Findings*.

3.2.1 Safety Review of 10 CFR 60.21(c)(1)

The staff's *Compliance Review* will consist of the following two steps. First, the staff will review the descriptive information provided for the geochemical system. This will provide an overall understanding of how DOE has presented its information on the many individual aspects of this system and how this information has been integrated. The types of descriptive information to be provided to other review plans are listed in Section 4.2.2.

Second, after the staff has conducted each of the *Compliance Reviews* for those sections of the license application identified in Section 4.2.2, the individual *Evaluation Findings* from these reviews will be considered on balance to determine whether the following Acceptance Criterion has been met:

(1) The descriptive information for the geochemical system provides an acceptable basis for all of the associated assessments that rely on this information.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	WM/PAHB	Performance Assessment and Hydrology Branch: Hydrologic Transport Section
Support:	None	

4.2 Interfaces

4.2.1 Input Information

Input Information	*Review Plan No.*
None	None

4.2.2 Output Information

Output from activities associated with this review plan will provide specific information important for use in other review plans as the following table indicates.

Output Information	*Review Plan No.*
See FCRG Section 3.1.3 for examples	3.2.1.4 - PAC: Evidence of Dissolution
See FCRG Section 3.1.3 for examples	3.2.1.11 - PAC: Presence of Naturally Occurring Materials
See FCRG Section 3.1.3 for examples	3.2.2.10 - PAC: Complex Engineering Measures
See FCRG Section 3.1.3 for examples	3.2.3.1 - FAC: Nature and Rates of Geochemical Processes
See FCRG Section 3.1.3 for examples	3.2.3.2 - FAC: Geochemical Conditions
See FCRG Section 3.1.3 for examples	3.2.3.3 - FAC: Mineral Assemblages
See FCRG Section 3.1.3 for examples	3.2.3.4 - PAC: Groundwater Conditions and the Engineered Barrier System
See FCRG Section 3.1.3 for examples	3.2.3.5 - PAC: Geochemical Processes
See FCRG Section 3.1.3 for examples	3.2.3.6 - PAC: Not Reducing Groundwater Conditions
See FCRG Section 3.1.3 for examples	3.2.3.7 - PAC: Gaseous Radionuclide Movement
See FCRG Section 3.1.3 for examples	3.2.5 - Assessment of Compliance with Criteria for Combination of Favorable Conditions and Potentially Adverse Conditions
See FCRG Section 3.1.3 for examples	3.4 - Effectiveness of Natural Barriers Against the Release of Radioactive Material to the Environment
See FCRG Section 3.1.3 for examples	4.1.2 - Description of Shafts and Ramps
See FCRG Section 3.1.3 for examples	4.1.3 - Description of Underground Facility
See FCRG Section 3.1.3 for examples	4.3 - Assessment of Compliance with Design Criteria for Shafts and Ramps
See FCRG Section 3.1.3 for examples	4.4 - Assessment of Compliance with Design Criteria for the Underground Facility
See FCRG Section 3.1.3 for examples	5.2 - Assessment of Compliance with the Design Criteria for the Waste Package and its Components
See FCRG Section 3.1.3 for examples	5.3 - Assessment of Compliance with the Design Criteria for the Engineered Barrier System
See FCRG Section 3.1.3 for examples	5.4 - Assessment of Compliance with the Engineered Barrier System Performance Objectives
See FCRG Section 3.1.3 for examples	6.1 - Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials

Output Information	*Review Plan No.*
See FCRG Section 3.1.3 for examples	6.2 - Assessment of Compliance with the Individual Protection Requirements
See FCRG Section 3.1.3 for examples	6.3 - Assessment of Compliance with the Groundwater Protection Requirements
See FCRG Section 3.1.3 for examples	8.1.3 - Performance Confirmation Program for the Natural Systems of the Geologic Setting: Geochemical System
See FCRG Section 3.1.3 for examples	8.2 - Structure, Systems, and Components of the Geologic Repository Operations Area
See FCRG Section 3.1.3 for examples	8.3 - Engineered Barrier System
See FCRG Section 3.1.3 for examples	8.4 - Radiation Protection During Performance Confirmation
See FCRG Section 3.1.3 for examples	8.5 - Analysis of Changes from Performance Confirmation Baseline
See FCRG Section 3.1.3 for examples	8.6 - Unresolved Safety Questions

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing, and the subsequent *Compliance Review*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis, should be documented in the staff's SER.

5.1 Finding for Acceptance Review

The NRC staff finds the information presented by DOE, as defined by the applicable 10 CFR Part 60 Regulatory Requirements, is acceptable (not acceptable) for docketing and a subsequent *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)

TBD from ongoing *Example Evaluation Findings Task*.

6 REFERENCES

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management, to identify the most current edition of the FCRG in effect.]

Table 3.1.3-1 Section of the License Application That Require Input from the "Description of the Individual Systems and Characteristics of the Site: Geochemical System" Section of the License Application.

License Application Section	*Title*
Siting Criteria	
(Favorable Conditions)	
3.2.3.1	Nature and Rates of Geochemical Processes
3.2.3.2	Geochemical Conditions
3.2.3.3	Mineral Assemblages
(Potentially Adverse Conditions)	
3.2.1.4	Evidence of Dissolution
3.2.1.11	Presence of Naturally Occurring Materials
3.2.2.10	Complex Engineering Measures
3.2.3.4	Groundwater Conditions and the Engineered Barrier System
3.2.3.5	Geochemical Processes
3.2.3.6	Not Reducing Groundwater Conditions
3.2.3.7	Gaseous Radionuclide Movement
3.2.5	Assessment of Compliance with Criteria for Integrated Analyses of Favorable Conditions and Potentially Adverse Conditions
3.4	Effectiveness of Natural Barriers against the Release of Radioactive Material to the Environment
Description of the GROA	
4.1.2	Description of Shafts and Ramps
4.1.3	Description of Underground Facility
Performance Objectives	
5.4	Assessment of Compliance with the Engineered Barrier System Performance Objectives
6.1	Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials
6.2	Assessment of Compliance with the Individual Protection Requirements
6.3	Assessment of Compliance with the Groundwater Protection Requirements
8.1.3	Performance Confirmation Program for the Natural Systems of the Geologic Setting: Geochemical System
8.2	Structure, Systems, and Components of the Geologic Repository Operations Area
8.3	Engineered Barrier System
8.4	Radiation Protection during Performance Confirmation
Design Criteria	
4.3	Assessment of Compliance with Design Criteria for Shafts and Ramps
4.4	Assessment of Compliance with Design Criteria for the Underground Facility
5.2	Assessment of Compliance with the Design Criteria for the Waste Package and its Components
5.3	Assessment of Compliance with the Design Criteria for the Engineered Barrier System
5.4	Assessment of Engineered Barrier System Compliance with the Performance Objectives

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

DESCRIPTION OF INDIVIDUAL SYSTEMS AND CHARACTERISTICS OF THE SITE: CLIMATOLOGICAL AND METEOROLOGICAL SYSTEMS

1 APPLICABLE REGULATORY REQUIREMENT(S)

For this review plan, the staff will determine if the regulatory requirement for the description and assessment of the climatological and meteorological systems of the site, defined in 10 CFR 60.21(c)(1), as applicable, has been met:

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing,

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The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

The descriptive material provided in Section 3.1.4 of the license application will support detailed *Safety Reviews* of information contained elsewhere in the license application. Thus, the information contained in Section 3.1.4 will be reviewed in parallel with the information contained in those sections of the license application concerning siting conditions, design, and performance. Therefore, during the Acceptance Review of Section 3.1.4, the reviewer should determine if the appropriate descriptive information needed to support the *Safety Reviews* has been provided in this section of the license application, and if the information is both internally consistent, and consistent from section-to-section.

If it is determined that the descriptive information in Section 3.1.4 of the license application is inadequate to support the *Compliance Reviews* described above, then additional information will be requested from DOE before these *Compliance Reviews* can begin.

2.2 Compliance Review

2.2.1 Safety Review

As noted above, most of the descriptive material provided in this section of the license application will be initially reviewed and then evaluated as part of the *Compliance Review* of those sections of the license application which use this information. Section 4.2 ("Interfaces") of this review plan describes where the *Compliance Review(s)* of the information in this section of the license application will take place.

For each of the *Compliance Reviews* described in Section 4.2, a portion of the review will therefore focus on whether the descriptive information provides an acceptable basis for the associated assessment. Thus, this portion of the review will result in an *Evaluation Finding* for the specific supporting information in that section of the license application in which it is being used.

Therefore, under this review plan, no additional *Compliance Review* will be done; the staff will make only an "aggregate" *Evaluation Finding* for the whole description of the climatological and meteorological systems of the site. Such a finding would collectively reflect the sum of the specific *Evaluation Findings* made in those sections of the license application described in Section 4.2.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare information in the license application concerning the description of the Climatological and Meteorological Systems of the site with the corresponding section of the FCRG and with the resolution status of staff objections to the license application submittal in the Open Item Tracking System (OITS). The staff will then determine whether this information meets the following Acceptance Criteria:

(1) The information presented in the license application is clear, completely documented, and consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) DOE has either resolved, at staff level, NRC objections to the license application submittal which apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections. Namely, it should be determined whether DOE has:

- Identified all unresolved objections.
- Explained the differences between NRC and DOE positions which precluded resolution of each objection.
- Described all attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful *Compliance Review* or the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the Acceptance Criteria specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented in the staff's Safety Evaluation Report (SER) to provide the basis for the actual *Evaluation Findings*.

3.2.1 Safety Review of 10 CFR 60.21(c)(1)

The staff's *Compliance Review* will consist of the following two steps. First, the staff will review the descriptive information provided for the climatological and meteorological systems. This will provide an overall understanding of how DOE has presented its information on the many individual aspects of these systems and how this information has been integrated. The types of descriptive information to be provided are listed in Section 4.2.2.

Second, after the staff has conducted each of the *Compliance Reviews* for those sections of the license application identified in Section 4.2, the individual *Evaluation Findings* from these reviews will be considered on balance to determine whether the following Acceptance Criterion has been met:

(1) The descriptive information for the climatological and meteorological systems provides an acceptable basis for all of the associated assessments that rely on this information.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	WP/PAHB	Performance Assessment and Hydrology Branch: Hydrologic Transport Section
Support:	None	

4.2 Interfaces

4.2.1 Input Information

Input Information	*Review Plan No.*
None	None

4.2.2 Output Information

Output from activities associated with this review plan will provide specific information important for use in other review plans as the following table indicates.

Output Information	*Review Plan No.*
See FCRG — Section 3.1.4 for examples	3.2.1.4 - PAC: Evidence of Dissolution
See FCRG — Section 3.1.4 for examples	3.2.1.10 - PAC: Evidence of Extreme Erosion
See FCRG — Section 3.1.4 for examples	3.2.2.1 - FAC: Nature and Rates of Hydrogeologic Processes
See FCRG — Section 3.1.4 for examples	3.2.2.3 - FAC: Groundwater Travel Time Substantially Exceeding 1000 Years
See FCRG — Section 3.1.4 for examples	3.2.2.4 - FAC: Unsaturated Zone Hydrologic Conditions
See FCRG — Section 3.1.4 for examples	3.2.2.5 - PAC: Flooding
See FCRG — Section 3.1.4 for examples	3.2.2.6 - PAC: Human Activity and Groundwater
See FCRG — Section 3.1.4 for examples	3.2.2.7 - PAC: Natural Phenomena Affecting Groundwater
See FCRG — Section 3.1.4 for examples	3.2.2.9 - PAC: Changes To Hydrologic Conditions
See FCRG — Section 3.1.4 for examples	3.2.2.11 - PAC: Potential For Unsaturated Zone Saturation
See FCRG — Section 3.1.4 for examples	3.2.2.12 - PAC: Perched Water Bodies
See FCRG — Section 3.1.4 for examples	3.2.3.1 - FAC: Nature and Rates of Geochemical Processes
See FCRG — Section 3.1.4 for examples	3.2.3.2 - FAC: Geochemical Conditions

Output Information	*Review Plan No.*
See FCRG — Section 3.1.4 for examples	3.2.3.7 - PAC: Gaseous Radionuclide Movement
See FCRG — Section 3.1.4 for examples	3.2.4.1 - FAC: Precipitation That Is a Small Percentage of Evapotranspiration
See FCRG — Section 3.1.4 for examples	3.2.4.2 - PAC: Changes To Hydrologic System From Climate
See FCRG — Section 3.1.4 for examples	3.3 - Assessment of Compliance With the Groundwater Travel Time Performance Objective
See FCRG — Section 3.1.4 for examples	6.1 - Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials
See FCRG — Section 3.1.4 for examples	6.2 - Assessment of Compliance With the Individual Protection Requirements
See FCRG — Section 3.1.4 for examples	6.3 - Assessment of Compliance with the Groundwater Protection Requirements
See FCRG — Section 3.1.4 for examples	8.1.4 - Performance Confirmation Program for the Natural Systems of the Geologic Setting: Climatological and Meteorological Systems

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing, and the subsequent *Compliance Review*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis, should be documented in the staff's SER.

5.1 Finding for Acceptance Review

The NRC staff finds the information presented by DOE, as defined by the applicable 10 CFR Part 60 Regulatory Requirements, is acceptable (not acceptable) for docketing and a subsequent *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(i)

TBD from ongoing *Example Evaluation Findings Task*.

6 REFERENCES

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

Table 3.1.4-1 Sections of the License Application That Require Input from the "Description of the Individual Systems and Characteristics of the Site: Climatological and Meteorological Systems" Section of the License Application.

License Application Section	*Title*
Siting Criteria	
(Favorable Conditions)	
3.2.2.1	Nature and Rates of Hydrogeologic Processes
3.2.2.3	Groundwater Travel Time Substantially Exceeding 1000 years
3.2.2.4	Unsaturated Zone Hydrogeologic Conditions
3.2.3.1	Nature and Rates of Geochemical Processes
3.2.3.2	Geochemical Conditions
3.2.4.1	Precipitation that is a Small Percentage of Potential Evapotranspiration
(Potentially Adverse Conditions)	
3.2.1.4	Evidence of Dissolution
3.2.1.10	Evidence of Extreme Erosion
3.2.2.5	Flooding
3.2.2.6	Human Activity and Groundwater
3.2.2.7	Natural Phenomena Affecting Groundwater
3.2.2.9	Changes to Hydrologic Conditions
3.2.2.11	Potential for Unsaturated Zone Saturation
3.2.3.7	Gaseous Radionuclide Movement
3.2.4.2	Changes to Hydrologic System from Climate
Performance Objectives	
3.3	Assessment of Compliance with the Groundwater Travel Time Performance Objective
8.1.4	Performance Confirmation Program for the Natural Systems of the Geologic Setting: Climatological and Meteorological Systems

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

FAVORABLE CONDITIONS: MINIMUM WASTE EMPLACEMENT DEPTH

1 APPLICABLE REGULATORY REQUIREMENT(S)

The subject of this review plan is the following favorable condition on a minimum waste emplacement depth for the geologic repository, defined in 10 CFR 60.122(b)(5):

Subpart E — Technical Criteria
SITING CRITERIA

§ 60.122 Siting criteria.

* * * * *

(b) *Favorable conditions.*

* * * * *

(5) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.)

* * * * *

For this review plan, the staff will determine if the subject favorable condition, identified above, has been described pursuant to the regulatory requirement defined in 10 CFR 60.21(c)(1), as applicable:

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

* * * * *

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) Analyses to determine the degree to which each favorable condition and potentially adverse condition enumerated in § 60.122 of this part has been characterized and found to be present. For each potentially adverse condition, the analysis shall demonstrate its absence or the extent to which it may be present and still undetected, taking into account the degree of resolution achieved by the investigations. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they may affect isolation within the controlled area.

* * * * *

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the DOE LA is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide FCRG.

Before the receipt of the LA, the staff will have conducted prelicensing reviews of the DOE program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-LA reviews, as open items. Some of these open items, referred to as objections to LA submittal, may be critical to the staff's LA review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to LA submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

2.2 Compliance Review

2.2.1 Safety Review

This regulatory requirement topic is limited to consideration of the DOE demonstration, through appropriate investigations, of the presence (or absence) of the FAC regarding waste emplacement at a minimum depth of 300 meters (~1,000 ft) from the ground surface. It is not concerned with considering the effects of extreme erosion or human intrusion associated with the presence of naturally occurring materials (e.g., Nuclear Regulatory Commission, 1983; pp. 15-18). These topics will be covered under Sections 3.2.1.10 and 3.2.1.11, respectively, of the LA and its respective review plans. The specific aspects of the LA on which the reviewer will focus are described below, and the Acceptance Criteria are identified in Section 3.2 of this review plan.

Based on early site suitability studies (Younker et al., 1992; Section 2.3.5), it is anticipated that the DOE will not take credit for the presence of this FAC. If this is the case, then the reviewer should require no additional information relative to the presence of this FAC, and combinations of other FACs will be relied on to meet the performance objectives (Nuclear Regulatory Commission, 1983; pp. 58-59).

If the DOE reports the FAC to be present, however, the reviewer should determine if the DOE has included a description of the proposed host horizon. To assess the depth at which the selected host horizon occurs, it may be necessary to describe how the proposed host horizon is identified in well logs and/or by geophysical means. Based on the elevation of the lowest point on the ground surface above the disturbed zone, the reviewer should then determine that the DOE has included a listing of depth to intercept in all boreholes that penetrate the chosen horizon. In conducting the *Safety Review*, the reviewer will also, at a minimum, determine the adequacy of the data and analyses presented in the LA to support the DOE demonstrations regarding 10 CFR 60.122(b)(5). Specifically, the DOE will need to: (1) provide site characterization and design information to determine the degree to which the FAC has been characterized, and (2) ensure the sufficiency of the lateral and vertical extent of the data collection.

To conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, information, and data such as the results of research activities being conducted by the NRC Office of Nuclear Regulatory Research, in addition to that provided by DOE in its LA. The reviewer should focus on additional data that can refine knowledge of the FAC, and should acquire, as necessary, additional information to confirm the resolution capabilities of the methodologies. The reviewer should have acquired a body of knowledge regarding these and other critical considerations in anticipation of conducting the *Safety Review* to ensure that the DOE site characterization program is sufficient in scope and depth to provide the information necessary for resolution of the concerns.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare information in the License Application (LA) concerning the Favorable Condition (FAC) on waste emplacement at a minimum depth of 300 meters from the ground surface (henceforth referred to as "minimum waste emplacement depth" with the corresponding section of the "Format and Content for the License Application for the High-Level Waste Repository (FCRG)," and with the staff's resolution status of objections to the LA submittal in the Open Item Tracking System (OITS) and determine if this information meets the following criteria:

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the proper references have been provided.

(2) The U.S. Department of Energy (DOE) has either resolved, at staff level, the Nuclear Regulatory Commission (NRC) objections (if any) to LA submittal that apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections (if any), namely, DOE has:

- Identified all unresolved objections.
- Explained the differences between NRC and DOE positions that have precluded resolution of each objection.
- Described all attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful *Compliance Review* and the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether Acceptance Criteria specified for the following *Compliance Review* have been met to provide adequate documentation of the presence or absence of the FAC on minimum waste emplacement depth. Results of the compliance determinations should be documented by the staff to provide the basis for *Evaluation Findings* in the Safety Evaluation Report (SER).

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(b)(5)

The staff will determine whether the assessment of presence or absence of minimum waste emplacement depth has been accomplished in an acceptable manner, and whether the description of the geology of the site properly supports the assessments required by 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(b)(5). For 10 CFR 60.21(c)(1)(ii)(A) specifically, the staff will review and evaluate information provided by DOE in the LA to support DOE analysis of the geology of the site as related to minimum emplacement depth and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(b)(5).

For 10 CFR 60.21(c)(1)(ii)(B) the staff will review and evaluate information provided by DOE in the LA to demonstrate whether all of the waste can be contained below a minimum depth of 300 meters, or the extent to which some part of the waste will be emplaced at depths less than 300 meters, taking into account the degree of resolution achieved by the investigation. The staff will also determine whether the analyses and investigations have been accomplished in an acceptable manner and whether lateral and vertical extent of the investigations are acceptable for supporting review of 10 CFR 60.122(b)(5).

For 10 CFR 60.21(c)(1)(ii)(F) the staff will review and evaluate information provided by DOE in the LA to support DOE analyses and models used to predict future conditions and changes in the geologic setting as related to minimum waste emplacement depth. The staff will also determine whether any analyses and models are properly supported by an appropriate combination of methods such as field and laboratory tests, monitoring data, or natural analog studies for assisting review of 10 CFR 60.122(b)(5).

In accomplishing the *Safety Review* of 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) and 10 CFR 60.122(b)(5), the staff will need to determine whether DOE is reporting the presence or absence of the FAC. If the LA reports that the FAC is absent (i.e., the waste cannot be contained everywhere at depths greater than 300 meters), and includes the bases for the determination that the FAC is absent, the review shall be considered complete. In the staff's view, it is not sufficient, for purposes of the *Safety Review Evaluation Finding*, to simply state in the LA that the FAC is absent. Bases should include, in addition to DOE (1988; p. 8.3.5.17-94), information such as that presented in recent relevant documents like Younker et al. (1992; Section 2.3.5) and TRW (1994; Figure 8.6.4-7). The *Evaluation Finding* for the *Safety Review* as described in Section 5.2.1 of this review plan shall be made.

If the LA reports that the FAC is present, the staff should determine whether the following additional Acceptance Criteria have been met:

(1) From surface topography maps, the lowest point above the disturbed zone has been accurately identified.

(2) From site characterization, the proposed repository horizon is appropriately identified at depth; intercepts in wells have been correctly identified based on commonly accepted methods such as well logging and geophysical techniques.

(3) From design information, the assumptions and analysis methods used by DOE in the LA adequately demonstrate that the waste can be completely emplaced in the proposed host horizon at depths greater than 300 meters beneath the lowest point above the disturbed zone. This information should include a contour map of the thickness between the surface of Yucca Mountain (YM) and the proposed repository horizon, similar to that presented by DOE (1995; Figure 4.1.1-1).

(4) Assumptions and analysis methods used by DOE during site characterization and repository design acceptably demonstrate the ability to achieve a minimum waste emplacement depth of 300 meters from the ground surface.

(5) DOE can demonstrate that the extent of characterization and repository design is sufficient to define the minimum waste emplacement depth over the entire repository.

(6) Results of DOE investigations are not in conflict with published results from various staff investigations or other independent studies, or the conflicts are adequately explained.

Any data used in a statistical evaluation by DOE should be a part of the LA so that the NRC reviewers can evaluate the data using the same or comparable statistical techniques and can assess the uncertainty ascribed by DOE to the calculations. Independent NRC processing of selected data should determine that the DOE results can be reproduced and should determine that the sensitivity of the results to the various input parameters are accurately described by DOE.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	WM/ENGB	Geosciences/Geotechnical Engineering Section

4.2 Interfaces

4.2.1 Input Information

Information derived from activities related to other review plans will provide input important for considering minimum waste emplacement depth. The input that is most relevant is a description of the elevation of the ground surface above the repository and the depth of waste emplacement anticipated in the design of the repository. A list of review plans for which this interface is anticipated to be particularly important is presented in the following table.

Input Information	*Review Plan No.*
- Surface Topography. - Geologic characteristics of the proposed host horizon. - Depth to proposed host horizon in repository block.	3.1.1 Geologic System Description
- Description of depth of repository, including tunnels, shafts, and ramps.	4.1.2 Description of the GROA Structure, Systems, and Components: Shafts and Ramps
- Description of depth of repository, including underground facilities.	4.1.3 Description of the GROA Structure, Systems, and Components: Underground Facilities
- Depth of waste emplacement	5.1 Description of the Engineered Systems and Components
- Areal extent of the disturbed zone.	3.3 Assessment of Compliance with the Groundwater Travel Time Performance Objective

4.2.2 Output Information

Whether or not the FAC is reported to be present, the information on the depth of waste emplacement will be carried in the repository design for use in assessing overall repository performance in Review Plan 6.1.

Output Information	*Review Plan No.*
- Determination regarding the presence or absence of this favorable condition.	3.2.5 Assessment of Compliance With Criteria for Integrated Analyses of Combinations of Favorable Conditions and Potentially Adverse Conditions

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing and the *Compliance Reviews*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds that the information presented by DOE on the FAC concerned with minimum waste emplacement depth is acceptable (not acceptable) for docketing and *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(b)(5)

The NRC staff finds that the presence (absence) of the FAC related to minimum waste emplacement depth has (has not) been acceptably demonstrated and that there is (is not) reasonable assurance that the regulatory requirements of 10 CFR 60.122(b)(5) will be met.

The staff is developing supporting *Example Evaluation Findings* for each regulatory requirement for inclusion in subsequent revisions of this review plan.

6 REFERENCES

Nuclear Regulatory Commission. 1983. *Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories."* NUREG-0804. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. "Format and Content for the License Application for the High-Level Waste Repository" (FCRG), Office of Nuclear Regulatory Research.

TRW Environmental Safety Systems, Inc. 1994. *Initial Summary Report for Repository/Waste Package Advanced Conceptual Design.* Document No. B00000000-01717-5705-00015, Rev. 00. Vol. II.

U.S. Department of Energy. 1988. *Site Characterization Plan: Yucca Mountain Site, Nevada Research and Development Area, Nevada.* DOE/RW-0199. Washington, DC: U.S. Department of Energy: 9 Vols.

U.S. Department of Energy. 1995. *Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion.* YMP/TBR-0001. Las Vegas, NV: U.S. Department of Energy.

Younker, J.L., et al. 1992. *Report of Early Site Suitability Evaluation of the Potential Repository at Yucca Mountain, Nevada.* Science Applications International Corporation, SAIC-91/8000.

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

POTENTIALLY ADVERSE CONDITIONS: HISTORICAL EARTHQUAKES

1 APPLICABLE REGULATORY REQUIREMENT(S)

The subject of this review plan is the following potentially adverse condition (PAC) on evidence of historical earthquakes, defined in 10 CFR 60.122(c)(12):

Subpart E — Technical Criteria
SITING CRITERIA

§ 60.122 Siting criteria.

* * * * *

(c) *Potentially adverse conditions.* The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

* * * * *

(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

* * * * *

For this review plan, the staff will determine if the subject PAC, identified above, has been described and assessed pursuant to the regulatory requirements defined in 10 CFR 60.21(c)(1), as applicable.

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

* * * * *

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) Analyses to determine the degree to which each favorable condition and potentially adverse condition enumerated in § 60.122 of this part have been characterized and found to be present. For each potentially adverse condition, the analysis shall demonstrate its absence or the extent to which it may be present and still undetected, taking into account the degree of resolution achieved by the investigations. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they may affect isolation within the controlled area.

* * * * *

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

2.2 Compliance Review

2.2.1 Safety Review

In conducting the *Safety Review*, the reviewer will, as a minimum, determine the adequacy of the data and analyses presented in the license application to support DOE's demonstrations regarding 10 CFR 60.122(c)(12). The specific aspects of the license application on which the reviewer will focus are discussed below, and the Acceptance Criteria are identified in Section 3.0 of this review plan. Specifically, the applicant will need to: (1) provide information to determine whether and to what degree the PAC is present; (2) provide information to determine to what degree the PAC is present, but undetected; (3) ensure the sufficiency of the lateral and vertical extent of data collected; and (4) evaluate the information presented under Items (1) and (2), with assumptions and analysis methods that adequately describe the presence of the PAC and ranges of relevant parameters.

Examples of specific review activities that will be required include confirmation that DOE has considered the following: (1) historically and instrumentally recorded earthquakes within the geologic setting that are appropriate for the analysis; (2) other earthquakes outside the geological setting that may affect waste isolation capability of the geological repository ; (3) valid and applicable assumptions; (4) the potential for and the effects of nuclear tests; (5) the potential for and the effects of human-induced seismicity; and (6) the tectonic models used reflect the natural system and that the conclusions presented are consistent.

DOE will also need to provide an explanation of the measures used to support models used to assess the presence or absence of evidence of historic earthquakes. Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests that are representative of field conditions, monitoring data, and natural analog studies.

In conducting the aforementioned evaluations, the reviewer should determine that DOE uses: (1) analyses that are sensitive to evidence of this PAC; and (2) assumptions that are not likely to underestimate its effects. In general, the reviewer will assess the adequacy of DOE's investigations of naturally occurring and human-induced earthquakes, both recorded within the site and within the geologic setting, as necessary, in the manner outlined in 10 CFR 60.21(c)(1)(ii)(B).

To conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, information and data such as the results of research activities being conducted by the NRC Office of Nuclear Regulatory Research, in addition to that provided by the DOE in its license application. Therefore, it is incumbent upon the reviewer to have acquired a body of knowledge regarding these and other such critical considerations in anticipation of conducting the *Safety Review*.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare information in the License Application (LA) concerning the Potentially Adverse Condition (PAC) on earthquakes which have occurred historically that, if they were to be repeated, could affect the site significantly (henceforth, historical earthquakes) with the corresponding section of the Format and Content Regulatory Guide (FCRG) and with the staff's resolution status of objections to the LA submittal in the Open Item Tracking System (OITS) and determine if this information meets the following criteria.

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the proper references have been provided.

(2) DOE has either resolved, at staff level, the NRC objections to LA submittal that apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections. Namely, DOE has:

- Identified all unresolved objections

- Explained the differences between NRC and DOE positions that have precluded resolution of each objection
- Described all attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) DOE has presented information and analyses in review areas listed in Section 3.2.1. If DOE has not presented information in these areas an explanation for not providing it should be presented.

(4) Unresolved objections individually or in combination with others will not prevent the reviewer from conducting a meaningful *Compliance Review* and the Commission from making a decision regarding construction authorization within the 3-year statutory period after the license application is submitted.

3.2 Compliance Reviews

The compliance determination undertaken by NRC staff will consider whether Acceptance Criteria specified for the following *Compliance Review* have been met. Results of the compliance determination should be documented by the staff to provide the basis for actual *Evaluation Findings* in the Safety Evaluation Report (SER).

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(12)

The staff will determine whether the assessment of presence or absence of historical earthquakes has been accomplished in an acceptable manner, and whether description of the geology and seismicity of the site properly supports the assessments required by 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(c)(12). For 10 CFR 60.21(c)(1)(ii)(A) specifically, the staff will review and evaluate information provided by DOE in the LA to support the DOE analysis of the geology of the site as related to historical earthquakes and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(c)(12). The staff restricts the analysis of this PAC to only those earthquakes and their locations that have been historically documented.

3.2.1.1 Determination of Historical Earthquakes

For the purposes of this review, historical earthquakes are those which are historically reported or instrumentally recorded that have affected or could reasonably be expected to have affected the site. Sources of historical earthquake knowledge include lists or catalogues prepared by individual researchers, groups or government agencies whose function it is to document such occurrences, newspapers, and historical diaries of early observers (e.g. with the U.S. Army or religious missions). In some cases, traditional accounts reported by members of Indian tribes may also be considered. The detail and reliability of information from these diverse sources may vary considerably.

Because of the potential for very large earthquakes at the Sierra Nevada-Basin and Range tectonic province border, and the considerable dispersion of data about the median attenuation functions, an area for the DOE historical earthquake considerations of radius 300 km centered on the site, is considered conservative.

The staff will evaluate the results and techniques used by DOE in their description of historical earthquakes to determine if the following acceptance criteria have been met.

- The areal extent of DOE characterization of historical earthquakes is sufficient to identify those that might affect the site.
- Detection capabilities of the geophysical methods used for identifying geological structures are evaluated and appropriately reported by DOE.

- The DOE investigations have included reasonably available historical accounts and lists of earthquakes. Criteria for acceptability of the listings are:

  — They include all earthquakes having Modified Mercalli Intensity (MMI) greater than or equal to IV or magnitude greater than or equal to 3.0, that have been reported within 300 km of the site. Magnitudes of less than 3 are not considered by the staff to be sufficiently well recorded to contribute to PSHA or to warrant their being listed and plotted. However, for studies of fault planes within the YM/NTS, location of earthquakes having magnitudes smaller than 3 should be used.

  — The descriptions of earthquakes on the lists include the following if available: epicenter coordinates, depth of focus, origin time, highest intensity, magnitude, moment, source mechanism, distance from the site and any strong motion recordings references from which the information was obtained and magnitude designations such as M_L, M_S, M_W, etc. are identified.

  — If available, reports of earthquake induced geologic failures, such as liquefaction, landsliding, landspreading, and lurching are completely described, including the level of strong motion that induced failure and properties of failed geological materials.

  — A regional scale map is presented which shows the listed earthquake epicenters.

  — A local scale map is presented which shows all earthquake epicenters within 100 km of the site and potentially related geologic structures.

- Correlations of historical earthquakes with faults, to the extent possible, have been made. acceptance criteria for the correlations are:

  — A rationale is developed for the correlation of a hypocenter or group of hypocenters with a geologic structure, which considers characteristics of the geologic structure based upon geologic and geophysical data, seismicity, tectonic history, and a regional tectonic model.

  — The descriptions of hypocenters includes identification of the methods used to locate them, an estimate of accuracy, and a detailed account that compares and contrasts the geologic structure involved with local seismicity and with earthquake activity in other areas of the tectonic province.

- Uncertainties in data acquisition, data representativeness, data reduction, and stratigraphic relationships and in analytical methods are presented and discussed. The means used by DOE to reduce uncertainty and the resultant residual uncertainty are prominently reported.

3.2.1.2 Determination of Historical Earthquakes that Could Significantly Affect the Site

The staff will review the DOE analysis of which historical earthquakes could significantly affect the site to determine if the following acceptance criteria have been met.

- Earthquake magnitudes, resulting peak ground accelerations, and association with each geologic structure have been assessed, and the earthquake that would produce the maximum vibratory ground motion at the site has been determined. Where an earthquake is associated with geologic structure, the maximum magnitude earthquake that could occur on that structure is evaluated, taking into account significant factors; for example, the type of faulting, fault length, fault slip rate, rupture length, moment, and earthquake history. If geologic or seismologic evidence warrants a maximum earthquake larger than the maximum historical earthquake, the rationale is discussed.

- Plausible effects to the site which could be caused by historical earthquakes, should they be repeated, include effects on waste isolation, i.e., damage to engineered barrier systems (EBS) that may result in the

release of radionuclides from engineered barriers to the geologic setting, and changes to pathways of radionuclide migration within the geologic setting

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	WM/ENGB	Geosciences/Geotechnical Engineering Section
Support:	None	

4.2 Interfaces

4.2.1 Input Information

Information derived from activities related to other review plans may provide input important for considering historical earthquakes. A list of review plans in which such information may be found follows.

Input Information	*Review Plan No.*
The geologic setting of historical earthquakes	3.1.1 Geologic System Description
Potential causes of historical earthquakes to aid in evaluation of associations of earthquakes with faults	3.2.1.7 Correlation of Earthquakes with Tectonic Processes
Evaluation of potential earthquakes to asses uncertainty in the historical earthquake assessment	3.2.1.8 Occurrence of more-Frequent/Higher Magnitude Earthquakes
Implications for the number of earthquakes of a given magnitude that should have been seen historically	3.2.1.1 Nature and Rate of Physical Processes
Implication of focal mechanisms for older historical earthquakes	3.2.1.5 Structural Deformation

4.2.2 Output Information

Earthquake information may be conveniently placed in a single location within the license application but may be relevant to the resolution of several PACs. Therefore, output from activities associated with this review plan may provide specific information important for use in other review plans. See the following table.

Output Information	*Review Plan No.*
Potential view of the Historical Earthquake PAC from a different perspective	3.2.5 Assessment of Compliance With Criteria For Integrated Analyses of Combinations of Favorable Conditions and Potentially Adverse Conditions
Possible assessment of uncertainty associated with the Historical Earthquake PAC	X.X.X. Assessment of Anticipated and Unanticipated Processes and Events
Possible consideration of the impact of the Historical Earthquake PAC on the site	6.1 Assessment of Compliance With the Requirement for Cumulative Releases of Radioactive Materials
Possible scenarios for significant effects on the site caused by historical earthquakes	6.2 Assessment of Compliance With Individual Protection Requirements

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing and the *Compliance Reviews*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds that the information presented by DOE on the PAC concerned with historical earthquakes is acceptable (not acceptable) for docketing and *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(12)

The NRC staff finds that the presence or absence of the PAC related to historical earthquakes has (has not) been acceptably demonstrated and that there is (is not) reasonable assurance that the regulatory requirements of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(12) will be met.

6 REFERENCES

Nuclear Regulatory Commission. "Format and Content For the License Application for the High-Level Waste Repository," Office of Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

POTENTIALLY ADVERSE CONDITIONS: EVIDENCE OF EXTREME EROSION

1 APPLICABLE REGULATORY REQUIREMENT(S)

The subject of this review plan is the following potentially adverse condition (PAC) concerning evidence of extreme erosion, defined in 10 CFR 60.122(c)(16):

Subpart E — Technical Criteria
SITING CRITERIA

§ 60.122 Siting criteria.

* * * * *

(c) *Potentially adverse conditions.* The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

* * * * *

(16) Evidence of extreme erosion during the Quaternary Period.

* * * * *

For this review plan, the staff will determine if the subject PAC, identified above, has been described and assessed pursuant to the regulatory requirement defined in 10 CFR 60.21(c)(1)(ii), as applicable:

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

* * * * *

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) Analyses to determine the degree to which each favorable condition and potentially adverse condition enumerated in § 60.122 of this part have been characterized and found to be present. For each potentially adverse condition, the analysis shall demonstrate its absence or the extent to which it may be present and still undetected, taking into account the degree of resolution achieved by the investigations. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they may affect isolation within the controlled area.

* * * * *

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the DOE LA is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the FCRG.

Before the receipt of the LA, the staff will have conducted prelicensing reviews of the DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these prelicense application reviews, as open items. Some of these open items, referred to as objections to LA submittal, may be critical to the staff LA review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to LA submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

2.2 Compliance Review

2.2.1 Safety Review

The regulatory requirement topic is limited to consideration of DOE demonstration, through appropriate investigations, of the evidence for (or against) extreme erosion during the Quaternary Period within the controlled area (and outside the controlled area, if considered necessary). For regulatory purposes, the definition of the Quaternary Period is the last 2 million years (Nuclear Regulatory Commission, 1983, p. 373). The specific aspects of the LA on which the reviewer will focus are described below, and the Acceptance Criteria are identified in Section 3.0 of this review plan.

In conducting the *Safety Review*, the reviewer will, at a minimum, determine the adequacy of the data and analyses presented in the LA to support DOE demonstrations regarding 10 CFR 60.122(c)(16). Specifically, DOE will need to: (1) provide information to determine whether and to what degree evidence of extreme erosion during the Quaternary Period is present; (2) provide information to determine to what degree evidence of extreme erosion during the Quaternary Period is present, but undetected; (3) ensure the sufficiency of the areal extent of the data collection; and (4) evaluate the information presented in support of Items (1) and (2), with assumptions and analysis methods that adequately describe the presence (or absence) of evidence of extreme erosion during the Quaternary Period and ranges of relevant parameters.

DOE will also need to provide an explanation of the measures employed to support models used to assess the presence or absence of evidence of extreme erosion during the Quaternary Period.

The NRC reviewer should determine that DOE has characterized erosion thoroughly at the proposed Yucca Mountain (YM) repository and nearby by discussing, at a minimum, the following:

- Short-term (c. 10,000 years and less) and long-term erosion rates (up to length of Quaternary Period) on hillslopes and in valleys. The established longterm rates should be compared to possible short term catastrophic rates of erosion which have occurred within the geologic setting (not necessarily only at YM). The likelihood of such extreme erosion having occurred and remaining undetected or the inability of such erosion to have ever occurred at YM should be discussed. The NRC reviewer should determine that DOE has mapped the repository relative to the elevations of the surrounding topography in order to identify those aspects of the proposed repository which would be most vulnerable to extreme erosion. The reviewer should be especially interested in DOE evaluation of erosion in those areas where the depth to the horizontal projection of the repository horizon is less than 100 m (e.g., valleys in SE portion of the controlled area). In these areas, erosion less than that required to unearth the repository might act to "short circuit" the distance to the accessible environment if extreme erosion were to occur in the valleys.

- Aggradational and degradational history of Fortymile Wash and its tributaries. The interpretational history of Fortymile Wash drainage system and its sedimentation should be demonstrated to be internally consistent and in agreement with the paleoclimate and erosional history of the surrounding region and hillslopes. The reviewer should determine that DOE has investigated erosion in at least one tributary channel to Fortymile Wash by conducting a sediment balance in the tributary basin. Many erosive events and processes are recorded in the visible desert landscape; however, it is possible that erosive events and processes that are recorded in the various sediments of the interfluvial basins in the YM area cannot be directly evaluated. The amount of erosion during a bounded time period may be derivable from backcalculations from the volume of known, and dated sediment in a particular basin. The volume of sediment within the basin should approximate (balance with) the volume of material expected to be deposited if the degradation rate on the hillslopes is similar to that proposed by DOE in their calculations of average regional denudation rates. A geologic map which indicates aggradational features relative to degradational erosional landscapes should be presented.

- Backwasting or scarp-retreat potential, particularly on west facing slopes on the Solitario Canyon side of YM. The reviewer should determine that DOE has investigated and documented any episodes of

backwasting on the YM slopes adjacent to Solitario Canyon. Field measurements of slope conditions and talus accumulation leading to backcalculation of likely erosion rates should be a part of the DOE presentation.

- Evidence of surface stability including soil catenas, sediment properties, effect of paleoclimate, significance of appropriately age-dated boulder stripes, or other surface features should be presented. The location of relatively-age-dated, indurated soil surfaces on the Solitario Canyon side of YM, for example, should be shown on a geologic map of the vicinity and appropriate conclusions should be expressed regarding the significance of such relatively ancient and stable soil deposits. Similarly, concretionary features on the east-facing slopes evident in the form of calcified boulder stripes should be discussed for their relevance to the demonstration of slope and landform stability during the Quaternary in the YM vicinity.

- The effects of local and regional base level change on the nature of erosion in the YM vicinity should be investigated and reported in the LA. The regional base level represented by Fortymile Wash should be contrasted with the downcutting potential of tributaries of Fortymile Wash and the apparent aggrading nature of the Fortymile Wash during the recent Quaternary.

- The effects of climate change on the nature of erosion during the Quaternary Period in the YM vicinity should be discussed including a demonstration of the severity of Quaternary climate changes and the suspected impact on erosion rates in the YM vicinity. If the DOE believes that the YM vicinity evidences a different response to Pleistocene glaciation than is interpreted elsewhere in the Southwestern United States or the world, the LA should contain the corroborating data and appropriate discussions to defend such conclusions.

- The effects of erosional events and processes which have initiated significant erosion within the geologic setting during the Quaternary Period and which could occur in the repository's future in YM should be discussed. The DOE should demonstrate that an erosive event of such magnitude as the catastrophic draining and subsequent extreme erosion at Lake Tecopa could not occur at YM, for example. DOE should state why such extreme erosion could not have occurred at YM in the past.

- Complementary evidence for the extent and magnitude of erosion during the Quaternary Period within the geologic setting and at YM. The reviewer should determine that DOE has demonstrated that its investigations rely on multiple techniques which support and complement its evaluatory results. Reliance on and discussion of only one technique to demonstrate absence of extreme erosion in the YM area is not acceptable without significant support.

In conducting the aforementioned evaluations, the reviewer should determine that DOE uses: (1) analyses that are sensitive to evidence of extreme erosion during the Quaternary Period; and (2) assumptions that are not likely to underestimate its effects. In general, the reviewer will assess the adequacy of DOE investigations for evidence of extreme erosion during the Quaternary Period, both within the controlled area and outside the controlled area, as necessary, in the manner outlined in 10 CFR 60.21(c)(1)(ii)(B).

To conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, information, and data such as the results of research activities being conducted by NRC Office of Nuclear Regulatory Research, in addition to that provided by DOE in its LA. The reviewer should focus on additional data that can refine knowledge of extreme erosion during the Quaternary Period, and should acquire, as necessary, additional information to confirm the resolution capabilities of the methodologies. The reviewer should have acquired a body of knowledge regarding these and other critical considerations, in anticipation of conducting the *Safety Review*, to ensure that DOE erosion program is sufficient in scope and depth to provide the information necessary for resolution of the concerns.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare information in the license application (LA) concerning the potentially adverse condition (PAC) on evidence of extreme erosion during the Quaternary Period (henceforth referred to only as "extreme erosion" with the corresponding section of the FCRG and with the staff resolution status of objections to the LA submittal in the Open Item Tracking System (OITS) and determine if this information meets the following criteria:

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the proper references have been provided.

(2) The U.S. Department of Energy (DOE) has either resolved, at staff level, the Nuclear Regulatory Commission (NRC) objections to LA submittal that apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections, namely, DOE has:

- Identified all unresolved objections.
- Explained the differences between NRC and DOE positions that have precluded resolution of each objection.
- Described all attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) DOE has presented information and analyses in review areas listed in Section 3.2.1 through 3.2.1.5. If DOE has not presented information in these areas an explanation for not providing the information should be presented.

(4) Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful *Compliance Review* or NRC from making a decision regarding construction authorization within the three-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether Acceptance Criteria specified for the appropriate aggregate of the following *Compliance Reviews* have been met. The staff is expected to employ its professional judgment and other expert opinion to evaluate the DOE demonstration of compliance with the regulation. The staff does not expect each of the topics discussed below will be addressed and reviewed individually. However, it is expected that a majority of the topics will need to be addressed by DOE to provide adequate documentation of the presence or absence of the PAC—Evidence of Extreme Erosion During the Quaternary Period. Results of the compliance determinations should be documented by the staff to provide the basis for actual *Evaluation Findings* in the Safety Evaluation Report (SER).

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) as they related to 10 CFR 60.122(c)(16)

Using its professional judgment or other expert opinion, the staff will determine whether the assessment of presence or absence of extreme erosion has been accomplished in an acceptable manner, and whether description of the geology of the site properly supports the assessments required by 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(c)(16). For 10 CFR 60.21(c)(1)(ii)(A) specifically, the staff will review and evaluate information provided by DOE in the LA to support DOE analysis of the geology of the site as related to extreme erosion and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(c)(16).

For 10 CFR 60.21(c)(1)(ii)(B) the staff will review and evaluate information provided by DOE in the LA to support analyses of the degree to which extreme erosion has been characterized and found to be present. The staff will review and evaluate information provided by DOE in the LA to demonstrate either the absence of extreme erosion or the extent to which its presence may have been underestimated or undetected, taking into account the degree of resolution achieved by the investigation. The staff will also determine whether the analyses and investigations have been accomplished in an acceptable manner and whether lateral and vertical extent of the investigations are acceptable for supporting review of 10 CFR 60.122(c)(16).

For 10 CFR 60.21(c)(1)(ii)(F) the staff will review and evaluate information provided by DOE in the LA to support analyses and models used to predict future conditions and changes in the geologic setting as related to extreme erosion. The staff will also determine whether the analyses and models are properly supported by an appropriate combination of methods such as field and laboratory tests, monitoring data, or natural analog studies for assisting review of 10 CFR 60.122(c)(16).

In accomplishing the *Safety Review* of 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(c)(16), the staff will need to determine whether the following Acceptance Criteria have been met:

(1) Assumptions and analysis methods used by DOE to evaluate the information presented to determine the absence or acceptably describe the presence of evidence of extreme erosion during the Quaternary Period encompass appropriate ranges of relevant parameters.

(2) DOE can demonstrate that the extent of characterization is sufficient to define evidence of extreme erosion in the geologic setting and to assure that potential effects on critical pathways for radionuclide migration are adequately described.

(3) DOE can demonstrate that the scope of investigations has bounded the range of conceptual models of extreme erosion during the Quaternary Period as supported by the available data.

(4) Results of DOE investigations are not in conflict with published results from various staff and investigations or other independent studies, or the conflicts are adequately explained.

(5) DOE has demonstrated that it has determined the highest credible magnitude for erosive process rates during the Quaternary Period for the Yucca Mountain (YM) vicinity.

(6) DOE has demonstrated that evidence of extreme erosion is (is not) present by showing that erosive processes active during the Quaternary would (would not) be capable of exhuming a waste package in the 10,000-year reference life of the repository or change the distance from the repository to the accessible environment.

The staff evaluation should be conducted with the following assumptions in mind:

- Waste will be emplaced at a depth approximately 200 meters below the YM crest. Therefore, the favorable condition (FAC) on Minimum Waste Emplacement Depth [License Application Review Plan (LARP) Section 3.2.1.2] will be assumed by the staff to not be present based on current DOE design plans (U.S. Department of Energy, 1995).

- At YM erosion is thought to be a concern with respect to performance only in the washes of ephemeral streams. These washes were formed mainly by the downcutting action of flash flooding and debris transport events. The incised bottoms of the washes are closest to the elevation of the proposed repository. Erosion at ridge crests or on interfluves should have little effect on repository performance during the reference 10,000 year timeframe. Landslides could temporarily block washes and produce short-lived catchments, but these would not be expected to significantly affect performance. In fact, this scenario is explicitly covered in LARP Section 3.2.2.7. PAC—Natural Phenomena and Groundwater and should not be a part of the Extreme Erosion PAC review.

- The estimated range of precipitation that occurred in the site vicinity during the last 45,000 years is a reasonable model for the range of precipitation that will occur at the site during the next 10,000 years. This time spans the interval from the Wisconsin glacial maximum through the present interglacial period. A perusal of the data indicates that fossil records show no evidence for an average annual precipitation increase of more than 40 percent of modern

amounts. Future precipitation is expected to continue to be controlled by the rain-shadow conditions that produce the modern-day climate of the Great Basin (Dewispelare, 1993). The amounts and type of precipitation expected during the next 10,000 years will control the nature of future flooding events.

Based on the evidence presented, the reviewer should be able to ascertain whether extreme erosion is present or absent or the degree to which it is present, or if it may be present but underestimated, or present but undetected. A discussion of extreme erosion should include both the long-term average as well as averages for shorter periods, approximating the 10,000 year reference life of the repository. The staff considers that any erosional process which could affect repository performance during that period should be addressed. This will include examination of erosional processes in addition to regional denudation. Topics such as scarp retreat, base level changes, surface fluvial erosion rates, aggradation rates, climate change, etc. should be addressed in order to provide adequate documentation on the condition of extreme erosion during the Quaternary Period.

Any data used in a statistical evaluation by DOE should be included in the LA so that the NRC reviewers can evaluate the data using the same or comparable statistical techniques and can assess the uncertainty ascribed by DOE to the calculations. Independent NRC processing of selected data should determine that the DOE results can be reproduced and should determine that the sensitivity of the results to the various input parameters are accurately described by DOE.

The reviewer should determine whether alternate conceptual models of factors such as paleoclimate, paleohydrology, and geomorphology are identified and discussed. Reliance on a single line of evidence should be viewed with skepticism. Information and discussion should be sufficient to demonstrate the validity of the DOE argument and conclusions. The reviewer should determine that appropriate references, particularly for age dates, do not include personal communication or unpublished information as part of their bases. The reviewer should determine whether data and manipulations of data which lead to a quantitative conclusion include a statistical evaluation of the uncertainty in analytical method and the data itself is properly documented. The information presented in the LA should include the data from which conclusions are drawn or, at a minimum, first-order references in which the data resides [such as in a Topical Report (TR)]. Unsubstantiated, or inadequately documented DOE arguments should be rejected by the staff because they can not be validated. The staff reviewer should be satisfied that the range of techniques and analyses employed by DOE sufficiently characterizes the erosional events and processes with little likelihood that significant erosion has been undetected and hence unevaluated for potential effect on waste isolation.

NRC has suggested, for regulatory purposes, that a timeframe of 2.0 million years be used for the Quaternary Period (Nuclear Regulatory Commission, 1983 p. 373) while DOE has suggested in some publications (DOE, 1993) a timeframe of 1.6 million years for the Quaternary Period. DOE should document that use of the shorter period will result in no material change in its analysis of the evidence of extreme erosion during the Quaternary Period. The timeframe suggested by NRC was meant to ensure that a reasonably long period which encompasses numerous shorter periods (duration of "shorter periods" is comparable to the 10,000-year period of regulatory interest of the repository) be investigated for possible events of extreme erosion of both long and short duration. The reviewer should determine if the timeframe investigated by DOE and the logic used by DOE to establish such a timeframe of reference are adequate to encompass the full range of erosive events and processes which acted during the Quaternary Period. A 1.6-million year timeframe, as proposed by DOE, would still allow for the evaluation and inclusion of numerous "shorter periods" and, depending on the range of processes and events described by DOE in the LA, might be considered adequate to describe the evidence of extreme erosion during the Quaternary Period.

To make compliance determinations, the staff should understand the program of exploration, laboratory testing, analysis, and characterization implemented by DOE. This review will include, but may not be limited to, aspects discussed below under Subsections 3.2.1.1, 3.2.1.2, 3.2.1.3, 3.2.1.4., and 3.2.1.5. These subsections present several areas of review, including field exploration methods, laboratory testing, conceptual modeling, computer modeling, and site characterization. It is not required that each of the areas of review below be evaluated by the reviewer, rather, an appropriate combination of the review areas, depending on the breadth of the DOE LA submittal, shall be conducted to provide reasonable assurance that the condition "evidence of extreme erosion" has been appropriately investigated and characterized as present or absent by DOE.

3.2.1.1 Field Exploration For Evidence of Extreme Erosion

For any field exploration information presented by DOE, the staff will review the DOE field exploration program to determine its sufficiency to establish bounds for the characteristics of evidence of extreme erosion in the geologic setting including age, character, and importance of identified evidence. A surficial or geomorphic map which identifies any areas of extreme erosion and demonstrates a thorough evaluation of erosive events and processes within the geologic setting, particularly for the controlled area and nearby, should be a part of the DOE submittal unless comparable maps generated by other investigations can be shown to provide the appropriate information. Uncertainty in assumptions, exploration and evaluation techniques, and conclusions should be treated explicitly by DOE in the LA.

Field Mapping—For any field mapping information presented by DOE the staff will review and assess the results relative to the definition of the distribution and characteristics of extreme erosion in the geologic setting. As applicable the staff will use the following review procedures and acceptance criteria in the assessment

(1) The areal extent of geologic mapping, in concert with other aspects of the field exploration program, is sufficient to define extreme erosion or the lack thereof in the geologic setting both within and outside the controlled area, including its absence or the degree to which it is present, or if it may be present and underestimated, or present but undetected. The aggregate of topics which may be supported by mapping include: (i) stream erosion; (ii) base level change; (iii) nature of erosive/sedimentary environment; (iv) short-term and long-term erosion rates in areas such as Solitario Canyon, Fortymile Wash, and YM slopes; (v) importance and likelihood of highly erosive but suspected infrequent events such as the debris flow evidenced on Jake Ridge in the early 1980's; (vi) importance of climate stability or change on erosion rates; (vii) presence or absence of types of erosion which might affect waste isolation, (viii) mapping of surficial features to allow the evaluation of sediment provenance and quantity including describing erosive events and processes, and (ix) description of pertinent landforms or features.

(2) The scale of mapping, including scales of aerial photographs used as base maps, is sufficient to provide the accuracy and precision required for locating and mapping any landforms resulting from extreme erosion, or geomorphic features which demonstrate slope stability and the absence of extreme erosion. Map scale should allow for the identification of land features resulting from erosive events and processes which if they were to occur in the future might affect waste isolation (i.e., downcutting or incision in the tens of meters).

(3) Location and identification of landforms or features described by DOE should be detailed enough for field verification of mapped characteristics and landforms. DOE should demonstrate that such features and characteristics are accurately located, described, and reported. The means for reporting should be sufficient to identify the location of the landform or deposit and to facilitate field verification by NRC (if desired).

(4) Alternative interpretations of the acquired data are provided when appropriate. Because geomorphology and the explanation of origin of landforms are interpretive science, there are usually multiple hypotheses to explain the action of the natural processes which sculpted the geologic features. Where viable, but conflicting, explanations for the origin, timing, and extent of an erosional or depositional feature are raised, DOE should demonstrate that it has sufficiently investigated each of the hypotheses. DOE discussions should demonstrate that conclusions are reasonable for a particular set of events.

(5) Uncertainties in data acquisition, accuracy of location, data representativeness, data reduction, age-dating, identification of strata and lithologies, stratigraphic relationships, and analytical methods are presented and discussed. The means used to reduce uncertainty and the resultant residual uncertainty are reported.

Geophysical Testing—For any geophysical testing data presented by DOE the staff will review and assess the results (e.g., seismic reflection, seismic refraction, seismic tomography) conducted at and around YM that were used to assess characteristics and distribution of events and processes of extreme erosion. Geophysical techniques are one of the means which can be used to define buried, otherwise unreachable strata and lithologies, particularly of aggradational and depositional features. As applicable the staff will use the following review procedures and acceptance criteria in the assessment if geophysical tests are used in the evaluation of this PAC.

(1) The number and location of geophysical tests, in concert with other aspects of the field exploration program, are sufficient to define the evidence of the PAC in the controlled area including its absence or the degree to which it may be present, present but underestimated, or present but undetected.

(2) Detection capabilities of the testing methods are evaluated and appropriately reported by DOE. For example, it is probable that geophysical testing could be used to identify the thickness and extent of various Quaternary Period alluvial deposits contained in Fortymile Wash and its tributaries. Geophysical results of this type would be expected to be correlated with and enhanced by results of borehole sampling of appropriate horizons in the geophysically defined strata.

(3) Resolution capabilities of the geophysical methods are evaluated and appropriately reported by DOE. Determination of the thickness and quality of depositional layers may be critical to developing the erosive history of YM slopes during the Quaternary Period; the correct evaluation of such properties depends upon the resolution characteristics of the instrumentation.

(4) Techniques for collection of geophysical field data are shown to be appropriate, limitations of the techniques are understood and are accounted for, and limitations and inherent uncertainties are accounted for in the final analyses.

(5) Capabilities and limitations of the geophysical data processing techniques are evaluated and appropriately reported by DOE. Uncertainties in interpretation should be discussed along with alternate explanations of structure and characteristics.

(6) The reproducibility and sensitivity of the results to the various input parameters are accurately described by DOE and are presented in an appropriate format to facilitate verification by independent processing of selected geophysical data which might be performed by NRC staff.

(7) Alternative interpretations of the acquired data are provided when appropriate. The sedimentation histories of Fortymile Wash and its tributaries are presented in the DOE TR on extreme erosion (U.S. Department of Energy, 1993) with alternate hypotheses including erosional removal of sediment down to the depth of the bedrock channel for the entire basin, and alternately, a set of cut-and-fill sequences in the Quaternary Period and the Holocene without enough erosion to remove all the basin sediments. Where such alternate explanations are viable, DOE should demonstrate the validity of its evaluation and final conclusion of presence or absence (if necessary, carry the consequence of multiple hypotheses through to its final consequence evaluations in the assessment of repository performance).

(8) Uncertainties in data acquisition, data representativeness, data reduction; age-dating, identification of strata, lithology and stratigraphic relationships, and analytical methods should be presented and discussed. The means used to reduce uncertainty and the resultant residual uncertainty are reported.

Drill Core and Borehole Logging—For any drill core and borehole logging information presented by DOE as applicable, the staff will use the following review procedures and acceptance criteria in the assessment of DOE program of drilling core recovery and borehole logging which results in data used in the evaluation of extreme erosion.

(1) The program of drilling and subsequent drill core analyses used during site characterization, in concert with other aspects of the field exploration program, is sufficient to define the PAC (in the sediments of Fortymile Wash, for example, where recovery of meaningful alluvial core is expected to be extremely difficult) including its absence or the degree to which it is present, present but underestimated, or present but undetected. Such drilling and subsequent subsurface data acquisition may be an important part of a demonstration that erosion and its extremes are adequately researched and that the full range of available information has been utilized to arrive at the conclusions included in the LA.

(2) The drilling techniques used, and their associated limitations, are accurately evaluated and reported by DOE. Information on field verification of drilling techniques during the acquisition of the data is available to the reviewer. The use of drill core analyses and borehole logging records in concert with age determinations in order to establish sediment quantities and provenance in the Fortymile Wash drainage basin, for example, is rigorously documented and the methods used to age-date deposits or structures are accurately presented.

(3) DOE evaluation of the core logs accurately reflects the character of the lithology encountered by the drilling. The DOE evaluation places emphasis on amounts and areas of alteration, locations of lithologic and stratigraphic contacts, and general lithologic descriptions. The core logging and analyses are based on standard industry practices for borehole logging. DOE should demonstrate that the core recovered is a representative sample of the field conditions.

(4) Comparison of the results of geophysical logging with the core and accompanying descriptive core logs shows results which are consistent.

(5) Alternative interpretations of the acquired data are provided when appropriate. [See (7) discussed under Geophysical Testing, earlier].

(6) Uncertainties in data acquisition, data representativeness, data reduction, age-dating, identification of strata, lithologies and stratigraphic relationships, and analytical methods are presented and discussed. The means used to reduce uncertainty and the resultant residual uncertainty are prominently reported.

Other Exploration Programs—For any other exploration techniques used by DOE in evaluating evidence of extreme erosion , as applicable, the staff will use the following review procedures to determine the acceptability of the results (e.g., trenching, acquisition of meteorologic and climatologic data).

(1) The number and location of planned tests and data acquisition, in concert with the field exploration program, are sufficient to define the evidence of extreme erosion in the geologic setting.

(2) The DOE in the LA utilizes defensible evidence in its discussion of the presence or absence of erosion during the Quaternary Period and its subsequent classification as extreme or not extreme. Detection capabilities of the methods used are evaluated and appropriately reported by DOE.

(3) Techniques for collection of field data are shown to be appropriate, limitations of the techniques are understood and are accounted for, and limitations and inherent uncertainties are carried through the required analyses. Any samples acquired in the field exploration and characterization activities are well-documented as to location, collection method, analytical method, and statistical inference. Data corroborating the discussions either are a part of the LA or are readily accessible in electronic format such as in the DOE computerized database. It is desirable that the LA contain appropriate maps as well as providing accessible, usable, electronic copies of such data in appropriate format (such access might be provided to the staff reviewer within the purview of the DOE electronic databases).

(4) Capabilities and limitations of the data processing techniques are evaluated and appropriately reported by DOE.

(5) Techniques which are controversial are appropriately supported in the LA with documentary evidence demonstrating the test of validity of the technique utilized. The reasons for application to the current problem as well as short-comings, limitations, and any inherent uncertainty are presented. Documentation of the technique in a peer reviewed journal is not to be considered, *a priori*, by the NRC reviewer as acceptable evidence of validity.

(6) Alternative interpretations of the data are provided when appropriate. When controversial or "cutting edge" techniques are used, objective evidence and evaluation of the validity and accuracy of the technique in the context of the conclusionary interpretation embraced by DOE is presented in the LA.

(7) Uncertainties in data acquisition, data representativeness, data reduction, age-dating, identification of strata, lithologies and stratigraphic relationships, and analytical methods should be presented and discussed. The means used to reduce uncertainty and the resultant residual uncertainty are reported.

3.2.1.2 Laboratory Testing To Support Evaluation Of Erosion

For any laboratory analyses which are a part of the DOE compliance demonstration, the staff reviewer should determine that the laboratory testing program is sufficient to establish the ages of the various pieces of evidence for and against extreme erosion, including the ages of any stable surfaces used to discount extreme erosion as a factor at the site. Additionally, NRC

staff should evaluate for sufficiency any laboratory evidence used to demonstrate the absence of extreme erosion in the recent geologic evolution (past 2.0 million years) of the geologic setting.

The staff will selectively review and assess procedures and results from the various laboratory testing programs used by DOE, including those from such tests as chemical analyses and age determinations. As applicable, the staff will use the following review procedures and acceptance criteria to determine the acceptability of the DOE demonstration of compliance:

(1) Approaches used in sampling various pieces of evidence of extreme erosion are either standard or, if not standard, are documented such that the sampling procedure can be repeated by those trained in the technique.

(2) Procedures used in the subsequent analyses are either standard or, if not standard, are documented such that the tests can be repeated by those trained in the technique. Techniques for sampling and analysis which rely on subjective judgment of the analyst and which are not easily described and accomplished by peers are not acceptable tests. For example, the selection of boulders and the subsequent laboratory methods used to determine cation-ratio ages for desert varnish on YM and nearby areas (U.S. Department of Energy, 1993) are replicable by NRC while using the DOE described technique.

(3) Resolution capabilities of the methods used are evaluated and appropriately reported. If state-of-the-art dating techniques, such as cation-ratio dating of desert varnish or cosmogonic methods are used, the reviewer should determine that DOE presents a cogent explanation of the theoretical basis of the technique and a scientifically valid explanation for the technique's applicability to the particular problem. When possible, multiple techniques are applied to the same geologic feature to support age determinations.

(4) Where calibration curves are used, DOE should provide sufficient documentation to permit a thorough evaluation of their bases and application.

(5) Results of all analyses are documented by DOE such that a technical reviewer can follow the steps used to arrive at a given conclusion.

(6) If DOE test results are culled or rejected, the technical bases for such rejection are clearly established and reported by DOE. An assessment of whether culling or rejection of data has unreasonably biased the results is included.

(7) Uncertainties in the analyses, including instrument analytical, sampling, data reduction, and data representativeness uncertainties, are appropriately reported and are a part of the uncertainty described in the data analyses. For example, cation-ratio age dating of desert varnish requires sophisticated instrumentation for analyses; the instrument(s) should be calibrated and their accuracy determined and reported in the LA in order for appropriate staff assessment of uncertainty of DOE results and conclusions.

(8) Alternative interpretations of the acquired data are provided when appropriate. [See Section 3.2.1.1 Item (7) under Geophysical Testing]

3.2.1.3 Conceptual Modeling To Explain Erosion

For any DOE conceptual models of extreme erosion during the Quaternary Period the staff should determine that the formulation and application of the models are sufficient to assure that an appropriate range of reasonable and realistic models has been considered. As applicable, the staff will use the following review procedures and acceptance criteria in determining that DOE conceptual models are acceptable.

(1) Interpretations drawn from the separate exploration, laboratory, or computer techniques corroborate one another, or differences are adequately explained. The relationships between calibration curve data and field-sampled data for calibrated age dating techniques, expected to be used in evaluating extreme erosion during the past 2.0 million years, are well documented and thoroughly explained.

(2) A range of reasonable and conservative alternative interpretations is presented when contradictions in interpretations do exist. For example, theories and explanations for Quaternary changes in climate in the geologic setting which

differ from widely understood and accepted temperature and precipitation regimes established in the Southwest and in the rest of the world must be defended by DOE through reference or original data.

(3) Uncertainties in the interpretations of extreme or other erosive processes and events are adequately documented and addressed by DOE. An analysis of the representativeness of the data from which conclusions are drawn is presented. All uncertainties, including analytical and calculational, are to be documented and discussed. Assumptions are to be clearly stated and any deviations from normally accepted analytical or calculation techniques are to be explained. Uncertainties introduced by programs [such as semi-quantitative program (SSQ) used in cation-ratio dating analyses by DOE in their TR on extreme erosion (U.S. Department of Energy, 1993)] or equipment chosen by DOE (with the knowledge of inherent uncertainties) are defended by inclusion of appropriate supporting data, discussion of appropriateness of analytical method, evaluation of uncertainty and likely residual uncertainty, and unequivocal conclusions based on the information presented.

(4) DOE basic assumptions are clearly described and subsequent conceptual models are consistent with the understanding of field and laboratory data. Conceptual hypotheses for initiating events and processes, such as Quaternary Period climate temperatures, are consistent with the results of work elsewhere in the world. For example, YM should experience its coldest Quaternary Period temperatures in cycles and ages similar to those of the rest of the world.

(5) Model descriptions clearly reflect the degree of resolution of the experimental and investigative techniques applied to acquire data for the modeling, including the degree of resolution of data related to what could be present but undetected due to limitations of the methods applied.

(6) Models provide an adequate qualitative and quantitative explanation of features which are present or could be present but undetected. The level of uncertainty in the models is described and the effect of such uncertainties on the validity of the conclusions is explained.

(7) DOE numerical models and their results are comparable to results of analyses of other scientists. Models and results are compatible with results of analyses using independent models, such as those developed by the NRC or elsewhere. DOE findings based on their models are not significantly different from conclusions which follow from widely accepted hypotheses.

(8) Conceptual models are compatible with those proposed for other geologic and physical phenomena, such as tectonics and climate (e.g., the extent and severity of past glaciations and their effect on local climate at YM).

(9) Models either fit within the range of reasonable and acceptable alternative models or, if they are bounding models, clearly demonstrate that features which may be present and undetected are taken into account.

3.2.1.4 Computer Modeling To Evaluate Extreme Erosion

For any computer modeling which is a part of the compliance demonstration of DOE the staff will determine that models of Quaternary Period extreme or other erosion is sufficient to assure an appropriate range of reasonable and realistic models have been considered. As applicable, the staff will use the following review procedures and acceptance criteria to determine the acceptability of the results of DOE computer modeling.

(1) Modeling incorporates reasonable and realistic bounds on the range of permissible parameters and input data. Computer models must follow from and be compatible with the appropriate conceptual models.

(2) Codes used are shown to be mathematically correct and to adequately represent the phenomena base on appropriate technical assumptions and simplifications.

(3) Resultant output of the models and codes can be readily compared to results from other similar models and codes.

(4) Ranges or bounds of the results are correctly reported along with the results of sensitivity and uncertainty analyses. [See Item (9) under Conceptual Models, Section 3.2.1.3]

(5) Alternative models and interpretations are provided when appropriate.

(6) Uncertainties in the analyses, including data sampling, reduction, representativeness, biases, and instrument analytical uncertainties, are appropriately reported and are a part of the uncertainty described in the data analyses.

3.2.1.5 Characterization of Evidence of Extreme Erosion

NRC staff will determine that the aggregate of the field exploration, laboratory testing, and conceptual and computer modeling is sufficient to assure that the broad range of erosive processes and events operating during the Quaternary Period has been investigated and evaluated within the geologic setting, as appropriate, and at Yucca Mountain, Nevada. Staff will determine whether characterization is sufficient to assure that an appropriate description and subsequent evaluation of potential effects of similar extreme or other erosion on waste isolation can be accomplished.

As applicable, the staff will use the following review procedures and acceptance criteria to determine the acceptability of DOE characterization of the presence or absence of extreme erosion.

(1) A time span of sufficient length to represent the approximately 2.0 million year duration of the Quaternary Period is investigated by DOE. Any deviation from investigating the entire 2.0 million years (assigned to the Quaternary Period by NRC staff) is justified by DOE.

(2) The areal extent of DOE investigations and characterization of erosive processes and events during the Quaternary Period is sufficient to identify extreme erosion which might affect waste isolation. Areas outside the controlled area should be investigated if extreme erosion there could affect waste isolation or the larger area provides the range of erosive events and processes which have occurred in the geologic setting during the Quaternary Period.

(3) The scale of DOE investigations is sufficient both in field studies and evaluations to assure that important erosive events and processes or features have not been missed. Events and processes that operated at a larger scale in earlier portions of the Quaternary (during mid-glacial cycles, for example) should be evaluated and discussed. If events and processes are dependent on a specific climate, for example, the reviewer should determine that DOE assesses and discusses whether such a climate (climate change) is expected to occur in the 10,000-year period of regulatory interest.

(4) Characterization efforts encompass alternative methods of age-dating, laboratory, and evaluatory techniques in order to provide a conservative estimate of the nature, rate, and extent of erosive processes and events during the Quaternary Period.

(5) Any discussions of processes and events during the Quaternary Period are shown to be substantiated in the literature or by DOE field studies. The reviewer should determine that DOE provides hard evidence for conclusions. For example, particular constructs designed to explain climate change at YM during the Quaternary Period which are not in agreement with other scholarly documentation should be extremely well supported and documented.

(6) Uncertainties in the data collection, sampling, representativeness, analyses, and evaluation including instrument analytical uncertainties are appropriately reported and are a part of the uncertainty described in the conclusions. For example, cation-ratio age dating of desert varnish requires a series of assumptions to allow for the dating technique to be applicable in the erosion context. The reviewer should determine that the uncertainties contained in the assumptions are presented and any resultant biasing of the results and conclusions is explained.

(7) DOE has characterized erosion thoroughly at the proposed YM repository and nearby by discussing, at a minimum, the following:

- Short-term (c. 10,000 years and less) and long-term erosion rates (up to length of Quaternary Period) on hillslopes and in valleys. The established long-term rates should be compared to any possible short-term catastrophic rates of erosion which have occurred within the geologic setting (not necessarily only at YM). The likelihood of such extreme erosion having occurred and remaining undetected or the inability of such erosion to have ever occurred at YM should be discussed. The NRC reviewer should determine that DOE

has mapped the repository relative to the elevations of the surrounding topography in order to identify those aspects of the proposed repository which would be most vulnerable to extreme erosion. The reviewer should be especially interested in DOE evaluation of erosion in those areas where the depth to the horizontal projection of the repository horizon is less than 100 m (e.g., valleys in SE portion of the controlled area). In these areas, erosion less than that required to unearth the repository might act to "short circuit" the distance to the accessible environment if extreme erosion were to occur in the valleys.

- Aggradational and degradational history of Fortymile Wash and its tributaries. The interpretational history of Fortymile Wash drainage system and its sedimentation are internally consistent and in agreement with the paleoclimate and erosional history of the surrounding region and hillslopes. The reviewer should determine that DOE has investigated erosion in at least one tributary channel to Fortymile Wash by conducting a sediment balance in the tributary basin. Many erosive events and processes are recorded in the visible desert landscape; however, it is possible that erosive events and processes that are recorded in the various sediments of the interfluvial basins in the YM area cannot be directly evaluated. The amount of erosion during a bounded time period may be derivable from back calculations from the volume of known, and dated sediment in a particular basin. The volume of sediment within the basin should approximate (balance with) the volume of material expected to be deposited if the degradation rate on the hillslopes is similar to that proposed by DOE in calculations of average regional denudation rates. A geologic map which indicates aggradational features relative to degradational erosional landscapes should be presented.

- Backwasting or scarp-retreat potential, particularly on west facing slopes on the Solitario Canyon side of YM. The reviewer should determine that DOE has investigated and documented any episodes of backwasting on the YM slopes adjacent to Solitario Canyon. Field measurements of slope conditions and talus accumulation leading to back calculation of likely erosion rates should be a part of the DOE presentation.

- Evidence of surface stability including soil catenas, sediment properties, effect of paleoclimate, significance of appropriately age-dated boulder stripes, or other surface features should be presented. The location of relatively age-dated, indurated soil surfaces on the Solitario Canyon side of YM, for example, should be shown on a geologic map of the vicinity. Appropriate conclusions should be expressed regarding the significance of such relatively ancient and stable soil deposits. Similarly, concretionary features on the east-facing slopes evident in the form of calcified boulder stripes should be discussed for their relevance to the demonstration of slope and landform stability during the Quaternary in the YM vicinity.

- The effects of local and regional base level change on the nature of erosion in the YM vicinity should be investigated and reported in the LA. The regional base level represented by Fortymile Wash should be contrasted with the downcutting potential of tributaries of Fortymile Wash and the apparent aggrading nature of the Fortymile Wash during the recent Quaternary.

- The effects of climate change on the nature of erosion during the Quaternary Period and in the regulatory future in the YM vicinity should be discussed including a demonstration of the severity of Quaternary climate changes and the suspected impact on erosion rates in the YM vicinity. If DOE believes that the YM vicinity evidences a different response to Pleistocene glaciation than is interpreted elsewhere in the Southwestern United States or the world, the LA should contain the corroborating data and appropriate discussions to defend such conclusions.

- The effects of erosional events and processes which have initiated significant erosion within the geologic setting during the Quaternary Period and which could occur in the repository's future in YM should be discussed. DOE should demonstrate, for example, that an erosive event of such magnitude as the catastrophic draining and subsequent extreme erosion at Lake Tecopa could not occur at YM. DOE should state why such extreme erosion could not have occurred at YM in the past.

- Complementary evidence for the extent and magnitude of erosion during the Quaternary Period within the geologic setting and at YM. The reviewer should determine that DOE has demonstrated that investigations rely on multiple techniques which support and complement evaluatory results. Reliance on and discussion

of only one technique to demonstrate absence of extreme erosion in the YM area is not acceptable without significant support.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	DWM/ENGB	Geosciences/Geotechnical Engineering Section
Support:	DWM/PAHB	Geochemistry

4.2 Interfaces

4.2.1 Input Information

Information derived from activities related to other review plans will provide input important for considering evidence of extreme erosion. A list of review plans for which this interface is anticipated to be particularly important is presented in the following table.

Input Information	*Review Plan No.*
Geologic System—Data on the geomorphology of the region and site. Topographic maps. Surficial deposit maps. Geomorphologic maps. Discussions of the geomorphic processes and associated landforms in the region and the site. Information on aggradation/degradation including history of sedimentation in Crater Flat and Fortymile Wash, in particular.	3.1.1
Hydrologic System—Data on the surface hydrology.	3.1.2
Geochemical System—Data on solution features.	3.1.3
Climatological and Meteorological Systems Descriptions Paleoclimate—Discussions of likely past climates during the Quaternary Period.	3.1.4 3.1.4.X
FAC: Nature and Rates of Physical Processes—Discussion of the rates of erosive processes in the area and at YM.	3.2.1.1
FAC: Minimum Waste Emplacement Depth—Discussion of likely depth from repository location to the overlying surface.	3.2.1.2
FAC: Nature and Rates of Hydrologic Processes—Discussion of likely surface hydrology.	3.2.2.1
FAC: Nature and Rates of Geochemical Processes—Discussion of rate of solutioning.	3.2.3.1

Input Information	*Review Plan No.*
PAC: Changes to Hydrologic System From Climate—Discussion of climate change and associated change in hydrology which might influence anticipated rates of erosion.	3.2.4.2

4.2.2 Output Information

Output from activities associated with this review plan will provide specific information important for use in other review plans as the following table indicates.

Output Information	*Review Plan No.*
PAC: Flooding—Likely rates of erosion, mass wasting, and other degradational phenomena.	3.2.2.5
PAC: Changes in Hydrologic Conditions—Drainage changes resulting from erosion.	3.2.2.9
PAC: Potential For Water Table To Rise and Inundate a Repository—Drainage changes resulting from erosion.	3.2.2.11
Assessment of Compliance With Criteria For Integrated Analyses of Combinations of Favorable Conditions and Potentially Adverse Conditions—Expected rates of erosion during the regulatory period. Determination regarding the existence of this PAC—Anticipated erosion (if extreme) must be considered with other physical changes in the system.	3.2.5
Assessment of Compliance With The Requirements For Cumulative Releases of Radioactive Materials. Models of Erosion—Extreme and/or other erosion rates will be provided for consideration in performance assessment. Assessment of Anticipated and Unanticipated Processes and Events—Extreme and/or other erosion rates will be provided for consideration in performance assessment. Nature and Rates of Quaternary Period Extreme Erosion—Extreme and/or other erosion rates will be provided for consideration in performance assessment.	6.1
Assessment of Compliance With The Individual Protection Requirements. Models of Erosion—Extreme and/or other erosion rates will be provided for consideration in performance assessment. Assessment of Anticipated and Unanticipated Processes and Events—Extreme and/or other erosion rates will be provided for consideration in performance assessment.	6.2

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing and the *Compliance Reviews*. The Acceptance Review findings and the actual *Evaluation Findings* resulting from the *Compliance Reviews*, including the supporting bases for all findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds that the information presented by DOE on the PAC concerned with evidence of extreme erosion is acceptable (not acceptable) for docketing and *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) as they relate to 10 CFR 60.122(c)(16)

The NRC staff finds that the PAC related to evidence of extreme erosion has (has not) been acceptably demonstrated to be present and that there is (is not) reasonable assurance that the regulatory requirements of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) as they relate to 10 CFR 60.122(c)(16) will be met.

The staff is developing supporting *Example Evaluation Findings* for each of the indicated 10 CFR 60.21 regulatory requirements for inclusion in subsequent revisions of this review plan.

6 REFERENCES

DeWispelare, A.R., L.T. Herren, M.P. Miklas, and R.T. Clemen. 1993. *Expert Elicitation of Future Climate in the Yucca Mountain Vicinity; Iterative Performance Assessment Phase 2.5*. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

Nuclear Regulatory Commission. 1983. *Staff Analysis of Public Comments on Proposed Rule 10 CFR Part 60, Disposal of High-Level Radioactive Waste in Geologic Repositories*. NUREG-0804. Washington, DC: Office of Nuclear Regulatory Research.

Nuclear Regulatory Commission. *Format and Content for the License Application for the High-Level Waste Repository*. Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of Waste Management to identify the most current edition of the FCRG in effect.]

U.S. Department of Energy. 1988. *Erosion, in Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada*. DOE/RW-0199. Washington, DC: U.S. Department of Energy: Chapter 8, Section 8.3.1.6. Vol. V, Part B.

U.S. Department of Energy. 1993. *Evaluation of the Potentially Adverse Condition—Evidence of Extreme Erosion During the Quaternary Period At Yucca Mountain, Nevada*. Yucca Mountain Site Characterization Project Topical Report OCRWM. YMP/92-41-TPR. Washington, DC: U.S. Department of Energy, p. 71.

U.S. Department of Energy. 1995. *Technical Basis Report for Surface Characteristics, Preclosure Hydrology, and Erosion, Office of Civilian Radioactive Waste Management*. YMP/TBR-001. Rev. 0. Washington, DC: U.S. Department of Energy.

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

POTENTIALLY ADVERSE CONDITIONS: FLOODING

1 APPLICABLE REGULATORY REQUIREMENT(S)

The subject of this review plan is the following potentially adverse (PAC) condition concerning the potential for flooding of the underground facility, defined in 10 CFR 60.122(c)(1).

Subpart E — Technical Criteria
SITING CRITERIA

§ 60.122 Siting criteria.

* * * * *

(c) *Potentially adverse conditions.*

The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(1) Potential for flooding of the underground facility, whether resulting from the occupancy and modification of floodplains or from the failure of existing or planned man-made surface water impoundments.

* * * * *

For this review plan, the staff will determine if the subject PAC, identified above, has been described and assessed pursuant to the regulatory requirements defined in 10 CFR 60.21(c)(1), as applicable:

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance.

* * * * *

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) Analyses to determine the degree to which each favorable condition and potentially adverse condition enumerated in § 60.122 of this part has been characterized and found to be present. For each potentially adverse condition, the analysis shall demonstrate its absence or the extent to which it may be present and still undetected, taking into account the degree of resolution achieved by the investigations. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionculide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area if they may affect isolation within the controlled area.

* * * * *

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

2.2 Compliance Review

2.2.1 Safety Review

This regulatory requirement topic is limited to considering DOE's demonstration, through appropriate investigations, of the potential for surface-water flooding of the underground facility. It is not concerned with future flooding of the repository due to a rise of the water table, which is covered in Section 3.2.2.11 ("PAC: Potential for the Water Table to Rise and Inundate a Repository") of the license application. Flooding due to future or existing perched water bodies is covered in Section 3.2.2.12 ("PAC: Perched Water Bodies"). Section 3.2.5 (Assessment of Compliance with Criteria for Integrated Analyses of Combinations of Favorable Conditions and Potentially Adverse Conditions) will examine compliance with 10 CFR 60.122 (a)(2). The effectiveness of seals and other engineering measures to preclude post-closure flooding of the geologic repository will be addressed in various sections of Chapter 3.2 ("Siting Criteria"), Section 4.3 ("Assessment of Compliance with Design Criteria for Shafts and Ramps"), and Section 5.4 ("Assessment of Engineered Barrier System Compliance with Performance Objectives"). Findings under this review plan will provide input to review plans 4.2, 4.3, and 4.4.

In conducting the *Safety Review*, the reviewer will, as a minimum, determine the adequacy of the data and analyses presented in the license application to support DOE's demonstrations regarding 10 CFR 60.21(c)(1)(ii) (A) (B), and (F) as they relate to 10 CFR 60.122(c)(1). The specific aspects of the license application on which the reviewer will focus are discussed below. The Acceptance Criteria are identified in Section 3 of this review plan. Specifically, DOE should have: (1) assessed whether and to what extent this PAC is present (i.e., the potential for flooding of the geologic repository operations area (GROA) underground facility); (2) evaluated the extent to which the presence of this PAC may have been underestimated or undetected taking into account the degree of resolution achieved by the investigations; (3) assured that the lateral and vertical extent of field data collection is sufficient to support items (1) and (2); and (4) further evaluated the information presented under items (1) and (2), using assumptions and analysis methods that encompass the ranges of all relevant parameters.

The reviewer will also evaluate the support for DOE models that are used to assess the presence or absence of the potential to flood the GROA underground facility. Analyses and models that are used to predict the preclosure flooding shall be supported with an appropriate combination of such methods as field tests, in-situ tests, and laboratory tests that are representative of field conditions, monitoring data, and natural analog studies.

In conducting the aforementioned evaluations, the reviewer should determine whether DOE used: (1) analyses that are sensitive to evidence of the potential for flooding the GROA underground facility; and (2) assumptions that are not likely to underestimate its effects. In general, the reviewer will assess the adequacy of DOE's investigations for evidence of this PAC, both within the controlled area and outside the controlled area, as necessary, in the manner outlined in 10 CFR 60.21(c)(1)(ii)(B).

To conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, information, and data in addition to that provided by DOE in its license application. The reviewer should focus on additional data which can refine knowledge of this PAC, and should acquire, as necessary, additional information to confirm the resolution capabilities of the methodologies. The reviewer must acquire a body of knowledge regarding these and other critical considerations in anticipation of conducting the *Safety Review* to assure that DOE's submittal is sufficient in scope and depth to provide the information necessary for resolution of the concerns.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the *Acceptance Review* for docketing, the staff will compare the information in the License Application (LA) concerning GROA surface facility descriptions with the corresponding section of the FCRG and with the staff's resolution status of objections to LA submittal in the Open Item Tracking System (OITS) and determine if this information meets the following criteria.

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) DOE has either resolved, at the staff level, the NRC objections to LA submittal that apply to this regulatory requirement topic, or provided all information requested in Section 1.6 of the FCRG for unresolved objections, namely, DOE has:

- Identified all unresolved objections
- Explained the differences between NRC and DOE positions that have precluded resolution of each objection
- Described all attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60

(3) In addition, unresolved objections, individually or in combination with others, will not prevent the reviewer from conducting a meaningful *Compliance Review* and the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the *Acceptance Criteria* specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented by the staff to provide the basis for actual *Evaluation Findings* documented in the Safety Evaluation Report (SER).

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F), and 10 CFR 60.122(c)(1)

The staff will determine whether the assessment of presence or absence of flooding of the underground facility has been accomplished in an acceptable manner, and whether description of the site properly supports the assessments required by 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(c)(1). For 10 CFR 60.21(c)(1)(ii)(A) specifically, the staff will review and evaluate information provided by DOE in the LA to support DOE's analysis of the geology, hydrology, and meteorology of the site as related to the potential for flooding and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(c)(1). For 10 CFR 60.21(c)(1)(ii)(B), the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses of the degree to which the flooding potential of the GROA underground facility has been characterized and found to be present. The staff will review and evaluate information provided by DOE in the LA to demonstrate either the absence of flooding of the GROA underground facility, or the extent to which its presence may have been underestimated or undetected, taking into account the degree of resolution achieved by the investigation. The staff will also determine whether the analyses and investigations have been accomplished in an acceptable manner and whether the lateral and vertical extent of the investigations are acceptable for supporting review of 10 CFR 60.122(c)(1). For 10 CFR 60.21(c)(1)(ii)(F), the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses and models used to predict preclosure flooding. The staff will also determine whether the analyses and models are properly supported by an appropriate combination of methods such as field and laboratory tests and monitoring data for assisting review of 10 CFR 60.122(c)(1).

To make compliance determinations for these *Acceptance Criteria*, the staff must review the program of site characterization, analysis, and design implemented by DOE. This review is discussed below under Subsections 3.2.1.1 and 3.2.1.2 of this review plan. These subsections present review procedures and *Acceptance Criteria* related to potential flooding of the underground facility.

3.2.1.1 Hydrologic Features and Design Assumptions

To begin the *Safety Review*, staff must be familiar with basic information on designs and surface hydrologic characteristics of the site. This information is described below, and provided from those parts of the LA listed in Section 4.2.1 of this review plan:

- Drainage basin characteristics, including soil types and characteristics, vegetative cover, local topography, floodplains, and surficial and bedrock geology.
- Maps or aerial photographs showing the site location and the upstream drainage areas.
- Site geomorphological characteristics, including slopes, gradients, and processes.
- Drawings and photographs of GROA features, including the locations of portals to all shafts, ramps, tunnels, and boreholes in relation to the topography.
- Schedule for repository closure.

Based on the above information, staff must determine the following:

(1) No unusual engineering protection measures will be relied on, and erosion, hydraulic transport of debris, and debris damming effects will be conservatively accounted for or minimized in the probable maximum flood (PMF) calculations.

(2) Any water impoundments that may be built to support site operations will be located at elevations below the portals of nearby shafts, tunnels, or ramps.

(3) During the pre-closure period, all wells and boreholes (many of which occur in the floors of washes) would be outfitted with covers that would minimize the downward flow of water to the underground facility during flash-flood events.

Acceptance Criteria for items 1 and 2 will be met if portals for shafts, ramps, and tunnels are sited above the PMF, and above any surface water impoundments that may be constructed. However, if items 1 or 2 are not met, then a review different from that described in Subsection 3.2.1.2 of this review plan would be needed. Such a review would require independent staff evaluations of engineering protection measures and the potential impacts of any water impoundments that could be sited at elevations above portals for shafts, ramps, or tunnels.

The *Acceptance Criterion* for item 3 is that DOE will have properly covered the tops of wells and boreholes. This is a conservative design approach to the pre-closure protection of wellheads from the effects of flooding. Pre-closure flood events of large magnitude could occur, including hydraulic transport of debris. However, it is expected that even if borehole casings should be damaged or eroded by floods, flowpaths would not be created that could conduct large inflows to the repository.

3.2.1.2 Review Procedure for Flooding Potential

DOE can acceptably show that this PAC is absent if its GROA design shows that the lowest parts of all portals for shafts, ramps, and tunnels have been located above the level of the calculated PMF. The following four-step procedure will be used by the staff to perform the *Safety Review*.

Step 1 — Confirm Portal Elevations for GROA Shafts and Ramps

Staff shall examine general information on the GROA design submitted by DOE in review plans 4.1.1 ("Description of GROA Structures, Systems, and Components: Surface Facilities") and 4.1.2 ("Description of GROA Structures, Systems, and Components: Shafts and Ramps") of the LA. Staff shall determine if the following *Acceptance Criterion* has been met: The elevations of portals to all shafts, ramps, and tunnels of the GROA are provided in tabular form, or are depicted on engineering drawings of the GROA.

Step 2 — Review Estimates for Probable Maximum Precipitation (PMP)

Staff shall review DOE's estimates of the PMP that would be used to calculate the PMF. The PMP is defined in ANSI-2.8 (ANS, 1992; p. 2) as:

> "[t]he estimated depth of precipitation for a given duration, drainage area, and time of year for which there is virtually no risk of exceedance. The probable maximum precipitation for a given duration and drainage area approximates the maximum that is physically possible within the limits of contemporary hydrometeorological knowledge and techniques."

Generalized estimates of PMP for the United States have been prepared by the National Weather Service (NWS). The NWS has also made site specific PMP estimates for Federal water projects. As an *Acceptance Criterion*, Hansen *et al.* (1977) is an acceptable reference for DOE to use to estimate reasonable PMP values for the Yucca Mountain site. Estimates should include appropriate adjustments to the PMP based on the areas of drainage basins, rainfall durations, and land surface elevations. An additional *Acceptance Criterion* applies to cases where times of concentration are very short, 15 minutes or less. In such cases, it would be acceptable to calculate the PMP using modified methods described by Nelson *et al.* (1986, p. 10, Table 2.1).

Step 3 — Review Estimate of the PMF

Staff shall examine DOE's calculations of the PMF. The PMF is defined in ANSI-2.8 (ANS, 1992; p. 1) as:

> "[t]he hypothetical flood (peak discharge, volume, and hydrograph shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of probable maximum precipitation and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelt."

HEC1 (USCOE, 1981 and 1985) is an acceptable model for DOE to use to compute the PMF in various drainage basins at Yucca Mountain. *HEC2* (USCOE) is acceptable for delineating water surface profiles. Input parameters for *HEC1* include runoff and infiltration relationships, time of concentration (time of concentration is the amount of time required for runoff to reach the outlet of a drainage basin from the most remote point in that basin), lag times, and PMP distributions. The NRC staff recommends, based on the steepness of basin slopes at Yucca Mountain, that conservative values of input parameters be selected. This is especially true for input parameters, such as time of concentration, that are based on empirically derived formulas. If a calculation method requiring time of concentration is used, field studies to determine overland and gully flow velocities may provide the best estimates for time of concentration. Kirpich's formula (Kirpich, 1940), or other applicable empirical methods, can be used if the time of concentration is conservatively chosen. If the method uses a unit hydrograph, the likely non-linear transformation of runoff to streamflow should be recognized and accounted for. If a kinematic-wave method is used, attention should be given to the conservatism of the friction coefficient and the need for proper representation of small-channel geometry. A field investigation is recommended for the use of the kinematic flow method.

The staff recommends that DOE use a velocity-based method (such as the Kirpich method, as discussed by Nelson *et al.*, 1986) to compute time of concentration. The staff considers that methods based on flow velocities are more appropriate for the short and steep surface-water basins at the Yucca Mountain site. Some other methods may tend to overestimate the time of concentration because they were designed for larger drainage basins with lower overall hydraulic gradients. Overestimating the time of concentration can result in non-conservative PMF estimates.

The NRC staff should compare DOE's PMF estimates to estimates developed by the U.S. Bureau of Reclamation (Bullard, 1986), as appropriate. Further, the staff should compare DOE estimates to historic flood peaks in the southwestern United States, to provide assurance that the PMF estimates are reasonable.

The *Acceptance Criterion* that DOE must meet is that the evaluation of PMF is based on the site-specific PMP and the guidance contained in ANS (1992).

Step 4 — Compare the Portal Elevations for GROA Shafts and Ramps with the PMF

DOE can acceptably show that this PAC is absent if the GROA design demonstrates that the portals for all shafts, ramps, and tunnels have been located above the level of the calculated PMF, and above any surface water impoundments that may be constructed. Confirmation that the portals are all above PMF boundaries comprises the final *Acceptance Criterion* in the

staff's *Safety Review*. If it appears that a portal may be susceptible to a PMF, staff should obtain field confirmation before reaching a negative finding. Based on its pre-licensing consultations, the staff is expected to know well in advance of the LA submittal whether the locations of portals are susceptible to PMF conditions.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	DWM/PAHB	Hydrologic Transport Section
Support:	DWM/PAHB	Performance Assessment and Health Physics Section

4.2 Interfaces

4.2.1 Input Information

To properly review compliance with regulatory requirements for flooding, staff will require information from other sections of DOE's LA. The needed information is shown in the following table.

Input Information	*Review Plan No.*
Surface Hydrology	3.1.2
Site Geology, Topography and Geomorphology	3.1.1
Estimates for Probable Maximum Precipitation	3.1.4
Drawings and photographs showing GROA design features, including portal elevations for GROA shafts, ramps, and tunnels	4.1.1, 4.1.2

4.2.2 Output Information

Information from this section of the LA, that will be important to other review plans, is listed in the following table.

Output Information	*Review Plan No.*
Estimation of the PMP for the Yucca Mountain site.	4.2
Delineation of floodplain boundaries for the PMF near portals for shafts, ramps, and tunnels	4.2, 4.3, 4.4
Determination regarding the existence of this PAC	3.2.5
Anticipated Processes and Events to be considered in assessment of compliance with 10 CFR Part 60 performance objectives	4.5, 5.4, 6.1, 6.2, 6.3

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the *Acceptance Criteria* set forth in Section 3 when making the actual *Evaluation Findings* resulting from the *Acceptance Review* for docketing and the *Compliance Reviews*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds the information presented by DOE on the PAC concerning pre-closure flooding of the underground facility is (is not) acceptable for docketing and *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(c)(1)

The NRC staff finds the conclusions presented by DOE on the PAC related to pre-closure flooding of the underground facility are (are not) acceptable and there is (is not) reasonable assurance that the regulatory requirements of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) as they relate to 10 CFR 60.122(c)(1) will be met.

The DOE has shown that the portals of all tunnels, ramps, and shafts are (are not) located above the local probable maximum flood for each drainage area in which they are located. Therefore, the staff concludes with reasonable assurance that the maximum flood resulting from the probable maximum precipitation will not (will) cause flooding of the underground facility as designed.

If DOE has acceptably demonstrated that portals for all tunnels, shafts, and ramps are above the PMF, then staff can have reasonable assurance that the following have been satisfied:

(1) Assumptions and analysis methods used by DOE to evaluate the information presented demonstrate the absence or acceptably describe the presence of the PAC and encompass appropriate ranges of relevant parameters.

(2) DOE can demonstrate that the extent of characterization is sufficient to define flooding in the geologic setting and to assure that potential effects on critical pathways for radionuclide migration have been adequately described.

(3) DOE can demonstrate that the scope of investigations has bounded the range of conceptual models supported by the available data.

(4) DOE investigations at the site and in the geologic setting have been conducted in sufficient detail to assure that the potential effects of underground facility flooding are well enough understood to be appropriately considered in the design.

(5) Results of DOE investigations are not in conflict with published results from various staff investigations or other independent studies, or the conflicts are adequately explained.

6 REFERENCES

ANS, 1992, "American National Standard - Determining Design Basis Flooding at Power Reactor Sites," American Nuclear Society Standards Committee, Working Group ANS-2.8, ANSI/ANS-2.8-1992, 54 p.

Bullard, K. L., 1986, "Comparison of Estimated Probable Maximum Flood Peaks with Historic Floods," U. S. Department of the Interior, 165 p.

Hansen, E. M., F. K. Schwarz, and J. T. Riedel, 1977, "Probable Maximum Precipitation Estimates," Colorado River and Great Basin Drainages: Hydrometeorological Report No. 49, U. S. Army Corps of Engineers, prepared by the Office of Hydrology, National Weather Service, Silver Spring, MD, 161 p.

Kirpich, Z. P., 1940, "Time of Concentration of Small Agricultural Watersheds," Civil Engineering, Vol. 10, No. 6 (June).

Nelson, J. D., S. R. Abt, R. L. Volpe, D. van Zyl, N. E. Hinkle, and W. P. Staub, 1986, "Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments," NUREG/CR-4620, prepared by Colorado State Univ. and Oak Ridge National Laboratory for U.S. Nuclear Regulatory Commission, 145 p.

Nelson, J. D., R. Volpe, R. E. Wardwell, S. A. Schumm, and W. P. Staub, 1983, "Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments," NUREG/CR-3397, prepared by Colorado State Univ. and Oak Ridge National Laboratory for U.S. Nuclear Regulatory Commission, 163 p.

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

USCOE (U.S. Army Corps of Engineers), "Water Surface Profiles," Computer Program 723-X6-L202A, HEC-2, Hydrologic Engineering Center, Davis, California [continuously updated and revised].

USCOE (U.S. Army Corps of Engineers), 1981, "Flood Hydrograph Package," Computer Program 723-X6-L2010, HEC-1, Hydrologic Engineering Center, Davis, California.

USCOE (U.S. Army Corps of Engineers), 1985, HEC-1 Flood Hydrograph Package: Users Manual, Computer Program 723-X6-L2010, U.S. Army Corps of Engineers, Water Resources Support Center, 190 p.

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

FAVORABLE CONDITIONS: PRECIPITATION THAT IS A SMALL PERCENTAGE OF ANNUAL POTENTIAL EVAPOTRANSPIRATION

1 APPLICABLE REGULATORY REQUIREMENT(S)

The subject of this review plan is the following favorable condition addressing annual potential evapotranspiration defined in 10 CFR 60.122(b)(8)(v):

Subpart E -- Technical Criteria
SITING CRITERIA

§ 60.122 Siting criteria.

* * * * *

(b) *Favorable conditions.*

* * * * *

(8) For disposal in the unsaturated zone, hydrogeologic conditions that provide:

(i) Low moisture flux in the host rock and in the overlying and underlying hydrogeologic units;

(ii) A water table sufficiently below the underground facility such that fully saturated voids contiguous with the water table do not encounter the underground facility;

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

(iii) A laterally extensive low-permeability hydrogeologic unit above the host rock that would inhibit the downward movement of water or divert downward moving water to a location beyond the limits of the underground facility;

(iv) A host rock that provides for free drainage; or

(v) A climatic regime in which the average annual historic precipitation is a small percentage of the average annual evapotranspiration.

* * * * *

For this review plan, the staff will determine if the subject favorable condition, identified above, has been described and assessed pursuant to the regulatory requirements defined in 10 CFR 60.21(c)(1), as applicable.

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located, with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

* * * * *

(ii) The assessment shall contain:

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site,

(B) Analyses to determine the degree to which each favorable condition and potentially adverse condition enumerated in 10 CFR 60.122 of this part has been characterized and found to be present. For each potentially adverse condition, the analysis shall demonstrate its absence or the extent to which it may be present and still undetected, taking into account the degree of resolution achieved by the investigations. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the controlled area, if they may affect isolation within the controlled area.

* * * * *

(F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, *in-situ* tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

2.2 Compliance Review

2.2.1 Safety Review

This regulatory requirement topic is limited to considering DOE's demonstration, through appropriate investigations, of the degree to which average annual historic precipitation is a small percentage of average annual potential evapotranspiration. This favorable condition concerns an assessment of the modern-day climatic regime. It is not concerned with future projections of climate, which are covered in Section 3.2.4.2 ("PAC: Changes to Hydrologic System from Climate"), nor is it relevant to studies of paleoclimatic conditions. Findings under this review plan will provide input to other review plans (see Section 4.2.?).

In conducting the *Safety Review*, the reviewer will, at a minimum, determine the adequacy of the data and analyses presented in the license application to support DOE's demonstrations regarding 10 CFR 60.21(c)(1)(ii)(A)(B) and (F) as they relate to 10 CFR 60.122(b)(8)(v) (see Appendix F of the LARP for applicable text). The specific aspects of the license application on which the reviewer will focus are discussed below. The Acceptance Criteria are identified in Section 3 of this review plan. Specifically, DOE should have (1) assessed whether and to what extent this favorable condition is present (i.e., that average annual historic precipitation is a small percentage of average annual potential evapotranspiration); (2) evaluated the extent to which the presence of this favorable condition may have been overestimated or undetected, taking into account the degree of resolution achieved by the investigations; (3) assured that the lateral and vertical extent of field data collection is sufficient to support items (1) and (2); and (4) further evaluated the information presented under items (1) and (2), using assumptions and analysis methods that encompass the ranges of all relevant parameters.

In conducting the aforementioned evaluations, the reviewer should determine whether DOE used: (1) analyses that are sensitive to evidence of whether the favorable condition is present or absent; and (2) assumptions that are not likely to overestimate its effects. In general, the reviewer will assess the adequacy of DOE's investigations for evidence of this favorable condition, both within the controlled area and outside the controlled area, as necessary, in the manner outlined in 10 CFR 60.21(c)(1)(ii)(B).

To conduct an effective review, the reviewer will rely on staff expertise and independently acquired knowledge, information, and data in addition to that provided by DOE in its license application. The reviewer should focus on additional data which can refine knowledge of this favorable condition, and should acquire, as necessary, additional information to confirm the resolution capabilities of the methodologies. The reviewer must acquire a body of knowledge regarding these and other critical considerations in anticipation of conducting the *Safety Review* to assure that DOE's submittal is sufficient in scope and depth to provide the information necessary for resolution of the concerns.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare the information in the License Application (LA) concerning precipitation and potential evapotranspiration with the corresponding section of the FCRG and with the staffs resolution status of objections to LA submittal in the Open Item Tracking System (OITS) and determine if this information meets the following criteria.

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) DOE has either resolved, at the staff level, the NRC objections to LA submittal that apply to this regulatory requirement topic, or provided all information requested in Section 1.6 of the FCRG for unresolved objections, namely, DOE has:

- Identified all unresolved objections
- Explained the differences between NRC and DOE positions that have precluded resolution of each objection
- Described all attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60

(3) In addition, unresolved objections, individually or in combination with others, will not prevent the reviewer from conducting a meaningful *Compliance Review* and the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the Acceptance Criteria specified for the following *Compliance Review* have been met. The results of the compliance determinations shall be documented by the staff to provide the basis for actual *Evaluation Findings* documented in the Safety Evaluation Report (SER).

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(ii)(A),(B),(F), and 10 CFR 60.122(b)(8)(v)

This *Safety Review* shall be conducted only if the DOE asserts that the favorable condition regarding precipitation as a small percentage of potential evapotranspiration (PE) (i.e., climatic moisture) is present at the Yucca Mountain site. If DOE does not assert that this favorable condition is present, then no *Safety Review* will be necessary and the staff shall document a negative finding (see Section 5.2).

The staff will determine whether the assessment of presence or absence of the favorable condition on precipitation and PE has been accomplished in an acceptable manner, and whether the description of the site properly supports the assessments required by 10 CFR 60.21(c)(1)(ii)(A),(B), and (F) as they relate to 10 CFR 60.122(b)(8)(v). For 10 CFR 60.21(c)(1)(ii)(A) specifically, the staff will review and evaluate information provided by DOE in the LA to support DOE's analysis of the meteorology of the site as related to precipitation and PE and determine whether the analysis has been conducted in a manner acceptable for supporting review of 10 CFR 60.122(b)(8)(v). For 10 CFR 60.21(c)(1)(ii)(B), the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses of the degree to which this favorable condition has been characterized and found to be present. The staff will review and evaluate information provided by DOE in the LA to demonstrate either the presence of this favorable condition, or the extent to which its presence may have been overestimated or undetected, taking into account the degree of resolution achieved by the investigation. The staff will also

determine whether the analyses and investigations have been accomplished in an acceptable manner and whether lateral and vertical extent of the investigations are acceptable for supporting review of 10 CFR 60.122(b)(8)(v). For 10 CFR 60.21(c)(1)(ii)(F), the staff will review and evaluate information provided by DOE in the LA to support DOE's analyses and models used to investigate PE and precipitation. The staff will also determine whether the analyses and models are properly supported by an appropriate combination of methods such as field and laboratory tests, monitoring data, or natural analog studies for assisting review of 10 CFR 60.122(b)(8)(v).

To make compliance determinations for these Acceptance Criteria, the staff must review the results of site characterization and analyses conducted by DOE. This review is discussed below under Subsections 3.2.1.1 and 3.2.1.2 of this review plan. These subsections present review procedures and Acceptance Criteria related to PE and precipitation at the Yucca Mountain site.

3.2.1.1 Meteorologic and Climatologic Information for the Yucca Mountain region

To begin the *Safety Review*, staff must be familiar with and review the breadth and applicability of meteorological and climatological data for the Yucca Mountain site and the region of southern Nevada. This information is described below, and provided from those parts of the LA listed in Section 4.2.1 of this review plan:

- Historical data on the climatology and meteorology of southern Nevada, with particular emphasis on historical precipitation data
- Meteorological data from the Yucca Mountain site, including annual and monthly averages for temperature, precipitation, evaporation, humidity, wind patterns, and other appropriate meteorological data
- Maps showing the locations of data collection points used in the analyses, such as meteorological stations and precipitation gages, with respect to topography
- Precipitation and temperature data covering the historical period of data collection in southern Nevada

The Acceptance Criterion is that all of the above types of information must be presented in sufficient detail to provide an adequate understanding of the site.

3.2.1.2 Review Procedure for Average Annual Precipitation as a Small Percentage of Average Annual Potential Evapotranspiration

DOE can acceptably show that this Favorable Condition is present if supporting analyses show that average annual historic precipitation is 33 percent or less than the amount of average annual potential evapotranspiration (see Rationale in Section 3.3).

Step 1 -- Review Estimates for Average Annual Historic Precipitation for the Yucca Mountain Climate Regime

DOE's estimates of average annual historic precipitation for the climate regime shall be acceptable to the staff if the following Acceptance Criteria are met:

- Precipitation estimates are based on available precipitation data from meteorological stations that are located within about 100 km of Yucca Mountain. DOE (1988, p. 5-4 to 5-6) provided information on meteorological stations in the vicinity of Yucca Mountain. Precipitation data were collected at the Beatty monitoring station from 1931 to 1960. This station apparently provides the earliest precipitation data in the vicinity of Yucca Mountain. The next oldest set of records with which the staff is familiar date from 1957 through 1967, collected at a station on the Nevada Test Site.
- Documentation of the DOE search for data is sufficient to provide reasonable assurance that the search was exhaustive. [Note: Even though extensive precipitation data are being collected at the Yucca Mountain site, those data will not be representative of average annual historical conditions for the climate regime. The site measurements are not widespread enough to define the climate regime and the period of record has been too short. Precipitation

data vary considerably on both spatial and temporal scales. For this reason, averages based on a reasonably large region with good coverage through time are appropriate.]

- Estimates of average annual historic precipitation used to characterize the Yucca Mountain climate regime have been appropriately corrected for the range of land surface elevations at the data collection sites.

Step 2 -- Review Estimates of Average Annual Potential Evapotranspiration for Yucca Mountain

DOE's estimates of average annual potential evapotranspiration (PE) at Yucca Mountain shall be acceptable to the staff if the following Acceptance Criteria are met:

- DOE has used the definition of PE from the National Handbook of Recommended Methods for Water-Data Acquisition (USGS, 1982, p. 8-39):

  "Potential evapotranspiration is defined as the rate of water loss from a wet soil or well-watered, actively growing vegetation, **or as the rate of evaporation from a water surface** [emphasis added]."

- DOE has used the average annual rate of evaporation from a water surface, also known as free water surface (FWS) evaporation, to estimate the modern-day rate of average annual PE. Estimates of Yucca Mountain FWS evaporation are obtained from meteorological stations at the Yucca Mountain site, and these are compared to longer-term regional data from the National Weather Service (Farnsworth et al., 1982). For a conservative estimate, the data set (site vs. regional) that has the smaller rate should be reported as the average rate of annual FWS evaporation.

- DOE has obtained an estimate of average annual PE for Yucca Mountain using either the empirical method of Thornthwaite (1948) or a comparable method.

Step 3 -- Compare Average Annual Precipitation to Average Annual Potential Evapotranspiration

Staff will compare DOE's estimate of average annual historic precipitation to the average annual PE. Staff must ensure that the PE estimate is the smallest obtained by any method (i.e., from FWS evaporation, the empirical method of Thornthwaite (1948), and any other relevant methods). If the precipitation value, as a percentage of the PE value, is 33 percent or less, then the Favorable Condition is present. Otherwise, the Favorable Condition is absent. Staff will document a corresponding *Evaluation Finding* in Section 5 of this review plan.

If DOE has acceptably demonstrated that average annual historic precipitation is a small percentage of average annual potential evapotranspiration, then staff can have reasonable assurance that the following have been satisfied:

(1) Assumptions and analysis methods, used by DOE to evaluate the information presented determine the absence or acceptably describe the presence of the favorable condition and encompass appropriate ranges of relevant parameters.

(2) DOE can demonstrate that the extent of characterization is sufficient to characterize evapotranspiration in the geologic setting.

(3) DOE can demonstrate that the scope of investigations has bounded the range of conceptual models supported by the available data.

(4) DOE investigations at the site and in the geologic setting have been conducted in sufficient detail to assure that the benefits of this favorable condition are well enough understood to be appropriately considered in performance assessment and design.

(5) Results of DOE investigations are not in conflict with published results from various staff investigations or other independent studies, or the conflicts are adequately explained.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	DWM/PAHB	Hydrologic Transport Section
Support:	None needed	

4.2 Interfaces

4.2.1 Input Information

To properly review issues related to precipitation and PE, staff will require information from other sections of DOE's LA. The needed information is shown in the following table.

Input Information	*Review Plan No.*
Meteorological data for the Yucca Mountain region, including data on historical precipitation, temperatures, free water surface evaporation, etc.	3.1.4
Drawings, maps, or photographs showing the locations of all meteorological data collection sites in the Yucca Mountain region (meteorological stations, precipitation gages, etc.)	3.1.4
Site topography (to examine siting of meteorological stations)	3.1.1

4.2.2 Output Information

Information from this section of the LA, that will be important to other review plans, is listed in the following table.

Output Information	*Review Plan No.*
Estimation of average annual historic precipitation for the Yucca Mountain site	3.2.2.1, 3.2.2.4, 3.2.2.9, 3.2.2.12, 3.2.4.2
Estimation of average annual free water surface evaporation rates for the Yucca Mountain site	3.2.2.1, 3.2.2.4, 3.2.2.9, 3.2.2.12, 3.2.4.2
Determination regarding the existence of this favorable condition	3.2.5
Anticipated Processes and Events to be considered in assessment of compliance with 10 CFR Part 60 performance objectives	6.1, 6.2

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing and the *Compliance Reviews*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds the information presented by DOE on the favorable condition concerning average annual precipitation and potential evapotranspiration is (is not) acceptable for docketing and *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)(1)(ii)(A),(B),(F) and 10 CFR 60.122(b)(8)(v)

Negative Finding: DOE has reported that the favorable condition is absent. DOE has thereby chosen not to take credit for the favorable condition on average annual historic precipitation as a small percentage of average annual potential evapotranspiration. Therefore, DOE cannot use this favorable condition in assessments of waste isolation to compensate for the presence of potentially adverse conditions.

Positive Finding: The NRC staff finds the conclusions presented by DOE on the favorable condition related to precipitation and evapotranspiration are acceptable and there is reasonable assurance that the regulatory requirements of 10 CFR 60.21(c)(1)(ii)(A),(B),(F) as they relate to 10 CFR 60.122(b)(8)(v) will be met. The staff concludes with reasonable assurance that the average annual historic precipitation is a small percentage (33% or less) of the average annual potential evapotranspiration.

6 REFERENCES

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U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

DESCRIPTION OF THE GROA STRUCTURES, SYSTEMS, AND COMPONENTS: SURFACE FACILITIES

1 APPLICABLE REGULATORY REQUIREMENT(S)

For this review plan, the staff will determine if the following regulatory requirements on the description and the discussion of the surface facilities that comprise geologic repository operations area (GROA) structures, systems, and components (SSCs), defined in 10 CFR 60.21(c), as applicable, are met:

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description area,

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The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

(E) The geochemical properties; and

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

* * * * *

(ii) The assessment shall contain:

* * * * *

(2) A description and discussion of the design, both surface and subsurface, of the geologic repository operations area, including: (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission, (ii) the design bases and the relation of the design bases to the principal design criteria, (iii) information relative to materials of construction (including geologic media, general arrangement, and approximate dimensions), and (iv) codes and standards that DOE proposes to apply to the design and construction of the geologic repository operations area.

(3) A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository, which are important to safety. This analysis shall consider — (i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena.

* * * * *

(9) Plans for coping with radiological emergencies at any time prior to permanent closure and decontamination or dismantlement of surface facilities.

* * * * *

(11) A description of design considerations that are intended to facilitate permanent closure and decontamination or dismantlement of surface facilities.

(12) A description of plans for retrieval and alternate storage of the radioactive wastes should the geologic repository prove to be unsuitable for disposal of radioactive wastes.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

The description provided in Section 4.1.1 of the license application will form the basis for the *Compliance Review* of the information contained in Section 4.2 ("Assessment of Compliance with Design Criteria for Surface Facilities") of the license application. Thus, the information contained in Section 4.1.1 will be reviewed in parallel with the information contained in Section 4.2. Therefore, the reviewer should determine that all appropriate descriptive information necessary for the staff to conduct a *Compliance Review* of the GROA surface facilities design (see Section 4.2, "Assessment of Compliance with Design Criteria for Surface Facilities") is present in this section of the license application.

Information to be reviewed under Section 4.1.1 includes, at a minimum, acceptable descriptions of the following:

(1) The location and general layout of the surface facilities relative to the GROA and the general character of proposed activities for the surface facilities;

(2) The subsurface site conditions expected to be encountered in constructing surface facilities;

(3) The identification of major SSCs important to radiological safety, and retrievability;

(4) The schedules for inspections, testing, and maintenance; and

(5) The details specified in Sections 4.1.1.1 through 4.1.1.12 of the FCRG.

If it is determined that the descriptive information in Section 4.1.1 of the license application is inadequate to support the *Compliance Review* of Section 4.2, then additional information to be requested from DOE should be identified as a part of the review.

2.2 Compliance Review

2.2.1 Safety Review

As noted above, most of the descriptive material provided in this section of the license application will be initially reviewed and then evaluated as part of the *Compliance Review* of those sections of the license application which use this information. Section 4.2 ("Interfaces") of this review plan describes where the *Compliance Review(s)* of the information in this section of the license application will take place.

For each of the *Compliance Reviews* described in Section 4.2, a portion of the review will therefore focus on whether the descriptive information provides an acceptable basis for the associated assessment. Thus, this portion of the review will result in an *Evaluation Finding* for the specific supporting information in that section of the license application in which it is being used.

Therefore, under this review plan, no additional *Compliance Review* will be done; the staff will make only an "aggregate" *Evaluation Finding* for the whole description of the surface facilities of the GROA. Such a finding would collectively reflect the sum of the specific *Evaluation Findings* made in those sections of the license application described in Section 4.2.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare the information in the license application (LA) concerning GROA surface facility descriptions with the corresponding section of the FCRG and with the staff's resolution status of objections in the Open Item Tracking System and determine if this information meets the following Acceptance Criteria:

(1) The information presented in the LA is clear, is completely documented, consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) The DOE has either resolved, at the staff level, the NRC objections that apply to this regulatory requirement topic or provided the information requested in Section 1.6 of the FCRG for unresolved objections. Namely, it should be determined whether the DOE has:

- Identified the unresolved objections.
- Explained the differences between the NRC and DOE positions that precluded resolution of each objection.
- Described the attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful *Compliance Review* or the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by the NRC staff will consider whether the Acceptance Criteria specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented in the staff's Safety Evaluation Report (SER) to provide the basis for the actual *Evaluation Findings*.

3.2.1 Safety Review of 10 CFR 60.21(c) (as applicable)

The staff's *Compliance Review* will consist of the following two steps. First, the staff will review the descriptive information provided for GROA surface facilities. This will provide an overall understanding of how DOE has presented its information on the many individual aspects of the GROA surface facility design and how this information has been integrated.

Second, after the staff has conducted each of the *Compliance Reviews* for those sections of the license application identified in Section 4.2 of this review plan, the individual *Evaluation Findings* from those reviews will be considered on balance to determine whether the following Acceptance Criterion has been met:

- The descriptive information for the GROA surface facility design provides an acceptable basis for the associated compliance assessment of the surface facilities that relies on this information.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are identified in the following table.

Lead:	NMSS-DWM-ENGB-GES
Support:	NMSS-DWM-ENGB-GEO NMSS-DWM-ENGB-EMS NMSS-DWM-PAHB-PAHP NMSS-DWM-PAHB-HTS

4.2 Interfaces

4.2.1 Input Information

Information[1] needed from other License Application that will provide input important to this Review Plan is listed in the following table.

Input Information	*Review Plan No.*	
Geotechnical information on the subsurface and environmental conditions such as design basis events, stratigraphy and physical and strength parameters, and design parameters for the materials at the surface facilities - required for the description of GROA Surface Facilities	3.1.X	Description of Individual Systems and Characteristics of Site
List/identification of Structures Systems and Components (SSCs) of surface facilities that are important to radiological safety and retrievability	4.2	Assessment of Compliance with Design Criteria for Surface Facilities

4.2.2 Output Information

Information[1] from this section of the License Application that will be important to other Review Plans is listed in the following table.

Output Information	*Review Plan No.*	
Identification and description of structures systems and components at the interface between surface facilities and shafts and ramps.	4.1.5	Description of GROA Structures, Systems, and Components: Interfaces between Structures, Systems, and Components

[1] The degree of applicability of input/output information cited below will depend upon how the DOE organizes the information in its license application and how it cross-references this information.

Output Information	*Review Plan No.*	
Description of all Structures, Systems, and Components identified in Table 4.1.1-1 of this review plan. The scope of the description, as a minimum, should include Items 1 through 9 listed in Section 2.2.1 of this review plan.	4.2	Assessment of Compliance with Design Criteria for Surface Facilities
	4.5	Assessment of Integrated GROA Compliance with Performance Objectives:
The description of the surface facilities should include design information on the Structures, Systems, and Components intended for radiation protection.	4.5.1	Protection against Radiation Exposure and Releases of Radioactive Materials to Unrestricted Areas
The description of surface facilities should include information on the plans and provisions in the design to address how the retrievabililty requirement of the regulation is complied with?	4.5.2	Retrievability of Waste
General description and functions of surface facilities to enable identifying the SSCs that require research and development to confirm the adequacy of the design.	8.5	Unresolved Safety Questions
Information on general description and functions of surface facilities that is required for developing plans for conduct of normal activities at the GROA surface facilities.	7.1	Plans for Conduct of Normal Activities

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* given below when making the final actual *Evaluation Findings* resulting from the Acceptance Review, for docketing, and the subsequent *Compliance Review*. The actual *Evaluation Findings* resulting from the *Compliance Review*, and the supporting basis, should be documented in the staff's SER.

5.1 Finding for Acceptance Review

The NRC staff finds that the information presented by DOE, as defined by the Applicable 10 CFR Part 60 Regulatory Requirements, is acceptable (not acceptable) for docketing and a subsequent *Compliance Review*.

5.2 Findings for Compliance Reviews

The NRC staff finds the information for descriptions, assessments, and analyses is (is not) adequate, and there is (is not) reasonable assurance the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this Review Plan, will be met for the GROA surface facilities.

6 REFERENCES

Nuclear Regulatory Commission. 1990. *Format and Contents for the License Application for the High-Level Waste Repository*. Draft Regulatory Guide DG-3003. Washington, DC: Nuclear Regulatory Commission.

Table 4.1.1-1 A Minimum Set of Structures, Systems, and Components for Geologic Repository Operations Area System Facilities.

1.	Hot cells
2.	On-Site radioactive waste management systems
3.	Ventilation systems (intake and exhaust)
4.	Fire suppression and explosion protection systems
5.	Utility systems
6.	Emergency systems
7.	Communication systems
8.	Operational support systems
9.	Decommissioning and decontamination systems
10.	Instrumentation and control systems (including radiation)
11.	On-Site transportation systems (personnel and material)
12.	Waste handling systems
13	Electrical support systems
14.	Excavation and ground support systems
15.	Waste retrieval systems

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

DESCRIPTION OF THE GROA STRUCTURES, SYSTEMS, AND COMPONENTS: SHAFTS AND RAMPS

1 APPLICABLE REGULATORY REQUIREMENT(S)

For this review plan, the staff will determine if the following requirements on the description and discussion of the shafts and ramps that comprise geologic repository operations area (GROA)[1] structures, systems, and components (SSCs), defined in 10 CFR 60.21(c), as applicable, are met:

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where

[1] As used in this document, the term "shafts and ramps" also includes boreholes.

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Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

(E) The geochemical properties; and

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

* * * * *

(2) A description and discussion of the design, both surface and subsurface, of the geologic repository operations area including: (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission, (ii) the design bases and the relation of the design bases to the principal design criteria, (iii) information relative to materials of construction (including geologic media, general arrangement, and approximate dimensions), and (iv) codes and standards that DOE proposes to apply to the design and construction of the geologic repository operations area.

(3) A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository, which are important to safety. This analysis shall consider — (i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena.

* * * * *

(9) Plans for coping with radiological emergencies at any time prior to permanent closure and decontamination or dismantlement of surface facilities.

* * * * *

(11) A description of design considerations that are intended to facilitate permanent closure and decontamination or dismantlement of surface facilities.

(12) A description of plans for retrieval and alternate storage of the radioactive wastes should the geologic repository prove to be unsuitable for disposal of radioactive wastes.

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2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the "Regulatory Guide Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

The description provided in Section 4.1.2 of the license application will form the basis for the *Compliance Review* of the information contained in Section 4.3 ("Assessment of Compliance with Design Criteria for Shafts and Ramps") of the license application. Thus, the information contained in Section 4.1.2 will be reviewed in parallel with the information contained in Section 4.3. Therefore, the reviewer should determine that all appropriate information necessary for the staff to conduct a *Compliance Review* of the shafts and ramps design (see Section 4.3, "Assessment of Compliance with Design Criteria for Shafts and Ramps," of the license application) has been provided. In addition, the reviewer should determine that all appropriate information regarding boreholes specified in Section 4.1.2.7 of the FCRG is also provided in the license application.

Information to be reviewed under Section 4.1.2 includes, at a minimum, acceptable descriptions of the following:

(1) The location and general layout of shafts and ramps relative to the GROA;

(2) Subsurface site conditions expected to be encountered in constructing shafts and ramps;

(3) Identification of major SSCs important to safety of shafts and ramps;

(4) Identification of SSCs important to retrievability and waste isolation;

(5) Details specified in Sections 4.1.2.1 through 4.1.2.7 of FCRG.

If it is determined that the information in Section 4.1.2 of the license application is inadequate to support the *Compliance Review* of Section 4.3, then additional information to be requested from DOE should be identified as a part of the review.

2.2 Compliance Review

2.2.1 Safety Review

As noted above, most of the descriptive material provided in this section of the license application will be initially reviewed and then evaluated as part of the *Compliance Review* of those sections of the license application which use this information. Section 4.2 ("Interfaces") of this review plan describes where the *Compliance Review(s)* of the information in this section of the license application will take place.

For each of the *Compliance Reviews* described in Section 4.2, a portion of the review will therefore focus on whether the descriptive information provides an acceptable basis for the associated assessment. Thus, this portion of the review will result in an *Evaluation Finding* for the specific supporting information in that section of the license application in which it is being used.

Therefore, under this review plan, no additional *Compliance Review* will be done; the staff will make only an "aggregate" *Evaluation Finding* for the whole description of the shafts and ramps of the GROA. Such a finding would collectively reflect the sum of the specific *Evaluation Findings* made in those sections of the license application described in Section 4.2.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare the information in the license application (LA) concerning shafts, ramps, boreholes, and their seals (SRBS) with the corresponding section of the FCRG and with the staff's resolution status of objections in the Open Item Tracking System and determine if this information meets the following Acceptance Criteria:

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) The DOE has either resolved, at the staff level, the NRC objections that apply to this regulatory requirement topic or provided the information requested in Section 1.6 of the FCRG for unresolved objections. Namely, it should be determined whether the DOE has:

- Identified the unresolved objections.
- Explained the differences between the NRC and DOE positions that precluded resolution of each objection.
- Described the attempts to achieve resolution.
- Explained why resolution has not been achieved.
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60.

(3) Unresolved objections, individually or in combination with others, will not prevent either the reviewer from conducting a meaningful *Compliance Review* or the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determination undertaken by the NRC staff will consider whether the Acceptance Criteria specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented in the staff's Safety Evaluation Report (SER) to provide the basis for the actual *Evaluation Findings*.

3.2.1 Safety Review of 10 CFR 60.21(c) (as applicable)

The staff's *Compliance Review* will be conducted to determine the adequacy of the descriptive information required by the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this Revision Plan, for SRBS design and performance assessment. The entire information will be read to obtain an overall understanding of how the DOE has presented its information on the many individual aspects of the SRBS and how this information has been integrated. The acceptance criterion for this regulatory requirement is directly related to Review Plan 4.3 wherein the design of the SRBS will be reviewed. Thus the *Evaluation Findings* (acceptance or nonacceptance) for this requirement cannot be arrived at independent of the findings for Review Plan 4.3. Once the SRBS design has been reviewed according to the method set in Review Plan 4.3, the staff shall determine whether the following Acceptance Criterion has been met:

- The descriptive information for the SRBS provides an acceptable basis for the associated assessment (SRBS design and performance assessment) that relies on this information.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are identified in the following table.

Lead:	NMSS-DWM-ENGB-GES
Support:	NMSS-DWM-ENGB-GEO NMSS-DWM-ENGB-EMS NMSS-DWM-PAHB-PAHP NMSS-DWM-PAHB-HTS

4.2 Interfaces

4.2.1 Input Information

Information needed from other sections of the License Application that will provide input important to this Review Plan is listed in the following table.

Input Information	*Review Plan No.*	
Geotechnical information on subsurface and environmental conditions such as design basis events, stratigraphy and physical and strength parameters, and design parameters for the materials at the SRBS - required for the description of GROA SRBS.	3.1.X	Description of Individual Systems and Characteristics of Site
List/identification of Structures Systems and Components (SSCs) of SRBS that are important to radiological safety and retrievability	4.3	Assessment of Compliance with Design Criteria for Shafts and Ramps

4.2.2 Output Information

Information[2] from this section of the License Application that will be important to other Review Plans is listed in the following table.

Output Information	*Review Plan Nos.*	
Identification and description of structures systems and components at the interface between SRBS and Underground Facilities.	4.1.5	Description of GROA Structures, Systems, and Components: Interfaces between Structures, Systems, and Components

[2]The degree of applicability of input/output information cited below will depend upon how the DOE organizes the information in its License Application and how it cross-references this information.

Output Information	*Review Plan Nos.*	
Description of all Structures, Systems, and Components of SRBS. The scope of the description, as a minimum, should include Items 1 through 9 listed in Section 2.2.1 of this review plan.	4.3	Assessment of Compliance with Design Criteria for SRBS
	4.5	Assessment of Integrated GROA Compliance with Performance Objectives:
The description of the SRBS should include design information on the Structures, Systems, and Components intended for radiation protection.	4.5.1	Protection against Radiation Exposure and Releases of Radioactive Materials to Unrestricted Areas
The description of SRBS should include information on the plans and provisions in the design to address how the retrievability requirement of the regulation is complied with?	4.5.2	Retrievability of Waste
General description and functions of SRBS to enable identifying the SSCs that require research and development to confirm the adequacy of the design.	8.5	Unresolved Safety Questions
Information on general description and functions of Shafts and Ramps that is required for development plans for conduct of normal activities at the GROA shafts and ramps.	7.1	Plans for Conduct of Normal Activities

5 EXAMPLE EVALUATION FINDINGS

5.1 Finding for Acceptance Review

The NRC staff finds that the information presented by the DOE, as defined by the Applicable 10 CFR Part 60 Regulatory Requirements, is acceptable (not acceptable) for docketing and a subsequent *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)

The NRC staff finds the information for descriptions, assessments, and analyses is (is not) adequate, and there is (is not) reasonable assurance the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this Review Plan, will be met for the SRBS.

6 REFERENCES

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most recent edition of the FCRG in effect.]

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

DESCRIPTION OF THE GROA STRUCTURES, SYSTEMS, AND COMPONENTS: UNDERGROUND FACILITY

1 APPLICABLE REGULATORY REQUIREMENT(S)

For this review plan, the staff will determine if the following regulatory requirements on the description and discussion of the underground facilities that comprise geologic repository operations area (GROA) structures, systems, and components (SSCs), defined in 10 CFR 60.21(c), as applicable, are met:

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material. The detailed information referred to in this paragraph shall include:

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities;

(B) The presence and characteristics of other potential pathways such as solution features, breccia pipes, or other potentially permeable features;

(C) The geomechanical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrogeologic properties and conditions;

(E) The geochemical properties; and

(F) The anticipated response of the geomechanical, hydrogeologic, and geochemical systems to the maximum design thermal loading, given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass and groundwater.

* * * * *

(2) A description and discussion of the design, both surface and subsurface, of the geologic repository operations area including: (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission, (ii) the design bases and the relation of the design bases to the principal design criteria, (iii) information relative to materials of construction (including geologic media, general arrangement, and approximate dimensions), and (iv) codes and standards that DOE proposes to apply to the design and construction of the geologic repository operations area.

(3) A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository, which are important to safety. This analysis shall consider — (i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena.

* * * * *

(9) Plans for coping with radiological emergencies at any time prior to permanent closure and decontamination or dismantlement of surface facilities.

* * * * *

(11) A description of design considerations that are intended to facilitate permanent closure and decontamination or dismantlement of surface facilities.

(12) A description of plans for retrieval and alternate storage of the radioactive wastes should the geologic repository prove to be unsuitable for disposal of radioactive wastes.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the DOE LA is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository (FCRG)."

Before the receipt of the LA, the staff will have conducted prelicensing reviews of the DOE program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-LA reviews, as open items. Some of these open items, referred to as objections to LA submittal, may be critical to the staff's LA review, because the lack of acceptable DOE resolution would prevent the NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to LA submittal to the effective conduct of licensing activities is, using the criteria given in Section 3.1 of this review plan.

The descriptions provided in Section 4.1.3 of the LA will form the basis for the *Compliance Review* of the information contained in Section 4.4 "Assessment of Compliance with the Design Criteria for the Geologic Repository Operations Area (GROA) Underground Facility" of the LA. Thus, the review of the information contained in Section 4.1.3 will be performed in parallel with the review of the information contained in Section 4.4. Therefore, during the Acceptance Review of the section, the reviewer should determine whether all appropriate information necessary for the staff to conduct a *Compliance Review* of the GROA underground facility design in Section 4.4 has been provided.

In reviewing the descriptions of the GROA underground facility, the reviewer should ascertain whether the DOE has provided, as a minimum, acceptable descriptions of:

(1) The location and general layout of the underground facility relative to the GROA and the general character of proposed activities for the underground facility

(2) The subsurface site conditions expected to be encountered in constructing the underground facility

(3) The identification of major structures, systems, and components important to radiological safety, retrievability, containment, and waste isolation for the underground facility

(4) The sealing and drainage for the underground facility, including any plans for backfilling

(5) The details specified in Sections 4.1.3.1 through 4.1.3.10 of the FCRG for the underground systems.

2.2 Compliance Review

2.2.1 Safety Review

As noted above, most of the descriptive material provided in this section of the LA will be initially reviewed and then evaluated as part of the *Compliance Review* of those sections of the LA that use this information. Section 4.2 "Interfaces" of this review plan describes where the *Compliance Review(s)* of the information in this section of the LA will take place.

For each *Compliance Review* described in Section 3.2, a portion of the review will, therefore, focus on whether the descriptive information provides an acceptable basis for the associated assessment. Thus, this portion of the review will result in an actual *Evaluation Finding* for the specific supporting information in that section of the LA in which it is being used.

Therefore, under this review plan, no additional *Compliance Review* will be done; the staff will make only an "aggregate" *Evaluation Finding* for the whole description of the underground facility of the GROA. Such a finding would collectively reflect the sum of the specific *Evaluation Findings* made in those sections of the LA described in Section 4.2.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare the information in the license application (LA) concerning the underground facility with the corresponding section of the "Format and Content Regulatory Guide" (FCRG) and with the staff's resolution status of objections to the LA submitted in the Open Item Tracking System (OITS) and determine if this information meets the following Criteria.

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the proper references have been provided.

(2) DOE has either resolved, at the staff level, the NRC objections that apply to this regulatory requirement topic, or provided the information requested in Section 1.6 of the FCRG for unresolved objections, namely, DOE has:

- Identified all unresolved objections
- Explained the differences between NRC and DOE positions that precluded resolution of each objection
- Described all attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60

(3) In addition, unresolved objections, individually or in combination with others, will not prevent the reviewer from conducting a meaningful *Compliance Review* or the Commission from making a decision regarding construction authorization within the 3-yr statutory period.

3.2 Compliance Reviews

The compliance determination undertaken by the NRC staff will consider whether the Acceptance Criteria specified for the following *Compliance Review* have been met. Results of the compliance determination should be documented by the staff to provide the basis for *Actual Evaluation Findings* (AEF) in the Safety Evaluation Report (SER).

3.2.1 Safety Review of 10 CFR 60.21(c)(1)(i),(2),(3),(9),(11), and (12)

The staff's *Compliance Review* will be conducted to determine the adequacy of the descriptive information required by the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this Review Plan, for the underground facility design and performance assessment. First, the entire section of the LA will be read to obtain an overall understanding of how the DOE has presented its information on the many individual aspects of the underground facility and how this information has been integrated. Second, after the staff has conducted each of the *Compliance Reviews* for those sections of the LA identified in Section 4.2, the individual AEFs from these reviews will be considered on balance to determine whether the following Acceptance Criterion has been met.

- The descriptive information for the underground facility provides an acceptable basis for the associated assessments (underground facility design and performance assessment) that rely on this information.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are identified in the following table.

Lead:	NMSS-DWM-ENGB-GES
Support:	NMSS-DWM-ENGB-GEO NMSS-DWM-ENGB-EMS NMSS-DWM-PAHB-PAHP NMSS-DWM-PAHB-HTS

4.2 Interfaces

4.2.1 Input Information

Information needed from other sections of the LA that will provide important input to this Review Plan is listed in the following table.

Input Information	*Review Plan No.*	
Geotechnical information on subsurface and environmental conditions, such as design basis events, stratigraphy and physical and strength parameters, and design parameters for the materials in the underground facility—required for the description of the GROA (underground facility).	3.1.X	Description of Individual Systems and Characteristics of Site

4.2.2 Output Information

Information from this section of the LA that will be important to other Review Plans is listed in the following table.

Output Information	*Review Plan No.*	
Identification and description of structures systems and components at the interface between the underground facility and the shafts, ramps, and boreholes.	4.1.5	Description of GROA Structures, Systems, and Components: Interfaces Between Structures, Systems, and Components
Description of all Structure, Systems, and Components (SSCs) of the underground facility. The scope of the description, as a minimum, should include Items 1 through 5 listed in Section 2.1 of this review plan.	4.4	Assessment of Compliance with Design Criteria for the Underground Facility
Description of the underground facility, which includes design information on the SSCs intended for radiation protection.	4.5.1	Protection Against Radiation Exposure and Releases of Radioactive Materials to Unrestricted Areas
Description of the underground facility which includes information on the plans and provisions in the design to address how the retrievability requirement of the regulation is complied with.	4.5.2	Retrievability of Waste
Information on general description and functions of the underground facility that is required for developing plans for conduct of normal activities in the underground portion of the GROA.	7.1	Plans for Conduct of Normal Activities

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth

in Section 3.0 when making the AEFs resulting from the Acceptance Review for docketing and the *Compliance Reviews*. The AEFs resulting from *Compliance Reviews*, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds that the descriptive information presented by the DOE on the underground facility, as defined by the applicable 10 CFR Part 60 regulatory requirements, is acceptable (not acceptable) for docketing and subsequent *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)

The NRC staff finds the information for descriptions, assessments, and analyses is adequate (not adequate), and there is (is not) reasonable assurance the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this Review Plan, will be met for the underground facility.

6 REFERENCES

Nuclear Regulatory Commission. "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most recent edition of the FCRG in effect.]

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

DESCRIPTION OF ENGINEERED SYSTEMS AND COMPONENTS THAT PROVIDE A BARRIER BETWEEN THE WASTE AND THE GEOLOGIC SETTING

1 APPLICABLE REGULATORY REQUIREMENT(S)

For this review plan, the staff will determine if the following regulatory requirements on the description and discussion of the engineered systems and components that a barrier between the waste and the geologic setting, defined in 10 CFR 60.21(c), as applicable, are met:

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

* * * * *

(2) A description and discussion of the design, both surface and subsurface, of the geologic repository operations area including: (i) the principal design criteria and their relationship to any general performance objectives promulgated by the Commission, (ii) the design bases and the relation of the design bases to the principal design criteria, information relative to materials of construction (including geologic media, (iii) general arrangement, and approximate dimensions), and (iv) codes and standards that DOE proposes to apply to the design and construction of the geologic repository operations area.

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

* * * * *

(6) An identification and justification for the selection of those variables,conditions, or other items which are determined to be probable subjects of license specifications. Special attention shall be given to those items that may significantly influence the final design.

* * * * *

(14) An identification of those structures, systems, and components of the geologic repository, both surface and subsurface, which require research and development to confirm the adequacy of design. For structures, systems, and components important to safety and for the engineered and natural barriers important to waste isolation, DOE shall provide a detailed description of the programs designed to resolve safety questions, including a schedule indicating when these questions would be resolved.

* * * * *

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the Department of Energy's (DOE's) license application is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the license application, the staff will have conducted pre-licensing reviews of DOE's program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these pre-license application reviews, as open items. Some of these open items, referred to as objections to license application submittal, may be critical to the staff's license application review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to license application submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

The description of the engineered systems and components in Section 5.1 of the license application will provide the basis for the detailed *Compliance Reviews* of the information provided in the following sections of the license application:

License Application Section	*Title*
5.2	Assessment of Compliance with the Design Criteria for the Waste Package and its Components
5.3	Assessment of Compliance with the Post-Closure Features of the Design Criteria for the Post-Closure Features of the Underground Facility
5.4	Assessment of Compliance with the Engineered Barrier System Performance Objectives
5.5	Radiation Protection

Thus, information contained in Section 5.1 will be reviewed in parallel with the information contained in Sections 5.2, 5.3, 5.4, and 5.5. Therefore, the reviewer should determine that all appropriate descriptive information necessary for the staff to conduct a *Compliance Review* of the engineered barrier systems is present in Section 5.1 of the license application.

If it is determined that the descriptive information in Section 5.1 of the license application is inadequate to support any of the *Compliance Reviews* called for in Sections 5.2, 5.3, 5.4, and 5.5, then additional information will be requested from DOE before the *Compliance Reviews* of the sections in question can continue.

2.2 Compliance Review

2.2.1 Safety Review

As noted above, most of the descriptive material provided in this section of the license application will be initially reviewed and then evaluated as part of the *Compliance Review* of those sections of the license application which use this information. Section 4.2 ("Interfaces") of this review plan describes where the *Compliance Review(s)* of the information in this section of the license application will take place.

For each of the *Compliance Reviews* described in Section 4.2, a portion of the review will therefore focus on whether the descriptive information provides an acceptable basis for the associated assessment. Thus, this portion of the review will result in an *Evaluation Finding* for the specific supporting information in that section of the license application in which it is being used.

Therefore, under this review plan, no additional *Compliance Review* will be done; the staff will make only an "aggregate" *Evaluation Finding* for the whole description of the Engineered Barrier System. Such a finding would collectively reflect the sum of the specific *Evaluation Findings* made in those sections of the license application described in Section 4.2.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare information in the license application (LA) concerning the engineered systems and components that provide a barrier between the waste and the geologic setting with the corresponding section of the FCRG and with the staff's resolution status of objections in the Open Item Tracking System and determine if this information meets the following criteria.

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) DOE has either resolved, at the staff level, the NRC objections to LA submittal that apply to this regulatory requirement topic or provided all information requested in Section 1.6 of the FCRG for unresolved objections, namely, DOE has:

- Identified all unresolved objections
- Explained the differences between NRC and DOE positions that have precluded resolution of each objection
- Described attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60

(3) In addition, unresolved objections, individually or in combination with others, will not prevent the reviewer from conducting a meaningful *Compliance Review* and the Commission from making a decision regarding construction authorization within the three-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the Acceptance Criteria specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented in the staff's Safety Evaluation Report (SER) to provide the basis for the actual *Evaluation Findings*.

3.2.1 Safety Review of 10 CFR 60.21(c)

The staff's *Compliance Review* will consist of the following two steps. First, the staff will review the descriptive information provided for the engineered systems and components that provide a barrier between the waste and the geologic setting. This will provide an overall understanding of how DOE has presented its information on the many individual aspects of the engineered systems and components that provide a barrier between the waste and the geologic setting and how this information has been integrated. The types of descriptive information to be provided to other review plans are listed in Section 4.2.2.

Second, after the staff has conducted each of the *Compliance Reviews* for those sections of the LA identified in Section 4.2.2, the individual *Evaluation Findings* from these reviews will be considered on balance to determine whether the following Acceptance Criterion has been met:

(1) The descriptive information for the engineered systems and components that provide a barrier between the waste and the geologic setting provides an acceptable basis for all of the associated assessments that rely on this information

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	DWM/ENGB Engineering and Materials Section
Support:	DWM/PAHB Performance Assessment and Health Physics Section DWM/PAHB Performance Assessment and Health Physics Section DWM/PAHB Hydrologic Transport Section

4.2 Interfaces

4.2.1 Input Information

Input Information	*Review Plan No.*
Evaluation Findings	2.5—Radioactive Material
Evaluation Findings	5.2—Assessment of Compliance with the Design Criteria for the Waste Package and Its Components

Input Information	*Review Plan No.*
Evaluation Findings	5.3—Assessment of Compliance with the Design Criteria for the Post-Closure Features of the Underground Facility
Evaluation Findings	5.4—Assessment of Engineered Barrier System Compliance with the Performance Objectives
Evaluation Findings	8.3—Performance Confirmation Program for the Engineered Barrier System

4.2.2 Output Information

Output from activities associated with this review plan will provide specific information important for use in other review plans as the following table indicates. For further detail, see FCRG Sections 5.1 through 5.1.5.

Output Information	*Review Plan No.*
A description of the kind, amount, and specifications of the radioactive material proposed to be incorporated into waste packages.	2.5—Radioactive Material
Description of the waste package design and alternative designs, including the waste form; containers; shielding; packing; absorbent materials immediately surrounding an individual waste container; coatings; liners; structural supports; fillers; materials specifications; and manufacturing methods.	5.2—Assessment of Compliance with the Design Criteria for the Waste Package and its Components
Description of the design of the underground facility, including (1) the waste emplacement areas, panels, emplacement drifts, and boreholes; (2) backfill materials and their properties; (3) provisions for retrieval; and (4) pre-emplacement site conditions.	5.3—Assessment of Compliance with the Design Criteria for the Post-Closure Features of the Underground Facility
A description of (1) intended functions, including any assigned performance allocation, of each component of the EBS; (2) performance assessment codes, including assumptions and supporting research, testing, and model development; and (3) comparative evaluation of the alternative waste package designs.	5.4—Assessment of Engineered Barrier System Compliance with the Performance Objectives
A discussion of the EBS performance confirmation program, including (1) in situ waste package and waste form monitoring; (2) waste package external environment monitoring; (3) laboratory waste package monitoring; and (4) program schedule and duration.	8.3—Performance Confirmation Program for the Engineered Barrier System

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing, and the subsequent *Compliance Review*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis, should be documented in the staff's SER.

5.1 Finding for Acceptance Review

The NRC staff finds the information presented by DOE, as defined by the applicable 10 CFR Part 60 Regulatory Requirements, is acceptable (not acceptable) for docketing and a subsequent *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.21(c)

The NRC staff finds the information for descriptions, assessments, and analyses is (is not) adequate, and there is (is not) reasonable assurance the applicable regulatory requirements of 10 CFR 60.21(c), listed in Section 1.0 of this Review Plan, will be met for the engineered systems and components that provide a barrier between the waste and the geologic setting.

6 REFERENCES

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards

License Application Review Plan

LAND OWNERSHIP AND CONTROL

1 APPLICABLE REGULATORY REQUIREMENT(S)

The subject of this review plan is the land ownership and control and water rights regulatory requirements defined in 10 CFR 60.21(c)(8):

Subpart B — Licenses
LICENSE APPLICATIONS

§ 60.21 Content of application.

* * * * *

(c) The Safety Analysis Report shall include:

* * * * *

(8) A description of the controls that the applicant will apply to restrict access and to regulate land use at the site and adjacent areas,including a conceptual design of monuments which would be used to identify the controlled area after permanent closure.

* * * * *

For this review plan, the staff will determine if compliance with the land ownership and control and water rights requirement has been demonstrated, pursuant to the following regulatory requirement defined in 10 CFR 60.121(a-c).

The License Application Review Plan (LARP) is prepared for the guidance of the U.S. Nuclear Regulatory Commission staff responsible for the review of a U.S. Department of Energy (DOE) license application to receive and possess source, special nuclear, and byproduct material at a geologic repository for spent nuclear fuel and other high-level radioactive waste. These documents are available to the public as part of the Commission's policy to inform DOE and other interested parties of regulatory procedures and policies. Review Plans are not substitutes for the Commission's regulations and compliance with them is not required. The individual review plan sections are keyed to the Draft Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository."

Individual review plans in the LARP will be revised and updated, as the need arises, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Subpart E — Technical Criteria
LAND OWNERSHIP AND CONTROL

§ 60.121 Requirements for ownership and control of interests in land.

(a) *Ownership of land.* (1) Both the geologic repository operations area and the controlled area (GROA) shall be located in and on lands that are either acquired lands under the jurisdiction and control of DOE, or lands permanently withdrawn and reserved for its use.

(2) These lands shall be held free and clear of all encumbrances, if significant, such as: (i) Rights arising under the general mining laws; (ii) easements for right-of-way; and (iii) all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise.

(b) *Additional controls.* Appropriate controls shall be established outside of the controlled area. DOE shall exercise any jurisdiction and control over surface and subsurface estates necessary to prevent adverse human actions that could significantly reduce the geologic repository's ability to achieve isolation. The rights of DOE may take the form of appropriate possessory interests, servitudes, or withdrawals from location or patent under the general mining laws.

(c) *Water rights.* (1) DOE shall also have obtained such water rights as may be needed to accomplish the purpose of the geologic repository operations area.

(2) Water rights are included in the additional controls to be established under paragraph (b) of this section.

2 REVIEW STRATEGY

2.1 Acceptance Review

To determine whether this section of the DOE LA is acceptable for docketing, the staff will determine whether the information submitted is consistent with that identified in the corresponding section of the Regulatory Guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG).

Before the receipt of the LA, the staff will have conducted prelicensing reviews of DOE program, including technical reviews and quality assurance reviews and audits. The staff will have documented its concerns, resulting from these prelicense application reviews, as open items. Some of these open items, referred to as objections to LA submittal, may be critical to the staff's LA review, because lack of acceptable DOE resolution would prevent NRC from conducting a meaningful review. Therefore, as part of its Acceptance Review for docketing, the staff will evaluate how significant any unresolved objection to LA submittal is, to the effective conduct of licensing activities, using the criteria given in Section 3.1 of this review plan.

2.2 Compliance Review

2.2.1 Safety Review

The purpose of this section of the LA is to identify the interests in property that have been, or will be obtained by DOE, that are necessary to conduct geologic repository operations (including waste isolation). The information in this section of the LA shall be cross referenced to data submitted under other Sections of the LA, specifically Sections 3.2.2.6 [Potentially Adverse Conditions (PAC): Human Activity and Groundwater], 3.2.1.12 (PAC: Evidence of Subsurface Mining), 3.2.1.13 (PAC): Evidence of Drilling), and 7.10 (Site Markers). The reviewer will focus on the specific aspects of the LA discussed below, and the Acceptance Criteria are identified in Section 3.0 of this review plan.

In conducting the *Safety Review*, the reviewer will determine the correctness of the legal description and its conformance to other accepted methods of land description. The review should analyze for completeness the necessary Bureau of Land

Management (BLM) Master Title Plats (MTPs) for all sections contained within the controlled area to assure they identify existing (or proposed) title control and existing encumbrances. The reviewer should identify any encumbrances listed in the application and whether a clear description of how each will be addressed is included in the application. In addition, maps displaying relevant features within and outside the controlled area should be reviewed for appropriate notations and an analysis performed of data referenced in the application to ensure all controls proposed will be adequate. The reviewer shall identify the limits of the geologic repository operations area (GROA) and its relationship to the limits of the controlled area on MTPs, maps and diagrams, in order to aid the review of relevant and necessary controls to achieve isolation. If controls for the GROA are proposed by DOE to be different from those for the remainder of the controlled area, the extent of difference and the adequacy of the rationale shall be evaluated.

The review of controls proposed outside the controlled area should analyze the identification of limits of such area and the adequacy of the extent to which DOE proposes exercising jurisdiction. The reviewer should determine that existing rights and interests are adequately described, including a complete description of how they will be addressed.

The reviewer will assess the adequacy of the identification of all encumbrances currently located on the lands to be included in the controlled area and those existing outside the controlled area. A specific review of the potential impact of any encumbrance on the GROA's ability to achieve isolation shall be conducted. In addition, an assessment of the plan for extinguishing or compensating for existing rights or interests shall be made. The reviewer will identify the applicant's presentation of both interests in land and interest in the mineral estate as well as established rights of use or servitude to the lands of the controlled area and surrounding lands. Because the regulations specify "encumbrances, if significant" and "appropriate controls," it will be necessary for the reviewer to evaluate the presentation of not only the existence of rights, but also the extent to which they may impact operations and isolation in order to evaluate the appropriateness of DOE proposed actions. This evaluation will be coordinated with the assessments of compliance with those sections of the LA relating to evidence of mining and drilling for natural resources (e.g., Sections 3.2.1.12, 3.2.1.13, and 3.2.2.6).

The reviewer will analyze the presentation of water rights determined to be necessary for operations and required to prevent adverse impact on isolation for adequacy and support of conclusions. The review of needed permits and transfers shall focus on those identified as well as those not already obtained and a determination that appropriate schedules have been included. The review of water rights should identify discussion of both the time period of operations and the period after permanent closure. All needed permits and transfers shall be clearly identified and if not already obtained, a schedule included. The evaluation of information on water rights and water use in this section shall be cross referenced with information submitted under Section 3.2.2.6 of the LA.

Finally, the review of the description of access-restricting controls should determine the presence of site markers (or monuments) which would be used to identify the location of and control access to, those areas necessary to conduct geologic repository operations. The review of this section of the LA will not require a detailed description of the conceptual design for such markers; it should cross reference the information already presented in Section 7.10 of the LA. The final design details will be found in any subsequent application to decommission and permanently close the geologic repository.

3 REVIEW PROCEDURES AND ACCEPTANCE CRITERIA

3.1 Acceptance Review

In conducting the Acceptance Review for docketing, the staff will compare the information in the License Application (LA) concerning land ownership and control and water rights with the corresponding section of the FCRG and with the staff's resolution status of objections to LA submittal in the Open Item Tracking System (OITS) and determine if this information meets the following criteria.

(1) The information presented in the LA is clear, is completely documented consistent with the level of detail presented in the corresponding section of the FCRG, and the references have been provided.

(2) The U.S. Department of Energy (DOE) has either resolved, at the staff level, the NRC objections to LA submittal that apply to this regulatory requirement topic, or provided all information requested in Section 1.6 of the FCRG for unresolved objections, namely, the DOE has:

- Identified all unresolved objections
- Explained the differences between NRC and DOE positions which precluded resolution of each objection
- Described pertinent attempts to achieve resolution
- Explained why resolution has not been achieved
- Described the effects of the different positions on demonstrating compliance with 10 CFR Part 60

In addition, unresolved objections, individually or in combination with others, will not prevent the reviewer from conducting a meaningful *Compliance Review* or the Commission from making a decision regarding construction authorization within the 3-year statutory period.

3.2 Compliance Reviews

The compliance determinations undertaken by NRC staff will consider whether the Acceptance Criteria specified for each of the following *Compliance Reviews* have been met. The results of the compliance determinations shall be documented in the staff's Safety Evaluation Report (SER) to provide the basis for the actual *Evaluation Findings*.

3.2.1 Safety Review of 10 CFR 60.121(a) and 10 CFR 60.21(c)(8)

The staff will review the legal description and the documentation of DOE jurisdiction and control over the geologic repository operations area (GROA) and the controlled area to determine if the following acceptance criteria have been met.

- The legal documentation of ownership includes sufficient indexes of ownership and control as to satisfy a purchaser-of-record including, but not limited to, recorded title search showing any and all interests in land, and Bureau of Land Management's (BLM) Master Title Plan which indicates all recorded interests and claims.
- If a statutory withdrawal has been enacted, the LA includes a copy of the legislation, and the legal descriptions of the land area contained in the statute and the description in the application agree. Since the land area of the proposed repository site would be totally in Federal ownership, the statute will constitute complete ownership documentation, subject to subordinate interests.
- If a statutory withdrawal has not been enacted, the DOE has taken all steps within its control to establish effective and permanent jurisdiction and control, and legislative or other transfer activities underway will be completed prior to the completion of NRC review and decision on the application.
- The size and boundaries of the GROA and the controlled area and accessible environment are appropriately tied to specific design or natural features and consistent with the technical justification. The review of the technical justification for the GROA design contained in Chapter 4 of the LA is to be performed in that chapter and only incorporated and referenced in this review plan as indicated in Section 4.2 below.
- The means, such as title search and BLM records search, utilized to identify any existing or future encumbrances or other surface or subsurface interests of record in the land area of the GROA are adequate and complete.
- For the land area of the GROA, the DOE has identified any and all interests which include rights arising under the general mining laws, easements for right-of-way, and all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise, if any exist.

3.2.2 Safety Review of 10 CFR 60.121(b) and 10 CFR 60.21(c)(8)

The staff will review the appropriateness of the jurisdiction and control either established or proposed to be established by the DOE outside the controlled area to determine if the following acceptance criteria have been met.

- The legal documentation of ownership and/or control includes sufficient indexes of ownership and control of the area outside the controlled area as to satisfy a purchaser-of-record including, but not limited to, recorded title search showing any and all interests in land, and the BLM Master Title Plan which indicates all recorded interests and claims.

- If a statutory withdrawal has not been enacted, the DOE has taken all steps within its control to establish effective and permanent jurisdiction and control, and legislative or other transfer activities underway will be completed prior to the completion of NRC review and decision on the application.

- The size and boundaries of the area outside the controlled area are appropriately tied to specific design or natural features and consistent with the technical justification in order to assure the repository's ability to achieve isolation and prevent or reduce the risk of human activity which may adversely impact isolation. The review of the technical justification for the GROA design contained in Chapter 4 of the LA is to be performed in that chapter and only incorporated and referenced in this review plan as indicated in Section 4.2 below. The review of the technical justification for the natural features and their relationship to the extent of the size and boundaries outside the controlled area for which ownership and control of interests need to be established will be performed in Chapters 3 and 6 and incorporated and referenced in this review plan as indicated in Section 4.2 below.

- The demonstration identifies existing or proposed permissible rights or encumbrances which exist and may be continued, or which may be established outside the controlled area and assesses the nature of activities which may permissibly occur under the rights.

- The means, such as title search and BLM records search, utilized to identify any existing or future encumbrances or other surface or subsurface interests of record in the land area outside the controlled area are adequate and complete to ensure no competing interests remain, or that adverse human intrusion would not be facilitated.

- The assessment shall apply to surface and subsurface rights and, in accordance with the requirement of 10 CFR 60.121(c)(2), shall apply to water rights as well as land use and mineral rights.

3.2.3 Safety Review of 10 CFR 60.121(c)

The staff will review the documentation of water rights obtained by the applicant in support of accomplishing operations and other purposes of the GROA and for purposes of isolation of wastes after closure to determine if the following acceptance criteria have been met.

- The description regarding water rights shall address both the potential water needs of the GROA as described in Section 4.1 of the LA and the potential adverse impacts on isolation which may result from water usage on the lands within the controlled area as well as those identified outside the controlled area as described in Section 3.1.2.3 of the LA.

- The analysis shall include existing and projected water uses authorized under existing law and justification for the quantity projections from Chapter 4 of the LA, as well as potential consequences of estimated water usage both within and outside the controlled area.

4 IMPLEMENTATION

4.1 Review Responsibilities

The review responsibilities for this review plan are as follows:

Lead:	OGC
Support:	DWM/HLUR & DWM/ENGB

4.2 Interfaces

4.2.1 Input Information

Input from activities associated with other review plans as the following table indicates will provide specific information for use in this review plan.

Input Information	*Review Plan No.*
Technical characteristics to aid size and boundary of the GROA, controlled area and surrounding area	3.1—Description of Individual Systems and Characteristics of the Site
Size and boundary of the GROA, controlled area and surrounding area	4.1—Description of the GROA
Extent of area that could be adversely impacted by human intrusion or adverse water usage	6.1—Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials

4.2.2 Output Information

Output from activities associated with this review plan will provide specific information for use in other review plans as the following table indicates.

Output Information	*Review Plan No.*
Locations of boundaries	7.10—Site Markers

5 EXAMPLE EVALUATION FINDINGS

The staff should consider the *Example Evaluation Findings* presented below together with the Acceptance Criteria set forth in Section 3.0 when making the actual *Evaluation Findings* resulting from the Acceptance Review for docketing and the *Compliance Reviews*. The actual *Evaluation Findings* resulting from the *Compliance Reviews*, and the supporting basis for these findings, should be documented by the staff in the SER.

5.1 Finding for Acceptance Review

The NRC staff finds that the information presented by the DOE on land ownership and control and water rights is acceptable (not acceptable) for docketing and a *Compliance Review*.

5.2 Findings for Compliance Reviews

5.2.1 Finding for 10 CFR 60.121 and 10 CFR 60.21(c)(8)

The NRC staff finds that the applicant has (has not) demonstrated that the GROA, the controlled area, and the area outside the controlled area deemed essential to protecting human health and safety, are under DOE jurisdiction and control either by means of a permanent statutory withdrawal or other appropriate means. This jurisdiction and control applies to surface and subsurface estates and shall be exercised in order to prevent adverse human intrusion that could significantly reduce the GROA's ability to achieve isolation.

The staff finds that the lands are (are not) held free and clear of all encumbrances, if deemed significant. If encumbrances exist or are proposed to be permitted, the DOE has (has not) demonstrated that the permitted use or right will have no adverse effect on the GROA's ability to achieve waste isolation.

The staff further finds that the DOE has (has not) obtained the water rights needed to accomplish the purpose of the GROA, whether on lands within the controlled area or outside the controlled area.

6 REFERENCES

Nuclear Regulatory Commission, "Format and Content for the License Application for the High-Level Waste Repository," Office of Nuclear Regulatory Research. [Refer to the "Products List" for the Division of High-Level Waste Management to identify the most current edition of the FCRG in effect.]

APPENDIX A
CROSSWALK SHOWING THE RELATIONSHIP BETWEEN THE REGULATORY REQUIREMENTS IN 10 CFR PART 60 AND THE INDIVIDUAL REVIEW PLANS IN NUREG-1323

10 CFR Part 60 Section	*NUREG-1323 Review Plan No(s).*
Subpart B – Licenses	
LICENSE APPLICATIONS	
60.21(a)	1.7, 2.3[1]
60.21(b)(1)	1.1, 1.2
60.21(b)(2)	1.3
60.21(b)(3)	1.4
60.21(b)(4)	1.5
60.21(b)(5)	1.6.1, 1.6.2
60.21(c)(1)	3.1.4, 3.3, 5.4, 5.5
60.21(c)(1)(i)	3.1.1-3.1.5, 3.2.1.1-3.2.1.4, 3.2.2.1-3.2.2.12, 3.2.3.1-3.2.3.7, 3.2.4.1-3.2.4.2, 4.1.1-4.1.4, 4.3
60.21(c)(1)(i)(A)	3.1.1-3.1.3, 4.1.1-4.1.4, 4.5.2
60.21(c)(1)(i)(B)	3.1.1-3.1.3, 4.1.1-4.1.4
60.21(c)(1)(i)(C)	3.1.1, 3.1.2, 4.1.1-4.1.4
60.21(c)(1)(i)(D)	3.1.2, 4.1.1-4.1.4, 4.5.2
60.21(c)(1)(i)(E)	3.1.3, 4.1.1-4.1.4, 4.5.2
60.21(c)(1)(i)(F)	3.1.1-3.1.3, 3.1.5, 4.1.1-4.1.4
60.21(c)(1)(ii)(A)	3.1.1-3.1.4, 3.2.1.1-3.2.1.14, 3.2.2.1-3.2.2.12, 3.2.3.1-3.2.3.7, 3.2.4.1-3.2.4.2, 4.2-4.4, 4.5.2, 5.2, 5.3
60.21(c)(1)(ii)(B)	3.2.1.1-3.2.1.14, 3.2.2.1-3.2.2.12, 3.2.3.1-3.2.3.7, 3.2.4.1-3.2.4.2
60.21(c)(1)(ii)(C)	3.2.5, 4.3, 5.4, 6.1-6.3
60.21(c)(1)(ii)(D)	3.3, 4.3, 4.5.2, 5.2-5.4, 6.1-6.3
60.21(c)(1)(ii)(E)	4.2-4.4, 4.5.1, 4.5.2, 5.2, 5.4, 5.5, 8.4
60.21(c)(1)(ii)(F)	3.2.1.1-3.2.1.4, 3.2.2.1-3.2.2.12, 3.2.3.1-3.2.3.7, 3.2.4.1-3.2.4.2, 3.2.5, 3.3, 3.4, 4.1.4, 4.5.1, 4.5.2, 5.2-5.5, 6.1-6.3
60.21(c)(2)(i-iv)	4.1.1-4.1.5, 4.2-4.4, 4.5.1, 5.2, 5.3, 5.5, 8.4
60.21(c)(3)(i-ii)	4.1.1-4.1.5, 4.2-4.4, 4.5.2, 5.2, 5.3, 5.5, 7.8, 8.4
60.21(c)(4)	10.0
60.21(c)(5)	2.5
60.21(c)(6)	2.6, 4.1.3-4.1.4, 4.2-4.4, 4.5.1, 4.5.2, 5.1-5.3, 5.5, 7.8

[1] Section 60.21(a) notes that the overall format of a license application for a geologic repository shall consist of general information and a Safety Analysis Report (SAR). The review plans in Chapter 1 address the general information section of the license application section of the license application; review plans in Chapters 2-11 address the information to be submitted in the SAR.

10 CFR Part 60 Section	*NUREG-1323 Review Plan No(s).*
60.21(c)(7)	4.1.3–4.1.4, 4.2–4.4, 4.5.1, 4.5.2, 5.5, 7.2, 7.8
60.21(c)(8)	7.10, 9.0
60.21(c)(9)	4.1.1–4.1.4, 4.2–4.4, 4.5.1, 4.5.2, 7.2
60.21(c)(10)	2.7
60.21(c)(11)	4.1.1–4.1.4, 4.2–4.4, 4.5.2
60.21(c)(12)	4.1.1–4.1.3, 4.2–4.4, 4.5.1, 4.5.2
60.21(c)(13)	3.1.1–3.1.3[2]
60.21(c)(14)	2.4, 4.1.3–4.1.4, 4.2–4.4, 4.5.1, 4.5.2, 5.1–5.3, 5.5, 8.1.1–8.1.4, 8.2–8.5
60.21(c)(15)(i)	2.1, 7.3
60.21(c)(15)(ii)	7.3
60.21(c)(15)(iii)	7.3, 7.6
60.21(c)(15)(iv)	7.1, 7.2, 7.4, 7.7
60.21(c)(15)(v)	7.1, 7.2, 7.4, 7.5, 7.7
60.21(c)(15)(vi)	7.1, 7.2, 7.4, 7.7, 7.9, 7.10
60.21(c)(15)(vii)	7.1, 7.4, 7.7, 7.10
60.23	2.2
60.24(a)	2.3, 2.4
60.24(b)	[3]
60.24(c)	None[4]

Subpart D -- Records, Reports, Tests, and Inspections

60.71(a–b)	7.5
60.72(a–b)	7.5
60.73	7.5

[2] Evaluation of compliance with this regulatory requirement will be performed in parallel with the review of 10 CFR 60.122(c)(17)(i-ii) in Review Plan 3.2.1.11.

[3] This regulatory requirement is not applicable until the time that the U.S. Department of Energy (DOE) requests a license to receive or possess source, special nuclear, or byproduct material at a geologic repository, as provided in 10 CFR 60.3(a).

[4] As noted in 10 CFR 60.24(a), DOE shall supplement its environmental impact statement in a timely manner so as to take into account the environmental impacts of any substantial changes, in its proposed actions, or any significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts.

Subpart E – Technical Criteria
PERFORMANCE OBJECTIVES

60.111(a)	4.2-4.4, 4.5.1, 5.5, 8.4
60.111(b)(1-3)	4.3, 4.4, 4.5.2
60.112[5]	6.1-6.3
60.113(a)(1)(i-ii)	5.4
60.113(a)(2)	3.3
60.113(b)(1-4)	3.3, 5.4
60.113(c)	5.4

LAND OWNERSHIP AND CONTROL

60.121(a)(1-2)	9.0
60.121(b)	7.10, 9.0
60.121(c)	9.0

SITING CRITERIA

60.122(a)(1)	3.2.5, 3.3, 5.4, 6.1-6.3
60.122(a)(2)	3.2.5, 3.3, 5.4, 6.1-6.3
(Favorable Conditions)	
60.122(b)(1)	3.2.1.1, 3.2.2.1, 3.2.3.1
60.122(b)(2)(i-iii)	3.2.2.2
60.122(b)(3)(i-iii)	3.2.3.2
60.122(b)(4)	3.2.3.3
60.122(b)(5)	3.2.1.2
60.122(b)(6)	3.2.1.3
60.122(b)(7)	3.2.2.3
60.122(b)(8)(i-v)	3.2.2.4, 3.2.4.1[6]
(Potentially Adverse Conditions)	
60.122(c)(1)	3.2.2.5
60.122(c)(2)	3.2.2.6
60.122(c)(3)	3.2.2.7
60.122(c)(4)	3.2.2.8

[5] Section 60.112 is to be modified to conform to 40 CFR Part 191.

[6] Section 60.122(b)(8)(v) only.

10 CFR Part 60 Section	NUREG-1323 Review Plan No(s).
60.122(c)(5)	3.2.2.9
60.122(c)(6)	3.2.4.2
60.122(c)(7)	3.2.3.4
60.122(c)(8)	3.2.3.5
60.122(c)(9)	3.2.3.6
60.122(c)(10)	3.2.1.4
60.122(c)(11)	3.2.1.5
60.122(c)(12)	3.2.1.6
60.122(c)(13)	3.2.1.7
60.122(c)(14)	3.2.1.8
60.122(c)(15)	3.2.1.9
60.122(c)(16)	3.2.1.10
60.122(c)(17)(i–ii)	3.2.1.11
60.122(c)(18)	3.2.1.12
60.122(c)(19)	3.2.1.13
60.122(c)(20)	3.2.2.10
60.122(c)(21)	3.2.1.14
60.122(c)(22)	3.2.2.11
60.122(c)(23)	3.2.2.12
60.122(c)(24)	3.2.3.7

DESIGN CRITERIA FOR THE GEOLOGIC REPOSITORY OPERATIONS AREA

60.130	4.2, 4.3, 4.4, 5.5, 8.4
60.131(a)(1–6)	4.2, 4.3, 4.4, 5.5, 8.4
60.131(b)(1)	4.2, 4.3, 4.4
60.131(b)(2)	4.2, 4.3, 4.4
60.131(b)(3)(i–iv)	4.2, 4.3, 4.4
60.131(b)(4)(i–ii)	4.2, 4.3, 4.4
60.131(b)(5)(i–iii)	4.2, 4.3, 4.4
60.131(b)(6)	4.2, 4.3, 4.4
60.131(b)(7)	4.2, 4.3, 4.4, 4.5.2
60.131(b)(8)	4.2, 4.3, 4.4
60.131(b)(9)	4.2, 4.3, 4.4
60.131(b)(10)(i–iv)	4.3
60.132(a)	4.2, 4.5.2
60.132(b)	4.2
60.132(c)(1–2)	4.2
60.132(d)	4.2
60.132(e)	4.2

10 CFR Part 60 Section	*NUREG-1323 Review Plan No(s).*
60.133(a)(1)	4.4, 5.3
60.133(a)(2)	4.4
60.133(b)	4.4
60.133(c)	4.4, 4.5.2
60.133(d)	4.4
60.133(e)(1)	4.4. 4.5.2
60.133(e)(2)	4.4, 5.3
60.133(f)	4.4, 5.3
60.133(g)(1–3)	4.4
60.133(h)	4.4, 5.3
60.133(i)	4.5.2, 5.3
60.134.4(a–b)	4.3, 4.4
DESIGN CRITERIA FOR THE WASTE PACKAGE	
60.135(a)(1–2)	5.2
60.135(b)(1–4)	4.5.2[7], 5.2
60.135(c)(1–3)	5.2
60.135(d)	5.2
PERFORMANCE CONFIRMATION REQUIREMENTS	
60.137	4.2, 4.3, 4.4
Subpart F – Performance Confirmation Program	
60.140(a–d)	8.1.1–8.1.4, 8.2, 8.3, 8.5
60.141(a)	8.1.1–8.1.4, 8.2
60.141(b)	8.1.1–8.1.4, 8.2
60.141(c)	8.1.1–8.1.4, 8.2
60.141(d)	8.1.1–8.1.4, 8.2
60.141(e)	8.1.1–8.1.4, 8.2
60.142(a)	8.1.1, 8.1.2, 8.2, 8.3
60.142(b)	8.2, 8.3
60.142(c)	8.2, 8.3
60.142(d)	8.2

[7] Section 60.135(b)(3) only.

10 CFR Part 60 Section	*NUREG-1323 Review Plan No(s).*
60.143(a–d)	8.1.1–8.1.4,[8] 8.3
Subpart G – Quality Assurance	
60.150	10.0
60.151	10.0
60.152	10.0
Subpart H – Training and Certification of Personnel	
60.160	7.3
60.161	7.3
60.162	7.3
Subpart I[9]	

[8] Section 60.143(a) only.

[9] Development of the review plan on this subject, in Chapter 10.0, will be deferred until promulgation of a rulemaking on emergency planning criteria for 10 CFR Part 60.

APPENDIX C
STAFF REVIEW RESPONSIBILITIES IN NUREG-1323

Section 4.1 ("Review Responsibilities") of each individual review plan in NUREG-1323 identifies both the lead and supporting NRC division(s)/branch(s)/section(s) responsible for conducting the respective license application reviews. This appendix summarizes the information contained in Section 4.1 for the 97 individual review plans. The abbreviation used to describe the respective organizational review assignments are as follows:

Organization	*Abbreviation*
Division of Waste Management	**DWM**
Engineering and Geosciences Branch	*ENGB*
Engineering and Materials Section	*ENG*
Geosciences/Geotechnical Engineering Section	*GEOL*
Performance Assessment and Hydrology Branch	*PAHB*
Hydrologic Transport Section	*HYDRO*
Performance Assessment and Health Physics Section	*PA*
High-Level Waste (HLW) and Uranium Recovery Branch	*HLUR*
HLW and Quality Assurance Section	*PROJ*
Office of the General Counsel	**OGC**
Division of Fuel Cycle Safety and Safeguards	**FCSS**

The assignment of review responsibility for the respective individual review plans may change or be modified in the future, as LARP development proceeds.

Review Plan No.	*Lead Organization*	*Supporting Organization*

PART B — LICENSE APPLICATION REVIEW PLANS FOR GENERAL INFORMATION

1. General Information

1.1	ENGB/ENG	ENGB/GEOL
1.2	HLUR/PROJ	none
1.3	HLUR/PROJ	none
1.4	HLUR/PROJ	ENGB/ENG, FCSS
1.5	HLUR/PROJ	ENGB/ENG, FCSS
1.6.1	HLUR/PROJ	DWM
1.6.2	HLUR/PROJ	DWM
1.7	PAHB/PA	none

PART C — LICENSE APPLICATION REVIEW PLANS FOR THE SAFETY ANALYSIS REPORT

2. General Information for the Safety Analysis Report

2.1	HLUR/PROJ	none
2.2	HLUR/PROJ	none
2.3	HLUR/PROJ	DWM
2.4	HLUR/PROJ	none
2.5	ENGB/ENG	none
2.6	HLUR/PROJ	DWM
2.7	HLUR/PROJ	ENGB/ENG, FCSS

3. The Natural Systems of the Geologic Setting

3.1.1	ENGB/GEOL	none
3.1.2	PAHB/HYDRO	none
3.1.3	PAHB/HYDRO	none
3.1.4	PAHB/HYDRO	none
3.1.5	PAHB/HYDRO	ENGB
3.2.1.1	ENGB/GEOL	none
3.2.1.2	ENGB/GEOL	none
3.2.1.3	ENGB/GEOL	none
3.2.1.4	PAHB/HYDRO	ENGB/GEOL
3.2.1.5	ENGB/GEOL	none
3.2.1.6	ENGB/GEOL	none
3.2.1.7	ENGB/GEOL	none
3.2.1.8	ENGB/GEOL	none
3.2.1.9	ENGB/GEOL	none
3.2.1.10	ENGB/GEOL	none
3.2.1.11	ENGB/GEOL	none
3.2.1.12	ENGB/GEOL	none
3.2.1.13	ENGB/GEOL	none
3.2.1.14	ENGB/ENG	ENGB/GEOL

Review Plan No.	*Lead Organization*	*Supporting Organization*
3.2.2.1	PAHB/HYDRO	none
3.2.2.2	PAHB/HYDRO	none
3.2.2.3	PAHB/HYDRO	none
3.2.2.4	PAHB/HYDRO	none
3.2.2.5	PAHB/HYDRO	none
3.2.2.6	PAHB/HYDRO	none
3.2.2.7	PAHB/HYDRO	ENGB/GEOL
3.2.2.8	PAHB/HYDRO	ENGB/GEOL
3.2.2.9	PAHB/HYDRO	ENGB/GEOL
3.2.2.10	PAHB/HYDRO	DWM
3.2.2.11	PAHB/HYDRO	ENGB/GEOL
3.2.2.12	PAHB/HYDRO	none
3.2.3.1	PAHB/HYDRO	none
3.2.3.2	PAHB/HYDRO	none
3.2.3.3	PAHB/HYDRO	none
3.2.3.4	PAHB/HYDRO	ENGB/ENG
3.2.3.5	PAHB/HYDRO	none
3.2.3.6	PAHB/HYDRO	none
3.2.3.7	PAHB/HYDRO	none
3.2.4.1	PAHB/HYDRO	none
3.2.4.2	PAHB/HYDRO	none
3.2.5	HLUR/PROJ	DWM
3.3	PAHB/HYDRO	none
3.4	PAHB/PA	DWM

4. Geologic Repository Operations Area (GROA)

4.1.1	ENGB/ENG	none
4.1.2	ENGB/ENG	none
4.1.3	ENGB/ENG	none
4.1.4	ENGB/ENG	PAHB/PA
4.1.5	ENGB/ENG	none
4.2	ENGB/ENG	ENGB/GEOL
4.3	ENGB/ENG	ENGB/PAHB
4.4	ENGB/ENG	ENGB/PAHB
4.5.1	ENGB/ENG	none
4.5.2	ENGB/ENG	ENGB

5. Engineered Barrier Systems

5.1	ENGB/ENG	none

Review Plan No.	*Lead Organization*	*Supporting Organization*
5.2	ENGB/ENG	PAHB/HYDRO
5.3	ENGB/ENG	DWM
5.4	ENGB/ENG	PAHB/HYDRO
5.5	ENGB/ENG	PAHB/PA
6. Overall System Performance Assessment		
6.1	PAHB/PA	none
6.2	PAHB/PA	none
6.3	PAHB/PA	none
7. Conduct of Repository Operations		
7.1	ENGB/ENG	none
7.2	ENGB/ENG	HLHP/PA
7.3	HLUR/PROJ	ENGB/ENG
7.4	ENGB/ENG	HLUR/PROJ
7.5	ENGB/ENG	HLUR/PROJ
7.6	ENGB/ENG	HLUR/PROJ
7.7	HLUR/PROJ	ENGB/ENG
7.8	ENGB/ENG	HLUR/PROJ
7.9	HLUR/PROJ	none
7.10	ENGB/ENG	none
8. Performance Confirmation Program		
8.1.1	ENGB/GEOL	PAHB/PA
8.1.2	PAHB/HYDRO	PAHB/PA
8.1.3	PAHB/HYDRO	PAHB/PA
8.1.4	PAHB/HYDRO	PAHB/PA
8.2	ENGB/ENG	PAHB/PA
8.3	ENGB/ENG	PAHB/PA
8.4	ENGB/ENG	HLUR/PROJ

Review Plan No.	*Lead Organization*	*Supporting Organization*
8.5	ENGB	DWM
9.0 **LAND OWNERSHIP AND CONTROL**	OGC	HLUR/PROJ
10.0 **QUALITY ASSURANCE**	HLUR/PROJ	none
11.0 **EMERGENCY PLANNING**	TBD	TBD

APPENDIX D
STATUS OF REVIEW PLAN DEVELOPMENT IN NUREG-1323

This appendix gives the current revision number and status of development for each Review Plan in NUREG-1323—the License Application Review Plan. The status of development for each Review Plan is as follows: ***"RS"*** means *Review Strategy (Review Plan Sections 1, 2, 3, and 6)*, ***"RM"*** means *Review Method (Review Plan Sections 3, 4, 5, and 6).*

Individual Review Plan (designated in Italics)	*Revision No.*	*Status*
PART A -- LICENSE APPLICATION REVIEW STRATEGY	---	---
PART B -- LICENSE APPLICATION REVIEW PLANS FOR GENERAL INFORMATION	---	---
1.0 GENERAL INFORMATION	---	---
1.1 General Description of the Facility	*Revision 0*	*RS*
1.2 Basis for Licensing Authority	*Revision 0*	*RS*
1.3 Schedules	*Revision 0*	*RS*
1.4 Certification of Safeguards	*Revision 0*	*RS*
1.5 Physical Security Plan	*Revision 0*	*RS*
1.6 Site Characterization Program Review	---	---
1.6.1 Site Characterization Work Conducted	*Revision 0*	*RS*
1.6.2 Status of DOE Resolution of NRC Objections	*Revision 0*	*RS*
1.7 Statement of Compliance with the Performance Objectives of 10 CFR Part 60 and Summary of Performance Assessment Results	*Revision 0*	*RS*
PART C -- LICENSE APPLICATION REVIEW PLANS FOR THE SAFETY ANALYSIS REPORT	---	---
2.0 GENERAL INFORMATION FOR THE SAFETY ANALYSIS REPORT	---	---
2.1 Identification of Agents and Contractors	*Revision 0*	*RS*
2.2 Material Incorporated by Reference	*Revision 0*	*RS*
2.3 Use of NRC Staff Technical Positions	*Revision 0*	*RS*
2.4 Requirements for Further Technical Information	*Revision 0*	*RS*
2.5 Radioactive Material	*Revision 0*	*RS*
2.6 License Specifications	*Revision 0*	*RS*
2.7 Nuclear Material Control	*Revision 0*	*RS*
3.0 THE NATURAL SYSTEMS OF THE GEOLOGIC SETTING	---	---
3.1 Description of Individual Systems and Characteristics of the Site	---	---
3.1.1 Geologic System	*Revision 0*	*RS*
3.1.2 Hydrologic System	*Revision 1*	*RS, RM*
3.1.3 Geochemical System	*Revision 1*	*RS, RM*
3.1.4 Climatological and Meteorological Systems	*Revision 1*	*RS, RM*
3.1.5 Integrated Natural System Response to the Maximum Design Thermal Loading	*Revision 0*	*RS (Part 2)*
3.2 Assessment of Compliance with Siting Criteria	---	---
3.2.1 Geologic System: Individual Favorable Conditions and Potentially Adverse Conditions	---	---
(Favorable Conditions)		
3.2.1.1 Nature and Rates of Physical Processes	*Revision 0*	*RS*
3.2.1.2 Minimum Waste Emplacement Depth	*Revision 1*	*RS, RM*
3.2.1.3 Low Population Density	*Revision 0*	*RS*
(Potentially Adverse Conditions)		
3.2.1.4 Evidence of Dissolution	*Revision 0*	*RS*
3.2.1.5 Structural Deformation	*Revision 0*	*RS*
3.2.1.6 Historic Earthquakes	*Revision 1*	*RS, RM*
3.2.1.7 Correlation of Earthquakes with Tectonic Processes	*Revision 0*	*RS*
3.2.1.8 Increasing Earthquake Frequency/Magnitude	*Revision 0*	*RS*
3.2.1.9 Evidence of Igneous Activity	*Revision 0*	*RS, RM*
3.2.1.10 Evidence of Extreme Erosion	*Revision 1*	*RS, RM*
3.2.1.11 Naturally Occurring Materials	*Revision 0*	*RS*
3.2.1.12 Evidence of Subsurface Mining	*Revision 0*	*RS*
3.2.1.13 Evidence of Drilling	*Revision 0*	*RS*
3.2.1.14 Geomechanical Properties	*Revision 0*	*RS*

Individual Review Plan (designated in Italics)	*Revision No.*	*Status*
3.2.2 Hydrologic System: Individual Favorable Conditions and Potentially Adverse Conditions	---	---
(Favorable Conditions)		
3.2.2.1 Nature and Rate of Hydrogeologic Processes	*Revision 0*	*RS*
3.2.2.2 Saturated Zone Hydrogeologic Conditions	*Revision 0*	[1]
3.2.2.3 Groundwater Travel Time Substantially Exceeding 1000 years	*Revision 0*	*RS*
3.2.2.4 Unsaturated Zone Hydrogeologic Conditions	*Revision 0*	*RS*
(Potentially Adverse Conditions)		
3.2.2.5 Flooding	*Revision 1*	*RS, RM*
3.2.2.6 Human Activity and Groundwater	*Revision 0*	*RS*
3.2.2.7 Natural Phenomena and Groundwater	*Revision 0*	*RS*
3.2.2.8 Structural Deformation and Groundwater	*Revision 0*	*RS*
3.2.2.9 Changes in Hydrologic Conditions	*Revision 0*	*RS*
3.2.2.10 Complex Engineering Measures	*Revision 0*	*RS*
3.2.2.11 Potential for Unsaturated Zone Saturation	*Revision 0*	*RS*
3.2.2.12 Perched Water Bodies	*Revision 0*	*RS*
3.2.3 Geochemical System: Individual Favorable Conditions and Potentially Adverse Conditions	---	---
(Favorable Conditions)		
3.2.3.1 Nature and Rates of Geochemical Processes	*Revision 0*	*RS*
3.2.3.2 Geochemical Conditions	*Revision 0*	*RS*
3.2.3.3 Mineral Assemblages	*Revision 0*	*RS*
(Potentially Adverse Conditions)		
3.2.3.4 Groundwater Conditions and the Engineered Barrier System	*Revision 0*	*RS*
3.2.3.5 Geochemical Processes	*Revision 0*	*RS*
3.2.3.6 Not Reducing Groundwater Conditions	*Revision 0*	*RS*
3.2.3.7 Gaseous Radionuclide Movement	*Revision 0*	*RS*
3.2.4 Climatological and Meteorological System: Individual Favorable Conditions and Potentially Adverse Conditions	---	---
(Favorable Conditions)		
3.2.4.1 Annual Potential Evapotranspiration	*Revision 1*	*RS, RM*
(Potentially Adverse Conditions)		
3.2.4.2 Changes to Hydrologic System from Climate	*Revision 0*	*RS*
3.2.5 Assessment of Compliance with Criteria for Favorable Conditions and Potentially Adverse Conditions	*Revision 0*	*RS*
3.3 Assessment of Compliance with Groundwater Travel Time Performance Objective	*Revision 0*	*RS*
3.4 Effectiveness of Natural Barriers against the Release of Radioactive Material to the Environment	*Revision 0*	*RS*
4.0 GEOLOGIC REPOSITORY OPERATIONS AREA (GROA)	---	---
4.1 Description of the GROA Structures, Systems, and Components	---	---
4.1.1 Surface Facilities	*Revision 1*	*RS, RM*
4.1.2 Shafts and Ramps	*Revision 1*	*RS, RM*
4.1.3 Underground Facility	*Revision 1*	*RS, RM*
4.1.4 Radiation Protection Systems	*Revision 0*	*RS*
4.1.5 Interfaces between Structures, Systems, and Components	*Revision 0*	*RS*
4.2 Assessment of Compliance with Design Criteria for Surface Facilities	*Revision 0*	*RS*
4.3 Assessment of Compliance with Design Criteria for Shafts and Ramps	*Revision 0*	*RS*
4.4 Assessment of Compliance with Design Criteria for the Underground Facility	*Revision 0*	*RS*

[1] The U.S. Department of Energy's current site characterization plans obviate the need for this particular review plan.

Individual Review Plan (designated in Italics)	*Revision No.*	*Status*
4.5 Assessment of Integrated GROA Compliance with the Performance Objectives	---	---
4.5.1 Protection against Radiation Exposures and Releases of Radioactive Material to Unrestricted Areas	*Revision 0*	*RS*
4.5.2 Retrievability of Waste	*Revision 0*	*RS*
5.0 ENGINEERED BARRIER SYSTEMS	---	---
5.1 Description of Engineered Systems and Components that provide a Barrier between the Waste and the Geologic Setting	*Revision 1*	*RS, RM*
5.2 Assessment of Compliance with the Design Criteria for the Waste Package and its Components	*Revision 0*	*RS*
5.3 Assessment of Compliance with the Design Criteria for the Post-Closure Features of the Underground Facility	*Revision 0*	*RS*
5.4 Assessment of Compliance with the Engineered Barrier System Performance Objectives	*Revision 0*	*RS*
5.5 Radiation Protection	*Revision 0*	*RS*
6.0 OVERALL SYSTEM PERFORMANCE ASSESSMENT	---	---
6.1 Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials	*Revision 0*	*RS*
6.2 Assessment of Compliance with the Individual Protection Requirements	*Revision 0*	*RS*
6.3 Assessment of Compliance with the Groundwater Protection Requirements	*Revision 0*	*RS*
7.0 CONDUCT OF REPOSITORY OPERATIONS	---	---
7.1 Plans for Conduct of Normal Activities	*Revision 0*	*RS*
7.2 Description of Radiation Protection Program	*Revision 0*	*RS*
7.3 Organizational Structure, Management, and Administrative Controls	*Revision 0*	*RS*
7.4 Procedure Development	*Revision 0*	*RS*
7.5 Records and Reports	*Revision 0*	*RS*
7.6 Training Programs	*Revision 0*	*RS*
7.7 Schedules for Operations	*Revision 0*	*RS*
7.8 Identification of Operating Controls and Limits	*Revision 0*	*RS*
7.9 Preservation of Records	*Revision 0*	*RS*
7.10 Site Markers	*Revision 0*	*RS*
8.0 PERFORMANCE CONFIRMATION PROGRAM	---	---
8.1 Performance Confirmation Program for the Natural Systems of the Geologic Setting	---	---
8.1.1 Geologic System	*Revision 0*	*RS*
8.1.2 Hydrologic System	*Revision 0*	*RS*
8.1.3 Geochemical System	*Revision 0*	*RS*
8.1.4 Climatological and Meteorological Systems	*Revision 0*	*RS*
8.2 Performance Confirmation Program for Structures, Systems, and Components of the GROA	*Revision 0*	*RS*
8.3 Performance Confirmation for the Engineered Barrier Systems	*Revision 0*	*RS*
8.4 Radiation Protection during Performance Confirmation	*Revision 0*	*RS*
8.5 Analysis of Changes from Performance Confirmation Baseline	*Revision 0*	*RS*

Individual Review Plan (designated in Italics)	*Revision No.*	*Status*
9.0 LAND OWNERSHIP AND CONTROL	*Revision 1*	*RS, RM*
10.0 QUALITY ASSURANCE	*Revision 0*	*RS, RM*
11.0 EMERGENCY PLANNING	*TBD*	*TBD*

APPENDIX E
KEY TECHNICAL UNCERTAINTIES ASSOCIATED WITH INDIVIDUAL REVIEW PLANS

This appendix summarizes, by review plan topic, the Key Technical Uncertainties that have been identified by the staff in Revision 0 (designated "Rev. 0") of the License Application Review Plan (LARP). The staff has defined a "Key Technical Uncertainty" to be the uncertainty of how to demonstrate compliance with a 10 CFR Part 60 regulatory requirement, who existence poses a high-risk of non-compliance with a 10 CFR Part 60 performance objective. This includes uncertainty about:

- Methods for obtaining information;
- Methods for analyzing information; or
- The understanding of conditions or physical processes.

The *Review Strategy* Section (Section 2) of each individual review plan refers to the Key Technical Uncertainties by their respective titles. To understand the nature of the technical uncertainty being addressed, in the context of the review taking place, the staff will need to refer to this appendix. In referring to this appendix, however, the user should be aware that the staff plans on conducting a systematic review of the Key Technical Uncertainties identified here, to resolve inconsistencies among the individual topics and descriptions, in the future. As part of this review, both the number and subjects of Key Technical Uncertainties may be revised, as appropriate.

The following discussion should aid the staff's understanding of the information contained in this appendix. As shown by Table E-1 and indicated in the following pages, there are more than 50 Key Technical Uncertainties, of two types, that are distributed among 21 individual review plans, that have been initially identified. In listing the Key Technical Uncertainties, this summary shows their distribution and frequency within LARP chapters/sections, and association between the Key Technical Uncertainty and the type of review strategy (defined in Appendix B) contemplated by the staff.

As shown in Table E-1, more than half of the Key Technical Uncertainties identified in the LARP are of the *Detailed Safety Review Supported by Analyses* type. As noted in Appendix B, this type of review is an expansion or extension of the *Safety Review* to be conducted for some individual review plans; it is a detailed review of the adequacy of selected detailed information supporting the compliance demonstration. By contract, Table E-1 shows that there are the *Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations* types of Key Technical Uncertainties. This type of review further supports the detailed *Safety Review* with either analyses, tests (laboratory or field), or other investigation conducted by the staff or by using methods (e.g., numerical modeling) independently developed by the staff. Although there are fewer of this particular type of Key Technical Uncertainty, this review type is considered to require higher priority in the license application review, because the associated class of technical uncertainties is qualitatively judged to be the most difficult to consider in licensing.

Table E-1. Distribution of Key Technical Uncertainties in LARP by Type

LARP Chapter/ Section	*Title*	*Key Technical Uncertainties*[1]		*Type of Review Strategy*	
		Number	*Repeated*	*Detailed Safety Review Supported by Analyses*	*Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations*
3.	The Natural Systems of the Geologic Setting:	41	63	24	17
3.2	Siting Criteria:	39	59	24	15
3.2.1.X	Geologic System	11	12	4	7
3.2.2.X	Hydrologic System	14	31	9	5
3.2.3.X	Geochemical System	14	15	11	3
3.2.4.X	Climatological and Meteorological System	0	1	--	--
3.3	Assessment of Compliance with Groundwater Travel Time Performance Objective	2	4	--	2
4.	Geologic Repository Operations Area	5	8	5	--
5.	Engineered Barrier Systems	7	19	6	1
6.	Overall System Performance Assessment	5	8	3	2
	Totals	**58**	**98**	**38**	**20**

[1] This column shows both the *number* of Key Technical Uncertainties unique to a LARP chapter/section, as well as the frequency with which some Key Technical Uncertainties are *repeated* within a LARP chapter/section.

Review Plan 3.2.1.5 — Potentially Adverse conditions: Structural Deformation

Poor Resolution of Exploration Techniques to Detect and Evaluate Structural Features

Detailed Safety Review Supported by Analyses

Rock type, surficial geologic conditions, and the structural complexity at the Yucca Mountain site may result in low resolution imagery and inadequate data being acquired from standard geophysical techniques. For example, standard reflection and refraction seismic techniques may produce poor records of the subsurface because of dispersion and shallow refraction of induced (downgoing) energy. Energy transmission through the faulted volcanic rock units may thus be insufficient to obtain a return signal with acceptable amplitude and frequency spectra. As a result, interpretation of the data records and modeling of fault geometry are, accordingly, less constrained. Certain types of critical structural features, such as low-angle detachment faults, may be difficult to detect even using standard geophysical methods.

The projected depth (>3 km) of critical structural features such as detachment surfaces makes sampling through drilling impractical, except in a limited number of cases. In addition, as most major faults at Yucca Mountain, have dips greater than 50 degrees westward near the surface, standard vertical drilling may miss these features unless the boreholes are carefully, or fortuitously, located. The Key Technical Uncertainty associated with the use of available geophysical exploration methods is that determining the presence or absence of certain structural features may be severely hampered, such that important features could be present but undetected. Yet, geophysical imaging remains the primary method of studying faults in the deep subsurface. Therefore, understanding the process of structural deformation, and the extent and style of resultant structural geologic features has a degree of uncertainty that is very difficult to quantify.

Evaluation of Fault Mechanisms in Alluvium

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Several recent publications have noted the limitations of trenching as a mechanism for evaluation of fault activity, particularly for interpreting recency of fault displacement and inferring fault recurrence intervals. Much of the problem appears related to complex transmission of tectonic stresses through unconsolidated deposits.

The Key Technical Uncertainty associated with faulting mechanisms in alluvium is considered to involve a Detailed Safety Review Supported by Independent Tests, or Other Investigations, because it introduces significant uncertainty regarding determination of structural deformation features that may be present, but undetected, and consequent investigation and evaluation of these features. High-priority research that is currently in progress is addressing this Key Technical Uncertainty. Depending on results of this research, the level of review necessary for this uncertainty may change.

Development and Use of Conceptual Tectonic Models as Related to Structural Deformation

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Geologic data at Yucca Mountain are, and will most likely remain, permissive for development of multiple geologic models for describing the presence and origin of tectonic features. Models currently in use range from those with minor variations to those that are incompatible and produce results that are mutually exclusive. The Key Technical Uncertainty associated with conceptual models is considered to involve a Detailed Safety Review Supported by Independent Tests, or Other Investigations, because various plausible models introduce considerable uncertainty regarding the validity of the model selected for analysis and investigation.

Review Plan 3.2.1.7 — Potentially Adverse Conditions: Correlation of Earthquakes with Tectonic Processes

Inability to Predict the Likelihood of Earthquake Occurrence during the Next 10,000 Years

Detailed Safety Review Supported by Analyses

Because of the complexity of tectonic processes, the lack of knowledge about how the different tectonic processes behave in the Yucca Mountain area, and the short timeframe of collected historical and instrumental earthquake data at Yucca Mountain, it will be difficult to predict the recurrence rate of seismic activity at the site. Existing earthquake data for the site can be used for predictions over the short timeframe (i.e., up to 100 years). However, for extrapolations of up to 10,000 years, as required by 10 CFR Part 60, there will be a large band of uncertainty that may be difficult to quantify.

Correlation of Earthquakes with Tectonic Features

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Understanding the relationship between seismic activity (earthquakes) and tectonic features for the Basin and Range Province has been and is still the subject of significant uncertainty. The choice of a conceptual tectonic model can have a significant effect on the interpretation of the seismic hazard assumed to affect the geologic repository. For example, in seismic hazard analysis, where seismic source zones are defined based on a correlation between seismic activity and specific structural features, a lack of correlation will lead to large uncertainty in the analysis of the hazard. The choice of one or more conceptual tectonic models could cause changes in the results of the seismic hazard calculations including whether earthquakes are more frequent or are of higher magnitude than is typical of the area if the geologic setting, over a 10,000 year period. Because of this large range in permissible models, and the associated uncertainty, this Key Technical Uncertainty is considered to involve a *Detailed Safety Review Supported by Independent Tests, or Other Investigations* type of review.

Review Plan 3.2.1.8 — Potentially Adverse Conditions: Occurrence of More-Frequent/Higher-Magnitude Earthquakes

Inability to Predict the Likelihood of Earthquake Occurrence during the Next 10,000 Years

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.1.7.

Migrating Seismicity Between Fault Systems in the Basin and Range Tectonic Province

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Analysis of available paleofaulting data indicates that seismic activity has migrated randomly from one range front fault system to another, in the Basin and Range tectonic province. The data imply that faults which are long enough to support a magnitude 7 earthquake are subject to this phenomenon. Yucca Mountain lies at the intersection of northwest-southeast and north-south trending major lineations. Several faults in the vicinity are estimated as capable of supporting a magnitude 7 or greater earthquake. Without additional analysis, at least the most frequent and highest magnitude earthquakes observed in the Basin and Range tectonic province must be assumed possible, over a 10,000-year period, at the site. Because of the relatively short historical record of seismicity, it is not possible to prove, without additional paleofault-offset data and analysis of seismicity to tectonic structure relationships, that more frequent or higher-magnitude earthquakes than are typical of the area of the geologic setting will not occur at Yucca Mountain within a 10,000-year time period. Further,

there may not be sufficient data available to make an adequate analysis. It is possible that a better understanding of tectonics may result in a rationale that would limit future seismic activity to a lesser degree than the highest level possible in the Basin and Range tectonic province.

Uncertainty in Fault Plane Solutions

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Neither the nature of earthquakes nor the stress systems in which they occur are well understood in the Yucca Mountain region. Many fault plane solutions from the historical seismic record do not agree with the fault movement indicated by striae (slickensides) on exposed fault planes; therefore fault movement, earthquake strong motions and their radiation patterns, which will be used in tectonic models, are uncertain. Accordingly, there may be substantial uncertainty concerning variations in seismic activity now and estimations for a 10,000 year period in the future.

Correlation of Earthquakes with Tectonic Features

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Listed previously in Review Plan 3.2.1.7.

Review Plan 3.2.1.9 — Potentially Adverse Conditions: Evidence of Igneous Activity

Low Resolution of Exploration Techniques to Detect and Evaluate Igneous Features

Detailed Safety Review Supported by Analyses

Geologic conditions at the Yucca Mountain site render low resolution results from most geophysical techniques. For example, standard reflection and refraction techniques may produce poor records of the subsurface in the Yucca Mountain region because of problems related to transmission of sufficient energy through the rock units. Teleseismic tomographic techniques, such as those used by Evans and Smith, have resolution capabilities on the order of kilometers. In addition, if dikes are assumed to be the prevalent igneous feature in the region, the fact that they are commonly vertical makes them difficult to detect in the subsurface using standard vertical drilling techniques.

Because many features which are presumed to bear a relationship to magmatic processes are deep-seated and cannot be sampled directly, the use of exploration techniques is required for their investigation. One example of such a feature is the low velocity feature described by Evans and Smith which underlies Crater Flat at lower crustal depths, for which they suggest one possible interpretation as a zone of partial (basaltic) melt beneath Crater Flat. Clearly, such features can be evaluated only through indirect measurements and development of alternative interpretations. In addition, many properties (e.g., heat flow) are known to bear a relationship to volcanic and magmatic processes, but the exact nature of the relationship is poorly understood at present. Consequently, processes, features, and characteristics related to igneous activity possesses a degree of uncertainty in adequately understanding them which can be very difficult to quantify.

Inability to Sample Igneous Features

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Many features related to volcanic/magmatic activity cannot be directly sampled. This Key Technical Uncertainty stems from the fact that many features determined from low-resolution geophysical techniques cannot be sampled, so that considerable judgment will be required in interpretation of anomalies detected by geophysical methods.

For example, the low-velocity feature in the lower crust-upper mantle, interpreted by Evans and Smith as a possible zone of partial melt and the potential source for basaltic volcanism in Crater Flat, is known only from imaging by teleseismic tomography. Although Evans and Smith favor this interpretation, they are careful to point out that this low velocity zone

may be interpreted in other ways as well. Another example is seen in data discussed by Brocher et al., which indicate a seismic "bright spot" in the lower crust beneath the Amargosa Desert at a location south of Yucca Mountain. This high-amplitude reflection may be interpreted, by analogy with records from other locations, as reflections from thin, discontinuous magma chambers. Brocher et al. are also careful to indicate that other interpretations of their data are both possible and reasonable. In addition, other variables (e.g., magma temperature and volatile content) can be constrained only through detailed studies of past eruptions. It may be determined that Key Technical Uncertainties also exist in relation to adequacy of age-dating techniques for accurately representing temporal distribution of volcanic/magmatic events.

Development and Use of Conceptual Tectonic Models as Related to Igneous Activity
Detailed Safety Review Supported by Independent Tests, or Other Investigations

The geologic data at Yucca Mountain are, and will most likely remain, permissive for the development of multiple geologic models to describe the presence and origin of many volcanic/magmatic and tectonic features. The choice of a conceptual geologic model can have a significant effect on interpretation of the hazards which may affect the repository. For example, currently available models include one assuming a northwest-trending controlling structural feature, and another assuming a north-northeast controlling structural feature. These two models can be viewed as mutually exclusive, although existing data can be used to support either model. While it may be possible to determine a preferred model, the staff recommends that neither of the two be eliminated from consideration at the present time. The choice of one could strongly affect the results of performance calculations for assessing potential volcanic hazards in the vicinity of Yucca Mountain. Because of the range in permissible models and the associated uncertainties, this Key Technical Uncertainty is considered to involve a *Detailed Safety Review Supported by Independent Tests, or Other Investigations* type of review.

Review Plan 3.2.2.6 — Potentially Adverse Conditions: Human Activity Affecting Groundwater

Adverse Effects of Future Groundwater Withdrawals on the Groundwater Flow System
Detailed Safety Review Supported by Analyses

It is impractical to predict the locations and extent of future groundwater withdrawals that may adversely affect the saturated leg of the groundwater flow system in the controlled area.

Review Plan 3.2.2.8 — Potentially Adverse Conditions: Structural Deformation and Groundwater

Understanding the Cause of the Large Hydraulic Gradient Located North of Yucca Mountain, and Potential for Tectonic Disruption of Fault-Related Barriers
Detailed Safety Review Supported by Analyses

The cause of the large hydraulic gradient located north of Yucca Mountain is unknown. Whatever geologic feature causes the high gradient appears to function as a groundwater barrier. This causes hydraulic heads in the saturated zone north of Yucca Mountain to be much higher than those underlying the site. At Yucca Mountain, the water table occurs at depths of about 150 to 360 m below the proposed underground facility.

Review Plan 3.2.2.9 — Potentially Adverse Conditions: Changes in Hydrologic Conditions

Adverse Effects of Future Groundwater Withdrawals on the Groundwater Flow System

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.6.

Understanding the Cause of the Large Hydraulic Gradient Located North of Yucca Mountain, and Potential for Tectonic Disruption of Fault-Related Barriers

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.8.

Modeling Groundwater Flow through Unsaturated Fractured Rock Caused by the Lack of Codes Tested against Field and Laboratory Data

Detailed Safety Review Supported by Analyses

Demonstration of compliance with this regulatory requirement topic will require quantitative prediction of the potential for future perched water bodies to form or to provide a faster flow path from an underground facility to the accessible environment. Computational models will be the primary methods used to estimate the likelihood of perched water bodies forming in the unsaturated zone. This is because the conditions that trigger fracture flow and the rate of flow when it does occur have a big effect on the potential for perched water bodies to form.

There are currently three approaches to modeling unsaturated fractured rock flow. These approaches are the equivalent continuum model of Klavetter and Peters, the dual continuum approach, and models that directly incorporate discrete fractures. However, these approaches were theoretically developed and need to be tested against laboratory or field experiments to build confidence. No experimental methods currently available allow the composite continuum model to be verified.

Identifying Which Conceptual Models Adequately Represent Isothermal and Nonisothermal Liquid and Vapor Phase Movement of Water through Unsaturated Fractured Rock at Yucca Mountain

Detailed Safety Review Supported by Analyses

To address this regulatory requirement topic, predictions will be made through the use of computational models that are based on conceptual and mathematical models of the dominant physical-chemical mechanisms. These conceptual models will also be used to decide what site characterization parameters should be obtained, to design the characterization program, to interpret data from the tests, to interpret the distribution of site characterization parameters, to assign model inputs, and to interpret model results. Any uncertainty in the appropriateness of the conceptual models will, therefore, reduce the reliability of model predictions, as well as the adequacy of that portion of the site characterization program designed to address this regulatory requirement topic.

Uncertainties Associated with Determining Characterization Parameters in the Unsaturated Zone

Detailed Safety Review Supported by Analyses

To address this regulatory requirement topic, predictions will be made that are based on the values of numerous characterization parameters. These parameters will contain uncertainties due to experimental and measurement error, errors in test interpretation, conceptual model errors, and errors from incorrectly defined parameter ranges and distributions.

Equal or Increased Capacity of Alteration Mineral Assemblages to Inhibit Radionuclide Migration

Detailed Safety Review Supported by Analyses

There is significant technical uncertainty associated with the determination of whether or not altered mineral assemblages will have an equal or increased capacity to inhibit radionuclide migration.

Predicting Precipitation and Temperature (Climate) at the Yucca Mountain Site for 10,000 years into the Future

Detailed Safety Review Supported by Analyses

There is considerable difficulty in predicting climatic variations (precipitation, temperature, etc.) over the next 10,000 years.

Developing a Conceptual Groundwater Flow Model That is Representative of the Yucca Mountain Site Groundwater Flow System

Detailed Safety Review Supported by Analyses

The focus of this Key Technical Uncertainty is the groundwater flow system of the site. A conceptual model of the Yucca Mountain site groundwater flow system will be based on descriptive information, much of which will be input to a mathematical model (i.e., governing equations embodied in a computer code) used to predict the pre-waste emplacement groundwater travel time (GWTT). There are limitations in the type and amount of descriptive information that can be obtained because only a portion of the total system can be characterized and because of limitations inherent in the current state of the art in testing technology.

Prediction of Future Changes to the Hydrologic System Resulting from a Combination of Climatic and Tectonic Changes and Human Activities (Including Heat Effects from Waste Emplacement)

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Future changes to the hydrologic system will result from a combination of three things: climate change, human activities, and tectonic modifications of the groundwater flow system. In order to evaluate the potential for adverse future changes in the groundwater flow system, it is necessary to have a starting point. The hydrologic conditions used to estimate groundwater travel time for the Yucca Mountain site will be considered the initial conditions for this analysis of future hydrologic conditions. Quaternary hydrologic trends identified in Section 3.2.2.1 of the License Application will also be used to evaluate initial conditions.

The staff believes that it may be very difficult to predict climatic variations (precipitation, temperature, etc.) over 10,000 years. This difficulty directly translates to difficulty in estimating recharge rates to the groundwater system.

The groundwater flow system may be modified, in the future, by tectonic processes. For example, the cause of the large hydraulic gradient north of Yucca Mountain is unknown, but is presently assumed to be of tectonic origin. Whatever geologic feature causes the high gradient appears to function as a groundwater barrier. This causes hydraulic heads in the saturated zone north of Yucca Mountain to be much higher than those underlying the site.
Human activities, especially groundwater withdrawals, influence the groundwater system today, and can be expected to have much greater impacts in the future. However, it is impractical to predict the locations and extent of future withdrawals that may adversely affect the saturated leg of the groundwater system in the controlled area.

The future effects of heat generated by emplaced high-level nuclear wastes (HLW) are expected to strongly influence flow conditions in the near-field unsaturated zone. It will be difficult to evaluate these heat effects in combination with the other

phenomena that will influence the future hydrologic system.

Experimental Confirmation of the Basic Physical Concepts of Groundwater Flow through Unsaturated Fractured Rock is Needed

Detailed Safety Review Supported by Independent Tests, or Other Investigations

To address this regulatory requirement topic, predictions will use models of groundwater flow through unsaturated fractured rock. The conditions that trigger fracture flow and the rate of flow when it occurs have a significant effect on the potential for perched water bodies to form.

All models are simplifications of basic governing physical laws of the process being modeled. If the basic concepts are incorrect, computational models based on these concepts may be inaccurate. To date, few experiments have been identified that rigorously test the concepts of unsaturated flow in fractured rock. This is supported by the Site Characterization Plan for Yucca Mountain, which states that "Theoretical models for liquid-water flow in single fractures have been developed but have not been field and laboratory tested." Therefore, models of groundwater flow through unsaturated rock may be inaccurate.

Development of New Data Collection and Interpretation Techniques are Required for Codes that Model Groundwater Flow through Unsaturated Fractured Rock

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Modeling groundwater flow through unsaturated fractured rock will be an important part of addressing this regulatory requirement topic. However, if appropriate methods to collect data for unsaturated fractured rock flow codes do not exist, it will not be possible to adequately characterize the site or to calibrate the models used to predict groundwater flow through the unsaturated zone.

Currently, unsaturated fractured rock flow models designed for use at Yucca Mountain require either individual or bulk fracture properties. Furthermore, these codes require data on how the hydraulic properties of the fractures change as a function of changing moisture contents. However, appropriate measurement techniques for collecting unsaturated fracture hydraulic property data have neither been developed nor identified. Particular computer codes may use unique parameters that require different data collection or parameter estimation techniques. For example, dual continuum approaches to modeling unsaturated groundwater flow consist of one continuum for the porous matrix and one continuum for the fractures. The continua are connected by a fracture matrix transfer term that simulates flow between the fracture and the matrix. However, the fracture-matrix transfer term is a parameter that cannot be measured in the field or laboratory at this time.

Modeling the Formation of Perched Zones by Thermally Driven Flow

Detailed Safety Review Supported by Independent Tests, or Other Investigations

It has been hypothesized that rock drying by heat generated by radioactive decay of the spent fuel may cause the formation of perched water zones. In this process water near waste canisters is vaporized and driven away from the repository (any direction, laterally or vertically), until it reaches an area where the rock temperature is cool enough to cause condensation. If the condensed water encounters a low permeability material, rock water saturations may increase and form a perched zone. Modeling nonisothermal liquid and vapor phase movement of water through unsaturated fractured rock is still an area of active research, and therefore standard approaches have not been established.

Developing a Mathematical Groundwater Flow Model That is Representative of the Yucca Mountain Site Groundwater Flow System

Detailed Safety Review Supported by Independent Tests, or Other Investigations

A mathematical model, in terms of one or more equations that represent an abstraction of the Yucca Mountain site groundwater flow system, is needed to predict the motion of groundwater and hence, to predict the effectiveness of the geologic setting as a barrier to the release of radionuclides in terms of calculated GWTT. This Key Technical Uncertainty covers three subtopics. These include: (1) the mathematical model(s) used to represent the conceptual model of the groundwater flow system; (2) the implementation of the mathematical model(s) as embodied in a computer code(s); and (3) the application of the computer code(s) for compliance calculations. Considered together, they define the integrated modeling strategy. Mathematical models, computer codes and their subsequent application for compliance calculations all contain elements of uncertainty.

Review Plan 3.2.2.12 — Potentially Adverse Conditions: Perched Water Bodies

Modeling Groundwater Flow through Unsaturated Fractured Rock Caused by the Lack of Codes Tested against Field and Laboratory Data

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.9.

Identifying Which Conceptual Models Adequately Represent Isothermal and Nonisothermal Liquid and Vapor Phase Movement of Water through Unsaturated Fractured Rock at Yucca Mountain

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.9.

Uncertainties Associated with Determining Characterization Parameters

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.9.

Experimental Confirmation of the Basic Physical Concepts of Groundwater Flow through Unsaturated Fractured Rock is Needed

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Listed previously in Review Plan 3.2.2.9.

Development of New Data Collection and Interpretation Techniques are Required for Codes that Model Groundwater Flow through Unsaturated Fractured Rock

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Listed previously in Review Plan 3.2.2.9.

Modeling the Formation of Perched Zones by Thermally Driven Flow
Detailed Safety Review Supported by Independent Tests, or Other Investigations

Listed previously in Review Plan 3.2.2.9.

Review Plan 3.2.3.2 — Favorable Conditions: Geochemical Conditions

Identifying Geochemical Conditions That Would Inhibit Particulate and Colloid Formation
Detailed Safety Review Supported by Analyses

Different processes could potentially contribute to the formation of particulates and colloids. Particulates and colloids can be produced by precipitation or condensation processes or by weathering or dispersion processes. These phases can be originally composed of radionuclides (termed radiocolloids) as, for example, particles from the spallation of waste form or Pu(IV) colloid. These phases can also be natural or manmade to which radionuclides sorb. When the phase is a colloid to which radionuclides sorb, the phase is often called a pseudocolloid. In addition to the processes described above, other processes not normally considered by geochemists can result in particulate formation. Nitsche et al. described for americium experiments how steady-state conditions were not attained because the soluble americium formed pseudocolloids together with Teflon particles that were dislodged from the container material by α-radiation. Given the various processes that could contribute to the formation of particulates and colloids, it is uncertain which geochemical conditions would inhibit formation of particulates and colloids that could increase radionuclide mobility.

Characterizing the Chemistry of the Groundwater in the Partially-Saturated Hydrologic Zone of Yucca Mountain, Nevada
Detailed Safety Review Supported by Analyses

Little information is available on the groundwater chemistry for the hydrologically partially-saturated zone of Yucca Mountain, Nevada. Although some efforts to extract aqueous solutions by triaxial compression ("high pressure") of rock samples taken from the partially-saturated zone of Yucca Mountain are underway, there are large variabilities in the chemical compositions of solutions derived using this technique. Aqueous samples have also been extracted from partially-saturated soils and sands by ultracentrifugation techniques. It is uncertain whether compositions of water extracted from rock pores by ultracentrifugation or by high-pressure "squeezing" techniques accurately represent the compositions of in-situ water. The compositions of in-situ water extracted in these manners are likely to be different due to several possible processes: (1) dilution of pore solutions by water desorbed from hydrated minerals like zeolites and clays; (2) dissolution reactions due to increased mineral solubility and/or higher carbon dioxide concentration at higher pressures; (3) membrane filtration by clays and zeolites; and (4) ion exchange with the zeolites and clays. In addition, colloids which may be present in pore waters are likely to be altered, destabilized, or filtered out of solution during the extraction process. No method is currently known to give unambiguous, accurate data on the chemistry of pore waters in partially-saturated crystalline rock.

Understanding the Effects of Degree of Saturation on Geochemical Processes Such as Radionuclide Sorption and Precipitation and Formation of Particulates and Colloids, and on the Transport of Radionuclides by Particulates, Colloids, and Complexes
Detailed Safety Review Supported by Analyses

The proposed repository is located in a hydrologically partially-saturated horizon underneath Yucca Mountain. However, it is uncertain how the degree of hydrologic saturation will affect sorption, precipitation, colloid formation, and transport of radionuclides by particulates, colloids, and complexes. All batch sorption experiments and most column sorption studies are conducted under conditions where the sorbing medium is fully saturated with water. It is not known if radionuclide sorption coefficients determined using fully-saturated experiments can be extrapolated to conditions of variable saturation. It is not clear whether undersaturated conditions will inhibit radionuclide migration more than fully-saturated conditions,

or whether they can actually enhance migration of certain radionuclides. It is not known what the effect of degree of saturation is on the formation of particulates and colloids, and on the transport of radionuclides by particulates, colloids, and complexes.

J. Wan from New Mexico Tech presented her work on the effect of hydrologically unsaturated conditions on colloid transport at the Yucca Mountain Site Characterization Project Colloid Workshop, May 3-5, 1993. It was noted in this presentation that hydrophilic colloids are preferentially sorbed at the gas/water interface, whereas hydrophobic colloids sorb at both the gas/water and solid/water interfaces.

Parametric Representation of Retardation Processes Involving Radionuclide-Bearing Particulates, Colloids, and Complexes

Detailed Safety Review Supported by Analyses

Performance assessment calculations typically use a single retardation factor (R_f) to represent the attenuation of radionuclide transport. This factor is frequently based on an experimentally measured sorption coefficient (K_d), which is assumed to represent equilibrium sorption/desorption processes alone. However, other processes may contribute to retardation, including diffusion, dispersion, and precipitation. Although using R_f simplifies transport calculations, it is empirical in nature and has no theoretical basis for extrapolation beyond the particular conditions of the initial experiments. It is well-known that sorption of radionuclides on rock and mineral substrates is influenced by the physical and chemical characteristics of the groundwater (e.g., pH, composition, temperature) and of the substrate (e.g., mineralogy, surface area, surface properties). R_f (K_d) tends to be assigned as a "property" of the medium. This does not accurately reflect the role of systematic chemical variations in determining the extent of retardation of radionuclide migration. The use of R_f also does not allow discrimination between the contributions of various processes involved in retardation. Therefore, it is not clear how quantitative representation of retardation processes can be undertaken.

Review Plan 3.2.3.3 — Favorable Conditions: Mineral Assemblages

Determining the Alteration of Mineral Assemblages due to Thermal Loading

Detailed Safety Review Supported by Analyses

Although various data and analyses indicate that mineral assemblages are likely to be altered due to thermal loading, the type and extent of alteration and the properties of the minerals in the alteration assemblage are uncertain.

Equal or Increased Capacity of Alteration Mineral Assemblages to Inhibit Radionuclide Migration

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.9.

Review Plan 3.2.3.4 — Potentially Adverse Conditions: Groundwater Conditions and the Engineered Barrier System

Understanding the Effect of Groundwater Conditions on Mode and Rate of Waste Package Corrosion

Detailed Safety Review Supported by Analyses

There is consensus within the technical community that groundwater conditions will have a major impact on the corrosion of waste packages. For example, Stahl and Miller present and discuss the potential corrosion modes enhanced by the geochemical conditions of the groundwater. Stephens et al. state that knowledge of the environmental conditions (e.g.,

temperature, chemical composition, redox potential, pH, etc.) will be needed to determine waste package corrosion. Similar arguments are offered by Glassley, Apted, Davis et al., O'Connell et al., and Walton et al., to name a few.

Although there is little controversy regarding the need to know the groundwater conditions to estimate waste package corrosion, there seems to be considerable uncertainty regarding the specific corrosion modes affected or enhanced. The belief is that the presence of groundwater will enhance localized corrosion (pitting corrosion, crevice corrosion, and stress corrosion cracking) as opposed to uniform corrosion. However, the manner in which the changing groundwater conditions will affect corrosion over the length of the regulatory period is largely unknown. If a corrosion model is based on average or typical groundwater chemistry for the repository region, there is the risk that the effect of specific and potentially significant corrosion modes could be underestimated or overlooked. Therefore, there is uncertainty associated with the effect that groundwater conditions will have on waste-package corrosion.

Understanding/Predicting the effect of Groundwater Conditions on Dissolution of Waste Form

Detailed Safety Review Supported by Analyses

Groundwater conditions, particularly chemical conditions, will play a major role on the dissolution of the waste form for both HLW and spent nuclear fuel. Releases of radionuclides from the waste form will be limited by the dissolution rate. However, the specific mechanisms by which groundwater conditions affect waste-form dissolution seem to be highly speculative.

For HLW, the chemistry of the groundwater in contact with the waste form is believed to be governed by the dissolution and/or precipitation of various primary and secondary solid phases that can form during the course of reaction. Some calculations suggest that formation of alteration phases in the waste matrix change the groundwater chemistry sufficiently to, in turn, change the solubility limits of the radionuclides.

For spent nuclear fuel, the situation seems to be more complex because spent fuel is composed of several different sources of radionuclides (e.g., UO_2 matrix, the cladding, the gap region between the fuel matrix and the cladding, and the grain boundaries), and each of these sources contains a different radionuclide inventory. Also, each of these sources of radionuclides is believed to react differently with groundwater. For some sources, the radionuclides will be highly soluble and the waste-form dissolution rate will be inventory-limited (e.g., cesium, iodine, and technetium), whereas for others, the radionuclides will not be readily soluble and the dissolution rate will be solubility-limited (e.g., actinides). In either case, the groundwater conditions will largely govern the dissolution rate. Two different dissolution mechanisms have been postulated for the UO_2 matrix: (1) solubility limit for reducing conditions; and (2) kinetic-controlled dissolution for oxidizing conditions as a result of the electrochemical nature of the dissolution reactions that are largely dictated by the chemical composition of the groundwater.

Results of laboratory studies suggest that reaction of the waste matrix with groundwater will result in an alteration of the matrix, and that such alteration will impact the rate of dissolution of the radionuclides. For example, conversion of UO_2 in spent nuclear fuel to U_3O_8, due to reactions with groundwater, can lead to the increased release of both actinides and fission products. The reaction rates are highly dependent on the redox potential of the groundwater.

Prediction of the Evolution of Groundwater Conditions near and within the EBS

Detailed Safety Review Supported by Independent Tests, or Other Investigations

There is a suite of phenomena and processes that can directly and indirectly affect and cause changes to the chemical and physical conditions of the groundwater at Yucca Mountain. For example, radiolysis, temperature, and chemical reactions with the host rock and the waste form could alter the concentration of chemical and ionic species, the pH, and the redox potential (Eh) of the groundwater. Also, the cyclic evaporation/condensation of groundwater in the vicinity of the waste package could affect the concentration of salts in that region. For example, one concept is that the concentration of salts, such as Na_2CO_3, NaCl, $NaNO_3$, and $CaCl_2$, might increase to the point where the vapor pressure of water in the film of liquid on the wall of the waste package is lowered sufficiently to reduce the rate of evaporation of the water. As the rate of evaporation of water decreases, more water is available to come in contact with the waste package, thus increasing the

likelihood of corrosion. However, the manner in which these phenomena and processes interact, and the temporal and spatial scales over which they occur are not known. Furthermore, establishing the scale at which the phenomena and processes take place relative to the scale of the engineered barrier system as well as the spatial variability is not readily possible. Prediction of the evolution of the geochemical environment, in general, and the groundwater conditions, in particular, in the vicinity of the waste package would be difficult.

Review Plan 3.2.3.5 — Potentially Adverse Conditions: Geochemical Processes

Identifying Geochemical Processes That Reduce Radionuclide "Retardation"

Detailed Safety Review Supported by Analyses

Identifying those geochemical processes whose contributions to the existence of this PAC are, respectively, likely, unlikely, or uncertain, can be used to assign the appropriate level of review. Those processes that are unlikely to contribute to the PAC are assumed to be unlikely to affect performance. Thus technical uncertainties with regard to those processes would not be "Key Technical Uncertainties."

Consequently, evaluation of those processes would be limited to a Safety Review. Processes whose contributions to the existence of the PAC are likely or uncertain may affect performance. The technical uncertainties associated with these processes would be "key" and require a Detailed Safety Review level of review or higher. Those processes that could affect performance but have no associated technical uncertainties will be considered in the Safety Review.

The geochemical processes whose contributions to the PAC are likely or uncertain are listed in Table E-2.

Table E-2 Geochemical Processes Potentially Reducing Radionuclide Retardation

precipitation	£	diffusion	£	volatilization	L
dissolution	£	dehydration	£	sorption	£
oxidation	L	anion exclusion	L	desorption	£
speciation	£	hydrolysis	£	solation	L
gelation	L	microbial	L	ion exchange	£
corrosion	£	processes		flocculation	L
catalysis	£	alteration	£		

L = process is considered likely to contribute to PAC

£ = process is considered likely to affect (i.e., contribute to or compensate for) the PAC

Identifying Geochemical Processes that Adversely Affect the Engineered Barrier System (EBS)

Detailed Safety Review Supported by Analyses

The identification of geochemical processes whose contributions to the existence of the PAC are, respectively, likely, unlikely, or uncertain, can be used to assign the appropriate level of review. Those processes that are unlikely to contribute to the PAC are assumed to be unlikely to affect performance. Thus technical uncertainties with regard to those processes would not be "key." Consequently, evaluation of those processes would be limited to a Safety Review. Processes whose contributions to the existence of the PAC are likely or uncertain may affect performance. The technical uncertainties associated with these processes would be "key" and require a Detailed Safety Review Supported by Analysis level of review or higher. Those processes that could affect performance but have no associated technical uncertainties will be considered in the Safety Review.

The geochemical processes whose contributions to the PAC are likely or uncertain are listed in Table E-3.

Table E-3 Geochemical Processes Potentially Adversely Affecting the Performance of the Engineered Barrier System

precipitation	L	diffusion	L	volatilization	L
dissolution	L	dehydration	L	nucleation	L
oxidation	L	anion exclusion	L	desorption	L
reduction	L	osmosis	L	speciation	L
hydrolysis	L	solation	L	radiolysis	L
crystallization	L	gelation	L	microbial processes	L
coprecipitation	L	evaporation	L	radioactive decay	L
condensation	L	ion exchange	£	alteration	L
metamictization	L	flocculation	L	catalysis	L
corrosion	L	expansion	L	contraction	L
filtration	L				

L = process is considered likely to contribute to PAC
£ = process is considered likely to affect (i.e., contribute to or compensate for) the PAC

Determining the Magnitude of the Effect of the Geochemical Processes that Reduce Radionuclide "Retardation"

Detailed Safety Review Supported by Independent Tests, or Other Investigations

The geochemical processes whose contribution to the PAC is likely or uncertain are listed in Table E-2.

The degree to which each of these processes can reduce radionuclide retardation depends on many factors. These factors include thermodynamic properties for solids and aqueous and gaseous species such as Gibbs free energy of formation from the elements, enthalpy of formation from the elements, and entropy. Also concentrations of chemical components, activity coefficients, rate constants, and conditions like temperature and pressure, and flow rates are required. As a further illustration of the large number of parameters necessary for characterizing processes, one need only consider the triple layer model for surface complexation (sorption), where seven adjustable parameters are required.

Performance assessment calculations typically use a single retardation factor (R_f) to represent the attenuation of radionuclide transport. This factor is frequently based on an experimentally measured sorption coefficient (K_d), which is assumed to represent equilibrium sorption/desorption processes alone. However, other processes may contribute to retardation, including diffusion, dispersion, and precipitation. Although using R_f simplifies transport calculations, it is empirical in nature and has no theoretical basis for extrapolation beyond the particular conditions of the initial experiments. It is well-known that sorption of radionuclides on rock and mineral substrates is influenced by the physical and chemical characteristics of the groundwater (e.g., pH, composition, temperature) and of the substrate (e.g., mineralogy, surface area, surface properties). R_f (K_d) tends to be assigned as a "property" of the medium. This does not accurately reflect the role of systematic chemical variations in determining the extent of retardation of radionuclide migration. The use of R_f also does not allow discrimination between the contributions of various processes involved in retardation. Therefore, it is not clear how quantitative representation of retardation processes can be undertaken using the R_f approach.

Determining the Magnitude of the Effect of the Geochemical Processes that Adversely Affect the EBS

Detailed Safety Review Supported by Independent Tests, or Other Investigations

The geochemical processes whose contributions to the PAC are likely or uncertain are listed in Table E-3.

These processes involve both radioactive and nonradioactive constituents of the repository, both manmade (or introduced) and indigenous. The range of conditions to be considered in demonstrating compliance with this PAC is more extensive than with the PAC on radionuclide retardation. Temperatures can vary up to 250°C, groundwaters could be as dilute as rainwater or as concentrated as brine. Geochemical modeling that will be used to demonstrate compliance with this regulatory requirement involves the simultaneous solution of linear and nonlinear equations representing mass balance and mass action, respectively, of the chemical components. The large number of components, processes, and conditions expected at the site precludes quantitative characterization of all possible (and expected) combinations of these parameters.

The degree to which each of these processes can adversely affect the performance of the EBS depends on many factors. These factors include thermodynamic properties for solids and aqueous and gaseous species such as Gibbs free energy of formation from the elements, enthalpy of formation from the elements, and entropy. Also, concentrations of chemical components, activity coefficients, rate constants, and conditions like temperature and pressure and flow rates are required.

Review Plan 3.2.3.7 — Potentially Adverse Conditions: Gaseous Radionuclide Movement

Volatility and Stability of Chemical Species of Radionuclides

Detailed Safety Review Supported by Analyses

Gaseous transport of radionuclides can occur only if the nuclides exist in volatile chemical species. $^{14}CO_2$ is widely recognized as a likely predominant volatile radionuclide species derived from nuclear waste, and carbon dioxide chemistry is generally well understood. However, uncertainty exists with regard to the volatility and stability of other potential ^{14}C bearing species such as $^{14}CH_4$. Additional uncertainty exists with regard to the volatility and stability of other potential radionuclide carrying species including SeO_2, I_2 and Tc_2O_7. Because the PAC of the potential for gaseous transport of radionuclides clearly exists at Yucca Mountain, a Detailed Review will be required to evaluate uncertainties with regard to the volatility and stability of chemical species of radionuclides. This review will require independent analyses using existing data for environmental conditions projected for the Yucca Mountain repository and for the chemical stability and volatility of potentially volatile radionuclide species.

Gas Flow and Gaseous Radionuclide Transport

Detailed Safety Review Supported by Analyses

Transport occurs in the gas phase by advection and diffusion. Large uncertainties exist in predicting gas flow because of the complexity of two-phase nonisothermal flow and the heterogeneity of the system. Nevertheless, conservative assessments must include significant gas flow from the repository horizon to the accessible environment at the surface of the earth throughout the period of regulatory concern. Intrinsic gas phase diffusion coefficients are relatively well known, but tortuosity, gas-filled porosity, gas conductivity, and mechanical dispersion effects are uncertain. Distribution of carbon and other volatile species among solids, solid surfaces, liquid, and gas can be estimated only approximately. The chemistry of the aqueous phase will remain uncertain, and sorption of carbon and other potential species on mineral surfaces has been poorly studied.

The magnitudes and heterogeneity of post-emplacement gas flow is unlikely to be well characterized before waste emplacement. For these reasons, there will be significant uncertainty in any calculation of gas flow and transport. This

uncertainty will require a detailed review, especially of hydrologic properties and independent analyses using existing computer models.

Review Plan 3.2.4.2 — Potentially Adverse Conditions: Changes to Hydrologic System from Climate

Predicting Precipitation and Temperature (Climate) at the Yucca Mountain Site for 10,000 years into the Future

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.9.

Review Plan 3.3 — Assessment of Compliance with the Groundwater Travel Time Performance Objective

Developing a Conceptual Groundwater Flow Model That is Representative of the Yucca Mountain Site Groundwater Flow System

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 3.2.2.9.

Developing a Mathematical Groundwater Flow Model That is Representative of the Yucca Mountain Site Groundwater Flow System

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Listed previously in Review Plan 3.2.2.9.

Determining the Fastest Path of Likely Radionuclide Travel from the Disturbed Zone to the Accessible Environment

Detailed Safety Review Supported by Independent Tests, or Other Investigations

The performance objective for the geologic setting specifies that 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 1,000 years or such other travel time as may be approved or specified by the Commission. The staff believes that the fastest path of likely radionuclide travel cannot be determined, in an absolute sense, given the state of the knowledge of interactions in hydrogeologic systems.

Determining the Extent of the Disturbed Zone

Detailed Safety Review Supported by Independent Tests, or Other Investigations

The disturbed zone is defined as that portion of the controlled area the physical or chemical properties of which have been changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository (10 CFR 60.2). Determining the extent of the disturbed zone, as defined in the current rule, is enigmatic. The staff believes that determining the extent of the disturbed zone requires establishing quantitative limits, unspecified in the rule, for some properties of the geologic setting, also unspecified in the rule, wherein any construction- or heat-induced changes in those properties beyond those limits would have a significant effect on the performance of the geologic repository. The staff assumes that the phrase "significant effect on the performance of the geologic repository" refers to effects on the

geologic setting that significantly alter performance of the geologic repository in a negative way (e.g., reducing GWTT thereby concomitantly increasing the cumulative release of radionuclides to the accessible environment from the geologic repository; a geologic repository is defined in 10 CFR 60.2 as a system used for disposal of radioactive wastes in excavated geologic media).

Review Plan 4.3 — Assessment of Compliance with Design Criteria for Shafts and Ramps

Predicting the Long-Term Performance of Seals for Shafts, Ramps, and Boreholes

Detailed Safety Review Supported by Analyses

Review of the post-closure portion of the design for shafts, ramps, and boreholes in 10 CFR 60.134 demands consideration of the performance of seals (and backfill materials), and an evaluation of the impact of repository-generated thermal loads and repeated seismic loads on the long-term performance of these repository features. For example, in order to have confidence in applying current sealing technology to the repository environment, two technical uncertainties relevant to the effectiveness and performance of seals remain to be resolved. These uncertainties are: (1) whether the seals will remain effective over thousands of years (i.e., seal long-term performance); and (2) whether technology exists to effectively install seals such that the intended performance of seals can be achieved. There is little experience regarding long-term performance of seals. Although available observations of the performance of some seal materials (for example, low permeability cements) seem to indicate that these components may have great durability, it is also uncertain what impact thermal loads and repeated seismic loads will have on their performance. Also, other observations about deterioration of high-quality cement grouts in dam foundations within a decade after installation seem to indicate otherwise. Considerable uncertainty exists regarding the installation of seals in the underground excavations. This is especially true regarding the determination of optimum grouting conditions and preferable grouting pressures to seal fractures around the excavations due to construction. It is uncertain how to prevent the fractured zone around the excavations from becoming dominant bypass flow paths around the seals and thereby negating the effectiveness of the seals.

It should be noted that this Key Technical Uncertainty could be sub-divided into two more specific technical uncertainties: (1) prediction of thermal-mechanical effects on the performance of seals, including the surrounding rock mass; and (2) prediction of thermal-hydrological effects on the chemical properties of the seal materials.

Prediction of the Thermal-Mechanical-Hydrological-Chemical Responses of the Host Rock, Surrounding Strata, and Groundwater System to Thermal Loads

Detailed Safety Review Supported by Analyses

Section 60.133(i) requires that the underground facility for the geologic repository operations area (GROA) be designed so that the performance objectives will be met, taking into account the predicted thermal and thermomechanical responses of the host rock, surrounding strata, and groundwater system. The rule thus recognizes that an understanding of thermal loads caused by the emplacement of nuclear wastes, and the corresponding thermomechanical response is essential to the design of the underground facility. One must also understand the uncertainties associated with predicting the thermal loading and corresponding rock and groundwater responses, so that these uncertainties can be accommodated by the GROA shafts, ramps, and boreholes design. Many aspects of the GROA design, including, for shafts, ramps, and boreholes, the opening configurations, dimensions, and support requirements, may depend on predictions of heat transfer, and thermally-induced responses such as rock deformations, groundwater flow (both liquid- and vapor-phase transport), and the dissolution and precipitation of mineral species.

The emplacement of spent nuclear fuel underground will generate heat and result in the expansion of the rock mass, produce thermal stresses, and cause potential normal and shear displacements of fractures, which could affect the performance of shafts, ramps, and boreholes. For example, Kemeny and Cook have reported that, in the worst-case scenario, approximately 38 percent of the waste emplacement boreholes may fail as the repository heats up. Rock failure inside waste emplacement boreholes may cause waste package degradation. Although the ramps may be sufficiently far

away from the thermal pulse, the lower portions of any additional shafts or boreholes within the repository block will likely be subjected to high thermal stresses. The long-term thermomechanical response of the host rock and surrounding strata over the lifetime of the repository is difficult to predict and thus difficult to account for in the design of the facility.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following two more specific technical uncertainties: (1) prediction of thermomechanical (including seismic load) effects on drifts and emplacement boreholes for retrievability; and (2) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes, to provide input for waste package design and performance assessments.

Demonstration of Compliance with the Requirement to Maintain the Ability to Safely Retrieve HLW

Detailed Safety Review Supported by Analyses

The U.S. Department of Energy (DOE) is required to provide a plan that describes how HLW can be safely retrieved and stored. Retrieval of waste package canisters on a mass scale from an underground repository has never been attempted or accomplished anywhere. Also, the U.S. program is the only waste management program considering retrieval; thus the U.S. HLW program participants cannot learn from the experience of others. This lack of experience makes retrieval a riskier activity than an activity for which there is experience. The uncertain nature of retrieval is acknowledged in the Statement of Considerations for 10 CFR Part 60, in which it is said, "...the Commission recognizes that any actual retrieval operation would be an unusual event and may be an involved and expensive operation." Although the retrieval plan will probably have undergone Detailed Safety Review Supported by Analysis by the DOE, NRC should still perform a detailed review with independent analyses to determine that health and safety will not be adversely affected by what will probably be a largely unproven retrieval system.

Another aspect of this Key Technical Uncertainty is that DOE will have only limited test results available to convince the NRC staff at the time of license application of its ability to retrieve any or all of the inventory of waste. The future conditions during which retrieval would take place, and upon which the retrieval plan is based, will themselves be based on model predictions. Such predictions are bound to have uncertainties, some of which will probably be significant. Examples of uncertain predictions include the effects of coupled thermal-mechanical-hydrological-chemical processes on the waste package, rock, and rock support; the effects of heating on material properties; and the effects of heating and then cooling on strengths and material properties.

In addition to the predictive uncertainties, there will be uncertainties regarding the conduct of the retrieval operation itself. Examples of operational uncertainties include how the possible presence of leaking waste canisters would affect worker health and safety, the ability to cool the repository, and the ability to safely store contaminated material, particularly if large amounts of backfill and/or rock are contaminated. There will likely be uncertainties regarding the conduct of the retrieval operation, which would result in uncertainties regarding the radioactive doses that workers, and even the public, may receive. Because the retrieval operations might rely upon or be affected by the shafts and ramps of the GROA, the uncertainty about retrievability creates uncertainty regarding the design of the shafts and ramps.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following two more specific technical uncertainties: (1) prediction of thermal-mechanical effects on drifts and emplacement boreholes for retrievability; and (2) the lack of experience with retrieval operations.

Review Plan 4.4 — Assessment of Compliance with Design Criteria for the Underground Facility

Prediction of the Thermal-Mechanical-Hydrological-Chemical (T-M-H-C) Response of the Host Rock, Surrounding Strata, and Groundwater System to Thermal Loads

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 4.3.

Demonstration of Compliance with the Requirement to Maintain the Ability to Safely Retrieve HLW

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 4.3.

Predicting the Long-term Performance of Seals for the Underground Test Boreholes

Detailed Safety Review Supported by Analyses

There will be test boreholes drilled from the underground facility for site characterization and performance confirmation tests. These test boreholes need to be sealed after the tests are completed. Review of the design of the post-closure portion of underground test boreholes (10 CFR 60.134) demands consideration of the performance of seals (and backfill materials), and an evaluation of the impact of repository-generated thermal loads and repeated seismic loads on the long-term performance of these repository features. For example, to have confidence in applying current sealing technology to the repository environment, two technical uncertainties relevant to the effectiveness and performance of seals remain to be resolved. These uncertainties are: (1) whether the seals will remain effective over thousands of years (i.e., seal long-term performance); and (2) whether technology exists to effectively install seals such that the intended performance of seals can be achieved.

There is little experience regarding long-term performance of seals. Some available observations of the performance of some seal materials (for example, low-permeability cements) seem to indicate that these components may have great durability. However, other observations about deterioration of high-quality cement grouts in dam foundations within a decade after installation seem to indicate otherwise. It remains uncertain what impact thermal loads and repeated seismic loads will have on their performance. Considerable uncertainty exists regarding the installation of seals in underground excavations. This is especially true regarding the determination of optimum grouting conditions and preferable grouting pressures to seal fractures around the excavations due to construction. It is uncertain how to prevent the fractured zone around the excavations from becoming dominant bypass flow paths around the seals and thereby negating the effectiveness of the seals.

The issue of postclosure seals in an unsaturated medium is discussed in the NRC staff "Technical Position on Postclosure Seals, Barriers, and Drainage System in an Unsaturated Medium." This Staff Technical Position (STP) offers guidance to DOE on sealing and drainage concepts for a geologic repository in an unsaturated medium. If DOE chooses a methodology different from that in the STP, the reviewer should assess if the alternative methodology considers sealing in a manner that is not likely to underestimate the unfavorable aspects of seal performance or overestimate the favorable aspects of seal performance.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following two more specific technical uncertainties: (1) prediction of thermal-mechanical effects on the performance of seals, including the surrounding rock mass; and (2) prediction of thermal-hydrological effects on the chemical properties of the seal materials. Such detailed considerations of the Key Technical Uncertainty will be examined in Section 4.3 of the License Application.

Review Plan 4.5.2 — Assessment of Integrated GROA Compliance with the Performance Objectives: Retrievability of Waste

Demonstration of Compliance with the Requirement to Maintain the Ability to Safely Retrieve HLW

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 4.3.

Prediction of the Thermal, Mechanical, and Hydrological Impact on the Host Rock Surrounding the Waste Package

Detailed Safety Review Supported by Analyses

Section 60.133(i) requires that the underground facility for the GROA be designed so that the performance objectives will be met, taking into account the predicted thermal and thermomechanical responses of the host rock, surrounding strata, and groundwater system. One performance objective is that in 10 CFR 60.111(b), concerning the ability to retrieve waste. The rule thus recognizes that an understanding of thermal loads caused by the emplacement of nuclear wastes, and the corresponding thermomechanical response is essential to the design of the underground facility. One must also understand the uncertainties associated with predicting the thermal loading and corresponding rock and groundwater responses, so that these uncertainties can be accommodated by the GROA design or retrieval plans. Many aspects of the GROA design, including waste package canister spacing, opening configurations and dimensions, and support requirements, depend on predictions of heat transfer, and thermally-induced responses such as rock deformations, groundwater flow (both liquid- and vapor-phase transport), and the dissolution and precipitation of mineral species.

The emplacement of spent nuclear fuel underground will generate heat and result in the expansion of the rock mass, produce thermal stresses, and cause potential normal and shear displacements of fractures. Kemeny and Cook have reported that, in the worst-case scenario, some waste emplacement boreholes may fail as the repository heats up. Rock failure inside waste emplacement boreholes may cause waste package degradation. The long-term thermomechanical response of the host rock and surrounding strata over the lifetime of the repository is very difficult to predict and thus difficult to account for in the design of the facility.

It should be noted that this Key Technical Uncertainty could be sub-divided into the following three more specific technical uncertainties: (1) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes to provide input for waste package design; (2) prediction of thermal-mechanical-hydrological effects on emplacement drifts and emplacement boreholes to provide input for performance assessments; and (3) extrapolation of short-term laboratory and field test results to predict long-term thermal-mechanical-hydrologic effects.

Review Plan 5.2 — Assessment of Compliance with the Design Criteria for the Waste Package and its Components

Prediction of Thermomechanical Effects on the Waste Package and the EBS

Detailed Safety Review Supported by Analyses

Heat from emplaced waste packages will induce mechanical stresses in the waste package, the emplacement borehole, backfill, and other features of the underground facility. These thermomechanical stresses may result in the degradation of repository host rock, backfill, or EBS components. Stresses may also be induced by impingement of repository materials on the waste package. It will be difficult to quantify these stresses and even more difficult to predict the resultant consequences. The heat released will also result in elevated temperatures of the waste package material and other EBS

components for hundreds to thousands of years. These elevated temperatures may result in transformations of metallic phases or other unexpected behavior of the waste package material or other EBS components.

Prediction of Environmental Effects on the Waste Package and the EBS
Detailed Safety Review Supported by Analyses)

The environment of the waste package and the EBS is expected to change with time. Methodologies for predicting the changing environment are not currently available to the extent necessary to predict effects on long-term performance of the waste package or the EBS.

To predict the long-term performance of waste packages for containment and the EBS for gradual release, it will be necessary to understand the waste package and EBS environments at the time of emplacement, as well as changes in the environments with time. The areas most likely to contribute to uncertainty in service life prediction are: (1) geochemistry (water chemistry, pH, Eh, rock chemistry, and trapped, dissolved, or circulating gases); (2) radiation and radiolysis; (3) microbial effects; and (4) synergistic effects.

In addition to the above, there are other environmental concerns that may influence the response of the waste packages and EBS. These concerns fall broadly into the following classifications: (1) hydrology and climatology; (2) geology; (3) tectonics (including repeated dynamic motions); and (4) waste package internal corrosion.

There is also high risk that some significant degradation modes due to environmental effects will not be identified or will be erroneously deemed insignificant or incredible.

Prediction of Criticality Events in Waste Packages
Detailed Safety Review Supported by Analyses

There is considerable uncertainty about the long-term performance of the criticality control measures that will be incorporated into the waste package. The criticality control materials now used in spent fuel transportation casks or storage racks have only been demonstrated to be effective over relatively short periods of time. The staff is concerned that, subsequent to the period of waste package containment, the criticality control structure and features of the waste package design will degrade before the spent fuel assemblies lose their integrity and structure. This would leave the affected waste packages vulnerable to a criticality event and concomitant loss of waste package integrity and release of radionuclides.

Prediction of Release Path Parameters (such as the Size, Shape, and Distribution of Penetrations of Waste Packages) due to Thermomechanical, Environmental, or Criticality Effects
Detailed Safety Review Supported by Analyses)

For any particular waste package degradation mode, it will be difficult to accurately predict release path parameters (such as the size, shape, and distribution of the resulting waste package penetrations) as functions of time and simplifying assumptions will probably be required.

Prediction of the Releases of Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period
Detailed Safety Review Supported by Analyses)

Large uncertainties exist in estimating the quantities of gaseous radionuclides that may be generated from the waste forms and that would be released from penetrated waste packages. It is also uncertain whether, for gaseous radionuclides, the regulatory requirements regarding containment (10 CFR 60.113(a)(1)(ii)(A)) and gradual release (10 CFR 60.113(a)(1)(ii)(B)) are attainable.

Prediction of the Releases of Non-Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period

Detailed Safety Review Supported by Analyses

Two significant mechanisms for the release of non-gaseous radionuclides from penetrated waste packages and the EBS will be: (1) diffusion; and (2) convective transport by air or water. Estimating the diffusion of radionuclides from a penetrated waste package or from the EBS will likely be difficult and require the use of simplifying assumptions of uncertain accuracy. Estimating the flow rate of air or water through the waste package or the EBS will also likely be difficult and require the use of simplifying assumptions of uncertain accuracy. Furthermore, even if the flow rate of air or water effluent streams could be accurately estimated, the concentration of the individual radionuclide species in these effluent streams will likely be uncertain.

Extrapolation of Short-Term Laboratory and Prototype Test Results to Predict Long-Term Performance of Waste Packages and EBS

Detailed Safety Review Supported by Independent Tests, or Other Investigations

The length of time specified in the regulations for containment by the waste package (300 to 1000 years) and for gradual release from the EBS (following the containment period) exceeds the functional times commonly required in engineering design and also far exceeds the functional times that will be available for the testing and analysis of materials. Also, the large number of waste packages (45,000 to 80,000) expected to be emplaced at the geologic repository implies that scaling up from laboratory and prototype tests to the size of the repository is a unique endeavor. After the repository is closed and sealed, the waste package will be inaccessible during the required containment and isolation periods, which will be up to thousands of years. Therefore, a determination of reasonable assurance for containment and subsequent gradual release must come from a very high level of confidence in a scientific understanding of the effects of time and the environment on a repository system composed of a large number of waste packages. The reference material for the waste package, as described in the 1988 Site Characterization Plan (SCP), is a stainless steel, and such steels have been in existence for less than 100 years. As part of the ongoing development of the waste package enhanced conceptual design, DOE is expected to identify the specific material for the waste package along with further design details. The specific alloy chosen for the waste package material is expected to be one which, like the stainless steel reference material identified early in the process, has a short service and experience history. Also, for such a material, natural analogs may not exist. Even for materials (e.g., iron and copper) for which human experience reaches thousands of years, there are considerable uncertainties in translating that experience to repository-relevant conditions.

Review Plan 5.3 — Assessment of Compliance with the Design Criteria for the Post-Closure Features of the Underground Facility

Prediction of Thermomechanical Effects on the Waste Package and the EBS

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of Environmental Effects on the Waste Package and the EBS

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of the Releases of Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of the Releases of Non-Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Extrapolation of Short-Term Laboratory and Prototype Test Results to Predict Long-Term Performance of Waste Packages and EBS
Detailed Safety Review Supported by Independent Tests, or Other Investigations

Listed previously in Review Plan 5.2.

Review Plan 5.4 — Assessment of Compliance with the Engineered Barrier System Performance Objectives

Prediction of Thermomechanical Effects on the Waste Package and the EBS
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of Environmental Effects on the Waste Package and the EBS
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of Criticality Events in Waste Packages
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of Release Path Parameters (such as the Size, Shape, and Distribution of Penetrations of Waste Packages) due to Thermomechanical, Environmental, or Criticality Effects
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of the Releases of Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 5.2.

Prediction of the Releases of Non-Gaseous Radionuclides from Waste Packages during the Containment Period and from the EBS during the Post-Containment Period

Detailed Safety Review Supported by Analyses)

Listed previously in Review Plan 5.2.

Extrapolation of Short-Term Laboratory and Prototype Test Results to Predict Long-Term Performance of Waste Packages and EBS

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Listed previously in Review Plan 5.2.

Review Plan 6.1 -- Assessment of Compliance with the Requirement for Cumulative Releases of Radioactive Materials

Conceptual Model Representations of the Natural and Engineered Systems

Detailed Safety Review Supported by Analyses

Conceptual models of the site regarding the presence and origin of tectonic and magmatic/volcanic features and the potential flow and transport paths (for the aqueous and gas phase radionuclides) through the variably saturated, fractured, heterogeneous rock of Yucca Mountain are highly uncertain. Similarly, long-term stability of the engineered barriers (waste packages, borehole seals, etc.) is also difficult to predict. In addition, the environment to which the engineered barriers will be subjected soon after waste emplacement will be considerably different from the ambient due to the thermal pulse as well as to other disturbances introduced during repository construction.

Although some of these technical uncertainties are expected to be resolved by the time of the License Application submittal, significant residual uncertainties are expected to remain, as is evidenced at the Waste Isolation Pilot Project site and noted in the Phase 1 demonstration of a performance assessment capability by the NRC staff.

Variability in Model Parametric Values

Detailed Safety Review Supported by Analyses

Many features of a repository system can be measured directly in-situ or in a laboratory (e.g., ground-water levels or corrosion rates) or can be inferred from direct measurements (e.g., hydraulic conductivity). In natural heterogeneous systems like Yucca Mountain, parameters will vary both temporally and spatially. In addition, even in direct measurements, there may be significant uncertainties associated with the applicability of test methods, potential instrument errors, and procedural errors. Thus, it is not uncommon to have large uncertainty bands for geologic parameters; sometimes the standard deviations of these parameters may be orders of magnitude greater than their mean values.

DOE, through performance allocation tables in its SCP, has stated a target for acceptable levels of uncertainties. Some of these will invariably be revised as site characterization proceeds, but some targets will not be met in the end. Under this eventuality, DOE is expected to modify its initial performance allocation. At issue in all these iterations of performance allocation is technical support for the estimated uncertainty bands. DOE is expected to estimate parameter values for its performance assessment models, based on a combination of site and design data and expert elicitation.

Appropriateness of Assumptions and Simplification in Mathematical Models

Detailed Safety Review Supported by Analyses

To perform analyses of overall repository system performance, mathematical models and numerical computer codes will

be developed to represent a conceptual understanding of the important processes operative at the site. Various assumptions and simplifications will be required in these models and codes so that the important processes (e.g., groundwater flow through unsaturated, fractured rock) can be represented as realistically as possible and yet not be so detailed as to be unworkable. Some of the simplifications will necessarily be due to computer hardware constraints (e.g., computer code run times). These assumptions and simplifications will in general be non-unique and controversial.

Validation of Mathematical Models

Detailed Safety Review Supported by Independent Tests, or Other Investigations

Since mathematical models will be used for compliance demonstration, the "truthfulness" of models is at issue. Mathematical models are abstract representation of "reality" as perceived by the analyst. The models depend on the scales of representation, the processes under consideration, the type and extent of measurements available from the site, and the available computer hardware. Although the testing and benchmarking of models (and associated computer codes) are reasonably well-defined and understood, validation is expected to be an open issue at the time of review of the license application. Provisions of 10 CFR 60.21(c)(1)(ii) require that models be validated with data from an appropriate combination of such methods as field tests, in-situ tests, laboratory tests, and natural analog studies. However, a model validation strategy has yet to be formulated either by DOE or NRC. Most likely, this strategy will define the acceptable levels of validation, since it is known that full and unequivocal validation of models is not possible.

Prediction of Future System States

Detailed Safety Review Supported by Independent Tests, or Other Investigations

This performance objective requires that repository performance be estimated (in terms of cumulative radionuclides released to the accessible environment) for a period of 10,000 years following permanent closure, for both anticipated and unanticipated processes and events. Such calculations necessitate the identification of appropriate future conditions to consider and estimate their probabilities of occurrence. The U.S. Environmental Protection Agency's radiation protection standards (40 CFR Part 191) require some precision in the estimation of these probabilities. If not entirely subjective, a significant amount of expert judgment is expected in this process. Thus, substantial uncertainty is expected to remain through the time of license application submittal.

To identify likely future states of the repository system, it is necessary to gain an understanding of the processes that have operated and the events that have occurred in the past within the geologic setting of the site. Based on this understanding, reasonable projections about those potential processes and events that could affect a geologic repository during the period of performance are possible. This appears to work very well in a qualitative sense, especially if the time periods involved are long -- on the order of millions of years. The regulatory period of interest -- 10,000 years -- is short for such geologic predictions (both of the processes and events of interest and their probabilities of occurrence). It is for this reason that a significant dependence on expert elicitation is inevitable for defining scenarios.

Review Plan 6.2 — Assessment of Compliance with the Individual Protection Requirements

Conceptual Model Representations of the Natural and Engineered Systems

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 6.1.

Variability in Model Parametric Values

Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 6.1.

Appropriateness of Assumptions and Simplification in Mathematical Models
Detailed Safety Review Supported by Analyses

Listed previously in Review Plan 6.1.

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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

The License Application Review Plan (LARP) provides guidance to the NRC staff for its review of the U.S. Department of Energy's (DOE's) license application to construct a mined geologic repository for the disposal of spent nuclear field and other high-level radioactive waste at Yucca Mountain. The LARP, Revision 0 was issued September 1994. Revision 0 represented the staff's initial efforts in developing the LARP and was comprised of both completed and outlined individual review plans. The LARP was and continues to be, however, a work in progress. This draft revision, designated Revision 1, represents the staff's latest efforts in the development of the LARP. Appendix D provides a status of the development of the individual review plans. Future revisions to the LARP, however, are uncertain due to a changing high-level waste program and associated budget constraints.

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