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Draft Technical Position on Tectonic Models in the Assessment of Performance of High-Level Radioactive Waste Repositories

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Sincerely,

Eileen T. Tana

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TECHNICAL POSITION ON TECTONIC MODELS IN THE ASSESSMENT OF PERFORMANCE OF HIGH-LEVEL RADIOACTIVE WASTE REPOSITORIES

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1. INTRODUCTION

1.1 Purpose

This Technical Position on tectonic models is undertaken to document the Division of High-Level Waste Management (DHLWM) staff's position on the requirement for the support and implementation of tectonic model(s) in performance allocation and performance assessment. The need for this Position stems from the DHLWM staff's concern about the use of models in performance allocation and performance assessment. In the Consultation Draft Site Characterization Plan (CDSCP) (see Ref. 1) and the Site Characterization Plan (SCP) (see Ref. 2), the U.S. Department of Energy (DOE) has indicated that it intends to use models in the performance assessment process. As a result, DOE is required, under 10 CFR 60 (§ 60.21 and § 60.101) (see Ref. 3) to provide thorough support of those models. The objectives of this Position are to outline the regulatory requirements for support of tectonic models, to discuss the implementation of the requirements, and to suggest the process for integrating tectonic models into data collection activities of the Site Characterization program. Adherence to this Technical Position will result in use of tectonic models that are acceptable to the DHLWM staff and will help to assure the adequacy of the information provided in support of the License Application.

1.2 Scope

The guidance presented in this Technical Position on tectonic models will provide DOE with a regulatory perspective on the use of tectonic models during site characterization and the licensing process. This guidance will outline the DHLWM staff's position on the use of tectonic models in the performance allocation and performance assessment processes. This Technical Position does not address the criteria by which a tectonic model will be reviewed and evaluated, procedures that are more appropriately contained in a review plan.

1.3 Structure of Technical Position

Specific points to be addressed in the Technical Position include:

1) a regulatory analysis of the implementation of "predictive models," in general, and tectonic models, in particular, under 10 CFR 60;

2) the DHLWM staff's position on the use of tectonic models in the performance allocation and performance assessment processes;

3) a discussion of the need for a representative database and the use of probabilities in the construction of tectonic models.

1.4 Alternatives

Technical Positions are issued to describe and make available to the public criteria and methods acceptable to the DHLWM staff for implementing specific parts of the Commission's regulations, and to provide guidance to DOE. Technical Positions are not substitutes for regulations, and compliance with them is not required. Methods and solutions different from those set out in the Position will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a construction authorization or license by the Commission.

2. REGULATORY BACKGROUND

2.1 Requirements

Under 10 CFR 60, DOE is required to thoroughly support models used for determining the long-term performance of a repository. This requirement for the development and confirmation of models is specified in § 60.21(c)(1)(ii)(F), and supported in § 60.101(a)(2). They state that:

> DOE should provide "...An explanation of measures used to support models used to perform the assessments required..." and "Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported 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." [§ 60.21(c)(1)(ii)(F)] and
>
> Demonstration of compliance with long-term performance objectives and criteria will "...involve the use of data from accelerated tests and predictive models that are supported by such measures as field and laboratory tests, monitoring data and natural analog studies." [§ 60.101 (a)(2)]

2.2 Implementation of Requirements under 10 CFR 60

As defined in § 60.21(c)(1)(ii)(F), "predictive models" are models used to predict future conditions and changes in the geologic setting. In this Technical Position, tectonic models are considered to be predictive models, because they can be used to predict future conditions and changes in the geologic setting in response to tectonic processes.

Predictive models are useful in assessing the future behavior of tectonic features in the geologic setting. Gaps in the geologic record and the absence

of a thorough understanding of driving forces behind tectonic events can lead to high levels of uncertainty about the nature and rates of tectonic events in the area of the site. A tectonic model or set of models supported by a representative database can form conceptual bases from which reasonably conservative and technically defensible judgments about the nature, likelihood, and magnitude of future tectonic events can be made. Reliance on an empirical database without integrating the data into a model is likely to result in substantial uncertainties regarding the presence of "undetected" features at the site and, as a result, an inability to accurately assess the future behavior of natural systems.

For example, an estimate of the likelihood and/or magnitude of offset along a fault that could disrupt the repository can be made on the basis of the geologic record for a particular site. However, gaps in the geologic record (e.g., the absence of Quaternary sediments) and/or uncertainties about tectonic processes active at the site (e.g., strike-slip vs. normal fault movement) may lead to substantial uncertainty about the likelihood of this event or inaccurate assumptions about expected magnitudes. In circumstances where the database is insufficient, then reliance on alternative tectonic models provides a reasonably conservative approach for assessing the likelihood and bounding the magnitude of possible disruptive fault events over the period of performance.

2.2.1 Preclosure Period

The performance objectives for releases of radioactive material in the preclosure period [§ 60.111(a)] and the retrievability of waste [§ 60.111(b)] require that the design of the repository operations area must be such that: 1) "...until permanent closure ...radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20...," and 2) "...any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated...." To assure that the design of the repository operations area will meet the performance requirements, the bounding conditions of possible tectonic events in the repository operations area should be established to develop design bases. The use of thoroughly supported tectonic models is a mechanism for bounding the tectonic events that are reasonably likely to occur in the preclosure period.

2.2.2 Postclosure Period

Objectives of the long-term performance of a potential repository during the postclosure period are described in § 60.112 (performance requirements for the overall system) and § 60.113 (performance requirements of particular barriers after permanent closure). More generally, 10 CFR 60.15 (in conjunction with § 60.2) and § 60.122 identify the requirements for investigating geologic conditions at the site.

Under § 60.112,

"The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases... conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events."

Tectonic models have a key role in determining the processes and events that are sufficiently likely to occur in the period of concern for the repository and, therefore, in defining anticipated and unanticipated processes and events. For DOE to provide reasonable assurance that the long-term performance of the repository will meet the requirements under § 60.112, it should be demonstrated that the full range of alternative tectonic models, supported by available evidence and inclusive of anticipated and unanticipated processes and events, has been identified.

Under § 60.113,

"The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW [high level waste] will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times."

Similar to the overall system performance requirement, § 60.113(a)(1)(i) requires that the engineered barrier system be designed assuming anticipated processes and events that can, with respect to tectonics, largely be defined using a combination of data collected during site characterization and alternative tectonic models. However, § 60.113(a)(1)(i) also requires that releases from the engineered barrier system be gradual over long periods of time. This requirement places constraints on the allowable uncertainty in identifying anticipated events used in the design of the engineered barrier system. For example, rupturing of canister(s) by fault movement could result in an abrupt release of radionuclides from the engineered barrier over a relatively short period of time. If this is reasonably likely to occur, there may be a violation of 10 CFR 60.113. DOE should demonstrate that the methods used to derive projections of future tectonic processes and events, including the use of tectonic models, are sufficient to assure that the design of the engineered barrier system will meet the performance objective.

10 CFR 60.2 indicates that the program of exploration and research undertaken during site characterization should establish the geologic conditions and the ranges of relevant parameters at a particular site. The procedure for

achieving this objective is outlined in 10 CFR 60.122(a)(2)(i) and (ii), which state that DOE should demonstrate that:

> " The potentially adverse...natural condition[s] has [have] been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations"; and that "The effect of the potentially adverse ... natural condition on the site has been evaluated using analyses which are sensitive to the potentially adverse ...natural condition and assumptions which are not likely to underestimate its effect."

Tectonic models describe the geometric, mechanical, and kinematic relationships among observed structural features and past, present and future tectonic processes. In addition to describing observed structural features, tectonic models, as defined in this report, may also lead to the recognition of significant structural features or processes that are not readily detected by conventional methods of investigation.

2.2.3 Anticipated and Unanticipated Processes and Events

Tectonic models have a key role in identifying anticipated and unanticipated processes and events. The DHLWM staff considers that the geologic record for the Quaternary Period should provide the basis for the classification of processes and events and that processes and events that have not occurred during the Quaternary Period would not normally be considered to be sufficiently credible to warrant consideration (Draft Generic Technical Position on "...Anticipated Processes and Events and Unanticipated Processes and Events," see Ref. 4). However, an incomplete geologic record in the area of the repository and uncertainty about the underlying processes indicate that, with respect to tectonics, alternative conceptual models based on empirical geologic data derived during site characterization could be employed to identify processes not evidenced in the Quaternary record, but likely to have been active in the geologic setting during the Quaternary Period.

2.2.4 Tectonic Models as a Basis for Scenario Selection

As a result of their role in defining which processes and events are anticipated and unanticipated processes and events, tectonic models will also play a key role in the development of a comprehensive list of scenarios. To develop a list of mutually exclusive scenarios involving tectonics that is sufficiently complete to demonstrate compliance with 10 CFR 60.112, a comprehensive model or set of models of tectonic activity must be available on which to base the selection. The DHLWM staff emphasized the need for models in the development of scenarios during the DOE-NRC Alternative Conceptual Models Workshop (April, 1988, see Ref. 5). In that meeting, the DHLWM staff stated that models:

"...if confirmed, be used to calculate releases for all scenarios needed to show compliance with the EPA standard" (see Ref. 5).

3. TECHNICAL POSITION

A) Tectonic models should form the basis for preliminary performance allocation, with respect to tectonic factors, and for prioritizing those investigations that have the greatest potential for resolving issues associated with tectonic features, events, or processes that could lead to major licensing concerns or to substantial change in the site characterization program.

B) The iterative process of model creation, modification, abandonment, and model confirmation should begin during site characterization and continue until permanent closure (§ 60.140 and § 60.141). This process will permit field evidence actually encountered to be taken into account.

C) A full range of tectonic models supported by existing data should form one of the principal bases for planning tectonic investigations carried out during site characterization and for assessing the ability of the site to meet the performance objectives identified in 10 CFR 60. Such alternative tectonic models should:

1) form one of the principal bases for input related to tectonics in the development of a comprehensive list of scenarios needed to show compliance with 10 CFR 60.112; and

2) form one of the principal bases for input into the identification of anticipated processes and events and, therefore, in the design of the engineered barrier system needed to show compliance with 10 CFR 60.113.

D) The iterative process of model creation, modification, abandonment, and confirmation and the identification of processes and events that will be considered to be anticipated processes and events should be based on deterministic considerations, not probabilities (Draft Generic Technical Position, see Ref. 4). For example, the identification of volcanism as an anticipated process in the geologic setting should be based on a deterministic assessment of whether volcanism has occurred in the geologic setting during the Quaternary.

E) DOE should demonstrate that the program of site characterization, designed to provide support for, and differentiate between alternative tectonic model(s), will provide data that are sufficiently representative of the events and processes in the geologic setting that the full range of conditions at the site can be identified and their effects on waste isolation can be assessed.

4. DISCUSSION

4.1 Rationale for the Position on the Use of Alternative Tectonic Models

Concerns about the use of predictive models during characterization of the proposed repository at Yucca Mountain were presented to DOE in the staff's review of the Nevada Nuclear Waste Storage Investigations (NNWSI) CDSCP (see Refs. 6 and 1). In that review, the DHLWM staff noted that the full range of alternative conceptual models supported by available evidence from the Yucca Mountain area had not been systematically and clearly identified. The DHLWM staff concluded that alternative conceptual models should form the basis for preliminary performance allocations. The staff expects that such alternatives would be considered in performance assessments of repository systems and subsystems.

In the statutory SCP (see Ref. 2), DOE has provided tables listing alternate hypotheses for the local model in the preclosure and postclosure programs. However, providing tables of alternative conceptual tectonic models or alternate hypotheses in conceptual models does not, by itself, resolve the staff's concern that alternative conceptual models should form the basis for preliminary performance allocations and performance assessment. As outlined previously, the staff considers that tectonic models should form a conceptual basis on which to identify those processes and events that are reasonably likely to occur, as well as form a conceptual basis for assessing the likelihood and magnitude of tectonic events over the period of performance. Specifically, tectonic models developed from and used in conjunction with data obtained from characterization of individual tectonic features should form one of the principal bases for predicting the behavior of the tectonic system and, as a result, allocating performance to repository barriers. For example, faults at the site that are favorably oriented for failure in the present stress regime should be viewed both in the context of faults with demonstrated Quaternary movement and in the context of a realistic conceptual tectonic model(s). One possible tectonic model might indicate that the current stress field is such that favorably oriented faults, even though they may not display Quaternary offset, are susceptible to failure. In this example, the site characterization program should evaluate and the performance allocation for repository barriers should consider all favorably oriented faults as faults that are subject to failure.

An example of using tectonic models in the assessment of the magnitude of future tectonic events might involve a detachment fault model. In a detachment fault model, the hazard posed to the repository by faulting should include not only the evidence generated in the study of individual faults, but should also consider the behavior of other faults in the fault system defined by the fault model (i.e., detachment faulting). The controlling feature in the consideration of the magnitude of offset and recurrence interval expected on an individual fault in a detachment fault system may be the detachment fault

itself. Therefore, in the assessment of hazard to the repository posed by individual fault strands, consideration should be given to the offset histories of all faults interpreted to be controlled by the detachment.

4.2 Representativeness of Database

In order to assess the future performance of a repository, data must be available to establish the geologic conditions and the ranges of relevant parameters. 10 CFR 60.15 (in conjunction with § 60.2) requires that DOE establish the geologic conditions and the ranges of relevant parameters at a particular site. Therefore, data collected during site characterization and used to create, modify, abandon, or confirm tectonic models should be sufficiently representative of tectonic conditions at the site that the range of tectonic conditions can be established. A key component in the development of a database sufficient to establish the ranges of tectonic conditions at the site (i.e., a representative database) is the requirement (§ 60.122) that potentially adverse conditions be adequately investigated. 10 CFR 60.122 (see heading 2.2.2, "Postclosure Period," p. 3) states that potentially adverse conditions must be investigated "...including the extent the condition may be present and still be undetected...." Such an approach to investigating potentially adverse conditions helps provide reasonable assurance that the full range of tectonic models for the site can be identified for use in the assessment of performance of the repository.

4.3 The Use of Probabilities in Tectonic Models

Probabilistic hazard analysis is considered to be a valuable supportive tool in the consideration of credible processes and events included in tectonic models. However, the Commission has recognized (Federal Register, Vol. 48, No. 120, June 21, 1983, see Ref. 7) and the staff has reiterated (Draft Generic Technical Position, see Ref. 4) that the "Identification of anticipated and unanticipated processes and events for a particular site will require considerable judgment and will not be amenable to accurate quantification, by statistical analysis, of their probability of occurrence." In an assessment of tectonics using a probablistic approach for determining the likelihood of events and processes that might affect the performance of a repository, Callender (Sandia 86-0196, see Ref. 8) said that: "At present, no tectonic or seismologic method is completely adequate to quantitatively assess, with a high degree of certainty, the probability of tectonic activity at a repository site." Therefore, in accordance with the DHLWM staff position on the use of probabilities in the identification of anticipated and unanticipated processes and events (Draft Generic Technical Position, see Ref. 4), primary methods for the identification of anticipated and unanticipated processes and events used in conjunction with tectonic models should be based primarily on deterministic criteria.

The effectiveness of probabilistic hazard analysis is its ability to integrate a wide range of information and judgment and associated uncertainties into a

flexible framework (Reiter, 1988, see Ref. 9). An example of the use of probabilistic hazard analysis in the assessment of credible tectonic events might involve support for and quantification of judgments that a specific tectonic event(s) not evidenced in the Quaternary Period, but possible under an alternative tectonic model, is (are) to be considered in the assessment of overall system performance.

5. REFERENCES

1. U.S. Department of Energy, "Consultation Draft Site Characterization Plan" for the Yucca Mountain Site, January 8, 1988.

2. U.S. Department of Energy, "Site Characterization Plan," Yucca Mountain Site, Nevada Research and Development Area, Nevada, December, 1988.

3. 10 CFR Part 60 (Code of Federal Regulations), Title 10, Energy, Part 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," U.S Government Printing Office, Washington, D.C., 1988.

4. U.S. Nuclear Regulatory Commission, " Draft Generic Technical Position entitled "Guidance for Determination of Anticipated Processes and Events and Unanticipated Processes and Events," Notice of Availability in Federal Register, Vol. 53, No. 39, February 29, 1988, p. 6040.

5. U.S. Nuclear Regulatory Commission, "Comments at the DOE-NRC Technical Meeting on Alternative Conceptual Models of the Yucca Mountain Groundwater System," April 11-14, 1988.

6. U.S. Nuclear Regulatory Commission, Letter, from R.E. Browning, U.S. Nuclear Regulatory Commission, to R. Stein, U.S. Department of Energy, dated May 11, 1988, Subject, "NRC Staff Review of the Department of Energy's January 8, 1988, Consultation Draft Site Characterization Plan for the Yucca Mountain Site."

7. U.S Nuclear Regulatory Commission, "Disposal of High-Level Radioactive Wastes in Geologic Repositories, Technical Criteria," Federal Register, Vol. 48, No. 120, June 21, 1983, 28194-28229.

8. J.F. Callender, "Tectonics and Seismicity in Techniques for Determining Probabilities of Events and Processes Affecting the Performance of Geologic Repositories," SAND86-0196, Final Draft, 1988.

9. L. Reiter, "Probabilistic Seismic Hazard Analysis - Lessons Learned, A Regulator's Perspective," Presentation to Second Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping, Electric Power Research Institute, 1988.

*10. American Geological Institute, Glossary of Geology, 1972, Washington, D.C., 805 pp.

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* Found in Technical Position Glossary, next page.

6. GLOSSARY*

Geologic Setting: "the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located." (10 CFR 60.2)

Tectonics: "A branch of geology dealing with the broad architecture of the upper part of the Earth's crust, that is, the regional assembling of structural or deformational features, a study of their mutual relations, their origin, and their historical evolution." (American Geological Institute Glossary, see Ref. 10.) (Under 10 CFR 60, tectonics would be one of the systems operating in the region in which the geologic repository operations area is located.)

Conceptual Model: "A pictorial and/or narrative description of the repository system or subsystem that is intended to represent one or more of the following:

- relevant components of a system and/or subsystem

    - interactions between the various components and/or subsystems and/or systems." (NRC comments, DOE-NRC Alternative Conceptual Models Workshop, April, 1988, see Ref. 5 of this Technical Position.)

Predictive Model: A conceptual model involving interactions between the various components and/or subsystems and/or systems that is used to predict future conditions or changes in the geologic setting.

Tectonic Model: A predictive model that provides a description of the tectonics of the geologic setting. The tectonic model in a regulatory framework would emphasize events and processes having occurred in the Quaternary and would include a projection of the rates of tectonic processes and events into the future.

Representative Database: Data sufficient to establish the range of conditions in the geologic setting.

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* Some definitions are taken from the American Geological Institute's Glossary of Geology (see Ref. 10).