

COMPLIANCE DETERMINATION STRATEGY

RRT 3.2.1.7 POTENTIALLY ADVERSE CONDITION: CORRELATION OF EARTHQUAKES WITH TECTONIC PROCESSES

APPLICABLE REGULATORY REQUIREMENTS:

10 CFR 60.21(c)(1)(ii)(B)
10 CFR 60.21(c)(1)(ii)(F)
10 CFR 60.122(c)(13)

TYPES OF REVIEW:

Acceptance Review (Type 1)
Safety Review (Type 3)
Detailed Safety Review Supported by Analyses (Type 4)
Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations (Type 5)

RATIONALE FOR TYPES OF REVIEW:

Acceptance Review (Type 1) Rationale:

This regulatory requirement topic is considered to be license application-related because, as specified in the license application content requirements of 10 CFR 60.21(c) and regulatory guide "Format and Content for the License Application for the High-Level Waste repository (FCRG)," it must be addressed by the U.S. Department of Energy (DOE) in its license application. Therefore, the staff will conduct an Acceptance Review of the license application for this regulatory requirement topic.

Safety Review (Type 3) Rationale:

This regulatory requirement topic is considered to be related to containment and waste isolation. It is a requirement for which compliance is necessary to make a safety determination for construction authorization as defined in 10 CFR 60.31(a) (i.e., regulatory requirements in Subparts E, G, H, and I). Therefore, the staff will conduct a Safety Review of the license application to determine compliance with this regulatory requirement topic.

This regulatory requirement topic, concerning a potentially adverse condition (PAC), focuses on DOE's demonstration, through appropriate investigations, of evidence for (or against) this PAC within the controlled area in order to understand the projected effect of this condition, if present, on the waste isolation capability of the proposed geologic repository. It concerns evidence that, based on correlations of earthquakes with tectonic processes and features, either the frequency of occurrence or magnitude of earthquakes may increase. In addition, such investigations must extend beyond the controlled area if it is ascertained that this PAC might adversely impact isolation within the controlled area.

The Yucca Mountain site is located in an area that is tectonically active (see DOE, 1988, pp. 1-151 - 1-200). Therefore, there is no question that this PAC exists for the Yucca Mountain site; however, there is ongoing debate about the degree to which this condition is present, or may be present and undetected.

Detailed Safety Review Supported by Analyses (Type 4) Rationale:

Projections concerning the potential for and effects of a correlation of tectonic features with earthquakes, that may indicate increasing earthquake activity during the period of performance, may contain a large degree of uncertainty. This uncertainty could cause a high risk of non-compliance with the overall system performance objective specified in 10 CFR 60.112 and the subsystem performance objective for the engineered barrier system specified in 10 CFR 60.113(a). Therefore, the staff considers that findings made under this requirement may be highly uncertain due to the following Key Technical Uncertainty.

The Key Technical Uncertainty associated with techniques to predict the likelihood of earthquake occurrence for 10,000 years is considered to require a Type 4 review because there is a risk of non-compliance with the performance objectives related to containment and waste isolation. This risk necessitates analyses above and beyond that required for Type 3 reviews to assure that the uncertainty, and the effects on performance, have been reduced to the extent practical.

Key Technical Uncertainty Topic: The inability to predict the likelihood of earthquake occurrence during the next 10,000 years.

Description of uncertainty: Due to the complexity of tectonic processes, the lack of knowledge about how the different tectonic processes behave in the Yucca Mountain area, and the short time frame 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 time frame (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 which may be difficult to quantify.

Performance Objectives at Risk: 10 CFR 60.112 and 10 CFR 60.113(a).

Explanation of Nature of Risk: A lack of knowledge about the rate of earthquake occurrence may lead to an underestimation of the design earthquake needed for structures, systems, and components important to containment and waste isolation. For example, uncertainties regarding the effects of vibratory ground motion on the stability of a corroded waste package canister, or in changes to the waste isolation characteristics of the repository block could result in non-compliance with the performance objectives of 10 CFR 60.113(a) and 10 CFR 60.112, respectively. Therefore, understanding the processes, features, and characteristics related to earthquake activity, both direct and secondary, has a degree of uncertainty which is hard to quantify.

Description of Resolution Difficulty: Closure of this issue will be difficult because, currently, there are no proven methods for extrapolating relatively short-term earthquake data up to the period of 10,000 years after repository closure. Methods are needed to provide reasonable assurance that the effects of increasing earthquake activity are identified and that predictions regarding these effects will not underestimate the actual effects of earthquakes on repository design and performance. As research in this area has not been done, the resolution difficulty for this Key Technical Uncertainty cannot be determined at this time. It is expected that a significant amount of expert judgment will be used in extrapolating

short-term seismic data. However, if no methods for extrapolating relatively short-term data, over the period of regulatory concern, are developed, the staff would consider this Key Technical Uncertainty to require a Type 5 review.

Detailed Safety Review Supported by Independent Tests, Analyses, or Other Investigations (Type 5) Rationale:

Because the following Key Technical Uncertainty may be difficult to resolve, there may be the highest potential risk of non-compliance with the performance objectives specified below.

Key Technical Uncertainty Topic: Correlation of earthquakes with tectonic features.

Description of Uncertainty: 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. Because of this large range in permissible models, and the associated uncertainty, this Key Technical Uncertainty is considered to involve a Type 5 review.

Performance Objectives: 10 CFR 60.112 and 10 CFR 60.113(a).

Explanation of Nature of Risk: By definition, models are a simplification of reality, and both conceptual and mathematical models will be used in the high-level waste program. The conceptual model selected can have a significant effect on the scope of the field investigation program, and on the interpretation of the data obtained. In addition, the regulatory requirement itself relates to more than just the presence of certain features; it also requires an assessment of what may be present and undetected. Without a conceptual model of what is being investigated, it is impossible to comply with either the regulatory requirement for this potentially adverse condition or the regulatory requirement related to overall system performance. Conceptual models can be used to describe the assumed physical and/or chemical processes which have, are, or will be taking place within the system under consideration; mathematical models are used in performance assessment to "predict" the behavior of the system. It is impossible to completely sample and describe any physical system which is as complex as that represented by the tectonic activity in the vicinity of Yucca Mountain. Because uncertainty will exist in the data and parameters, there will be an inherent uncertainty in the understanding of the physical system being represented by the model, and a consequent inherent uncertainty in the correctness or validity of any conceptual model used. This uncertainty will be propagated through the performance assessments, along with the mathematical model uncertainties, introducing an unknown amount of uncertainty in any final results from performance assessment analyses.

Description of Resolution Difficulties: The Key Technical Uncertainty related to correlating earthquakes with tectonic features is considered to require a Type 5 review because very little has been done to reduce the risk of non-compliance with the performance objectives related to containment and waste isolation at this time. According to Davis *et al.* (1990), there is currently no methodology designed to quantify the uncertainty in conceptual models. Also, selection of the model(s) to be used, to correlate seismic activity and tectonic features, will be based, at least in part, on subjective judgement of experts and can, at best,

be formalized and documented only to the extent that the assumptions used are clear, reasonable, and traceable.

Summary

The reasons for a Type 5 review can be summarized as follows:

- (1) Quantitative knowledge about tectonic processes, including the ability to predict the occurrence of earthquakes for the next 10,000 years or the ability to correlate earthquakes with known tectonic structures, in the Yucca Mountain area is, and will most likely remain, uncertain;
- (2) Alternative conceptual models of tectonic processes will remain at the time of licensing;
- (3) The alternative models for addressing both the probability of tectonic activity and potential effects from this activity may span several orders of magnitude;
- (4) There is no proven method for extrapolating relatively short-term seismic data and experience to the long performance periods (i.e., 10,000 years) required for a geologic repository; and
- (5) The effects of tectonic activity on the ability to demonstrate compliance with the overall system and subsystem performance objective will be highly contentious during licensing.

REVIEW STRATEGY:

Acceptance Review:

In conducting the Acceptance Review of the potentially adverse condition (PAC), concerning either an increase in the frequency of occurrence or magnitude of earthquakes (based on correlations of earthquakes with tectonic processes and features), the reviewer should determine if the information presented in the license application and its references for determining compliance with the regulatory requirements applicable to this PAC is complete in technical breadth and depth as identified in the regulatory guide "Format and Content for the License Application for the High-Level Waste Repository" (FCRG). The reviewer should determine that all appropriate information necessary for the staff to review this PAC is presented such that the assessments required by the regulatory requirements associated with total system and subsystem performance objectives can be performed.

The information presented in the license application should be presented in such a manner that the assumptions, data and logic leading to a demonstration of compliance with the requirements are clear and do not require the reviewer to conduct extensive analyses or literature searches. The reviewer should also determine that controversial information and appropriate alternative interpretations and models have been adequately described and considered.

Finally, the reviewer shall determine if the U.S. Department of Energy (DOE) has either resolved all the NRC staff objections that apply to this regulatory requirement topic or provided all the information

requested in Section 1.6.2 of the FCRG for unresolved objections. The reviewer will evaluate the effect of any unresolved objections, both individually and in combination with others, on: (1) the ability of the reviewer to conduct a meaningful and timely review; and (2) the ability of the Commission to make a decision regarding construction authorization within the three-year statutory period.

Safety Review:

This regulatory requirement topic is limited to the consideration of the correlation of earthquakes with tectonic features or processes that may indicate increases in either the frequency of occurrence or magnitude of earthquakes. It does not specifically address changes to hydrologic conditions caused by seismic or tectonic activity. These topics will be covered under Sections 3.2.2.7 through 3.2.2.9 of the license application and its attendant review plans.

The specific aspects of the license application 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 license application to support DOE's demonstrations regarding 10 CFR 60.122(c)(13). Specifically, DOE will need to: (1) provide information to determine whether and to what degree evidence of a correlation of earthquakes with tectonic features may indicate that increasing frequency of occurrence or magnitude of earthquakes is present; (2) provide information to determine to what degree this PAC is present, but undetected; (3) assure the sufficiency of the lateral and vertical 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 increasing frequency of occurrence or magnitude of earthquakes and ranges of relevant parameters. Examples of the specific review activities that will be required of the staff include confirmation that DOE has fully considered the historically reported and instrumentally recorded earthquakes, site and regional tectonic models, and paleoseismic events that are appropriate for the aforementioned analysis.

DOE will also need to provide an explanation of the measures used to support the tectonic models used to assess the presence (or absence) of evidence of increasing frequency of occurrence or magnitude of 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 that a correlation of earthquakes with tectonic features may indicate increasing frequency of occurrence or magnitude of earthquakes; and (2) assumptions which are not likely to underestimate its effects. In general, the reviewer will assess the adequacy of DOE's investigations for evidence of increasing frequency of occurrence or magnitude of earthquakes, both within the controlled area and outside the controlled area, as necessary, in the manner outlined in § 60.21(c)(ii)(B).

In order 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's Office of Nuclear Regulatory Research, in addition to that provided by DOE in its license application. The reviewer should focus on additional data which can refine knowledge of increasing frequency of occurrence or magnitude of earthquakes, and should perform, as necessary, additional

analyses to confirm the resolution capabilities of the methodologies. It is incumbent upon the reviewer to have acquired a body of knowledge regarding these and other critical considerations in anticipation of conducting the review to assure that DOE's seismic program is sufficient in scope and depth to provide the information necessary for resolution of the concerns.

Finally, investigations in the following DOE site characterization program study plans are expected to result in data and analyses needed to help in the review described above to address the presence (or absence) of this PAC:

<u>Study Plan No.</u>	<u>Title</u>
8.3.1.17.3.1	<i>Relevant Earthquake Sources, (DOE,1990)</i>
8.3.1.17.4.1	<i>Historical and Current Seismicity at Yucca Mountain (DOE,1991)</i>

Reports presenting the results from additional study plans related to this PAC, when available, will also be reviewed.

Detailed Safety Review Supported by Analysis:

A Detailed Safety Review supported by analysis will be needed for evaluation of the Key Technical Uncertainty regarding the inability to predict the likelihood of earthquake occurrence during the next 10,000 years. This will ensure that DOE has adequately demonstrated Items (1)-(4), listed in the previous section (see Section 2.2.1 ("Safety Review"), paragraph 2).

Examples of specific review activities that will be required include the review of DOE's seismic analyses to ensure that they have included: (1) all the regional geologic structures and tectonic activity which are significant in predicting the likelihood of earthquake occurrence; (2) a coherent and well documented discussion (of both regional and site tectonics) of the basis for determining earthquake occurrence; (3) an examination of the data and the approach used to predict earthquake occurrence; and (4) a discussion and rationale describing the preferred approach.

Detailed Safety Review Supported by Independent Tests, Analyses, or Investigations:

A Detailed Safety Review, independent modeling and the use of the results of staff investigations will be needed for the Key Technical Uncertainty concerning the correlation of earthquakes with tectonic features. This will ensure that DOE has adequately demonstrated Items (1)-(4) listed in the section on "Safety Review" (see Section 2.2.1, paragraph 2).

For the Key Technical Uncertainty concerning the correlation of earthquakes with tectonic features, the staff detailed review will be supported by conceptual and numeric models developed by the staff to determine if the models being used by DOE provide an adequate explanation of the phenomenon of earthquake activity. In conducting this review, the staff must evaluate the different conceptual models to determine if they are consistent with the models being proposed for other related processes. Through various modeling exercises, the staff will develop various tectonic models and attempt to define the correlation between earthquake data and tectonic structures presented by the model.

Examples of specific review activities that will be required include: (1) comparing both the DOE models and models developed by the staff to determine if these models provide an adequate explanation of how

earthquakes are generated, and whether historical or predicted earthquakes can be correlated with the tectonic features described in these models; (2) examining the consistency of DOE's models with field observations made during site characterization; and (3) reviewing the assumptions proposed for constructing these models and their rationales, and comparing the results presented by DOE, in its license application, to the results of the NRC's independent confirmatory analysis. In conducting this review, the staff must evaluate the consistency and accuracy of the tectonic models developed. The staff investigations may also include collecting field data and constructing 3-D models.

When reviewing and creating models, it should be recognized that, in addition to field data, subjective judgement will also be required. It is important that the various assumptions necessary for the various models be carefully documented and thoroughly reviewed. Bounding assessments, field data, and the results of the various research activities should be included to narrow and distinguish between the various models proposed. It is anticipated that several conceptual models may be reasonable at the time of licensing. In reviewing these models, the staff must assure that they reflect the degree of resolution of the experimental and investigative methods, including what could be present but may still be undetected due to the limitations of the various methods applied. The staff must also assure that the models used incorporate all appropriate field data and assumptions.

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RATIONALE FOR REVIEW STRATEGY:

In view of the complexity of the key technical uncertainty addressed above, it is appropriate that the NRC conduct the following independent activities: 1) develop the licensing tools and technical basis necessary to judge the adequacy of DOE's license application; 2) assure sufficient independent understanding of the basic physical processes taking place at the geologic repository; and 3) maintain independent but limited confirmatory research capability under NRC auspices.

APPLICABLE REGULATORY REQUIREMENTS FOR EACH TYPE OF REVIEW:

Type 1:

10 CFR 60.21(c)(1)(ii)(B)

10 CFR 60.21(c)(1)(ii)(F)

10 CFR 60.122(c)(13)

Type 3:

10 CFR 60.122(c)(13)

Type 4:

10 CFR 60.122(c)(13)

Type 5:

10 CFR 60.122(c)(13)

REFERENCES:

Davis, P.A., E.J. Bonano, K.K. Wahi, and L.L. Price, "Uncertainties Associated with Performance Assessment of High-Level Radioactive Waste Repositories," Nuclear Regulatory Commission, NUREG/CR-5211, November 1990.

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. Department of Energy, "Chapter 1, Geology," in "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area," Office of Civilian Radioactive Waste Management, DOE/RW-0199, Vol. I, Part A, December 1988.

U.S. Department of Energy, "Study Plan for 'Relevant Earthquake Sources'," Office of Civilian Radioactive Waste Management, Study Plan No. 8.3.1.17.3.1, July 1990. [Prepared by the U.S. Geological Survey.]

U.S. Department of Energy, "Study Plan for 'Historical and Current Seismicity at Yucca Mountain'," Office of Civilian Radioactive Waste Management, Study Plan No. 8.3.1.17.4.1, November 1991. [Prepared by the U.S. Geological Survey.]