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PROPOSED STAFF POSITION ON
THE CONCEPT OF TECTONICALLY SIGNIFICANT FAULT

PURPOSE:

The purpose of this handout on the concept of tectonically significant fault is to provide points for discussion at the DOE-NRC Technical Exchange on Significant Fault. The staff considers the concept of tectonically significant fault to be consistent with the requirements in 10 CFR 60 and the associated Statement of Considerations.

SCOPE:

The draft position on the concept of tectonically significant fault is applicable to fault related discussions in DOE's Site Characterization Plan, study plans, and activities and NRC's comments on DOE's Site Characterization Plan (NUREG-1347). This draft position addresses those aspects of faults and/or faulting that are related to seismicity and fault displacement. The level or degree of investigations of faults will be discussed in a technical position in preparation on the Methods of Seismic Hazard Investigation.

INTRODUCTION:

One observation derived from the staff's review of the SCP and participation in the tectonics technical exchanges was that there appears to be a gap between what the NRC staff considers as adequate characterization of faulting and the plans for characterizing faults as presented in the Site Characterization Plan (SCP). The staff's concern generally relates to the characterization parameters that DOE has used in the tectonics program presented in the SCP and the perception on the part of the staff that all faults of significance to the repository may not be evaluated. This perception is the result of apparent weaknesses in the characterization parameters for preclosure and postclosure fault investigations. Part of this gap may be the result of the level-of-detail provided in the SCP, however, the staff considers that the gap is greater than that expected from ambiguities in the SCP.

In an attempt to close the apparent gap between the NRC staff and DOE, the staff has developed an approach to designating those faults or fault zones that might be of significance to the repository and require characterization. This approach encompasses the staff's views on the definition and implementation of the concept of tectonically significant or active fault which, for the purposes of this discussion, are considered to be equivalent terms.

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CURRENT STATUS:

At the present time, two definitions for "active fault" exist on the regulatory table. One was proposed by DOE in a letter from D. Vieth to Project personnel. That definition is:

> "a fault that has slipped in historic or during Holocene (approximately the last 10,000 years) time, and that is, therefore, expected to have renewed displacement during some comparable time in the future. In the context of this position paper, slip along an active fault is an anticipated event. In addition to direct historic or geologic evidence of activity, the spatial association of earthquakes with a fault indicates that it is active, although such evidence is not certain."

The second definition comes from 10 CFR 960 which states that an active fault is:

> "a fault along which there is recurrent movement, which is usually indicated by small, periodic displacements or seismic activity."

In the SCP, DOE has proposed two additional terms:

> "potentially significant Quaternary faults" - faults within 100 m of FTTS that have apparent Quaternary slip rates > 0.001 mm/yr or that measurably offset materials less than 100,000 yr old (SCP, p. 8.3.1.17-9). [This term is apparently equivalent to the term "significant late Quaternary fault" as used in the SCP and Study Plan 8.3.1.17.4.2.]

> "Significant Quaternary faults in the repository block" - faults in the repository with > 1 m offset of Quaternary materials or with > 100 m offset of Tertiary rocks (SCP, p. 8.3.1.17-10).

The definitions for "active fault" presented above are not consistent with the U.S. Geological Survey's criteria for recognizing an "active fault" (Hays, 1980; see Appendix 1 to this draft position) nor do they match the concepts of significant fault outlined in the SCP (see above). Generally, these definitions for "active fault" are not considered comprehensive enough to provide for adequate characterization of faulting.

Both of the terms defined in the SCP are used as characterization parameters in the performance allocation process to drive preclosure and postclosure tectonics characterization efforts by defining the required fault investigations. The staff considers that the interdependence of data collection activities associated with pre- and

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postclosure fault investigations necessitate common criteria for preclosure and postclosure fault investigations. Under the current characterization process, uncertainties involved with detecting offset along faults of up to several meters, and uncertainties related to the accuracy and precision of age dating techniques in defining late Quaternary stratigraphic units used to accurately determine offset, result in considerable confusion as to which faults will actually be characterized. In the review of the SCP, the staff has commented on the use of the SCP characterization parameters indicating that:

> "The NRC does not consider that DOE has presented a justifiable basis for the use of 100,000 years as a base age to determine if the offset is significant. The basis for most information within 10 CFR Part 60 is the Quaternary, and other similar nuclear facilities such as those licensed under 10 CFR 72 have used Appendix A criteria for determining the significance of fault activity (i.e., once in 35,000 years or more than once in 500,000 years)" (SCA Comment # 60); and
>
> "The NRC staff is uncertain as to what is meant by the term 'potentially significant Quaternary faults.' The NRC staff considers that until site characterization is complete, the interrelationship of faults is known, the interrelationship of site parameters to design parameters has been established, and the potential effect of the various faults on meeting the various performance objectives has been determined, the staff cannot determine what faults are potentially significant" (SCA Comment # 64).

In the opinion of the staff defining and using the characterization parameters as specified in the SCP could result in a less than adequate job of characterization of faulting. As a result, the characterization efforts might possibly provide inadequate input into design bases and performance assessments.

With this document, the staff is providing to the DOE an acceptable approach for the consideration of faults in the geologic setting that require characterization and terms these faults "tectonically significant faults." The concept of "tectonically significant fault" relies on the use of common criteria for defining tectonically significant faults in both preclosure and postclosure activities and is based on 10 CFR Part 60 requirements, past regulatory experience, and on past implementation by scientists working in the field.

PROPOSED GUIDANCE:

1. Definition

The staff considers that a tectonically significant fault is:

Tectonically Significant Fault: A fault that:

1) has had movement within the past two million years; or

2) has seismicity, instrumentally determined with records of sufficient precision, to demonstrate a direct relationship with the fault; or

3) is susceptible to failure in the existing stress field; or

4) has a structural relationship to a fault that meets one or more of the above criteria.

2. Discussion

During characterization, the designation of a fault as a tectonically significant fault can be used as the characterization parameter for both pre- and postclosure investigations of faulting. Following an assessment of existing geologic data and alternative tectonic models for the site, faults within the geologic setting of Yucca Mountain that meet one, several, or all of the criteria listed above would be designated as "tectonically significant faults." Faults that cannot be demonstrated to be either significant or non-significant under the criteria listed above would be assumed to be significant until "proven" otherwise. Faults or fault zones for which it can be demonstrated that they do not meet the criteria for tectonically significant faults (i.e., tectonically non-significant faults) most likely would require no further characterization under the tectonics program, but may require consideration in the determination of and assessment of unanticipated processes and events.

One aspect of "tectonically significant fault" not addressed in the definition is size. In other words, if a fault in the controlled area meets one of the criterion listed above in the definition of "tectonically significant fault," but is only two inches in length, how "significant" can it really be? Based on preliminary performance assessments, this fault and other faults of similar size, could, quite possibly, be designated as "tectonically significant faults, not of regulatory concern" and would require no further characterization. In these cases, the burden is placed on the DOE to justify to the NRC staff the characterization or non-characterization of faults of a particular size based on technical and waste isolation criteria. In

any event, the staff's concept of "tectonically significant fault" is considered to be size independent.

Basis and Philosophy Behind Definition of Tectonically Significant Fault:

The definition of tectonically significant fault is an adaptation of the regulatory term "capable fault" (10 CFR Part 100, Appendix A) modified for use in site characterization for a high-level waste repository. The term "capable fault" has not been used in connection with a high-level waste repository because "capable fault" was originated to help define the hazard posed to nuclear power facilities and thus was developed in a substantially different context than high-level waste repository performance. The term "active fault" is not used in this guidance because "active fault" has the temporal uncertainty as to when a fault is considered active, but more importantly has the inherent tendency to limit characterization of only faults that are considered active, possibly overlooking faults that are determined to be inactive, but likely to fail over the time period of consideration. In contrast to the term "active fault," tectonically significant fault does not rely on various geologic interpretations of active, but provides a straight-forward baseline for determining which faults require characterization. The term tectonically significant fault in no way limits the investigative efforts, but only serves as a starting point for judging whether more detailed study is necessary.

The major difference between the terms capable and tectonically significant fault is that tectonically significant fault embraces a larger time period of consideration when making the determination that a fault is one of significance. Specifically, faults are considered as capable if they have moved once in the past 35,000 yrs or at least twice in the last 500,000 years or are connected to a capable fault. A fault is considered significant if it has moved once in the past two million years, is connected to a tectonically significant fault, or is susceptible to failure in the current stress regime. While the definition of tectonically significant fault appears to imply that there is a more stringent concept being applied than that required by capable fault, that appearance is largely the result of the differing context in which the two terms are used. Specifically, while the time increment for designation as a tectonically significant fault is longer than that prescribed by the definition of capable fault, the concept of capable fault was much broader. Capable fault was used as a characterization tool, a design criteria tool, and a site suitability tool, with established practices under which nuclear power station sites that include capable faults are not considered suitable (SECY-79-300). In contrast, the concept of tectonically significant fault as defined here provides only part of the information in the initial step of assessing site suitability, that is, the characterization phase. The definition of a tectonically significant

fault serves only as a measure (i.e., characterization tool) to describe the basic fault element requiring characterization.

The definition of "tectonically significant fault" considers the Quaternary (i.e., the past two million years) Period as the basic time increment for the determination of fault significance to preclosure concerns. The staff does not believe that the use of this time increment as a baseline for characterization is unusual or unnecessarily conservative. While the staff recognizes the importance of the late Quaternary record in assessing the hazard related to faulting (Allen, 1975), the use of the entire Quaternary record in characterization activities for the preclosure attempts to capture sentiments such as those expressed by Allen (1975) who indicates that "...the distribution of faults with Quaternary displacements seems to be a valid general guide to modern seismicity" and "... understanding the Quaternary period is much more important than understanding earlier periods, and this is where attention should first be concentrated."

Past usage of the Quaternary record as the basic time increment for judging the significance of faults has not been uncommon. Specifically, Hays (1980, after Cluff, 1972) has used the offset of Quaternary deposits as an indication that a fault is "active." In addition, Rogers and others (1987) have attempted to correlate historical seismicity in the Yucca Mountain area with known Quaternary faults. DOE has also used the Quaternary record for definition of fault hazard by relying on the determination of Quaternary slip-rate (8.3.1.17-7). Therefore, in attempts to characterize the hazard to repository elements posed by faulting for determining input into the design for these elements, the Quaternary period does provide a justifiable and conservative time increment of geologic time to be studied. The staff suggests that the term "potentially significant late Quaternary fault" be abandoned in the context of fault characterization.

The definition of "tectonically significant fault" also incorporates a criterion that a fault is "significant" if it is susceptible to failure in the present stress regime. This criterion reflects situations such as those at Yucca Mountain where the present stress regime is interpreted to suggest that favorably oriented faults are in a state of incipient failure (Stock and others, 1985). Support for using this criterion in the assessment of tectonically significant faults is also provided by Rogers and others (1987) who indicated that faults in the region with azimuths ranging from about north to east-northeast should be considered favorably oriented for activation in the current stress regime.

Characterization of the movement history of tectonically significant faults to establish whether temporal or spatial clustering of fault activity is of importance to the repository, may necessitate an

assessment of the pre-Quaternary movement history. The definition of "tectonically significant fault" is in no way intended to preclude an examination of the pre-Quaternary record. The burden is on the DOE to justify the need or lack of need for an examination of the pre-Quaternary record of fault movements.

REFERENCES CITED:

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Hays, W.W., 1980, Procedures for estimating earthquake ground motions: U.S. Geological Survey Professional Paper 1114, 77 p.

Rogers, A.M., Harmsen, S.C., and Meremonte, M.E., 1987, Evaluation of the seismicity of the southern Great Basin and its relationship to the tectonic framework of the region: U.S. Geological Survey Open-File Report 87-408.

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U.S. Nuclear Regulatory Commission, SECY-79-300, "Identification of Issues Pertinent to Seismic and Geologic Siting Regulation, Policy, and Practice for Nuclear Power Plants," April 27, 1979.

U.S. Nuclear Regulatory Commission, NUREG-1347, "NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain, Nevada," August, 1989.

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Appendix 1

Active Fault (after Hays, 1980): indicated by young geomorphic features such as: fault scarps, triangular facets, fault rifts, fault slice ridges, shutter ridges, offset streams, enclosed depressions, fault valleys, fault troughs, sidehill ridges, fault saddles; ground features such as: open fissures, mole tracks and furrows, rejuvenated streams, folding or warping of young deposits, ramps, ground-water barriers in recent alluvium, echelon faults in alluvium, and fault paths on young surfaces. Usually a combination of these features is generated by fault movements at the surface. Erosional features are not indicative of active faults, but they may be associated with some active faults. Stratigraphic offset of Quaternary deposits by faulting is indicative of an active fault."

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