NUREG–1451

Staff Technical Position on Investigations to Identify Fault Displacement Hazards and Seismic Hazards at a Geologic Repository

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Office of Nuclear Material Safety and Safeguards

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FOREWORD

On August 24, 1989, the Nuclear Regulatory Commission published, in the *Federal Register*, the "Notice of Availability" for the draft Technical Position (TP) on "Methods of Evaluating the Seismic Hazard at a Geologic Repository" and solicited public comments (see 54 *FR* 35266). Approximately 40 comments were received from three different parties. On December 19–20, 1989, the staff conducted the first of two Technical Exchanges with the U.S. Department of Energy (DOE), the State of Nevada, and DOE program participants to discuss the intent of the draft TP and related topics. Following the December 1989 Technical Exchange, and a staff review of the public comments, significant changes and clarifications were incorporated into the draft TP. Staff responses to these comments were documented separately as an appendix to the draft TP.

On February 20, 1991, the NRC staff conducted a second Technical Exchange with DOE to discuss the revised 1989 draft TP and the staff's response to public comments. The State of Nevada; Nye County, Nevada; and the Edison Electric Institute also participated in this Technical Exchange. In light of the additional comments received at the Technical Exchange, and because the revised TP contained significant revisions, the staff decided to make the revised TP available again for public comment.

On May 13, 1991, NRC published the "Notice of Availability" for the draft TP in the *Federal Register* (see 56 *FR* 22020), now renamed "Staff Technical Postion (STP) on Investigations to Identify Fault Displacement and Seismic Hazards at a Geologic Repository" and solicited public comments. As a result, more than 80 comments were received from five different parties. The NRC staff reviewed these comments and, as a result, changes and clarifications were incorporated into the current STP. Staff responses to these comments are documented separately as Appendix E to the current STP.

On December 18, 1991, the NRC staff briefed the Advisory Committee on Nuclear Waste (ACNW) on the revised STP following the end of the public comment period. As a result, the staff received a number of comments from the ACNW. The staff's responses to these comments are documented separately, as Appendix F to the current STP.

Also included in the STP is the staff response to a set of comments submitted by DOE after the December 19–20, 1989, Technical Exchange. These comments, dated February 27, 1990, were considered, along with the public comments made on the May 1991 draft STP. Staff responses to DOE's February 27, 1990 comments are documented separately, as Appendix D to the current STP.

Copies of the earlier draft 1989 TP, including the staff disposition of the comments received from the public, and the meeting summaries from the December 19–20, 1989 and February 20, 1991, Technical Exchanges cited above are available for public inspection and/or copying at the NRC Public Document Room.

ABSTRACT

10 CFR Part 60 does not specify the manner in which potential fault displacement hazards and seismic hazards at a candidate site for a geologic repository are to be identified. The purpose of this Staff Technical Position (STP), therefore, is to provide guidance to the U.S. Department of Energy (DOE) on **acceptable** geologic repository investigations that can be used to identify fault displacement hazards and seismic hazards. The staff considers that the approach this STP takes to investigations of fault displacement and seismic phenomena is appropriate for the collection of sufficient data for **input** to analyses of fault displacement hazards and seismic hazards, both for the preclosure and postclosure performance periods. However, detailed analyses of fault displacement and seismic data, such as those required for comprehensive assessments of repository performance, may identify the need for additional investigations.

Section 2.0 of this STP describes the 10 CFR Part 60 requirements that form the basis for investigations to describe fault displacement hazards and seismic hazards at a geologic repository. Technical position statements and corresponding discussions are presented in Sections 3.0 and 4.0, respectively. Technical position topics in this STP are categorized thusly: (1) investigation considerations, (2) investigations for fault-displacement hazards, and (3) investigations for seismic hazards.

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ACKNOWLEDGMENTS

The authors gratefully acknowledge substantial contributions from Michael P. Lee and Philip S. Justus, Division of High-Level Waste Management, which have been incorporated into the text, appendices, and figures of this staff technical position, as well as editorial guidance, from Ellen Kraus.

1 INTRODUCTION

The Nuclear Regulatory Commission's regulations that pertain to the licensing of a mined geologic repository for the disposal of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) are contained in 10 CFR Part 60 (*Code of Federal Regulations*, Title 10, "Energy"). According to 10 CFR Part 60, the applicant for a license to dispose of SNF and HLW shall investigate potentially adverse conditions that may affect the design, operation, and performance of the geologic repository.* 10 CFR Part 60 does not, however, specify the manner in which these potentially adverse conditions are to be identified and analyzed.

The purpose of this Staff Technical Position (STP), therefore, is to provide guidance, to DOE, on appropriate investigations that can be used to **identify** fault displacement hazards and seismic hazards at a geologic repository. The intent of providing such guidance, to DOE, is to help ensure that DOE's solutions to actual or potential geologic and seismic effects at a candidate site would be based on investigations of sufficient detail such that the geologic and seismic characteristics are understood well enough to permit an evaluation of the proposed candidate site, and to provide sufficient information to support any determinations based on these investigations.

(The terms "fault displacement hazards" and "seismic hazards," as used in this STP, are limited to the hazards resulting from fault displacement (i.e., stratigraphic offset) and vibratory ground motion that can affect the design and performance of the geologic repository.)

Guidance on methods of **analysis** of fault displacement hazards and seismic hazards at a geologic repository is being developed separately.

1.1 Background

The objective of investigations described in this STP is to provide information needed for both the identification and analysis of fault displacement hazards and seismic hazards. Knowledge of the fault and seismic characteristics of the site and the region in which the site is located is fundamental to the development of design bases and to the evaluation of the performance of the repository. Consideration of the geologic history of faults that are thought to have the ability to generate displacements and earthquakes, in accordance with criteria described in this STP, should help pinpoint the most severe displacements and earthquakes that can be associated with faults. Likewise, the investigations that provide data for input into the determination of the design basis for the maximum vibratory ground motion should be conducted through evaluation of the geology, seismology, and the geologic and seismic history of the site and the surrounding region. These investigations would include consideration of historically reported or instrumentally recorded earthquakes associated with tectonic structures or with seismic source zones, to assist in identifying the most severe earthquakes associated with these features. An analysis of the information acquired through these investigations should lead to an estimation of the rates of fault slip and of seismic activity.

In general terms, this STP draws on experience gained in applying the concepts in Appendix A of 10 CFR Part 100 (*Code of Federal Regulations*, Title 10, "Energy"), to establish appropriate investigations for providing input for the determination of design basis fault displacement hazards and vibratory ground-motion hazards for a geologic repository. It is emphasized here that this STP **does not adopt** Appendix A of 10 CFR Part 100 for guidance in investigating fault displacement hazards and seismic hazards at a geologic repository. Moreover, Appendix A to 10 CFR Part 100 does not apply to the geologic repository program. A more thorough discussion of the relationship between this STP and Appendix A of 10 CFR Part 100 is provided in Appendix A of this document.

1.2 Scope

The guidance presented in this STP is considered most applicable for candidate sites west of the Rocky Mountain Front, approximately 104° west longitude. Seismic activity can, in general, be better correlated with tectonic structures and seismic source zones in areas west of the Rocky Mountain Front, than can similar activity in areas east of the Rocky Mountain Front, where the surface expression of tectonic structures is more obscure.

1.3 STPs as Technical Guidance

STPs are issued to describe, and make available to the public, methods acceptable to the Nuclear Regulatory Commission staff, for implementing specific parts of the Commission's regulations, and to provide regulatory guidance to DOE. STPs are not substitutes for regulations, and compliance with them is not required. They suggest approaches that are acceptable to the staff for meeting regulatory requirements. Methods and solutions

* 10 CFR Part 60 is structured around the multiple-barrier concept and the Commission's principles of defense-in-depth, and primarily focuses on repository performance. The applicant (the U.S. Department of Energy (DOE)) must demonstrate compliance with the performance objectives of Subpart E of 10 CFR Part 60 in order to have a potential geologic repository licensed. To ensure that such compliance can be demonstrated, 10 CFR Part 60 sets out a number of specific siting and design criteria. Performance issues are, therefore, closely linked with siting and design issues, and the staff position setout herein must be understood in that context.

differing from those set out in the STPs will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission. Published STPs will be revised, as appropriate, to accommodate comments and to reflect new information and experience.

2 REGULATORY FRAMEWORK

There are a number of regulatory requirements in 10 CFR Part 60 that form the basis for investigations to describe the fault displacement hazards and seismic hazards at a geologic repository. For example, the criteria set forth in 10 CFR 60.21(c)(1)(ii) require a description and assessment of the site at which the proposed geologic repository operations area (GROA) is to be located, with appropriate attention to those features of the site that might affect GROA design and performance. The description and assessment called for in 10 CFR 60.21(c)(1)(i–ii) must be in sufficient depth to support the assessment of the effectiveness of engineered and natural barriers called for in 10 CFR 60.21(c)(1)(ii)(D), as well as the analysis of design and performance requirements for structures, systems, and components important to safety called for in 10 CFR 60.21(c)(3).

Elsewhere in 10 CFR Part 60, NRC requirements related to siting, design criteria, and performance establish additional bases for investigations related to fault displacement hazards and seismic hazards. These investigations apply to both the preclosure and postclosure periods of performance. For example, during the preclosure period, according to 10 CFR 60.111, the GROA is to be designed to provide protection against radiation exposures and releases of radioactive material, in accordance with standards set forth in 10 CFR Part 20 (see *Code of Federal Regulations*, Title 10, "Energy"). Also, during the preclosure period, 10 CFR 60.111 requires that the GROA be designed so that the option to retrieve the emplaced radioactive waste is preserved. Section 60.131(b)(1) states that structures, systems, and components important to safety must be designed so that natural phenomena and environmental conditions expected at the GROA will not interfere with necessary safety functions.

It is expected that much of the information needed to support the fault displacement hazards and seismic hazards evaluation required by 10 CFR 60.111 and 60.131(b)(1), for the preclosure period, can also be used to support fault displacement hazards and seismic hazards evaluation for the period after permanent closure, with due consideration given to the uncertainties associated with projections over the much longer period of postclosure performance. Accordingly, the investigations performed to address the requirements of 10 CFR 60.131(b)(1) should be conducted concurrently with investigations to address postclosure performance. These include evaluations of performance under 10 CFR 60.112 and 60.113, as well as evaluations of potentially adverse conditions under 10 CFR 60.122—especially the conditions addressed under 10 CFR 60.122(c)(3), 60.122(c)(4), 60.122(c)(11), 60.122(c)(12), 60.122(c)(13), and 60.122(c)(14).

3 STAFF TECHNICAL POSITIONS

It is the NRC staff's position that the approach to the identification of fault displacement hazards and seismic hazards, defined in detail in succeeding parts of this section, would be acceptable to geologic repository investigations. Further, it is the position of the staff that the approach to investigations for fault displacement and seismic phenomena described in this section is expected to result in the collection of sufficient data for **input** to analyses of the fault displacement hazards and seismic hazards, both for the preclosure period and the postclosure period of performance. However, performance assessments such as those used to demonstrate compliance with the overall system performance requirements (i.e., 10 CFR 60.112) may result in the need for additional investigations beyond those described in this STP.

In acquiring the data on faulting and seismic phenomena, it is possible that the applicant may collect more data than are needed to perform the necessary assessments called for in 10 CFR 60.21(c)(1)(i) and 60.122(c)(2). However, the staff believes that it is better to err on the side of identifying some matters that, on further analysis, are found to be unimportant, than to leave open the possibility that some matters that arguably are significant have been overlooked. The staff considers that any investigative program contingent on probabilistic criteria is subject to this criticism and may, therefore, prove to be inadequate.

An acceptable approach to the identification and investigation of fault displacement hazards is described in Subsections 3.1 and 3.2 and is illustrated in Figure 1. Section 3.3 describes an acceptable approach to the investigation of seismic hazards.

The approach described in Subsection 3.1 leads to the identification of three types of faults:

"Type III" faults: Faults or fault zones either (1) not subject to displacement or (2) subject to displacement, but of such length, or located in such a manner, that they will not affect repository design and/or performance. Consequently, they do not need to be investigated in detail;

"Type II" faults: Faults or fault zones that are candidates for detailed investigation; and

"Type I" faults: Faults or fault zones that are subject to displacement and of sufficient length and located such that they may affect repository design and/or performance. As such, they should be investigated in detail. Only faults that are determined to be "Type I" are of regulatory concern, because it is those faults, both inside and outside the controlled area, that may require consideration in repository design, could have an effect on repository performance, or could provide significant input into models used to assess repository performance.

3.1 Investigation Considerations

The guidance in this section provides the basis for more detailed investigations described in Sections 3.2 and 3.3.

3.1.1 Identification of the Region to be Investigated

The region encompassing features relating to fault displacement hazards and seismic hazards used as the basis for geologic repository investigations should be identified. An acceptable approach would employ the following considerations:

(1) The boundaries of the region to be investigated for fault displacement hazards and seismic hazards should be determined by the geologic setting within which the proposed repository site is located. The geologic setting can be viewed as a hierarchy, with the "geologic setting" element as the uppermost element in the hierarchy (see Figure 2). The geologic setting, as defined in 10 CFR 60.2, encompasses the geologic, hydrologic, and geochemical systems present in the region in which a potential repository site is to be located. These systems can have constituent components (e.g., the "faulting" component of the "geologic" system within the geologic setting). The final definition of the geologic setting would result from the investigation of all of the components of each of the systems that may affect repository design and/or performance.

(2) Faulting and seismicity are interrelated, but separate, components of the "geologic" system, acting within the geologic setting (see Figure 2 and Appendix B). Therefore, the boundary of the region to be investigated for fault displacement hazard (i.e., the boundary of the "faulting" component of the "geologic" system) will in all likelihood not coincide with the boundary of the region to be investigated for seismic hazard (i.e., the boundary of the "seismic" component of the "geologic" system). The

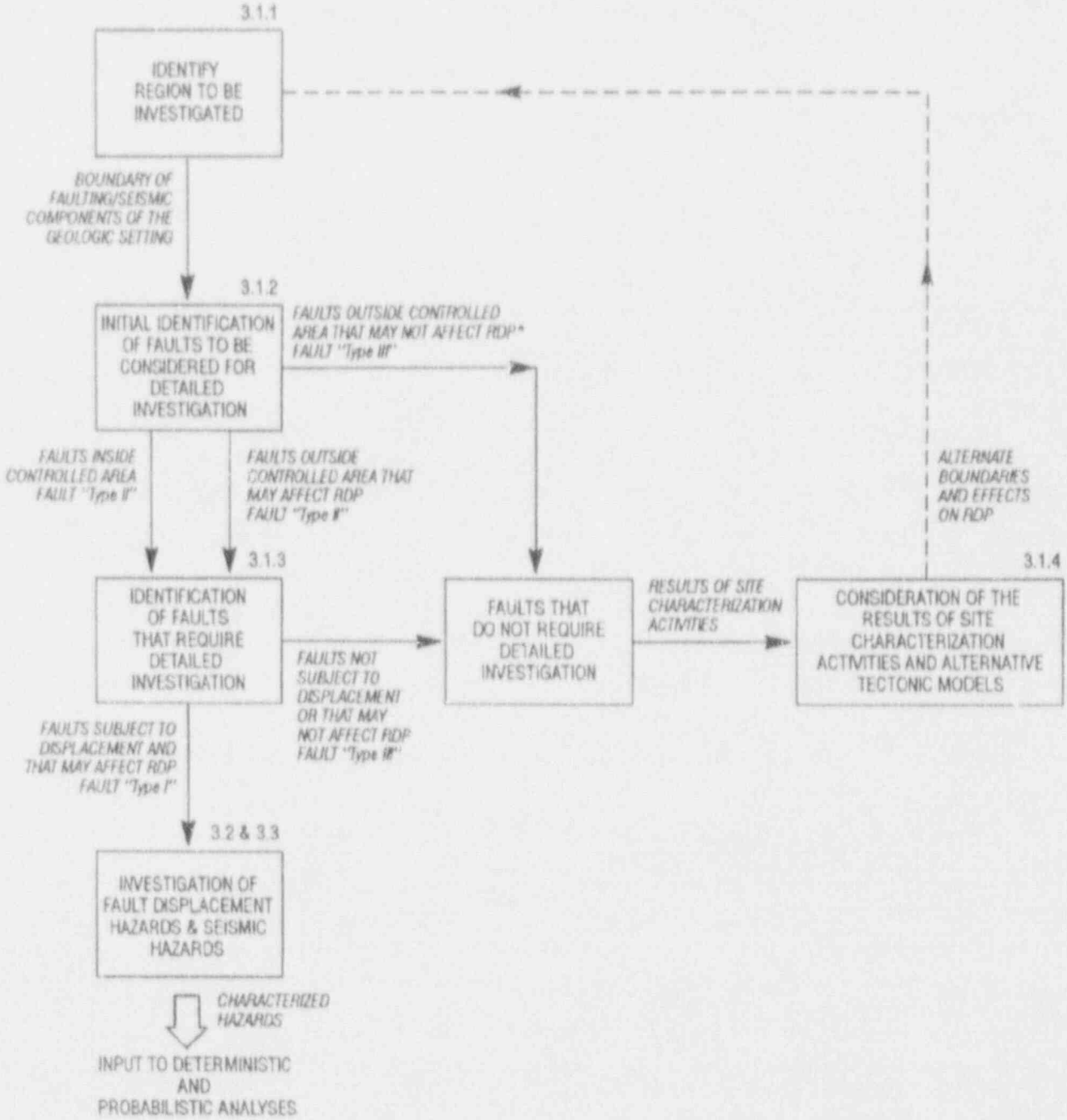
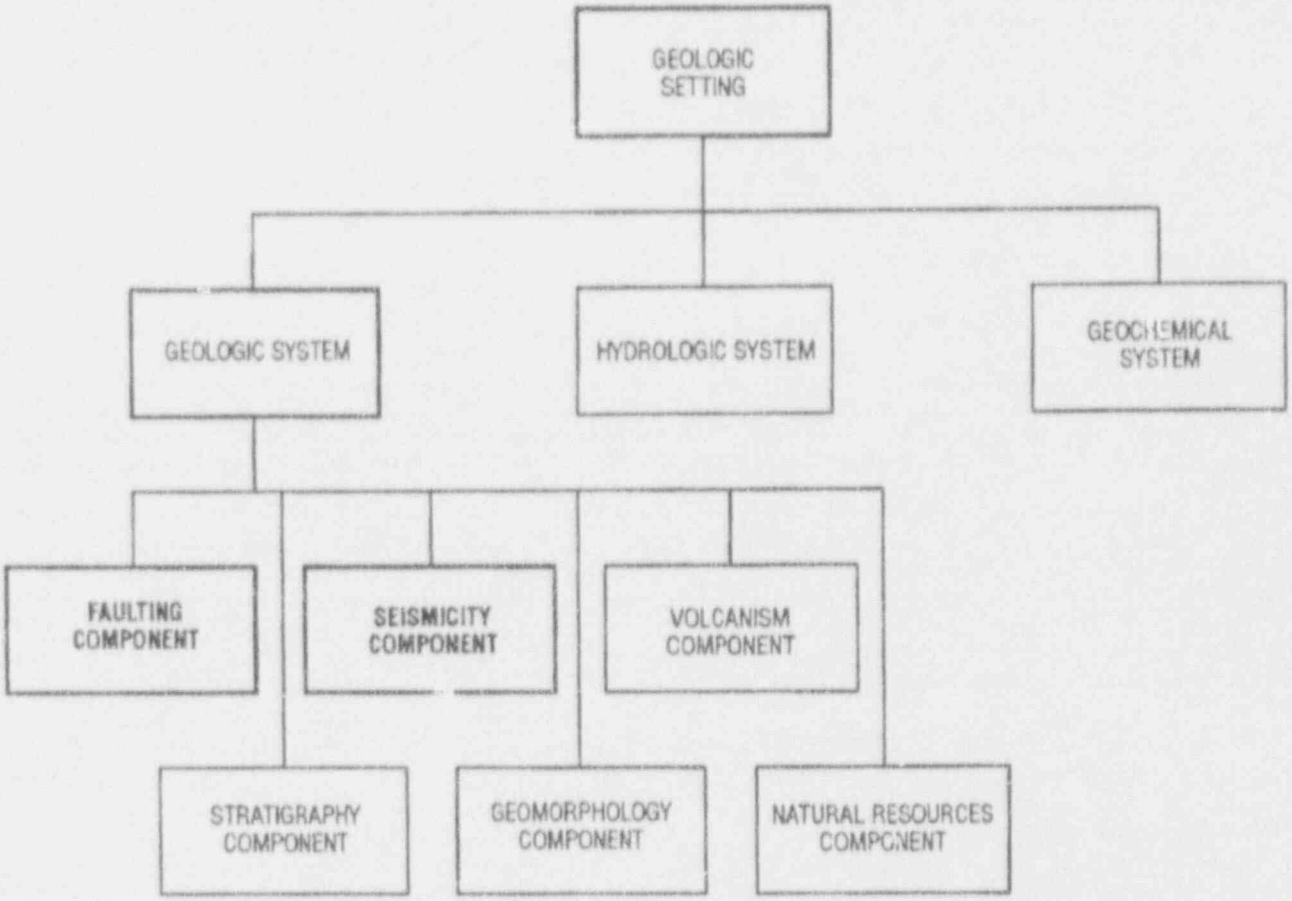


FIGURE 1 — Example of an Acceptable Approach to the Identification of Fault Displacement Hazards and Seismic Hazards. Numbers next to the process blocks correspond to the technical position statements described in the text. See Figure 3 for an expansion of process block 3.1.3.
* "RDP" means reposit ry design and/or performance.



EXPLANATION

The geologic setting consists of the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is located. For the purposes of this STP, the geologic system is divided into:

- a faulting component;
- a seismicity component;
- a volcanism component;
- a geomorphology component;
- a stratigraphy component;
- a natural resources component

Only the faulting and seismicity components are addressed in this STP.

Figure 2 — Hierarchy of Elements in the Geologic Setting.

boundaries of the components should be based on assessments of the potential to affect repository design and/or performance.

(3) In identifying the region to be investigated, the selection of component boundaries for the faulting and seismicity components should be based on a review of the pertinent literature, relevant field investigations, and the consideration of alternative tectonic models.

(4) The results of site characterization should be factored back into the initial identification of the region to be investigated, to ensure that the size of the region is sufficient to permit adequate characterization of the hazards.

3.1.2 Initial Identification of Faults to be Considered for Detailed Investigation

After identifying the region to be investigated, those faults or fault zones in the geologic setting that may require detailed investigation should be initially identified. An acceptable approach would include the following:

(1) If faulting during the Quaternary Period is characteristic of the controlled area, any fault or fault zone, any part of which is inside the controlled area, should be considered as a candidate for detailed investigation (i.e., a "Type II" fault), based on the approach described in Subsection 3.1.3.

(2) Where fault displacement outside the controlled area may affect isolation within the controlled area, faults or fault zones outside the controlled area, but within the geologic setting, should also be considered as candidates for detailed investigation (i.e., "Type II" faults), based on the approach described in Subsection 3.1.3.

An acceptable approach to determining which faults, outside the controlled area, are relevant and material to geologic repository investigations, should be based primarily on assessments of fault length and location. Additional fault characteristics, such as fault (zone) width, may also be considered. Fault length and location can be used as coarse screens to judge when displacement along a fault may require consideration in repository design and in evaluations of performance of structures, systems, and components important to safety, containment, or waste isolation, or may provide significant input into models used in assessing design and performance. The staff considers that initial assessments of which faults outside of the controlled area are relevant and material should be deterministic, but recognizes the utility of probabilistic analyses in supporting these deterministic assessments.

(3) Those faults ou[illegible] area not considered as cand[illegible] nvestigations, according to Ite[illegible]n (i.e., "Type III" faults) will req[illegible]estigation except as outlined in Sub[illegible]

3.1.3 Identification of Faults That Require Detailed Investigation (i.e., The Identification of "Type I" Faults)

After the initial identification of candidate faults to be considered for detailed investigation (i.e., "Type II" faults), those faults or fault zones that require detailed investigation should be identified.

(1) The staff considers that faults that require detailed investigation (i.e., "Type I" faults) are those faults that:

(a) are subject to displacement (see Step No. 1 below); and

(b) may affect the design and/or performance of structures, systems, and components important to safety, containment, or waste isolation; and/or (c) may provide significant input into models used in the design or in the assessment of the performance of structures, systems, and components important to safety, containment, or waste isolation.

(2) The identification of "Type I" faults or fault zones can be described as a two-step process. This process is described below and illustrated in Figure 3.

Only those faults that meet the criteria described in both Step Nos. 1 and 2, below, need to be considered as "Type I" faults and therefore characterized in detail.

Process to Identify "Type I" Faults

Step No. 1: Identification of Faults Subject to Displacement

The primary criterion for the identification of faults subject to displacement is evidence of displacement during the Quaternary Period. Any candidate fault, identified in the screening process described in Subsection 3.1.2, that has evidence of displacement in the Quaternary Period, is considered to be subject to displacement and should continue to be a candidate for detailed investigation.

In cases where the Quaternary record is incomplete or unclear, the following additional criteria should be applied to the candidate faults, to determine if such faults could be subject to displacement. Specifically, in those cases where the Quaternary record is incomplete or unclear, faults are considered subject to displacement if they exhibit one or more of the following criteria:

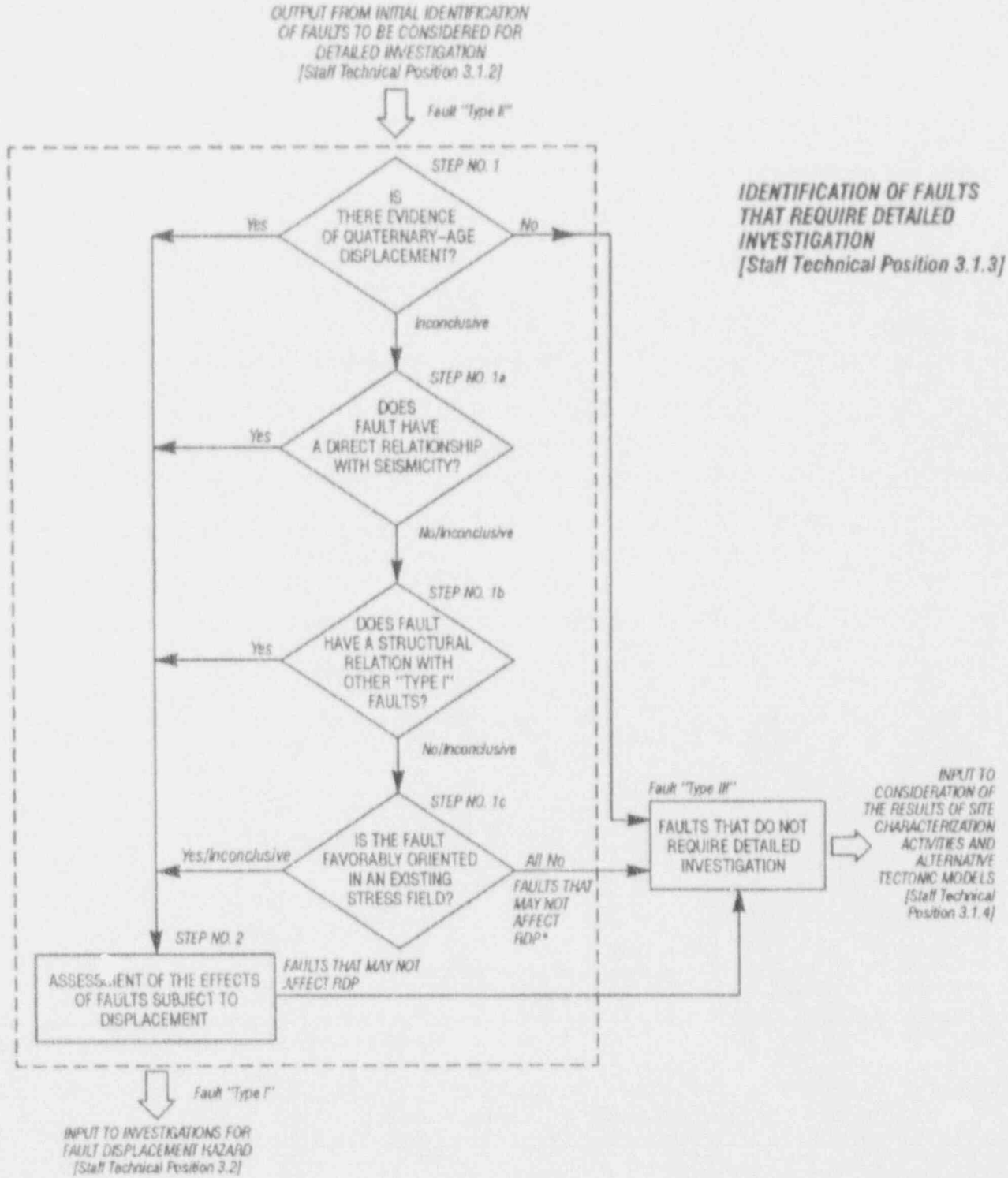


Figure 3 — Staff Technical Position 3.1.3: Detail to the "Approach to the Identification of Faults that Require Detailed Investigation (i.e., "Type I" Faults)". Refer to the text for the discussion of this two-step process. Also see Figure 1.
* "RDP" means repository design and/or performance.

(a) have seismicity, instrumentally determined, with records of sufficient precision, that suggests a direct relationship with a candidate fault, or;

(b) have a structural relationship (i.e., displacement on one fault could cause displacement on another) to a fault that meets one or more of the other criteria (i.e., Quaternary-age displacement or Items (a) and (c)); or

(c) are oriented such that they are subject to displacement in the existing stress field.

For those cases where, after consideration, the technical basis in making a judgment about a particular criterion described above (and shown in Figure 3) is unclear or inconclusive, the next criterion should be considered.

To ensure that faults of potential significance to repository design and/or performance are not overlooked, prudence dictates that, even in cases where no Quaternary-age displacement can be documented along a particular fault, the aforementioned additional criteria in Step No. 1 should be considered.

An acceptable approach to providing the information necessary for evaluating the criteria indicated in Step No. 1 would include:

(a) investigation of geologic conditions within the boundaries of the component, such as lithology, stratigraphy, structural geology, stress field, and geologic history;

(b) determination of the existence of Quaternary-age displacement on faults within the component boundaries;

(c) tabulation of each historically reported and instrumentally recorded earthquake that can reasonably be associated with a fault or fault zone, including the date of occurrence, magnitude or highest intensity, and a plot of the epicenter or region of highest intensity; and

(d) consideration of alternative tectonic models for the geologic setting, where the alternative models may indicate that one or more of the criteria in Step No. 1 may apply.

Step No. 2: Assessment of the Potential Effects of Faults Subject to Displacement

Fault length should be used as a measure to assess the possible effects of fault displacement on repository design and/or performance. As fault or fault zone length was applied as a discriminator used for screening faults or fault zones outside the controlled area for further investigation (Item (2) in Subsection 3.1.2), length also can be considered in determining which faults or fault zones inside the controlled area continue to be relevant and material to geologic repository investigations. The evaluation should take into account the potential effects of faults on the design and performance of structures, systems, and components important to safety, containment, or waste isolation, or on models used in assessing the design and performance of these structures, systems, and components. DOE should develop technically defensible criteria for identifying what length faults or fault zones, assuming that displacement will occur, may affect repository design and/or performance.

Faults that meet the criteria in Step No. 1, but do not meet the criteria of Step No. 2, are not considered "Type I" faults, but are considered "Type III" faults.

"Type III" faults may require further investigation for reasons described in Subsection 3.1.4.

3.1.4 Consideration of the Results of Site Characterization Activities and Alternative Tectonic Models

The process of determining which fault displacement and seismic phenomena are relevant and material to geologic repository investigations is iterative. Therefore, faults that were eliminated from further consideration during early evaluations described in Subsections 3.1.2 and 3.1.3 (i.e., "Type III" faults) should be subject to periodic reevaluation, based on the results of subsequent site characterization activities, development of alternative tectonic models for the site or region under consideration, and iterative assessments of performance.

3.2 Investigations for Fault Displacement Hazards

After identification of "Type I" faults, consideration should be given to the detailed investigation of "Type I" faults. The investigations described in this section should provide sufficient data for **input** to analyses of the fault displacement for both the preclosure and the postclosure periods of performance.

(1) an acceptable approach to the detailed investigation of "Type I" faults or fault zones should include:

(a) a description of the character of the fault or fault zone, including its three-dimensional geometry (e.g., geometry determined using geophysical and/or borehole techniques);

(b) a description of the relationship of the fault or fault zone to other tectonic structures in the

controlled area and within the boundaries of the component(s);

(c) nature, magnitude, and geologic history (e.g., slip rates) of displacements along the fault or fault zone, including particularly the estimated Quaternary-age displacement. For each event, the length of rupture, amount of displacement, and area of rupture surface should be described;

(d) correlation of hypocenters, or locations of highest intensity, of historically reported and instrumentally recorded earthquakes with faults or fault zones, any parts of which are within the component boundaries; and

(e) consideration of alternative tectonic models at the scale of the controlled area or larger area, as they may affect alternative interpretations of the character and significance of "Type I" faults.

(2) These investigations apply to both "Type I" faults expressed at the surface and those with no surface expression (i.e., those faults identified or inferred in the subsurface).

3.3 Investigations for Seismic Hazards

The investigations described in this section should be conducted to obtain information needed to provide input for the analysis of vibratory ground motion in the vicinity of the proposed geologic repository. In addition to the investigations described in Subsection 3.1.5, an acceptable vibratory ground-motion hazard investigation should include the following:

(1) An assessment of the physical evidence concerning the behavior during prior earthquakes of surficial materials and the geologic substrata underlying the site. The lithologic, stratigraphic, and structural geologic studies are described in Section 3.2.

(2) A determination of the static and dynamic engineering properties of the materials underlying the site, as well as an assessment of the properties needed to determine the behavior of the underlying materials as a result of earthquakes, and the characteristics (such as seismic wave velocities, density, water content, porosity, and strength) of the underlying materials in transmitting earthquake-induced motions to those structures, systems, and components important to safety, containment, or waste isolation.

(3) Tabulation of all historically reported and instrumentally recorded earthquakes that have affected or that could reasonably be expected to have affected the site, including the date of occurrence and the following measured or estimated data: magnitude or highest intensity, and a plot of the epicenter or location of highest intensity. Where historically reported or instrumentally recorded earthquakes could have caused a ground acceleration of at least one-tenth the acceleration of gravity (0.1g) at the site, the acceleration or intensity, and duration of ground-shaking at the site, should also be estimated. (For earthquakes that produce ground accelerations of less than 0.1g, data should be tabulated to the extent necessary to support the values used to ensure that the design incorporates such features as may be needed to achieve the performance objectives.) Where available, the time history for those earthquakes that may be significant in an analysis of liquefaction and other design factors should be provided. (Since earthquakes have been reported in terms of various parameters such as magnitude, intensity at a given location, and effect on ground, structures, and people at a specific location, some of these data may have to be estimated by use of appropriate empirical relationships. Measured data, when available, are preferable to estimated data.) A description and comparison of the characteristics of the material underlying the epicentral location or region of highest intensity, to the material underlying the site, in transmitting earthquake vibratory ground motion, should also be considered.

(4) An estimation of the regional attenuation of vibratory ground motion.

(5) A correlation of epicenters or locations of highest intensity of historically reported and instrumentally recorded earthquakes, where possible, with tectonic structures. Epicenters or locations of highest intensity that cannot be reasonably correlated with tectonic structures should be associated with seismic source zones.

(6) (a) An estimation of which "Type I" faults may be important in the consideration of vibratory ground motion for design. The "Type I" faults that should be considered are those with displacements sufficient to generate an earthquake with the equivalent of 0.1g or greater ground acceleration at the location of the controlled area. "Type I" faults that can produce earthquakes with vibratory ground motion of less than 0.1g at a site will require no additional investigation, under the guidance in this STP, for the identification of vibratory ground motion hazard, except as described in Subsection 3.1.4; and

(b) A determination of the fault parameters, described in Section 3.2, of those "Type I" faults that

may be important in establishing the design basis vibratory ground motion.

It should be noted that vibratory ground motion determinations for a point on the surface, using accepted attenuation functions that are typically derived from surface observations, will generally be conservative for the underground facility beneath the surface point (except for cases of unusual channeling of the motion). However, if "Type I" faults are located such that there is a potential for vibratory ground motion to impact the underground facility, investigations should be undertaken to determine if areas exist, within the underground facility, where vibratory ground motion at depth would be higher than at the surface. Vibratory ground-motion should also be monitored as early as possible during the site characterization phase, both on the surface above the proposed underground facility and at the level of the proposed underground facility itself, to observe possible differences in the motion between these locations. Observed differences may be used, in conjunction with analytical techniques, to estimate the vibratory ground motion attenuation with depth.

4 DISCUSSION

The Nuclear Waste Policy Act of 1982, as amended, and 10 CFR Part 60 require that DOE conduct a program of site characterization to obtain the data necessary to support a potential license application to construct and operate a geologic repository. Although 10 CFR Part 60 does not specify the manner in which the site characterization process (e.g., the collection of data) must be conducted, it does contemplate that the geologic setting must be adequately investigated (10 CFR 60.21(c)(1)), including the extent to which a potentially adverse condition may be present and still be undetected (10 CFR 60.122(a)(2)(i)) and evaluated, using assumptions that are not likely to underestimate its effect (10 CFR 60.122(a)(2)(ii)). In addition, 10 CFR 60.122(a)(2) requires site characterization to include identification and evaluation of the significance of any "potentially adverse condition" that might compromise the ability of a repository to isolate wastes.

The staff considers that an acceptable approach to the characterization of those potentially adverse conditions that relate to the identification of fault displacement hazards and seismic hazards (i.e., 10 CFR 60.122(c)(3), 60.122(c)(4), 60.122(c)(11), 60.122(c)(12), 60.122(c)(13), and 60.122(c)(14)) should rely on **deterministic** criteria to determine which faults require detailed investigation. Deterministic criteria provided in this STP include "displacement in the Quaternary Period," and "seismicity associated with the fault," as well as other criteria that relate to fault length and location. The staff considers that the criteria provided in this STP are sufficiently comprehensive in that their implementation is expected to result in the collection of data sufficient to demonstrate that the potentially adverse conditions have been characterized adequately.

In the characterization of potentially adverse conditions such as fault displacement hazards and seismic hazards, the staff considers unacceptable those approaches that would rely on the use of a combination of existing geologic data and expert judgment to set a probabilistic threshold below which a fault would not be considered for detailed investigation. The staff considers such approaches unacceptable because known faults that may be contributors to an adverse condition, but do not meet an estimated probability threshold, may not be investigated during the site characterization phase. In addition, this approach may discourage attempts to find currently undetected faults because of inferences that they would not meet the probability threshold. As a result, the staff considers that the regulatory requirements for the investigation of potentially adverse conditions (i.e., 10 CFR 60.21(c)(1)(i) and 10 CFR 60.122(a)(2)(i)) would not be met.

A significant part of the staff's concern about the use of probabilistic thresholds relates to the potential for misuse of expert judgment. As Bonano *et al.* (1990, p. 46) have noted:

> "Expert judgments should not be considered equivalent to technical calculations based on universally accepted scientific laws or to the availability of extensive data on precisely the quantities of interest .... Expert judgments are sometimes inappropriately used to avoid gathering additional management or scientific information."

In this regard, the staff recognizes that expert judgment will be widely used in a repository performance assessment, but would not consider it acceptable to substitute expert judgment for field or experimental data, or other more technically rigorous information that is reasonably available or obtainable (NRC, 1991b, p. E-11).

A comparison of the probabilistic-threshold-approach vs. the approach described in this STP can be illustrated with the example where a known fault, 1000 feet in length and for which evidence of Quaternary-age displacement is inconclusive, exists in the vicinity of the geologic repository. Existing geologic data and expert judgment might suggest that, due to the absence of evidence of Quaternary-age displacement, this fault has an extremely low likelihood of exceeding a certain amount of displacement during the period of concern. Using the approach that incorporates a probabilistic threshold for determining which faults require detailed characterization, this fault may not require further consideration during the site characterization phase. Using the guidance provided in this STP, however, the significance of the fault in question would be weighed against the other geologic criteria provided. If the geologic factors that are the bases for the criteria suggest that the fault is subject to displacement, the fault would undergo further investigation. The staff considers that the regulatory requirements to investigate potentially adverse conditions, to the extent that they "... may be present and still be undetected" and "... using... assumptions which are not likely to underestimate its effect...," can be achieved in this way.

The above discussion is not intended to imply that the staff considers that probabilistic analyses of fault displacement and seismicity have no place in licensing. On the contrary, the staff considers that, in the analyses of the risk to public health and safety from fault displacement hazards and seismic hazards, deterministic and probabilistic techniques are complementary, and both techniques should be employed.

Given the aforementioned considerations, there are several motivating factors behind the staff's position on an acceptable approach to the identification of fault displacement hazards and seismic hazards at a geologic repository. The suggested approach illustrated in Figure 1 is acceptable because it encompasses a systematic process to: (1) document the identification and assessment of all faults or fault zones within the region identified for investigation; (2) identify those faults or fault zones that are of potential importance to the design and performance of the geologic repository and, as a result, require detailed investigation; and (3) provide for the disposition of those faults or fault zones that are eliminated from further consideration, but that may require reexamination, based on the results of site characterization. The various steps illustrated in Figures 1 and 3 should not be interpreted as an NRC staff suggestion that DOE develop separate evaluation documents corresponding to the particular steps in the process. The process selected and the manner in which the effectiveness of that process is demonstrated are DOE management prerogatives.

The following discussion parallels the list of technical positions given in Section 3.0.

4.1 Investigation Considerations

This section provides supporting discussion for the identification of the region to be investigated and for the identification of faults requiring detailed investigation.

4.1.1 Identification of the Region to be Investigated

The areal extent of the region to be investigated (i.e., component boundary) needs to be of sufficient size such that the geologic and seismic characteristics are understood and described so as to permit evaluation of the proposed site, to provide input for solutions to actual or potential faulting and seismic effects at the proposed site, and to test alternative models of faulting and seismicity applicable to the site.

For the purposes of this STP, these investigations apply to both the preclosure and postclosure performance periods. Accordingly, flexibility is needed to permit the results of ongoing site characterization activities to be factored into establishing the areal extent of the investigations. The determination of the region to be investigated should be considered to be an iterative process, to be addressed throughout the site characterization phase.

4.1.2 Initial Identification of Faults to be Considered for Detailed Investigation

10 CFR 60.122(c)(11) indicates that structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period is a potentially adverse condition if it is characteristic of the controlled area or may affect isolation within the controlled area. The staff considers that if faulting during the Quaternary Period is characteristic of the controlled area, then in order to meet the investigative requirements of 10 CFR 60.122(a)(2)(i) and 60.122(a)(2)(ii), all faults within the controlled area need to be considered as candidates for detailed investigation, as outlined in Subsections 3.1.2 and 3.1.3.

For faults outside of the controlled area that may affect isolation within the controlled area, 10 CFR 60.21(c)(1)(i) provides that the Safety Analysis Report is to include information on subsurface conditions to the extent that it is relevant and material. To satisfy this requirement, the information collected (and submitted with the license application) must include whatever has a natural tendency or capability to influence the decision of the Commission. Consistent with this principle, information should be considered to be material if the NRC staff would or should consider it in reaching a reasoned conclusion with respect to any position it might take as to the adequacy of the license application or the issuance of a license (see NRC, 1976). This STP provides DOE with guidance to assist in assessing, in this context, what information on faults outside of the controlled area is relevant and material. The guidance involves a procedure designed to ensure that the impacts of such faults on design, containment, and isolation within the controlled area are evaluated sufficiently so as to determine which of such faults outside of the controlled area may influence a decision and therefore require further investigation.

4.1.3 Identification of Faults That Require Detailed Investigation (i.e., The Identification of "Type I" Faults)

The concept of a "Type I" fault is based on 10 CFR Part 60 requirements, and builds on past regulatory experience (i.e., the application of Appendix A of 10 CFR Part 100). For purposes of this STP, a "Type I" fault serves only to identify those faults or fault zones that may impact repository design and/or performance and, as a result, should undergo detailed investigation. The term "capable fault," as defined in Appendix A to 10 CFR Part 100, has not been adopted in this STP, because the term "capable fault" was originated to help identify fault-related hazards faced by nuclear power stations, and thus was developed within a substantially different context. In contrast to faults that are identified as "Type I" faults in this STP, "capable fault" has been used as a site suitability tool, with established criteria under which proposed sites for

nuclear power stations could be evaluated for licensability (see NRC, 1975 and 1979).

After an assessment of existing geologic data and alternative tectonic models for a candidate site, faults that meet the criteria listed in Section 3.1.3 would be designated as "Type I" faults.

The identification of "Type I" faults is considered to be an iterative process in that faults discovered during the characterization process must be evaluated using the criteria established in Subsections 3.1.1 through 3.1.4. Furthermore, when evaluations leading to the demonstration that faults do not affect repository design and/or performance are inconclusive under the criteria listed in Subsection 3.1.3, Step No. 2, these faults should be assumed to be "Type I."

Process to Identify "Type I" Faults

Step No. 1: Identification of Faults Subject to Displacement

The approach to identifying "Type I" faults considers the Quaternary Period as the basic time increment for the determination of fault significance. The staff considers that the use of this time increment as a baseline for characterization is reasonable and conservative. Consideration of the entire Quaternary Period in characterization activities is based on requirements of 10 CFR Part 60 and supported by the staff analysis of public comments on the draft rule (see NRC, 1983, p. 373). Based on this analysis, it was concluded that, in regard to the investigation of potentially adverse conditions, "...all that is important is that processes operating during the Quaternary Period be identified and evaluated ...." (48 *FR* 28211) The use of the entire Quaternary record is also consistent with technical views such as those expressed by Allen (1975), who indicated that "...the distribution of faults with Quaternary displacements seems to be a valid general guide to modern seismicity" (p. 1046) and "... understanding the Quaternary Period is much more important than understanding earlier periods, and this is where attention should first be concentrated" (p. 1056). In addition, Hays (1980, p. 10) indicated that "...stratigraphic offset of Quaternary deposits by faulting is indicative of an active fault." Finally, consideration of the record for the entire Quaternary Period is necessary to ensure that faults having long recurrence intervals (i.e., greater than 100,000 years) will be included in the investigation.

The use of the Quaternary Period to identify "Type I" faults does not preclude an examination of the pre-Quaternary geologic record. An assessment of pre-Quaternary movement history may be necessary to establish whether temporal or spatial clustering of fault activity is important to geologic repository investigations.

The approach to the identification of "Type I" faults incorporates a criterion that faults subject to displacement in the existing stress regime need to be considered for detailed investigation. This criterion relates to two separate conditions. The first condition is one in which the existing stress regime is interpreted to suggest that faults trending in certain directions (i.e., favorably-oriented faults) are in a state of incipient failure. An example of this condition occurs at the proposed repository site at Yucca Mountain, where Rogers and others (1987) have 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. The second condition is one in which emplaced waste contributes to possible perturbations in the local stress regime. In the process of identifying faults, the term "existing stress regime" is intended to include the stress regime that will continue to exist in the repository after the emplacement of waste. Therefore, the effect(s) of waste emplacement should be considered in the identification and further study of "Type I" faults.

Step No. 2: Assessment of the Potential Effects of Faults Subject to Displacement

In this step, a second assessment is made of potential impact on repository design and/or performance. The assessments made in this step need to consider fault length, in determining if faults identified in Step No. 1 as being subject to displacement may affect repository design and/or performance or may provide significant input into models used to assess performance. A fault length and location assessment was previously used to eliminate from further consideration those faults outside the controlled area that are not of concern to repository design and/or performance (Subsection 3.1.2).

This STP provides only general guidance on the lengths of faults or fault zones that require detailed investigation. Step No. 2 calls for a demonstration that displacement along faults of a certain dimension, individually, or collectively, if part of a system, will not be a factor in design, will not adversely affect the performance of structures, systems, and components important to safety, containment, or waste isolation, and will not provide significant input into models used to assess performance. Faults that fall into this category are not considered to be in "Type I" and will require no further investigation (i.e., "Type III" faults), except as prescribed by Subsection 3.1.4.

4.1.4 Consideration of the Results of Site Characterization Activities and Alternative Tectonic Models

The initial screening discussed in Subsection 4.1.2, and all subsequent screenings of faults, are considered to be an iterative processes, in that faults determined to require no further consideration under the guidance should be

reconsidered if the results of subsequent site characterization activities indicate that assumptions used in the screening process have changed. Therefore, the approach defined in Technical Position 3.1.4 needs to be implemented in those instances where the results of subsequent site characterization activities indicate that the assumptions used in earlier screening processes have changed.

4.2 Investigations for Fault Displacement Hazards

The results of investigations described in Section 3.2, together with the evaluations described in Section 3.1, should be sufficient to provide input to the determination of fault displacement hazards that needs to be taken into account for the design of structures, systems, and components of a geologic repository, that are important to safety, containment, or waste isolation.

It is unlikely that fault displacement could occur at the surface above an underground facility without also occurring within the underground facility. If, however, faults are encountered in the underground facility, it may be impractical to study such faults in the manner described in Section 3.2. Instead, special attention should be paid to the nature of the fault trace, its extent as observed in other openings, and its orientation relative to the trends of faults identified as "Type I" faults in the vicinity of the underground facility.

4.3 Investigations for Seismic Hazards

A key element driving the investigations for vibratory ground motion is the acceleration value of 0.1g. Using 0.1g as a discriminator to determine the scope of investigations to be undertaken, or the type of information to be gathered, facilitates the use of various relationships between maximum ground acceleration and parameters of interest. It should not be construed that maximum ground acceleration alone provides the necessary input for the consideration of vibratory ground motion in design. A minimum value of 0.1g is reasonable when considering the uncertainties encountered in the earthquake data base, as well as in the various relationships that have been derived for earthquakes and faulting. This value has been cited in a number of regulatory and other guidance documents as a discriminator for the minimum value of consideration for the determination of design basis earthquakes.

Earthquakes that have generated or can reasonably be assumed to generate an acceleration of 0.1g or greater at the site, should be correlated with structures or associated with seismic source zones. In a similar fashion, the faults that should be characterized are those faults that lie within imaginary circles, centered on the location of the controlled area, wherein radii are a function of earthquake magnitude and the vibratory ground motion attenuation determined for the region. Each radius represents the distance at which vibratory ground motion of a particular magnitude earthquake would be attenuated to the equivalent of 0.1g.

It is generally observed that vibratory ground motion at depth is less than that observed on the surface above the underground observation point for sources at some distance from the observation points (Marine, 1982). Obviously, if the underground facility itself contains "Type I" faults, and these faults undergo movement resulting in earthquakes, then a region will exist surrounding the faults where vibratory ground motion might exceed that experienced at the surface. It might be necessary to identify the extent of such zones of potentially higher vibratory ground motion.

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APPENDIX A
RELATIONSHIP BETWEEN THIS STAFF TECHNICAL POSITION AND APPENDIX A TO 10 CFR PART 100

Background

Current Nuclear Regulatory Commission siting and design policy related to geological and seismological hazards for nuclear power stations is contained in Appendix A to 10 CFR Part 100 (*Code of Federal Regulations*, Title 10, "Energy"). In conjunction with the Standard Review Plan for nuclear power stations and other applicable regulatory guides, Appendix A ("Geologic Siting and Design Criteria for Nuclear Power Plants") sets forth a regulatory framework that guides the NRC staff in its evaluation of the adequacy of an applicant's investigations of geologic phenomena and proposed design parameters for nuclear power stations. Also, independent spent fuel storage installations (ISFSIs), monitored retrievable storage systems, and mine-tailings dams for uranium processing mills refer to Appendix A for guidance on faulting and seismic siting criteria.

The staff **has not adopted** Appendix A for guidance on geologic and seismologic criteria for application to geologic repositories. Instead, the staff has opted to develop a Staff Technical Position (STP) that acknowledges differences in function and periods of performance between geologic repositories and other nuclear facilities, and endorses an iterative approach toward compliance demonstration with 10 CFR Part 60 in contrast to the more prescriptive approaches required to meet Appendix A's criteria.

Discussion

Because of site- and design-specific considerations, the language in 10 CFR Part 60 is intentionally non-prescriptive. It leaves to the U.S. Department of Energy responsibility, in the first instance, to determine, among other things, how to site and design the repository. The staff does consider that the Commission's intent, under 10 CFR Part 60, for DOE to select a site with favorable geologic conditions, is consistent with the approach used in siting other nuclear facilities. Moreover, the staff considers that current NRC design policy, as derived from Appendix A to 10 CFR Part 100 (see NRC, 1977), is not applicable to the geologic repository program, considering the character of a geologic repository.

It should be noted that the surface waste-handling facilities designed under 10 CFR Part 60 need not be designed to the same geologic and seismologic criteria as those covered under 10 CFR Part 72 (*Code of Federal Regulations*, Title 10, "Energy"), which incorporates, by reference, Appendix A to 10 CFR Part 100. When preparing 10 CFR Part 72, the staff recognized that the seismic design requirements for ISFSIs could be less restrictive than those for nuclear power stations. However, the staff recognized that ISFSIs would, in most cases, be collocated with nuclear power stations, with a candidate site already analyzed thoroughly. Therefore, the staff chose to reference Appendix A to 10 CFR Part 100 in 10 CFR Part 72, as both a conservative approach and a matter of convenience, because the Appendix A siting and design criteria were the only such regulatory criteria available at the time. Thus, although NRC's regulatory requirements, in 10 CFR Part 60, regarding the siting and design for a geologic repository, are different from those that pertain to the regulatory requirements for other types of nuclear facilities, NRC's health and safety standards for all types of nuclear facilities are consistent with the Commission's defense-in-depth safety philosophy and, accordingly, are considered to provide appropriate levels of protection against radiological hazards.

Future Actions

Although NRC has licensed many nuclear power stations under Appendix A to 10 CFR Part 100, the licensing and adjudicatory difficulties that resulted from the application of Appendix A (see NRC, 1979), and the need to more clearly reflect the current licensing practices, led the NRC staff to consider revision of the requirements and application of Appendix A to 10 CFR Part 100. Under review as part of this reassessment are recommendations that NRC's geological and seismological investigations and design criteria be modified to better reflect the current state-of-the-art in these areas. The staff is closely following the efforts, by NRC's Office of Nuclear Regulatory Research, on the revision of the geologic and seismic siting criteria in Appendix A. The staff expects that any future revisions will focus primarily on the current state-of-the-art in areas of the **analysis of** and **design for** seismic phenomena. This current state-of-the-art would include, among other things, the recognition of probabilistic techniques, to address the uncertainties associated with different parameters used in the analysis of and design for seismic phenomena. However, the staff expects that the revisions currently contemplated will not substantially change the types of information or investigations required under Section IV of Appendix A. Moreover, the staff understands that the revisions to Appendix A will be directed towards nuclear power stations and will **not be considered applicable to geologic repositories**.

Any relevant information forthcoming after the publication of this STP, such as a revision of Appendix A, will be considered and the STP updated, as appropriate.

References

Code of Federal Regulations, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Part 60, Chapter I, Title 10, "Energy."

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APPENDIX B
GLOSSARY

As used in this guidance:

"Controlled Area"* means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure.

"Geologic Setting"* means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

"Geologic System" is the stratigraphic, geomorphic, faulting, seismic, volcanic, and natural resource framework of the area in which a geologic repository is located. Each of the elements of the framework is considered to be a component to the geologic system (e.g., stratigraphic component of the geologic system).

"Faulting Component" means that portion of the earth's crust that needs to be investigated to encompass those faults that might have an effect on repository design and/or performance or provide significant input into models used to assess repository performance due to fault displacement.

"Seismicity Component" means that portion of the earth's crust that needs to be investigated to encompass those earthquakes that might have an effect on repository design and/or performance or provide significant input into models used to assess repository performance due to vibratory ground motion.

"Seismic hazard" is a set of conditions, based on the potential for the occurrence of earthquakes, that might operate against health and safety.

"Seismic source zone" is assumed to be a planar representation of a three-dimensional domain, with similar tectonic features, in which all potential earthquakes occurring will have the same characteristics such as constant spatial and temporal occurrences and identical maximum magnitude (modified from Bernreuter, *et al.*, 1989).

"Site"* means the location of the controlled area.

"'Type I' faults" refers to those faults or fault zones that are subject to displacement and of sufficient length and located such that they may affect repository design and/or performance. As such, they should be investigated in detail.

"'Type II' faults" refers to those faults or fault zones that are candidates for detailed investigation.

"'Type III' faults" refers to those faults or fault zones either (1) not subject to displacement or (2) subject to displacement, but of such length, or located in such a manner, that they will not affect repository design and/or performance. Consequently, they do not need to be investigated in detail.

For definitions of other relevant terms, see 10 CFR 60.2.

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Code of Federal Regulations, Title 10, "Energy."

APPENDIX C
APPLICABLE 10 CFR PART 60 REGULATIONS

§60.21(c)(1)(i–ii)

(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:

(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 geochemical properties and conditions, including pore pressure and ambient stress conditions;

(D) The hydrologic 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 host rock mass and groundwater.

(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 of the favorable and potentially adverse conditions, if present, has been characterized, and the extent to which it contributes or detracts from isolation. 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 affect isolation within the controlled area.

(C) An evaluation of the performance of the proposed geologic repository for the period after permanent closure, assuming anticipated processes and events, giving the rates and quantities of releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

(D) The effectiveness of engineered and natural barriers, including barriers that may not be themselves a part of the geologic repository operations area, against the release of radioactive material to the environment. The analysis shall also include a comparative evaluation of alternatives to the major design features that are important to waste isolation, with particular attention to the alternatives that would provide longer radionuclide containment and isolation.

(E) An analysis of the performance of the major design structures, systems, and components, both surface and subsurface, to identify those that are important to safety. For the purposes of this analysis, it shall be assumed that operations at the geologic repository operations area will be carried out at the maximum capacity and rate of receipt of radioactive waste stated in the application.

(F) An explanation of the 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.

§60.21(c)(3)

[The Safety Analysis Report of the license application shall include:] (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.

§60.111 Performance of the geologic repository operations area through permanent closure.

(a) Protection against radiation exposures and releases of radioactive material. The geologic repository

operations area shall be designed so that until permanent closure has been completed, 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 of this chapter and such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency.

(b) Retrievability of waste. (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that 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, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area before the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

§60.112 Overall system performance objective for the geologic repository after permanent closure.

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

§60.113 Performance of particular barriers after permanent closure.

(a) General provisions—(1) Engineered barrier system. (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW 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. For disposal in the saturated zone, both the partial and complete filling with groundwater of available void spaces in the underground facility shall be appropriately considered and analyzed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 60.113(b) provided, that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1 percent of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

(2) Geologic setting. The geologic repository shall be located so that pre-waste-emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

(b) On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period or pre-waste-emplacement groundwater travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied. Among the factors that the Commission may take into account are:

(1) Any generally applicable environmental standard for radioactivity established by the Environmental Protection Agency;

(2) The age and nature of the waste, and the design of the underground facility, particularly as these factors bear upon the time during which the thermal pulse is dominated by the decay heat from the fission products;

(3) The geochemical characteristics of the host rock, surrounding strata and groundwater;and

(4) Particular sources of uncertainty in predicting the performance of the geologic repository.

(c) Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

§60.122(a)(2) Siting Criteria. [Selected requirements considered directly or indirectly related to seismic hazard]

(2) If any of the potentially adverse conditions specified in paragraph (c) [60.122(c)] of this section is present, it may compromise the ability of the geologic repository to meet the performance objectives relating to the isolation of waste. In order to show that a potentially adverse condition does not so compromise the performance of the geologic repository, the following must be demonstrated:

(i) The potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still undetected, taking into account the degree of resolution achieved by the investigations; and

(ii) The effect of the potentially adverse human activity or natural condition on the site has been adequately evaluated using analyses which are sensitive to the potentially adverse human activity or natural condition and assumptions which are not likely to underestimate its effect; and

(iii)(A) The potentially adverse human activity or natural condition is shown by analysis pursuant to paragraph (a)(2)(ii) of this section not to affect significantly the ability of the geologic repository to meet the performance objectives relating to the isolation of waste, or

(B) The effect of the potentially adverse human activity or natural condition is compensated for by the presence of a favorable combination of the favorable characteristics so that the performance objectives relating to the isolation of the waste are met, or

(C) The potentially adverse human activity or natural condition can be remedied

§60.122(c) Potentially adverse conditions. [Selected conditions considered directly or indirectly related to seismic hazard]

(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 ....

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional groundwater flow system....

(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

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

(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

§60.131(b)(1) Protection against natural-phenomena and environmental conditions. [With respect to the general design criteria for the geologic repository operations area.]

(b) Structures, systems, and components important to safety—(1) Protection against natural phenomena and environmental conditions. The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.

APPENDIX D
DISPOSITION OF DEPARTMENT OF ENERGY (DOE) COMMENTS DATED FEBRUARY 27, 1990*

Note: "Technical position" (TP) refers to the public comment draft TP, dated August 24, 1989 (54 *FR* 35266), and "STP" refers to the current Staff Technical Position, dated May 13, 1991 (56 *FR* 22020).

DOE COMMENTS

1. We continue to believe that additional regulatory guidance on data needs for seismic hazards is unnecessary because the Department's published plans for acquiring and analyzing earthquake-related data and for demonstrating compliance with the performance criteria of 10 CFR Part 60 are adequate and will ensure a safe seismic design. However, our objections to the draft Technical Position (which have been detailed in letters dated 9/20/89** and 11/3/89 [DOE's November 1989 comments are contained in Appendix C of the May 13, 1991, draft STP], and are not repeated here) are mostly specific to that document. If, after our recent Technical Exchange on the subject, the staff remains convinced that additional guidance is needed, we would like to suggest that the staff consider recasting the draft Technical Position as an "acceptance criteria" for seismic hazards analysis as part of documentation needed to support a license application. Items to be explicitly addressed might include, for example:

   Alternative tectonic models;
   Identification of significant Quaternary faults;
   Criteria for determining which faults or features to characterize;
   Subsurface fault geometries;
   Fault segmentation;
   Fault lengths and widths;
   Fault slip rates;
   Displacements associated with discrete faulting events;
   Subsidiary faulting;
   Magnitude-frequency relationships;
   Non-Poissonian recurrent models;
   Characteristic earthquakes;
   Maximum-magnitude earthquakes;
   Ground-motion attenuation relationships;
   Ground-motion site effects; and
   Exceedance probabilities for ground-motion parameters.

   It may not be necessary, or possible, to quantify every item, but each could be discussed, at a minimum.

Response

First, the staff does not agree with DOE's position that additional regulatory guidance on data needs for seismic hazards is unnecessary because the Department's published plans for acquiring and analyzing earthquake-related data and for demonstrating compliance with the performance criteria of 10 CFR Part 60 are adequate and will ensure a safe seismic design. In its review of DOE's Site Characterization Plan (DOE, 1988, p. 8.3.1.17–7), the staff noted its concerns with regard to the conservatism of DOE's plans to characterize seismic and faulting phenomena (see NRC, 1989b, pp. 3–6—3–7). In light of these concerns and the lack of progress on the concerns raised by the staff in its evaluation of DOE's review of NRC's Site Characterization Analysis (SCA) (see Bernero, 1991, pp. 77–87), the staff attempted to describe (in the STP) the level of conservatism it thought sufficient, in the context of the regulation, for adequately characterizing fault activity and thus avoiding the potential to underestimate the fault displacement hazards and seismic hazards at the Yucca Mountain site.

The second portion of this comment suggests that "acceptance criteria" be prepared for a number of topics related to the investigation of fault displacement hazards and seismic hazards, if the staff continues to believe that guidance is necessary. The guidance presented in this STP focuses on investigations of fault displacement hazards and seismic hazards and specifies what is considered to be an acceptable approach (or, in essence, the "acceptance criteria" suggested by this comment) for two topics cited in the comment, namely, the "identification of significant Quaternary-age faults," and the "criteria for determining which faults or features to characterize." Development of an approach to address these two topics is considered to be a necessary precursor step that forms the basis for the analysis and interpretation of data derived from site characterization activities.

The suggestion that "acceptance criteria" be prepared on the other topics mentioned in the comment will be

*DOE's additional comments were submitted after its earlier September 20, 1989, comments on the August 24, 1989, public comment draft TP.

**The September 20, 1989, letter stated DOE's concerns with the staff's August 24, 1989, Technical Position (54 *FR* 35266) that the methodologies contained in Appendix A to 10 CFR Part 100 were considered appropriate for 10 CFR Part 60 investigations. The staff has subsequently amended this position by stating that this STP no longer adopts Appendix A to 10 CFR Part 100. See Appendix A of this document for the staff's current position on the relationship of this STP to Appendix A to 10 CFR Part 100.

addressed elsewhere, most likely in a subsequent STP under development at this time.

2. Additional, more general, attributes of an acceptable seismic hazards evaluation might include identification of:

   Conservatisms and non-conservatisms in analyses;
   Parameter uncertainties;
   Sensitivity of hazard estimates to parameters; and
   Anticipated usage of hazard estimates in design.

Response

This suggestion is noted. As previously discussed in the staff response to DOE Comment No. 1, development of an approach to address the identification of fault displacement hazards and seismic hazards is considered to be a necessary precursor that forms the basis for the analysis and interpretation of data derived from site characterization activities. Guidance in the analysis of data related to fault displacement hazards and seismic hazards such as those listed in this comment will be addressed in a subsequent STP under consideration at this time.

References

Bernero, R.M., Office of Nuclear Material Safety and Safeguards, Letter to J.W. Bartlett, U.S. Department of Energy/Office of Civilian Radioactive Waste Management [Subject: "Status of Site Characterization Analysis Open Items"], U.S. Nuclear Regulatory Commission, July 31, 1991.

U.S. Department of Energy, "Chapter 8, Section 8.3.1.17, Preclosure Tectonics," in "Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Center, Nevada," Vol. V, Part B, DOE/RW-0199, December 1988.

U.S. Nuclear Regulatory Commission, "Availability of Draft Technical Position on Methods of Evaluating the Seismic Hazard at a Geologic Repository," *Federal Register*, Vol. 54, No. 163, August 24, 1989a, p. 35266.

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

U.S. Nuclear Regulatory Commission, "Availability of Draft Staff Technical Position; Investigations to Identify Fault Displacement and Seismic Hazards at a Geologic Repository," *Federal Register*, Vol. 56, No. 92, May 13, 1991, p. 22020.

APPENDIX E
DISPOSITION OF PUBLIC COMMENTS ON MAY 13, 1991, DRAFT STAFF TECHNICAL POSITION

Note: Although Nuclear Regulatory Commission staff Technical Positions (STPs) are generic in nature, some of the public comments and the attendant staff responses contained in this appendix are in the context of the candidate site at Yucca Mountain, Nevada. Also, the draft STP referenced here is dated May 13, 1991 (56 *FR* 22020).

ASSOCIATION OF ENGINEERING GEOLOGISTS COMMENTS

The Association of Engineering Geologists (AEG) has reviewed the above referenced staff technical position and is providing comments in accordance with the extended deadline granted by NRC. Review of the STP was performed by two AEG technical committees. The comments from each committee are attached for your review and publication.

A common theme in our comments is the concern with the use of probabilistic techniques. The Engineering Geology Standards Committee comments address the uncertainty of the use of these techniques without regard to region and the availability of historical data. The Seismic Safety Committee comments provide guidance concerning limitations in developing probabilistically-based conclusions.

AEG ENGINEERING GEOLOGY STANDARDS COMMITTEE GENERAL COMMENTS:

1. The iterative process of investigation described in the STP has been used for many years in those cases where new information became available during the course of an investigation. It has been applied in a haphazard way and has contributed to substantial overruns in design and construction costs. Formalizing it in the STP is appropriate and useful.

Response

The staff agrees with this comment. No modification of the STP is requested, and thus no changes are necessary.

2. We are somewhat uncomfortable with the name "susceptible fault," but recognize the desire to avoid using "capable" fault because of its prior usage in Appendix A to 10 CFR Part 100. A "capable" fault is one that is considered "capable" of generating surface rupture or ground motion of significance to a site. Applying this logic to "susceptible faults" would suggest that they are "susceptible" to future surface rupture or generating ground motion. Throughout the STP, "susceptible faults" are described as "faults that are subject to displacement." We are concerned that unique terminology may be developed for different applications (i.e., nuclear power versus radioactive waste disposal) for the same features. The term "significant" or "important" faults may be more appropriate to suggest they are "significant" in the hazard investigation process and may be "significant" in assessment of the suitability of site (i.e., some "significant faults" become "capable faults" upon detailed investigation). We recommend that additional thought be given to this issue.

Response

The staff notes the concerns made in this comment and has given additional thought to the use of the term "susceptible fault" in response to this and other comments. The term "susceptible fault" has been abandoned in the final version of the STP and what might be regarded as a less prejudical categorization scheme has been substituted. However, the logic behind the concept remains the same. Thus, the following discussion addresses the concerns raised by this comment over the "susceptible fault" concept.

As this comment correctly states, the concept of "susceptible faults" considered those faults to be susceptible to future displacement much like "capable" faults described in Appendix A to 10 CFR Part 100 (see Section IV, "Required Investigations," in 10 CFR Part 100, Appendix A (*Code of Federal Regulations*, Title 10, "Energy")) could be assumed to be capable of future displacement. However, the concept of "susceptible faults" is unique in definition and application to a geologic repository. Specific differences between "capable" and "susceptible faults" include: (a) the period used to define "susceptible faults" (the Quaternary Period vs. 35,000 to 500,000 years for "capable faults"); (b) the interest in fault lengths less than those identified for "capable" faults; and (c) the application of a stress field criterion to define "susceptible faults," a criterion that was not used in defining "capable faults."

In previous drafts of the STP, the term "tectonically significant" fault was used to describe what in this draft was referred to as a "susceptible fault." Reviewers criticized the term "tectonically significant fault" because of the concern that the response of the public to the siting of a nuclear facility on, or in the vicinity of, a "significant fault" would unnecessarily prejudice and complicate the licensing process.

For the purposes of a geologic repository, the process used to identify "susceptible faults" clearly and explicitly

defines those faults that are subject to displacement under the geologic conditions at the candidate site and that, assuming displacement does occur, may (due to their location or size) impact repository design and/or performance. Faults are not considered susceptible unless a determination is made that they are of sufficient size or are located in such a manner as to affect repository design and/or performance. No consideration is given to the likelihood of that displacement in the identification of "susceptible faults."

3. We believe that using "the Quaternary Period as the basic time increment for the determination of fault significance" (STP, top of page 17) is appropriate, as stated, to ensure that faults with long recurrence intervals (> 100,000 years) will be included in the investigation. The STP does not, however, provide adequate guidance on the definition of "Quaternary," for use in the context of identifying significant faults. In some instances, datable Quaternary stratigraphy may not be present, or uncertainty may exist about whether an unfaulted layer is 1.8 or 2.0 million years old. This is likely to become a critical issue and should be addressed in the STP.

Response

In the staff analysis of the public comments on the proposed rule (e.g., 10 CFR Part 60), the staff noted the problems in precisely dating (radiometrically) faults of concern to the geologic repository (see NRC, 1983b, p. 373). Rather than attempting to define or quantify the age of the Quaternary Period, the staff noted that what was important was that the U.S. Department of Energy (DOE) identify and evaluate the **processes operating during the Quaternary Period**, so as to enable recent geologic history to be interpreted and to permit near-term geologic changes to be projected with relatively high confidence (48 *FR* 28210). Accordingly, the staff has taken the position that, "for regulatory purposes," the definition of the Quaternary Period is 2 million years (NRC, 1983b, p. 373). In those cases where no datable Quaternary-age stratigraphy is present, the other, subjective criteria (e.g., Step No. 1 in Subsection 3.1.3) are to be used to determine if a fault is subject to displacement.

4. We disagree with the concept that probabilistic techniques should be avoided because they are not sufficiently conservative to be used as determining factors in identifying faults requiring detailed investigation. In fact, the STP is contradictory in this regard by suggesting that a deterministic approach be used to address issues that inherently have statistical variability (e.g., the age of a faulted or unfaulted stratum) or phenomenological uncertainty (e.g., attenuation of ground motion with distance). In some situations, probabilistic assessments may result in overly conservative conclusions. We believe that the most responsible guidance would be to exercise care in formulating and applying probabilistic techniques, where appropriate, to investigations to identify significant hazards. Similarly, care is also needed to appiying deterministic techniques. We believe that deterministic and probabilistic approaches are complementary, and each should be used where appropriate.

Response

The staff recognizes that deterministic and probabilistic approaches are complementary in investigations to identify and evaluate potential geologic hazards to the repository. In a subsequent STP now under development, the staff intends to discuss an acceptable approach to the application of deterministic and probabilistic techniques in the analysis of fault displacement hazards and seismic hazards.

However, the staff does not agree that the STP is contradictory on this matter. The staff considers that in the initial attempts to identify potential hazards and to collect data to provide input into hazard analysis, use of deterministic criteria is the most transparent (i.e., readily understandable) and most effective approach to ensure that relevant data are collected. The staff does recognize, however, the utility of using probabilistic techniques to support deterministic analyses for determining which faults outside the controlled area are of regulatory concern and the STP has been modified to indicate as much.

10 CFR Part 60 requires that potentially adverse conditions relating to structural deformation (including faulting and seismicity) must be adequately investigated to the extent to which the potentially adverse condition may be present and still be undetected (10 CFR 60.122(c)(2)(i)), and evaluated, using assumptions that are not likely to underestimate its effect (10 CFR 60.122(c)(2)(ii)). To meet these requirements, the staff believes that potentially adverse conditions must be investigated, using conservative approaches, so as to permit recent and near-term geologic processes to be well-understood.

The staff believes that knowledge of the existing and future state of geologic conditions at a candidate site for a geologic repository requires thorough investigations of those features that can be measured directly *in situ* or that can be inferred from direct measurements.* Measurements should be required unless there are persuasive reasons to believe that they would not contribute in a

*When direct measurements of repository systems are not possible, 10 CFR 60.21(c)(1)(ii)(F) suggests consideration of the geologic record of the candidate site and analogs with similar geologic structures elsewhere may provide information about the characteristics of the geologic system, such as rates of tectonic processes or disruptive events. However, the applicability of such sources of information will depend on the completeness of the geologic record or on the closeness of the analogy.

meaningful way to the assessments and findings that are necessary for licensing.

By contrast, there are "probabilistic" approaches to the investigation of repository conditions. Unlike the approaches described above, probabilistic approaches rely on numerical estimates to describe the likelihood of a repository condition or event. However, under such an approach, only those conditions or events estimated to have a given probability of occurrence would then be investigated. Such an approach might be reasonable under some circumstances, particularly when there are practical limits on the types or amounts of information that can be collected. However, if a probabilistic approach results in the failure to carry out physical investigations, any assumptions made in characterizing the system may introduce further uncertainties into the assessment. The staff believes that probabilistically-based investigations are subject to this criticism, and that some important matters may be overlooked, especially where the assignments of probabilities involve the extensive use of expert judgment.

In light of these concerns, the staff has questioned the conservatism of probabilistic approaches (NRC, 1989b, pp. 4-53—4-54), as proposed by DOE in its Site Characterization Plan (SCP) (DOE, 1988), inasmuch as they might lead to overly optimistic predictions about the effects of faulting on repository design and/or performance. The staff considers that the use of probabilistic assessments of fault displacement are not a substitute for the collection of data relevant to characterization of the site, especially where such data can be obtained by reasonable means. In particular, in determining which faults require detailed investigation, the staff considers unacceptable the elimination of certain faults or classes of faults from investigations, based solely on an arbitrary cutoff of the likelihood of displacement, as currently proposed by DOE (see DOE, 1988, p. 8.3.1.17-7).

SPECIFIC COMMENTS:

1. At the bottom of paragraph (2) on page 2, reference is made to a companion document for guidance on methods of analyses of fault displacement and seismic hazards. Issues contained in such a document may be more controversial than those expressed in this STP.

Response

The staff agrees with this comment. No modification of the STP is requested, and thus no changes are necessary.

2. At the beginning of the bottom paragraph on page 2, the STP indicates that it is most applicable for sites west of the Rocky Mountain Front, where tectonic features and seismic activity generally can be correlated better than areas to the east. What guidance is given for sites where such correlation is difficult? Furthermore, recent "blind fault" earthquakes in California (e.g., the Coalinga and Whittier Narrows earthquakes) demonstrate that even west of the Rocky Mountains significant faults may not be geomorphically expressed nor can they be exposed by conventional investigative methods, such as trenching.

Response

At the present time, the only candidate site undergoing investigation is west of the Rocky Mountain Front, with no other candidate sites currently being considered. If, in the future, other sites east of the Rocky Mountain Front become candidates for investigation, this STP will be updated to address the concern about the difficulty about the correlation of seismic activity with tectonic features.

The concern about "blind fault" earthquakes lacking geomorphic expression, mentioned in the comment, is addressed by Sections 3.1 and 3.2 of the STP; namely, the identification and investigation of "Type I" faults require consideration of alternative tectonic models for the site. If faults such as blind thrusts or detachments are a part of alternative models for the site, then they must be considered in the identification of "Type I" faults. Specific reference to investigations of this type of fault is given in Section 3.2, where it is stated that "these investigations apply to both 'Type I' faults expressed at the surface and those with no surface expression (i.e., identified or **inferred** in the subsurface)." The identification in the subsurface can be achieved by means of shafts, tunnels, and boreholes, or indirectly, by the use of geophysical techniques and alternative tectonic models.

3. The middle paragraph on page 3 is unclear. It may refer to avoiding significant design and/or performance problems, but it could be interpreted to refer to avoiding fault displacement and seismic hazards. Hazards can be ameliorated; they cannot be avoided.

Response

This comment is noted. NRC's strategic planning assumptions call for the early identification and closure of issues, to the extent practicable, before the receipt of a license application to construct a geologic repository. The principal means for achieving this goal is through informal, pre-licensing consultation with DOE, the State of Nevada, Indian Tribes, and affected units of local government. This approach is designed to attempt to reduce the number of, and to better define, the issues that will be litigated during a potential licensing hearing, by obtaining input to, and striving for consensus, on such issues, from the technical community, or other interested parties.

Thus, the use of the word "avoided" is not meant to suggest that faulting, seismic hazards, and their attendant effects can be avoided *per se* at any candidate site. Rather, the word "avoided" should be considered in the broader context of this paragraph, whose intention is to communicate the staff's expectation that DOE's solutions to actual or potential geologic and seismic effects at a candidate site should be based on investigations of sufficient detail such that the geologic and seismic characteristics are understood well enough to permit an evaluation of the proposed candidate site, and **to provide sufficient information to support any determinations based on these investigations.** The staff believes that this objective is consistent with its broader pre-licensing goals defined previously.

However, the staff appreciates the concerns raised in this comment. Accordingly, the sentence (and paragraph) in question in Section 1.0 ("Introduction") have been revised, and the paragraph now reads as follows:

> "The intent of providing such guidance, is to help ensure that DOE's solutions to actual or potential geologic and seismic effects at a candidate site would be based on investigations of sufficient detail such that the geologic and seismic characteristics are understood well enough to permit an evaluation of the proposed candidate site, and to provide sufficient information to support any determinations based on these investigations."

4. Paragraph (1)(c) on page 7 refers to faults requiring detailed investigation to be those that "will provide significant input into the models used in design." The word "significant" is subjective; what is significant to one person may be trivial to another. Guidance is needed on this issue.

Response

The staff is aware of the confusion that could arise through the use of such subjective terms as "significant." However, the intent of this STP is to reduce the confusion, in this area, by describing a screening procedure that helps evaluate faults that might affect the design and/or performance of a potential repository, and that, therefore, merit further detailed investigation. This STP provides DOE with guidance to help it determine what information is relevant in these assessments.

5. Paragraph (1) on page 11 indicates that ground-motion hazard investigations should include an assessment of the physical evidence concerning the behavior of geologic materials during prior earthquakes. We believe that this cannot be done with a strictly deterministic investigation. Our experience with materials indicates a range of behaviors; the behavior can be assumed to be the mean of the observed behaviors or the mean plus or minus one or two standard deviations. We believe that a responsible method of assessment can be accomplished with a probabilistic technique.

Response

This comment has correctly pointed out that there are many repository parameters for which there is an inherent statistical variability. However, regardless of the variability of these features, they can be measured directly *in situ* or inferred from direct measurements with relatively high confidence.

6. The second paragraph (2) on page 11 indicates that the static and dynamic engineering properties of the site materials should be determined. Again, such "determinations" may be made responsibly with probabilistic techniques because the uncertainty in the range in values due to the inherent variability of geologic materials can be expressed this way.

Response

This comment is noted. See staff response to AEG Engineering Geology Standards Committee Specific Comment No. 5.

7. Paragraph (3) on pages 11 and 12 indicates that all historically reported earthquakes should be tabulated that have affected or could reasonably be expected to have affected the site. Parameters such as magnitude, intensity, epicenter location, estimated ground acceleration, and estimated duration of shaking should also be tabulated. Again, such parameters are not strictly deterministic in nature. Furthermore, six lines from the bottom of paragraph (3), on page 12, [a sentence] acknowledges that some seismic data may have to be estimated by use of appropriate empirical relationships. Empirical relationships are statistical regressions of a dependent variable on one or more independent variables and form the foundation for the probabilistic approach.

Response

With regard to the first portion of this comment, it should be noted that Item (3) of Technical Position 3.3 does request that seismic parameters such as magnitude, intensity, epicenter location, estimated ground acceleration, and estimated duration of shaking be tabulated as part of the analysis of vibratory ground motion.

In consideration of the second portion of this comment, this comment has correctly pointed out that there are many repository parameters for which there is an inherent statistical variability. Regardless of their variability, they can be measured directly *in situ* or inferred from direct measurements with relatively high confidence.

8. Paragraph (4) on page 12 refers to an estimation of the regional attenuation of ground motion. The basis for such an estimation is not stated. Guidance on this issue is needed.

Response

In addition to the investigations described in Subsection 3.1.3, the staff considers the investigations described in Section 3.3 are necessary, to obtain the information needed to provide input to the analysis of vibratory ground motion hazards. For each candidate site, a regional attenuation model needs to be developed. Therefore, the staff believes that there is a need to arrive at an estimate of acceleration at the site.

9. At the bottom of page 12, reference is made to accepted attenuation functions. Attenuation functions are empirical relationships among acceleration, as the dependent variable, and distance, magnitude and site conditions, as the independent variables. These are statistical relationships which have means and standard deviations that can be used in probabilistic analyses of ground motion attenuation.

Response

The staff agrees with this comment. No modification of the STP is requested, and thus no changes are necessary.

Moreover, discussion of the analysis of seismic phenomena is beyond the scope of the STP; however, these issues are the subject of consideration for additional guidance in a companion STP that deals with the analysis of seismic phenomena.

10. At the bottom of the first paragraph on page 13, the instruction is made to use observed differences in ground motion at the surface and ground motion at depth to estimate ground motion attenuation with depth. This is [an] instruction to conduct a statistical analysis of ground motion attenuation which would be needed in a probabilistic assessment.

Response

The staff agrees with this comment. No modification of the STP is requested, and thus no changes are necessary.

Moreover, discussion of the analysis of seismic phenomena is beyond the scope of the STP; however, these issues are the subject of consideration for additional guidance in a companion STP that deals with the analysis of seismic phenomena.

11. At the bottom of page 17 reference is made to consideration of the existing stress regime. Definition of stress regimes is inherently uncertain. Differentiating existing and paleo-stress regimes is particularly difficult; guidance is needed on this issue.

Response

The staff agrees with this comment. The text in Section 3.1.3 has been changed to be less restrictive in the application of criterion related to the definition and differentiation of existing and paleo-stress regimes. The STP now indicates that the Criteria a–c in Step No. 1 of Subsection 3.1.3 are secondary criteria to be applied only in those cases where the data on a particular fault are inconclusive with respect to the occurrence of Quaternary-age displacement.

AEG SEISMIC SAFETY COMMITTEE SPECIFIC COMMENTS:

1. **Subsection 3.1.3., Item (2), Step No. 2**

   Some consideration may be appropriate to allow for faults that cannot be found, as was the case at Coalinga. Seismic zones are appropriate in areas of faults as well as in areas, such as eastern United States, where the faults are not known though earthquakes have occurred.

Response

See staff response to AEG Standards Committee Specific Comment No. 2.

2. **Subsection 3.1.4**

   The statement that faults "should periodically be reconsidered" is vague.

Response

The staff notes this comment and is aware that the statement referred to could be considered as "vague." However, the staff has attempted to constrain what is meant by the phrase "should periodically be reconsidered" by indicating that reconsideration of faults in relation to repository design and/or performance should be based on the results of site characterization activities that suggest that the prior assumptions may have changed.

3. **Section 4.3**

   "Radius" implies a point source for vibratory ground motion. Some other expression is needed for a fault source.

Response

The staff notes this comment. Fault sources can be a point source, a line source, or an area source. The radius

described here refers to the closest point to the site from any of these fault sources.

4. **Appendix C**

The most disturbing part of the STP is in Appendix C, specifically in the DOE comments. The DOE insists on probabilistic procedures, not once but **eighteen times**:

page 40: 2nd paragraph
page 41: 1st paragraph, 2nd sentence
page 42: 3rd paragraph, 3rd sentence
page 43: 2nd paragraph
page 44: 1st paragraph, 4th sentence; 2nd paragraph
page 46: 5th and 6th paragraphs
page 47: 3rd paragraph
page 49: 2nd and 3rd paragraph
page 50: 1st paragraph
page 51: 4th paragraph
page 52: 2nd paragraph
page 56: 3rd, 4th, and 5th paragraphs (5th paragraph continued on page 57)
page 61: Section 16—References

DOE is pushing probability theory awfully hard. The AEG regards their stand as unfortunate because the latest knowledge suggests that probability theory is a great deal less satisfactory than what they claim it to be. Some of the difficulties in probability theory are as follows:

(a) There are serious problems with b-lines. Fault mechanisms for generating earthquakes involve: (1) **stick-slip**; (2) **phase lock**; and (3) **thermodynamic slip**. Stick-slip relates well to b-lines; phase lock does not, especially where there are **characteristic** earthquakes; and thermodynamic slip deviates powerfully from b-lines. Thermodynamic slip affects the large earthquakes ($M > 6$) that are of the greatest concern in engineering. The applicability or nonapplicability of the b-line is crucial since its use for predicting time-dependent recurrences of large earthquakes makes it the heart of seismic probability theory;

(b) The way multiple earthquakes are combined to get peak motions in the probability method makes the results too crude for use today, in sophisticated dynamic analyses requiring representative accelerograms, because those accelerograms need to represent earthquakes as they might happen, and not earthquakes that are smeared together;

(c) What is being learned of paleoseismic events is that they do not project through space and through time with a linear uniformity, thus they are not suitable for repairing the insufficiencies of data affecting b-lines; and

(d) Finally, there is the statistical absurdity of taking an uneven seismic record of about 150 years and giving it a probabilistic projection to 10,000 years as is contemplated for hazardous nuclear waste sites.

Unfortunately, views that highlight the uncertainties in probability theory do not appear to be getting a hearing. The AEG asks the NRC to be as objective as possible in examining these extremely important questions.

Response

The staff notes the concerns raised by this comment. In response to the concern raised by this and other commentors, the staff has modified the discussions in Sections 3.0 and 4.0 of this STP to further clarify the staff views regarding deterministic and probabilistic criteria in the investigation of faulting and seismic phenomena. The staff response to AEG Engineering Geology Standards Committee General Comment No. 4 also attempts to address the staff's concerns about the conservatism of probabilistic approaches to the investigation of faulting and seismic phenomena.

DOE COMMENTS

1. DOE proposes that the staff hold in abeyance this STP and other planned STPs on tectonic and seismic issues, for the reasons discussed below.

Although the draft STP has been considerably enhanced with respect to earlier versions, DOE believes that a demonstrated technical basis for the STP is lacking, and that the STP is not needed for regulatory purposes. In addition, the STP could limit DOE's ability to optimize the allocation of resources among site characterization and design efforts with respect to reducing total uncertainty in assessing repository systems performance. DOE appreciates the NRC staff's legitimate concern that the site characterization program provide data that are sufficient to validate models used to predict the performance of potential repository systems, and we are preparing a position paper on earthquake-hazard investigations that will address this issue. In addition, the American Society of Civil Engineers (ASCE) is preparing a Guideline for High-Level Waste Repository Seismic Design, and the U.S. Nuclear Regulatory Commission's Office of [Nuclear Regulatory] Research is revising the seismic and geological siting criteria for

nuclear power plants. We hereby propose that the NRC staff hold in abeyance the subject STP and planned STPs on tectonic and seismic issues until these documents have been issued and then re-evaluate the need for the STP.

Response

The staff disagrees with the first portion of the comment, namely, that the STP lacks a technical basis and is not needed for regulatory purposes. Because of site- and design-specific considerations, the language in 10 CFR Part 60 is intentionally non-prescriptive in the area of site characterization; that is, it leaves to DOE in the first instance the opportunity and responsibility to determine, among other things, how to conduct a program of site characterization. It is also DOE's responsibility to describe, on an iterative basis (10 CFR 60.18(g)), how this process is proceeding. Similarly, NRC (and other interested parties) will have an opportunity to review how DOE is meeting this responsibility, and NRC can then apply its own judgment and provide more specific guidance to DOE, on a case-by-case basis.

In its review of the SCP, the staff had concerns about DOE's plans for the characterization of faulting and seismic phenomena, specifically questioning the conservatism of the approaches to be used by DOE to characterize fault activity. In its Site Characterization Analysis (SCA), the NRC staff cited the potential to underestimate the seismic hazard (see NRC, 1989b, pp. 4-53--4-61), inasmuch as it might lead to overly optimistic predictions about the effects of faulting on repository design and performance. The staff considers that the use of probabilistic assessments of fault displacement is not a substitute for the collection of data relevant to characterization of the site, especially where such data can be obtained by reasonable means. In particular, in determining which faults require detailed investigation, the staff considers unacceptable the elimination of certain faults or classes of faults based solely on an arbitrary cutoff of the likelihood of displacement, as proposed by DOE (see DOE, 1988, p. 8.3.1.17-7). Such an approach is considered unacceptable because ... is likely to result in an incomplete assessment of faulting phenomena at the repository and, as a result, could lead to a significant underestimation of fault displacement hazards and seismic hazards at the Yucca Mountain site.

In light of these concerns and the lack of significant progress in resolving the concerns as raised by the staff in its evaluation of DOE's response to NRC's SCA (see Bernero, 1991, pp. 77-87, the staff attempted to describe (in the STP), the level of conservatism it thought sufficient, in the context of the regulation, for characterizing fault activity and thereby resolving the problem of possibly underestimating fault displacement hazards and/or seismic hazards at the Yucca Mountain site. To the extent that it would respond to the staff's SCA comments, the staff is prepared to discuss with DOE its proposed position paper on earthquake hazard investigations.

As regards DOE's second comment, the staff does not consider that the approach identified in the STP will unnecessarily limit DOE's flexibility to focus its resources, nor will it limit DOE's ability to optimize the allocation of resources among site characterization and design efforts, with respect to reducing total uncertainty in assessing repository systems performance, as the second comment states. Due to the nature of the Yucca Mountain site geology, faulting and seismicity are potentially adverse conditions that must be understood in order to determine site suitability, to provide input to performance assessments, and, later, to support a potential license application. In acquiring the data needed to evaluate faulting and seismic phenomena, it is possible that the applicant may collect more data than are needed to perform the necessary assessments called for in 10 CFR Part 60. The staff believes that it is better to err on the side of identifying some matters which, upon further analysis, are found to be unimportant, than to leave open the possibility that some matters that arguably are significant have been overlooked. The staff believes that using probabilistic criteria as the sole bases for investigations has the potential to overlook some important matters, especially where the assignments of probabilities involve the development of probabilistic cutoffs for faults that will be investigated.

With regard to DOE's reference to the efforts of the ASCE to develop seismic design guidelines for a geologic repository, the staff is always willing to consider new or alternative solutions or approaches on ways to demonstrate compliance with NRC's regulations. These efforts are welcome and the results of these studies, if they are available, will be considered in the development of the STP on the analysis of fault displacement hazards and seismic hazards. However, design considerations are outside the scope this STP and, as such, are not expected to have a direct influence on the investigations required to identify fault displacement hazards and seismic hazards at a geologic repository.

DOE should also be advised that the staff is tracking the efforts by the Office of Nuclear Regulatory Research on the revision of the seismic and geological siting criteria for nuclear power stations (i.e., Appendix A to 10 CFR Part 100).* However, Appendix A to 10 CFR Part 100 is not applicable to a geologic repository, primarily because of the difference in the period of performance between nuclear power stations and a fuel cycle facility such as a

*As part of the reassessment of Appendix A to 10 CFR Part 100, it has been recommended that NRC's geological and seismological investigations and design criteria, such as those contained in Appendix A, be modified to better reflect the state-of-the-art in this area; this current state-of-the-art would include, among other things, the incorporation of probabilistic techniques.

geologic repository, and the difference in risk to the public presented by the two facilities. Therefore, although efforts related to siting criteria for nuclear power stations are being tracked, they do not have a direct influence on the investigations to identify fault displacement and seismic hazard at a geologic repository.

Accordingly, given the lack of progress related to the resolution of the concerns raised by the staff in its review of DOE's SCP, the planned scope of the ASCE seismic design guidelines for a geologic repository, and the scope of contemplated revisions to Appendix A to 10 CFR Part 100, the staff can see no compelling reason not to proceed with the issuance of this guidance at this time.

2. DOE believes that the technical basis for the STP has not yet been demonstrated. The methodology proposed in the STP appears to be based, in part, on a judgment by the NRC staff that the risk to public radiological health and safety would be unacceptable if a fault with certain characteristics was not investigated in detail. Such a fault would be one that: (1) is oriented so that it could theoretically move in the existing stress field and might impact repository performance, even if that fault does not displace Quaternary-age materials; (2) has no apparent correlation with historical seismicity; and (3) has no structural relationship to another fault thought to be subject to displacement. The DOE believes that this apparent *a priori* judgment is highly debatable, and that no technical basis for the approach has been provided.

Response

The staff agrees with the supposition of this comment that the technical basis for this STP rests in the need to provide a conservative approach to the identification of fault displacement hazards and seismic hazards. The staff believes that the approach described in this STP is consistent with the approach that has been applied to the licensing of other nuclear facilities. The comment suggests that the staff considers that "... the risk to public radiological health and safety would be unacceptable if a fault with certain characteristics was [sic] [were] not investigated in detail." This is not the case. Rather, the staff considers that those faults with the potential to affect repository design or performance must be adequately characterized so that the level of risk to public health and safety can be accurately established. In this regard, the staff also considers that the STP provides well-defined criteria for establishing which faults have the potential to affect repository design or performance and, as a result, should be characterized in detail.

3. Another concern of DOE is the explicit rejection by the STP, again without any technical basis, of the use of probabilistic techniques in determining which faults require detailed investigation. DOE has proposed and continues to believe that a combined probabilistic-deterministic approach to earthquake hazard investigations and design-basis development is the most appropriate and is representative of the current state of the art. We note that the revised version of 10 CFR Part 100, Appendix A is likely to endorse a combination of probabilistic and deterministic approaches, as is the ASCE guideline noted above. Therefore, for consistency, publication by NRC of a documented technical basis for rejecting the probabilistic approach should be provided before issuing the STP.

Response

The staff disagrees with this comment. It should be noted that when the issue of probabilistic techniques was recently raised with respect to the application of Appendix A to 10 CFR Part 100 to independent spent fuel storage installations (e.g., 10 CFR Part 72), the Commission noted that "... the use of probabilistic techniques was appropriate as a **site selection** criterion; **it [is] not intended to be used in determining the design ... [of] structures**" due to inadequate development of probabilistic techniques at a site-specific scale (Emphasis added) (45 *FR* 74697). In reaching this conclusion, the Commission also noted that **"...it was not possible to reach consensus among experts on what degree of conservatism in design measures was necessary to offset the uncertainties associated with probabilistic assessments at a specific site"** (*opt. cit.*). (Also see staff response to DOE Comment No. 1.)

4. A key component of DOE's strategy for investigating seismic and other hazards is an iterative approach to site characterization and performance assessment, in which the performance of a potential repository system is analyzed in light of available site information, and the need for more information is assessed in light of remaining uncertainties. This strategy demands a flexible approach to the investigation of earthquake hazards. The deterministic, "susceptible fault" methodology that is proposed in the STP is too prescriptive and would, if implemented, unnecessarily limit DOE's ability to focus its resources on that set of site characterization, performance assessment, and design activities that will most effectively and efficiently reduce uncertainties in the performance of potential repository systems.

Response

The staff does not consider that the approach identified in the STP will "unnecessarily limit DOE's flexibility to focus its resources," as the comment states, nor is in conflict with the iterative approach to performance assessment. Because of the nature of the Yucca Mountain

site geology, faulting and seismicity are potentially adverse conditions that must be understood to determine site suitability, to provide input to performance assessments and, later, to support a potential license application. In its review of the SCP, the staff has noted its concerns with regard to DOE's plans for the characterization of faulting and seismic phenomena, specifically questioning the conservatism of the approaches to be used to characterize fault activity, and in doing so, cited the potential to underestimate the seismic hazard (see NRC, 1989b, pp. 4-53—4-54). In light of these concerns, the staff attempted to describe (in the STP) the level of conservatism it thought sufficient, in the context of the regulation, for characterizing fault activity and thus avoiding the potential to underestimate the seismic hazard at the Yucca Mountain site.

In acquiring the data needed to evaluate faulting and seismic phenomena, it is possible that the applicant may collect more data than are needed to perform the necessary assessments called for in 10 CFR 60.122(c)(2). As previously noted, the staff believes that it is better to err on the side of identifying some matters which, upon further analysis, are found to be unimportant, than to leave open the possibility that some matters, that arguably are significant, have been overlooked.

5. As stated in our letter to you of February 27, 1990 [see DOE comments in Appendix D], we believe that additional regulatory guidance on investigations of fault displacement and seismic hazards is unnecessary because DOE's published plans for acquiring and analyzing fault and earthquake-related data and for demonstrating compliance with the performance criteria of 10 CFR Part 60 are adequate and will ensure a safe seismic design. DOE's position paper referred to earlier will address the concerns expressed by the NRC staff in its comments on the Site Characterization Plan (SCP) and in discussions at the various technical exchanges on tectonics. Previously, the NRC staff has informally expressed the opinion that additional clarification of DOE's program beyond the descriptions in the SCP and responses to NRC comments on the SCP/Consultation Draft and Site Characterization Analysis, might lead to the resolution of several comments and obviate the need to complete several draft STPs on tectonics and seismicity. We would be pleased to discuss with you the focus for the proposed position paper. We would then provide a draft of the position paper to the NRC staff for its consideration and formal comment. DOE agrees with several aspects of the STP, most notably that it does not defer to Appendix A of 10 CFR Part 100 for guidance in addressing fault displacement and seismic hazards at a geologic repository. The proposed guidance on correlating historical earthquakes with geologic structures or seismic source zones now includes a reasonable test for potential significance, the previous 200-mile radius test having been dropped. Review of the current draft of the STP shows that the NRC staff considered and incorporated many of the comments provided by DOE and other parties in previous reviews, including the technical exchange held on February 20, 1991.

Response

As noted in the response to DOE Comment No. 1, the staff does not agree with DOE's assertion that additional regulatory guidance on data needs for seismic hazards is unnecessary because of the Department's published plans for acquiring and analyzing earthquake-related data. The NRC staff is prepared to discuss, with DOE, DOE's proposed position paper on earthquake hazard investigations. However, the staff considers that, to lessen the potential for significant delays to any site characterization program, the issuance of this STP is necessary and appropriate.

6. DOE's primary concern remains the potential significance to siting and design of the proposed concept of "susceptible faults." As indicated by DOE as well as representatives of the State of Nevada and the Edison Electric Institute at the February 20, 1991, Technical Exchange, it is imperative that the role of "susceptible faults" in any future guidance on tectonic models and design be specified before the concept is finalized. One indication of the need to review this related guidance is the statement on page 69 of Appendix C: "The staff is currently considering additional guidance on an acceptable approach to setback of facilities ... from 'susceptible faults' ...." Such potential impacts on design and performance assessments must be considered in determining the appropriateness of the "susceptible fault" concept.

   The concept of "susceptible faults" has not been reviewed by, and is not recognized by, the geologic community. It is a unique NRC concept. As noted by the State of Nevada representative at the February 20, 1991, Technical Exchange, this concept should be submitted for review by a broad range of earth science professionals. This review is essential to legitimize a concept with such potentially significant impacts. Further, the term "susceptible faults" has no regulatory basis or precedent. It would be inappropriate to introduce to the repository program a concept that would undoubtedly be the subject of protracted controversy during licensing proceedings, due largely to its uniqueness.

   Also, the term "susceptible" connotes a high probability for future displacement. In actuality, a fault could meet the criteria for being "susceptible" and have a very low probability of displacement, or even

of being active. Additionally, the term "susceptible faults" could be incorrectly perceived by both the scientific community and the public to be equivalent to "capable" faults, as defined in the reactor siting criteria of Appendix A to 10 CFR Part 100, in essence, a capable fault by another name. Although the STP specifically addresses the differences between these concepts, comparisons are probably unavoidable. DOE recommends that the NRC staff simply refer to "faults that require detailed investigation;" a new nomenclature is not needed.

Response

In response to this and other comments, the term "susceptible fault" has been abandoned and replaced by a new, three-step categorization scheme. Under this scheme, those faults that fall into the category designated as "Type I" faults (see Section 3.0) are those faults that were formerly considered to be "susceptible faults." However, the logic underpinning the identification of faults of regulatory concern has remained unchanged and, as such, the following discussion is provided to address the concerns raised in the comment over the philosophy in question.

The "susceptible fault" concept was introduced by the staff as a means of identifying those faults that are of regulatory concern in the licensing of a geologic repository. Generally, faults that are considered to be of possible regulatory concern to the geologic repository are those faults that are subject to displacement and that may either affect the design and/or performance of structures, systems, and components important to safety, containment, or waste isolation, and/or may provide significant input into models used in assessments of design or performance of structures, systems, and components important to safety, containment, or waste isolation. Faults that meet these criteria were considered previously to be "susceptible faults" and now are designated as "Type I" faults under the guidance given in this STP, and are, in essence, potentially adverse conditions, as defined by 10 CFR 60.122(c)(11).

The criteria used to identify "Type I" faults (e.g., Subsections 3.1.2 and 3.1.3) are regarded as solid technical indicators for defining those faults subject to displacement under certain tectonic conditions. The basic approach used in setting up the criteria has been tested in past regulatory actions for other critical nuclear facilities, and, as such, provides a consistent approach to identifying those faults of regulatory concern. The concept of a "Type I" fault exists in parallel with the concept of capable fault, in that both terms define faults of regulatory concern with respect to specific types of nuclear facilities. The definition and method of application of the terms are different, because they apply to different types of nuclear facilities that have inherently different performance periods and constitute different risks to public health and safety. However, both terms are defined by deterministic criteria for their identification and investigation. The staff believes that the term "faults that require detailed investigation," as suggested by this comment, is not suitable for providing a basis on which to develop future guidance on fault displacement and seismic hazard analysis, because it is so generic that it applies equally well to those faults that may represent conduits or barriers to groundwater flow, or be hosts to economic mineral deposits. The staff considers that understanding the nature of fault displacement is a more immediate and direct concern during the site characterization phase and needs to be specifically identified as such.

Finally, the staff does not consider that complete development of future guidance related to the implementation of "Type I" faults is a prerequisite to the issuance of the STP on the identification of fault displacement and seismic hazards. It is the staff's position that the approach identified in this STP provides a basis for DOE's solutions to actual or potential geologic and seismologic conditions at a candidate site.

Moreover, it should be noted that the "susceptible fault" concept (now "Type I" fault concept), as proposed, has been reviewed by the U.S. Geological Survey, DOE, the State of Nevada, NRC's Advisory Committee for Nuclear Waste, the Edison Electric Institute, and the AEG. The staff considers that this array of organizations represents the relatively broad cross-section of earth science professionals that is requested for the comment. However, it should be noted that published STPs will be revised, as appropriate, to accommodate additional comments and to reflect new information and experience.

7. In conclusion, it is our position that the subject STP is unnecessary given the scope of planned investigations presented in the SCP, a document accepted by the NRC. For this reason, comments beyond those in this letter should not be anticipated. However, if the NRC staff is going to revise and finalize the STP, there are several major concerns that must be addressed. Most notably, a "susceptible fault," both the term and the concept, is unscientific and has no technical basis as currently drafted.

Response

DOE's position with regard to the need for this STP is noted. As regards DOE's first comment that the NRC staff has accepted the SCP, the staff believes that the SCP is a usable document for proceeding with site characterization, **subject to the concerns raised by the staff in its SCA.** In the staff response to DOE Comment No. 1, the staff identified its concerns with regard to the scope of planned investigations presented in the SCP. This discussion is based on the staff's SCA comments (see NRC, 1989b, pp. 4-53 – 4-54) as they relate to the investigation

of faulting and seismic phenomena. (Also, in the staff response to AEG Engineering Geology Standards Committee General Comment No. 4, the staff has discussed the concerns it has on applying probabilistic criteria to the investigation of faulting and seismic phenomena.)

As regards DOE's second comment, there are several major concerns that must be addressed, most notably the "susceptible fault" concept; the staff believes that it has addressed this issue in its response to DOE Comment No. 6.

EDISON ELECTRIC INSTITUTE/UTILITY NUCLEAR WASTE AND TRANSPORTATION PROGRAM (EEI/UWASTE) COMMENTS

By letter dated October 23, 1989, EEI/UWASTE responded to the NRC's draft "Technical Position on Methods of Evaluating the Seismic Hazard at a Geologic Repository" (54 *FR* 35266). [EEI/UWASTE's earlier comments are contained in Appendix C of the May 13, 1991, draft STP (56 *FR* 22020).] Thereafter, the NRC issued a revised public comment draft, "Staff Technical Position on Investigations to Identify Fault Displacement and Seismic Hazards at a Geologic Repository," dated January 1991. On February 20, 1991, EEI/UWASTE participated in a Technical Exchange addressing this latter document. In a letter dated March 1, 1991, EEI/UWASTE emphasized a number of critical points raised during the course of that Exchange, and offered suggestions for improvements.*

Most recently, the NRC Staff issued a Revised Public Comment Draft of the "Staff Technical Position on Investigations to Identify Fault Displacement and Seismic Hazards at a Geologic Repository," dated April 1991 (see 56 *FR* 22020). While improving on earlier versions, this latest draft, unfortunately, fails to remedy a number of deficiencies. These comments address three points which EEI/UWASTE believes to be particularly significant, and conclude that development of the Staff Technical Position should be suspended.

First, attempts in the current draft to clarify the relationship between (1) Appendix A to 10 CFR Part 100 and, (2) fault displacement and seismic hazards considerations for a repository, are inadequate. The staff addresses earlier EEI/UWASTE comments—as well as those of Nevada—in Appendix C on page 67 with the statement that "10 CFR Part 100, Appendix A, **should be considered a point of departure** in the development of these guidelines and **should not be considered to be required geologic and seismic siting criteria for a geologic repository**." (Emphasis added.) The "point of departure," however, is vague, and the statement that "Appendix A ... should not be considered to be required" is not actually contained in the body of the current draft Technical Position, itself.

The NRC staff should both: (1) state explicitly and clearly that Appendix A to 10 CFR Part 100 is not applicable to repositories; and (2) set forth fully the reasons why, i.e., the great difference between nuclear reactors and repositories in terms of the nature of their construction and operation, and their vulnerabilities to, and the consequences of, faults and earthquakes.

Second, the draft Staff Technical Position continues to use the term "susceptible fault," and it is unclear as to whether or not a repository site containing a "susceptible fault" would be acceptable for licensing. For example, page 3 states "The objective of ... [this STP is] to identify ... the potential for significant design and or performance problems ... so that they **can be avoided**." Page 4, however, indicates that "[S]tructures, systems, and components important to safety must be **designed** so that natural phenomena and environmental conditions ... will not interfere with necessary safety functions" (emphasis added in both quotations). The implication, on the one hand, that faults—particularly "susceptible faults"—be avoided, but, on the other hand, that the problems they pose may be accommodated by design, is confusing.

The use of the term "susceptible fault" is vague, prejudicial and misleading within the context of the draft Staff Technical Position. More accurate, descriptive phraseology, such as "candidate fault for detailed characterization," should be employed. More fundamentally, the NRC staff should clearly and unequivocally state that faults may be accommodated by positioning and/or designing repository elements such that displacement along them will not result in a failure of the repository system or its components to perform their containment and/or isolation functions.

Third, the draft Staff Technical Position applies only to site investigations, and not to analysis or repository design. This division, however, is artificial and inappropriate in that the required scope and nature of investigations will depend—at least in part—on the analysis and application of resulting data. In this regard, a Working Group of the ASCE Dynamics Committee is currently preparing a guideline addressing, among other things, repository loads and facility design. This document should provide useful input concerning the propriety of various investigatory techniques and strategies.

Based on the foregoing, EEI/UWASTE strongly urges that development of the subject Staff Technical Position

*The March 1, 1991, letter stated EEI/UWASTE's concerns with the staff's revised 1989 draft TP, after the February 20, 1991, Technical Exchange. In light of these and the other comments and suggestions received at the Technical Exchange, the staff decided to make significant revisions to the TP and made it available for public comment again, renaming it "Staff Technical Position on Investigations to Identify Fault Displacement and Seismic Hazards at a Geologic Repository." Copies of EEI/UWASTE's March 1, 1991, letter are available for public inspection and/or copying at the NRC Public Document Room.

should be indefinitely suspended. EEI/UWASTE perceives no urgent need for the document—if, indeed, any exists at all—and delaying finalization will allow for appropriate consideration of new input, such as the ASCE guideline. This guideline is now expected in draft form this October, and will be the subject of a conference currently being planned for August of next year.

Response

With regard to EEI/UWASTE's first comment, the staff has noted in this STP that it considers Appendix A to 10 CFR Part 100 not applicable to the geologic repository program, and the STP has been modified to more clearly reflect this position. This position is based on two factors. First, an accurate assessment of the performance of the geologic repository for a period of 10,000 years in a geologic setting characterized by historical faulting requires a much greater understanding of the nature of faulting and seismic behavior in order to attempt to quantify the uncertainty associated with those assessments. Second, policy statements regarding the application of Appendix A to 10 CFR Part 100, to the siting of nuclear power stations, contained what are, in effect, regionally extensive avoidance criteria, because of the consequences of failure of nuclear power stations, because of geologic activity (NRC, 1979). In contrast to a nuclear power station, the consequences of failure at a fuel cycle facility, such as a geologic repository, are considered less severe, and regionally extensive avoidance criteria, therefore, are not believed to required, from a public health and safety standpoint.

It should be noted though, that this STP does share one similarity with Appendix A to 10 CFR Part 100, in that it takes a parallel approach to the identification of faults of regulatory concern. Generally, for the purposes of this guidance, faults that are considered to be of possible regulatory concern to the geologic repository are those faults that are subject to displacement, and that may either affect the design or performance of geologic repository structures, systems, and components important to safety, containment, or waste isolation, and/or may provide significant input into models used in assessments of design or performance of geologic repository structures, systems, and components important to safety, containment, or waste isolation. The staff considers the parallel approach to the identification of faults of concern to be of benefit to the geologic repository program, because the approach used in the siting of other nuclear facilities has been tested in past regulatory processes. With respect to EEI/UWASTE's second comment, the staff considers that sites containing what were previously considered "susceptible faults" and are now considered "Type I" faults would be "acceptable for licensing," as the comment states, so long as it can be demonstrated, with reasonable assurance that the siting, design criteria, and performance objectives in 10 CFR Part 60 could be met. However, the staff also considers that, to provide reasonable assurance that these requirements can be met, the location of structures, systems, and components important to safety, containment, and waste isolation may have to avoid "Type I" faults.

Accordingly, the staff has modified the text and abandoned the term "susceptible fault" to avoid using any term that could be construed as "vague," "prejudicial," or "misleading," as suggested by the EEI/UWASTE's second comment.

Lastly, as regards EEI/UWASTE's third comment, the staff considers that before the data derived from the investigation of faulting and seismicity can be analyzed and developed as input into a design basis, a process must exist to identify and categorize those faults that may represent significant factors in the design and performance of a geologic repository. The strategy for developing guidance in the area of fault displacement hazards and seismic hazards is necessary to provide a critically evaluated basis (or foundation) on which future elements in the strategy (i.e., analysis of data, and input into design) can be built. The strategy takes this approach because of the highly contentious nature of fault displacement hazards and seismic hazards. In the development of the strategy, the staff considered and rejected an approach that would have encompassed, in this document, all aspects of fault displacement and seismic hazard relevant to licensing. However, it was considered to be advantageous to develop some level of consensus on the fundamental question—identifying faulting and seismic phenomena—before initiating succeeding elements of the strategy.

STATE OF NEVADA COMMENTS
GENERAL COMMENTS:

This STP is a revised version of the draft Staff Technical Position, "Methods of Evaluating the Seismic Hazard Present at a Geologic Repository," which was reviewed by the Nevada Agency for Nuclear Projects/ Nuclear Waste Project Office and comments provided to the NRC on October 23, 1989 [The State of Nevada's October 1989 comments are contained in Appendix C of the May 13, 1991 draft STP.]. In that review, we concurred with the basic principles proposed by the NRC. On February 4, 1991, the NRC issued a revised draft retitled, "Staff Technical Position on Investigations to Identify Fault Displacement and Seismic Hazards at a Geologic Repository." The NRC did not solicit formal comment on the February 4 draft, but accepted informal comments at a February 20, 1991, NRC/DOE Technical Exchange meeting in Rockville, MD. In the meeting, we noted that the revised version contained significantly different language than the original draft, but that most of the principal concepts remained essentially unchanged. The

subject of this letter is the May 13, 1991, revised draft and the additional concepts embodied in the revision.

1. **Definition of Geologic Setting**

The definition of "geologic setting" is a new concept, not discussed in previous drafts of the STP. The geologic setting is defined as "The geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located." The focus of this STP is limited to the faulting and seismicity components of the geologic setting. While we do not quarrel with the definition of geologic setting, we question whether this STP serves as an appropriate guide for an applicant to establish a cost effective and appropriate plan for characterizing fault displacements and seismic hazards for a geologic repository. The STP fails to define criteria or a reasonable process to determine what constitutes the "geologic setting" (or province or region or system) and the "components of the geologic system" acting within the "geologic setting." If the STP would provide such guidance criteria, then such issues as radius of investigation for fault studies, earthquake history, volcanic processes, and hydrologic effects, become much more tractable.

[Sub]section 3.1.1 of the STP attempts to provide guidance on how the DOE is to identify the region to be investigated based upon the "nature of the geologic setting." The guidance is very generic. It is unclear to this Agency what the "nature of the geologic setting" is. Equally as important as defining criteria or a process for determining the geologic setting, is an identifiable process or procedure that the applicant and other interested parties can use to determine whether the [Sub]section 3.1.1 guidance has been appropriately applied before proceeding to the next step in the STP ([Sub]section 3.1.2—Initial Identification of Faults to be Considered for Detailed Investigation). We recommend [Sub]section 3.1.1 be amplified to include specific guidance on determining what constitutes the geologic setting and the components of the geologic system acting within the geologic setting.

We note that the definition of "geologic setting" is that which was established in the DOE's Siting Guidelines (10 CFR Part 960) (*Code of Federal Regulations*, Title 10, "Energy"), with NRC's concurrence. Also contained in DOE's Guidelines is a definition of "Geohydrologic system" which sets out an explicit means of determining the boundaries of that "system" for purposes of characterization. The STP could follow this example and establish a definition for determining the boundaries of the geologic system in which fault displacement and seismicity are to be considered.

Response

The staff disagrees with the suggestion made in this comment that the STP fails to describe criteria that define the "geologic setting" or "components of the geologic system." Implicitly, the geologic setting is an area that encompasses all components of the "geologic, hydrologic, and geochemical systems." "Components of the geologic system," in turn, are the "faulting" and "seismicity" elements that could affect the design or performance of geologic repository structures, systems, and components important to safety, containment, or waste isolation, and/or will provide significant input into models used in assessments of design or performance of geologic repository structures, systems, and components important to safety, containment, or waste isolation.

The approach to the definition of "geologic setting" in the STP recognizes that the true limits of specific component boundaries probably will not be known until site characterization is nearly finished, and that flexibility is required to allow for site-specific variation in geology (see NRC, 1983b, p. 187). In addition, the staff considers that the guidance given in Subsections 3.1.2, 3.1.3, and Section 3.3 permits the initial identification of the component settings to be modified.

However, the staff agrees that additional clarification of this guidance is needed to aid in the identification of the components of the "geologic setting." Rather than modifying Subsection 3.1.1, as suggested by this comment, a definition for the "geologic system" is now provided in Appendix B, as are definitions for the faulting and seismicity component settings. They are:

Geologic System: The stratigraphic, geomorphic, faulting, seismic, volcanic and natural resource framework (i.e., components) of the area in which a geologic repository is located.

Faulting Component: That portion of the earth's crust that needs to be investigated to encompass those faults that might have an effect on repository design and/or performance or provide significant input into models used to assess repository performance due to fault displacement.

Seismicity Component: That portion of the earth's crust that needs to be investigated to encompass those earthquakes that might have an effect on repository design and/or performance or provide significant input into models used to assess repository performance due to vibratory ground motion.

2. **Use of 10 CFR Part 100, Appendix A Methodologies**

In the original 1989 draft STP [54 *FR* 35266], the NRC staff's position was that the methodologies

contained within Appendix A of 10 CFR Part 100 were acceptable for investigating seismic and related faulting phenomena. In the revised STP [56 *FR* 22020], this position remains more or less unchanged, but Appendix A-type language and selected specifications have been deleted or modified. The use of the term "capable fault," for example, has been dropped, but a new term, "susceptible fault," is defined which has similar specifications but which is more appropriate for pre- and post-closure tectonic assessments. Susceptible faults are defined in terms of seismic and structural-tectonic connections without dependence upon recency of movement. This approach obviates the need to rely upon arbitrary age criteria to determine fault activity or inactivity (such as the 40,000 year datum for capable faults), which is particularly important at Yucca Mountain because of the relatively long interseismic intervals associated with most faults. Similarly, the five-mile site area defined for fault study by Appendix A is now replaced by a more generalized region designated for fault and seismic hazard study on the basis of structural-tectonic relations within the geologic setting. If faults outside of the repository controlled area have a tectonic connection to faults inside the controlled area or have a bearing on seismic hazard within the controlled area, they will also be individually investigated. We believe this is an appropriately conservative approach which ensures that all significant faults which define the seismotectonic setting of Yucca Mountain will be identified, and is, in fact, a more scientifically reasonable approach than utilizing the more restrictive language of Appendix A.

Response

Although the term "susceptible fault" has been abandoned, the staff agrees with this comment. No modification of the STP is requested, and thus no changes are necessary.

3. Use of Term "Susceptible Fault"

While this Agency supports the use of the term "susceptible fault" for determining the presence of a fault or seismic hazard for a geologic repository, the consensus of the scientific community for the term and its use should be solicited. The terms "capable fault" and "active fault," when used in the contexts of fault displacement hazard analysis, have been extensively debated in both the legal and scientific arenas, and thus have produced some level of resolution in the definitions and their use. Review of the term "susceptible fault" by the scientific community should be initiated, so that some resolution could be achieved prior to license application. To do otherwise could result in protracted debate during the application review on the definition of the term and its use.

Response

The staff is sensitive to the concern raised in this comment that review of the term "susceptible fault" by the scientific community should be initiated. However, as noted in the response to DOE Comment No. 6, the staff believes that the issuance of this STP for public comment has achieved that level of debate requested in this comment. As a result of that debate, the term "susceptible fault" has been abandoned in favor of the less prejudical term "Type I" fault.

4. Deterministic Approach

Although a deterministic analysis may in some cases be overly conservative, such criticism is outweighed by the need to maintain transparency (recognition of significant factors influencing the hazard), which the singular use of a probabilistic analysis does not provide. The identification in the STP of deterministic criteria that can be used as input for supplementary probabilistic analyses is well-conceived. The NRC position that deterministic criteria are appropriate for the collection of data is scientifically sound, given the complex seismotectonic setting of Yucca Mountain. The STP notes that probabilistic techniques for defining an approach to the investigation of fault displacement and seismic hazard have not been shown to be adequately developed for site licensing purposes. The more prudent deterministic approach is warranted by the presence of several active faults at and near the repository site.

The STP makes a clear statement that "A deterministic approach to investigations of fault displacement and seismic phenomena should be applied to DOE's site characterization program," rather than the probabilistic approach (i.e., the Cumulative Slip Earthquake Model) outlined in the DOE Site Characterization Plan for Yucca Mountain. With respect to the relatively low rate of slip associated with active faults in the Yucca Mountain region and the scientific community's general ignorance concerning the long-term mechanical behavior of earthquake faults in regions of low strain accumulation, uncertainties associated with any probabilistic approach are likely to be so large as to yield [sic] [render] the probabilistic estimates of hazard or ground failure meaningless. This is confirmed in a recent article by J.C. Savage, U.S. Geological Survey ("Criticism of Some Forecasts of the National Earthquake Prediction Evaluation Council," *Bulletin of the Seismological Society of America*, in press), which questions the validity of the probability of rupture assignments, for various segments of the San Andreas fault, based on the log-normal distribution of recurrence times of

characteristic earthquakes. He concludes that, based on the log-normal distribution of recurrence approach, the same method would have assigned only a 5% chance of rupture, before mid-1993, to the southern Santa Cruz Mountains segment, the segment that failed in the October 1989 Loma Prieta Earthquake. Therefore, the probabilistic approach may well underestimate the maximum hazard (e.g., ground failure or strong ground motion) that could occur at a site during a given period of time. The deterministic approach advocated by the NRC's STP is more conservative in the sense that the approach will likely result in a hazard assessment which accounts for the largest earthquakes and strong ground motions possible on the faults under consideration.

Response

The staff agrees with this comment and, as previously noted, has concerns about the use of probabilistic criteria in identifying fault displacement hazards and seismic hazards. No modification of the STP is called for.

5. Fault Size as a Discriminator

We are concerned that the use of fault size (length) as a singular criterion for assessing the significance of "susceptible faults" may not be sufficient for the recognition and estimation of seismic hazard at and near the site. It is stated that assessments need only consider fault size in the determination of whether identified susceptible faults may affect repository design or performance. Fault length is one, but not the only, determining criterion in estimating seismic hazard. Maximum surface and subsurface displacements are equally, if not more, important criteria. Maximum fault displacement and length are both used to calculate seismic movement (M), an input value for precisely estimating earthquake magnitudes. This is a particularly important parameter at Yucca Mountain, because of the growing body of evidence indicating that the principal faults are interconnected, and that rupturing events may be distributive in nature. In such events, fault length estimates would not be as important as net tectonic slip estimates made from summing the displacements on all faults.

Response

The staff agrees that fault size (length) should not be used as a singular criterion for assessing the significance of susceptible faults. Maximum surface and subsurface displacements are also important criteria to consider. However, fault size (length) does represent a viable "coarse screen" for restricting the number of faults that require detailed investigation to those faults that might have an effect on repository design and/or performance. The staff considers that any attempt to exclude faults from investigation, based on size or length criteria, would have to gain acceptance from both the technical community and the NRC staff.

One of the advantages of the systematic approach to the investigation of faulting described in this STP is that a process is required to track what the disposition of faults investigated during site characterization was, to include those faults that are excluded from further investigation (see Subsection 3.1.4). This process will ensure that should the assumptions change, the required information is not irretrievably lost during DOE's design process, and that it is periodically reevaluated, based on the results of site characterization and alternative tectonic models consideration.

6. Emphasis on Flexibility

On page 15, the STP states in a discussion of the region to be investigated: "Accordingly, DOE is afforded the flexibility to establish the areal extent of the investigations needed to fully characterize the hazards posed by fault displacement and seismic phenomena." This statement is a continuation of a previous discussion on page 14, regarding the staff's position on the acceptable methodology for the identification and characterization of fault displacement and seismic hazards, where the STP states that, "the process selected and the manner in which the effectiveness of that process is demonstrated are DOE management prerogatives." Further, on page 17, the STP states: "DOE is afforded the flexibility to determine the need for an examination of the pre-Quaternary record of fault movements."

The above quotations indicate a pattern of over-emphasis on encouragement of flexibility in how the applicant approaches the investigations of fault displacement and seismic hazards. Such statements reduce the effectiveness of the guidance provided by the STP. As with any technical position produced by the NRC, the applicant is free to present an alternative approach with appropriate justification to the staff. The statement on page 3, "Methods and solutions differing from those set out in the STPs will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission," appears to provide sufficient flexibility to the applicant and is consistent with NRC policy on technical position guidance. We recommend that specific acknowledgments to "DOE flexibility," such as statements on pages 14, 15, and 17, be removed from the STP.

Response

The staff has no objection to the recommendation made in this comment and has modified the text in Section 4.0 ("Discussion") to more clearly state the staff's intent.

7. Relation to Other STPs

On page 2, the STP states: "Ultimately, data from these investigations provide input to the determination of the fault displacement and vibratory ground motion that need to be taken into account for the design of structures, systems, and components of a geologic repository, that are important to safety, containment, or waste isolation. Guidance on methods of analyses of fault displacement and seismic hazards will be provided in a companion document." The guidance document on methods of analyses of fault displacement and seismic hazards has not been provided to the State for review. Without the companion document, it is difficult to understand the context and significance of the investigative methodology provided in this STP. Because of the uncertainty in how the methodology will be applied in the analysis document, the State may choose to comment further on this STP after a review of the companion document.

Response

This comment is noted, and no modification of the STP is called for. However, the staff believes that questions about the context and significance of this guidance, raised by this comment, have been addressed in Section 2.0 ("Regulatory Framework") of the STP, which describes the pertinent regulatory requirements that these investigations apply to.

8. Use of Terms "Material" and "Relevant"

The phrase "material and relevant" appears in the draft STP at six separate places (page 7, paragraphs 1 and 2; page 9, paragraph 2; page 10, paragraph 1; page 15, paragraph 5; and page 16, paragraph 1) and the word "relevant" alone appears once (page 6, paragraph 4). At four places (pages 6, 7, 9, and 10) the phrase "material and relevant" is used in the context of describing the process by which faults and seismic phenomena will be identified. These statements are:

> **page 7**—(identification of) "faults outside the controlled area but within the component setting ... to the extent that they are material and relevant ...."
>
> **page 7**—(An acceptable approach to) "determining which faults outside the controlled area are material and relevant ...."
>
> **page 9**—"determining which faults inside the controlled area continue to be material and relevant ...."

At the three other places the phrase "material and/or relevant" is used in the context of the information that will be obtained. These statements are:

> **page 15**—"information on the subsurface conditions outside the controlled area need(s) to be collected to the extent that it is material and relevant."
>
> **page 16**—"Provides DOE with the flexibility to assess what information on faults outside the controlled area is material and relevant."
>
> **page 6**—"identification of the component setting for fault displacement and seismic hazards should be based on ... relevant field investigations ...."

It seems obvious, based on the foregoing citations, that the staff had a definite purpose in mind by using the phrase "material and relevant" to provide guidance to the DOE through this STP. We assume that the staff was fully cognizant of the definition of the word "material" as used historically by the Commission when speaking to its responsibility, under the Atomic Energy Act, for protecting the public health and safety. However, the various contexts within which the term "material" is used in this STP make us uncertain whether the ramifications have been completely recognized.

The different usages seem to present conflicting and, in one case, erroneous guidance. The erroneous statement occurs on page 16, where it is stated that DOE (is provided) with the flexibility to assess what information outside the controlled area is material and relevant. As will be subsequently shown, the decision as to whether or not information is material, and the weight to be accorded that information in the decision process for any site suitability determination, is, in the end, the job of the Commission, not the applicant. If the DOE is afforded the luxury of unilaterally deciding the materiality of information regarding which faults, fault systems, and seismic phenomena it will investigate at this stage of site characterization, the results could likely be what the Commission notes as "... imprudent expenditures and subsequent delays, and ultimately could result in denial of the application for the proposed site" (see April 1991 draft STP [56 *FR* 22020], page 3, paragraph (3)).

The following summary discussion is provided primarily to support the above conclusion. The summary is also meant to benefit those who may not be familiar with the NRC's use and meaning of the word "material," or perhaps have not fully considered the possible ramifications insofar as developing the extent of information that will be used to determine site suitability.

Section 186 of the Atomic Energy Act of 1954 as amended (42 USC 2236) specifically provides, in part: "(a) Any license may be revoked for any material false statement of fact required under Section 182 ...." Section 182 essentially sets forth the prescribed content and form of a license application. The first case in which an applicant was charged with violating Section 186 of the Act by making material false statements concerned Virginia Electric and Power Company's (VEPCO's) four-unit North Anna Power Station. This case is important to the discussions here since the violations all concerned the materiality of geologic information. The lengthy history of the licensing proceedings on these issues is set forth in detail in the opinions of the Atomic Safety and Licensing Board, LBP-75-54 (1975); Atomic Safety and Licensing Appeal Board ALAB-324 (1976); and the Nuclear Regulatory Commission final determination, CLI-76-22 (1976).

According to the Licensing Board there were two principal issues: the first addressed the responsibility of the applicant to disclose and supply material information to the Commission in a timely manner, and the second involved what constitutes a material false statement. The Commission in their finding stated the issue more succinctly in that "the case does not concern the safety of the North Anna site but rather whether VEPCO fulfilled its obligation to provide (accurate and full) information about the site."

Briefly, VEPCO was originally charged by the intervenors with nineteen counts of making material false statements to the Commission concerning the geology at North Anna. Sixteen of the nineteen specified allegations consisted of affirmative representations about the geology of the site. The following are examples of statements attributed to VEPCO's geotechnical consultants: the "nearest known fault is several miles from the site" or "faulting of rock at the site is neither known nor is suspected." Three of the nineteen specifications were of a different nature. They consisted of omissions, that is, complete failure to provide information. Two of the alleged omissions were failures to present evidence in the consultants' possession about suspected faulting, during the time that site suitability was decided. The third alleged omission was the failure to provide the staff with a report prepared by a consultant to their geotechnical contractor which had concluded that the suspected faulting might be reactivated. This alleged omission also dealt with the non-delegable duty to report material information. VEPCO decided not to forward the consultant's report to the staff after being told by their geotechnical contractor that they disagreed with the conclusions and therefore the report lacked credibility.

The licensing board found VEPCO culpable on 12 of the 19 allegations including the three alleged omissions. The board summarized their findings as follows: VEPCO "violated Section 186 of the act ... in that it knew, or should have known, of the presence of a geologic fault; known, or should have known, that a seismic or geological fault question arising as to the suitability of the site was of major importance; knew, or should have known, that the Act, the rules and regulations of the Commission and the cases decided thereunder by the Commission required full and complete reporting of any material information bearing on an application for construction permits; knew, or should have known, of its non-delegable duty to report material information; and knew of its duty to conduct itself and its affairs with a high degree of care required of one conducting a business impacting on the public health and safety and yet knowing all of this, it failed to properly and fully report [sic] [to] the staff in a timely manner material information related to the presence of a geological fault (which at the time, may or may not have been 'active' or 'capable') ...."

The Atomic Safety and Licensing Appeals Board (ASLAB) disagreed with the Licensing Board only on the issue of omissions. The ASLAB concluded that an omission was simply not a "statement" and accordingly could not be punished as such, no matter how wrongful the omission might be. The Commission later reversed the Appeals Board on this issue and essentially affirmed the original Licensing Board findings.

A summary of those findings that are most germane to the subject STP is as follows:

- Section 186 of the Atomic Energy Act covers not only material false statements in a license application, but any "violation or a failure to observe any of the terms and provisions of the Act or any regulation of the Commission."
- A statement is **"material"** within the meaning of Section 186 of the Atomic Energy Act, if it has a natural tendency or capability to influence—not whether it does so in fact—the decision of the person or body to whom the statement is submitted. The principal criterion in

determining materiality is whether a reasonable staff member would, or should, consider the information in reaching a conclusion or determining a course of action; it is not important whether or not the statement ultimately played a role in the decision.

- A statement may be "**false**" within the meaning of Section 186 of the Atomic Energy Act, even if it is made without knowledge of its falsity. The falsity and materiality of a statement submitted to the staff for its review hinges on the message which would likely be conveyed to a reasonable staff member by what was said or left unsaid.

- The term "**statement**" as used in Section 186 of the Atomic Energy Act is not limited to affirmative representations; the omission of a material fact can be treated by itself, as a statement. Failure to include material information in a submission to, or a filing before, the Commission, can comprise a false and misleading statement. Anything less than full and accurate disclosure of information on which to base its review is unacceptable and "nothing less than candor is sufficient."

- With respect to the matter of "**timeliness**," the Commission concluded that a "material false statement" results if, in the light of all the circumstances, an applicant fails to make a timely disclosure for the purposes of the review of its submissions. An "incongruous" situation results if an applicant responsible for disclosing material information fails to do so in a timely manner, and for one reason or another does not disclose the information until it becomes stale or relatively meaningless.

- In regards to the responsibility for determining the materiality of information, the Commission stated repeatedly and without equivocation that the accurate and full disclosure by the applicant of all relevant information is vital if the Commission is to fulfill its primary duty to protect the health and safety of the public. Arguably relative data must be promptly furnished if the Commission is to perform its function. The weight accorded to relevant information is, in the end, the job of the Commission, not the applicant.

Although the foregoing discussion may seem protracted, we feel that it was necessary to develop support for the point that the decision regarding the definition of the geologic setting and consequent determination of which faults and seismic phenomena to investigate is not a trivial exercise. These decisions made now by the DOE could determine the course of the program for many years to come. If the program is to succeed, a reasonable consensus between all of the principal scientific participants (NRC, DOE, the State of Nevada, etc.) must be reached early as to what constitutes the boundaries of the geologic setting surrounding Yucca Mountain. Once the geologic setting is agreed upon, the geologic system can be determined.

Response

Because of site- and design-specific considerations, the language in 10 CFR Part 60 is intentionally non-prescriptive in the area of site characterization; that is, it leaves to DOE in the first instance the opportunity and responsibility to determine, among other things, how to conduct a program of site characterization. It is also DOE's responsibility in the first instance to describe, on an iterative basis (10 CFR 60.18(g)), how this process is proceeding. Similarly, NRC (and other interested parties) will have an opportunity to review how DOE is meeting this responsibility, and NRC can then apply its own judgment and provide more specific guidance to DOE on a case-by-case basis. In addition to the review of site characterization activities specified under 10 CFR 60.18, the Commission also noted in its final rule that it contemplated an ongoing review of other information on site investigation and site characterization, such as those involving long lead-time procurement actions, so as to allow for the early identification and resolution of potential licensing issues.

In its review of DOE's SCP (DOE, 1988), the NRC staff noted its concerns with DOE's site characterization programs, specifically questioning the conservatism of the approaches to be used to characterize fault activity and in doing so, cited the potential to underestimate the seismic hazard (see NRC, 1989b, pp. 3-6—3-7). In light of these concerns, the staff attempted to describe (in the STP) the level of conservatism it thought sufficient, in the context of the regulation, for characterizing fault activity and thus avoiding the potential to underestimate the seismic hazard at the Yucca Mountain site.

The unusual aspect of this STP is that the regulation to which it refers (i.e., 10 CFR 60.21(c)(1)(i)) specifically limits the information that is required to that which is "relevant and material." The STP must therefore provide guidance on the meaning of these terms (e.g., "how much," "what type," and "to what extent") in the context of the regulation. Thus, the staff believes that the guidance to DOE on this concept can be improved by incorporating the language that explains the concept of materiality, as proposed by the commenter. Accordingly, the staff has revised the second paragraph in Subsection 4.1.2 to read as follows:

> "For faults outside of the controlled area that may affect isolation within the controlled area, 10 CFR 60.21(c)(1)(i) provides that the Safety Analysis Report is to include information on subsurface conditions to the extent that it is relevant and material. To satisfy this requirement, the information collected (and submitted with the license application) must include whatever has a natural tendency or capability to influence the decision of the Commission. Consistent with this principle, information should be considered to be material if the NRC staff would or should consider it in reaching a reasoned conclusion with respect to any position it might take as to the adequacy of the license application or the issuance of a license (see NRC, 1976). This STP provides DOE with guidance to assist in assessing, in this context, what information on faults outside of the controlled area is relevant and material. The guidance involves a procedure designed to assure that the impact of such faults on design, containment, and isolation within the controlled area is evaluated sufficiently so as to determine which of such faults outside of the controlled area, but within the geologic setting, may influence a decision and therefore require further investigation."

Moreover, in order to be consistent with the language in 10 CFR 60.21(c)(1)(i), the term "relevant and material" now replaces the term "material and relevant" in the STP.

9. In summary, our concern is that the STP does not provide sufficient guidance to the DOE such that the site characterization program for Yucca Mountain would provide appropriate and acceptable information to effectively resolve two of the more critical geological issues, the effect of fault displacement in the repository and the design-basis earthquake(s) for both pre-closure facilities design and post-closure performance assessment. This STP does not appear to help meet the intent of the Site Characterization Plan to "provide a vehicle for early NRC, State, Indian tribal, and public input on DOE's data-gathering and development work so as to avoid postponing issues to the point where modifications would involve major delays or disruptions in the program" (NRC, 1987, p. vi).

Response

As noted earlier, NRC's strategic planning assumptions call for the early identification and closure of issues, to the extent practicable, before the receipt of a potential license application to construct a geologic repository. The principal means for achieving this goal is through informal, pre-licensing consultation with DOE, the State of Nevada, Indian Tribes, and affected units of local government. This approach is designed to attempt to reduce the number of, and to better define, the issues that will be litigated during a potential licensing hearing, by obtaining input and striving for consensus from the technical community, interested parties, or other targeted groups on such issues.

In this regard, the staff has undertaken the development of this STP as a means of reaching closure on what degree of conservatism is sufficient for demonstrating compliance with NRC's rule in this area of identifying fault displacement hazards and seismic hazards. Moreover, the staff believes that agreement on an acceptable approach to the investigation of these phenomena is an important precursor step before faulting and seismic data can be analyzed and interpreted, and the necessary design bases formulated.

SPECIFIC COMMENTS:

The following comments on the NRC Staff Technical Position (STP) are provided by the State of Nevada to assist the staff in improving clarity and minimizing ambiguity in the text of the STP.

1. **Page 1, Second Paragraph**

   The third sentence speaks to the "determination of the most severe displacement and earthquakes that can be associated with faults." We assume that this equates to establishing the maximum credible earthquake or the so-called design basis earthquake (DBE) for the geologic setting as defined and required by DOE General Design Criteria (DOE Order 6430.1A, dated April 6, 1989). According to DOE Order 6430.1A, the DBE shall, by definition, be equivalent to the Safe Shutdown Earthquake (SSE). We assume that, because determination of an SSE is defined by the NRC only in 10 CFR Part 100, Appendix A—the procedures to be used in establishing the "maximum credible earthquake" (DBE) source. LBL–9143 (pages 4 and 5) defines the maximum credible earthquake as the largest magnitude earthquake that appears possible within the known tectonic framework. In 10 CFR Part 100, Appendix A(V)(a), the earthquake which could cause the maximum vibratory ground motion at the site is designated the SSE. LBL–9143 further states that in determining the maximum credible earthquake, little regard is given to the probability of occurrence, except that the probability is great enough to be of concern. DOE Order 6430.1A states that the DBE shall be assumed capable of occurring at any time and shall have a ground acceleration of 0.1g or greater. Since there appears to be no significant differences

between the DBE and the SSE or the recommended methodology by which the source for either is determined, it is suggested that a statement be added to the STP that acknowledges DOE Order 6430.1A and LBL-9143 by reference and accepts the DBE/SSE equivalence.

Response

The staff considers that "design basis earthquake" and "safe shutdown earthquake" are concepts that were developed as specific design goals for nuclear facilities other than a geologic repository. Although the concepts that these terms imply and their application may eventually be used in the context of the design of a geologic repository, these design issues are considered to be beyond the scope of this STP. Accordingly, the staff does not intend to amend the STP, specifically acknowledging DOE Order 6430.1A (DOE, 1989) and LBL-9143 (Eagling, 1983) by reference, or to accept the DBE/SSE equivalence, as suggested by this comment.

2. **Page 2, Third Paragraph**

The second sentence appears to be out of place in the context of this paragraph. It is suggested that the sentence be either removed or moved to the second paragraph on page 13. Also in the third paragraph, the same type of guidance is found here as contained in DOE Order 6430.1A and its referenced documents regarding determination of the DBE/SSE source. It appears this is further support for accepting the equivalence of DBE and SSE.

Response

The staff is aware of the concern raised in the first portion of this comment and has revised Sections 1.1 ("Background") and 4.0 ("Discussion") and added a new appendix to this STP ("Appendix A") to address this and other comments on the applicability of Appendix A (to 10 CFR Part 100) to the technical positions discussed in this STP.

As regards the concern raised in the second portion of this comment, the staff noted in the response to the State of Nevada Specific Comment No. 2 that DBE and SSE are concepts that were developed as specific design goals for nuclear facilities other than a geologic repository. Although the concepts that these terms imply and their application may eventually be used in the context of the design of a geologic repository, these design issues are considered to be beyond the scope of this STP. Accordingly, the staff does not intend to amend the STP at this time to accept the DBE/SSE equivalence.

3. **Page 2**

Paragraph four makes a generic statement regarding candidate sites west of the Rocky Mountain Front. The STP could be substantially improved if a more definitive statement could be made that focuses on what the NRC considers to be the geologic setting of the Yucca Mountain site as defined by the present SCP.

Response

See staff response to State of Nevada General Comment No. 1.

4. **Page 3, First Paragraph, First Sentence, Third Line**

It is suggested that the "or" be changed to an "and" in order to reflect the broader purpose served by the STP. In addition, it is suggested that reference be made to the scientific community at large outside the DOE (e.g., National Academy of Sciences committees, the Nuclear Waste Technical Review Board, State of Nevada, etc.) who are also implicitly involved in the regulatory process and therefore could benefit from the guidance.

Response

The staff has no objection to making the proposed modification requested in the first comment.

However, the staff does not agree with the recommended revision proposed by the second comment. The staff believes that the existing language of the STP in the first sentence of paragraph one of Section 1.3 is consistent with its regulatory authority. The staff believes that the proposed revision would exceed that authority.

5. **Page 3, Second Paragraph**

The last part of the first sentence refers to avoidance of design and/or performance problems in the future. Avoidance of the problems at Yucca Mountain may only be possible by abandoning the site. The faults will always be there and there will always be a relatively high potential for earthquakes. It might be better to substitute the word "accommodated" for the word "avoided."

Response

The staff notes the State of Nevada comment. See staff response to the AEG Engineering Geology Standards Committee Specific Comment No. 3.

6. **Page 3, Third Paragraph.**

The first sentence describes the informal process that is presently in place. This process has not

proved satisfactory to all participants to date and its acceptance is unlikely to improve in the future. The last sentence appears to be a veiled threat that is unlikely to have any influence on the course of the repository program. We suggest that the sentence be removed and included in a separate memo from the NRC to the DOE or some other more appropriate place. The entire third paragraph might be more appropriately placed somewhere in Section 4.0 on page 13.

Response

Although the staff does not agree with the conclusion reached in this comment that the paragraph or specific language in the paragraph constitutes a "... veiled threat" to the applicant, it will delete the paragraph in question from Section 1.0 of the STP. However, it should be noted that the subject paragraph is based in large part upon the statements of consideration behind the Commission's proposed licensing procedures for a geologic repository for high-level waste (HLW) (44 *FR* 70408). In its final rule (see 46 *FR* 18971), the Commission set forth those requirements applicable to DOE when submitting an application to receive and dispose of HLW, and specified the procedures the Commission will follow in considering such an application. These procedural requirements call for extensive informal involvement of the staff during the site characterization phase.

As noted in the statement of considerations, the provision for the early review of the Department's site characterization plans was the "desirability of evaluating whether the Department's [site characterization] program will generate data suitable to support a Commission licensing decision" (44 *FR* 70409). Consistent with this philosophy, the staff has prepared STPs as a means to provide guidance to DOE on what information the staff will require for the review of a license application, what standards will be employed in the staff review of the license application, and those methods that the staff finds acceptable for implementing the general criteria found in NRC regulations. It is believed that the existence of such guidance therefore makes the licensing process more efficient.

The existence of formal NRC guidance does not preclude the license applicant from using a method different from that contained in the guidance document, to demonstrate compliance with NRC's regulations. The staff is willing to consider new or alternative solutions or approaches. However, DOE should recognize that substantial time and effort have gone into the development of STPs, and that a corresponding amount of time and effort will probably be required to review (and accept) new or alternative solutions or approaches. Thus, in proposing new or alternative solutions or approaches, DOE must expect longer review times, more extensive questioning, and the possibility of non-acceptance by the NRC staff.

7. Page 5, Second Paragraph

The first sentence gives the NRC staff's position that a deterministic approach should be applied to geologic repository investigations. A strong deterministic approach is in fact required before any probabilistic results would have meaning. The NRC may want to consider allowing for a primary deterministic approach supplemented by a probabilistic approach to the extent that DOE feels necessary. This is [a] common practice of the NRC in reactor licensing. However, the issue may be moot, since DOE Order 6430.1A (pages 1-99) requires that the DBE (SSE) be established deterministically and the effects handled probabilistically.

Response

This comment is noted. The staff agrees that deterministic and probabilistic analyses are complementary and has revised Sections 3.0 and 4.0 of the STP to describe the staff's views regarding the use of deterministic criteria in the consideration of faulting and seismic hazards.

8. Page 6, Subsection 3.1.1, Item 2

The boundary of the region to be investigated for fault displacement should be referenced to Subsection 3.1.3 and the boundary of the region to be investigated for seismic hazards expanded and referenced to Section 3.3.

Response

The staff disagrees with the proposal made in this comment. The boundary of the region to be investigated for both fault displacement hazards and seismic hazards should be initially established using the approaches described in Subsections 3.1.1 and 3.1.2.

9. Page 6, Subsection 3.1.2, First Sentence

It is suggested that the addition of the phrase, "or fault zones" after the phrase, "those faults" in the first line would clarify the intent. Also, such an addition would make the sentence consistent with the terminology used on page 10, Item (1)(a).

Response

The staff has no objection to making the proposed modification requested in this comment.

10. Page 6, Subsection 3.1.2., Item 1

It is suggested that by adding the phrase, "or fault systems, any part of which is" after the phrase, "all faults," in the first line would clarify the intent.

Response

The staff has no objection to making the proposed modification requested in this comment.

11. Page 6, Subsection 3.1.2., Item 2

It is suggested that adding the phrase, "or fault zones" after the word, "faults" in the second line would clarify the intent.

Response

The staff has no objection to making the proposed modification requested in this comment.

12. Page 7, First Line

It is suggested that adding the word, "geologic" ahead of the phrase, "component setting" would clarify the meaning.

Response

The staff has no objection to revising the STP, as recommended, and has modified the STP to more accurately convey the staff's intent.

13. Page 7, Subsection 3.1.3

Subsection 3.1.3 states that faults that required detailed investigations are faults subject to displacement, affect design and performance, and provide significant input to models. We suggest adding a phrase in Item (1) to the effect that "all faults within the controlled area should be considered as candidates for detailed investigations" so as to be consistent with Subsection 3.1.2, or provide a reference back to Subsection 3.1.2.

Response

The staff does not agree with the proposed revision made in this comment. Subsections 3.1.1 and 3.1.2 provide input to the identification of faults that require detailed investigation. Referring back to Subsection 3.1.2 from Subsection 3.1.3, as suggested by this comment, would be redundant, in the opinion of the staff.

14a. Page 8, Section Titled "Process to Identify 'Susceptible' Faults"

We suggest changing the title of this Section to read "Process to Identify Susceptible Faults That Require Detailed Investigation." Also, we suggest changing the title for Step No. 1 to read "Identification of Faults That Require Detailed Investigation."

Response

By definition, faults that are determined to be "susceptible" require detailed investigation. Changing the title as suggested in the comment would make it redundant. Changing the title for Step No. 1, as suggested by this comment, would change the intent of the paragraph in that identifying faults that require detailed investigation is a two-step process, the first step being determination of which faults are subject to displacement.

However, as noted in the staff response to DOE Comment No. 6, the term "susceptible fault" has been abandoned and replaced by a new, three-step categorization scheme. Under this scheme, those faults that fall into the category designated as "Type I" faults (see Section 3.0) are those faults that were formerly considered to be "susceptible faults." It should be noted, though, that the logic underpinning the identification of faults of regulatory concern has remained unchanged.

14b. Page 8, Section Titled "Process to Identify 'Susceptible' Faults"

The criteria on page 8 for identifying "susceptible faults" are of sound scientific basis. Significantly, the criteria do not preclude the detailed study of a fault for which evidence of Quaternary-age movement is absent. Such an approach is reasonable, given that Quaternary-age deposits may be absent along given faults.

Response

The staff agrees with this comment. No modification of the STP is requested, and thus no changes are necessary.

14c. Page 8, Section Titled "Process to Identify 'Susceptible' Faults"

In the description of this process, we suggest that the phrase "subject to displacement" be replaced with the phrase "that require detailed investigation" throughout.

Response

See staff response to State of Nevada Specific Comment No. 14a.

14d. Page 8, Section Titled "Process to Identify 'Susceptible' Faults"

In the second paragraph of Step No. 1 (first sentence), we suggest that the word, "are," after "such faults," be replaced by the phrase, "could be." Also, at the end of the second sentence we suggest adding the phrase, "exhibit any one or more of the following."

Response

The staff has no objection to making the proposed modifications requested in this comment.

14e. Page 8, Section Titled "Process to Identify 'Susceptible' Faults"

In the third paragraph (Item (a)), we suggest adding the word, "or" after the word "fault."

Response

The staff has no objection to making the proposed modification requested in this comment.

14f. Page 8, Section Titled "Process to Identify 'Susceptible' Faults"

In the third paragraph (Item (b)), we assume that the reference to displacement on one fault that could cause displacement on another includes the blind thrusts and detachments that could be present beneath the Yucca Mountain site area. A future clarification of a "structural relationship" may be required.

Response

This comment is a correct interpretation of the process described in Subsection 3.1.3. Faults that have a structural relationship with a fault that meets one of the other criteria do include blind thrusts and detachments.

15a. Page 9, First Paragraph, Item (a), First Line

We suggest replacing the word "evaluating" with the phrase "providing the necessary information for evaluating." In addition, we suggest replacing the word "would" with "could" in the second line.

Response

The text has been changed to reflect the first suggestion in this comment. However, the second suggestion made in this comment was not accepted by the staff.

15b. Page 9, First Paragraph, Item (a)

In Item (a), investigation of geologic conditions within the component settings is covered under Section 3.2. The process referred to in Item (a) is for all intents and purposes a screening. We assume that this step is intended to be essentially a first cut using existing information.

Response

This comment is a correct interpretation of the process described in Subsection 3.1.3. Item (a), under the acceptable approach to providing the information necessary for evaluating the criteria in Step No. 1, is part of the methodology for identifying "Type I" faults or fault systems. The criteria in Section 3.2 are information needs to be developed on those faults that are identified as "Type I."

15c. Page 9, First Paragraph, Item (c)

Under Item (c), it is suggested that the phrase "or fault zone" be added after the word "fault" in the second line.

Response

The staff agrees with this comment and has changed the text to reflect the recommended revision.

16. Page 9, Step No. 2—Assessment of the Potential Effects of Faults Subject to Displacement

Step No. 2 encompasses "assessment of the potential effects of faults subject to displacement." The evaluation is to be deterministic and take into account the potential effects of fault size on the design and performance of facilities important to safety. It is stated that fault length is the critical parameter for evaluation and that the "DOE should develop a defensible approach to determine what size fault needs to be characterized in detail." Because earthquakes in the Great Basin have been associated with distributed faulting, the dependence of analysis on the assessment of potential fault length will be associated with significantly greater uncertainty than, for example, along the strike-slip faults of the California [tectonic] plate boundary. The estimation of the maximum sized earthquake associated with the distributed nature of mapped faults in the Yucca Mountain region should also take into account the regional record of the largest historical earthquakes. Dependence solely on the mapped length of individual faults or fault segments in the region may well underestimate the maximum size earthquake that can be associated with the mapped faults. Also, an issue that could be addressed appropriately here is the collective effect on the hydrologic performance of the site if all of the small faults within the system are displaced due to an earthquake.

Response

As regards the suggestion made in this comment that "The estimation of the maximum sized earthquake associated with the distributed nature of mapped faults in the Yucca Mountain region should also take into account the regional record of the largest historical earthquakes," the staff agrees with this comment. However, this concern, which relates to the **analysis** of seismic phenomena, is beyond the scope of this STP. The staff expects that after the investigation of faulting and seismic phenomena, DOE will use this information to estimate what type of earthquake is to be used to design the repository.

The staff considers that the single most important indicator of fault significance is fault length; however, it is also aware that fault length does not stand alone as far as determining fault significance, and that other factors would have to be considered in the development of a defensible approach to determine what size fault needs to be considered. Step No. 2 in Item (2) of Subsection 3.1.3 addresses the scenario where small tectonic fractures that have lengths on the order of a couple of feet, with minimal detectable offset, are encountered in an underground facility. Although fractures such as those noted in the above scenario should be mapped and considered in the context of their setting, the staff considers that an extensive effort to investigate these tectonic fractures in the detail suggested by this comment is unnecessary.

Finally, consideration of the effects, if any, that fault displacement may have on the hydrology of the site is considered beyond the scope of this STP. The staff intends to address this issue during the development of a companion STP on the analysis of hazards due to fault displacement and seismicity.

17. Page 10, Subsection 3.1.4

The first paragraph suggests that faults eliminated from further consideration "should" periodically be reconsidered. We suggest that the STP provide more specific guidelines on the framework for accomplishing this "reconsideration" and the decision process and criteria required for reconsideration.

Response

See staff response to AEG Seismic Safety Committee Specific Comment No. 2.

18. Page 10, Section 3.2

The approach to investigating a fault-displacement hazard appears reasonable; however, Items (a) through (e) are really information requirements and do not represent a scientific approach. We suggest adding the phrase, "or fault zone" after the word "fault" in Items (b), (c), and (d) for consistency with the wording used in Item (a). The last sentence regards "susceptible" faults with no surface expression but identified in the subsurface. We assume that this is meant to include detachment faults and blind thrusts that are reasonably inferred from the geologic data.

Response

The staff finds the revision suggested by the State of Nevada in its first comment acceptable and has changed the sentence accordingly.

With regard to the second comment, consideration of faults with no surface expression is meant to address faults such as blind thrusts, including bedding plane thrusts and ramps, and detachment faults.

19. Page 11, Section 3.2

Item (2) needs to more succinctly define what constitutes the "underground facility" and this definition added to the glossary. Does this include just the drifts or does it also include boreholes, shafts, and parts which constitute the disturbed zone?

Response

Item (2) of Section 3.2 has been deleted because it repeats information in the previous paragraph in this section. Faults without surface expression, including those in boreholes and shafts, should be investigated in the manner described in Item (1) of Section 3.2.

20a. Page 11, Section 3.3

The section outlines a viable approach to collecting data needed to assess the expected vibratory ground-motion hazard but does not indicate whether application of the data to ground motion assessment will follow a deterministic or probabilistic approach. There is an implication in this section that there exists an accepted earthquake size—source to site distance—strong ground-motion relationship that may be used to determine which faults are capable of producing given levels of strong ground motion at the site of interest. The question will most certainly arise as to the validity of whatever relationship is used to estimate expected strong ground motions at the site.

Response

The staff does not agree with the suggestion made in this comment that Section 3.3 implies that there already exists an accepted earthquake size, source-to-the-site, or a specific attenuation model to be used in design decisions. These analyses will be developed when characterization of the site is completed.

20b. Page 11, Section 3.3

In Item (3), we suggest adding the phrase, "within the geologic setting and immediately contiguous provinces" after the word "earthquakes" in the first line and replacing the word "affected" with the phrase "been felt at" in the second line.

Response

It is not clear how this proposed revision would improve or clarify this technical position. The staff considers that if an earthquake could reasonably be expected to affect the site, then it implicitly is within the geologic setting of the site and therefore subject to investigation, as called for by this technical position. The fact that the earthquake could be in an immediately contiguous tectonic province, as noted in this comment, is vague and an unnecessary text addition. In addition, the staff is more concerned with the effects of earthquakes on site performance rather than the earthquake having been felt at the site, as recommended in the comment.

21. Page 12, Section 3.3

In Item (5) the second sentence requires guidance on how and when "seismic source zones" should be established. In addition, the STP needs to provide guidance on what constitutes the differences, if any, between "seismic source zones" and "fault zones."

Response

The staff considers that no additional guidance is needed on "how and when to establish 'seismic source zones,'" inasmuch as the manner in which these features are defined is already well-established.

However, as regards to the request made in the second portion of this comment to describe the differences, if any, between "seismic source zones" and "fault zones," the staff wishes to note that a seismic source zone is an area that includes that portion of the earth's crust that is considered to have uniform seismic characteristics (same expected maximum earthquake and frequency of occurrence). When the site characterization program is completed and information about the seismic and tectonic features are available, it will be possible to delineate seismic source zones. Seismic source zones will be one of the parameters needed by DOE for estimating the seismic hazard at Yucca Mountain. Seismic source zones include fault zones.

22a. Page 14

In the second paragraph, the STP clearly states that probabilistic techniques for defining an approach to the investigation of fault displacement and seismic hazards have not been shown to be adequately developed for licensing applications for a specific site. This is in direct conflict with aspects of the approach of hazard assessment put forth by the DOE in the Site Characterization Plan for Yucca Mountain.

Response

This comment is noted and as previously stated in the staff response to AEG Engineering Geology Standards Committee General Comment No. 4, the staff has concerns about DOE's plans for the characterization of faulting and seismic phenomena, specifically questioning the conservatism of the approaches to be used to characterize fault activity and in doing so, citing the potential to underestimate fault displacement hazards and seismic hazards (see NRC, 1989b, pp. 3-6—3-7). In light of these concerns, the staff attempted to describe (in the STP) the level of conservatism it thought sufficient, in the context of the regulation, for characterizing fault activity and thus avoiding the potential to underestimate the seismic hazard at the Yucca Mountain site.

Moreover, in response to the observation raised by this and other commentors, the staff has modified the discussion in Sections 3.0 and 4.0 to describe the staff views regarding deterministic and probabilistic criteria for investigations identifying faulting and seismic hazards.

22b. Page 14

In the third paragraph regarding documentation, the STP needs to provide guidance on the form of the document and the timing for submittal relative to the results of the screening process used.

Response

The staff considers that the form and timing of the submittal of documents are the prerogative of the potential licensee. The staff will evaluate submittals to assess whether the information in them is sufficient.

23. Page 15, Subsection 4.1.1

In the first sentence, we suggest adding the phrase "in the geologic setting and" after the word "investigated."

Response

This concern is noted and the staff has modified the first sentence of Subsection 4.1.1 to address this comment. This sentence now reads as follows:

"The areal extent of the region to be investigated (i.e., component boundary) needs to be of sufficient size such that the geologic and seismic characteristics are understood and described so as to permit

evaluation of the proposed site, to provide input for solutions to actual or potential faulting and seismic effects at the proposed site, and to test alternative models of faulting and seismicity applicable to the site."

24. **Page 15, Subsection 4.1.2**

The last line in the first paragraph should refer to Subsections 3.1.2 and 3.1.3.

Response

The staff has no objection to making the proposed modification requested in this comment.

25. **Page 16, First Paragraph, Last Sentence, Last Line**

The text should read geologic "component" rather than geologic "setting."

Response

The staff has no objection to making the proposed modification requested in this comment.

26. **Page 16, Subsection 4.1.3**

In the first paragraph, the last sentence states that "capable fault" is used as a site suitability tool. This statement is not entirely correct. There are no suitability tests in 10 CFR Part 100, Appendix A, nor are there any regulations that prohibit the construction of a nuclear facility on or near a "capable fault." The third sentence in the paragraph is a more accurate description of "capable fault." It is suggested that the third sentence be retained and the last sentence deleted.

Response

As this comment correctly notes, there are no regulations that prohibit the siting of a nuclear facility on or near a "capable fault." However, in light of the concerns raised in this comment, the staff has modified the text in Subsection 4.1.3 to more clearly state the staff's intent regarding the identification of "Type I" faults.

27a. **Page 17, Second Paragraph**

At the end of the last sentence, we suggest adding the phrase "outside of the controlled area."

Response

The staff does not agree with the proposed revision made in this comment. The staff considers that establishing spatial or temporal clustering of faulting through examination of the pre-Quaternary record of fault movements may be necessary for faults both inside and outside of the controlled area.

27b. **Page 17**

In the third paragraph, the first sentence implies that the existing stress regime can be defined for the geologic setting in which a repository is proposed. For Yucca Mountain, it is presently an open question whether the existing stress regime can be defined given the complexity of the geologic setting. The clarity of this paragraph would be improved if the STP provided guidance on defining the geologic setting (i.e., its boundaries) within the context of existing stress regimes.

Response

The staff is aware of the difficulty in establishing the existing stress field for a region of the earth's crust at scales that would be important for individual tectonic fractures, as noted in this comment. However, published reports for Yucca Mountain (Rogers, *et al.*, 1987) have attempted to define the existing stress field and have implied that faults with specific orientations in the existing stress field are subject to displacement (*loc cit.*, p. 90). This information on the stress field at Yucca cannot be ignored and must be factored into the evaluation of fault displacement hazard. As noted in the text and identified in the approach illustrated in Figure 3, the key factor in determining fault significance is displacement in the Quaternary Period; the stress field only becomes a factor when evidence of displacement in the Quaternary / conclusive.

28. **Page 18, Third Paragraph**

In the second sentence, we suggest adding the phrase "individually or collectively if part of a zone or system" after the word "dimension."

Response

The staff has no objection to making the proposed modification requested in this comment.

29. **Page 19, Second Paragraph**

The last sentence needs to be rephrased. A technical position cannot be implemented. Technical positions are established by the NRC staff. The procedures outlined by NRC can be "implemented" by DOE if they so choose (e.g., see first paragraph, Section 1.2, on page 1-3).

Response

The staff has no objection to making the proposed modification requested in this comment.

30. Page 19, Third Paragraph

In the first sentence, it is suggested that the phrase "results of" be added before the word "investigations."

Response

The staff has no objection to making the proposed modification requested in this comment.

31. Page 20, First Paragraph

By citing Section IV of 10 CFR Part 100, Appendix A, NRC implies that the requirements under Section IV(6) "... correlation of epicenters or locations of highest intensity of historically reported earthquakes, where possible, with tectonic structures any part of which is located with 200 miles of the site" are to be followed. We agree. However, a more appropriate reference in the context of this STP statement might be Sections V(a)(1)(i) and V(iii) with the language changed to incorporate the phrases "geologic component and seismic component of the geologic setting."

Response

The staff does not agree with the recommendation made in this comment that Sections V(a)(1)(i) and V(iii) of Appendix A to 10 CFR Part 100 are a more appropriate reference. These sections deal with the formulation of seismic and geologic design bases, which are beyond the scope of this STP.

32. Page 20, Second Paragraph

Regarding earthquakes that should be correlated with structures or associated with seismic source zones, we assume that the NRC would consider the Walker Lane Structural Zone, Nevada-California Seismic Zone and the East-West Seismic Zone as defined by the DOE in the Site Characterization Plan for Yucca Mountain and its references as the major seismic source zones that need to be considered for evaluating the seismic hazard at the Yucca Mountain site.

Response

The assumption made by the State of Nevada is correct. The staff does consider the Walker Lane Structural Zone, the Nevada-California Seismic Zone, and the East-West Seismic Zone, as defined by the DOE in its SCP and its references, as the major seismic source zones that need to be considered for the evaluation of seismic hazards at the Yucca Mountain site.

33. Page 21

The Reference list should be expanded to include DOE Order 6430.1A [DOE, 1989]; LBL-9143 [Eagling, 1983]; UCRL-53582 [Coats and Murray, 1984]; USGS OFR-84-854 [Carr, 1984]; USGS OFR-88-560 [Gawthrop and Carr, 1988]; and the version of the Site Characterization Plan for Yucca Mountain that is considered by the NRC staff to represent the current DOE position.

Response

See staff response to the State of Nevada Specific Comment No. 1.

34. Page 23

The "Bibliography" needs to include a reference(s) that the NRC staff believes suitable as guidance in characterizing seismic hazards west of the Rocky Mountain front in addition to or instead of Bernreuther, D.L., *et al.*, UCID-20421; Eagling, D.G., ed., 1983, "Seismic Safety Guide," LBL-9143; and Reiter, L., 1990, "Earthquake Hazard Analysis," are possible candidates.

Response

The "Bibliography" (Section 6.0) has been modified as suggested by this comment.

35. Page 28, Definition of "Geologic Setting"

The definitions given on Figure 2, page 26 that the "region is within the geologic setting [sic] and on page 6, item (2) where "components of the geologic system (are) acting within the geologic setting" appear to be in conflict with each other and the definition for geologic setting given here. The conflict might be resolved if the glossary was expanded to include the definition(s) for the various "systems," "settings," and "components." In addition, although the "geologic setting" definition is cast in the concrete language of 10 CFR Part 60, this glossary offers an ideal opportunity to remedy shortcomings of the 10 CFR Part 60 language by expanding on that definition, particularly as it relates to the southern Basin and Range region that includes Yucca Mountain.

Response

The staff considers that the term "region" can have varying definitions, depending on the application. With respect to Figure 2, the term refers to the area which encompasses the boundaries of the "geologic," "hydrologic," and "geochemical" system settings; with respect to the definition of "geologic system setting," the

staff considers the "geologic setting" to be that area encompassing all of the geologic component settings.

The text has been modified to address the comment made regarding the definition of the term "geologic setting;" however, site-specific definitions of component settings are outside the purview of this STP. As suggested, the "Glossary" has been amended to include definitions of "geologic system," "faulting component setting," and "seismic component setting."

36. Page 28, Definition of "Seismic Hazard"

> The statement is made that a seismic hazard may be characterized in "either" deterministic "or" probabilistic terms. This appears to be in conflict with the statements made earlier in the STP on page 5, paragraph two, that a deterministic approach only will be acceptable.

Response

The staff is aware of the potential for confusion in the use of this term, as noted in this comment. Therefore, the definition of "seismic hazard" in Appendix B ("Glossary") has been modified.

37. Page 29

> An additional reference(s) for seismic source zones west of the Rocky Mountain front needs to be added to the definition of "Seismic Source Zone."

Response

See staff response to State of Nevada Specific Comment No. 34.

U.S. GEOLOGICAL SURVEY COMMENTS

This draft STP has been improved in that it allows considerably more flexibility to the applicant than the earlier version; and it does not incorporate, as did the earlier version, Appendix A of 10 CFR Part 100 for nuclear power plants which is largely inappropriate for a geologic repository. Basically, the [draft] STP provides criteria for the applicant to use in deciding what faults to investigate in detail for designing and assessing the performance of a repository. The criteria are deterministic, an approach which the United States Geological Survey (USGS) has endorsed in the past. Deterministic criteria enable the parties to a licensing action to have a relatively clear understanding of what is or is not under consideration. All faults within the controlled area must be examined to see if they merit detailed investigation according to the criteria discussed below. However, outside the controlled area, only faults relevant to performance and design need to be considered. After these initial steps, the criteria for determining if detailed investigations are necessary are applied. These criteria seem appropriate. Consistent with 10 CFR Part 60, which requires that processes operating in the Quaternary Period be addressed, the STP suggests that faults showing Quaternary offset be investigated in detail. This stipulation may result in inclusion of some faults with relatively long recurrence intervals. However, since the time required for maintaining waste isolation is measured in thousands of years, the possibility of unpredictable episodic, or chaotic, behavior of geologic features over these time periods must be taken into account. Faults that have long been dormant may become active over the next 100,000 years and presently active faults may become quiescent. Thus, a reasonably conservative approach requires that Quaternary[-age] faults be investigated in detail if movement on them could affect a proposed repository. The same considerations dictate that faults for which evidence for Quaternary movement is indeterminate should also be investigated if they meet any of the three subcriteria of Subsection 3.1.3, Item (2). The applicant will, of course, have to use a probabilistic approach to assessing fault movement in complying with the EPA release standards in 40 CFR Part 191 in its current form. The combination of deterministic and probabilistic approaches that will eventually be used should provide a clear indication of the likely effects of faulting and seismicity on repository performance and design. The criteria outlined in this STP are a useful first step.

Response

The staff agrees with this comment. No modification of the STP is requested and thus no changes are necessary.

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APPENDIX F
DISPOSITION OF ACNW COMMENTS

Note: The Advisory Committee on Nuclear Waste (ACNW) comments listed in this appendix were made on the final draft of the subject Staff Technical Position (STP), dated December 1991.

ACNW COMMENT #1

The term "susceptible faults" should be abandoned. We suggest that the staff use a categorization scheme for faults or substitute some other nonprejudicial term.

Response

In response to this and other comments regarding the use of the term "susceptible fault," the staff has decided to abandon its use in favor of a three-step categorization scheme that identifies three types of faults. This scheme, described below and in Section 3.0, follows the logic originally underlying the "susceptible fault" concept. The three fault types are:

"Type I" faults: Faults or fault zones that are subject to displacement and of sufficient length and located such that they may affect repository design and/or performance. As such, they should be investigated in detail;

"Type II" faults: Faults or fault zones that are candidates for detailed investigation; and

"Type III" faults: Faults or fault zones either (1) not subject to displacement or (2) subject to displacement, but of such length, or located in such a manner, that they will not affect repository design and/or performance. Consequently, they do not need to be investigated in detail.

ACNW COMMENT #2

The definition and use of the term "geologic setting" are confusing. The staff should clarify the meaning of this term. For guidance on this matter, we suggest that the staff refer to the definition in 10 CFR 60.2.

Response

The term "geologic setting" is already defined in 10 CFR 60.2, in the context of its constituent parts (e.g., the "geologic," "hydrologic," and "geochemical" systems). In the context of the investigations described in this STP, the staff has attempted to provide additional definitions of how the constituent parts, themselves, may be viewed. However, in response to this comment, the staff has revised the text in Subsection 3.1.1 and Figure 2 to further clarify the staff's intent in this area.

ACNW COMMENT #3

The staff should consider clarifying the use of the term "relevant and material" in the STP, and substitute, where possible, the technical equivalent.

Response

This comment is noted. However, in the staff's view, the STP needs to use the term "relevant and material" because that specific language appears in the regulation that the STP addresses (see 10 CFR 60.21(c)(1)(ii)); there is no technical equivalent. It is a standard that calls for information that may be needed in order to arrive at an informed judgment, yet that allows for the exclusion of information that clearly has no bearing upon the determinations that must be made in the licensing proceeding. The term "relevant and material" must be applied sensitively, on a case-by-case basis, to ensure that a sound decision can be arrived at with confidence. If a quantitative or technical measure were substituted, as suggested by this comment, there is a risk that important information might not be provided or, alternatively, that unnecessary information might have to be provided. (Also see the staff response to the State of Nevada General Comment No. 8.)

ACNW COMMENT #4

The staff should further emphasize that Appendix A of 10 CFR Part 100 does not apply to a high-level waste repository. Such a statement should be included in the introduction of the subject STP. There still appears to be some confusion among certain reviewers of the STP as to the staff's intent in this regard.

Response

The staff agrees with the recommendation made in this comment and has made modifications to both Section 1.1 and Appendix A of the STP, noting that Appendix A to 10 CFR Part 100 does not apply to the geologic repository program.

ACNW COMMENT #5

The STP should not preclude the use of probabilistic assessments of candidate faults lying outside the controlled area. A clarifying statement that a qualitative probabilistic performance assessment is acceptable should be added to the text accompanying Figure 1.

Response

The staff agrees with this comment and has modified the STP to indicate that probabilistic techniques are of value in supporting deterministic analyses of which faults outside of the controlled area are of regulatory concern.

ACNW COMMENT #6

The staff should revise Figure 3 of the STP to indicate that only if Quaternary-age evidence is incomplete or unclear, should secondary criteria be evoked.

Response

The staff agrees with this comment and has revised both the text and Figure 3, as suggested.

ACNW COMMENT #7

With respect to the use of fault length as a criterion (page 12 of the STP), it is important to consider the length of both discrete faults and fault zones, portions of which may rupture during an earthquake (e.g., Cedar Mountain earthquake of 1932). A statement to that effect should be added to the STP.

Response

The staff agrees with this comment and has revised the STP to indicate that both faults and fault zones need to be considered.

ACNW COMMENT #8

The staff should revise the STP to reflect more specifically the three-dimensional aspect of fault structures.

Response

The staff agrees with the suggestion and has revised the STP to address the concern on the three-dimensional aspect of fault structures. This revision is contained in Section 3.2.

ACNW COMMENT #9

The title of the STP should be changed to "seismic and fault displacement hazards" to clarify that hazards refer to both areas of concern.

Response

The staff agrees with the recommendation made by this comment and has modified both the title and the text of this STP in order to provide the clarification requested.

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U.S. NUCLEAR REGULATORY COMMISSION

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11. ABSTRACT (200 words or less)

10 CFR Part 60 does not specify the manner in which potential fault displacement hazards and seismic hazards at a candidate site for a geologic repository are to be identified. The purpose of this staff technical position (STP), therefore, is to provide guidance to the U.S. Department of Energy (DOE) on acceptable geologic repository investigations that can be used to identify fault displacement hazards and seismic hazards. The staff considers that the approach this STP takes to investigations of fault displacement and seismic phenomena is appropriate for the collection of sufficient data for input to analyses of fault displacement hazards and seismic hazards, both for the preclosure and postclosure performance periods. However, detailed analyses of fault displacement and seismic data, such as those required for detailed assessments of repository performance, may identify the need for additional investigations.

Section 2.0 of this STP describes the 10 CFR Part 60 requirements that form the basis for investigations to describe the fault displacement hazards and seismic hazards at a geologic repository. Technical position statements and corresponding discussions are presented in Sections 3.0 and 4.0, respectively. Technical position topics in this STP are categorized thusly: (1) investigation considerations, (2) investigations for fault-displacement hazards, and (3) investigations for seismic hazards.

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