AD93-1
PDR

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

November 6, 1992

TO: REGULATORY GUIDE DISTRIBUTION LIST FOR DIVISION 1

SUBJECT: SPECIFIC ISSUES FOR COMMENT

This proposed Draft Regulatory Guide DG-1015, "Identification and Characterization of Seismic Sources, Deterministic Source Earthquakes, and Ground Motion," outlines concepts and procedures to be used in conjunction with the probabilistic/deterministic seismic hazard evaluations. The rationale for the approach is discussed in Section V.B(3) of the Federal Register notice that presents the revision of Appendix A to Part 100 for public comment. The specific questions stated below are contained in Section XI.B of the same Federal Register notice.

The staff is currently performing confirmatory studies to evaluate and refine these proposed procedures. A limited study has been completed demonstrating the feasibility of procedures and the validity of the concepts. However, the NRC staff would like to solicit comments on the concepts outlined in the proposed guide. Results of the application of the proposed procedure to four test sites are in a letter report from D. Bernreuter of LLNL to A. Murphy of NRC, dated September 24, 1992, which is available in the NRC Public Document Room at 2120 L Street NW, Washington, DC, for inspection or copying for a fee.

There are divergent views on the role probabilistic seismic hazard analysis should play in the licensing arena. There is a general consensus among the NRC staff that the revised seismic and geological siting criteria should allow considerations for a probabilistic hazard analysis. There is also a general belief that the outcome of a probabilistic analysis should be compared with the results of past practices for siting and licensing the current generation of nuclear power plants. There is a general consensus that ground motions should be calculated using deterministic methods once the controlling earthquakes are determined. With regard to the role of the probabilistic analysis, views range from an advocacy of a predominantly probabilistic analysis to the probabilistic/deterministic evaluation proposed here to a predominantly deterministic approach as used currently. Given these divergent views, the NRC staff invites comments regarding the use of probabilistic seismic hazard analysis and the balance between the deterministic and probabilistic evaluations. This and other associated issues are itemized below. As the detailed technical studies are completed some of the staff positions may be confirmed, but specific comments would be helpful at this time.

1. In making use of both deterministic and probabilistic evaluations, how should they be combined or weighted, that is, should one dominate the other? (The NRC staff feels strongly that deterministic investigations and their use in the development and evaluation of the Safe Shutdown Earthquake Ground Motion should remain an important aspect of the siting regulations for nuclear power plants for the foreseeable future. The NRC staff also feels that probabilistic seismic hazard assessment methodologies have reached a level of maturity to warrant a specific role in siting regulations.)

2. In making use of the probabilistic and deterministic evaluations as proposed in Draft Regulatory Guide DG-1015, is the proposed procedure in Appendix C to DG-1015 adequate to determine controlling earthquakes from the probabilistic analysis?

3. In determining the controlling earthquakes, should the median values of the seismic hazard analysis as described in Appendix C to Draft Regulatory Guide DG-1015 be used to the exclusion of other statistical measures, such as mean or 85th percentile? (The NRC staff has selected probability of exceedance levels associated with the median hazard analysis estimates as they provide more stable estimates of controlling earthquakes.)

4. The proposed Appendix B to 10 CFR Part 100 states: "The annual probability of exceeding the Safe Shutdown Earthquake Ground Motion is considered acceptably low if it is less than the median annual probability computed from the current [EFFECTIVE DATE OF THE REGULATION] population of nuclear power plants." This is a relative criterion without any specific numerical value of the annual probability of exceedance because of the current status of the probabilistic seismic hazard analysis. However, this requirement ensures that the design levels at new sites will be comparable to those at many existing sites, particularly more recently licensed sites. Method-dependent annual probabilities or target levels (e.g., 1E-4 for Lawrence Livermore National Laboratory or 3E-5 for the Electric Power Research Institute) are identified in the proposed regulatory guide. Sensitivity studies addressing the effects of different target probabilities are discussed in the Bernreuter to Murphy letter report. Comments are solicited as to (a) whether the above criterion, as stated, needs to be included in the regulation and (b) if not, should it be included in the regulation in a different form (e.g., a specific numerical value, a level other than the median annual probability computed for the current plants)?

5. For the probabilistic analysis, how many controlling earthquakes should be generated to cover the frequency band of concern for nuclear power plants? (For the four trial plants used to develop the criteria presented in Draft Regulatory Guide DG-1015, the average of results for the 5 Hz and 10 Hz spectral velocities was used to establish the probability of exceedance level. Controlling earthquakes were evaluated for this frequency band, for the average of 1 and 2.5 Hz spectral responses, and for peak ground acceleration.)

Comments on the above issues should be accompanied by appropriate supporting data. Written comments should be sent to the Regulatory Publications Branch, DFIPS, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

L. C. Shao

Lawrence C. Shao, Director
Division of Engineering
Office of Nuclear Regulatory Research

U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REGULATORY RESEARCH

DRAFT REGULATORY GUIDE

November 1992
Division 1
Task DG-1015

Contact: A. J. Murphy (301)492-3860

DRAFT REGULATORY GUIDE DG-1015

IDENTIFICATION AND CHARACTERIZATION OF SEISMIC SOURCES, DETERMINISTIC SOURCE EARTHQUAKES, AND GROUND MOTION

A. INTRODUCTION

Paragraph IV, "Required Investigations," of proposed Appendix B, "Criteria for the Seismic and Geologic Siting of Nuclear Power Plants on or After [Effective Date of this Regulation]," to 10 CFR Part 100, "Reactor Site Criteria," requires investigations to assess the proposed site for (a) vibratory ground motion, (b) tectonic surface deformation, and (c) nontectonic deformation. Paragraph V (in a through d) of Proposed Appendix B to 10 CFR Part 100 requires the determination of (a) deterministic source earthquakes, (b) ground motions at the site, (c) safe shutdown earthquake ground motion, and (d) the need to design for surface tectonic and nontectonic deformations.

The purpose of this guide is to provide general guidance on acceptable procedures to (1) identify and characterize seismic sources, (2) determine deterministic source earthquakes (DSEs) and controlling earthquakes (CEs), and (3) compare the seismic hazard level to that at operating plants. These procedures are required by Appendix B to 10 CFR Part 100.

This guide contains several appendices. Appendix A contains a list of definitions of pertinent terms. Appendix B describes the acceptance criteria for the annual probability of exceedence level for safe shutdown earthquake ground motions. Appendix C discusses the determination of controlling

This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received complete staff review and does not represent an official NRC staff position.

Public comments are being solicited on the draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Regulatory Publications Branch, DFIPS, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Copies of comments received may be examined at the NRC Public Document Room, 2120 L Street NW., Washington, DC. Comments will be most helpful if received by March 24, 1993.

Requests for single copies of draft guides (which may be reproduced) or for placement on an automatic distribution list for single copies of future draft guides in specific divisions should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Office of Administration, Distribution and Mail Services Section.

earthquakes from the probabilistic analysis, and Appendix D discusses the investigations to characterize seismic sources.

Any information collection activities mentioned in this regulatory guide are contained as requirements in the proposed amendments to 10 CFR Part 50 that would provide the regulatory basis for this guide. The proposed amendments have been submitted to the Office of Management and Budget for clearance that may be appropriate under the Paperwork Reduction Act. Such clearance, if obtained, would also apply to any information collection activities mentioned in this guide.

B. DISCUSSION

Appendix B requires consideration of both probabilistic and deterministic approaches to obtain site geologic and seismologic characteristics. The approach required by Appendix A to 10 CFR Part 100 for determining the safe shutdown earthquake ground motion (SSE) is deterministic, and thus does not explicitly incorporate uncertainties about the seismic hazard into the ground motion determination. Current probabilistic seismic hazard analyses rely heavily on expert opinion, and since their results are driven by the tails of the probability distributions, they need to be benchmarked by simpler deterministic analysis. Therefore, the role of the probabilistic analysis is to ensure that the uncertainties have been included in the assessment of the seismic hazard, and the role of the deterministic analysis is to ensure that the resultant design provides protection against a scenario based on historical seismicity and recent geological history.

Before providing specific guidance, the following synopsis of the development of the SSE is presented. The development of the SSE follows two required, parallel paths. One path is referred to in Figure 1 as Deterministic Analysis (DA) and one path as Probabilistic Analysis (PA). The initial step in the process is to obtain the site- and region-specific geological, seismological, and geophysical data. Branching from the first step to DA, the seismic sources around the site are identified and the deterministic source earthquake (DSE) for each source is determined. Ground motion is calculated using DSEs and the methods acceptable to the NRC staff described in Standard Review Plan (SRP) Section 2.5.2, "Vibratory Ground Motion." The controlling earthquakes for this path are determined as illustrated in Figure 2. The

initial step along PA is to conduct an Electric Power Research Institute (EPRI) or a Lawrence Livermore National Laboratory (LLNL) seismic hazard assessment of the site (EPRI-NP-6395-D, Ref. 1, and NUREG/CR-5250, Ref. 2) for Eastern U.S. sites. The results of this assessment are compared to the collective assessments of the currently operating plants as described in Appendix B of this guide. The site seismic hazard assessments are deaggregated as described in Appendix C of this guide to obtain the controlling earthquakes for PA. Ground motion based on the controlling earthquakes from PA are also calculated as described in SRP 2.5.2. The ground motions from the DA and PA controlling earthquakes are compared to the SSE ground motion or are used to develop the SSE.

1. IDENTIFICATION AND CHARACTERIZATION OF SEISMIC SOURCES

"Seismic source" is a general term referring to both seismogenic sources and capable tectonic sources. A "seismogenic source" is a portion of the earth that is considered to have uniform seismicity (same DSE and frequency of recurrence). A seismogenic source would not cause surface displacement. Seismogenic sources cover a wide range of possibilities from a well-defined tectonic structure to simply a large region of diffuse seismicity (seismotectonic province). A "capable tectonic source" is a tectonic structure that can generate both earthquakes and deformation such as faulting or folding at or near the surface in the present tectonic regime. Appendix A contains definitions of these and other terms used in this regulatory guide.

Investigations of the site and region around the site are necessary to identify seismic sources and determine their potential for generating earthquakes and causing surface deformation. Identification and characterization of seismic sources are based on regional and site geological and geophysical data, historical and instrumental seismicity data, the regional stress field, and geologic evidence for prehistoric earthquakes. The bases for the identification of the seismic sources should be documented. Appendix D describes investigation procedures that may be used in identifying and defining seismic sources.

The following is a general list of characteristics to be determined for a seismic source:

1. Source zone geometry (location and extent, both surface and subsurface).

2. Description of Quaternary (last 2 million years) displacements (sense of slip on the fault, fault length and width, age of displacements, estimated displacement per event, estimated magnitude per offset, rupture length and area, and displacement history or uplift rates of seismogenic folds).

3. Historical and instrumental seismicity associated with each source.

4. Evidence of paleoseismicity.

5. Relationship of the fault to other potential seismic sources in the region.

6. Deterministic Source Earthquake. (Details for the determination of the DSEs are provided in section 2.)

7. Recurrence model (frequency of earthquake occurrence versus magnitude).

8. Effects of human activities such as withdrawal of fluid from or addition of fluid to the subsurface, extraction of minerals, or the effects of dams or reservoirs.

9. Volcanism. Volcanic hazard is not addressed in this regulatory guide. It will be considered on a case by case basis in regions where this hazard exists.

10. Other factors that can contribute to the characterization of seismic sources such as strike and dip of tectonic structures, orientations of regional and tectonic stresses, fault segmentation (both along strike and down-dip).

The level of detail for investigations around the site is governed by the Quaternary tectonic regime and the geological complexity of the site and region. Regional investigations such as geological reconnaissances and literature reviews should be conducted within a radius of 320 km (200 miles)

of the site to identify seismic sources. Geological, seismological, and geophysical investigations should be carried out within a radius of 40 km (25 miles) to identify and characterize the seismic and surface deformation potential of capable tectonic sources and the seismic potential of seismogenic sources, or to demonstrate that such structures are not present. Detailed geological, geotechnical, seismological, and geophysical investigations should be conducted within a radius of 8 km (5 miles) of the site to determine the potential for tectonic deformation at or near the ground surface in the site vicinity. Sites that are located such that there are capable or seismogenic structures within a radius of 40 km (25 miles) should have more extensive geologic and seismic investigations and analyses (similar to those within a 8 km (5 mile) radius). The areas of investigations may be asymmetrical and larger than specified above in areas near capable tectonic sources, high seismicity, or complex geology.

For the site and the area surrounding the site, the lithologic, stratigraphic, hydrologic, and structural geologic conditions will need to be determined. The investigations should include the determination of the static and dynamic engineering properties of the materials underlying the site and an evaluation of physical evidence concerning the behavior during prior earthquakes of the surficial materials and the substrata underlying the site. The properties needed to determine the behavior of the underlying material during earthquakes and the characteristics of the underlying material in transmitting earthquake ground motions to the foundations of the plant (such as seismic wave velocities, density, water content, porosity, elastic moduli, and strength) should be determined. Geological, seismological, and geophysical investigations are described in Appendix D to this guide and geotechnical investigations are described in Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants."

Where it is determined that surface deformation need not be taken into account, sufficient data to clearly justify the determination should be presented. Because engineering solutions cannot always be demonstrated for the effects of permanent ground displacement phenomena, it is prudent to avoid a site that has a potential for surface deformation.

Eastern United States

The area east of the Rocky Mountains within the North American Plate and well away from the active plate margins is described as the "stable continental region" (SCR). In the SCR, characterization of seismic sources is more problematic than in the active plate margin region because there is generally no clear association between seismicity and known tectonic structures. The observed geologic structures were generated in response to tectonic forces that no longer exist and that bear little correlation with current tectonic forces. Thus, more judgment must be used than for active plate margin regions, and it is important to account for this uncertainty by the use of alternative models.

Based on current knowledge, seismic sources in the SCR are generally relatively large areas, or seismotectonic provinces. The identification of seismic sources in the SCR considers hypotheses presently accepted for the occurrence of earthquakes in the SCR (for example, the reactivation of favorably oriented zones of weakness or the local amplification and release of stresses concentrated around a geologic structure).

Western United States

For the active plate margin region, where earthquakes can often be correlated with tectonic structures, those structures should be assessed for their seismic and surface deformation potential. In the Western United States, at least three types of sources exist: (1) faults that are known at the surface, (2) buried (blind) sources and, (3) subduction zone sources, such as exist in the Pacific Northwest. The nature of surface faults can be determined by conventional surface and near-surface investigation techniques to determine strike, geometry, sense of displacements, length of rupture, Quaternary history, etc.

Buried (blind) faults are often accompanied by coseismic surficial deformation such as folding, uplift, or subsidence. The surface expression of blind faulting can be detected by the mapping of uplifted or down-dropped geomorphological features or stratigraphy, survey leveling, and geodetic methods. The nature of the structure at depth can often be determined by core borings and geophysical techniques.

Subduction zones are seismic sources in the Pacific Northwest and Alaska. The seismic sources associated with subduction zones are the interface between the subducting and overriding lithospheric plates, faults within the overriding plates, and intraslab sources in the interior of the downgoing oceanic slab. The characterization of subduction zone seismic sources should include consideration of the geometry of the subducting plate, rupture segmentation of subduction zones, the geometry of historical ruptures, constraints on the up-dip and down-dip extent of rupture, and comparisons with other subduction zones worldwide.

2. DETERMINISTIC SOURCE EARTHQUAKES (DSES)

DSEs are the largest earthquakes that can reasonably be expected to occur in a given seismic source in the current tectonic regime. Deterministic source earthquakes are characterized by their magnitudes and, as a minimum, will be the largest historical earthquake associated with each source. A larger earthquake is warranted when specific geological evidence is available, e.g., paleoliquefaction evidence of larger prehistoric earthquakes or when the rate of occurrence of earthquakes indicates the likelihood of a larger earthquake than the largest historical event.

Eastern United States

In the SCR there is a short record of the historical seismicity and considerable uncertainty about the underlying causes of earthquakes. Because of this uncertainty, it is necessary to use considerable judgment and a variety of approaches to establish the DSEs. In addition to the maximum historical earthquake, the determination of the DSE earthquake for each identified seismogenic source is based on the pattern and rate of seismic activity, the Quaternary (2 million years and younger) development and characteristics of the source, the current stress regime and how it aligns with the known tectonic structures in the source, and paleoseismic data.

Western United States

In the Western United States, earthquakes can often be associated with tectonic structures. For faults, the magnitude of an earthquake is related to

the characteristics of the estimated rupture, such as the length or the amount of fault displacement. The following empirical correlations can be used to estimate DSEs from fault behavioral data and also to predict the amount of displacement that might be expected for a given magnitude.

1. Surface rupture length versus magnitude (Refs. 3-6).

2. Subsurface rupture length versus magnitude (Ref. 7).

3. Rupture area versus magnitude (Ref. 8).

4. Maximum and average displacement versus magnitude (Ref. 9).

In the Pacific Northwest and Alaska, DSEs must be assessed for subduction zone seismic sources. Worldwide observations indicate that the largest earthquakes are associated with the plate interface, although intraslab earthquakes (e.g., the 1949 Puget Sound earthquake) can also be large. DSEs for subduction zone sources can be based on estimates of the expected dimensions of rupture or analogies to other subduction zones worldwide.

3. PROBABILISTIC SEISMIC HAZARD ANALYSIS

A probabilistic seismic hazard analysis (PSHA) should be carried out for the site. A PSHA allows the use of multi-valued models to estimate the likelihood of earthquake ground motions occurring at a site. The PSHA systematically takes into account uncertainties that exist in various parameters (such as seismic sources, maximum earthquakes, and ground motion attenuation). Alternative hypotheses are considered in a quantitative fashion. The PSHA can be used to determine the effects of varying significant parameters, to identify significant sources in terms of magnitude and distance, and to provide hazard estimates for use in seismic probabilistic risk assessments.

The results of a PSHA are specifically used to derive controlling earthquakes as discussed below and in Appendix C. It can also be used to estimate the annual probability of exceeding the SSE and demonstrate that the annual probability of exceeding the SSE design ground motion at the site compares favorably with that for the currently operating nuclear power plants. (The procedure for this demonstration is described in Appendix B.)

Either the Lawrence Livermore National Laboratory (LLNL) (Ref. 2) or Electric Power Research Institute (EPRI) (Ref. 1) seismic hazard analyses, including associated data bases, should be used for plant sites in the SCR. However, alternative seismic hazard analyses may be used with proper justification. For the PSHA, use of the seismic sources identified in the LLNL and EPRI studies is considered acceptable except in regions of the SCR with high activity rates, e.g., near New Madrid and Charleston. In these cases, either describe additional site-specific seismic sources or show that the regional seismic sources in the LLNL and EPRI probabilistic studies adequately model the tectonics in the vicinity of the site.

Probabilistic methodologies similar to the LLNL and EPRI seismic hazard studies have not been performed for the Western United States. For Western U.S. sites, a site-specific PSHA must be performed and documented in such detail that a thorough review can be carried out by the NRC staff (Refs. 10-12).

4. CONTROLLING EARTHQUAKES

Controlling earthquakes are those earthquakes that have the greatest effect on the ground motion at the nuclear power plant site. There may be several controlling earthquakes for a site, e.g., a moderate nearby earthquake may control the high-frequency portion of the ground motion spectrum, and a large distant earthquake may control the low-frequency portion of the spectrum. See Figure 2.

In the Deterministic Analysis (Figure 1), the controlling earthquakes are determined by the following procedure.

1. For each seismic source, place the DSE at the closest approach of that source to the site. For the seismic source in which the site is located, the DSE should be considered to occur at about 15 km (9 mi) from the site.

2. Determine the DSEs that produce the largest ground motions at the site. Ground motions at the site from DSEs are estimated using the procedures described in Standard Review Plan Section 2.5.2, "Vibratory Ground Motion." The earthquakes producing the largest ground motions at the site are the controlling earthquakes.

In the Probabilistic Analysis (see Figure 1), the controlling earthquakes are determined by the following procedure.

1. Perform a probabilistic seismic hazard analysis for the site. The analysis will develop uniform hazard spectra at several annual probabilities of exceedence.

2. Deaggregate the probabilistic seismic hazard analysis results to identify controlling earthquakes; their description includes magnitude (M) and distance (D) from the site (see Appendix C). This deaggregation should be done at the annual probability of exceedence level discussed in Appendix B.

The controlling earthquakes thus derived from the deterministic and probabilistic analyses can be compared at this stage to determine whether the controlling earthquakes from these two approaches are similar and also to determine if the controlling earthquake or earthquakes that will dominate the ground motion estimates at the site are easily identifiable. If the dominant controlling earthquake can be identified, the ground motions are determined only for this identified controlling earthquake. If the controlling earthquakes from the two approaches are dissimilar, ground motion estimates are made for various controlling earthquakes and compared to derive the final ground motion estimates for use in establishing the SSE ground motion or comparing it with the SSE ground motion.

C. REGULATORY POSITION

1. During the site selection phase, the preferred sites are those with a minimum likelihood of surface or near-surface deformation or the occurrence of earthquakes on faults in the site vicinity (within a radius of 8 km (5 miles)). Because of the uncertainties and difficulties in mitigating the effects of permanent ground displacement phenomena such as surface faulting or folding, fault creep, subsidence or collapse, the NRC staff considers it prudent to select an alternative site when the potential for permanent ground displacement exists at a site.

2. Regional investigations such as geological reconnaissances and literature reviews should be conducted within a radius of 320 km (200 miles) of the site to identify seismic sources.

3. Geological, seismological, and geophysical investigation should be carried out within a radius of 40 km (25 miles) to identify and characterize the seismic potential of capable tectonic and seismogenic sources or demonstrate that such structures are not present.

4. Detailed geological, geotechnical, seismological, and geophysical investigations should be conducted within a radius of 8 km (5 miles) of the site to determine the potential for tectonic deformation at or near the ground surface in the site vicinity. Geological, seismological, and geophysical investigations are described in Appendix D to this guide, and geotechnical investigations are described in Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants."

5. Sites that are located such that there are capable or seismogenic faults within a radius of 40 km (25 miles) should have more extensive geologic and seismic investigations and analyses (similar to those within an 8-km (5-mile) radius). The area of investigation may be asymmetrical and extend beyond 40 km (25 miles).

6. Seismic sources that were not considered in the LLNL or EPRI PSHA should be identified and characterized using the information developed by the investigations. Alternative seismic sources should be developed to incorporate a range of interpretations, and the bases for the identification of these sources should be documented. Source zone geometry should be defined for each seismic source. For faults, the type of slip, length of rupture, amount of displacement per maximum event, and area of the rupture surface should be determined.

7. Deterministic source earthquakes, which are the best judgment of the maximum earthquake that can reasonably be expected to occur in a given seismic source, should be defined for each seismic source.

8. A PSHA for the site should be performed to estimate the annual probability of exceeding the SSE. Either the LLNL or EPRI probabilistic seismic hazard analyses with associated data bases should be used for plants in the Eastern United States. For western plants, a site-specific PSHA should be performed. Use the PSHA to identify sources in terms of magnitude and distance that contribute significantly to the seismic hazard at the site.

9. Determine the CEs that produce the largest ground motions at the site. Ground motions at the site from CEs are estimated using the procedures described in Section 4 of the Discussion section of this guide and Standard Review Plan Section 2.5.2, "Vibratory Ground Motion."

D. IMPLEMENTATION

The purpose of this section is to provide guidance to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

This draft guide has been released to encourage public participation in its development. Except in those cases in which the applicant proposes an acceptable alternative method for complying with the specified portions of the Commission's regulations, the method to be described in the active guide reflecting public comments will be used in the evaluation of applications for construction permits, operating licenses, early site permits, or combined licenses submitted after the implementation date to be specified in the active guide. This guide would not be used in the evaluation of an application for an operating license submitted after the implementation date to be specified in the active guide if the construction permit was issued prior to that date.

REFERENCES

1. Electric Power Research Institute, "Probabilistic Seismic Hazard Evaluations at Nuclear Power Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue," NP-6395-D, April 1989.

2. D. L. Bernreuter et al., "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," NUREG/CR-5250, January 1989.

3. D. B. Slemmons, "Faults and Earthquake Magnitude," U.S. Army Corps of Engineers, Waterways Experiment Station, Misc. Papers S-73-1, Report 6, 1977.

4. D. B. Slemmons, "Determination of Design Earthquake Magnitudes for Microzonation," Proceedings of the Third International Microzonation Conference, Volume 1, pp. 119-130, 1982.

5. M. G. Bonilla, H.A. Villabobos, and R.E. Wallace, "Exploratory Trench Across the Pleasant Valley Fault, Nevada," Professional Paper 1274-B, U.S. Geological Survey, pp. B1-B14, 1984.

6. S. G. Wesnousky, "Relationship Between Total Affect, Degree of Fault Trace Complexity, and Earthquake Size on Major Strike-Slip Faults in California" (Abs), Seismological Research Letters, Volume 59, Number 1, 1988.

7. D. L. Wells et al., "New Earthquake Magnitude and Fault Rupture Parameters: Part II. Maximum and Average Relationships" (Abs), Seismological Research Letters, Volume 60, Number 1, 1989.

8. M. Wyss, "Estimating Maximum Expectable Magnitude of Earthquakes from Fault Dimensions," Geology, Volume 7 (7), pp. 336-340, 1979.

9. D. L. Wells and K. J. Coppersmith, "Analysis of Empirical Relationships Among Magnitude, Rupture Length, Rupture Area, and Surface Displacement" (Abs), Seismological Research Letters, Volume 63, Number 1, 1992.

10. Pacific Gas and Electric Company, "Final Report of the Diablo Canyon Long Term Seismic Program; Diablo Canyon Power Plant," NRC Docket Nos. 50-275 and 50-323, 1988.*

11. USNRC, "Safety Evaluation Report Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2," NUREG-0675, Supplement No. 34, June 1991.

12. Letter from G. Sorensen, Washington Public Power Supply System, to USNRC. Subject: Nuclear Project No. 3, Resolution of Key Licensing Issues, Response to Question on Seismic Hazard, February 29, 1988.*

---

*Available for inspection or copying for a fee at the NRC Public Document Room, 2120 L Street NW., Washington, DC.

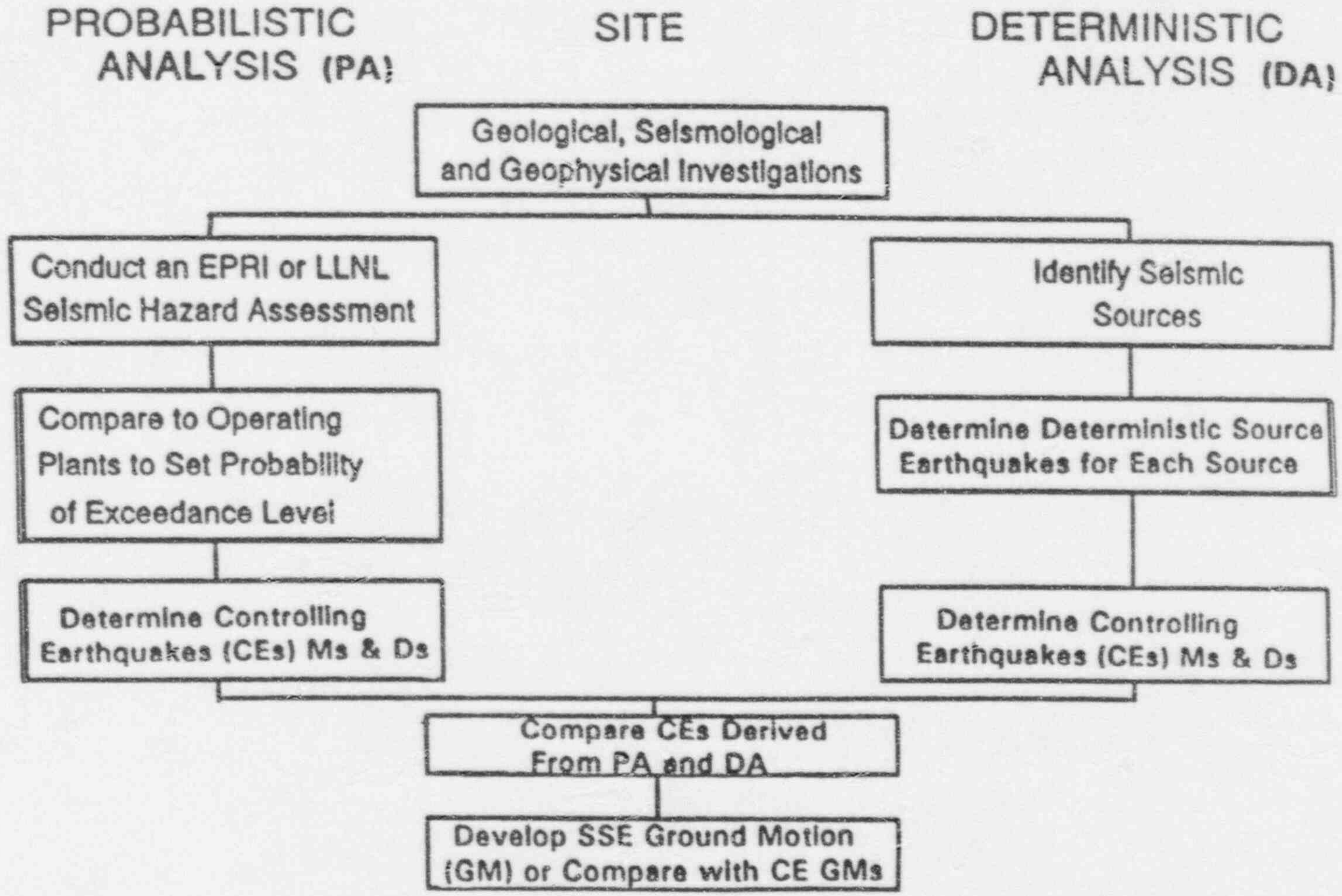

Figure 1. Flow Chart for Determination of the SSE in the Eastern United States.

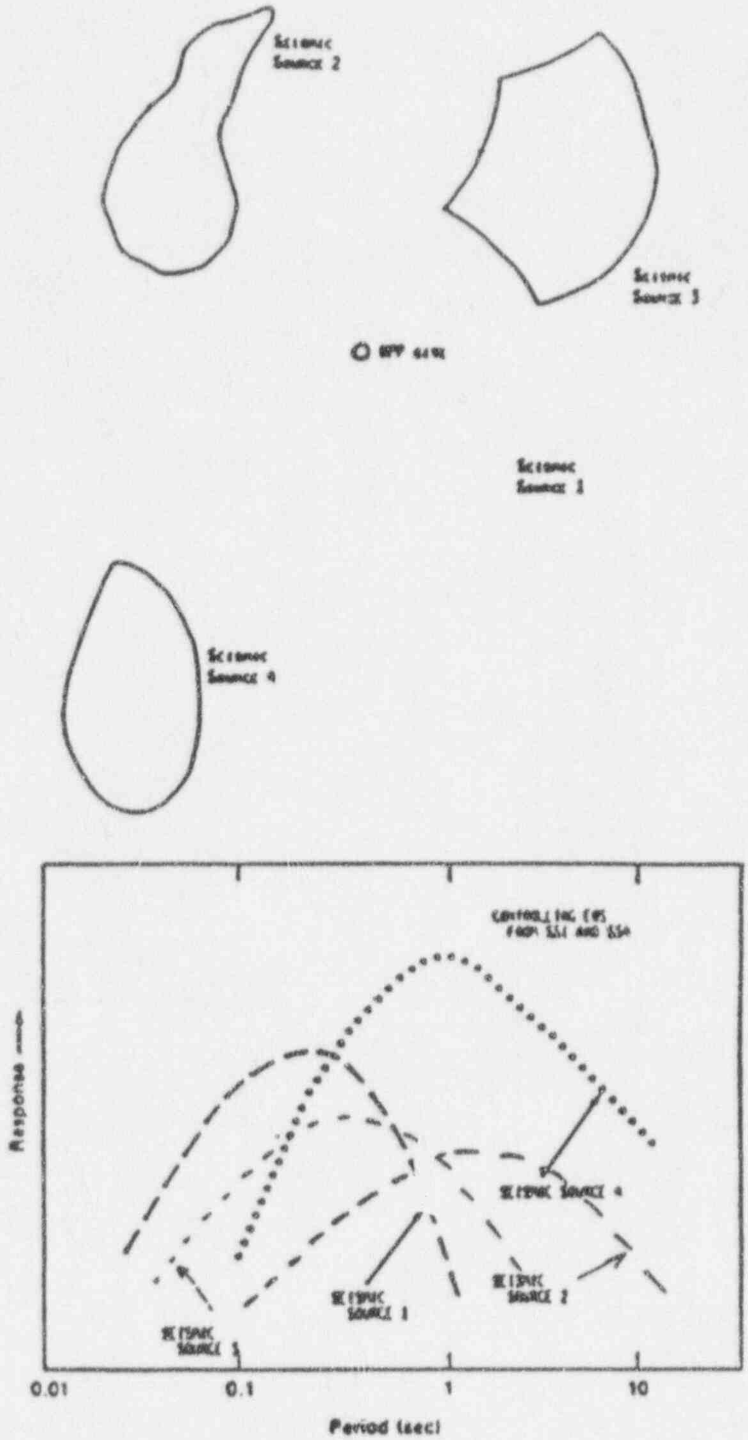

Figure 2. Schematic Representation of the Determination of the Controlling Earthquakes for the Deterministic Analysis Path.

APPENDIX A

DEFINITIONS

A capable tectonic source is a tectonic structure that can generate both earthquakes and tectonic surface deformation such as faulting or folding at or near the surface in the present seismotectonic regime. It is characterized by at least one of the following characteristics:

a. Presence of surface or near-surface deformation of landforms or geologic deposits of a recurring nature within the last approximately 500,000 years or at least once in the last approximately 50,000 years.

b. A reasonable association with one or more large earthquakes or sustained earthquake activity, usually accompanied by significant surface deformation.

c. A structural association with a capable tectonic source having characteristics of a of this paragraph, such that movement on one could be reasonably expected to be accompanied by movement on the other.

In some cases, the geologic evidence of past activity at or near the ground surface along a particular capable tectonic source may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the structure from which an evaluation of its characteristics in the vicinity of the site can reasonably be based. Such evidence should be used in determining whether the structure is a capable tectonic source within this definition.

Notwithstanding the foregoing paragraphs, structural association of a structure with geologic structural features that are geologically old (at least pre-Quaternary) such as many of those found in the eastern region of the United States will, in the absence of conflicting evidence, demonstrate that the structure is not a capable tectonic source within this definition.

Controlling earthquakes (CEs) are the earthquakes that produce the largest estimated ground motions at the site. There may be several CEs for a site.

A deterministic source earthquake (DSE) is the largest earthquake that can reasonably be expected to occur in a given seismic source in the current tectonic regime, and it is used in a deterministic analysis. It is generally based on the maximum historical earthquake associated with that seismic source, unless geological evidence warrants a larger earthquake or the rate of occurrence of earthquakes indicates the likelihood of larger than the largest historical event.

The intensity of an earthquake is a measure of its effects on humans, human-built structures, and the earth's surface at a particular location. Intensity is described by a numerical value on the Modified Mercalli scale.

An earthquake magnitude is a measure of the strength of an earthquake as determined by seismographic observations.

Nontectonic deformation is distortion of surface or near-surface soils or rocks that is not directly attributable to tectonic activity. Such deformation includes features associated with subsidence, karst terrane, glaciation or deglaciation, and growth faulting.

The safe shutdown earthquake ground motion (SSE) is the vibratory ground motion for which certain structures, systems, and components are designed to remain functional.

A seismic source is a general term referring to both seismogenic sources and capable tectonic sources.

A seismogenic source is a portion of the earth that has uniform earthquake potential (same expected maximum earthquake and frequency of recurrence) distinct from the surrounding area. A seismogenic source will not cause surface displacement. Seismogenic sources cover a wide range of possibilities from a well-defined tectonic structure to simply a large region of diffuse seismicity (seismotectonic province) thought to be characterized by the same earthquake recurrence model. A seismogenic source is also characterized by its involvement in the current tectonic regime as reflected in the Quaternary (approximately the last 2 million years).

A *stable continental region* (SCR) is composed of continental crust, including continental shelves, slopes, and attenuated continental crust, and excludes active plate boundaries and zones of currently active tectonics directly influenced by plate margin processes. It exhibits no significant deformation associated with the major Mesozoic-to-Cenozoic (last 240 million years) orogenic belts. It excludes major zones of Neogene (last 25 million years) rifting, volcanism, or suturing.

A *tectonic structure* is a large-scale dislocation or distortion usually within the earth's crust. Its extent is on the order of miles.

APPENDIX B

ACCEPTANCE CRITERIA FOR THE ANNUAL PROBABILITY OF EXCEEDENCE LEVEL FOR SAFE SHUTDOWN EARTHQUAKE GROUND MOTIONS

B.1 INTRODUCTION

This appendix outlines a procedure to calculate the annual probability of exceeding the safe shutdown earthquake ground motion (SSE). This procedure can be used (1) to compare the calculated annual probability of exceeding the SSE at proposed plants to the calculated annual probabilities for the currently operating plants as required by Appendix B to 10 CFR Part 100 and (2) to establish controlling earthquakes in the probabilistic hazard analysis as discussed in Appendix C to this regulatory guide. Uniform hazard spectra (spectra that have a uniform probability of exceedence over the frequency range of interest) should be calculated to estimate the annual probability of exceeding the SSE design response spectrum.

B.2 PROCEDURE

The following procedure is one approach acceptable to the NRC staff to assure that the annual probability of exceeding the SSE compares favorably with that for the nuclear power plants operating as of the date of the final version of Appendix B to Part 100.

B.2.1 Eastern U.S. Sites

There are two state-of-the-art approaches (outlined in Refs. 1B and 2B) currently available to calculate the probabilistic seismic hazard for sites east of the Rocky mountains (Eastern United States). These approaches, however, produce different hazard estimates for a given site. Therefore, the NRC staff is recommending the following interim procedure until the differences between the two hazard methods are resolved. This procedure relies on relative measures to ensure that the annual probability of exceeding the SSE is comparable to that of operating plants. The procedure is based on studies conducted for the Eastern Seismicity Issue and the IPEEE program (Ref. 3B).

Either the LLNL or EPRI methodology can be used to carry out the following calculations, with the appropriate set of limits associated with each method. If any analysis other than the LLNL or EPRI methods is used in the Eastern United States, annual probabilities of exceeding the SSE would need to be developed for all operating plant sites in addition to the site under consideration in order to make the appropriate comparison.

Step 1. Calculate the Uniform Hazard Response Spectra (UHRS) with various return periods. Figure B.1 shows a sample set of median UHRS for various return periods. The UHRS should be developed at the same location as the location of the SSE (i.e. either at the free ground surface or at a hypothetical rock outcrop).

Step 2. Calculate composite annual probabilities of exceeding the SSE and compare those probabilities with operating plants using median hazard estimates. (Although the median estimates are used for carrying out the procedure outlined in this appendix, the hazard analysis should be performed with consideration of uncertainties to develop complete insights.) The procedure is illustrated in Figure B.2.

1. Estimate the annual probabilities of exceeding the SSE spectrum at two discrete frequencies (5 and 10 Hz) using the UHRS.

2. Calculate the composite annual probability using the following formula:

   Composite Annual Probability = 1/2(a1) + 1/2(a2)

   where a1 and a2 represent annual probabilities of exceeding SSE spectral ordinates at 5 and 10 Hz, respectively.

   Example: From Figure B.2, for a median UHRS derived using the LLNL methodology, at points a1 and a2 corresponding to 5 and 10 Hz:

Composite Annual Probability = 1/2(4E-5) + 1/2(8E-5)
= 6E-5.

3. Figure B.3 shows the distribution of median annual probabilities of exceeding SSEs for operating Eastern U.S. plants using LLNL hazard estimates. This figure also indicates a limit; approximately 50% of the currently operating plants have an annual probability of exceeding the SSE ground motion below this limit. (Limits for both the current EPRI and LLNL seismic hazard studies are listed in Table B.1.) The SSE is adequate when the annual probability of exceeding the SSE compares favorably to the limits shown in these figures.

Table B.1

Method	Annual Probability of Exceedance Limits for Median Hazard Estimates
LLNL	1E-4
EPRI	3E-5

For the hypothetical example, the calculated annual probability of exceedance of 6E-5 is less than the limit of 1E-4, and thus the probability of exceeding the SSE compares favorably with that of operating plants.

Figure B.4 presents the same information from the use of the EPRI UHRS estimates. This limit should be used when the EPRI method is used to calculate the annual probability of exceeding the SSE.

B.2.2 Western U.S. Sites

For the Western U.S. sites, a probabilistic data base, such as that compiled in the LLNL and EPRI studies, is not available. To date no procedure exists to compare the annual probability of exceeding the SSE to other sites

in the Western United States. In addition, the probabilistic hazard at a site in the Western United States may be governed by clearly identifiable seismic sources, such as faults (or folds) observed at the surface that have better defined seismicity characteristics. Therefore, for Western U.S. sites, a site-specific analysis should be developed using suitable methodologies to estimate the annual probability of exceeding the SSE and to identify significant contributors to the hazard (Ref. 4B).

REFERENCES

1B. Electric Power Research Institute, "Probabilistic Seismic Hazard Evaluations at Nuclear Power Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue," NP-6395-D, 1989.

2B. D. L. Bernreuter et al., "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," NUREG/CR-5250, January 1989.

3B. J.T. Chen et al., "Procedural and Submittal Guidance for Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," USNRC, NUREG-1407, June 1991.

4B. USNRC, "Safety Evaluation Report Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2," NUREG-0675, Supplement No. 34, June 1991.

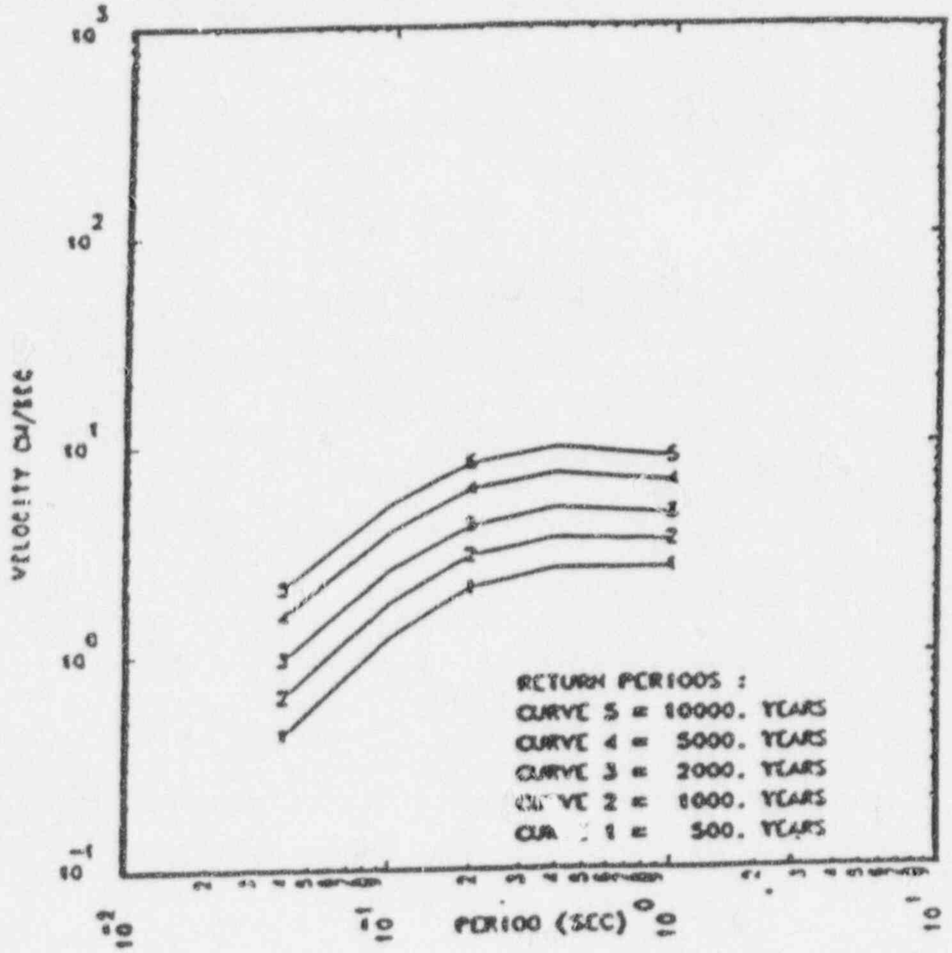

Figure B.1 Median Uniform Hazard Response Spectra

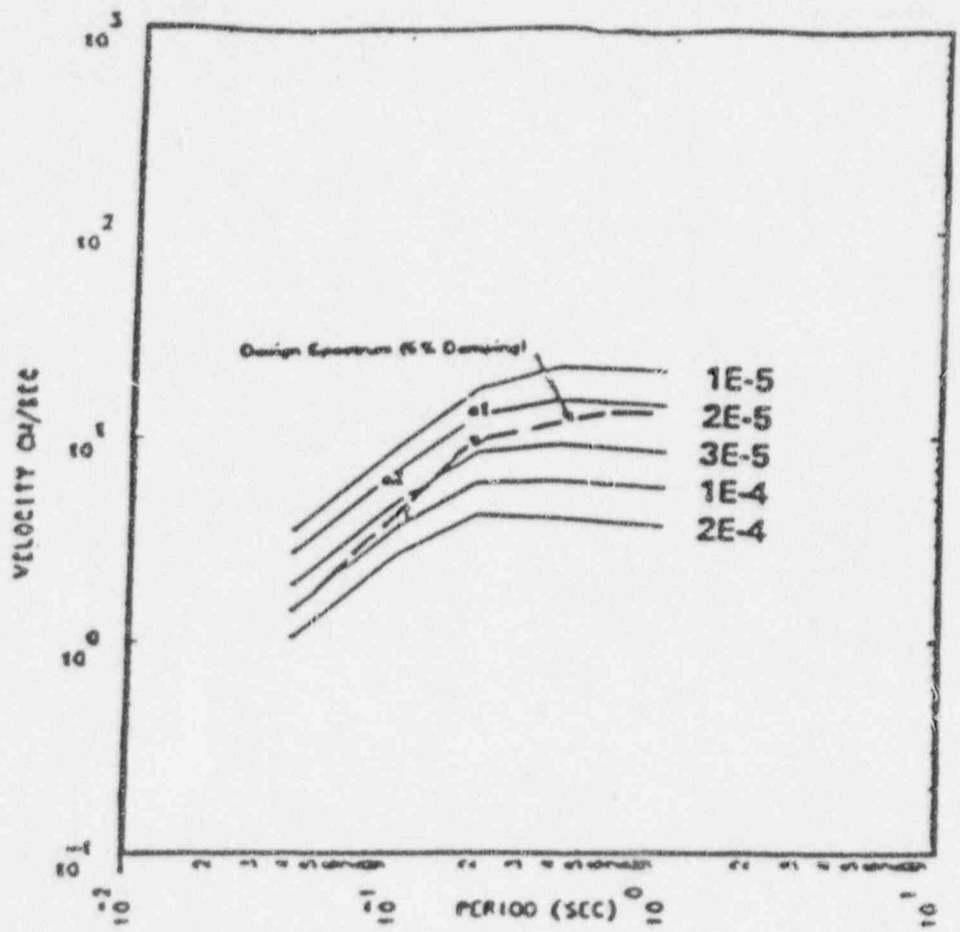

Figure B.2 Computed Annual Probability of Exceeding Design Basis

Composite Annual Probability = 1/2(a1) + 1/2(a2)

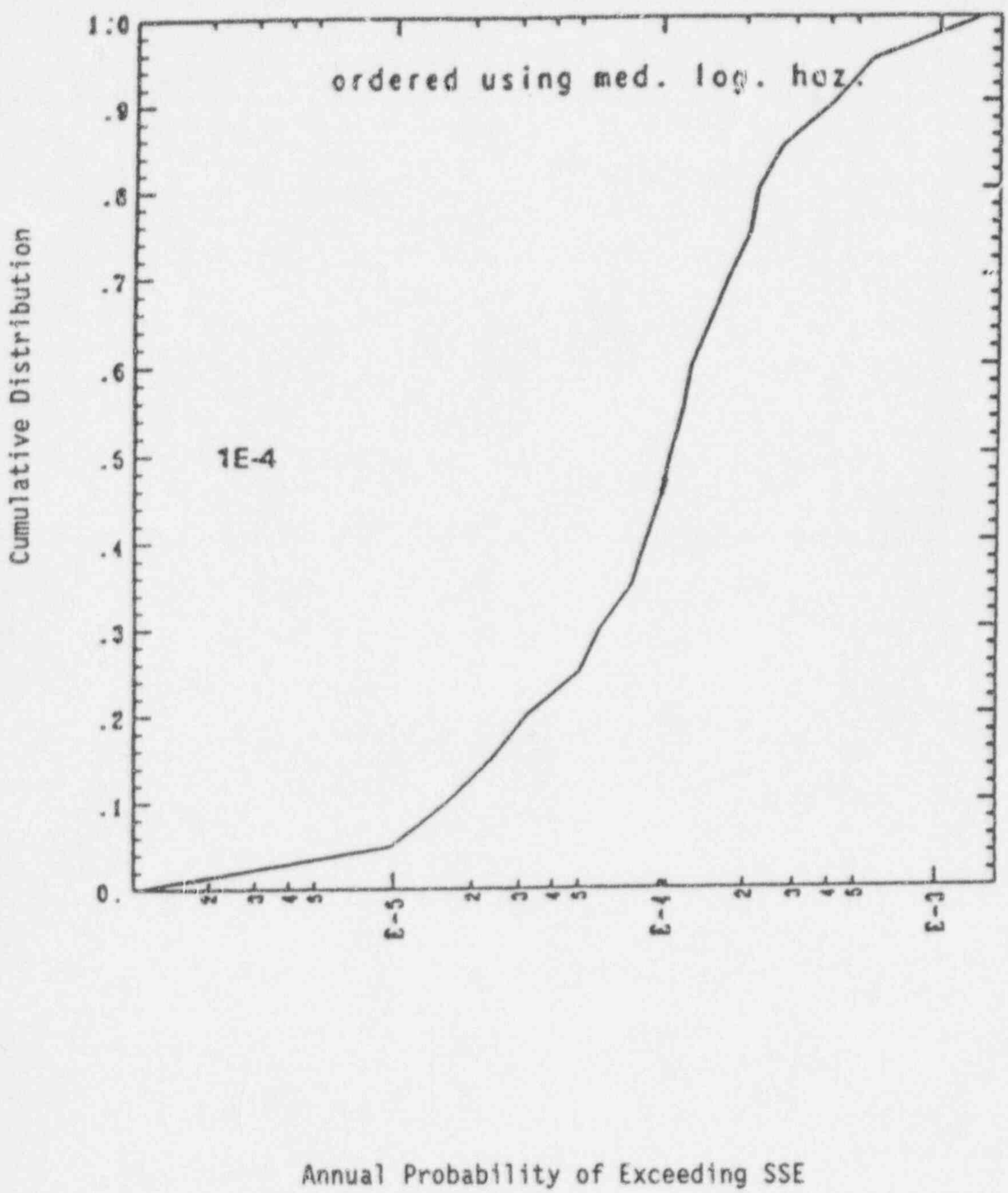

Figure B.3 Annual Probability of Exceeding SSE Using Median LLNL Hazard Estimates

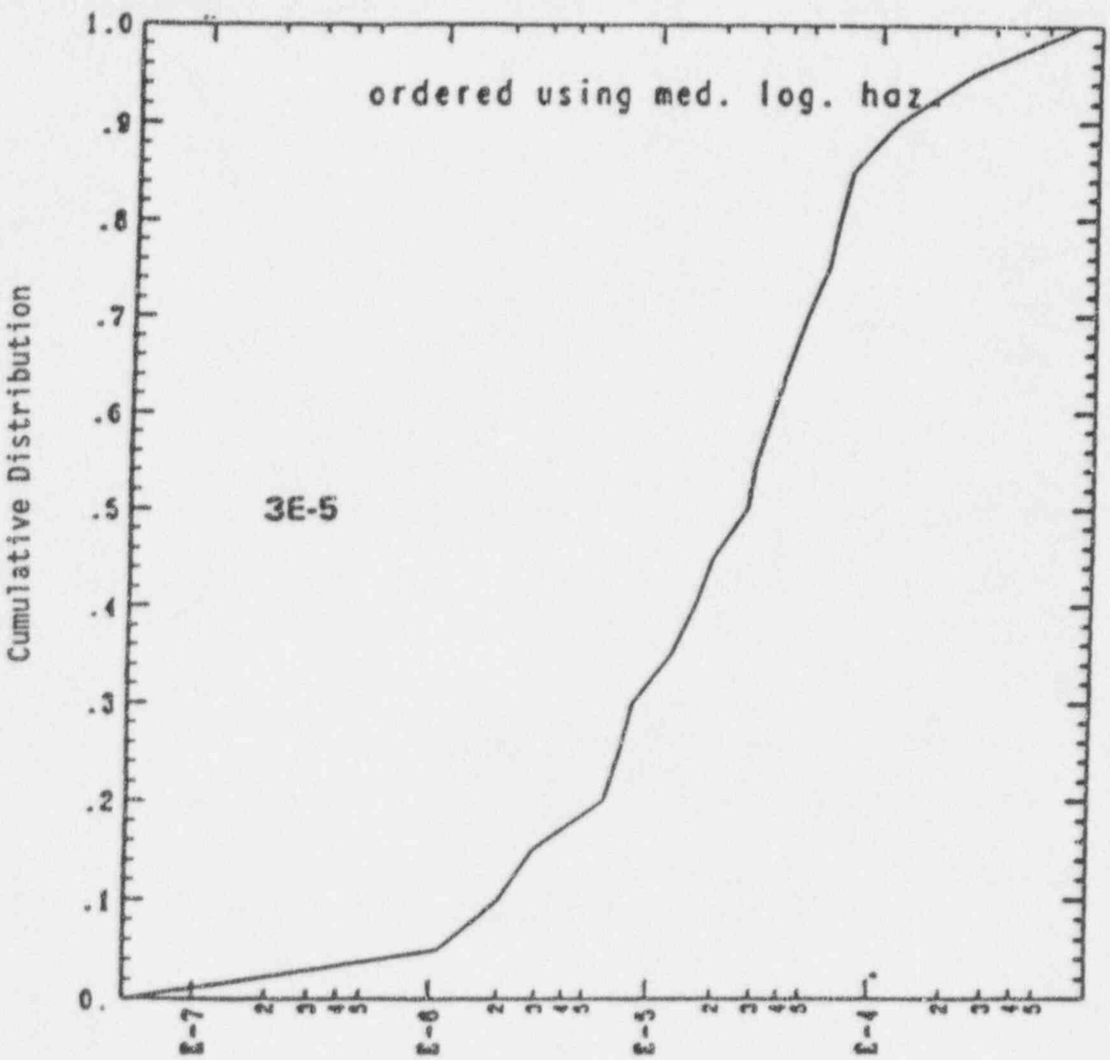

Figure B.4 Annual Probability of Exceeding SSE Using Median EPRI Hazard Estimates

APPENDIX C

DETERMINATION OF CONTROLLING EARTHQUAKES FROM THE PROBABILISTIC ANALYSIS

C.1 INTRODUCTION

This appendix outlines a procedure to determine controlling earthquakes from the probabilistic hazards analysis for a site. The ground motions from these controlling earthquakes should be determined following the procedures outlined in Section 2.5.2 (Subsection 2.5.2.6) of the Standard Review Plan. Controlling earthquakes should be determined for the median seismic hazard limit used to satisfy the requirement of Appendix B to 10 CFR Part 100 and discussed in Section C.2 below and Appendix B of this regulatory guide to demonstrate that the annual probability of exceeding the safe shutdown earthquake ground motion (SSE) compares favorably with that of the currently operating nuclear power plants.

C.2 PROCEDURE

The following procedure is one approach acceptable to the NRC staff to determine controlling earthquakes from a probabilistic hazards analysis.

C.2.1 Eastern U.S. Sites

As discussed in Appendix B of this regulatory guide, there are two approaches (Refs. 1C and 2C) currently available to calculate probabilistic seismic hazards for sites east of the Rocky mountains (Eastern United States). Either of these methods can be used to carry out the following calculations, with the appropriate set of limits associated with each method.

Step 1. Perform the site-specific hazard analysis using the LLNL or EPRI method and associated data. From this analysis, compute median hazard curves for the average of the 5 and 10 Hz spectral velocities, S_{V5-10}. That is a curve showing the annual probability of exceeding various levels of the average of the 5 and 10 Hz spectral velocity.

Step 2. Using the appropriate annual probability of exceedance level, P_E (e.g., for the median S_{V5-10} hazard curve derived from the LLNL method, P_E is 1E-4 according to Figure B.3 and Table B.1 of Appendix B), enter the hazard curve of step 1 at P_E to determine the corresponding spectral velocity.

Step 3. Deaggregate the median of the average of the 5 and 10 Hz hazard curves as a function of magnitude and distance by calculating the contribution to the hazard for all of the earthquakes in a selected set of magnitude and distance bins to determine the relative contribution to the hazard, H_{md}, for each bin centered at magnitude m and distance d. H_{md} is the annual probability of exceeding $S_V(P_E)$ computed for a bin at magnitude m and distance d.

Step 4. Compute the magnitude of the controlling earthquake for the median estimate using the contributions H_{md} computed in Step 3.

$$\bar{M} = \sum_m \sum_d mH_{md} / \sum_m \sum_d H_{md}$$

The distance of the controlling earthquake from the site is determined from

$$\log \bar{D} = \sum_m \sum_d \log(d) H_{md} / \sum \sum H_{md}$$

Step 5. Using the same P_E and steps 1 through 4 as above, also determine controlling earthquakes for median spectral response for the average of the 1 and 2.5 Hz spectral responses, and for the median estimates of the peak ground acceleration.

Step 6. The ground motions corresponding to the controlling earthquakes are determined as outlined in Section 2.5.2 (Subsection 2.5.2.6) of the Standard Review Plan.

C.2.2 Western U.S. Sites

For the Western U.S. sites, a probabilistic data base, such as compiled in the LLNL or EPRI studies, is not available. In a region of active tectonics, there is less uncertainty about the significant contributors to the seismic hazard, and the controlling earthquakes can generally be defined deterministically. For regions of lower, less active tectonics, an analysis similar to the one outlined above in Steps 1-4 can be performed. Step 1 would be omitted and the S_v level used would correspond to the value selected for the SSE.

C.3 EXAMPLE FOR EASTERN U.S. SITE

To illustrate the above procedure, calculations are shown here for an Eastern U.S. site using the LLNL methodology given in NUREG/CR-5250 (Ref. 1C).

Step 1 is omitted.

Step 2. Table C.1 gives the annual probability of exceeding various levels of the average of the 5 and 10 Hz spectral velocity hazard curves from the LLNL study.

Table C.1

Average of 5 and 10 Hz S_v Curves for the Site

Spectral Velocity (S_v-cm/s)	Annual Probability of Exceedance (Median)
2	2.6E-3
5	3.7E-4
10	5.8E-5

Interpolating the annual probability of exceedence (P_E) values given in Table B.1 from Table C.1, the corresponding value for $S_v(P_E)$ is as given in Table C.2.

Table C.2

Spectral Velocity (Avg. 5 to 10 Hz)	Median
$S_v(P_r)$-cm/s	8

Step 3. For this example, to deaggregate the hazard and determine the H_{md}, it is first necessary to compute the contribution to the average hazard for the 5 and 10 Hz spectral velocities for the matrix of magnitudes and distance bins such as given in Table C.3.

Table C.3

Magnitudes and Distance Bins Used in Example

Distance Range of Bin (km)	Magnitude Range of Bin					
	5 - 5.5	5.5 - 6	6 - 6.5	6.5 - 7	7 - 7.5	>7.5
0-25						
25-50						
50-100						
100-150						
150-200						
>200						

For each bin, a complete hazard analysis is performed to give the contribution to the hazard from all earthquakes within the bin, e.g., all earthquakes with magnitudes 6 to 6.5 and distance 25 to 50 km from the site. The results for this bin are given in Table C.4.

Table C.4

Contribution to the Hazard From all Earthquakes in the Range of $6 \leq M \leq 6.5$ and distances $25 \leq d \leq 50$ to the average of the 5 and 10 Hz Spectral Velocity

Spectral Velocity, S_v	Annual Median Probability of Exceedance
5	1.4E-5
10	3.1E-6
12.5	1.1E-6

The value of H_{md} (annual probability of exceeding $S_v(P_E)$) for this bin is obtained from Table C.4 using the $S_v(P_E)$ values given in Table C.2 and computing H_{md} by interpolation. The values for H_{md} for this bin are given in Table C.5.

Table C.5

Value for H_{md} for the Bin $6 \leq m \leq 6.5$ and $25 \leq d \leq 50$ for the Example Site

Annual Probability of Exceeding $S_v(P_E)$ For a Bin	Median
H_{md}	5.0E-6

Table C.6 gives the complete matrix of the H_{md} values for the example site.

Table C.6

H_{md} Values for All Bins Based on the Median Hazard
(Note: If $H_{md} \le$ 1.E-10, it is listed as 0.)

Distance Range Bin	Magnitude Range of Bin					
	5 - 5.5	5.5 - 6	6 - 6.5	6.5 - 7	7 -7.5	>7.5
0-25	2.0E-5	1.1E-5	2.4E-6	0	0	0
25-50	6.2E-6	8.9E-6	5.0E-6	6.5E-9	0	0
50-100	6.0E-7	2.3E-6	6.8E-6	8.4E-7	0	0
100-150	1.6E-9	1.6E-7	1.5E-6	2.8E-6	0	0
150-200	0	1.1E-9	2.1E-8	4.6E-7	0	0
>200	0	0	0	6.0E-9	0	0

Step 4. To compute $\bar{M}$, $\bar{D}$ for the example site, the values of H_{md} given in Table C.6 are used with m and d values corresponding to the midpoint of the magnitude of the bin (5.25, 5.75, 6.25, 6.75, 7.25, 7.75) and centroid of the ring area (16.7, 38.9, 77.8, 126, 176 and somewhat arbitrarily 300 km).

Thus for the example site, the controlling earthquakes, in $\bar{M}$, $\bar{D}$ values, are given in Table C.7.

Table C.7

Magnitude and Distance of Controlling Earthquake From the LLNL Probabilistic Analysis

	Based on Median Hazard Estimates
$\bar{M}$	5.8
$\bar{D}$	32

Controlling earthquakes for other frequency ranges (Step 5 of C.2.1) are calculated by repeating the above four steps.

C.4 EXAMPLES FOR WESTERN U.S. SITES

Since a general approach for the Western U.S. sites is not available, two specific cases illustrating determination of controlling earthquakes are discussed below.

C.4.1 - Diablo Canyon

The Diablo Canyon site is located on the California coast. A logic tree approach has been used to assign weights to variables associated with faults near the site and determine maximum magnitude distributions (Ref. 3C). The logic tree approach was also part of the probabilistic seismic hazard analysis. The result was that the Hosgri fault zone was the most significant source. The controlling earthquake for the Diablo Canyon site is a magnitude 7.2 event on the Hosgri fault zone at the closest distance of this fault zone to the site (4.5 km). The controlling earthquake magnitude is larger than the maximum historical earthquake (the 1927 magnitude 7.0 Lompoc earthquake), which may have occurred on a structure related to the Hosgri.

C.4.2 - WNP-3

The WNP-3 site is located in western Washington and lies above the Cascadia subduction zone. The staff considered four controlling earthquakes for the site (Ref. 4C):

1. The applicant proposed that a maximum random earthquake in the crust near the site is magnitude 5-1/2 to 6. This earthquake is based on the largest historical earthquakes in the Coastal Plain seismotectonic province (about magnitude 5) and the resolution of geological studies in the site region.

2. The maximum earthquake associated with the Olympia Lineament, which is 35 km northeast of the site, is a magnitude 7.5 based on estimated maximum rupture length.

3. The maximum magnitude earthquake for the intraslab subduction zone source is about magnitude 7-1/2, based on the maximum historical event

associated with the Cascadia subduction zone intraslab source (the 1949 magnitude 7.1 Puget Sound earthquake) and comparisons with intraslab sources in other subduction zones worldwide.

4. The interface subduction zone source is capable of great (larger than magnitude 8) earthquakes. This maximum magnitude is still under review in light of ongoing geological studies. At this time, the staff considers the maximum magnitude to be 8-1/4, based on arguments about the likely dimensions of rupture and comparisons with other subduction zones with slow convergence rates.

REFERENCES

1C. D. L. Bernreuter et al., "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," NUREG/CR-5250, January 1989.

2C. Electric Power Research Institute, "Probabilistic Seismic Hazard Evaluations at Nuclear Power Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue," NP-6395-D, 1989.

3C. "Safety Evaluation Report Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2," NUREG-0675, Supplement No. 34, June 1991.

4C. Letter from Marvin Mendonca, NRC, to D.W. Mazur, Washington Public Power Supply System, "NRC Review of Seismic Report for WNP-3," January 4, 1991.*

---

*Available for inspection or copying for a fee in the NRC Public Document Room, 2120 L Street NW., Washington, DC.

APPENDIX D

GEOLOGICAL, SEISMOLOGICAL, AND GEOPHYSICAL INVESTIGATIONS TO CHARACTERIZE SEISMIC SOURCES

D.1 INTRODUCTION

Seismic sources are areas where future earthquakes are likely to occur. Geological and seismological investigations provide the information needed to characterize source parameters, including the size and geometry of the seismic sources, earthquake recurrence models, and deterministic source earthquakes (DSE). The amount of data available about earthquakes and their causative sources varies substantially between the Western U.S. and the stable continental region (SCR), and also from region to region within these broad areas. In active tectonic regions, the focus will be on the identification of both capable tectonic sources and seismogenic sources, and the methods described in Section D.2 of this appendix can be applied. In the SCR east of the Rocky Mountains, seismogenic sources play a significant role because of the difficulty in unequivocally correlating earthquake activity with known tectonic structures.

In the SCR a number of significant tectonic structures exist that have been suggested as potential seismogenic sources (e.g., the New Madrid fault zone, Nemaha Ridge, Meers fault, Ramapo fault zone, Clarendon-Linden fault). There is no clear procedure to follow to characterize the DSE magnitude associated with such possible seismogenic sources; therefore, it is most likely that the determination of the seismogenic nature of the source will be inferred rather than demonstrated by strong correlations with seismicity and/or geologic data. Furthermore, it is not known what relations exist between observed tectonic structures in a given seismogenic source and the current earthquake activity loosely correlated with that source. Generally, the observed tectonic structure resulted from ancient tectonic forces that are no longer present, and thus the structural extent may not be a very meaningful indicator of the size of future earthquakes in the source. Careful analysis of the historical record and the results of regional and site studies and judgment play key roles. If, on the other hand, such strong correlations and/or data exist between seismicity and seismic sources, then approaches used for active tectonic regions can be applied.

The following is a general list of characteristics to be determined for a seismic source:

- Source zone geometry (location and extent, both surface and subsurface).

- Description of Quaternary (last 2 million years) displacements (sense of slip on the fault, fault length and width, age of displacements, estimated displacements per event, estimated magnitudes per offset, rupture length and area, and displacement history or uplift rates of seismogenic folds).

- Historical and instrumental seismicity associated with each source.

- Paleoseismicity.

- Relationship of the fault to other potential seismic sources in the region.

- Deterministic Source Earthquake.

- Recurrence model (frequency of earthquake occurrence versus magnitude).

- Effects of human activities such as withdrawal of fluid from or addition of fluid to the subsurface, extraction of minerals, or the effects of dams or reservoirs.

- Volcanism. Volcanic hazard is not addressed in this regulatory guide. It will be considered on a case-by-case basis in regions where this hazard exists.

- Other factors that can contribute to characterization of seismic sources such as strike and dip of tectonic structures, orientations of regional and tectonic stresses, fault segmentation (both along strike and downdip).

D.2. INVESTIGATIONS TO CHARACTERIZE SEISMIC SOURCES

D.2.1 General

Investigations of the site and region around the site are necessary to identify both seismogenic sources and capable tectonic sources and to determine their potential for generating earthquakes and causing surface deformation. If it is determined that surface deformation need not be taken into account, sufficient data to clearly justify the determination should be presented in the license application or early site review.

In the siting of nuclear power plants, engineering solutions are generally available to mitigate the potential vibratory effect of earthquakes through design. However, such solutions cannot always be demonstrated as being adequate for mitigation of the effects of permanent ground displacement phenomena such as surface faulting or folding, subsidence, ground collapse, or fault creep. For this reason, it is prudent to select an alternative site when the potential for permanent ground displacement exists at the site (Ref. 1D). In most of the Eastern United States, tectonic structures at seismogenic depths, as determined from earthquake hypocenters, apparently bear no relationship to geologic structures exposed at the ground surface. Young faults either do not extend to the ground surface or there is insufficient geologic material of the appropriate age available to date the faults. Seismogenic faults are not always exposed at ground surface in the Western United States as demonstrated by the buried (blind) reverse sources of the 1983 Coalinga, 1988 Whittier Narrows, and 1989 Loma Prieta earthquakes. These factors emphasize the need to not only conduct thorough investigations at the ground surface but also to identify structures at seismogenic depths.

The level of detail for investigations should be governed by the current and late Quaternary tectonic regime and the geological complexity of the site and region. Whenever faults or other structures are encountered at a site (including in the SCR) either in outcrop or excavations, it is necessary to perform many of the investigations described below to demonstrate whether or not they are capable tectonic sources.

Regional investigations extend to a distance of 320 km (200 mi) from the site, and data are presented at a scale of 1:500,000 or smaller. Investigations of greater detail are conducted to a distance of 40 km (25 mi) from the site and the data presented at a scale of 1:50,000 or smaller. Detailed

investigations are carried out within a radius of 8 km (5 mi) from the site and data are presented at a scale of 1:5000 or smaller. Data from investigations within the site area (approximately 1 square kilometer) are presented at a scale of 1:500 or smaller. The areas of investigations may be asymmetrical and larger than those described above in regions of late Quaternary activity or historical seismic activity (felt or instrumentally recorded data) or where a site is located near a capable tectonic source such as a fault zone.

Regional and site information needed to assess the integrity of the site with respect to potential ground motions and surface deformation caused by capable tectonic sources include determination of (1) the lithologic, stratigraphic, geomorphic, hydrologic, geotechnical, and structural geologic characteristics of the site and the area surrounding the site, including its geologic history, (2) geologic evidence of fault offset or other distortion such as folding at or near the ground surface at or near the site, and (3) whether or not any faults or other tectonic structures, any part of which are within a radius of 8 km (5 mi), are capable tectonic sources. This information will be used to evaluate tectonic structures underlying the site, whether buried or expressed at the surface, with regard to their potential for generating earthquakes and for causing surface deformation at or near the site. The evaluation is to consider the possible effects caused by human activities such as withdrawal of fluid from or addition of fluid to the subsurface, extraction of minerals, or the loading effects of dams or reservoirs.

D.2.2 Reconnaissance Investigations, Literature Review, and Other Sources of Preliminary Information

Site and regional investigations can be planned based on field reconnaissance data from previous investigations and reviews of available documents. Possible sources of information may include universities, consulting firms, and government agencies. A detailed list of possible sources of information is given in Regulatory Guide 1.132.

D.2.3 Detailed Investigations To Characterize Seismic Sources

The following methods are suggested but they are not all-inclusive and investigations should not be limited to them. Some procedures will not be applicable to every site, and situations will occur that require

investigations that are not included in the following discussion. It is anticipated that new technologies will be available in the future that will be applicable to these investigations.

D.2.3.1 Surface Investigations

Surface exploration needed to assess neotectonic conditions of the geology of the area around the site is dependent on the site location and may be carried out with the use of any appropriate combination of geological, geophysical, seismological, and geotechnical engineering techniques.

D.2.3.1.1. Geological interpretations of aerial photographs and other remote-sensing imagery, as appropriate for the particular site conditions, to assist in identifying rock outcrops, faults and other tectonic features, fracture traces, geologic contacts, lineaments, soil conditions, and evidence of landslides or soil liquefaction.

D.2.3.1.2. Mapping of topographic, geologic, geomorphic, and hydrologic features at scales and contour intervals suitable for analysis, stratigraphy (particularly Quaternary), surface tectonic structures such as fault zones, and Quaternary geomorphic features. For offshore sites, coastal sites, or sites located near lakes or rivers, this includes topography, geomorphology (particularly mapping marine and fluvial terraces), bathymetry, geophysics (such as seismic reflection), and hydrographic surveys to the extent needed for evaluation.

D.2.3.1.3. Identification and evaluation of vertical crustal movements by (1) geodetic land surveying to identify and measure short-term crustal movements (Refs. 2D and 3D) and (2) geological analyses such as analysis of regional dissection and degradation patterns, marine and lacustrine terraces and shorelines, fluvial adjustments such as changes in stream longitudinal profiles or terraces, and other long-term changes such as elevation changes across lava flows (Ref. 4D).

D.2.3.1.4. Analysis of offset, displaced, or anomalous landforms such as displaced stream channels or changes in stream profiles or the upstream migration of knickpoints (Refs. 5D-10D), abrupt changes in fluvial deposits or

terraces, changes in paleochannels across a fault (Ref. 9D), or uplifted, downdropped, or laterally displaced marine terraces (Ref. 10D).

D.2.3.1.5. Analysis of Quaternary sedimentary deposits within or near tectonic zones such as fault zones and including: (1) fault-related or fault-controlled deposits, including sag ponds, graben fill deposits, and colluvial wedges formed by the erosion of a fault paleoscarp and (2) non-fault-related, but offset deposits including alluvial fans, debris cones, fluvial terrace, and lake shoreline deposits.

D.2.3.1.6. Identification and analysis of deformation features caused by vibratory ground motions, including seismically induced liquefaction features (sand boils, explosion craters, lateral spreads, settlement, soil flows), mud volcanoes, landslides, rockfalls, deformed lake deposits or soil horizons, shear zones, cracks, or fissures (Refs. 11D and 12D).

D.2.3.1.7. Estimation of the ages of fault displacements by analysis of the morphology of topographic fault scarps associated with or produced by surface rupture. Fault scarp morphology is useful in estimating age of last displacement, approximate size of the earthquake, recurrence intervals, slip rate, and the nature of the causative fault at depth (Refs. 13D-16D).

D.2.3.2 Seismological Investigations

D.2.3.2.1. Listing all historically reported earthquakes that can reasonably be associated with seismic sources, any part of which is within a radius of 320 km (200 miles) of the site, including date of occurrence and the following measured or estimated data: highest intensity, magnitude, epicenter, depth, focal mechanism, stress drop, etc. Historical seismicity includes both historically reported and instrumentally recorded data. For pre-instrumentally recorded data, intensity should be converted to magnitude, the procedure used to convert it to magnitude should be clearly documented, and epicenters should be determined based on intensity contours. Methods to convert intensity values to magnitudes in the central and eastern U.S. are described in References 17D-19D.

D.2.3.2.2. Seismic monitoring in the site area that is established as soon as possible after site selection.

D.2.3.3 Subsurface Investigations

Subsurface investigations in the site area or within the region to identify and define seismogenic sources and capable tectonic sources may include:

D.2.3.3.1. Geophysical investigations such as air or ground magnetic and gravity surveys, seismic reflection and seismic refraction surveys, borehole geophysics, and ground-penetrating radar.

D.2.3.3.2. Core borings to map subsurface geology and obtain samples for testing such as age dating.

D.2.3.3.3. Excavating and logging trenches across geological features as part of the neotectonic investigation and to obtain samples for age-dating those features.

At some sites, deep soil, bodies of water, or other material may obscure geologic evidence of past activity along a tectonic structure. In such cases, the analysis of evidence elsewhere along the structure can be used to evaluate its characteristics in the vicinity of the site (Refs. 10D and 20D).

D2.4 Age-Dating

An important part of the geologic investigations to identify and define potential seismic sources is the age-dating of geologic materials. The following techniques are useful in dating Quaternary deposits.

D2.4.1 Radiometric Dating Methods

- Carbon 14 for dating organic materials (upper limit ranges from 30,000 up to 100,000 years) (Ref. 21D).
- Potassium argon for dating volcanic rocks ranging in age from about 50,000 to 10 million years (Ref. 21D).

- Uranium series using the relative properties of various decay products of ^{238}U or ^{235}U. Ages range from 10,000 to 350,000 (Ref. 21D). $^{235}U/^{238}U$ can yield between 40,000 and 1,000,000 years (Ref. 22D).
- Fission track using minerals such as zircon and apatite, with fissionable uranium in volcanic rocks. Although some interpretation is required in counting tracks, the technique has no inherent age range limitations if suitable materials are available (Ref. 21D).
- Thermoluminescence (TZ) is best used for stratigraphic correlation and determining relative ages rather than absolute ages. The maximum age is 10 million years (Ref. 21D).
- Electron spin resonance (ESR) is used to date quartz that formed in fault gouge during the fault event (Ref. 23D).

D2.4.2 <u>Other Quantitative Numerical Methods</u>

- Paleomagnetic dating requires material containing magnetic-susceptible minerals with sufficient stratigraphic and time ranges to provide several reversals. An independent time datum for correlation with the polarity time scale is required (Ref. 21D).
- Thicknesses of weathering rind development on the margins of clasts, such as caused by obsidian hydration, can be used to estimate the age of deposits (Ref. 24D).
- Cation-ratio dating of desert varnish on rock surfaces by chemical analysis (Ref. 25D).
- Tephrochronology, which is the identification and correlation of undated and dated volcanic ashes by geochemical and petrographic analyses (Refs. 26D and 27D).
- Amino-acid racemization, which uses organic material and is based on time-dependent diagenetic conversion of one form of amino-acid polymer structure to another (Refs. 28D and 29D).
- Lichenometry is used to estimate ages from sizes of lichens growing on gravel or boulders (such as glacial deposits) (Ref. 30D).
- Soil profile development is used to determine age based on measured amounts of accumulated pedogenic materials (Ref. 31D).

- Dendrochronology is used to determine the ages of trees that were affected by a tectonic event or other phenomena such as landsliding or flooding (Refs. 32D-34D).

D2.4.3 Relative Age-Dating Methods

- The relative degree of soil profile development of B and C horizons can provide at least an order of magnitude estimate of the ages of buried soils or relict surface soils on surficial deposits (Refs. 21D and 35D). For B horizons, the diagnostic characteristics include thickness, depth, amount, texture, type of clay, soil structure and color, and amount of Fe oxides or Fe-Al-organic accumulation (Ref. 21D). For C horizons, the important diagnostic characteristics are thickness, depth, stage of development, and amount of pedogenic carbonate and other soluble salts (Refs. 36D and 37D). Other references for this subject include References 38D through 42D.

- The relative degree of weathering of surface and subsurface clasts in sedimentary deposits such as glacial moraines is useful but requires independent means of age calibration (Ref. 21D).

In the SCR it may not be possible to demonstrate, in an absolute manner, the age of last activity of a tectonic structure. In such cases the NRC staff will accept association of such structures with geologic structural features or tectonic processes that are geologically old (at least pre-Quaternary) as an age indicator in the absence of conflicting evidence.

These investigative procedures should also be applied, where possible, to characterize offshore structures (faults or fault zones, as well as folds, uplift, or subsidence related to faulting at depth) for coastal sites or those sites located adjacent to landlocked bodies of water. Investigations of offshore structures will rely heavily on seismicity, geophysics, and bathymetry rather than conventional geologic mapping methods that can be used effectively onshore. However, it is often useful to investigate similar features onshore to learn more about the significant offshore features.

D2.5 Distinction Between Tectonic and Nontectonic Deformation

Nontectonic deformation, like tectonic deformation, can pose a substantial hazard to nuclear power plants, but there are likely to be differences in the approaches used to resolve the issues raised by the two types of phenomena. Therefore, non-tectonic deformation should be distinguished from tectonic deformation at a site. In past nuclear power plant licensing activities, surface displacements caused by phenomena other than tectonic phenomena have been confused with tectonically induced faulting. Such features include faults on which the last displacement was induced by glaciation or deglaciation; collapse structures, such as found in karst terrain; and growth faulting, such as occurs in the Gulf Coastal Plain or in other deep soil regions subject to extensive subsurface fluid withdrawal.

Glacially induced faults generally do not represent a deep-seated seismic or fault displacement hazard because the conditions that created them are no longer present. However, residual stresses from Pleistocene glaciation may still be present in glaciated regions although they are of less concern than active tectonically induced stresses. These features should be investigated with respect to their relationship to current in situ stresses.

The nature of faults related to collapse features can usually be defined through geotechnical investigations and either can be avoided or, if feasible, adequate engineering fixes can be provided.

Large naturally occurring growth faults such as found in the coastal plain of Texas and Louisiana can pose a surface displacement hazard, even though offset most likely occurs at a much less rapid rate than that of tectonic faults. They are not regarded as having the capacity to generate damaging earthquakes, can often be identified and avoided in siting, and their displacements can be monitored. Some growth faults and antithetic faults related to growth faults are not easily identified; therefore, investigations described above with respect to capable tectonic faults and fault zones should be applied in regions where growth faults are known to be present. Local human-induced growth faults can be monitored and controlled or avoided.

If questionable features cannot be demonstrated to be of non-tectonic origin they should be treated as tectonic deformation.

REFERENCES

1D. International Atomic Energy Agency, "Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting," Safety Series No. 50-SG-S1, Revision 1, 1991.

2D. R. Reilinger, M. Bevis, and G. Jurkowski, "Tilt from Releveling: An Overview of the U.S. Data Base," *Tectonophysics*, Vol. 107, p. 315-330, 1984.

3D. R. K. Mark et al., "An Assessment of the Accuracy of the Geodetic Measurements that Led to the Recognition of the Southern California Uplift," *Journal of Geophysical Research*, Volume 86, pp. 2783-2808, 1981.

4D. T. K. Rockwell et al., "Chronology and Rates of Faulting of Ventura River Terraces, California," *Geological Society of America Bulletin*, Volume 95, pp. 1466-1474, 1984.

5D. K. E. Sieh, "Lateral Offsets and Revised Dates of Prehistoric Earthquakes at Pallett Creet, Southern California," *Journal of Geophysical Research*, Volume 89, No. 89, pp. 7641-7670, 1984.

6D. K. E. Sieh and R. H. Jahns, "Holocene Activity of the San Andreas Fault at Wallace Creek, California," *Geological Society of America Bulletin*, Volume 95, pp. 883-896, 1984.

7D. K. E. Sieh, M. Stuiver, and D. Brillinger, "A More Precise Chronology of Earthquakes Produced by the San Andreas Fault in Southern California," *Journal of Geophysical Research*, Volume 94, pp. 603-623, 1989.

8D. R. J. Weldon, III, and K. E. Sieh, "Holocene Rate of Slip and Tentative Recurrence Interval for Large Earthquakes on the San Andreas Fault, Cajon Pass, Southern California," *Geological Society of America Bulletin*, Volume 96, pp. 793-812, 1985.

9D. F. H. Swan, III, D. P. Schwartz, and L. S. Cluff, "Recurrence of Moderate to Large Magnitude Earthquakes Produced by Surface Faulting on the

Wasatch Fault Zone," Bulletin of the Seismological Society of America, Volume 70, pp. 1431-1462, 1980.

10D. Pacific Gas and Electric Company, "Final Report of the Diablo Canyon Long Term Seismic Program; Diablo Canyon Power Plant," Docket Nos. 50-275 and 50-323, 1988.*

11D. S. F. Obermeier et al., "Geologic Evidence for Recurrent Moderate to Large Earthquakes Near Charleston, South Carolina," Science, Volume 227, pp. 408-411, 1985.

12D. D. Amick et al., "Paleoliquefaction Features Along the Atlantic Seaboard," U.S. Nuclear Regulatory Commission, NUREG/CR-5613, October 1990.

13D. R. E. Wallace, "Profiles and Ages of Young Fault Scarps, North-Central Nevada," Geological Society of America Bulletin, Volume 88, pp. 1267-1281, 1977.

14D. R. E. Wallace, "Discussion--Nomographs for Estimating Components of Fault Displacement from Measured Height of Fault Scarp," Bulletin of the Association of Engineering Geologists, Volume 17, pp. 39-45, 1980.

15D. R. E. Wallace, "Active Faults, Paleoseismology, and Earthquake Hazards: Earthquake Prediction--An International Review," Maurice Ewing Series 4, American Geophysical Union, pp. 209-216, 1981.

16D. A. J. Crone and S. T. Harding, "Relationship of Late Quaternary Fault Scarps to Subjacent Faults, Eastern Great Basin, Utah," Geology, Volume 12, pp. 292-295, 1984.

17D. O. W. Nuttli, "The Relation of Sustained Maximum Ground Acceleration and Velocity to Earthquake Intensity and Magnitude, State-of-the-Art for

---

*Available for inspection or copying for a fee at the NRC Public Document Room, 2120 L Street NW., Washington, DC.

Assessing Earthquake Hazards in the Eastern United States," U.S. Army Corps of Engineers Misc. Paper 5-73-1, Report 16, 1979.

18D. R. L. Street and F. T. Turcotte, "A Study of Northeastern North America Spectral Moments, Magnitudes and Intensities," Bulletin of the Seismological Society of America, Volume 67, pp. 599-614, 1977.

19D. R. L. Street and A. Lacroix, "An Empirical Study of New England Seismicity," Bulletin of the Seismological Society of America, Volume 69, pp. 159-176, 1979.

20D. H. Rood et al., "Safety Evaluation Report Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2," USNRC, NUREG-0675, Supplement No. 34, June 1991.

21D. J. F. Callender, "Tectonics and Seismicity," Chapter 4 in "Techniques for Determining Probabilities of Events and Processes Affecting the Performance of Geologic Repositories," NUREG/CR-3964 (SAND 86-0196), Volume 1, Edited by R. L. Hunter and C. J. Mann, pp. 89-125, June 1989.

22D. D. R. Muhs and B. J. Szabo, "Uranium-Series Age of the Eel Point Terrace, San Clemente Island, California," Geology, Volume 10, pp. 23-26, 1982.

23D. M. Ikeya, T. Miki, and K. Tanaka, "Dating of a Fault by Electron Spin Resonance on Intrafault Materials," Science, Volume 215, pp. 1392-1393, 1982.

24D. S. M. Colman and K. L. Pierce, "Weathering Rinds on Andesitic and Basaltic Stones as a Quaternary Age Indicator, Western United States," Professional Paper 1210, U.S. Geological Survey, 1981.

25D. R. I. Dorn, "Cation-Ratio Dating: A New Rock Varnish Age-Determination Technique," Quaternary Research, Volume 20, pp. 49-73, 1983.

26D. P. D. Sheets and D. K. Grayson, eds., Volcanic Activity and Human Ecology, Academic Press, New York, 1979.

27D. S. Self and R. J. S. Sparks, eds., "Tephra Studies," Proceedings of the NATO Advanced Studies Institute, Tephra Studies as a Tool in Quaternary Research, D. Reidel Publ. Co., Dordrecht, Holland, 1981.

28D. J. L. Bada and P. M. Helfman, "Amino Acid Racemization Dating of Fossil Bones," World Archeology, 1975.

29D. J. L. Bada and R. Protsch, "Racemization Reaction of Aspartic Acid and its Use in Dating Fossil Bones," Proceedings of the National Academy of Science, Volume 70, pp. 1331-1334, 1973.

30D. W. W. Locke, J. T. Andrews, and P. J. Webber, "A Manual for Lichenometry," Technical Bulletin 26, British Geomorphological Research Group, University of East Anglia, Norwich, 1979.

31D. M. N. Machette, "Dating Quaternary Faults in the Southwestern United States by Using Buried Calcic Paleosols," U.S. Geological Survey Journal of Research, Volume 6, pp. 369-381, 1978.

32D. R. Page, "Dating Episodes of Faulting from Tree Rings: Effects of the 1958 Rupture of the Fairweather Fault on the Tree Growth," Geological Society of America Bulletin, Volume 81, pp. 3085-3094, 1970.

33D. K. E. Sieh, "Prehistoric Earthquakes Produced by Slip on the San Andreas Fault at Pallett Creek, California," Journal of Geophysical Research, Volume 83, pp. 3907-3939, 1978.

34D. B. F. Atwater and D. K. Yamaguchi, "Sudden, Probably Coseismic Submergences of Holocene Trees and Grass in Coastal Washington State," Geology, Volume 19, pp. 706-709, 1991.

35D. M. N. Machette, "Soil Dating Techniques, Western Region (United States)," Open-file Report OFR-82-840, U.S. Geological Survey, p. 137-140, 1982.

36D. L. D. McFadden and J. C. Tinsley, "Soil Profile Development in Xeric Climates: A Summary," in J. C. Tinsley, J. C. Matti, and L. D. McFadden,

eds., Guidebook, Field Trip No. 12, Geological Society of America, Cordillera Section, pp. 15-19, 1982.

37D. J. W. Hardin, "A Quantitative Index of Soil Development from Field Descriptions: Examples from a Chronosequence in Central California," Geoderma, Volume 28, pp. 2-18, 1982.

38D. J. C. Matti et al., "Holocene Faulting History as Recorded by Alluvial Stratigraphy Within the Cucamonga Fault Zone; A Preliminary View," in J. C. Tinsley, J. C. Matti, and L. D. McFadden, eds., Guidebook, Field Trip No. 12, Geological Society of America, Cordillera Section, pp. 29-44, 1982.

39D. P. A. Pearthree and S. S. Calvo, "Late Quaternary Faulting West of the Santa Rita Mountains South of Tucson, Arizona," Masters Thesis, University of Arizona, Tucson, AZ, 1982.

40D. P. A. Pearthree, C. M. Menges, and L. Mayer, "Distribution, Recurrence, and Possible Tectonic Implications of Late Quaternary Faulting in Arizona," Open-file Report 83-20, Arizona Bureau of Geology and Mineral Technology, Tucson, 1983.

41D. E. A. Keller et al., "Tectonic Geomorphology of the San Andreas Fault Zone in the Southern Indio Hills, Coachella Valley, California," Geological Society of America Bulletin, Volume 93, pp. 45-56, 1982.

42D. O. A. Chadwick, S. Hecker, and J. Fonseca, "A Soils Chronosequence at Terrace Creek: Studies of Late Quaternary Tectonism in Dixie Valley, Nevada," Open-file Report 84-0090, U.S. Geological Survey, 1984.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. The draft regulatory analysis, "Proposed Revision of 10 CFR Part 100 and 10 CFR Part 50," provides the regulatory basis for this guide and examines the costs and benefits of the rule as implemented by the guide. A copy of the draft regulatory analysis is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW. (Lower Level), Washington, DC, as Enclosure 2 to Secy 92-215.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

FIRST CLASS MAIL
POSTAGE AND FEES PAID
USNRC
PERMIT NO. G-67

AD93-1
PDR

STANDARD REVIEW PLAN 2.5.2
VIBRATORY GROUND MOTION
PROPOSED REVISION 3

November 1992
Contact:
A. J. Murphy
(301) 492-3860

REVIEW RESPONSIBILITIES

Primary - Structural and Geosciences Branch (ESGB)

Secondary - None

AREAS OF REVIEW

The Structural and Geosciences Branch review covers the seismological and geological investigations carried out to ~~establish~~ **evaluate** ~~the acceleration for~~ the safe shutdown earthquake **ground motion** (SSE) ~~and the operating basis earthquake (OBE)~~ for the site. ~~The safe shutdown earthquake is that earthquake that is based upon an evaluation of the maximum earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material. It is that earthquake that produces the maximum vibratory ground motion for which safety-related structures, systems, and components are designed to remain functional. The operating basis earthquake is that earthquake that, considering the regional and local geology, seismology, and specific characteristics of local subsurface material, could reasonably be expected to affect the plant site during the operating life of the plant; it is that earthquake that produces the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation without undue risk to the health and safety of the public are designed to remain functional.~~ **The SSE represents the potential for earthquake ground motion at the site and is the vibratory ground motion for which certain structures, systems, and components are designed to remain functional. The SSE is based upon a detailed evaluation of the earthquake potential, taking into account regional and local geology, Quaternary tectonics, seismicity, and specific characteristics of local subsurface material. It is defined as the free-field ground response spectra at the plant site and is described by horizontal and vertical response spectra corresponding to the expected ground motion at the free-field ground surface or a hypothetical rock outcrop.**

Guidance is being developed on seismological and geological investigations and it is described in Draft Regulatory Guide DG-1015, "Identification and Characterization of Seismic Sources, Deterministic Source Earthquakes, and Ground Motion." These

investigations describe the seismicity of the site region and the correlation of earthquake activity with seismic sources. Seismic sources are identified and characterized, including the deterministic source earthquake (DSE) associated with each seismic source. All seismic sources that have any part within 320 km (200 miles) of the site must be identified. More distant sources that are capable of earthquakes large enough to affect the site must also be identified. Seismic sources can be capable tectonic sources or seismogenic sources; a seismotectonic province is a type of seismogenic source. Both deterministic and probabilistic evaluations are used to assess the SSE. Acceptable deterministic procedures are described in this SRP (Subsections 2.5.2.1 through 2.5.2.4). Probabilistic and deterministic methods are described in Draft Regulatory Guide DG-1015.

The principal regulation used by the staff in determining the scope and adequacy of the submitted seismologic and geologic information and attendant procedures and analyses is ~~Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."~~ **Appendix B, "Criteria for the Seismic and Geologic Siting of Nuclear Power Plants on or After [Effective Date of this Regulation]" to 10 CFR Part 100 (Ref. 1).** Additional guidance **information** (regulations, regulatory guides, and reports) is provided to the staff through References 2 through 8 **and 54**.

Specific areas of review include seismicity (Subsection 2.5.2.1), geologic and tectonic characteristics of the site and region (Subsection 2.5.2.2), correlation of earthquake activity with geologic structure or **seismotectonic** provinces (Subsection 2.5.2.3), maximum earthquake potential **and controlling earthquakes** (Subsection 2.5.2.4), seismic wave transmission characteristics of the site (Subsection 2.5.2.5), **and** safe shutdown earthquake **ground motion** (Subsection 2.5.2.6)~~, and operating basis earthquake (Subsection 2.5.2.7)~~.

The geotechnical engineering aspects of the site and the models and methods employed in the analysis of soil and foundation response to the ground motion environment are reviewed under SRP Section 2.5.4. The results of the geosciences review are used in SRP Sections 3.7.1 and 3.7.2.

II. ACCEPTANCE CRITERIA

The applicable regulations (Refs. 1, 2, and 3) and regulatory guides (Refs. 4, 5, 6, **and 54**) and basic acceptance criteria pertinent to the areas of this section of the Standard Review Plan are:

1. 10 CFR Part 100, ~~Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."~~ **Appendix B, "Criteria for the Seismic and Geologic Siting of Nuclear Power Plants on or After [Effective Date of this Regulation]."** These criteria

describe the kinds of geologic and seismic information needed to determine site suitability and identify geologic and seismic factors required to be taken into account in the siting and design of nuclear power plants (Ref. 1).

2. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants"; General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena" (Ref. 2). This criterion requires that safety-related portions of the structures, systems, and components important to safety ~~shall~~ be designed to withstand the effects of earthquakes, tsunamis, and seiches without loss of capability to perform their safety functions.

3. 10 CFR Part 100, "Reactor Site Criteria" (Ref. 3). This part describes criteria that guide the evaluation of the suitability of proposed sites for nuclear power and testing reactors.

4. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants." This guide describes programs of site investigations related to geotechnical aspects that would normally meet the needs for evaluating the safety of the site from the standpoint of the performance of foundations under anticipated loading conditions, including **an** earthquake. It provides general guidance and recommendations for developing site-specific investigation programs as well as specific guidance for conducting subsurface investigations, including the spacing and depth of borings as well as sampling intervals (Ref. 4).

5. Regulatory Guide 4.7 **(Proposed Revision 2, DG-4003)**, "General Site Suitability Criteria for Nuclear Power Stations." This guide discusses the major site characteristics related to public health and safety ~~**which**~~ **that** the NRC staff considers in determining the suitability of sites for nuclear power stations (Ref. 5).

6. Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants." ~~This guide gives one method acceptable to the NRC staff for defining the response spectra corresponding to the expected maximum ground acceleration (Ref. 6). See also~~ **Smoothed response spectra are generally used for design purposes - for example, a standard spectral shape that has been used in the past is presented in Regulatory Guide 1.60 (Ref. 6). These smoothed spectra are still acceptable when an appropriate peak acceleration is used as the high-frequency asymptote and the smoothed spectra compare favorably with site-specific response spectra derived from the ground motion estimation procedures discussed** in Subsection 2.5.2.6.

7. **Draft Regulatory Guide DG-1015 (Ref. 54), "Identification and Characterization of Seismic Sources, Deterministic Source Earthquakes, and Ground Motion," is being developed to describe probabilistic and deterministic methodologies for determining the controlling earthquakes for nuclear power plant sites.**

The primary required investigations are described in 10 CFR Part 100, **in** Section IV(a) of Appendix ~~A~~ B(Ref. 1)**;** ~~The acceptable~~ procedures for ~~determining~~ **assessing** the seismic design bases are given in Sections V(a), **(b), and (c).** ~~and Section VI(a) of the appendix.~~ **Draft Regulatory Guide DG-1015 (Ref. 54) is being developed to provide more detailed guidance on investigations.** The seismic design bases are predicated on a reasonable, conservative determination of the SSE ~~and the OBE~~. As ~~defined~~ **stated** in Section**s** ~~III~~ **IV and V** of Appendix ~~A~~ B(Ref. 1) to 10 CFR Part 100, the SSE ~~and OBE are~~ **is** based on consideration of the regional and local geology and seismology and on the characteristics of the subsurface materials at the site. ~~and~~ **The SSE** ~~are~~ **is** described in terms of the vibratory ground motion **expected** ~~that they would produce~~ at the site. No comprehensive definitive rules can be promulgated regarding the investigations needed to establish the seismic design bases; the requirements vary from site to site.

2.5.2.1 Seismicity. In meeting the requirement of Reference 1, this subsection is accepted when the complete historical record of earthquakes in the region is listed and when all available parameters are given for each earthquake in the historical record. The listing should include all earthquakes having Modified Mercalli Intensity (MMI) greater than or equal to IV or magnitude greater than or equal to 3.0 that have been reported ~~in all tectonic provinces~~ **for all seismic sources**, any parts of which are within **320 km** (200 miles) of the site. A regional-scale map should be presented showing all listed earthquake epicenters and should be supplemented by a larger-scale map showing earthquake epicenters of all known events within **80 km** (50 miles) of the site. The following information concerning each earthquake is required whenever it is available: epicenter coordinates, depth of focus, origin time, highest intensity, magnitude, seismic moment, source mechanism, source dimensions, distance from the site, and any strong-motion recordings (sources from which the information was obtained should be identified). All magnitude designations such as m_b, M_L, M_s, M_w should be identified. In addition, any reported earthquake-induced geologic failure, such as liquefaction, landsliding, landspreading, and lurching should be described completely, including the level of strong motion that induced failure and the physical properties of the materials. The completeness of the earthquake history of the region is determined by comparison to published sources of information (e.g., Refs. 9 through 13). When conflicting descriptions of individual earthquakes are found in the published references, the staff should

determine which is appropriate for licensing decisions.

2.5.2.2 Geologic and Tectonic Characteristics of Site and Region. In meeting the requirements of References 1, 2, and 3, this subsection is accepted when all ~~geologic structures within the region and tectonic activity~~ **seismic sources** that are significant in determining the earthquake potential of the region are identified, or when an adequate investigation has been carried out to provide reasonable assurance that all significant ~~tectonic structures~~ **seismic sources** have been identified. Information presented in Section 2.5.1 of the applicant's safety analysis report (SAR) and information from other sources (e.g., Refs. 9 and 14 through 18) dealing with the current tectonic regime should be developed into a coherent, well-documented discussion to be used as the basis **for** characterizing the earthquake-generating potential of **seismogenic sources and capable tectonic sources.** ~~the identified geologic structures~~ Specifically, each ~~tectonic province~~ **seismic source**, any part of which is within **320 km (**200 miles**)** of the site, must be identified. The staff interprets **seismo**tectonic provinces to be regions of uniform ~~earthquake potential (seismotectonic provinces)~~ **seismicity (same DSE and frequency of recurrence) distinct from the seismicity of the surrounding area**. The proposed **seismo**tectonic provinces may be based on seismicity studies, differences in geologic history, differences in the current tectonic regime, etc. The staff considers that the most important factors for the determination of **seismo**tectonic provinces include both (1) development and characteristics of the current tectonic regime of the region that is most likely reflected ~~in the neotectonics (Post-Miocene or about 5~~ **in the Quaternary (approximately the last 2** million years and younger geologic history) and (2) the pattern and level of historical seismicity. Those characteristics of geologic structure, tectonic history, present and past stress regimes, and seismicity that distinguish the various **seismo**tectonic provinces and the particular areas within those provinces where historical earthquakes have occurred should be described. Alternative regional tectonic models derived from available literature sources, including previous SARs and NRC staff Safety Evaluation Reports (SERs), should be discussed. The model that best conforms to the observed data is accepted. In addition, in those areas where there are capable ~~faults~~ **tectonic sources**, the results of the additional investigative requirements described in ~~10 CFR Part 100, Appendix A, Section IV(a)(8) (Ref. 1),~~ **SRP Section 2.5.1** must be presented. The discussion should be augmented by a regional-scale map showing the ~~tectonic provinces~~ **seismic sources**, earthquake epicenters, locations of geologic structures and other features that characterize the **seismogenic sources (including seismotectonic** provinces), and the locations of any capable ~~faults~~ **tectonic sources**.

2.5.2.3 Correlation of Earthquake Activity with ~~Geologic Structure~~ **Seismogenic Sources (Including Seismotectonic Provinces) and Capable Tectonic Sources** ~~or Tectonic Provinces~~. In meeting the

requirements of Reference 1, acceptance of this subsection is based on the development of the relationship between the history of earthquake activity and the ~~geologic structures or seismotectonic provinces~~ **seismic sources** of a region. The applicant's presentation is accepted when the earthquakes discussed in Subsection 2.5.2.1 of the SAR are shown to be associated with either ~~geologic structure or tectonic province~~ **capable tectonic sources or seismogenic sources**. Whenever an earthquake hypocenter or concentration of earthquake hypocenters can be reasonably correlated with geologic structures, the rationale for the association should be developed considering the characteristics of the geologic structure (including geologic and geophysical data, seismicity, and the tectonic history) and the regional tectonic model. The discussion should include identification of the methods used to locate the earthquake hypocenters, an estimation of their accuracy, and a detailed account that compares and contrasts the geologic structure involved in the earthquake activity with other areas within the ~~tectonic province~~ **seismotectonic province**. Particular attention should be given to determining the ~~capability~~ **recency and level of activity** of faults with which instrumentally located earthquake hypocenters are associated.

The presentation should be augmented by regional maps, all of the same scale, showing the ~~tectonic provinces~~ **seismic sources**, the earthquake epicenters, and the locations of geologic structures and measurements used to define **seismic sources** ~~provinces~~. Acceptance of the proposed ~~tectonic provinces~~ **seismic sources** is based on the staff's independent review of the geologic and seismic information.

2.5.2.4 Maximum Earthquake Potential **and Controlling Earthquake (CE)**. In meeting the requirements of Reference 1, this subsection is accepted when the vibratory ground motion ~~due to~~ **from** the ~~maximum credible earthquake~~ **DSE** associated with each ~~geologic structure or the maximum historic earthquake associated with each tectonic province~~ **seismic source** has been assessed and when the earthquake**(s)** that would produce the ~~maximum~~ **most severe** vibratory ground motion at the site has been determined. The ~~maximum credible earthquake~~ **DSE** is the largest earthquake that can reasonably be expected to occur on a ~~geologic structure~~ **given seismic source** in the current tectonic regime. **Considerable judgment is involved in estimating the magnitude of the DSE. Recommended procedures for estimating the DSE are described in Draft Regulatory Guide DG-1015 (Ref. 54).** ~~Geologic or seismological evidence may warrant a maximum earthquake larger than the maximum historic earthquake.~~ Earthquakes associated with each ~~geologic structure or tectonic province~~ **seismic source** must be identified. ~~Where~~ **If** an earthquake is associated with a geologic structure, the ~~maximum credible earthquake~~ **DSE** that could occur on that structure should be evaluated, taking into account significant factors, for example, the type of the faulting, fault length, fault slip rate, rupture length, rupture area, moment, and earthquake history (e.g., Refs. 19 through 22).

In order to determine the ~~maximum credible earthquake~~ **DSE** that could occur on those faults that are shown or assumed to be capable **tectonic sources**, the staff accepts conservative values based on historic experience in the region and specific considerations of the earthquake history and geologic history of movement on the faults. Where the earthquakes are associated with a **seismogenic source** ~~tectonic province~~, the largest historic earthquake within the **source** ~~province~~ should be identified. Isoseismal maps should also be presented for the most significant earthquakes. The ground motion at the site should be evaluated assuming appropriate seismic energy transmission effects and assuming that the ~~maximum earthquake~~ **DSE** associated with each ~~geologic structure or with each tectonic province~~ **seismic source** occurs at the point of closest approach of the structure or province to the site. (Further description is provided in Subsection 2.5.2.6.)

The earthquake(s) that would produce the most severe vibratory ground motion at the site should be defined. If different potential earthquakes would produce the most severe ground motion in different frequency bands, these earthquakes should be specified. The description of the potential earthquake(s) is to include the maximum intensity or magnitude and the distance from the assumed location of the potential earthquake(s) to the site. **For the seismotectonic province surrounding the site, the DSE is assumed to occur about 15 km from the site.** The staff independently evaluates the site ground motion produced by the ~~largest earthquake~~ **DSE** associated with each ~~geologic structure or tectonic province~~ **seismic source**.

Controlling earthquakes are those earthquakes that produce the largest ground motion at the nuclear power plant site. Procedures for deriving controlling earthquakes from a probabilistic seismic hazard analysis are discussed in Appendix C of Draft Regulatory Guide DG-1015 (Ref. 54). Acceptance of the description of the ~~potential~~ **controlling earthquakes** ~~that would produce the largest ground motion at the site~~ is based on the staff's independent analysis.

<u>2.5.2.5 Seismic Wave Transmission Characteristics of the Site</u>. In meeting the requirements of Reference 1, this subsection is accepted when the seismic wave transmission characteristics (amplification or deamplification) of the materials overlying bedrock at the site are described as a function of the significant frequencies. The following material properties should be determined for each stratum under the site: seismic compressional and shear wave velocities, bulk densities, soil index properties and classification, shear modulus and damping variations with strain level, and water table elevation and its variation. In each case, methods used to determine the properties should be described in Subsection 2.5.4 of the SAR and cross-referenced in this subsection. For the ~~maximum earthquake~~ **CE(s)** determined in

Subsection 2.5.2.4 **and Draft Regulatory Guide DG-1015 (Ref. 54)**, the free-field ground motion (including significant frequencies) must be determined, and an analysis should be performed to determine the site effects on different seismic wave types in the significant frequency bands. If appropriate, the analysis should consider the effects of site conditions and material property variations upon wave propagation and frequency content.

The free-field ground motion (also referred to as control motion) should be defined to be on a ground surface and should be based on data obtained in the free field. Two cases are identified, depending on the soil characteristics at the site and subject to availability of appropriate recorded ground-motion data. When data are available, for example, for relatively uniform sites of soil or rock with smooth variation of properties with depth, the control point (location at which the control motion is applied) should be specified on the soil surface at the top of the **site** finished grade. The free-field ground motion or control motion should be consistent with the properties of the soil profile. For sites composed of one or more thin soil layers overlying a competent material, or in **the** case of insufficient recorded ground-motion data, the control point is specified on an outcrop or a hypothetical outcrop at a location on the top of the competent material. The control motion specified should be consistent with the properties of the competent material.

Where vertically propagating shear waves may produce the maximum ground motion, a one-dimensional equivalent-linear analysis (e.g., Ref. 23 or 24) or nonlinear analysis (e.g., Refs. 25, 26, and 27) may be appropriate and is reviewed in conjunction with geotechnical and structural engineering. Where horizontally propagating shear waves, compressional waves, or surface waves may produce the maximum ground motion, other methods of analysis (e.g., Refs. 28 and 29) may be more appropriate. However, since some of the variables are not well defined and the techniques are still in the developmental stage, no generally agreed-upon procedures can be promulgated at this time. Hence, the staff must use discretion in reviewing any method of analysis. To ensure appropriateness, site response characteristics determined from analytical procedures should be compared with historical and instrumental earthquake data, when available.

<u>2.5.2.6 Safe Shutdown Earthquake **Ground Motion**</u>. In meeting the requirements of Reference 1, this subsection is accepted when the vibratory ground motion specified for the SSE is described in terms of the free-field response spectrum and is at least as conservative as that which would result at the site from the ~~maximum earthquake~~ **CEs** determined in Subsection 2.5.2.4, considering the site transmission effects determined in Subsection 2.5.2.5. If several different ~~maximum potential earthquakes~~ **CEs** produce the largest ground motions in different frequency bands (as noted in Subsection 2.5.2.4), the vibratory ground motion specified

for the SSE must be as conservative in each frequency band as that for each earthquake.

The staff reviews the free-field response spectra of engineering significance (at appropriate damping values). Ground motion may vary for different foundation conditions at the site. When the site effects are significant, this review is made in conjunction with the review of the design response spectra in Section 3.7.1 to ensure consistency with the free-field motion. The staff normally evaluates response spectra on a case-by-case basis. The staff considers compliance with the following conditions acceptable in the evaluation of the SSE. In all these procedures, the proposed free-field response spectra ~~shall~~ **will** be considered acceptable if they equal or exceed the estimated 84th percentile ground-motion spectra from the ~~maximum or controlling earthquake~~ **CE** described in Subsection 2.5.2.4.

The following steps summarize the staff review of the SSE.

1. Both horizontal and vertical component site-specific response spectra should be developed statistically from response spectra of recorded strong motion records that are selected to have similar source, propagation path, and recording site properties as the controlling earthquakes. It must be ensured that the recorded motions represent free-field conditions and are free of or corrected for any soil-structure interaction effects that may be present because of locations and/or housing of recording instruments. Important source properties include magnitude and, if possible, fault type, and tectonic environment. Propagation path properties include distance, depth, and attenuation. Relevant site properties include shear velocity profile and other factors that affect the amplitude of waves at different frequencies. A sufficiently large number of site-specific time-histories or response spectra or both should be used to obtain an adequately broadband spectrum to encompass the uncertainties in these parameters. An 84th percentile response spectrum for the records should be presented for each damping value of interest and compared to the SSE free-field and design response spectrum (e.g., Refs. 30, 31, 32, and 33). The staff considers direct estimates of spectral ordinates preferable to scaling of spectra to peak accelerations. In the Eastern United States, relatively little information is available on magnitudes for the larger historic earthquakes; hence, it may be appropriate to rely on intensity observations (descriptions of earthquake effects) to estimate magnitudes of historic events (e.g., Refs. 34 and 35). If the data for site-specific response spectra were not obtained under geologic conditions similar to those at the site, corrections for site effects should be included in the development of the site-specific spectra.

2. Where a large enough ensemble of strong-motion records is not available, response spectra may be approximated by scaling that ensemble of strong-motion data that represent the best estimate of source, propagation path, and site properties (e.g., Ref. 36). Sensitivity studies should show the effects of scaling.

3. If strong-motion records are not available, site-specific peak ground acceleration, velocity, and displacement (if necessary) should be determined for appropriate magnitude, distance, and foundation conditions. Then response spectra may be determined by scaling the acceleration, velocity, and displacement values by appropriate amplification factors (e.g., Ref. 37). ~~Where~~ **If** only estimates of peak ground acceleration are available, it is acceptable to select a peak acceleration and use this peak acceleration as the high frequency asymptote to standardized response spectra such as described in Regulatory Guide 1.60 (Ref. 6) for both the horizontal and vertical components of motion with the appropriate amplification factors. For each controlling earthquake, the peak ground motions should be determined using current relations between acceleration, velocity, and, if necessary, displacement, earthquake size (magnitude or intensity), and source distance. Peak ground motion should be determined from state-of-the-art relationships. Relationships between magnitude and ground motion are found, for example, in References 38, 39, 40, and 41 and relationships between ground motion and intensity are found, for example, in References 41, 42, and 43. ~~Due to~~ **Because of** the limited data for high intensities greater than Modified Mercalli Intensity (MMI) VIII, the available empirical relationships between intensity and peak ground motion may not be suitable for determining the appropriate reference acceleration for seismic design.

4. Response spectra developed by theoretical-empirical modeling of ground motion may be used to supplement site-specific spectra if the input parameters and the appropriateness of the model are thoroughly documented (e.g., Refs. 19, 44, 45, ~~and~~ 46**, and 53**). Modeling is particularly useful for sites near capable ~~faults~~ **tectonic sources or for deeper structures** that may experience ground motion that is different in terms of frequency content and wave type from ground motion caused by more distant earthquakes.

5. Probabilistic estimates of seismic hazard should be calculated ~~(e.g., Refs. 41 and 47)~~ and the underlying assumptions and associated uncertainties should be documented **as discussed in Draft Regulatory Guide DG-1015 (Ref. 54).** ~~to assist in the staff's overall deterministic approach.~~ The probabilistic studies should highlight which seismic sources are significant to the site. ~~Uniform hazard spectra (spectra that have a uniform probability of exceedance over the frequency range of~~

~~interest) showing uncertainty should be calculated for 0.01, 0.001, and 0.0001 annual probabilities of exceedance at the site.~~ The **annual** probability of exceeding the SSE response spectra should also be estimated and compare**d**~~ison of results made with other probabilistic studies.~~ **with those of the currently operating plants as required in Appendix B to 10 CFR Part 100. Procedures for deriving the CEs from a PSHA and estimating the annual probability of exceedance of the SSE are contained in the Draft Regulatory Guide DG-1015 (Appendices B and C) (Ref. 54).**

The time duration and number of cycles of strong ground motion are required for analysis of site foundation liquefaction potential and for design of many plant components. The adequacy of the time history for structural analysis is reviewed under SRP Section 3.7.1. The time history is reviewed in this SRP section to confirm that it is compatible with the seismological and geological conditions in the site vicinity and with the accepted SSE model. At present, models for deterministically computing the time history of strong ground motion from a given source-site configuration may be limited. It is therefore acceptable to use an ensemble of ground-motion time histories from earthquakes with similar size, site-source characteristics, and spectral characteristics or results of a statistical analysis of such an ensemble. Total duration of the motion is acceptable when it is as conservative as values determined using current studies such as References 48, 49, 50, and 51.

~~2.5.2.7 Operating Basis Earthquake. In meeting the requirements of Reference 1, this subsection is acceptable when the vibratory ground motion for the OBE is described and the response spectrum (at appropriate damping values) at the site specified. Probability calculations (e.g., Refs. 41, 47, and 52) should be used to estimate the probability of exceeding the OBE during the operating life of the plant. The maximum vibratory ground motion of the OBE should be at least one-half the maximum vibratory ground motion of the SSE unless a lower OBE can be justified on the basis of probability calculations. It has been staff practice to accept the OBE if the return period is on the order of hundreds of years (e.g., Ref. 31).~~

III. REVIEW PROCEDURES

Upon receiving the applicant's SAR, an acceptance review is conducted to determine compliance with the investigative requirements of 10 CFR Part 100, Appendix ~~A~~ B (Ref. 1). The reviewer also identifies any site-specific problems, the resolution of which could result in extended delays in completing the review.

After SAR acceptance and docketing, ~~those areas are identified where~~ **the reviewer identifies areas that need** additional information ~~is required~~ to determine the earthquake hazard. These

are transmitted to the applicant as draft requests for additional information.

A site visit may be conducted during which the reviewer inspects the geologic conditions at the site and the region around the site as shown in outcrops, borings, geophysical data, trenches, and those geologic conditions exposed during construction if the review is for an operating license. The reviewer also discusses the questions with the applicant and his consultants so that it is clearly understood what additional information is required by the staff to continue the review. Following the site visit, a revised set of requests for additional information, including any additional questions that may have been developed during the site visit, is formally transmitted to the applicant.

The reviewer evaluates the applicant's response to the questions, prepares requests for additional clarifying information, and formulates positions that may agree or disagree with those of the applicant. These are formally transmitted to the applicant.

The Safety Analysis Report and amendments responding to the requests for additional information are reviewed to determine that the information presented by the applicant is acceptable according to the criteria described in Section II (Acceptance Criteria) above. Based on information supplied by the applicant **and information** obtained from site visits, ~~or from~~ staff consultants, or literature sources, the reviewer independently identifies **and evaluates** the relevant ~~seismotectonic provinces~~ **seismogenic sources and capable tectonic sources**, evaluates the capability of faults in the region, and determines the earthquake potential for each ~~province and each capable fault or tectonic structure~~ **seismogenic source or capable tectonic source** using procedures noted in Section II (Acceptance Criteria) above. The reviewer evaluates the vibratory ground motion that the ~~potential earthquakes~~ **CEs** could produce at the site and ~~defines~~ **compares that ground motion to** the **SSE.** ~~safe shutdown earthquake and operating basis earthquake~~.

IV. EVALUATION FINDINGS

~~If the evaluation by the staff,~~ On completion of the review of the geologic and seismologic aspects of the plant site, **if the evaluation by the staff** confirms that the applicant has met the requirements or guidance of applicable portions of References 1 through 6 **and 54**, the conclusion in the SER states that the information provided and investigations performed support the applicant's conclusions regarding the seismic integrity of the subject nuclear power plant site. In addition to the conclusion, this section of the SER includes (1) ~~definitions~~ **an evaluation** of ~~tectonic provinces~~ **seismogenic sources and capable tectonic sources**, (2) evaluations of the capability of geologic structures in the region, (3) ~~determinations~~ **evaluation** of the ~~SSE earthquake(s)~~ **DSEs** and free-field response spectra based on

evaluation of the ~~potential earthquakes~~ **CEs, and** (4) time-history of strong ground motion~~, and (5) determinations of the OBE free-field response spectra~~. Staff reservations about any significant deficiency presented in the applicant's SAR are stated in sufficient detail to make clear the precise nature of the concern. The above evaluation**s** ~~determinations or redeterminations~~ are made by the staff during ~~both~~ the construction permit (CP), ~~and~~ operating license (OL)**, combined license (COL) or early site permit** phases of review **as appropriate**.

OL applications are reviewed for any new information developed subsequent to the CP ~~safety evaluation report~~ SER. The review will also determine whether the CP recommendations have been implemented.

A typical OL-stage summary finding for this section of the SER follows:

> In our review of the seismologic aspects of the plant site, we have considered pertinent information gathered since our initial seismologic review ~~which~~ **that** was made in conjunction with the issuance of the Construction Permit. This new information includes data gained from both site and near-site investigations as well as from a review of recently published literature.
>
> As a result of our recent review of the seismologic information, we have determined that our earlier conclusion regarding the safety of the plant from a seismological standpoint remains valid. These conclusions can be summarized as follows:
>
> 1. Seismologic information provided by the applicant and required by Appendix ~~A~~ **B** to 10 CFR Part 100 provides an adequate basis to establish that no ~~capable faults~~ **seismic sources** exist in the plant site area ~~which~~ **that** would cause earthquakes to be centered there.
>
> 2. The response spectrum proposed for the safe shutdown earthquake is the appropriate free-field response spectrum in conformance with Appendix ~~A~~ **B** to 10 CFR Part 100.
>
> The new information reviewed for the proposed nuclear power plant is discussed in Safety Evaluation Report Section 2.5.2.
>
> The staff concludes that the site is acceptable from a seismologic standpoint and meets the requirements of (1) 10 CFR Part 50, Appendix A (General Design Criterion 2), (2) 10 CFR Part 100, and (3) 10 CFR Part 100, Appendix ~~A~~ **B**. This conclusion is based on the following:

1. The applicant has met the requirements of:

a. 10 CFR Part 50, Appendix A, General Design Criterion 2 with respect to protection against natural phenomena such as faulting.

b. 10 CFR Part 100, Reactor Site Criteria, with respect to the identification of geologic and seismic information used in determining the suitability of the site.

c. 10 CFR Part 100, ~~Appendix A (Seismic and Geologic Siting Criteria for Nuclear Power Plants)~~ **Appendix B (Criteria for the Seismic and Geologic Siting of Nuclear Power Plants on or After [Effective Date of this Regulation] (Ref. 1))** with respect to obtaining the geologic and seismic information necessary to determine (1) site suitability and (2) the appropriate design of the plant. Guidance for complying with this regulation is contained in Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants" (Ref. 4); **Draft Regulatory Guide DG-1015, "Identification and Characterization of Seismic Sources, Deterministic Seismic Sources, and Ground Motion" (Ref. 54);** Regulatory Guide 4.7, "General Site Suitability Criteria for Nuclear Power Stations" **(Proposed Revision 2)** (Ref. 5); and Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants" (Ref. 6).

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant or licensee proposes an acceptable alternative method for complying with specific portions of the Commission's regulations, the methods described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides and NUREGs (Refs. 4 through 8 **and 54**).

The provisions of this SRP section apply to reviews of construction permits (CP), operating licenses (OL), **early site permits,** ~~preliminary design approval (PDA), final design approval (FDA),~~ and combined license (CP/OL) applications docketed **pursuant to the proposed Appendix B to 10 CFR Part 100.** ~~after the date of issuance~~

~~of this SRP section.~~

VI. <u>REFERENCES</u>

1. 10 CFR Part 100, ~~Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."~~ **Proposed Appendix B, "Criteria for the Seismic and Geologic Siting of Nuclear Power Plants on or After [Effective Date of this Regulation]."**

2. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

3. 10 CFR Part 100, "Reactor Site Criteria."

4. USNRC, "Site Investigations for Foundations of Nuclear Power Plants," Regulatory Guide 1.132.

5. USNRC, "General Site Suitability Criteria for Nuclear Power Stations," Regulatory Guide 4.7 **(Proposed Revision 2, DG-4003).**

6. USNRC, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Regulatory Guide 1.60.

7. US NRC, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants **(LWR Edition)**," Regulatory Guide 1.70.

8. USNRC, "Report of Siting Policy Task Force," NUREG-0625, August 1979.

9. N. L. Barstow et al., "An Approach to Seismic Zonation for Siting Nuclear Electric Power Generating Facilities in the Eastern United States," prepared by Roundout Associates, Inc., for the USNRC, NUREG/CR-1577, May 1981.

10. C. W. Stover et al., "Seismicity Maps of the States of the U.S.," Geological Survey Miscellaneous Field Studies Maps, 1979-1981.

11. "Earthquake History of the United States," Publication 41-1, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 1982.

12. T. R. Toppozada, C. R. Real, S. P. Bezore, and D. L. Parke, "Compilation of Pre-1900 California Earthquake History, Annual Technical Report-Fiscal Year 1978-79, Open File Report 79-6 SAC (Abridged Version)," California Division of Mines and Geology, 1979.

13. P. W. Basham, D. H. Weichert, and M. J. Berry, "Regional Assessment of Seismic Risk in Eastern Canada," <u>Bulletin of the</u>

Seismological Society of America, Vol. 65, pp. 1567-1602, 1979.

14. P. B. King, "The Tectonics of North America - A Discussion to Accompany the Tectonic Map of North America, Scale 1:5,000,000," Professional Paper 628, U.S. Geological Survey, 1969.

15. A. J. Eardley, "Tectonic Divisions of North America," Bulletin of the American Association of Petroleum Geologists, Vol. 35, 1951.

16. J. B. Hadley and J. F. Devine, "Seismotectonic Map of the Eastern United States," Publication MF-620, U.S. Geological Survey, 1974.

17. M. L. Sbar and L. R. Sykes, "Contemporary Compressive Stress and Seismicity in Eastern North America: An Example of Intra-Plate Tectonics," Bulletin of the Geological Society of America, Vol. 84, 1973.

18. R. B. Smith and M. L. Sbar, "Contemporary Tectonics and Seismicity of the Western United States with Emphasis on the Intermountain Seismic Belt," Bulletin of the Geological Society of America, Vol. 85, 1974.

19. USNRC "Safety Evaluation Report (Geology and Seismology) Relat to the Operation of San Onofre Nuclear Generating Station, Units 2 and 3," NUREG-0712, February 1981.

20. D. B. Slemmons, "Determination of Design Earthquake Magnitudes for Microzonation," Proceedings of the Third International Earthquake Microzonation Conference, 1982.

21. M. G. Bonilla, R. K. Mark, and J. J. Lienkaemper, "Statistical Relations Among Earthquake Magnitude, Surface Rupture, Length and Surface Fault Displacement," Bulletin of the Seismological Society of America, Vol. 74, pp. 2379-2411, 1984.

22. T. C. Hanks and H. Kanamori, "A Moment Magnitude Scale," Journal of Geophysical Research, Vol. 84, pp. 2348-2350, 1979.

23. P. B. Schnabel, J. Lysmer, and H. B. Seed, "SHAKE-A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites," Report No. EERC 72-12, Earthquake Engineering Research Center, University of California, Berkeley, 1972.

24. E. Faccioli and J. Ramirez, "Earthquake Response of Nonlinear Hysteretic Soil Systems," International Journal of Earthquake Engineering and Structural Dynamics, Vol. 4, pp. 261-276, 1976.

25. I. V. Constantopoulos, "Amplification Studies for a Nonlinear Hysteretic Soil Model," Report No. R73-46, Department of Civil Engineering, Massachusetts Institute of Technology, 1973.

26. V. L. Streeter, E. B. Wylie, and F. E. Richart, "Soil Motion Computation by Characteristics Methods," Proceedings of the American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, Vol. 100, pp. 247-263, 1974.

27. W. B. Joyner and A. T. F. Chen, "Calculations of Nonlinear Ground Response in Earthquakes," Bulletin of the Seismological Society of America, Vol. 65, pp. 1315-1336, 1975.

28. T. Udaka, J. Lysmer, and H. B. Seed, "Dynamic Response of Horizontally Layered Systems Subjected to Traveling Seismic Waves," Proceedings of the Second U.S. National Conference on Earthquake Engineering, 1979.

29. L. A. Drake, "Love and Raleigh Waves in an Irregular Soil Layer," Bulletin of the Seismological Society of America, Vol. 70, pp. 571-582, 1980.

30. USNRC, "Development of Site-Specific Response Spectra," NUREG/CR-4861, March 1987.

31. USNRC, "Safety Evaluation Report Related to Operation of the Sequoyah Nuclear Plant, Units 1 and 2," NUREG-0011, 1979.

32. USNRC, "Safety Evaluation Report Related to the Operation of Midland Plant, Units 1 and 2," NUREG-0793, May 1982.

33. USNRC, "Safety Evaluation Report Related to the Operation of Enrico Fermi Atomic Power Plant, Unit No. 2," NUREG-0847, July 1981.

34. R. L. Street and F. T. Turcotte, "A Study of Northeastern North American Spectral Moments, Magnitudes, and Intensities," Bulletin of the Seismological Society of America, Vol. 67, pp. 599-614, 1977.

35. O. W. Nuttli, G. A. Bollinger, and D. W. Griffiths, "On the Relation Between Modified Mercalli Intensity and Body-Wave Magnitude," Bulletin of the Seismological Society of America, Vol. 69, pp. 893-909, 1979.

36. T. H. Heaton, F. Tajima, and A. W. Mori, "Estimating Ground Motions Using Recorded Accelerograms," Surveys in Geophysics, Vol. 8, pp. 25-83, 1986.

37. USNRC, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," NUREG/CR-0098, June 1978.

38. W. B. Joyner and O. M. Boore, "Peak Horizontal Acceleration and Velocity from Strong Motion Records Including Records from the 1979 Imperial Valley, California Earthquake," Bulletin of the Seismological Society of America, Vol. 71, 2011-2038, 1981.

39. K. W. Campbell, "Near-Source Attenuation of Peak Horizontal Acceleration," Bulletin of the Seismological Society of America, Vol. 71, pp. 2039-2070, 1981.

40. O. W. Nuttli and R. B. Herrmann, "Consequences of Earthquakes in the Mississippi Valley," Preprint 81-519, American Society of Civil Engineers Meeting, 1981.

41. D. L. Bernreuter et al., "Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains," NUREG/CR-5250, January 1989.

42. M. D. Trifunac and A. G. Brady, "On the Correlation of Seismic Intensity Scales with Peaks of Recorded Strong Ground Motion," Bulletin of the Seismological Society of America, Vol. 65, 1975.

43. J. R. Murphy and L. J. O'Brien, "Analysis of a Worldwide Strong Motion Data Sample To Develop an Improved Correlation Between Peak Acceleration, Seismic Intensity and Other Physical Parameters," prepared by Computer Sciences Corporation for the USNRC, NUREG-0402, January 1978.

44. USNRC, "Safety Evaluation Report Related to Operation of Virgil C. Summer Nuclear Station, Unit No. 1," NUREG-0717, 1981.

45. USNRC, "State-of-the-Art Study Concerning Near-Field Earthquake Ground Motion," NUREG/CR-1340, August 1980.

46. H. J. Swanger et al., "State-of-the-Art Study Concerning Near-Field Earthquake Ground Motion," NUREG/CR-1978, March 1981.

47. "Seismic Hazard Methodology for the Central and Eastern United States," Electric Power Research Institute, Report NP-4726, 1986.

48. R. Dobry, I. M. Idriss, and E. Ng, "Duration Characteristics of Horizontal Components of Strong-Motion Earthquake Records," Bulletin of the Seismological Society America, Vol. 68, pp. 1487-1520, 1978.

49. B. A. Bolt, "Duration of Strong Ground Motion," Proceedings of the Fifth World Conference on Earthquake Engineering, 1973.

50. W. W. Hays, "Procedures for Estimating Earthquake Ground

Motions," Professional Paper 1114, U.S. Geological Survey, 1980.

51. H. Bolton Seed et al., "Representation of Irregular Stress Time Histories by Equivalent Uniform Stress Series in Liquefaction Analysis," National Science Foundation, Report EERC 75-29, October 1975.

52. S. T. Algermissen et al., "Probabilistic Estimate of Maximum Acceleration and Velocity in Rock in the Contiguous United States," U. S. Geological Survey Open-File Report 82-1033, 1982.

53. USNRC, "Safety Evaluation Report Related to the Operation of Diablo Canyon Nuclear Power Plant, Units 1 and 2," NUREG-0675, Supplement No. 34, June 1991.

54. USNRC, "Identification and Characterization of Seismic Sources, Deterministic Source Earthquakes, and Ground Motion," Draft Regulatory Guide DG-1015.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

FIRST CLASS MAIL
POSTAGE AND FEES PAID
USNRC
PERMIT NO. G-67

AD93-1
PDR

* * * * *

Done at Washington, DC, on December 16, 1992.

H. Russell Cross,
Administrator, Food Safety and Inspection Service.

[FR Doc. 93-57 Filed 1-4-93; 8:45 am]

BILLING CODE 3410-DM-M

NUCLEAR REGULATORY COMMISSION

10 CFR Parts 50, 52 and 100

RIN 3150-AD93

Reactor Site Criteria; Including Seismic and Earthquake Engineering Criteria for Nuclear Power Plants and Proposed Denial of Petition From Free Environment, Inc. et al.

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule: Extension of comment period.

SUMMARY: On October 20, 1992 (57 FR 47802), the NRC published for public comment a proposed rule to update the criteria used in decisions regarding power reactor siting, including geologic, seismic, and earthquake engineering considerations for future nuclear power plants. The comment period for this proposed rule was to have expired on February 17, 1993. The availability of the five draft regulatory guides and the standard review plan section that were developed to provide guidance on meeting the proposed regulations was published on November 25, 1992 (57 FR 55601). Because the proposed rule would move the detailed guidance from the regulation and place it into a regulatory guide, a critical evaluation of the proposed rule could not be performed until the draft regulatory guides and standard review plan section were available. The NRC has stated that comments on the draft regulatory guides and standard review plan section would be most helpful if received by March 24, 1993. In view of the importance of the proposed rule and the differences in the comment period, the NRC has decided to extend the comment period on the proposed rule for an additional thirty six days. The extended comment period now expires March 24, 1993.

DATES: The comment period has been extended and now expires March 24, 1993. Comments received after this date will be considered if it is practical to do so, but the Commission is able to assure consideration only for comments received on or before this date.

ADDRESSES: Mail written comments to: Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch.

Deliver comments to 11555 Rockville, Pike, Rockville, Maryland, between 7:45 a.m. and 4:15 p.m., Federal workdays.

Copies of the regulatory analysis, the environmental assessment and finding of no significant impact, and comments received may be examined at the NRC Public Document Room at 2120 L Street NW. (Lower Level), Washington, DC.

FOR FURTHER INFORMATION CONTACT: Dr. Andrew J. Murphy, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 492-3860, concerning the seismic and earthquake engineering aspects and Mr. Leonard Soffer, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 492-3916, concerning other siting aspects.

Dated at Rockville, Maryland, this 29th day of December, 1992.

For the Nuclear Regulatory Commission.

Samuel J. Chilk,
Secretary of the Commission.

[FR Doc. 93-48 Filed 1-4-93; 8:45 am]

BILLING CODE 7590-01-M

FEDERAL RESERVE SYSTEM

12 CFR Part 230

[Regulation DD; Docket No. R-0791]

Truth in Savings; Proposed Regulatory Amendments

AGENCY: Board of Governors of the Federal Reserve System.

ACTION: Proposed rule.

SUMMARY: The Board is publishing for comment proposed amendments to Regulation DD (Truth in Savings) to implement recent changes made to the Truth in Savings Act by the Housing and Community Development Act of 1992. The law extends the mandatory date for compliance with the requirements of the Truth in Savings Act by three months, so that institutions must comply by June 21, 1993, rather than March 21, 1993. The law also modifies the advertising rules relating to signs in an institution's lobby, and makes a technical change to the provision dealing with notices required to be given to existing account holders. In addition, the Board is proposing to make a minor change to the regulation and clarify and provide additional guidance on a few issues that have been raised by institutions since publication of the final regulation on September 21, 1992.

DATES: Comments must be received on or before February 1, 1993.

ADDRESSES: Comments should refer to Docket No. R-0791, and may be mailed to Mr. William W. Wiles, Secretary, Board of Governors of the Federal Reserve System, 20th Street and Constitution Avenue, NW., Washington, DC 20551. Comments also may be delivered to room B-2222 of the Eccles Building between 8:45 a.m. and 5:15 p.m. weekdays, or to the guard station in the Eccles Building courtyard on 20th Street, NW (between Constitution Avenue and C Street) any time. Comments may be inspected in Room B-1122 between 9 a.m. and 5 p.m. weekdays, except as provided in 12 CFR 261.8 of the Board's rules regarding the availability of information.

FOR FURTHER INFORMATION CONTACT: Jane Ahrens, Kyung Cho, Kurt Schumacher, or Mary Jane Seebach, Staff Attorneys, Division of Consumer and Community Affairs, at (202) 736-5500; for the hearing impaired only contact Dorothea Thompson, Telecommunications Device for the Deaf, at (202) 452-3544, Board of Governors of the Federal Reserve System, Washington, DC 20551.

SUPPLEMENTARY INFORMATION:

(1) Background

The Truth in Savings Act (act) (contained in the Federal Deposit Insurance Corporation Improvement Act of 1991) was enacted in December 1991. The Board published proposed rules to implement the act on April 1?, 1992 (57 FR 12735), and published a final regulation, Regulation DD, on September 21, 1992 (57 FR 43337) (correction notice at 57 FR 46480, October 9, 1992).

The Housing and Community Development Act (HCDA) was enacted in October 1992 (Pub. L. 102-550, 106 Stat. 3672). The law contains three provisions that amend the Truth in Savings Act. The provisions extend the effective date for compliance with the act by three months, reduce the requirements that apply to some advertisements on the premises of a depository institution, and modify the provision that requires a notice to be given to existing account holders alerting them to the availability of account disclosures.

To implement the changes, the Board is proposing regulations for comment, and expects to adopt final amendments before March 21, 1993—the compliance date currently set forth in Regulation DD. In light of the minor nature of the

AD93-1
PDR

should consider developing vehicles for either eliminating or further discussing individual scores that vary widely from the average.

5. *Agency Staff*

(a) Agencies that rely on peer review should encourage their staff members to play a significant role in ensuring that reviewers are well-informed about, and strictly observe, applicable rules or guidelines on bias and conflict of interest.

(b) Agencies that administer multiple programs for awarding discretionary grants by peer review should consider rotating staff periodically among the programs. Especially in programs in which peer reviewers do not meet to reach collective judgments, agencies should rotate the staff responsible for making initial funding recommendations.

D. Audits for Potential Bias

Agencies that rely on peer review should experiment with random audits of the review process for bias and conflict of interest.

Dated: March 22, 1993.

Jeffrey S. Lubbers,

Research Director.

[FR Doc. 93-6824 Filed 3-25-93; 8:45 am]

BILLING CODE 6110-01-W

NUCLEAR REGULATORY COMMISSION

10 CFR Parts 50, 52, and 100

RIN 3150-AD93

Reactor Site Criteria Including Seismic and Earthquake Engineering Criteria for Nuclear Power Plants and Proposed Denial of Petition From Free Environment, Inc. et al.

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule: Extension of comment period.

SUMMARY: On October 20, 1992, (57 FR 47802) the NRC published for public comment a proposed rule to update the criteria used in decisions regarding power reactor siting, including geologic, seismic, and earthquake engineering considerations for future nuclear power plants. The comment period for this proposed rule was to have expired on February 17, 1993.

On January 5, 1993 the public comment period was extended to March 24, 1993 (58 FR 271). The Commission has received a request to once again extend the public comment period based on the fact that the proposed rule presents difficult iss. es requiring thoughtful and careful analysis if the comments are to be of maximum value to the Commission. In particular, preparation of such comments involves careful consideration of the interplay between the proposed demographic and seismic criteria and the relationship of the proposed criteria to the Commission's Safety Goals, severe accident requirements, and 10 CFR part 52, as well as preparation of supporting analyses.

The Commission therefore finds that it is reasonable to extend the public comment period to June 1, 1993, in order to allow all interested persons adequate time for such consideration.

DATES: The comment period has been extended and now expires June 1, 1993. Comments received after this date will be considered if it is practical to do so, but the Commission is able to assure consideration only for comments received on or before this date.

ADDRESSES: Mail written comments to: Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch. Deliver comments to 11555 Rockville Pike, Rockville, Maryland, between 7:45 a.m. and 4:15 p.m., Federal workdays.

Copies of the regulatory analysis, the environmental assessment and finding of no significant impact, and comments received may be examined at the NRC Public Document Room at 2120 L Street NW. (Lower Level), Washington, DC.

FOR FURTHER INFORMATION CONTACT: Dr. Andrew J. Murphy, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 492-3860, concerning the seismic and earthquake engineering aspects and Mr. Michael T. Jamgochian, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 492-3918, concerning other siting aspects.

Dated at Rockville, Maryland this 22d day of March, 1993.

For the Nuclear Regulatory Commission.

Samuel J. Chilk,

Secretary of the Commission.

[FR Doc. 93-6969 Filed 3-25-93; 8:45 am]

BILLING CODE 7590-01-M

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 39

[Docket No. 93-NM-14-AD]

Airworthiness Directives; Precise Flight, Inc., Pulselite Units, Model 1210-2405-2; as Installed in Various Small Airplanes; Installed in Accordance With Supplemental Type Certificate (STC) SA4005NM

AGENCY: Federal Aviation Administration, DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This document proposes the adoption of a new airworthiness directive (AD) that is applicable to certain Precise Flight, Inc., pulselite units. This proposal would require removal of certain pulselite units, or replacement of those units with improved units. This proposal is prompted by reports that pulselite units have overheated and failed due to the installation of underrated transistors and the location of these transistors in relation to the heat sink fins. The actions specified by the proposed AD are intended to prevent the presence of smoke in the cockpit, which could prompt the pilot to initiate an emergency landing.

DATES: Comments must be received by May 21, 1993.

ADDRESSES: Submit comments in triplicate to the Federal Aviation Administration (FAA), Transport Airplane Directorate, ANM-103, Attention: Rules Docket No. 93-NM-14-AD, 1601 Lind Avenue, SW., Renton, Washington 98055-4056. Comments may be inspected at this location between 9 a.m. and 3 p.m., Monday through Friday, except Federal holidays.

The service information referenced in the proposed rule may be obtained from Precise Flight, Inc., 63120 Powell Butte Road, Bend, Oregon 97701. This information may be examined at the FAA, Transport Airplane Directorate, 1601 Lind Avenue, SW., Renton, Washington.

FOR FURTHER INFORMATION CONTACT: Ms. Sheila I. Mariano, Aerospace Engineer, Seattle Aircraft Certification Office, Special Certification Branch, ANM-190S, FAA, Transport Airplane Directorate, 1601 Lind Avenue, SW., Renton, Washington 98055-4056; telephone (206) 227-2599; fax (206) 227-1181.