Department of Energy
Washington, DC 20585

August 31, 1995

The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, N.W.
Suite 700
Washington, D.C. 20004

Dear Mr. Chairman:

This is in response to your letter, dated June 13, 1995, which provided comments on DOE-STD-1023-94 from the Defense Nuclear Facilities Safety Board's staff and outside experts. This standard has been under development for a considerable period of time and included reviews by your staff. Enclosure 1 provides responses to the comments, which have resulted in additional revisions to the standard, now scheduled to be issued in August 1995. A copy of the revised standard that responds to your recent comments is included as Enclosure 2. We will monitor the evolving NRC activities in the same area and will consider future refinements that may come out of the commercial nuclear industry.

We appreciate the work that the staff and their outside experts have done in reviewing this standard. Their comments have contributed to improving the final document. Please contact Richard Stark (301) 903-4407 with questions or comments.

Sincerely,

Richard J. Black for
Orin F. Pearson
Deputy Assistant Secretary
Nuclear and Facility Safety

2 Enclosures

cc:
Dr. G. Cunningham, DNFSB
M. Whitaker, EH-9

Consolidated Review Comments by Staff and Outside Experts

Draft Standard DOE-STD-1023, November 1994
NATURAL PHENOMENA HAZARDS ASSESSMENT CRITERIA

The objective of this standard is to provide the requirements (criteria) for establishing adequate natural phenomena hazards (NPH) design basis load levels, which are required information to implement DOE-STD-1020-94 (1020). As the title of the standard indicates, issues related to the definition of manmade hazards, such as aircraft crash, accidental explosion, toxic material release and malevolent vehicles are not considered. Sections 1 (Scope), 2 (Applicable Documents), and 3 (Definitions) take up the first 10 pages. Seismic criteria dominate the document with 19 pages. Wind criteria take up only six pages and Flood criteria 10 pages. Review comments are provided under two main headings: General (primarily addressing major editorial concerns) and Technical.

GENERAL

The intent of the standard would be better served if the primary focus of the document shifts to defining *acceptance criteria* for the methodologies that are being used to estimate NPH load levels throughout the DOE complex. As it is presently structured, the standard attempts to cover several fronts simultaneously: The contents are a mixture of performance specifications (minimal), prescriptive step-by-step procedures (for major deliverables), and commentary (sprinkled throughout the document). These are at odds with both the title and the foreword of the standard. Once the acceptance criteria are segregated from the rest of the document, separate step-by-step recommended procedures/methods for producing the end products and an appropriate commentary could be prepared and included as Appendices if deemed necessary or even desirable.

Conflicts and overlaps with 1020, which could contribute to difficulties during applications of both standards, should be carefully edited. For example, Section 5.2.1.e of 1023 specifies that "a probabilistic wind hazard shall be conducted at a level appropriate for the performance categories of the SSCs at a site." This appears to be in conflict with Section D.1 of 1020, which does not require the use of a probabilistic wind hazard assessment, but relies on the methodology presented in ASCE 7. A clearer focus for this standard would minimize the level of conflicts and overlaps with 1020 requirements. Obviously 1020 and 1023 are companion documents and a better delineation of contents is necessary. Two alternatives are suggested:

1. All material on load levels may be edited out from 1020 and incorporated into this standard as appropriate and 1020 dedicated to only response analysis methodologies for NPH loads. Decoupling of load specification and response analysis is desirable during times of evolutionary developments in both. The temptation for easy, compensatory requirements might thus be eliminated.

2. The load level acceptance criteria in this standard could be subsumed into 1020 and the present document modified to become a stand-alone Commentary on 1020 and a Tutorial on recommended procedures.

Although several paragraphs are devoted to the *independent* review of the specification and assessment of NPH loads, prescriptive requirements are made relative to what is acceptable and what is not acceptable (section 5.1.5). By definition, independent reviewers should be left alone to determine if a given result is acceptable or not. The requirements for an independent review should be limited only to the composition of the review panel, the required credentials of the panelists and a general scope or level of the review.

TECHNICAL

Seismic: This Section reiterates, in general terms, the steps of how to generate:

1. Probabilistic hazard curves for both zero period acceleration (ZPA) and spectral amplification, for two rather arbitrarily selected frequency bands (which, incidentally, miss the very important frequency band of 2.5-5 Hz for reinforced concrete shear wall structures); and

2. How to deaggregate the results of the probabilistic seismic hazard assessment (PSHA) to obtain *controlling* magnitude and distance sets for the preselected frequency bands. This deaggregation is erroneously characterized as the *deterministic* approach (section 5.1.3.1).

Any deterministic approach should employ an *independent* methodology, as for example described in the Draft Regulatory Guide DG-1015. Moreover, the use and mixing of median, mean, 84th percentile ZPAs, analytic and empirical spectral shapes, needs to be clarified and a rational basis for the use of one or the other provided. The selection of means, medians and other fractiles should be based on sound technical arguments. Having a rational basis becomes particularly important when the concept of a *unified* approach is being promoted for seismic, wind and flood. Obviously, the selection of any exceedance fractile cannot be made without considering the inherent safety factors employed in the design process *and* the ultimate target reliability of a given structure, system or component (SSC).

It is expected that significant differences would exist between probabilistically and deterministically generated ground motions, particularly, when close-in faults or seismogenic regions are known to generate characteristic earthquakes. These differences should be explainable, since both the deterministic and probabilistic ground motions stem from the same basic site geology and seismology. Having explained and reconciled the different results, the *design basis* ground motion could then be specified based on the specific geologic and geotechnical facts at each site. Ground motions based on the so-called *controlling* magnitude and distance sets may not even be compatible with local site characteristics, except maybe in an average sense.

Except for fault offset estimation (as a possible design basis), earthquake induced ground failure modes, such as liquefaction, slope stability, lateral spreading and subsidence, are related to the *response* of soils subjected to ground shaking and thus must be covered outside of this standard, in a manner similar to, for example, the treatment of structures in 1020. However, the characterization of ground motion with *adequate energy* in the frequency range of engineering interest and/or duration of strong shaking is an important issue that needs to be directly addressed in the acceptance criteria. For example, liquefaction, slope stability and tank hydrodynamic analyses require that long period and long duration effects be adequately modeled into the design ground motions. Similarly, high frequency large impulses (thought to have caused the many cracks in the welded beam-column connections of steel high-rise buildings *during* the Northridge earthquake) should also be adequately considered in the specifications of the design ground motions.

The following is a sample of specific concerns:

- A choice, from among three methods, is provided to generate site specific spectra without any requirements as to how to select the one that is most appropriate. Differences in these spectra would suggest that some sensitivity checks be made during the selection process.

- A similar concern as above relates to the choice of control points where design ground motions are specified.

- Criteria to decide when a site is *near* a tectonic boundary is missing. And the basis for the different multipliers (1.5 and 1.25) requires justification.

- The level of simplification of the PSHA that would be acceptable for PC-3 is not provided.

- The use of existing hazard curves simply because they exist is questionable. Some evaluation as to the adequacy of the existing curves needs to be established.

- The use of the deterministic site spectra cannot be a choice by the user. Deterministic spectra should always be considered as a sanity check on the final ground motion selected.

Wind: It is not clear why industry standards (i.e., ASCE 7-93 and ANS 2.3) are not used to define *minimum* wind hazards, as the data base of extreme wind, particularly tornadoes, is not robust enough to apply on a site specific basis. Additionally, for PC-4 and PC-3 facilities a minimum tornado assessment should be considered (e.g., Fujita 2-157mph and Fujita 1-112 mph, respectively). It would also be prudent to require the exploration of other types of wind (e.g., "microbursts") that could be characteristic of certain sites.

Flooding: No significant concerns.

NOT MEASUREMENT SENSITIVE

DOE-STD-1023-95
July 1995

DOE STANDARD

NATURAL PHENOMENA HAZARDS ASSESSMENT CRITERIA

U.S. Department of Energy
Washington, D.C. 20585

FOREWORD

The Department of Energy (DOE) has issued an Order (DOE 5480.28) which establishes policy and requirements for Natural Phenomena Hazard (NPH) mitigation for DOE sites and facilities. To implement the NPH mitigation requirements, several standards have been developed for compliance with DOE Order 5480.28. This standard, DOE-STD-1023-94, provides general and detailed criteria for establishing adequate design basis load levels.

The criteria given in this standard should be used in conjunction with other DOE Orders and Standards as listed in Section 2 (Applicable Documents) of this Standard and with other pertinent National consensus codes and standards such as the model building codes.

DOE technical standards such as this technical standard do not establish requirements. However, all or part of the provisions in a technical standard can become requirements under the following circumstances:

(1) they are explicitly stated to be requirements in a DOE requirements document; or

(2) the organization makes a commitment to meet a standard in a contract or in a plan required by a DOE requirements document (such as in a implementation plan).

Throughout this standard, the words "should" and "shall" are used to clarify which actions need to be done to meet this standard. The word "shall" is used to denote actions which must be performed if this standard is to be met. The word "should" is used to indicate recommended practice. If the provisions in this technical standard are made requirements through one of the two ways discussed above, then the "shall" statements would become requirements but the "should" statements would not.

This DOE Standard is approved for use by all departments and contractors of the Department of Energy. The standard was circulated to DOE Standards Coordinators of all DOE Headquarters and Field Offices for review and comment. The comments received were resolved and incorporated in the standard.

TABLE OF CONTENTS

1. SCOPE

a. It is the policy of the Department of Energy (DOE) to design, construct, and operate DOE facilities so that workers, the general public, and the environment are protected from the impacts of natural phenomena hazards (NPHs). This policy and the related requirements for natural phenomena hazard (NPH) mitigation are established by DOE Order 5480.28 (USDOE, 1993a).

b. DOE 5480.28 requires that structures, systems, and components (SSCs) at DOE facilities are designed and constructed to withstand the effects of natural phenomena hazards using a graded approach. The graded approach is implemented by the five (5) performance categories established for SSCs based on criteria provided by DOE-STD-1021-93 (USDOE, 1993b). Performance Category (PC)-0 is for SSCs which require no NPH protection. The performance categories requiring NPH protection range from PC-1, which represents protection for life-safety at the level provided by model building codes, to PC-4, which represents protection from release of hazardous material similar to that provided by commercial nuclear power plants. For each performance category, NPH design, evaluation, and construction requirements of varying conservatism and rigor are provided in DOE-STD-1020-94 (USDOE, 199[illegible]).

c. In applying the design/evaluation criteria of DOE-STD-1020-94 for DOE facilities subjected to one of the natural phenomena hazards, the establishment of design basis load levels consistent with the corresponding performance category is required. Design basis load levels are established by conducting natural phenomena hazard assessments.

d. For sites containing facilities with structures, systems, and components (SSCs) in only Performance Category 1 or 2 and having no site-specific probabilistic NPH assessment, it is sufficient to utilize natural phenomena hazard maps from model building codes or national consensus standards if they have input values at the specified hazard probabilities. For sites which have site-specific probabilistic NPH assessments, the SSCs in Category 1 or 2 shall be evaluated or designed for the greater of the site specific values or the model code values unless lower site specific values can be justified and approved by DOE.

2. APPLICABLE DOCUMENTS

a. DOE Order 5480.1B, "Environment, Safety and Health Program for DOE Operations", of 9-23-86, which establishes the Environment, Safety, and Health (ES&H) Program for DOE Operations.

b. DOE Order 5480.23, "Nuclear Safety Analysis Reports", of 4/10/92, which specifies requirements for safety analysis involving DOE nuclear facilities and for submittal, review, and approval of contractor plans and programs.

c. DOE Order 5480.28, "Natural Phenomena Hazards Mitigation," of 1-15-93, which establishes policy and requirements for natural phenomena hazard (NPH) mitigation for DOE sites and facilities using a graded approach.

d. DOE Order 5480.30, "Nuclear Reactor Safety", of 1-19-93, which specifies requirements for DOE nuclear reactor safety.

e. DOE Order 5481.1B, "Safety Analysis and Review System", of 9-23-86, which establishes uniform requirements for the preparation and review of safety analyses of DOE operations.

f. 10CFR830.120, of 1-1-95, which establishes quality assurance requirements.

g. DOE-STD-1020-94, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities", April, 1994, which defines criteria for designing or evaluating structures, systems, and components for NPH loads.

h. DOE-STD-1021-93, "Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components", July 1993, which provides criteria for placing structures, systems, and components into performance categories.

i. DOE-STD-1022-94, "Natural Phenomena Hazards Site Characterization Criteria" March, 1994, which provides requirements for obtaining the necessary site-specific information to implement DOE-STD-1023-94.

3. CRITERIA

3.1 Detailed Criteria for Seismic Hazard Assessment

3.1.1 General

a. This Standard provides criteria for determining ground motion parameters for the Design/Evaluation Basis Earthquake (DBE). It also provides criteria for determining the acceptable design response spectral shape.

b. Seismic design and evaluation criteria for Department of Energy facilities are provided by DOE-STD-1020-94 (USDOE, 1994a). In accordance with DOE-STD-1020-94, DBE spectra shall be determined and used for the design/evaluation process.

c. In accordance with DOE-STD-1020-94, the DBE spectra shall be a site-specific shape anchored to the appropriate ground motion parameters following the provisions of Sections 3.1.3 and 3.1.5. When a site-specific response spectrum shape is unavailable, a standardized spectrum shape is acceptable.

d. The seismic hazard assessment shall consider all effects of earthquakes including not only earthquake ground shaking, but also earthquake-induced ground failure modes such as fault offset (see Section 3.1.4).

e. For sites containing facilities with SSCs in only Performance Category (PC) 1 or 2, it is sufficient to utilize seismic hazard maps from the current version of model building codes or national consensus standards if no site-specific probabilistic seismic hazard assessment (PSHA) has been conducted for the sites. In lieu of more specific data, (i.e. if seismic hazard maps are not available for the specified annual probability of exceedance), the PC-2 DBE may be taken as 1.5 times the PC-1 DBE, except for sites near tectonic plate boundaries where the PC-2 DBE may be taken as 1.25 times the PC-1 DBE. These factors are based on average hazard curve slopes. For sites which have site-specific probabilistic seismic hazard assessments, the SSCs in Performance Category 1 or 2 shall be evaluated or designed for the greater of the site-specific values or the model code values unless lower site-specific values are approved by DOE.

of the 1989 LLNL and EPRI methodologies can yield significantly different results. Guidance for addressing the differences between the two 1989 studies is provided in DOE-STD-1024-92 (USDOE, 1992). It is permissible to directly average the mean hazard curves from EPRI (1989a) and more recent hazard assessments from LLNL (Savy, et al., 1993 and Sobel, 1994).

b. This option is particularly suitable for DOE sites in the Eastern United States with the exception of sites located near active sources for large magnitude earthquakes, e.g., near New Madrid, Missouri and Charleston, South Carolina. In these cases, it is required to either incorporate additional site-specific seismic sources or show that the regional seismic sources in the LLNL or EPRI studies adequately model the tectonics in the vicinity of the site. See section 5.0 of DOE-STD-1024-92 for additional guidance.

3.1.2.2 Development of Seismic Hazard Curves Based on New Site-Specific PSHA

a. Acceptable methodologies for conducting new PSHA for DOE sites include, but are not limited to those used by Bernreuter, et al. (1989), EPRI (1989a), and Savy (1994). An acceptable methodology for the development of DOE site specific seismic hazard curves must accommodate uncertainties in the potential earthquake occurrence and ground motion attenuation processes affecting the site.

b. The description given here applies to facilities with SSCs in Performance Category 4, as specified in Section 3.1.1.f. For Performance Category 3, the same methodology as for Performance Category 4 is required but simplifications as described in Section A3.1.2.2.5 are acceptable.

c. The following elements shall be included in the methodology to conduct a new PSHA.

(1) Basic Hazard Model - The four steps required to determine the seismic hazard curve using the basic hazard model are shown in Fig. 3.1.

(2) Data Used in the Hazard Modeling - The PSHA shall consider available data in conformance with DOE-STD-1022-94 (USDOE, 1994b)

3.1.2.3 Level of Review

a. The credibility and defensibility of a modern PSHA depends on the quality of the input as well as the completeness of the documentation. All the information, input, and analysis should be fully documented and independently reviewed. The independent review should focus on the arguments and logic used to develop the hazard results. The review team should include personnel with expertise in the seismic hazard methodology and input parameters. The review should be documented including questions raised by reviewers and resolutions provided by the analyst. The SSHAC study should be consulted for guidance.

3.1.3 DBE Response Spectra Acceptance Criteria

a. The target DBE response spectrum is defined by the mean uniform hazard response spectrum (UHS) associated with the seismic hazard annual probability of exceedance over the entire frequency range of interest. However, considerable controversy currently exists concerning both the shape and the amplitude of the mean UHS. The issues of concern are briefly described in DOE-STD-1020-94 (USDOE, 1994a). The current position of the DOE Seismic Working Group (USDOE, 1992) does not recommend the use of UHS alone but recommends that it should be supplemented by the response spectrum shapes obtained from appropriate earthquake events such as the controlling events described in Section 3.1.3.1.

b. The current approach used to develop mean DBE response spectra is to anchor median spectral shapes to mean peak ground motion parameters. By comparing the scaled median shapes to the mean UHS and adjusting it as needed, the appropriateness and conservatism of the final DBE response spectrum can be assured.

c. Earthquake vibratory ground motions to be used as input excitation for design and evaluation of DOE facilities, according to DOE-STD-1020-94, is defined using an approach similar to that being developed by the NRC (USNRC, 1995). When site-specific response spectra are unavailable, a median standardized spectral shape may be used so long as such a spectrum shape is either reasonably consistent with or conservative for the site conditions.

There may be some instances where the spectrum generated from this controlling earthquake may not be sufficiently broad-banded to capture the contributions from all sources. Therefore, if the controlling earthquake for the frequency range of 1 to 2.5 Hz is from a significantly different source, e.g. a large, distant event, its effect on the spectral shape shall be included. In addition, for sites that have SSCs sensitive to low-frequency seismic response (e.g., below 1 Hz), it may be necessary to include the controlling earthquake based on seismic peak ground displacement (PGD).

3.1.3.2 Standardized DBE Response Spectra

a. As specified in Section 3.1.1.b, standardized response spectra developed from general site conditions instead of site-specific geotechnical studies are used if site-specific response spectra are unavailable. Acceptable methods to generate site-dependent standardized response spectra include those of Newmark and Hall (1978), Mohraz (1976), Seed et al. (1974), Kiremidjian and Shah (1980), ATC (1984), and BSSC (1988). An example of the application of standardized spectra can be found in Appendix A.

3.1.4 Earthquake-Induced Ground Failure Assessment

a. In addition to ground shaking, another direct effect of earthquakes can be surface expression of fault offset. A probabilistic assessment of this ground failure mode may be necessary if potential fault rupture may occur near a facility. If the annual probability of this ground failure mode is greater than the necessary performance goal, either the site should be avoided, mitigation measures taken, or an evaluation performed of the effects of fault offset.

3.1.5 Historical Earthquake Ground Motion Check

a. In assessing the DBE, the review will consider historical earthquakes that may have affected the site and ensure that the DBE is conservative relative to the historical earthquake. This is not meant to be a comparison to the "maximum credible" earthquake nor should it include infrequent paleoseismic events as part of the historical data set.

approaches used to derive the spectral shapes as discussed in Section A3.1.3.1.e. For PC-4 facilities, the DBE spectra shall be equal to or greater than the 84th percentile estimate. For PC-3 facilities, the DBE spectra should be equal to or greater than the median estimate. In general, the difference between the median and 84th percentile is about a factor of 1.7 to 2 in ground motion, which approximates the ground motion difference between PC-3 and PC-4 hazard probabilities coupled with typical hazard curve slopes.

1. For sites having no site-specific probabilistic wind hazard assessment, it is sufficient to utilize model building codes, such as ICBO (1991), or national consensus standards, such as ASCE (1993), to define the basic wind speed.

2. For sites which have site-specific probabilistic wind hazard assessment, the SSCs in Performance Category 1 or 2 shall be evaluated for the greater of the site-specific values or the model code values unless lower site-specific values can be justified and approved by DOE.

f. For sites containing facilities with SSCs in Performance Category 3 or 4, a site-specific probabilistic wind hazard assessment is conducted to establish the wind speed for design and/or evaluation of the facilities.

3.2.2 Criteria for Site-Specific Probabilistic Wind Hazard Assessment

a. For facilities with SSCs in Performance Category 3 or 4, a site-specific probabilistic wind hazard assessment is conducted to establish the wind speed.

b. The results of the probabilistic wind hazard assessment includes a mean wind hazard curve and other information regarding the uncertainty in the hazard assessment. The wind hazard curve represents the annual probability of exceedance as a function of wind speed at the site.

c. There are three types of winds : extreme (straight) wind, hurricane, and tornado. Extreme (straight) winds are non-rotating such as those found in a thunderstorm gust front. Tornadoes and hurricanes both are rotating winds. The potential for all three types of winds shall be determined in the site wind hazard assessment.

d. For practical purposes, the effects of hurricanes are treated the same as those of straight winds in accordance with DOE-STD-1020-94. As a result, both hurricane winds and straight winds will be represented by a single straight wind hazard curve although different wind hazard models are used for straight winds and hurricanes.

e. The site-specific probabilistic wind hazard assessment *is characterized* by the following traits:

3.3 Detailed Requirements for Flood Hazard Assessment

3.3.1 General

a. Design and evaluation criteria for Department of Energy facilities against flood hazards are provided by DOE-STD-1020-94 (USDOE, 1994b). In accordance with DOE-STD-1020-94, a Design Basis Flood (DBFL) shall be established in order to carry out the design/evaluation process. The DBFL is a flood level determined from the mean flood hazard curve and the hazard annual probability of exceedance specified in DOE-STD-1020-94. A probabilistic flood hazard assessment is required to develop the flood hazard curve at the site.

b. In accordance with Section 3.c, for sites containing facilities with SSCs in Performance Category 3 or 4, a site-specific probabilistic flood hazard assessment is required. A site-specific probabilistic flood hazard assessment at a site shall involve the following two steps:

   Step 1: Perform a flood screening analysis to evaluate the magnitude of flood hazards that may impact the SSCs under consideration. Specific criteria for a flood screening analysis are provided in Section 3.3.2 of this Standard.

   Step 2: Perform a comprehensive flood hazard assessment, if needed, based on the results of the flood screening evaluation. Specific criteria for a comprehensive flood hazard assessment are provided in Section 3.3.3 of this Standard.

c. In accordance with Section 3.a, for sites containing facilities with SSCs in only Performance Category 1 and 2 and having no existing site-specific probabilistic flood hazard assessment, it is sufficient to utilize flood insurance studies or equivalent to estimate the DBFL.

d. However, for sites containing facilities with SSCs in Performance Category 2, a reduced-scope flood hazard assessment is generally required because most flood insurance studies available have not been conducted at a level which is compatible with the hazard annual probability of exceedance (5×10^{-4}) associated with flooding so that safety from flooding is obvious and can be documented with minimal effort.

b. In the case of flood-dry sites, the flood screening analysis will conclude that flooding is not a design basis event.

c. In the case of non flood-dry sites, the flood screening analysis will provide a preliminary measure of the magnitude and probability of occurrence of extreme floods.

d. The flood screening analysis includes the following three steps:

Step 1: Identification of the sources of flooding.

Step 2: Evaluation of flooding potential.

Step 3: Preliminary flood hazard analysis.

e. Examples of acceptable previous flood screening analyses for 10 DOE sites are presented in McCann and Boissonnade (1988a, 1988b, and 1991) and summarized in Savy and Murray (1988). The elements comprising a flood screening analysis are further described in Appendix A.

3.3.3 Comprehensive Flood Hazard Assessment

a. Results of the flood screening analysis determine whether floods could impact DOE operations. For sites that could be exposed to flooding and do not meet the design basis, a comprehensive flood hazard analysis is required. The need to perform a site comprehensive hazard assessment depends on the potential DBFL impact on the facilities for the flood hazard exceedance probabilities. Guidelines to evaluate these impacts are provided in DOE-STD-1020-94. These guidelines recommend the design basis for DOE facilities based on the following factors:

(1) Types of potential flood hazard

(2) Performance category

d. A full scope probabilistic approach to model river flooding shall include temporal and spatial frequency estimates of the random meteorological parameters that contribute to precipitation and runoff and an estimate of the modeling uncertainty of the watersheds (NRC, 1988).

e. Three of the acceptable approaches are available to evaluate the frequency of extreme flows and/or levels due to hydrologic events (NRC, 1988) and (IACWD, 1986) are:

(1) statistical methods

(2) probabilistic hydrologic modeling (including, Bayesian analysis, joint probability methods, etc.)

(3) paleohydrologic analysis (i.e., evaluating ancient evidence using age dating techniques to deduce early extreme hydrologic events).

f. The causes of dam failure to be evaluated include: hydrologic, seismic, hydrostatic, operation error, random structural failure, upstream dams, and landslides (McCann and Boissonnade, 1988b).

g. Dam failure-induced flood levels shall be determined by analyses using validated dam break models (Fread, 1984). Uncertainty for the dam break model analysis parameters (e.g., breach size, time to failure, flood time arrival) shall be accounted for in the analysis (McCann and Boissonnade, 1988b).

h. Simplified dam failure analysis is acceptable (McCann, et al., 1985b) if the analysis accounts for uncertainty.

3.3.4 Flood Event Combinations

a. For each primary potential flood source the DBFL shall consider several event combination cases as specified below:

(1) River Flooding: Case 1: Peak flood elevation due to all flooding contributors with the exception of upstream dam failure.

DBFL conservatively accounts for a recurrence of the event causing the flooding. Since the hydraulic characteristics of the basin might have changed since the maximum historical flood, the flood level itself may not be able to form a direct comparison to the DBFL. Rather, the amount of water produced, or the rainfall intensity and distribution, should be compared to the event leading to the DBFL. For PC-3 and PC-4 facilities, the DBFL event should be equal to or greater than the maximum historical event in the basin.

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6. DEFINITIONS

Annual Flood The maximum instantaneous peak discharge or level of flood in each year of record.

Atmospheric Pressure Change (APC) A wind hazard design parameter consisting of a reduction in atmospheric pressure generated by a tornado.

Backwater Effect The rise in water surface elevation in an area caused by an obstruction which limits the water flow from the area.

Basic Wind Speed The wind hazard design parameter used to determine wind pressure on buildings or other facilities.

Basin, Watershed The total area from which surface runoff is carried away by a drainage system.

Deaggregate Determine the fractional contribution of each magnitude-distance pair to the total seismic hazard. To accomplish this, a set of magnitude and distance bins are selected and the annual probability of exceeding selected ground acceleration parameters from each magnitude-distance pair is computed and divided by the total probability.

Design Basis Flood (DBFL) The peak flood level derived from the mean flood hazard curve in accordance with the annual probability of hazard exceedance associated with the SSC. The DBFL is used to design or evaluate SSCs of DOE facilities subjected to flood hazards.

Design/Evaluation Basis Earthquake (DBE) A specification of the mean seismic ground motion at a site; used for the earthquake-resistant design of structures, systems, and components. The DBE is defined by ground motion parameters determined from mean seismic hazard curves and a design response spectrum shape.

Design Basis NPH Event The NPH event used as a basis for the design and/or evaluation of SSCs at DOE facilities. The design/evaluation basis NPH event is called

(3) The life cycle stage of the facility;

(4) The programmatic mission of a facility;

(5) The particular characteristics of the SSCs; and

(6) The cost and replaceability of the SSCs.

Hydrodynamic Loads Dynamic fluid forces imposed on structures by the impact of moving fluid, including flood water.

Hydrostatic Loads Static fluid forces imposed on structures due to the pressure of contained and surrounding fluids, including flood water.

Model Building Codes Published documents that contain design and construction requirements applicable to normal commercial buildings. Examples are 1994 ICBO Uniform Building Code (UBC), the BOCA National Code and 1992 Supplement, SBCC Standard Building Code, 1994.

Natural Phenomena Hazard (NPH) An act of nature (for example: earthquake, wind, hurricane, tornado, flood, volcanic eruption, lightning strike, forest fire, snow, or extreme cold) which poses a threat or danger to workers, the public, or to the environment by potential damage to structures, systems, and components (SSCs).

Natural Phenomena Hazard Curve A frequency plot that characterizes the likelihood of occurrence of a natural phenomena hazard at a specific site by giving the return period or annual probability of exceedance as a function of a parameter used to characterize the level of the natural phenomena hazard. The mean NPH curve is used to determine the design basis NPH event.

Near-Field A region within 15 km (9.3 mi) of a seismic source.

NPH Mitigation An action taken to reduce the impacts of natural phenomena hazards (to become less harsh or hostile to workers, the public, facilities, and the environment). This includes NPH resistant design, evaluation, construction requirements, and operational procedures.

Probability of Exceedance The probability that a specified level of hazard occurrences or specified social or economic consequences of NPHs, will be exceeded at a site or in a region during a specified exposure time.

Response Spectrum A curve calculated from an earthquake accelerogram that gives the value of peak response in terms of acceleration, velocity, or displacement of a damped linear oscillator (with a given damping ratio) as a function of its period (or frequency) of vibration. For design purposes, a set of response spectra are usually generated for different damping ratios.

Seiche A cyclic oscillation or sloshing of a lake or large body of water due to the effect of winds, seismic forces, and/or atmospheric pressure.

Seismic Hazard One form of natural phenomena hazards caused by earthquakes. The primary effect of the seismic hazard is earthquake ground shaking. Other effects associated with the seismic hazard include differential ground deformation induced by fault displacement, liquefaction, and seismic induced slope instability and ground settlement.

Seismic Hazard Curve (SHC) A frequency plot that characterizes the seismic hazard at a specific site by giving the return period or annual probability of exceedance as a function of the peak ground acceleration (PGA) or any other ground motion parameter, e.g., PGV, PGD, or average spectral acceleration, used to characterize the level of earthquake ground motion at the site. The mean seismic hazard curve is used to determine the DBE.

Seismic Sources Portions of the earth that have a potential for abrupt releases of energy in the earth's crust (lithosphere), or to cause earthquakes. Seismic sources may include a region of diffuse seismicity (seismotectonic province) and/or a well-defined tectonic structure which can generate both earthquakes and ground deformation.

Site The area with one or more DOE facilities or activities that can be represented by the same natural phenomena hazard potential with local conditions that can be represented by the same parameters.

Stage Elevation above some arbitrary zero datum of the water surface at a gauging station.

7. ACRONYMS

ASCE-	American Society of Civil Engineers
APC -	Atmospheric Pressure Change
ATC -	Applied Technology Council
BOCA -	Building Officials and Code Administrators (International)
BSSC -	Building Seismic Safety Council
DBE -	Design/Evaluation Basis Earthquake
DBFL -	Design Basis Flood
DOE -	Department of Energy
EPRI -	Electric Power Research Institute
FEMA -	Federal Emergency Management Agency
HEC -	Hydrologic Engineering Center
IACWD -	Interagency Advisory Committee on Water Data
ICBO -	International Conference of Building Officials
LLNL -	Lawrence Livermore National Laboratory
NEHRP -	National Earthquake Hazards Reduction Program
NPH -	Natural Phenomena Hazard
NRC -	National Research Council, also Nuclear Regulatory Commission (Referenced as USNRC)
PC -	Performance Category
PGA -	Peak Ground Acceleration
PGD -	Peak Ground Displacement
PGV -	Peak Ground Velocity
PSHA -	Probabilistic Seismic Hazard Assessment
PSV -	Pseudo (response) Spectra Velocity
SBCCI -	Southern Building Code Congress International
SHC -	Seismic Hazard Curve
SSCs -	Structures, Systems, and Components
SSHAC -	Senior Seismic Hazard Analysis Committee
UBC -	Uniform Building Code
UHS -	Uniform Hazard (response) Spectra

Then, for the Eastern U. S. (non-plate boundary sites):

$$\frac{a_2}{a_1} = (4)^{\log 2} \approx 1.5$$

and for western U. S. (plate boundary sites):

$$\frac{a_2}{a_1} = (2)^{\log 2} \approx 1.25$$

A3.1.2 Development of Site-Specific Seismic Hazard Curves

A.3.1.2.1 Development of Seismic Hazard Curves Based on Existing PSHA

a. When the mean hazard curves from EPRI (1989a) and LLNL (Savy, et al., 1993 and Sobel, 1994) are directly averaged, the average should be based on averaging the mean annual probabilities at a given peak acceleration or spectral acceleration, completing the average at enough ground motion values to draw the entire hazard curve.

A3.1.2.2 Development of Seismic Hazard Curves Based on New Site-Specific PSHA

c. The following elements shall be included in the methodology to conduct a new PSHA:

(1) Basic Hazard Model - Section A3.1.2.2.1 provides further discussion of this element.

(2) Data Used in the Hazard Modeling - Data used in the hazard modeling exist in various degrees of quantity and quality. Section A3.1.2.2.2 provides further discussion of this element.

(3) Characterization of Uncertainty in Parameters of the Hazard Model - Section A3.1.2.2.3 provides further discussion of this element.

area or a fault (such as for western U. S. Sites) as shown in Fig. 3.1

Step 2: The recurrence (frequency-magnitude distribution) is defined for each zone. This step quantifies the total number of earthquakes greater than magnitude M_0 expected to occur during the period of interest (usually one year), and it describes the relative frequency of all the magnitudes greater than M_0. An upper bound (maximum) magnitude is defined for each recurrence distribution.

Step 3: The ground motion model provides the probability that g is exceeded at the site (at a hypothetical rock outcrop) when an earthquake of magnitude m has occurred at a given location. Usually, the direction of the origin of the earthquake is neglected and only the distance r to the site is considered in the ground motion modeling:

$$P\ (G \geq g, \text{ for given m and r}).$$

The measure of the source-to-site distance may vary depending upon the procedure used to estimate earthquake attenuation effects.

For a site where the ground motion model is not specifically applicable to the local geology, a site response evaluation should be completed. The site response evaluation should consider field investigations, sampling, and testing as described in DOE-STD-1022-94.

Depending on the PSHA methods, the site correction can be applied on the ground motion model (Bernreuter et al., 1989, and Savy, 1993) or on the resulting hazard curves (EPRI, 1989a) defined at rock outcrop.

recurrence rates several times higher than the empirical data) should be explained. All models and information provided should be thoroughly documented so that an independent party could review the study and understand the manner in which the data have been used to support the seismic hazard interpretations.

A3.1.2.2.3 Uncertainty in Hazard

a. Probabilistic seismic hazard analysis, as represented by the basic elements shown in Figure 3.1 and summarized in the seismic hazard curve, incorporates the random variability in the location, size, and ground motions associated with future earthquakes. In addition to this random variability, there is also a component of uncertainty related to lack of knowledge of the models and parameters that characterize the seismic hazard. For example, alternative seismic source maps could be developed, uncertainties in recurrence parameters can be quantified, and alternative ground motion attenuation relationships can be identified. These uncertainties result in a distribution of seismic hazard curves, from which the median (50th percentile) or mean seismic hazard curve may be selected. The mean seismic hazard curve is usually quite sensitive to uncertainties and, therefore, full inclusion of uncertainties in the seismic hazard analysis is necessary.

b. Two equally-permissible approaches can be used to quantify and propagate uncertainties in models and parameter values: the logic tree approach (e.g., EPRI, 1989a) and the Monte Carlo simulation approach (e.g., Bernreuter et al., 1989). In the logic tree approach, alternative models and alternative parameter values are identified and a relative weight is assigned to each alternative that expresses the relative credibility of that alternative in light of the available data. Elements of the logic tree are sequenced to provide for a logical progression in the assessment from general elements to more specific elements. In the simulation approach, uncertainties in inputs are characterized by continuous distributions, and multiple simulations are run to sample from the distributions. Both approaches have common application in seismic hazard analysis and lead to reliable estimates of mean hazard.

c. A second approach to quantifying uncertainties consists of a single analyst or contractor (such as a consulting company) conducting a seismic hazard analysis and subjecting the study to peer review by an independent panel of experts. The peer review should include review of the process as well as the inputs. The hazard analyst should strive to incorporate the range of scientific interpretations and the peer reviewers should ensure that all reasonable interpretations have been considered. Multiple cycles of peer review, focusing on particular components of the analysis, are often needed to allow for modification and updating of the inputs. The peer review approach has been applied at many DOE sites for seismic hazard analysis. Examples of this process can be found in Woodward-Clyde Consultants (1992) and Geomatrix Consultants (1990, 1991).

d. An important aspect of uncertainty characterization is documentation. Regardless of whether the expert elicitation or the peer review procedure is used, the technical basis for all assessments must be documented in a form suitable for third party review. For example, a seismic source map must be supported by a written description of the basis for the source boundaries in terms of evaluations of geologic, geophysical, and seismicity data. Likewise, the basis for alternative source maps must be documented. One purpose of the documentation is to provide a mechanism to examine the impact that new data and interpretations may have on the interpretations as new studies are conducted or new findings are made. For example, a potentially important consideration might be the occurrence of a moderate to large earthquake in the region of a site after the seismic hazard analysis has been completed. The location of the event and its magnitude can be compared with the sources considered in the analysis and the magnitude of earthquakes that were modeled for the source. Likewise, the level of recorded ground motions for the event can be compared with the levels predicted in the seismic hazard analysis. For additional guidance on the content and amount of documentation to support PSHAs, the SSHAC document should be consulted.

Step 2: Using the appropriate annual probability of exceedance value, P_H (e.g., 1×10^{-4} for Performance Category 4), enter the hazard curve from Step 1 at P_H to determine the corresponding S_A.

Step 3: Deaggregate the mean S_A seismic hazard curve as a function of magnitude and distance and calculate the contribution to this hazard curve for all of the earthquakes in a selected earthquake magnitude and distance set (size M x N) to determine the relative contribution to the hazard. This requires the calculation of the annual probability of exceedance, $H(m_i,r_j)$, for each magnitude/distance bin: magnitude m_i ($i = 1,2,..,M$) and distance r_j, ($j = 1,2,...,N$).

Step 4: Compute the magnitude of the controlling earthquake for the mean estimates of $S_{A\,(5\text{-}10)}$ using the contributions $H(m_i, r_j)$ computed in Step 3 in accordance with the following (or similar) equation:

$$M(1) = \sum_{i=1}^{M} \sum_{j=1}^{N} m_i H(m_i,r_j) \Big/ \sum_{i=1}^{M} \sum_{j=1}^{N} H(m_i,r_j)$$

The distance of the controlling earthquake from the site is next determined from the following (or similar) equation:

$$\log R(1) = \sum_{i=1}^{M} \sum_{j=1}^{N} \log(r_j)\, H(m_i, r_j) \Big/ \sum_{i=1}^{M} \sum_{j=1}^{N} H(m_i, r_j)$$

Step 5: Select, from the site-specific PSHA results, the mean seismic hazard curve for the ground motion parameter $S_{A(1\text{-}2.5)}$, i.e., the average spectral acceleration at 1 and 2.5 Hertz, and use the same P_H and Step 1 through 4 as above to determine the magnitude m(2) and distance r(2) that control the $S_{A(1\text{-}2.5)}$.

frequencies as a function of magnitude, distance, and site soil profile. Methodologies used to develop relationships such as those described by Joyner and Boore (1981), Sadigh (1983), Nuttli and Herrmann (1987), Campbell (1985), Joyner and Boore (1988), Bernreuter, et al. (1989), EPRI (1993), Boore, et al. (1993), and Atkinson (1993) are acceptable. However, recent data shall be used when available.

(3) Numerical modeling

The median response spectrum shape is calculated from numerical models such as band-width-limited-white-noise/random vibration theory models benchmarked against response spectra from actual ground motion records associated with magnitudes, distances, and soil profiles as similar to those of the site under study. For this method, the input parameters, the numerical model used, and the validation of the appropriateness of the model shall be documented.

A3.1.3.2 Standardized DBE Response Spectra

a. As an example, the procedure for constructing a standardized DBE response spectrum based on Newmark and Hall (1978) (using the authors' original units) is summarized below:

(1) Determine the horizontal ground motion parameters: PGA, PGV, and PGD.

a. Obtain the design basis mean peak ground acceleration (PGA) in units of "g" based on a site specific probabilistic seismic hazard assessment.

b. For a competent alluvium site with V_S (shear wave velocity) < 3500 ft/sec, determine the peak ground velocity (PGV) in "in/sec" and peak ground displacement (PGD) in "in" by the following formulas:

$$PGV = 48\ PGA$$
$$PGD = 36\ PGA$$

A3.2 Detailed Criteria for Wind Hazard Assessment

A3.2.2 Criteria for Site-Specific Probabilistic Wind Hazard Assessment

A3.2.2.1 Straight Wind Probabilistic Hazard Assessment

a. An acceptable method to estimate the annual probability that specified wind speeds at the site will be exceeded is included in Coats and Murray, 1985, and described by the following:

Step 1: Select a data set of annual extreme wind speeds from a weather station near the site of interest.

Step 2: Correct the annual extreme wind speeds to an anemometer height of 33 ft (10 meters) above ground in flat, open terrain using appropriate methodologies. For example, a power law (Simiu and Scanlan, 1986) could be used to make an adjustment, if needed. No recorded wind speeds from anemometers located on building roofs near the edges, sheltered by parapets or neighboring buildings, or too close to the roof surface (less than 5 feet (1.5 meters)) shall be used.

Step 3: Estimate the annual probability of exceedance of selected windspeeds with associated uncertainty.

b. Data sets of historical extreme winds shall be obtained from weather stations close enough to sites to represent the site conditions as described in DOE-STD-1022. If more than one station is available, they may be combined, provided they represent the same conditions as those at the site.

c. Several statistical models may be used to estimate frequency of winds. An estimate of the models fitting the data shall be performed. If only one statistical model is to be used, the Fisher-Tippet Type I *extreme value* distribution (also named Gumbel distribution) (Coats and Murray, 1985)

c. A preliminary hurricane wind hazard analysis may be performed to assess the magnitude of hurricane wind speeds by using reported results of hurricane hazard analyses such as those in Batts, et al., (1980).

A3.2.2.3 Tornado Wind Probabilistic Hazard Assessment

a. A tornado hazard analysis consists of the following steps:

Step 1: Compile, obtain, and update as necessary a data set of tornadoes for the area.

Step 2: Develop occurrence-intensity relationship.

Step 3: Develop area-intensity relationship.

Step 4: Calculate probability of a point experiencing tornado intensity.

Step 5: Calculate probability of tornado wind speeds exceeding specified values.

b. The tornado hazard model described in Coats and Murray (1985) is acceptable for use in conducting a site tornado probabilistic hazard analysis. Additional data may be found in Ramsdell and Andrews (1986).

A3. 3 Detailed Requirements for Flood Hazard Assessment

A3.3.2 Flood Screening Analysis

A3.3.2.1 Identification of potential Sources of Flooding

a. The following hydrologic events which are potential sources of flooding shall be included in the flood hazard analysis:

(1) River flooding

(2) Levee or dam failure

(3) Flood runoff/drainage

A3.3.2.3 Preliminary Flood Hazard Analysis

a. A preliminary flood hazard analysis is performed for all sources of flooding identified as having potential impacts on the site. This analysis shall provide a measure of the magnitude and probability of occurrence of extreme events. This analysis does not need to be comprehensive and can be based on existing studies. For example, it is sufficient to use flood insurance studies or equivalent, that estimate flood probability to $2x10^{-3}$ to measure the magnitude and probability of occurrence of river flooding, and extend these results to a lower probability value (10^{-5} to 10^{-3}) (Kite, 1988). Furthermore, the results of any available existing flood frequency analyses should be compared to the results of a preliminary flood hazard analysis.

b. A preliminary flood hazard analysis provides estimates of the probability of floods and an assessment of the uncertainty in the hazard estimate. Rivers or streams are the most common sources of flooding. For this type of flooding, a simplified acceptable method to estimate the probability that specified elevations at the DOE sites will be exceeded consists of the following steps (McCann and Boissonnade, 1988a):

Step 1: Compile, obtain and update a data base of peak discharge as described in DOE-STD-1022.

Step 2: Estimate the probability of exceedance of selected peak discharge levels with associated uncertainty.

An acceptable methodology using streamflow data, and including uncertainty estimates due to the statistical model selected and limited flood data is provided by McCann and Boissonnade, (1986).

Step 3: Determine the stage-discharge relationship (a relationship between flow discharge and flood stage).