

**Site Characterization Criteria (DOE-STD-1022-94)
for Natural Phenomena Hazards at DOE Sites**

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SITE CHARACTERIZATION CRITERIA (DOE-STD-1022-94) FOR NATURAL PHENOMENA HAZARDS AT DOE SITES

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ABSTRACT

This paper briefly summarizes requirements of site characterization for Natural Phenomena Hazards (NPH) at DOE sites. In order to comply with DOE Order 5480.28, site characterization criteria has been developed to provide site-specific information needed for development of NPH assessment criteria. Appropriate approaches are outlined to ensure that the current state-of-the-art methodologies and procedures are used in the site characterization. General and detailed site characterization requirements are provided in the areas of meteorology, hydrology, geology, seismology and geotechnical studies.

INTRODUCTION

The Department of Energy (DOE) has established policy and requirements for natural phenomena hazard (NPH) mitigation for DOE sites and facilities using a graded approach by DOE Order 5480.28 (USDOE, 1993a). The NPH requirements have been developed to provide the necessary information that assess the NPH safety basis for DOE facilities, which is documented in Safety Analysis Reports (SAR). The overall approach for NPH mitigation is consistent with the graded approach embodied in the SAR. The selection of structure, systems and components (SSCs) which require NPH design is based on the potential hazard from the facility quantified as necessary through accident analysis. Once the SSCs have been assessed, DOE Order 5480.28 specifies the NPH requirements to ensure that the SSCs are adequately designed to resist NPH.

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NPH performance categories are specified in DOE-STD-1021-93 (USDOE, 1993b) using overall facility hazard classification. The guidance for the preparations of facility hazard classification and accident analyses techniques is established in DOE-STD-1027-92 (USDOE, 1992). NPH site characterization criteria are provided in this standard, DOE-STD-1022-94 (USDOE, 1993c).

The purpose of this standard is to provide criteria to collect the site-specific information needed for implementing DOE 5480.28 requirements. Additionally, the purpose of this standard is also to develop a sitewide database related to NPH that should be obtained to support individual safety analysis reports (SARs). Appropriate approaches are outlined to ensure that the current state-of-the-art methodology is being used in the site characterization.

The requirements are given in two categories: general requirements which apply to all NPHs, and detailed requirements which specify criteria for a specific NPH.

GENERAL REQUIREMENTS

The meteorologic, hydrologic, geologic, seismological and geotechnical characteristics of a site and its environs shall be investigated in sufficient scope and detail to provide reasonable assurance that they are sufficiently well understood to permit an adequate evaluation of the proposed or existing site, and to provide sufficient information to support the evaluations required by other DOE standards for implementation of NPH mitigation requirements specified in DOE 5480.28. The size of the region to be investigated and the type of data pertinent to the investigations shall be determined by the nature of the region surrounding the proposed or existing site, and shall be consistent with the performance category of the facilities.

For sites containing facilities with SSCs in only Performance Category 1 or 2, at a minimum, sufficient site information shall be collected so that the NPH assessment, DOE-STD-1023-94 (USDOE, 1994b), and the design and evaluation of the facilities, DOE-STD-1020-94 (USDOE, 1994a) can be conducted by following the procedures provided in model building codes or national consensus standards (e.g., hazard zone maps, site coefficients, etc.).

For sites containing facilities with SSCs in Performance Category 3 or 4, more extensive site characterization shall be carried out to obtain the site information for the site-specific natural phenomena hazard assessment, and design and evaluation of DOE facilities in accordance with DOE-STD-1023-94 and DOE-STD-1020-94, respectively.

DOE sites are encouraged to develop a sitewise NPH database that can be referenced by facility specific SARs. Such an approach would minimize the amount of written material that would be required in individual SARs.

DETAILED REQUIREMENTS

Criteria are presented in this standard for meteorological, hydrological, geological, seismological, and geotechnical studies to characterize the site and to assess natural phenomena hazards. The scope and degree of detail of investigations to address these natural phenomena hazards depend on several factors, which include: the performance categories of the SSCs comprising the facilities; the subsurface conditions at the site; the meteorology, hydrology, and seismotectonic environment of the site region; and the extent of prior knowledge, investigations, and data regarding the site and site region. Although more detailed investigations are generally appropriate for facilities having higher performance categories, it should be kept in mind that investigations of lesser scope and detail may be appropriate when the existing knowledge of the site and region is extensive and up-to-date. Similarly, although less detailed investigations would generally be commensurate with lower performance categories, more comprehensive investigations may be needed if a critical site hazard exists and/or if investigations to define the hazards have not previously been conducted. The detailed requirements specified here are applicable for obtaining the site information which is needed for implementation of DOE NPH requirements.

Meteorology

The sources of meteorological hazards include winds (straight, hurricane, and tornado winds), precipitations and temperature changes. Meteorological data to be collected includes : (1) wind speeds and direction, (2) precipitation and snowfall records, and (3) air temperature. The extent of meteorological data needed to be collected is dependent upon the performance categories of facility SSCs.

For sites containing facilities with SSCs in Performance Category 1 or 2, it is sufficient to utilize

results of previous probabilistic wind hazard studies, if available, or to utilize information provided in model building codes or national consensus standard such as ANSI/ASCE 7-88 (ASCE, 1988) (currently updated to ANSI/ASCE 7-93). For sites containing facilities with SSCs in Performance Category 3 or 4, and for which no up-to-date site-specific probabilistic wind hazard studies have been performed in accordance with specifications in DOE-STD-1023-94, site-specific characterization criteria are provided in this standard.

Hydrology

The sources of hydrologic hazard include stream flooding, flood runoff, flood drainage, dam failure, levee or dike failure, storm surge, tsunami, seiche, wave action, volcano-induced hydrologic effects (e.g., rapid snow pack melting, mudflows to cause dam failure and excessive siltation/sedimentation), and ground water rise or decline. Collection of the characteristic data of these sources which could impact the site shall be performed. The impact of these hydrologic hazards shall be defined with respect to their proximity of the site and its elevation.

The extent of the data to characterize potential sources of flooding is dependent upon the performance categories of the structures. For sites containing facilities with SSCs in Performance Category 1 or 2, it is sufficient to utilize results of previous site-specific probabilistic flood hazard studies (e.g., McCann and Boissonnade, 1988a, 1988b, 1991, and Savy and Murray, 1988), if available, or to utilize information provided in the flood insurance studies by Federal Emergency Management Administration (FEMA) and any other reliable hydrology resource, such as U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, U.S. Geological Survey, Flood Insurance Administration, Department of Water Resources, Agricultural Department, National Weather Service, and universities.

For sites containing facilities with SSCs in Performance Category 3 or 4, and for which no site-specific probabilistic flood hazard studies have been performed in accordance with specifications in DOE-STD-1023-92, site-specific characterization criteria are provided in this standard, Section 5.3.

Requirements are given in details for considering hydrological data collection; flood history; river flooding; dam, levee, or dike failure; storm surge; tsunami; seiche; wave action; landslide and volcano created natural hydrological consequences; flood runoff/drainage; and ground water hydrology.

Geology and Seismology

The seismic-related hazards include site earthquake ground shaking, tectonic site deformation (fault rupture and associated tectonic surface deformation), ground failure induced by ground shaking including liquefaction, differential compaction and land sliding, and earthquake-induced flooding. Other geological hazards to be addressed

include non-tectonic site deformation and volcanic hazards.

The extent of the investigation to characterize the seismic-related hazards is dependent upon the performance categories of the structures, the geological and seismologic environment of the site region, and the local soil conditions at the site. Geologists, seismologists, geophysicists, and geotechnical engineers with the knowledge and experience of fulfilling the requirements stated in the Federal Regulations and Standards, e.g., 10 CFR 100 Appendix A (CFR, 1994) (Appendix A is to be deleted, and 10 CFR 50 and 10 CFR 52 are to be included as the requirements), NRC DG-1015 (USNRC, 1992) (currently revised as NRC DG-1032 (USNRC, 1994)), DOE 6430.1A (USDOE, 1989), DOE 5480.28, etc., for site characterization for DOE facilities should be consulted for defining the program of the investigation. Site experts who are knowledgeable of geological, seismological, and geotechnical aspect of site characterizations should also be consulted.

For sites containing facilities with SSCs only in Performance Category 1 or 2, it is sufficient to utilize results of previous site-specific probabilistic seismic hazard studies, if available, or to utilize information provided in the model building codes or national consensus standards (e.g., seismic zone maps). For sites containing facilities with SSCs in Performance Category 3 or 4, and for which no site-specific probabilistic seismic hazard studies have been performed in accordance with DOE-STD-1023-94, site-specific characterization criteria are provided in this standard.

Seismic Sources. Seismic sources define areas where future earthquakes are likely to occur. All seismic sources in the site region that could cause significant ground shaking at the site shall be identified and characterized. Seismic sources may include seismogenic sources and capable tectonic sources. A seismogenic source is a portion of the earth which is considered to have uniform seismicity. A seismogenic source may be a well-defined tectonic structure or simply a large region of diffuse seismicity. A seismogenic source would not cause surface displacement. A capable tectonic source is a tectonic structure which can generate both earthquakes and ground deformation. Geological, geophysical and seismological investigations provide the information needed to identify and characterize source parameters, including the location, size, and geometry of the seismic sources, maximum earthquake, and frequency of occurrence of earthquakes of various magnitudes (earthquake recurrence). U.S. NRC Regulatory Guide DG-1015 (currently revised as NRC DG-1032) and U.S. NRC NUREG-1451 (McConnell, et al., 1992) also provide guidance for identification of the region to be investigated.

The items shall be considered in collecting data for seismic source identification are: (1) area of investigations, (2) type of investigations, (3) source zones, (4) active faults, (5) source-to-site distance. The details of these

items are provided in Section 5.4.1.1 of this standard. The details of seismic source characterization, and surface-fault rupture and associated deformation are provided in Sections 5.4.1.2 and 5.4.1.3, respectively.

Vibratory Ground Motions. In general, the factors that influence site ground motions include the characteristics of the earthquake source, the travel path between the source and the site, and the local site conditions. Assessment of the influence of local soil conditions is described in Section 5.5.2. The attenuation effect of the geological materials in the travel path (e.g., Q factor) shall be estimated by regional seismology studies or based on the strong ground motion data, if a sufficient data base is available. The effect of local geology and rock conditions on the ground motions shall also be considered. With respect to the first two factors (i.e., earthquake source and travel path), it is suggested that one or both of these factors can result in significant differences in earthquake ground motions in three broad tectonic regimes in the United States—the Central and Eastern U.S. (EUS), Western U.S. (WUS), and areas in the vicinity of subduction zones. Precise geographic limits for the regions are not defined, but the WUS and EUS are generally west and east, respectively of the Rocky Mountains, while subduction zone earthquakes in the United States occur only along coastal northwest California, Oregon, Washington, and southern Alaska. Based on recent ground motion study by Electric Power Research Institute (1993), the EUS area can be further subdivided into the Mid-continent and the Gulf Coast regions. Different attenuation relationships would thus be appropriate for each region. Thus, care must be taken and uncertainties must be recognized in utilizing data bases, relationships, and methodologies applicable to each region.

Earthquake-induced Flooding. Earthquake-induced flooding at a site can be caused by a variety of phenomena including seiches, tsunamis, failures of dams and levees, landsliding within or into bodies of water, and tectonic uplift or subsidence. Criteria of site characterization for these hazards are specified in this standard.

Other Geologic Hazards. Other geologic hazards that should be the subject of appropriate geological investigations include volcanic hazards and non-tectonic surface deformation.

Geotechnical Studies

Geotechnical studies may include investigations for: (1) defining site soil properties as may be required for hazard evaluations, and engineering analyses and designs; (2) assessing local soil site effects on ground motions; (3) carrying out soil-structure interaction analyses; and (4) assessing potential of soil failure or deformation induced

by ground shaking (liquefaction, differential compaction, land sliding, etc.).

The extent of investigation to determine the geotechnical characteristics of a site depends on the performance categories of the facilities, the subsurface conditions, and the extent of available information. General requirements for site investigations and foundation design criteria can be found in DOE Order 6430.1A. For facilities with SSCs in Performance Category 4, the geotechnical studies shall include, at a minimum, the investigations specified in this standard. Reduced scope of investigation is allowed for sites containing facilities with SSCs in Performance Category 3 or lower, if the additional uncertainties resulting from the less extensive investigation are acceptable and justified based on analyses by the project team. By working with experienced geotechnical engineers and geologists, an appropriate scope of investigations can be developed for a particular facility.

Requirements are given in details for 1. site investigations, including subsurface exploration and laboratory tests, 2. site response analysis, 3. soil-structure interaction analysis, 4. ground failure evaluations, including seismic liquefaction of soils, subsidence, and slope instability.

SUMMARY

The DOE standard, DOE-STD-1022-94, has been prepared and issued for compliance with DOE Order 5480.28 for natural phenomena hazard mitigation at DOE sites. This standard provides criteria for site characterization and specifies the data needed for NPH assessment. The development of the standard is based on the state-of-the-art methodologies and procedures as well as the most recent available information and data. The standard have been reviewed by DOE community.

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REFERENCES

American Society of Civil Engineers, 1988, "Minimum Design Loads for Buildings and Other Structures," ANSI/ASCE 7-88; currently updated to ANSI/ASCE 7-93; ANSI approved May 1994.

Code of Federal Regulations (CFR), 1994, Title 10, Part

100, Appendix A, "Criteria for the Seismic and Geologic Siting of Nuclear Power Plants."

Electric Power Research Institute (EPRI), 1993, "Guidelines for Determining Design Basis Ground Motions, Vol. 1: Method and Guidelines for Estimating Earthquake Ground Motion in Eastern North America," EPRI TR-102293, Final Report.

McCann, M. W. and A. C. Boissonnade, 1988a, "Preliminary Flood Hazard Estimates for Screening Department of Energy Sites," UCRL-21045, Lawrence Livermore National Laboratory, Livermore, CA.

McCann, M. W. and A. C. Boissonnade, 1988b "Probabilistic Flood Hazard Assessment for the N Reactor, Hanford, Washington," UCRL-21069, Lawrence Livermore National Laboratory, Livermore, CA.

McCann, M. W. and A. C. Boissonnade, 1991, "Flood Hazard Evaluation for the Department of Energy New Production Reactor Site – Idaho National Engineering Laboratory," Prepared for Office of the New Production Reactor, United States Department of Energy, Prepared for Lawrence Livermore National Laboratory, Jack R. Benjamin and Associates, Inc.

McConnell, K. I., Blackford, M. E., and Ibrahim, A. K., 1992, "Staff Technical Position on Investigations to identify Fault Displacement Hazards at a Geologic Repository," U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, NUREG-1451.

Savy, J. B. and Murray, R. C., 1988, "Natural Phenomena Hazards Modeling Project: Flood Hazard Models for Department of Energy Sites," UCRL-53851, Lawrence Livermore National Laboratory, Livermore, CA.

U.S. Department of Energy (USDOE), 1989, "General Design Criteria," DOE Order 6430.1A.

U.S. Department of Energy (USDOE), 1992, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports," DOE-STD-1027-92.

U.S. Department of Energy (USDOE), 1993a, "Natural Phenomena Hazards Mitigation," DOE Order 5480-28.

U.S. Department of Energy (USDOE), 1993b "Performance Categorization Criteria for Structure, Systems, and Components at DOE Facilities Subjected to Natural Phenomena Hazards," DOE-STD-1021-93.

U.S. Department of Energy (USDOE), 1993c, "Natural Phenomena Hazards Site Characterization Criteria," DOE-STD-1022-94.

U.S. Department of Energy (USDOE), 1994a, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," DOE-STD-1020-94.

U.S. Department of Energy (USDOE), 1994b, "Natural Phenomena Hazard Assessment Criteria," DOE-STD-1023-94.

U.S. Nuclear Regulatory Commission (USNRC), 1992, "Identification and Characterization of Seismic Sources, Deterministic Source Earthquakes, and Ground Motions," Draft Regulatory Guide DG-1015.

U.S. Nuclear Regulatory Commission (USNRC), 1994, "Identification and Characterization of Seismic Sources, Deterministic Source Earthquakes, and Ground Motions," Draft Regulatory Guide DG-1032.