TS

NOT MEASUREMENT SENSITIVE

NE-STD-1020-2025
August 2025

Change Notice NO. 1
November 2025

NE STANDARD

Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities

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

Change Notice NO. 1 November 2025

CHANGE LOG

1. Returned Table 3-1 Limit States for SDC-2
2. Clarified 2-tier Table 2-1 for FFRDC Facilities (e.g. BEA DOME, FCF) and privately funded facilities.
3. Clarified privately funded facility dose table (bottom half) with <5 rem TED to public to establish a floor for NDC-1.
4. Replaced STD-3009-NE with STD-3009-2014 in section 2.3.3, Table 2-1. STD-3009-NE version drafted and not utilized but failed to remove in section 2.33 Table 2-1. STD-3009-2014 used in other sections of STD.
5. Table 2-1, footnote 5. Clarified privately funded DOE authorized facilities to use co-located worker or public dose. Compute public dose at the site boundary that is controlled by the privately funded facility and not the MOI at the INL site boundary. Alternatively, 100 meter co-located worker dose may be used, e.g. Aalo that is within 100 meters of MFC fence. Facilities in Utah will use the bottom half of the table to compute public dose at their controlled fence line.
6. Added FFRDC to acronyms list
7. Removed 9.3.6.5 reference to 420.1C chg. 3 and replaced with NE O 420.1

FOREWORD

1. This Department of Energy (DOE) Standard has been approved to be used by the Office of Nuclear Energy (NE) and its contractors.

2. This Standard is a revision of and successor to DOE-STD-1020-2016, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*. It provides updated requirements and guidance for (a) the analysis and design of facility structures, systems, and components (SSCs) necessary to implement the natural phenomena hazard (NPH) requirements of DOE NE Order (O) 420.1, *Facility Safety*, and (b) the use and reference of industry building codes and voluntary consensus standards in the NPH analysis and design of SSCs in DOE facilities.

3. This Standard applies to NE contractors to the extent compliance with the Standard is required by the provisions of their contracts. A deviation description should be provided when prior versions of this Standard are applied.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 PURPOSE

Department of Energy (DOE) Office of Nuclear Energy (NE) Standard (STD) 1020 has three purposes:

- Provide criteria and guidance for meeting the natural phenomena hazard (NPH) requirements of NE Order (O) 420.1C, Facility Safety;
- Ensure that structures, systems, and components (SSCs) in DOE facilities will perform assigned safety functions during and after design basis NPH events; and
- Provide requirements and guidance in the use of industry building codes and voluntary consensus standards in meeting NPH requirements.

1.2 APPLICABILITY AND SCOPE

(a) This Standard has the same applicability as Chapter IV of Attachment 2 of NE O 420.1C.

(b) The provisions of this Standard apply to new facilities, major modifications of existing facilities, and modifications of existing facilities triggered by periodic NPH assessments.

(c) This Standard provides analysis and design criteria of facilities affected by seismic events (e.g., earthquakes), extreme winds (e.g., straight-line, hurricanes, tornadoes), floods, lightning, precipitation, and volcanic eruptions.

(d) Other NPH phenomena not considered in this Standard may require analysis at certain sites. These phenomena include but are not limited to drought, fog, frost, extreme temperatures, landslides, subsidence, surface collapse (e.g., sinkhole), uplift, and waterspouts. The general approach of this Standard should also be applied to these phenomena.

(e) The word “shall” denotes a requirement, the word “should” denotes a recommendation, and the word “may” denotes a discretionary action that is neither a requirement nor a recommendation.

1.3 OVERVIEW

The NPH analysis and design process involves the following six steps:

Step 1: For a new facility, select a site location that minimizes NPH hazards to the extent possible.

Step 2: Conduct an NPH analysis and establish requirements for the site, if not previously determined.

Step 3: Identify SSCs relied upon for public and worker protection, based on the Documented Safety Analysis (DSA).[1]

Step 4: Identify all other SSCs that could ensure or adversely affect the safety function of SSCs, based on facility safety and hazard evaluation.

Step 5: Establish performance criteria and NPH categorization for the identified SSCs.

Step 6: Analyze and design the identified SSCs to ensure functional capability during NPH events identified in Step 2 based on the NPH Design Category (NDC) of the SSCs established in Step 5.

1.4 USE OF STANDARD

A multi-disciplinary approach is needed to ensure that the provisions of this Standard are correctly applied. For this reason, the following subject matter experts (SMEs) should participate:

- Safety analysts responsible for hazard and accident analyses;
- NPH design engineers responsible for NPH design;
- Equipment designers responsible for mechanical, electrical, instrumentation control, and structural design;
- SSC designers responsible for mechanical, electrical, structural, control and instrumentation, and civil engineering design and analysis; and
- Researchers and scientists with knowledge and understanding of NPH data, models, and analytical methods.

1.5 DEFINITIONS

This section explains important terms used in this Standard. To the extent practical, standard definitions have been used. In some cases, the general definitions have been supplemented in order to clarify how the term is used in this Standard. Brackets [ ] at the end of some definitions indicate the original source.

Design Basis Flood Level (DBFL): The DBFL is the highest projected flood level, considering all the credible flooding sources for the site, and corresponding to the design basis return period for the SSC's flood design categorization.

---

[1] Applicable to nuclear facilities where the DSA is defined in 10 CFR Part 830, *Nuclear Safety Management* as the "*documented analysis of the extent to which a nuclear facility can be operated safely with respect to workers, the public, and the environment, including a description of the conditions, safe boundaries, and hazard controls that provide the basis for ensuring safety*."

Design Basis Precipitation Level (DBPL): The DBPL for a given SSC is the highest flood level considering all the credible precipitation sources for the site corresponding to the design basis return period applicable for the SSC's precipitation design categorization.

Enhanced Fujita (EF) Scale: A rating system originally devised (Fujita [1]) to facilitate categorizing tornadoes according to the damage they produce and later modified (Enhanced Fujita [2]) and adopted by the National Weather Service. EF scale winds are defined to apply at the 33 ft. (10 m) height. [ANSI/ANS 2.3-2011 (R2021)]

Hazard Curve: Curve that gives the probability of a certain ground motion parameter [usually the peak ground acceleration (PGA), peak ground velocity (PGV), or response spectral values] being exceeded. Hazard curves are generally generated for periods of exposure of one year, and they give annual probabilities of exceedance. [ANSI/ANS-2.27-2020, (R2016)]

Limit State: The limiting acceptable deformation, displacement, or stress that an SSC may experience during or following an earthquake and can still perform its safety function. Four limit states are specified in ASCE/SEI 43-19:

A = Short of collapse, but structurally stable
B = Moderate permanent deformation
C = Limited permanent deformation
D = Essentially elastic

Radiological Facility: A DOE facility that contains radioactive material in a quantity less than Hazard Category 3 as defined in DOE-STD-1027-NE.

Return Period: The return period, sometimes called the recurrence interval, is the average time span between specifically-characterized NPH events. Return periods are often associated with extreme events such as major earthquakes, winds, floods, and precipitation.

Risk Category: A categorization of buildings and other structures for determination of flood, wind, snow, ice, and earthquake loads based on the risk associated with unacceptable performance. [IBC-2024]

Safety Class Structures, Systems, and Components: The structures, systems, or components, including portions of process systems, whose preventive or mitigative function is necessary to limit radioactive hazardous material exposure to the public, as determined from safety analyses. [10 CFR Part 830]

Safety Significant Structures, Systems, and Components: The structures, systems, and components which are not designated as safety class structures, systems, and components, but for which preventive or mitigative function is a major contributor to defense in depth and/or worker safety as determined from safety analyses. [10 CFR Part 830]

Safety Structures, Systems, and Components (SSCs): The set of both the safety class structures, systems, and components, and the safety significant structures, systems, and components. [10 CFR Part 830]

Seismic Design Category (SDC): A category assigned to an SSC that is a function of the severity of adverse radiological and toxicological effects of the hazards that may result from the seismic failure of the SSC on workers, the public, and the environment. SSCs may be assigned to SDCs that range from 1 through 5. For example, a conventional building whose failure may not result in any radiological or toxicological consequences is assigned to SDC-1; a safety-related SSC in a nuclear material processing facility with a large inventory of radioactive material is assigned to SDC-5. [ANSI/ANS-2.26-2004]

Target Performance Goal: The desired level of performance of facility or individual SSCs when subjected to a seismic hazard as noted in ANSI/ANS 2.27-2020. ASCE/SEI 43-19 defines target performance goal by defining target mean annual frequency of an SSC exceeding its specified limit state. [ANSI/ANS-2.27-2020 (R2016)]

1.6 ACRONYMS

APC	Atmospheric Pressure Change
CFHA	Comprehensive Flood Hazard Assessment
CFE	Critical Flood Elevation
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBFH	Design Basis Flood Hazard
DBFL	Design Basis Flood Level
DBPL	Design Basis Precipitation Level
DOE	U.S. Department of Energy
EO	Executive Order
FDC	Flood Design Category
FEMA	Federal Emergency Management Agency
FFRMS	Federal Flood Risk Management Standard
FSA	Flood Screening Analysis
IBC	International Building Code
ICSSC	Interagency Committee on Seismic Safety in Construction
NDC	NPH Design Category
FFRDC	Federally Funded Research & Development Contractor
NFPA	National Fire Protection Association
NPH	Natural Phenomena Hazard
NRC	Nuclear Regulatory Commission
O	Order
PAC	Protective Action Criteria
PDC	Precipitation Design Category
PISA	Potential Inadequate Safety Analysis
PMWP	Probable Maximum Winter Precipitation
PFHA	Probabilistic Flood Hazard Assessment
PPHA	Probabilistic Precipitation Hazard Assessment
PSHA	Probabilistic Seismic Hazard Assessment
PWHA	Probabilistic Wind Hazard Assessment
QA	Quality Assurance
QC	Quality Control
SASSI	System for Analysis of Soil-Structure Interaction
SDC	Seismic Design Category
SME	Subject Matter Expert
SSC	Structure, System, and Component
SSHAC	Senior Seismic Hazard Analysis Committee
STD	Standard
TED	Total Effective Dose
TPG	Target Performance Goal
TVA	Tennessee Valley Authority
USGS	United States Geological Survey
VDC	Volcanic Design Category
VHA	Volcanic Hazards Assessment
WDC	Wind Design Category

2.0 GENERAL CRITERIA AND GUIDANCE FOR NPH DESIGN

2.1 OVERVIEW

Criteria for NPH design of an SSC are dependent on the NDC of the SSC. This section provides criteria and guidance for selecting NDCs that are appropriate for SSCs considering failure consequences to facility workers, co-located workers, and the public. NDCs are established for each applicable NPH type: seismic, wind, flood, precipitation, and volcanic.

All DOE facilities, nuclear and non-nuclear, are required to comply with Public Law 101-614, *National Earthquake* Hazards *Reduction Program Reauthorization Act* (as amended), and Executive Orders regarding seismic and flooding safety.

2.1.1 For seismic safety evaluation of existing facilities, NIST IR 8458e2022, *Standards of Seismic Safety for Existing Federally Owned and Leased Buildings*, ICSSC RP 10-2022, shall be used. Use of this practice will ensure compliance with Public Law 101-614 and Executive Order 13717, *Establishing a Federal Earthquake Risk Management Standard* (Feb 2016). (See Section 9.4 for implementation guidance.)

2.1.2 Flood design parameters shall be in conformance with Executive Order (EO) 11988, *Floodplain Management* (May 1977), as amended by EO 13690 (Jan 2015), and with FEMA-2015-0006-0357, *Guidelines for Implementing Executive Order 11988, Floodplain Management, and EO 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input.*

2.2 NON-NUCLEAR FACILITIES

This Section applies to DOE facilities other than Hazard Category 1, 2, and 3 nuclear facilities. These facilities do not have nuclear material above DOE Hazard Category 3 thresholds (see NE--STD--1027--2025, *Hazard Categorization of DOE Nuclear Facilities*).

2.2.1 **Facilities Without Chemical or Toxicological Hazards:** For facilities that do not have any chemical or toxicological hazards, categorization and design of SSCs subjected to NPH loads shall be performed using the criteria and guidelines given in Chapter 16 (Structural Design) of IBC-2024.

2.2.2 **Facilities Containing Chemical or Toxicological Hazards:** NPH design of these facilities is required to meet the requirements of any applicable DOE rules and orders. NPH design of these facilities should follow a “graded approach.”[2] If the unmitigated failure consequences are such that the equivalent adverse effects are below those for “Highly Toxic,” as defined in 29 CFR §1910.1200, **Toxic and Hazardous Substances**, Appendix A, the SSCs should be designed following IBC-2024 requirements, as applicable. (See also Footnote b to Table 1604.5 of IBC--2024.)

2.2.3 **Radiological Facilities:** NPH design of SSCs in radiological facilities shall follow the criteria of IBC-2024.

[2] See 10 CFR 830 for definition of “graded approach.”

2.2.4 Criteria for Evaluating Lightning Hazards: Lightning protection shall be in accordance with NFPA-780-2023, *Standard for the Installation of Lightning Protection Systems*. Annex L of NFPA-780-2023 provides guidance to determine if a lightning protection system is required. For facilities in which a Faraday cage is selected, Chapter 42 of DOE-STD-1212-2019, *Explosives Safety*, provides guidance on installation, inspection, and maintenance. According to NFPA-780-2023, electrical distribution lines, utility connections, piping, and fencing are to be protected from lightning-induced current surges by surge protective devices, bonding, and grounding. Consideration should be given to lightning protection for bus shelters, guard shacks, and other structures where workers and co-located personnel may seek shelter.

2.2.5 Facilities Containing Explosives: Facilities containing explosives, or those that can be affected by inadvertent or planned detonation of explosives, are required to meet the explosives safety provisions of 10 CFR Part 851, *Worker Safety and Health Program*, which may be satisfied by meeting DOE-STD-1212-2019. Detailing of frangible (i.e., blowout) panels and the design and securing of industrial laboratory equipment and shelves for explosives storage should meet both this Standard and 10 CFR Part 851 criteria. See also 29 CFR §1910.109, *Explosives and Blasting Agents.*

2.2.6 Criteria for Evaluating Volcanic Eruption Hazards: For facilities at sites within 400 kilometers (248.5 miles) of a Quaternary volcanic vent (i.e., Idaho National Laboratory, Los Alamos National Laboratory, and Hanford site), Section 8 of this Standard may be considered to calculate potential ash loads on roofs and to determine the applicable design load combinations. A Volcanic Hazards Assessment (VHA) is not required for non-nuclear facilities.

2.2.7 Quality Assurance: For non-nuclear facilities, the quality assurance requirements specified in IBC-2024 are applicable. NE O 414.1, *Quality Assurance*, requires the implementation of quality assurance using a graded approach. The design of non-nuclear facilities should use the applicable guidance provided in Section 10 of this Standard for verification and validation of software used in analysis.

2.3 HAZARD CATEGORY 1, 2, AND 3 NUCLEAR FACILITIES

2.3.1 Background and Overview. ANSI/ANS-2.26-2004 (R2017), *Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design*, provides a process for determining a seismic design category (SDC) and limit state for SSCs with a safety function in a nuclear facility whose requirements are subjected to seismic hazards. The limit state defines the limiting acceptable deformation, displacement, or stress that an SSC may experience during, or following, an earthquake and still perform its safety function. SSCs are graded into five NDCs based on the unmitigated consequences of SSC failure or the SSC reaching its limit state. Deformation-related failures resulting from other, non-seismic NPHs are defined by the design codes and criteria used to design the SSCs.

In this Standard, SSCs are categorized into the following NDCs:

- For seismic hazards: SDCs 1 through 5;
- For extreme straight-line wind, tornado, and hurricane hazards: wind design categories (WDC)-1 through WDC-5;
- For flood, seiche, tsunami, and other flood-related hazards: flood design categories (FDC)-1 through FDC-5;

- For extreme precipitation hazards: precipitation design categories (PDC)-1 through PDC-5; and
- For volcanic eruption hazards: volcanic design categories (VDC)-1 through VDC-5.

Note that this approach extends the categorization scheme of ANSI/ANS-2.26-2004 (R2017) to other NPHs.

2.3.2 Scope of SSCs for NPH Design

The following SSCs shall be categorized for NPH design and evaluation purposes:

(a) Safety SSCs identified in a nuclear facility's DSA, where the SSC is required to perform its safety function in a design basis NPH event for protection of the public and co-located workers; and

(b) All other SSCs used to protect these SSCs or to prevent or mitigate common-cause failures and systems interaction effects in design basis NPH events.

With respect to (b) above, common-cause failure and system interaction (commonly referred to as 'two-over-one' phenomena) are defined in ANSI/ANS-2.26-2004 (R2017). The methods to address common-cause failure and system interaction as presented in ANSI/ANS-2.26-2004 (R2017) should be followed for design basis NPH events.

Sections 3 through 8 of this Standard provide applicable NPH requirements to ensure the functioning of the above-listed SSCs.

2.3.3 Criteria and Guidance for Establishing NPH Design Categories for Safety SSCs

2.3.3.1 The NDC for all SSCs shall be assigned based on unmitigated failure consequences, using the criteria in Table 2-1.

Table 2--1: Design Categories in an NPH Event

	FFRDC Facilities Unmitigated Consequence Thresholds[1]	
Category	**Co-located Worker**[2]	**Public**
NDC-1	< 5 rem TED Or ≥ PAC-1[3]	Not applicable[3,4]
NDC-2[4]	5 - 100 rem TED Or ≥ PAC-2	5 - 25 rem TED Or ≥ PAC-1
NDC-3	> 100 rem TED Or > PAC-3	> 25 rem TED Or > PAC-2
	Privately Funded Unmitigated Consequence Thresholds[5]	
NDC-1	N/A	< 5 rem TED[4]
NDC-2	N/A	5 - 25 rem TED Or ≥ PAC-1
NDC-3	N/A	> 25 rem TED Or > PAC-2

Notes:

1. The methodology given in DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis,* is used for determining unmitigated consequences of SSC failure to the co-located worker and the public for Government-Owned, Contractor-Operated (GOCO) and Government-Owned, Government-Operated (GOGO) facilities.
2. DOE's Protective Action Criteria (PAC) are found at: Protective Action Criteria (PAC) — DOE Directives, Guidance, and Delegations.
3. A Hazard Category 1, 2, or 3 nuclear facility with consequences to a co-located worker from failure of an SSC in an NPH event will require that SSC to be classified as NDC-1 at a minimum. Therefore, a public criterion for NDC-1 is not needed.
4. Exceptions to the application of Table 2-1 to NDC designation may be applied when comparing with Tables 1 and 2 of DOE-STD-3009-2014. For example, an SSC with an unmitigated failure consequence to the collocated worker below <25 rem (see Table 1) and likelihood of occurrence below 1E-4 (see Table 2) may be designed to either NDC-2 or NDC-1 when considering the functional role(s) of other supporting SSCs in preventing or mitigating accidents. If an exception to Table2-1 is applied as outlined above, the rationale for doing so must be documented.

5. The methodology given in DOE-STD-3009-2014, *Preparation of Nuclear Facility Documented Safety Analysis,* is used for determining unmitigated consequences of SSC failure to the public for privately funded DOE authorized facilities. Dose to the public is computed at the site boundary controlled by the privately funded DOE authorized contractor off of DOE owned property. Alternatively, the 100 meter co-located worker and public (at site boundary) dose thresholds for FFRDC Facilities will be used for selection using Table 2-1, if the facility is located on DOE land.

2.3.3.2 The NDC of an SSC establishes the target performance goal for the SSC, and the return period of the NPH event given in this Standard to which the SSC will need to be designed.

2.3.3.3 The need for an NDC-3 design should be evaluated for SSCs that protect in-facility workers assigned by emergency procedures to remain in the facility after an NPH event. This evaluation should include identification of controls to protect facility worker actions credited as part of the DSA post-event control strategy.

2.3.3.4 If the quantitative public criterion for NDC-3 in Table 2-1 is exceeded significantly for any project (by an order of magnitude or greater), or exceeded for a large population, the use of NDC-4 or NDC-5 criteria shall be evaluated.

2.3.3.5 DOE NE O 420.1, and 10 CFR Part 830, *Nuclear Safety Management*, require evaluation of chemical and toxicological hazards in the design of Hazard Category 1, 2, and 3 nuclear facilities and protection against these hazards. The NDC for SSCs that provide such protection shall be determined based on criteria given in Table 2-1.

2.4 GENERAL CRITERIA AND GUIDANCE FOR DEFINING LIMIT STATES

2.4.1 For determining the limit state of a safety SSC, the critical design parameters at which the SSC safety function fails shall be identified and analyzed in context with the limit state definitions found within Section 5 and the application examples provided in Appendix B of ANSI/ANS 2.26--2004 (R2017).

2.4.2 For seismic hazard evaluations, consistent with ANSI/ANS-2.26-2004 (R2017), the failure of an SSC shall be defined in terms of its limit state. For other NPHs where dynamic loads lead to deformation-related SSC failure, the definition of failure shall be consistent with the design codes being used. However, the hazard consequence evaluation process used in ANSI/ANS-2.26-2004 (R2017) provides applicable guidance for selecting NPH design categories and limit states for other than seismic events.

2.4.3 For NPH evaluations of hazards other than seismic (Section 3) and tornado/wind-borne missile impacts (Section 4.1.1(c)), an SSC failure for various NDCs shall be defined, in terms of load combinations, permissible stress, strain, or deformation given, as applicable, in IBC-2024 (for NDC-1 and NDC-2) and in ACI 349-13 and ANSI/AISC N690-18 (for NDC-3 through NDC-5).

2.4.4 The computed stress, strain, or deformation parameters for the SSC, when subjected to NPHs, shall not exceed the threshold value of any parameter at which the SSC fails to perform its safety function, or compromises the safety function of another SSC.

2.4.5 For a new facility, in designing a building structure that has a direct confinement safety function, the limit state level shall be commensurate with the degree of confinement needed or the permissible leak rate used in the hazard and safety evaluation (see Appendix B of ANSI/ANS-2.26-2004 (R2017) for examples). For the design of the confinement systems that are selected to fulfill the confinement requirement of NE O 420.1, Hazard Category 1, 2, and 3 nuclear facilities with uncontained radioactive materials shall be designed to protect the confinement function to the extent established by the safety basis.

3.0 CRITERIA AND GUIDELINES FOR SEISMIC DESIGN

3.1 SEISMIC DESIGN CATEGORIZATION AND LIMIT STATES

3.1.1 SSCs within the scope of Section 2.3.2 shall be categorized and assigned seismic limit states according to the criteria given in Section 2.3.3 and the methodology given in ANSI/ANS-2.26-2004 (R2017). Should any conflicts arise between ANSI/ANS-2.26-2004 (R2017) provisions and those in this Standard, the latter prevails.

3.1.2 SDC-3, SDC-4, and SDC-5 SSCs shall be designed according to the criteria of ASCE/SEI 43-19, Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities, and ASCE 4-16, Seismic Analysis of Safety-Related Nuclear Structures, subject to the requirements stated in this Standard. Where there is a conflict between the criteria in ASCE/SEI43-19 and ACI 349-13 or N690-18, the criteria in ACI 349-13 or N690-18 shall control.

3.1.3 (a) SSCs having a confinement and leak tightness safety function should usually be designed to limit state C or D to meet the intent of Section 5 and Appendix B of ANSI/ANS-2.26-2004 (R2017).

(b) SSCs having a confinement or leak rate defined safety function may be assigned to limit state B if the functional requirements are those described for the SSC Type “Confinement barriers and systems containing hazardous material (e.g., glove boxes, building rooms, and ducts)” for limit state B in ANSI/ANS-2.26-2004 (R2017), Appendix B.

3.1.4 SDC-1 and SDC-2 SSCs shall be designed according to the criteria of IBC-2024, for Risk Category II and Risk Category IV facilities, respectively, and using the response coefficients in Table 3-1 below.

Table 3--1: Response Modification Coefficients for Seismic Design of SDC-1 and SDC-2 SSCs

SDC	Limit State			
	A	B	C	D
1	ASCE/SEI 7-22, Use Risk Category II, I = 1.0 $R_a = R$ (See Note 2)	ASCE/SEI 7-22, Use Risk Category II, I = 1.0 $R_a = R/1.25$ $R_a \geq 1.2$	ASCE/SEI 7-22, Use Risk Category II, I = 1.0 $R_a = R/1.5$ $R_a \geq 1.2$	ASCE/SEI 7-22, Use Risk Category II, I = 1.0 $R_a = 1.2$
2	N/A	ASCE/SEI 7-22, Use Risk Category IV, I = 1.5 $R_a = R$	ASCE/SEI 7-22, Use Risk Category IV, I = 1.5 $R_a = R/1.2$ $R_a \geq 1.2$	ASCE/SEI 7-22, Use Risk Category IV, I = 1.5 $R_a = 1.2$

Notes:

1. This table may be used to design SDC-1 and SDC-2 SSCs with various safety functions requiring limit states A, B, C, or D. These limit states are to be used when SDC-1 and SDC-2 SSCs are designed by IBC--2024.

2. The IBC invokes the use of ASCE/SEI 7-22 that requires the use of R, where R = Response Modification Coefficient given in ASCE/SEI 7-22, Ra = Actual (reduced) Response Modification Coefficient to be used in the design substituting R values given in ASCE/SEI 7-22 to account for the difference between the limit states achieved by IBC-2024 and ASCE/SEI 7-22 and the limit state A, B, C, and D, as defined in ANSI/ANS-2.26-2004 and ASCE/SEI 43-19, and I = Importance Factor (see Table 1.5-2 of ASCE/SEI 7-22).

3.2 SELECTION OF DESIGN BASIS EARTHQUAKE (DBE) GROUND MOTIONS TO MEET TARGET PERFORMANCE GOAL

3.2.1 For SDC-3 through SDC-5 SSCs, DBE return periods (hazard exceedance probabilities) and appropriate design factors given in ASCE/SEI 43-19 (Table 1-1) shall be used to determine the seismic ground motion applicable for the facility site.

3.2.2 For SDC-1 and SDC-2 SSCs, the return periods in IBC-2024 shall be used.[3]

3.2.3 When assessing the potential for liquefaction, seismically induced permanent ground displacement and soil-strength loss for sites that support SDC-3 through SDC-5 SSCs, ground motions consistent with the mean annual frequency of exceedance specified for the target performance goals in ASCE/SEI 43-19 should be assumed. These ground motions should also be used for geotechnical applications or SSCs for which the seismic fragility functions assumed in ASCE/SEI 43-19 are not representative.

3.3 SITE CHARACTERIZATION FOR SEISMIC-RELATED HAZARDS

3.3.1 Site characterization for SDC-3 through SDC-5 shall follow ANSI/ANS-2.27-2020 (R2016), *Criteria for Investigation of Nuclear Facility Sites for Seismic Hazard Assessment.*

3.3.2 For SDC-1 and SDC-2 SSCs, site characterization is performed in accordance with IBC-2024 to obtain the data necessary for site classification, and for determining site soil properties necessary for designing the SSCs. Site characterization activities may also include the collection of data necessary to perform soil-structure interaction and the development of site-specific ground motion.

3.4 PROBABILISTIC SEISMIC HAZARD ANALYSIS

3.4.1 For facilities having SDC-3 through SDC-5 SSCs, provisions of ANSI/ANS-2.29-2020, *Probabilistic Seismic Hazards Analysis,* shall be used for performing site-specific probabilistic seismic hazard assessments (PSHAs).

For facilities having SDC-2 SSCs, the soil hazard curves available from the USGS Seismic Hazard Maps may be used, instead of performing a site-specific PSHA, to develop DBE ground motions.

[3] Site-specific hazards should be considered if the Maximum Considered Earthquake spectrum is exceeded by more than 25% by site-specific seismic hazard spectra of the same return period.

3.4.2 Site response analyses shall be performed for SDC-3 through SDC-5 SSCs in accordance with Section 4.4 of ANSI/ANS-2.29-2020. When performing site response analyses, a formal process shall be employed to capture epistemic uncertainty and aleatory variability, and peer review is required. Additional guidance can be found in Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.208, *Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion*; RIL2021-15, *Documentation Report for SSHAC Level 2: Site Response*; and NUREG/CR-6728, *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines*.

3.4.3 With respect to foundation input motions of embedded structures, it is necessary to define the Uniform Hazard Response Spectrum both at bedrock and ground surface outcrop. The PSHA should include a suite of representative (equally likely) soil profiles in order to have foundation motions compatible with the Uniform Hazard Spectrum.

3.4.4 For SDC-1 and SDC-2 SSCs located (a) on a site having facilities designated SDC-3 or higher, and (b) where a site-specific PSHA has been performed in accordance with ANSI/ANS-2.29-2020, it is acceptable to use the resulting site-specific ground motions.

3.5 BUILDING AND EQUIPMENT RESPONSE ANALYSIS TO DETERMINE SEISMIC DEMAND

3.5.1 Soil-structure interaction analyses are not required for SDC-1 and SDC-2 SSCs.

3.5.2 For SDC-3 through SDC-5 SSCs, soil-structure interaction analyses may rely on the applicable provisions of ASCE 4-16.

3.5.3 For new facilities, the method of determining design basis seismic ground motion shall satisfy the requirements of Section 2 of ASCE/SEI 43-19 and Section 2 of ASCE 4-16, provided these requirements are consistent with Section 2 of ASCE/SEI 43-19.

3.5.4 The requirements in ASCE 4-16 shall be met in performing dynamic response analyses and generating in-structure response spectra, provided such requirements are consistent with the requirements of ASCE/SEI 43-19.

3.6 BUILDING AND EQUIPMENT CAPACITY EVALUATION

3.6.1 The following five bullets should be taken to develop a design that minimizes the adverse consequences of earthquakes:

- Provide a continuous and traceable load path from the SSC to foundation;
- Ensure that applicable loads and load combinations are accounted for;
- Provide redundant structures or structural elements that can redistribute loads when one structural element is overloaded;
- Provide ductile elements and connections that can undergo deformations beyond yield without sudden and catastrophic collapse; and
- Anchor mechanical equipment on roofs to resist specified seismic loads.

3.6.2 When evaluating the adequacy of an SSC to withstand seismic demands combined with other applicable concurrent loads, the ratio of the total demand, D, to SSC capacity, C, shall be computed to code requirements, with the computed D/C value not exceeding unity.

3.6.3 Non-structural elements attached to the supporting structure shall be designed to allow for seismic deformations of the structure without excessive damage to the structure.

3.6.4 Seismic qualification of equipment may be performed by testing and/or by using actual earthquake experience or generic shake table test data, subject to the criteria and limitations given in DOE/EH-0545, *Seismic Evaluation Procedure for Equipment in U.S. Department of Energy Facilities*, and should be subject to the criteria and limitations in ASCE/SEI 43-19 and ASME QME-1, *Qualification of Active Mechanical Equipment Used in Nuclear Facilities.*

3.6.5 In designing attachments for the distribution lines (e.g., piping, tubing, conduit, or cables), sufficient flexibility shall be provided between the distribution line support nearest to the anchor point and the anchor point so that the distribution system can withstand the postulated relative displacement during a design basis seismic motion.

4.0 CRITERIA AND GUIDELINES FOR EXTREME STRAIGHT-LINE WIND, TORNADO, AND HURRICANE DESIGN

4.1 WIND DESIGN CATEGORIZATION

4.1.1 General Approach

(a) The design categorization process and criteria in ANSI/ANS-2.26-2004 (R2017) for seismic hazards shall also be used for extreme wind-related hazards design categorization (i.e., WDC-1 through WDC-5).

(b) The following wind hazards shall be included in a wind hazard assessment (1) extreme straight-line winds, (2) derecho winds, (3) hurricane winds, (4) tornado winds, (5) tornado atmospheric pressure change (APC), (6) extreme straight-line winds missiles, (7) tornado-generated missiles, (8) hurricane-generated missiles, (9) hurricane-induced water surges, and (10) wind-borne water impingement.

(c) Barriers, controls, and other SSCs provided to protect safety SSCs against damage from the potential impacts of extreme winds or wind-driven missiles shall be designed using hydrostatic and hydrodynamic limits appropriate for the protective function and the failure mode of the barriers and controls.

4.1.2 (a) Sites with WDC-1 and WDC-2 SSCs, the design for extreme wind-related hazards shall use the criteria in IBC-2024 for Risk Category II and Risk Category IV facilities, respectively.

(b) Sites with WDC-3, WDC-4, and WDC-5 SSCs, site-specific design parameters for extreme wind-related hazards (e.g., extreme wind speed, wind-driven missile characteristics) shall be determined by using (1) the guidelines and criteria provided in this section, or (2) the guidelines and criteria provided in ANSI/ANS-2.3-2011 (R2021), *Estimating Tornado, Hurricane, and Extreme Straight Line Wind Characteristics at Nuclear Facility Sites*, as supplemented in this section, or (3) a site-specific Probabilistic Wind Hazard Assessment (PWHA) that meets this Standard.

4.2 SITE CHARACTERIZATION FOR WIND-RELATED HAZARD DESIGN

4.2.1 General Requirements

4.2.1.1 Sites with facilities containing WDC-3, WDC-4, or WDC-5 SSCs shall be characterized for all wind-related hazards following the guidelines and criteria provided in either (a) this section, or (b) Section 4.3.3. If the latter is used, site wind hazard characterization shall be performed following the guidelines and criteria provided in ANSI/ANS-2.3-2011 (R2021).

4.2.1.2 (a) The extent and quality of meteorological data collected to characterize extreme wind-related hazards shall meet one of the following: (i) the requirements of IBC-2024 for determining the design basis for extreme straight-line and hurricane wind speed, (ii) the criteria of ANSI/ANS-2.3-2011 (R2021) for straight-line wind speed, tornado wind speed, tornado APC, and missiles caused by tornadoes, hurricanes, and extreme winds, or (iii) criteria in NRC RG 1.76 for tornadoes and NRC RG 1.221 for hurricanes.

(b) Sites with only WDC-1 and/or WDC-2 SSCs may be characterized using the requirements of IBC-2024, with wind data collected as needed for defining the IBC-2024 design parameters.

4.2.2 Characterization of Site Meteorological Data

Regardless of the selected wind hazard assessment method, relevant information shall be collected and analyzed on (a) facility location on the site, (b) size and orientation of other nearby facilities, (c) distances to off-site natural and manmade features that may affect extreme wind hazards, and (d) topographic and hydrologic features of the site and its environs that may affect extreme wind hazards.

4.2.3 Climatology and Meteorological Data Acquisition

The sources of atmospheric NPHs to be characterized are identified in Section 4.1.1(b). Guidelines and criteria for collecting meteorological data to be used in a site-specific PWHA are provided in the following subsections.

4.2.3.1 Regional Climatology Description and Extreme Wind Event History

(a) The general climate of the region shall be described. Climatology information on the following subjects shall be collected and analyzed:

- Topographic and hydrologic influences,
- General airflow patterns,
- Temperature and humidity,
- Precipitation,
- Relationships between regional atmospheric conditions and local meteorological conditions, and
- Regional extreme climatology history.

4.2.3.2 Wind and Barometric Data Collection.

(a) Wind data shall be collected to characterize three types of wind-related hazards:

(1) Extreme straight-line winds

(2) Hurricane winds; and

(3) Tornado winds.

Data associated with historical extreme wind events, as defined by ANSI/ANS-2.3-2011 (R2021), should be obtained from weather stations that are generally spatially representative of the site. If more than one station within a 50-km radius meets this criterion, wind data from them may be combined. Specific guidance on spatial representativeness of wind data is available in ANSI/ANS-3.11-2015.

(b) Extreme Straight-Line Wind Data. Collection of on-site meteorological data should be conducted in accordance with ANSI/ANS-3.11-2015.

On-site wind data bases of less than 10 years of data may be acceptable provided adequate supplementary data is available from nearby first-order National Weather Service stations having a similar topographic environment. Data collected by federal, state, and local agencies within 50 km of the site and located in the same wind environment may also be used to supplement on-site data, as necessary.

(c) Hurricane Wind and Barometric Pressure Data. Hurricane-prone regions of the continental United States are located along the coastal areas, since hurricanes draw their energy from the oceans or other large warm water bodies such as the Gulf of Mexico. For sites nearby hurricane-prone areas and for which no up-to-date site-specific PWHA has been performed, the meteorological data of past historical hurricanes shall be collected, including:

- Trajectories of hurricane tracks, including information on longitude and latitude, with landfall locations.
- Life-cycle hurricane intensity (Saffir-Simpson categorization).

- Minimal central barometric pressure near the coast or at point of landfall; and

- Maximum sustained and peak wind speeds near the coast or at point of landfall.

(d) Tornado Wind and APC Data. For sites in tornado-prone areas (e.g., south central and southeastern U.S.) and for which no up-to-date site-specific PWHA has been performed, the following data shall be collected for tornadoes striking within 50 km (31 miles) of the site:

- Tornado track, including latitude and longitude.
- Tornado intensity, history, and variations along track using the Enhanced Fujita scale.
- Tornado length and width and variations along track; and
- Data and information necessary for characterizing potential tornado wind-borne missiles.

4.3 PROBABILISTIC WIND HAZARD ASSESSMENT AND DETERMINATION OF WIND DESIGN PARAMETERS

4.3.1 General PWHA Criteria

4.3.1.1 For facilities containing WDC-3, WDC-4, or WDC-5 SSCs, a site-specific PWHA shall be performed and Section 4.3.2 applied, unless Section 4.3.3 is followed.

4.3.1.2 At sites using ANSI/ANS-2.3-2011 (R2021), the design basis wind-related hazard parameters shall be determined using the guidelines and criteria provided in Section 4.3.3.

4.3.2 Development of PWHA

Extreme-wind-related hazard design parameters for WDC-3, WDC-4, and WDC-5 SSCs shall be determined based on a site-specific PWHA, using the guidelines and criteria provided below.

4.3.2.1 The PWHA results shall include a mean-value, wind-related hazard curve, which reflects wind speed at the site as a function of mean return period in years.

4.3.2.2 The method for developing a site-specific PWHA should be based on Section 3.4 of ANSI/ANS-2.3-2011 (R2021) using the most recent occurrence data and accounting for aleatory and epistemic uncertainties.[4]

4.3.2.3 The PWHAs for extreme straight-line winds and hurricanes may be combined to produce a single extreme straight-line wind-related hazard curve by assuming that the two types of winds are mutually exclusive events.

4.3.2.4 The design basis extreme straight-line wind, tornado wind, and hurricane wind shall be based on a mean return period as depicted in Table 4-1 and as indicated in the ANSI/ANS-2.3-2011 (R2021) wind region maps and tables.

4.3.2.5 The return periods for the tornado winds may be justified to be the same as the extreme straight-line and hurricane wind speeds, as indicated in Figures 2-4 of ANSI/ANS-2.3-2011 (R2021), but longer return periods have been specified in Table 4-1 for the following reasons:

- The traditional approach for specifying tornado criteria has been to select extremely long return periods, and a precedent for doing this was established in specifying tornado criteria for commercial nuclear power plants in NRC RG 1.76, Rev. 1, *Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants*;
- The extreme straight-line wind speeds are higher than the tornado wind speeds at lower return periods; and
    - The use of longer return periods for tornadoes has been traditionally justified because it provides additional protection against uncertainty (i.e., defense in depth) without placing undue hardship or cost on the design.

Table 4--1: Mean Return Periods for Design Basis Wind Speeds WDC-3, WDC-4, and WDC-5 SSCs

WDC[1]	Design Basis Mean Return Period in Years		
	Extreme Straight-Line Winds	Hurricane Wind[2]	Tornado Wind[1]
WDC-3	2,500	2,500	50,000
WDC-4	6,250	6,250	125,000
WDC-5	*	*	*

* Extreme straight-line wind not evaluated in these categories. For acceptable methods, see NRC Regulatory Guide 1.76, Rev. 1, *Design Basis Tornado and Tornado Missiles for Nuclear Power Plants*, (R2011) for tornadoes, and NRC Regulatory Guide 1.221, *Design Basis Hurricane and Hurricane Missiles for Nuclear Power Plants*, (R2011) for hurricanes.

Notes:

1. Tornado wind hazards need not be considered if the straight-line wind speeds are greater than tornado wind speeds at the design basis return periods tabulated above; or see ANSI/ANS-2.3-2011 (R2021) for additional information. This is common in regions of the United States west of 105 degrees longitude. However, SSCs are required to be designed and evaluated for the maximum APC associated with the design tornado interface.
2. For hurricane-prone areas near the Gulf of Mexico and Atlantic coast only. Pacific coast hurricanes are rare. As indicated in NRC RG 1.117, *Protection Against Extreme Wind Events and Missiles for Nuclear Power Plants* (2016), tornado wind speeds may not bound hurricane wind speeds for certain portions of the Atlantic and Gulf

[4] See definition within ANSI/ANS-2.27-2020 (R2016).

coasts. In this case, SSCs should also be designed to withstand the effects of the design-basis hurricane and hurricane-generated missiles so that they remain functional, as defined in NRC RG 1.221.

4.3.3 For sites using ANSI/ANS-2.3-2011 (R2021), extreme wind-related hazard design parameters for WDC-3, WDC-4, and WDC-5 SSCs for a DOE site are as specified below.

4.3.3.1 Design basis wind speeds shall be determined using Figures 1 through 4 and in Table 2 of ANSI/ANS-2.3-2011 (R2021).

4.3.3.2 Table 4 of ANSI/ANS-2.3-2011 (R2021) shall be used to determine the characteristics of tornado and hurricane-borne missiles.

4.3.3.3 At sites where the extreme straight-line wind speed exceeding 110 mph controls the wind hazard, wind-generated missiles shall be addressed. The wind-generated missile spectrum and velocities for extreme straight-line winds should be defined using Section 4 of ANSI/ANS-2.3-2011 (R2021), or other technically defensible engineering methods based on available data and literature. Additional guidance may also be found in the references cited in Section 5 of ANSI/ANS-2.3-2011 (R2021).

4.4 SSC DESIGN TO MITIGATE WIND-RELATED HAZARDS

4.4.1 General Design Criteria

The following general design criteria should be used to develop a design for mitigating wind hazards:

- Provide a continuous and traceable load path from the SSC interface to foundation.
- Ensure that applicable loads and load combinations are accounted for.
- Provide redundant structures or structural elements that can redistribute loads when one structural element is overloaded.
- Provide ductile elements and connections that can undergo deformations beyond yield without sudden and catastrophic collapse.
- Provide missile-resistant walls and roof elements.
- Anchor mechanical equipment on roofs to resist specified wind and missile loads.
- Minimize or eliminate the potential for wind-borne missiles.

4.4.2 Design of SSCs in Categories WDC-3, WDC-4, and WDC-5

4.4.2.1 (a) WDC-3, WDC-4, and WDC-5 SSCs shall be designed in accordance with the criteria and methodology in this Standard, ANSI/ANS-2.3-2011 (R2021), and ASCE/SEI 7-22, *Minimum Design Loads for Buildings and Other Structures*.

(b) The criteria in ACI 349-13 and ANSI/AISC N690-18 shall be used to determine the capacities of the WDC-3, WDC-4, and WDC-5 SSCs.

4.4.2.2 In designing SSCs to withstand design basis tornado winds, the IBC-2024 methodology for determining extreme straight-line wind loads is modified as follows:

(a) In calculating the design basis forces on SSCs corresponding to design basis tornado wind speeds, the IBC-2024 provisions shall be used based on the applicable exposure category. However, if no data on exposure category is available, Exposure Category C may be used, regardless of the actual terrain roughness. For these cases, the Velocity Pressure Exposure Coefficient may also be determined by assuming Exposure Category C.

(b) For designing SSCs against extreme straight-line wind, hurricane wind, and tornado wind loads, the extreme environmental load combinations identified in ACI 349-13 and ANSI/AISC N690-18 shall be used.

4.4.2.3 Safety SSCs, or the barriers protecting them, shall be designed to withstand the impact of site-specific tornado and hurricane missiles, as characterized in Table 4 of ANSI/ANS-2.3-2011 (R2021), considering the impactive nature of the load and including the deformation characteristics of the missiles.

For design of barriers to protect safety-related SSCs against missiles, a deformation of the barrier beyond yield may be used to calculate the barrier capacity as defined in ACI 349-13, Appendix F or ANSI/AISC N690-12, Section NB 3. Perforation or spalling may be acceptable if shown not to degrade the protective capacity of the barrier.

4.4.2.4 The effects of internal pressure should be considered according to the applicable methodology in the IBC-2024 when (a) a structure is not intentionally sealed to maintain an internal negative pressure for confinement of hazardous materials, and (b) the structure has openings greater than one square foot per 1,000 cubic feet of volume, or (c) openings of this size can be caused by missile perforation.

4.4.2.5 When a structure is sealed, then the APC associated with a tornado, as shown in Table 2 of ANSI/ANS-2.3-2011 (R2021), shall be considered instead of internal pressures.

4.4.2.6 At the radius of maximum wind speed, the APC may be one-half its maximum value. For this reason, a critical tornado load combination for a sealed building shall be one-half the maximum APC pressure combined with the maximum tornado wind pressure, or one-half wind pressure and maximum APC, whichever controls design.

4.4.2.7 A rapid rate of pressure change caused by a tornado shall be analyzed to ensure that it does not damage safety-related ventilation systems.

5.0 CRITERIA AND GUIDELINES FOR FLOOD, SEICHE, AND TSUNAMI DESIGN

5.1 FLOOD DESIGN CATEGORIZATION

5.1.1 General Approach

(a) The design categorization process and criteria given in ANSI/ANS-2.26-2004 (R2017) for seismic hazards shall be used for flood design categorization (i.e., FDC-1 through FDC-5).

(b) Flood hazard design categorization and flood hazard assessments shall take into account flood-related and hydrology-related hazards that are applicable to the facility.

(c) If a new facility is constructed on a site with existing flood hazard analyses, then an updated flood hazard analysis considering the new facility design and engineered site characteristics shall conform with the requirements of this Standard.

(d) Barriers, controls, and other SSCs provided to protect safety SSCs against damage from the potential impacts of floods shall be designed using stress, strain, or deformation limits appropriate for the protective function and the failure mode of the barriers and controls.

5.1.2 Return Periods for Design Basis Floods

(a) Safety SSCs vulnerable to submersion in a design basis flood shall be designed using the return periods in Table 5-1 and the event combinations in Table 5-3.

(b) Safety SSCs not vulnerable to submersion in a design basis flood shall be designed using the return periods in Table 5-2 and the event combinations in Table 5-3. These return periods support the conclusion that only structural loads on safety SSCs need to be considered.[5]

Table 5--1: Return Period (Years) for Safety SSCs Exposed to Submersion

SSC Category	FDC-1	FDC-2	FDC-3	FDC-4	FDC-5
Return Period	500	2,000	10,000	25,000	*

Table 5--2: Return Period (Years) for Safety SSCs Not Exposed to Submersion

SSC Category	FDC-1	FDC-2	FDC-3	FDC-4	FDC-5
Return Period	100	200	2,500	6,250	*

* Extreme flood inundation and structural load hazards not evaluated. NRC JLD-ISG-2012-05, Rev. 0, "*Guidance for Performing the Integrated Assessment for External Flooding*," November 30, 2012; and NRC JLD-ISG-2016-01, Rev. 0, "*Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation: Focused Evaluation and Integrated Assessment*," July 11, 2016.

[5] The difference in return periods in Tables 5-1 and 5-2 recognizes that while the structural damage criteria of ASCE/SEI 43-19 and IBC-2024 have some inherent conservatism, an SSC is assumed to fail unconditionally when submerged.

Table 5--3: Design Basis Flood Event Combinations

Primary Hazard	Case No.	Event Combinations*
Stream, Extreme Local Precipitation, and River Flooding	1	Peak flood elevation due to all flooding contributors with the exception of upstream dam failure. The hazard analysis for river flooding should include all contributors to flooding, including releases from upstream dams, and ice jams. Flooding associated with upstream dam failure is included in the dam failure category.
	2	Wind-driven waves corresponding, as a minimum, to the 2-year wind acting in the most favorable direction coincident with the peak flood (i.e., Case 1, above) or as determined in a probabilistic flood hazard analysis (PFHA) that considers the joint occurrence of river flooding and wind-driven waves.
	3	Ice or debris forces (i.e., static and dynamic) and Case 1.
	4	Peak and ground water level and Case 1. Evaluate the potential for erosion and debris due to the primary hazard.
Dam, Levee, or Dike Failure	1	Peak flood elevation due to all modes of levee or dam failure: overtopping, structural failure, upstream dam failure, failure due to ice or debris forces.
	2	Wind-waves corresponding, as a minimum, to the 2-year wind acting in the most favorable direction coincident with the peak flood (i.e., Case 1) or as determined in a PFHA that considers the joint occurrence of river flooding and wind-driven waves.
	3	Potential erosion and debris due to the primary hazard should be evaluated as part of the PFHA if overtopping and/or failure occur.
	4	Peak and ground water level and Case 1. Potential for erosion and debris due to the primary hazard.
Extreme Local Precipitation	1	Peak flood based on runoff analysis due to extreme precipitation. Flooding based on the site runoff analysis should be used to evaluate the site drainage system and flood loads on individual facilities.
	2	Ponding on the roof to a maximum depth corresponding to the level of the secondary drainage system.
Storm Surge, Seiche	1	Peak flood levels plus mean high tide levels. Tide effects corresponding to the mean high tide above the mean low water (MLW) level, if not included in the PFHA.
	2	Surge-associated waves and Case 1. Wave action should include static and dynamic effects and potential for erosion.
Tsunami	1	Tide effects corresponding to the mean high tide above the MLW level, if not included in the PFHA.

* Events are added to the flood level produced by the primary hazard. There may be other event combinations that should be considered depending on the location of a site and/or a facility.

5.1.3 For sites with the potential for river flooding, a design basis flood shall be determined by combining the effects of stream and river flooding and extreme local precipitation.

5.2 SITE CHARACTERIZATION FOR FLOOD-RELATED DESIGN

5.2.1 General Requirements

5.2.1.1 Off-site precipitation data and hydrologic characteristics of a site and its surroundings shall be investigated in sufficient scope and detail to develop a Probabilistic Flood Hazard Assessment (PFHA).

5.2.1.2 The size of the region to be investigated and the type of data pertinent to the investigations is determined by the nature of the region surrounding the proposed or existing site. Information should be collected and analyzed on: (a) facility location on the site, (b) size and orientation of other facilities on the site, and (c) distances to off-site natural and manmade features that may affect flood hazards.

5.2.1.3 A topographic map shall be developed to show the character of surface drainage patterns and the topographic elevations of the site relative to nearby hydrologic features in its vicinity.

5.2.2 Characterization of Site Hydrological and Meteorological Data

5.2.2.1 When no up-to-date, site-specific PFHA has been performed in accordance with Section 5.3, monthly and annual summaries, including averages and periodic extremes, of precipitation and equivalent melted water contents at, or near,[6] the site shall be developed. Sources of relevant information include flood insurance studies by FEMA, and hydrological studies performed by universities, DOE, and other governmental agencies.

5.2.2.2 The following information shall be collected and analyzed to support development of the PFHA:

- Location, size, shape, and other hydrologic characteristics of streams, lakes, shore regions, and ground water environment influencing the site.
- Quantitative description of existing and planned water control structures (e.g., dams, weirs, settlement basins) that may influence the hydrologic conditions at the site.
- History of hydrologic events, including paleo floods, that are potential sources of flooding for the site.

5.2.3 Stream and River Flooding

5.2.3.1 Each stream and river in the regional area of the site that could affect the site shall be characterized with respect to its location and elevation relative to the site and its facilities.

5.2.3.2 The boundaries of the region to be investigated for the stream and river flooding hazard depend primarily on whether the streams and rivers could cause floods large enough under extreme conditions to contribute to flooding at the site.

---

[6] In Sections 5 and 7 of this Standard, the word "near" is to be interpreted in the sense of physical causality. For example, here "near" refers to averages and periodic extremes of precipitation in a zone where these extremes could affect the site.

5.2.3.3 The following information is needed to characterize potential river flooding:

- Location and elevation of the rivers at the location nearest the site.
- Historical records of stream and river flow data (maximum yearly peak discharge and stage elevation) with recording location.
- Maximum flood level that may be expected from a combination of the most extreme historical, meteorological, and hydrologic conditions.
- Geometric and hydraulic properties of the channel closest to the site. The geometric properties of the channel include Manning's roughness coefficient and top-width elevation tables for cross sections, and streambed slope.
- Presence of bridges or natural stream and river flow constrictions that could cause flooding due to ice or debris jams.

5.2.3.4 For rivers for which no peak discharge records are available, the following information is needed:

- Characteristics of the watershed basins of the streams and rivers.
- Properties of the drainage basins and topographic and land cover maps of the basin.

5.2.4 Dam, Levee, or Dike Failure

5.2.4.1 Historical experiences (e.g., paleo flood information) and analytical studies indicate that floods associated with a dam break can significantly exceed flood levels due to natural events. All upstream dams that could pose a threat to the site shall be identified and the following characteristics summarized: (a) Name; (b) Owner of dam; (c) Type of dam (earth fill, concrete); (d) Date of dam completion; (e) River name and location; (f) Total height of dam; (g) Capacity of dam; (h) Closest distance from the river to the site; and (i) Existing dam break studies.

5.2.4.2 Available dam break studies shall be used to support analysis of flood risk to the site.

5.2.4.3 Data shall be collected as necessary where available to perform: (a) a flooding hazard analysis of the river reach upstream of the dam, (b) seismic hazard analysis, (c) potential landslide hazard analysis of the embankment or the dam itself, and (d) dam break analysis. Such data include:

- Results of PFHAs.
- Information to support an upstream river flooding hazard analysis:
  - Data necessary to evaluate dam resistance to the seismic loads and overtopping, including material properties of the dam and abutment, and characteristics of gates and other mechanical equipment which could affect the dam performance.
- Reservoir depth, length and storage elevation tables.
- Manning's roughness coefficient, and top-width elevation tables for downstream cross sections.
- In the case of overtopping events, the depth of overtopping at which failure occurs.
- In the case of hydrologic events, an inflow hydrograph.

- Outflow characteristics for emergency spillway, outlets, and turbines.

5.2.5 Storm Surge

For sites located (a) near large bodies of water, and (b) within regions that experience hurricanes, tropical storms, or strong storm squalls from extreme straight-line winds, data on storm surges shall be collected from available flood hazard analyses and other sources for inclusion in the PFHA.

5.2.6 Tsunami

Sites located near an ocean exhibiting prior tsunami activity shall include tsunamis in the PFHA and collect (a) seismic data needed to assess the potential for off-shore earthquakes that could induce a tsunami, (b) historical records on prior tsunami occurrences, (c) local topographic data on the region between the site and the ocean, and (d) paleo flood data for sites where some safety SSCs are categorized FDC-4 or FDC-5.

5.2.7 Seiche

For sites located near large bodies of water, seismic, meteorological, and topographical data shall be collected to assess the potential of creating floods from seiche effects in the PFHA.

5.2.8 Wave

For sites located near a body of water in regions exposed to extreme winds, meteorological data, water depths, fetch characteristics, and local topographic data between the site and any large bodies of water shall be collected and evaluated in the PFHA.

5.2.9 Landslide

If a site is exposed to potential flooding caused by landslide effects on a nearby river, relevant information shall be collected and evaluated in the PFHA.

5.2.11 Flood Runoff

If a site is exposed to intense extreme precipitation or rapid snow melt, or both, data shall be collected on the local topographic characteristics of drainage areas, such as depressions, terrain slope, nature of soil vegetation or Manning's coefficients, and soil infiltration indices, and analyzed in the PFHA.

5.2.12 Change in Ground Water Level

In support of the PFHA, the following data shall be considered with respect to changes in ground water level:

1. Records on intense precipitation or snow melt and infiltration, reduced recharge, and droughts.

2. Records on changes in ground water level at any site that uses large volumes of water for industrial purposes.

3. Data on regional and local aquifers and aquitards, including formations and sources of the aquifers, local well log records, and drainage capacity, at any site with shallow ground water tables.

5.2.13 Mudflow

For sites located in areas where mudflows are possible, relevant information shall be collected and evaluated in the PFHA.

5.2.14 Subsidence-Induced Flooding

For sites located in areas where subsidence can be caused by supercritical fluid extraction, relevant information shall be collected and evaluated in the PFHA.

5.3 PROBABILISTIC FLOOD HAZARD ASSESSMENT AND DETERMINATION OF FLOOD DESIGN PARAMETERS

5.3.1 General Probabilistic Flood Hazard Assessment (PFHA) Criteria

5.3.1.1 For facilities containing FDC-3, FDC-4, or FDC-5 SSCs, a site-specific PFHA shall be performed.

5.3.1.2 At sites using ANSI/ANS-2.8-2019, the design basis extreme flood-related hazard parameters shall be determined using the guidelines and criteria provided in Section 5.3.2, augmented by that standard.

5.3.2 Determination of Design Basis Flood Level for Facilities with FDC-1 and FDC-2 SSCs

5.3.2.1 For sites and facilities with only FDC-1 and FDC-2 safety SSCs, the Design Basis Flood Level (DBFL) shall be determined based on the return periods in Tables 5-1 and 5-2 but cannot be lower than the DBFL associated with the IBC-2024 requirements. Return periods for determining the DBFL are provided in Table 5-1. The DBFL structural loads are based on the return periods provided in Table 5-2.

5.3.2.2 For FDC-1 safety SSCs at a site for which no site-specific PFHA has been performed, the DBFL shall be determined using FEMA flood insurance studies applicable to the site, with the DBFL corresponding to a return period of 500 years.

5.3.3 Determination of Design Basis Flood Level for Facilities with FDC-3, FDC-4, and FDC-5 SSCs

5.3.3.1 For sites and facilities with FDC-3, FDC-4, and FDC-5 safety SSCs, a site-specific Probable Flood Hazard Assessment (PFHA) shall be performed.

5.3.3.2 Probable Flood Hazard Assessment

The PFHA shall be performed as follows:

(a) Collect and compile site-specific flood-related hazard data.

(b) Identify the potential sources of flooding, if any, and perform a site characterization study following the guidelines and criteria given in Section 5.3.2. If the return period for a potential flood source is larger than the design basis return period applicable for the FDC in Table 5-1, the source does not need to be considered.

5.3.3.3 The PFHA shall be performed following the guidelines and criteria given below:

(a) The PFHA is risk-informed, considering and propagating the uncertainties in the parameters used to estimate the DBFL.

(b) The PFHA considers meteorological, hydrologic, and hydraulic assessments of all potential sources of flood hazards identified in the FSA and takes into account the reliability of preventive or mitigative flood protection systems (e.g., dams, levees), if present.

(c) The PFHA includes:

- Estimation of rainfall and snowfall frequency in watersheds.
- Overland flow assessment due to precipitation.
- Hydrologic modeling of watershed responses using verified and validated models.
- Assessment of discharge (i.e., flow rates) and flood elevations using detailed hydraulic modeling techniques.
- Estimation of joint natural hazard events frequency – joint probability analysis is performed to assess surge level frequencies.
- Assessment of likelihood of upstream dams and levees failure where all causes of dam and levee failure are accounted for.
- Assessment of the aleatory and epistemic uncertainties due to the limited data for estimating model parameters, modeling of physical processes, and the interpretation of the available data.

(d) A probabilistic model for river flooding includes 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.

(e) Three acceptable approaches are available to evaluate the frequency of extreme flows and/or levels due to hydrologic events, as follows:

- Stochastic methods.
- Probabilistic hydrologic modeling (e.g., Bayesian analysis, joint probability methods).
- Paleo flood analysis: evaluating ancient evidence using age-dating techniques to deduce early extreme hydrologic events.

(f) Dam or levee failure-induced flood levels are determined by analyses appropriate to the circumstances depending on flood level sensitivity and cost so that conservative assumptions, and simple to complex probabilistic dam failure analyses, are acceptable.

(g) Aleatory and epistemic uncertainties for the dam break model analysis parameters (e.g., breach size, time to failure, flood time arrival) shall be accounted for in the analysis. Use of the mean for the DBFL is acceptable.

(h) A simplified dam failure analysis is acceptable if the analysis addresses uncertainties.

5.4 SSC DESIGN AND EVALUATION TO MITIGATE FLOOD-RELATED HAZARDS

5.4.1 General Flood Design Criteria

5.4.1.1 Evaluation of the flood design basis for safety SSCs consists of the following steps:

1. Determine the DBFL for each flood-related hazard, as defined by the hazard return periods and applicable combinations of flood hazards.
2. Develop a flood design strategy for the DBFL that satisfies the design requirements.
3. Design civil engineering control systems (e.g., buildings, drainage, retaining walls, dikes) to the applicable DBFL and other design requirements.

5.4.1.2 For FDC-3, FDC-4, and FDC-5 safety SSCs, DBFLs shall be considered in the "Extreme Load" category and thus subject to analysis by ACI 349-13 and ANSI/AISC N690-18 criteria.

5.4.1.3 FDC-1 and FDC-2 SSCs shall be designed to withstand load combinations specified in IBC-2024 for Risk Category II and Risk Category IV SSCs, excluding a load factor for flood load.

5.4.2 Design Basis Flood Level

The DBFL is the highest projected flood level, considering all the credible flooding sources for the site, and corresponding to the design basis return period for the SSC's flood design categorization.

5.4.3 Flood Hazard Evaluation and SSC Design Process

5.4.3.1 The flood hazard evaluation process is illustrated in Figure 5-1. It is divided into the consideration of regional flood hazards and local precipitation (see Section 7).

5.4.3.2 For new construction, safety SSCs shall be located above the DBFL unless designed for immersion.

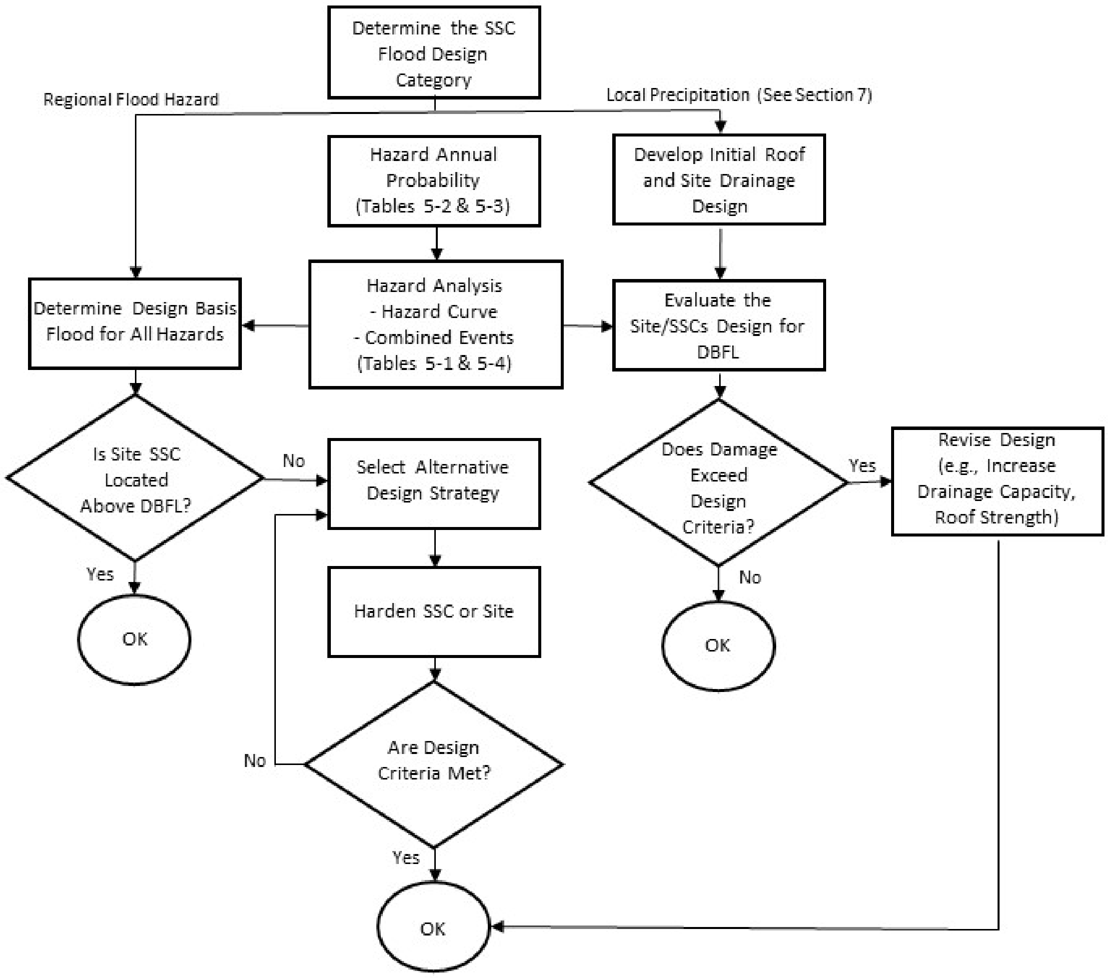

Figure 5--1: Flood Evaluation and SSC Design Process

5.4.3.3 The flood evaluation for a safety SSC is based on the steps in the flood-related design process:

(a) Determine the SSC's FDC.

(b) Determine the DBFL for each type or source of flooding.

(c) Assess the hydrostatic and hydrodynamic flood loads or other effects such as scouring and erosion on an SSC-by-SSC basis.

(d) For a new facility, locate the safety SSCs that may malfunction if submerged above the DBFL, if possible. If this cannot be done, develop a design strategy to mitigate flood hazards that affect the SSC. Options include hardening the SSC, modifying the path of floodwaters, and augmenting drainage systems.

5.4.4 Flood Design Mitigation Strategies

5.4.4.1 All safety SSCs that may fail when exposed to water intrusion or submergence from flood sources should be constructed or moved above the DBFL, if feasible. If not feasible, protection from intrusion or submersion shall be provided by engineered safety features.

5.4.4.2 The design of the protective features guidance is available in:

- NRC NUREG-0800, *Standard Review Plan*, Section 2.4.10, Flooding Protection Requirements; Section 2.5.5, Stability of Slopes; and Section 3.4.2, Analysis Procedures.
- NRC RG 1.102, Flood Protection for Nuclear Power Plants.
- ANSI/ASCE 1-82, N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures.

5.4.4.3 The hierarchy of flood design strategies is:

(a) Situate the SSC above the DBFL.

(b) Reduce the design basis flood hazard.

(c) Harden the site and/or the SSC.

(d) Develop procedures and plans to evacuate workers and secure hazardous and valuable materials.

5.4.5 Flood-Related Hazard Design Criteria

5.4.5.1 FDC-1 and FDC-2 safety SSCs shall be designed in accordance with Sections 5.3.2 and 5.4.1.3, considering the event combinations listed in Table 5-3.

5.4.5.2 FDC-3 and FDC-4 safety SSCs shall be designed using the return periods given in Tables 5-1 and 5-2, and the event combinations listed in Table 5-3.

5.4.5.3 FDC-5 safety SSCs, if needed, shall be designed using the NRC criteria identified in Sections 5.3.1, 5.4.1.2, and 5.4.4.2.

6.0 CRITERIA AND GUIDELINES FOR LIGHTNING DESIGN

6.1 SSCs within the scope of Section 2.3.3 that may be subjected to the effects of lightning strikes shall be either (a) designed to withstand the effects of such strikes, or (b) protected from strikes in accordance with the criteria of NFPA-780-2023. Additional guidance on lightning protection can be found within DOE-STD-1212-2019, *Explosives Safety*.

7.0 CRITERIA AND GUIDELINES FOR PRECIPITATION DESIGN

7.1 PRECIPITATION DESIGN CATEGORIZATION

7.1.1 General Approach

(a) The design categorization process and criteria given in ANSI/ANS-2.26-2004 (R2017) for seismic hazards shall also be used for extreme precipitation-related hazards design categorization (i.e., PDC-1 through PDC-5).

(b) If a new facility is to be constructed on a site with an existing precipitation hazard analysis, then the precipitation hazard analysis used for the new facility design shall conform with the requirements of this Standard.

(c) Precipitation design categorization shall take into account all precipitation-related hazards applicable to the facility.

(d) Precipitation design shall be coordinated with flood design (see Section 5 of this Standard).

7.2 SITE CHARACTERIZATION FOR PRECIPITATION-RELATED DESIGN

7.2.1 General Requirements

7.2.1.1 Site characterization, evaluation of SSCs, precipitation, hydrologic and meteorological characteristics, and topographical features of a site and its surroundings shall be investigated in sufficient scope and detail to obtain the data necessary for performing a site-specific Probabilistic Precipitation Hazard Assessment (PPHA) in accordance with this Standard.

7.2.1.2 The size of the region to be investigated and the type of data pertinent to the investigations are determined by the nature of the region (e.g., upstream dams, hydrologic features) surrounding the proposed or existing site.

7.2.1.3 Information should be collected and analyzed on: (a) facility location on the site, (b) size and orientation of other facilities on the site, and (c) distances to off-site natural and manmade features (e.g., upstream dams, hydrologic features) that may affect flood hazards.

7.2.1.4 A topographic map shall be developed to show the character of surface-drainage patterns and the topographic elevations of the site relative to nearby hydrologic features in its vicinity.

7.2.2 Characterization of Site Precipitation-Related Data

7.2.2.1 Sites for which no up-to-date, site-specific PPHA has been performed shall develop monthly and annual summaries, including averages and periodic extremes, of precipitation and equivalent melted water contents, at or near the site.

7.2.2.2 The following information shall be collected and analyzed to support development of the PPHA:

- Characterization of local site flooding from precipitation runoff in accordance with the guidelines and requirements given in Sections 7.3.1 and 7.3.2.

- Sources of relevant information including flood insurance studies by FEMA and hydrological studies performed by universities, DOE, and other governmental agencies (e.g., the Army Corps of Engineers, the Bureau of Reclamation, the United States Geological Survey, Flood Insurance Administration, Department of Water Resources, Agricultural Department, National Weather Service, Tennessee Valley Authority).

- Location, size, shape, and other hydrologic characteristics of streams, lakes, shore regions, and ground water environments influencing the site.

- Quantitative description of the existing and planned water control structures (e.g., dams, weirs, settlement basins) that may influence the hydrologic conditions at the site.

- History of meteorological events with precipitation rates and totals that are potential sources of flooding for the site.

- Topographic data, storm drainage data, and building location data for the site to determine the relevant watershed areas.

- Characterization of site precipitation by a review of pertinent literature and field investigations.

- Data and other relevant information obtained from prior investigations, supplemented by additional site-specific investigations.

7.3 PROBABILISTIC PRECIPITATION HAZARD ASSESSMENT AND DETERMINATION OF PRECIPITATION DESIGN PARAMETERS

7.3.1 Determination of DBPL for Facilities with PDC-1 and PDC-2 SSCs

7.3.1.1 For sites and facilities with only PDC-1 and PDC-2 SSCs, the Design Basis Precipitation Load (DBPL) shall be determined according to the return periods provided below in Table 7-1 and Table 7-2, and not be lower than the DBPL associated with the IBC-2024 requirements. Table 7-1 applies when evaluating the flooding caused by runoff of the site precipitation. Table 7-2 applies when evaluating structures for the effects of loads resulting from the precipitation.

7.3.2 Determination of DBPL for Facilities with PDC-3, PDC-4, and PDC-5 SSCs

7.3.2.1 For winter precipitation loads, the NRC criteria in NUREG-0800, Section 2.3.1, Regional Climatology, Revision 3, shall be used to determine the extreme structural loads for PDC-3, PDC-4, and PDC-5 SSCs.

7.3.2.2 The NRC criteria states that the extreme winter precipitation loads are based on the weight of the 100-year snowpack at ground level, plus the weight of the 48-hour probable maximum winter precipitation (PWMP) at ground level for the month corresponding to the selected snowpack. Depending on the location of the site, the 48-hour maximum event may not necessarily be in the form of frozen precipitation.

Table 7--1: Return Period (Years) for Design Basis Precipitation Flooding

SSC Category	PDC-1	PDC-2	PDC-3	PDC-4	PDC-5
Return Period (Years)	500	2,000	10,000	25,000	*

Table 7--2: Return Period (Years) for Design Basis Precipitation Structural Loads

SSC Category	PDC-1	PDC-2	PDC-3	PDC-4	PDC-5
Return Period (Years)	100	200	2,500	6,250	*

* Extreme precipitation flooding, and structural loads are not evaluated. See NRC COL/ESP-ISG-007, "*Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures*," June 23, 2009; NRC JLD-ISG-2012-05, Rev. 0, "*Guidance for Performing the Integrated Assessment for External Flooding*," November 30, 2012; and NRC JLD-ISG-2016-01, Rev. 0, "*Guidance for Activities Related to Near-Term Task Force Recommendation 2.1, Flooding Hazard Reevaluation: Focused Evaluation and Integrated Assessment*," July 11, 2016.

7.4 SSC DESIGN AND EVALUATION TO MITIGATE PRECIPITATION-RELATED HAZARDS

7.4.1 General Precipitation Design Criteria

7.4.1.1 Evaluation of the precipitation design basis for safety SSCs consists of the following steps:

- Determine the DBPL for each precipitation-related hazard, as defined by the hazard design periods and applicable combinations of precipitation hazards.
- Evaluate the site storm water management system.
- Develop a precipitation design strategy that satisfies the design requirements.
- Design civil engineering control systems (e.g., buildings, drainage, retaining walls, dikes) to mitigate the hazard.

7.4.2 Precipitation Hazard Evaluation and SSC Design Process

7.4.2.1 The precipitation hazard evaluation process is illustrated in the local precipitation portion of Figure 5-1.

7.4.2.2 Study local extreme precipitation events for possible effects on site and roof drainage, and design roofs to withstand the effects of the precipitation extremes.

7.4.2.3 Revise the design if the design criteria for the roof are exceeded.

7.4.2.4 Develop design modifications or other mitigation measures if the DBPL produces unacceptable levels of flooding.

7.4.3 Precipitation Design Mitigation Strategies

7.4.3.1 The hierarchy of precipitation design strategies is:

(a) Situate the SSC above the DBPL level.

(b) Reduce the DBP hazard.

(c) Harden the site and/or the SSC.

7.4.4 Precipitation-Related Hazard Design Criteria

7.4.4.1 PDC-1 and PDC-2 safety SSCs shall be designed for the DBPL based on the return periods in Table 7-1 and Table 7-2, using the load combinations in IBC-2024 for Risk Category II and Risk Category IV, respectively.

7.4.4.2 PDC-3, PDC-4, and PDC-5 safety SSCs shall be designed for the DBPL based on the return periods in Table 7-1 and Table 7-2.

7.4.4.3 The load combinations identified in ACI 349-13 and ANSI/AISC N690-18 shall be used for the DBPL flood extreme precipitation loads on walls, dikes, roofs, and protective structures.

7.4.5 Site Drainage and Roof Design Considerations

7.4.5.1 Once the site and facility drainage design has been developed, it shall be evaluated for the DBPL precipitation for each SSC.

7.4.5.2 The evaluation shall consider the site-drainage area, natural and manmade watercourses, and roof drainage. The analysis shall also determine the level of flooding that could occur at each SSC.

8.0 CRITERIA AND GUIDELINES FOR VOLCANIC ERUPTION DESIGN

8.1 APPLICABLE SITES

(a) Volcanic hazards shall be assessed at DOE sites and facilities lying within 400 kilometers (approximately 250 miles) of a volcanic center that erupted within the Quaternary Period (i.e., 2.6 million years before present).

(b) This section applies to facilities with envisioned life spans up to but not exceeding 100 years.

(c) This section does not apply to facilities such as geologic repositories with performance periods well beyond 100 years.

8.2 VOLCANIC HAZARDS ASSESSMENT

8.2.1. Sites within 100 km of a Quaternary volcanic vent shall perform a Volcanic Hazards Assessment (VHA) that addresses the phenomena listed below that are deemed credible.

- Ashfall (tephra);
- Lava flows;
- Ballistic projections;
- Pyroclastic density currents;
- Mudflows (lahars);
- Ground deformation;
- Tsunami (see Section 5);
- Atmospheric effects, such as lightning and downburst winds; and
- Emission of toxic gases.

8.2.2. A determination of which phenomena pose a credible hazard to a site can rely on existing geology literature. Certain phenomena may be screened out based on distance from the volcanic vents or the nature of the tectono-magmatic environment. A new national consensus standard, ANSI/ANS-2.34, *Characterization and Probabilistic Analysis of Volcanic Hazards*, is in preparation. Once published, it will contain detailed guidance on screening volcanic phenomena from consideration and assessing hazards posed by credible phenomena.

8.3 CHARACTERIZATION OF VOLCANIC HAZARDS

8.3.1 Sites between 100 and 400 km from a Quaternary volcanic vent shall use a graded approach for the VHA, as discussed below.

8.3.2 Only the hazards posed by ashfall and gases need to be evaluated. Small volcanoes with past eruptions of a volcanic explosivity index of 3 or lower and located beyond 100 km need not be analyzed, since those eruptions pose a negligible ashfall hazard beyond 100 km.

8.3.3 The hazard characterization process should support mapping all Quaternary volcanoes within 400 km, including (a) distances from the volcanoes to the site boundary; (b) information on the eruption history of these volcanoes assembled from available literature, such as USGS publications, DOE contractor technical reports, and published geology literature; and (c) parameters such as eruption ages, estimated volumes, eruption physical characteristics/ explosivity, and extent of ashfall, if known.

8.3.4 Ash deposits are highly erodible and, as such, poorly preserved in the geologic record. Ashfall thicknesses and eruption volume data may be sparse and highly uncertain. Most volcanoes and volcanic fields in the Western U.S. have been studied to some degree in the past, and parameters, such as the most recent eruption age and eruption characteristics, should be available for most of them. The eruption characteristics are much easier to assess than the eruption volumes, frequencies, and spatial extent.

8.3.5 Given the past research on Western U.S. volcanic centers, an adequate VHA for DOE facilities should require minimal additional data collection. In cases where data can be collected, at reasonable time and expense, that will significantly increase the understanding of the hazard posed by a volcano, such data collection is prudent. An example would be a radiometric age determination of an identified, but undated Quaternary ash deposit from a volcanic center within 400 km of a facility.

8.3.6 Well-characterized volcanoes outside the Western U.S. may serve as useful analogues for additional data on ashfall parameters (e.g., distances and ashfall thicknesses), assuming they demonstrate eruption characteristics similar to the volcanoes that are the subject of the VHA.

8.3.7 Volcanic eruption characterization is just the first step in a VHA. The wind conditions also need to be characterized, as the wind will control the distribution pattern of an ashfall. Meteorological data to characterize the prevailing winds around the volcanoes of interest will also be needed. These data should include probabilities by azimuth sector at various altitudes. Information on eruption probabilities, eruption characteristics, or volumes, and wind probabilities may be used to develop an annual frequency of the exceedance of ashfall with a given thickness, at a given distance from a volcano. Hoblitt and Scott (2011) provide an example of such a distribution for DOE's Hanford Site from the Cascade Range volcanoes. A much more sophisticated analysis of the ashfall hazard posed to the Hanford Site by Mt. St. Helens, both from accumulated thickness and airborne concentration during the fallout, is available in Mastin et al. (2020). This analysis uses the Ash3d atmospheric transport model.

8.3.8 In most cases, eruption data from relevant volcanoes may be too sparse to construct a probabilistic distribution as Hoblitt and Scott (2011) do for Hanford. With less data, a Monte Carlo simulation to capture the expected ranges of eruption frequency, volume, and wind direction may be constructed to produce ashfall hazard curves (i.e., thickness versus probability of exceedance) for given locations surrounding a volcano.

8.3.9 If a facility has ventilation or other systems likely to be affected by airborne ash, the airborne ash concentration and duration of ashfall are important considerations. Any existing data on eruption durations or ash cloud densities (i.e., airborne ash concentration) from volcanoes similar to those of interest should be assembled. In the absence of ashfall duration or cloud density data, assume that the maximum design ashfall occurs over a period of 12 hours. From these values, as well as an assumption of average ash particle size, and thus settling velocity, an estimate of cloud density (in milligrams of ash per cubic meter) during an ashfall event can be obtained.

8.4 DESIGN CONSIDERATIONS FOR VOLCANIC HAZARDS

8.4.1 SSCs within the scope of Section 2.2.2 shall be assigned a volcanic design category (VDC) of 1, 2, 3, 4, or 5. Performance goals for the five design categories should be selected using the same method as specified for seismic hazards in Table 1-1 of ASCE/SEI 43-19. However, the hazard exceedance probabilities, or hazard return periods, used for seismic design that appear in C2.2 of ASCE/SEI 43-19, should not be applied in design for volcanic hazards. Volcanic hazard return periods used in design will vary depending on the type of SSC and its failure mechanism.

8.4.2 Structural designs for ashfall loads are performed by static or equivalent static methods similar to that for flood water loads. SSCs with a structural mode of failure should be designed to withstand an ashfall hazard with a return period commensurate with the flood hazard, as shown in Table 8-1. These return periods are the same as those in Table 5-2 for flood structural loads.

Table 8--1: Return Periods for Volcanic Ashfall Structural Loads

SSC Category	VDC-1	VDC-2	VDC-3	VDC-4	VDC-5
Return Period (Years)	100	200	2,500	6,250	10,000

8.4.3 SSCs subject to non-structural failure, such as filter clogging, other mechanical or electrical malfunction, should be designed to more conservative hazard return periods. For these SSCs, as with failure due to inundation from flood hazards, failure is assumed to occur unconditionally if the design basis hazard occurs. No margin is assumed in the SSC design, so SSCs should be designed to withstand a hazard with a return period that is the inverse of the performance goal. SSCs subject to non-structural failure should be designed to hazards with return periods shown below in Table 8-2, which are the same as those in Table 5-2.

Table 8--2: Return Periods for Volcanic Ashfall Non-Structural Failures

SSC Category	VDC-1	VDC-2	VDC-3	VDC-4	VDC-5
Return Period (Years)	500	2,000	10,000	25,000	100,000

8.4.4 Ashfall loads, if applicable, shall be based on site-specific, probabilistic studies using the return periods discussed above. The design and evaluation of VDC-3 through VDC-5 SSCs shall be performed using ACI 349-13 and ANSI/AISC N690-18. For VDC-1 and VDC-2, the load combinations in IBC-2024 shall be used, substituting the ashfall load for the snow load in the load combinations.

8.4.5 Structural design shall consider ash density and the impact of precipitation combined with ashfall. Ash density estimates for volcanoes of interest are likely sparse. The density of uncompacted ash generally decreases with distance from a volcano, and a typical range is 0.5 to 1.3 g/cm^3. Saturating volcanic ash with rainfall or melted snow can increase density by 50 to 100 percent or more, on occasion exceeding a density of 2.0 g/cm^3, as shown in a 2011 USGS document, *Volcanic Ash and Gas Impacts & Mitigation*. Moreover, since ash particles are very effective condensation nuclei, if an ash cloud interacts with a precipitation front, heavy rainfall and ash saturation is likely. Site meteorological data shall be considered in calculating the probability of ashfall combining with rainfall, and an appropriate ash density derived.

8.4.6 The most likely non-structural effect of ashfall is on ventilation systems. Airborne ash concentration estimates should be based on an ashfall duration of at least 12 hours for purposes of ventilation system design. Key considerations will be filter loading time, cooling coil fouling, ability to keep critical systems in operation during filter change-out, and availability of spare filters. Depending on the facility's ongoing need for filtered air, re-suspension of ash deposits in the days and weeks following a large ashfall event may need to be considered.

Effects of ashfall and volcanic gases on other mechanical and electrical systems shall also be evaluated.

8.4.7 Facility designs are unlikely to mitigate effects from the largest credible lava flows, pyroclastic density currents, mudflows, and near-vent hazards that might affect a facility within 100 km of a volcanic eruption. However, these phenomena would most likely strike with some advance warning. Administrative procedures shall be prepared to ensure safe process shutdown and personnel evacuation if the facility is endangered by volcanic phenomena. Some ongoing monitoring and hazard analysis of potentially active volcanic vents near a site, possibly in partnership with the USGS, is a good practice. Secondary effects (such as flooding from river channel blockage) of lava flows, pyroclastic density currents, and mudflows should also be addressed.

9.0 MAJOR MODIFICATION AND PERIODIC EVALUATION OF EXISTING NUCLEAR FACILITIES

This section provides the requirements and guidance related to the modification of existing Hazard Category 1, 2, and 3 nuclear facilities, as well as the requirements for periodic reviews of natural phenomena hazard (NPH) analyses and subsequent facility evaluations.

9.1 MAJOR MODIFICATIONS OF EXISTING HAZARD CATEGORY 1, 2, AND 3 NUCLEAR FACILITIES

9.1.1 For major modifications of existing facilities, the design of SSCs shall be based on the methods and criteria given in this Standard for new facilities, with the following exception. On a case-by-case basis, analyses may be performed to evaluate the need to upgrade existing SSCs (including interfacing SSCs) in accordance with the criteria in this Standard. Sections 9.3 and 9.4 provide the requirements and guidance on the conduct of such analyses. The analyses are required to be submitted to DOE for approval, in the form of a report or a section in the project's Safety Design Strategy (see Section 5 and Appendix G of DOE-STD-1189-2016 for guidance).

9.1.2 For major modifications that involve any new or existing SSCs classified as NDC-3 or higher, site-specific NPH assessments compliant with the relevant site characterization requirements (Sections 3.3, 4.2, 5.2, 7.2, and 8.3) are also applicable. If the facility is located at a site that has site-specific NPH assessments, and the assessments are not overdue for their 20-year reviews, earlier assessments may be used to support the major modification design work. However, if any site-specific assessment is overdue for its 20-year review, the Standard requires that a review, and a possible natural hazard update, be completed prior to finalizing the design inputs for the NDC-3 or higher SSCs. A major modification does not necessarily trigger an NPH assessment review for the facility.

9.1.3 Existing SSCs that do not interface with the major modification are not subject to re-evaluation as part of the modification. However, they are subject to re-evaluation as part of a facility condition assessment triggered by an NPH assessment update.

9.2 PERIODIC REVIEW AND UPDATE OF NPH ASSESSMENTS

9.2.1 NE O 420.1 requires facility or site NPH assessments to be reviewed every 20 years for NDC-3 and greater to identify and address significant changes in NPH data, models, or assessment techniques. If the review concludes that updating or replacing the NPH assessment is warranted, then the updated assessment must be performed following the criteria in this Standard for new facilities. If no update is necessary, then the decision must be justified and submitted to the Safety Basis Approval Authority. For site-specific NPH assessments, the guidelines for performing these periodic reviews begin with Section 9.2.1.2 below.

9.2.1.1 In performing the periodic reviews of the NPH assessments, the following guidelines should be met regarding schedule:

(a) The periodic review should be completed no later than three years after the 20-year mark.

(b) Facility condition assessments (see below), if necessary, should be completed within eighteen months after completion of an updated NPH assessment.

9.2.1.2 Periodic NPH assessment reviews should begin with the following criteria:

(a) Are the changes to data, models, or assessment techniques likely to cause a change in the estimates of the major inputs to hazard calculations?

(b) Given the potential changes to hazard inputs, by what magnitude might the calculated hazard results change, and how might the results affect current facility or site design standards and facility margins to existing hazards?

9.2.1.3 In the case of seismic hazard assessments, a determination of whether an existing assessment remains adequate for future use should consider the criteria in Section 4.2 of NUREG-2213, *Updated Implementation Guidelines for SSHAC Hazard Studies*. This guidance is approved for use at DOE nuclear facilities. It calls for first performing a SSHAC Level 1 seismic hazard study using available information, then comparing the results of that study with the existing assessment to decide whether an updated assessment is necessary. Following these steps is a best practice, but can be expensive and time-consuming. An alternative is to rely on one or more knowledgeable experts to review the existing hazard assessment in light of new seismic data, models, and hazard assessment techniques, and make a judgment on the technical viability of the existing assessment.

9.2.1.4 In addition to the criteria listed in Section 4.2 of NUREG-2213, such as changes to hazard input data, models, and technical bases, a decision on whether to update an NPH assessment should also consider the intended use of the updated assessment results. Such considerations include:

(a) The number of facilities affected by the NPH assessment, and the hazards posed by such facilities.

(b) The life-cycle stages of the facilities affected by the NPH assessment.

(c) Whether the assessment results will be used as design input for any future facilities.

9.3 FACILITY CONDITION ASSESSMENTS

9.3.1 If the revised mean hazard increases by less than one standard deviation, then that particular SSC may be considered acceptable for fulfilling its safety function during the design-basis NPH event. The risk from this minor design shortfall is likely to be small, and modifying the SSC for a small reduction in risk is likely not cost-effective. If demand exceeds capacity by more than 10 percent, additional opportunities for relief may be explored, as discussed below.

9.3.2 If the mean hazard of the updated NPH assessment is within one standard deviation of the mean hazard of the NPH assessment of record, then no further evaluation is required. If an SSC cannot meet this criterion and warrants modification, then the modified design should be based on the design criteria for new SSCs defined in this Standard.

9.3.3 The SSC load capacity evaluations described above shall be submitted to DOE along with a mitigation plan for SSCs found to have an inadequate NPH design. This plan addresses how the inadequacies will be rectified (physical retrofitting versus demonstration of adequacy using more refined analysis methods), and should consider cost-versus-risk reduction of potential improvements, possible time or funding constraints, and programmatic or facility mission. Also, it should incorporate a prioritized schedule for upgrading the SSCs. If a structural upgrade is required for any existing facility that can be performed quickly and inexpensively, it should be implemented. Priorities for upgrading SSCs should be established on the basis of the NDC level, cost of modifying, and margin between as-built SSC capacity and the capacity required by the design criteria in this Standard.

9.3.4 For facilities with a remaining service life of five years or less, it may not be necessary to upgrade the facility SSCs for NPH mitigation, unless the presence of hazardous materials or other special conditions present an exceptionally high risk to co-located workers or the public. For DOE nuclear facilities, the designation of "exceptionally high risk" is based on:

- Hazard category of the facility;
- The percent by which the revised NPH loads exceed those used in the original design;
- The total number of safety SSCs that do not meet the design requirements;
- The dose that a co-located worker and a member of the public may likely receive resulting from the NPH-related failure;
- The number of co-located workers and members of the public that are likely to be adversely affected; and
- Strategic and economic importance of the facility.

9.3.5 The following data and information should be collected to support the evaluation of the existing SSCs:

- The safety basis documentation to identify and list individual SSCs in the safety basis of the facility;
- Identification of the safety function, functional requirements, and NPH performance criteria for each of the SSCs from the safety basis documentation;
- Construction or fabrication of as-built drawings and specifications of the SSCs;
- Data and information from site visits and walk-downs performed to verify that the SSCs are built according to written plans and specifications;
- Modifications not shown on the drawings or physical deteriorations;
- Documents that establish an appropriate determination of material properties to be used in the analyses; and
- Data related to ductile design details that are necessary to evaluate the appropriate inelastic energy absorption factor (F_μ) that can be used for seismic re-evaluation.

Using the above data and information, an evaluation of the SSCs should be performed using the criteria given in this Standard. For SSCs that do not meet the criteria, a revised evaluation should be performed using median values of material properties if median values were not used in the original design (the use of median values of material properties should be obtained, which will allow an estimate of the degree of conservatism in the design if other than median values were used in the original design). Applicable industry practice should be followed in developing sampling criteria to determine median values.

9.3.6 Facilities that are being used beyond their design lives and planned for extended use (beyond five years) should be evaluated for aging-related degradation and their ability to continue to perform their safety functions, in accordance with the steps listed below.

9.3.6.1 DOE O 433.1B (Attachment 2, Section 2.m, "Aging Degradation and Technical Obsolescence") requires nuclear maintenance programs to include a process for conducting inspections of facility SSCs to ensure design features within the safety basis can continue to perform their intended safety functions.

9.3.6.2 Contractors of DOE nuclear facilities are required (by 10 CFR Part 830, Subpart B) to maintain a valid Documented Safety Analysis (DSA); the requirement for a valid DSA includes the assumptions upon which the DSA is based (see DOE-STD-3009-2014, for example, for further discussion). If the facility design life is identified as an explicit assumption in the DSA (e.g., stated in the DSA or supporting design calculations) or an implicit DSA assumption (e.g., a specific lifetime is assumed by a design code that is used in a design calculation that supports a DSA), and the facility is beyond the identified design life, these DSA-related assumptions are required (by 10 CFR Part 830, Subpart B) to be addressed and updated to maintain a valid facility design and safety basis.

9.3.6.3 New natural hazards analyses are considered new regulatory requirements and will not be subject to the Unreviewed Safety Question process.

9.3.6.4 If a facility is being used beyond its identified design life, a comprehensive plan should be developed and implemented to evaluate the performance of safety SSCs, identify any performance gaps in comparison to current codes and standards, assess the impact of such gaps, and either mitigate the impacts or provide technical basis for acceptance. Such evaluations are expected to lead to informed decisions regarding cost-effective facility modifications that will lower the risk of extended use.

9.3.6.5 If facility modifications are needed to support life extension, a review is required (by 10 CFR Part 830, Subpart B, and DOE O 420.1C) to determine whether these changes to the SSCs or the design basis constitute a "major modification." DOE-STD-1189-2016 provides additional information on identifying major modifications and performing design upgrade reviews.

9.4 NPH EVALUATION OF SSCS IN EXISTING HAZARD CATEGORY 1, 2, AND 3 NUCLEAR FACILITIES

9.4.1 Seismic Evaluation

To comply with Public Law 101-614 and EO 13717, the guidelines provided in ICSSC RP-8 should be used to determine when a seismic evaluation and retrofitting of an existing nuclear facility will be necessary, and to establish the evaluation and mitigation requirements.

In addition, general guidelines for the seismic evaluation of existing facilities presented in the following documents should also be considered:

- *Seismic Evaluation and Retrofit of Existing Buildings*, ASCE/SEI 41-13, Structural Engineering Institute of the American Society of Civil Engineers, 2013;
- Seismic Evaluation Procedure for Equipment in U.S. Department of Energy Facilities, DOE-EH-0545, 1997; and
- Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment, Revision 3A, Seismic Qualification Utility Group, 1997.

These documents, and the peer-reviewed consensus documents referenced therein, should be used to develop a plan and criteria document for evaluating seismic adequacy of existing facilities, as well as for specific guidelines on upgrading and retrofitting. The plan should consider cost-versus-risk-reduction and remaining facility life to prioritize detailed and refined seismic evaluation, and upgrading of candidate facilities. High priority should be given to those SSCs identified as weak links by the preliminary investigation and to SSCs that are most important to personnel safety and operations with hazardous materials. Input from safety personnel and from accident analyses should be used as an aid in determining safety priorities.

Once the as-is condition of a facility has been verified and deficiencies or weak links have been identified, detailed seismic evaluation and/or upgrading of the facility should be considered. Obvious deficiencies that can be readily improved should be remedied as soon as possible. A realistic schedule to address all safety-related deficiencies should be developed.

Seismic evaluation for existing facilities would be similar to evaluations performed for new designs except that a single as-is configuration is evaluated instead of several configurations in an iterative manner (as is often required in the design process). The evaluation of existing facilities for seismic hazards can result in a number of options based on the evaluation results. If the existing facility can be shown to meet the design and evaluation criteria presented in Section 3 of this Standard and good seismic design practice had been employed, the facility would be judged to be adequate for potential seismic hazards to which it might be subjected. If the facility does not meet the seismic evaluation criteria of Section 3, an analysis should be conducted to determine appropriate action. Several alternatives may be considered:

- If an existing SSC is close to meeting the criteria, a slight increase in the annual risk to natural phenomena hazards may be allowed within the tolerance of meeting the target performance goals. Note that reduced criteria for seismic evaluation of existing SSCs is supported in IEBC-2024, *International Existing Building Code*, ASCE/SEI 41-13, and ICSSC RP-8. As a result, some relief in the criteria may be allowed by performing the evaluation using higher hazard exceedance probability, as permitted in Section 9.3 above.
- The SSC may be strengthened such that its seismic resistance capacity is sufficiently increased to meet these seismic criteria. When upgrading is required, it should be designed for the current design criteria.
- The usage of the facility may be changed such that it falls within a less hazardous performance category and, consequently, less stringent seismic requirements.
- It may be possible to conduct the aspects of the seismic evaluation in a more rigorous manner that removes conservatism such that the SSC may be shown to be adequate. Alternatively, a probabilistic assessment may be undertaken in order to demonstrate that the performance goals can be met.

9.4.2 Wind Hazard Evaluation

The following guidelines are provided for use in evaluating WDC-1 through WDC-5 SSCs in an existing facility:

9.4.2.1 The key to the evaluation of existing SSCs is to identify potential failure modes and to calculate the minimum wind speed that would cause the postulated failure. A critical failure mechanism could be (a) the failure of the main wind-force resisting system of a structure, (b) a breach of the structure envelope that allows the release of toxic materials to the environment, or (c) a breach which results in wind and water damage to the building contents. Also, in situ strengths of existing structures need to be adequately estimated when required.

9.4.2.2 Experience from wind storm damage investigations provides the best guidelines for anticipating the potential performance of existing SSCs under wind loads. The paper by Mehta et al., “Procedures for Predicting Wind Damage to Buildings,” provides a methodology for estimating the performance of existing SSCs based on identification of weak links in the building structure. The approach is directed primarily to structures, but can be adapted to systems and components as well.

9.4.2.3 The methodology described in Mehta et al. involves two levels of evaluation:

- Level I, which is essentially a screening process, should be performed before proceeding to Level II, which is a detailed evaluation.
- The Level II process includes the following three steps:
  1. Data collection;
  2. Analysis of element failures; and,
  3. Postulation of failure sequence.

9.4.3 Flood Hazard Evaluation

The following guidelines are provided for use in evaluating FDC-1 through FDC-5 SSCs in an existing facility:

9.4.3.1 SSCs in existing facilities may be situated below the DBFL as defined in this Standard. In this case, an evaluation should be performed to determine the level of external flooding, if any, that can be sustained, without negating the SSC functional safety requirements.

9.4.3.2 For each SSC, there is a critical elevation, which, if exceeded, causes damage or disruption such that design safety requirements are not satisfied. This level is referred to as the Critical Flood Elevation (CFE). The CFE may be located:

- Below grade due to the structural flooding vulnerability of exterior walls or instability due to uplift pressures on supporting or enclosing the safety function of the structure;
- At the elevation of utilities that support SSCs; or
- At the actual base elevation of an SSC.

Typically, the first floor-elevation or a below-grade elevation (i.e., foundation level) is assumed to be the critical elevation. However, based on a review of an SSC, it may be determined that greater flood depths will occur to cause safety function failure (e.g., critical equipment or materials may be located above the first floor).

9.4.3.3 If the CFE for an SSC exceeds the DBFL, the design criteria is satisfied. If the CFE is higher than the DBFL, no further evaluation will be necessary. If the CFE does not exceed the DBFL, options should be considered to harden the SSC or relocate it.

9.4.3.4 This situation may not be unique for existing facilities. For new facilities, it may not be possible to situate all facilities above the DBFL, in which case other design strategies should be considered. For example, it may be possible to waterproof an SSC, thus allowing some level of flooding to occur.

9.4.4 Precipitation Hazard Evaluation

The following guidelines are provided for use in evaluating PDC-1 through PDC-5 SSCs in an existing facility:

9.4.4.1 The precipitation evaluations of the SSCs may be performed using the same criteria as for new facilities.

9.4.4.2 For SSCs that are affected by the precipitation evaluations, the following mitigation measures may be considered:

- Modifying roofs to minimize ponding on the roofs, such as removing roof parapets, increasing the size and number of scupper openings in the roof parapets;
- Providing protective shielding structures for critical SSCs to prevent water intrusion from potential roof leaks;
- Relocating critical SSCs away from potential roof leaks;
- Providing protective dikes around the facility;
- Relocating critical SSCs to higher elevations in the facility to protect from precipitation runoff;
- Modifying site grading or provide detention ponds to protect the facility; and
- Implementing emergency operations plans to secure areas where critical SSCs are located.

10.0 QUALITY ASSURANCE, USE OF EXPERTS, AND PEER REVIEW

10.1 Quality Assurance

The activities related to the design, construction, and evaluation of SSCs performance to meet the NPH criteria are done so in accordance with an approved quality assurance program. NE O 414.1 requires that the graded approach be defined and approved by DOE, and that the levels of analyses, documentation, and actions used to meet the requirements are commensurate with the criteria described in the Order. Other grading criteria identified in this Standard may be used as applicable.

In general, the quality assurance (QA) requirements given in the design codes and standards specified elsewhere in this Standard should be used as applicable. For NDC-1 and NDC-2 SSCs in nuclear facilities, the QA requirements specified in IBC-2024 are applicable. For these facilities, if appropriate QA requirements are not specified in IBC-2024, then they should be derived from material and design codes and standards cited elsewhere in this Standard.

For Hazard Category 1, 2, and 3 nuclear facilities, independent peer review shall be conducted for NDC-3 and greater.

10.2 Software Quality Assurance

Software used in the analysis and design of SSCs, whether acquired or developed, should be controlled, and verified and validated prior to use in accordance with the documented QA program. The verification and validation process should ensure that (a) the computer program produces correct solutions for the applied mathematical model within defined limits for parameters of interest, and (b) the mathematical model produces a valid solution for the design components and phenomena being modeled. Verification and validation should be based on a plan that addresses the following, using a graded approach:

(a) Identifies significant features of the program that need to be verified for the project;
(b) Identifies the type of test or benchmark problems that are needed to implement the plan;
(c) Establishes the acceptance limits that computed results could vary from the closed-form results or other verified results;
(d) Includes for validation purposes a full suite of test cases covering all program features used; and
(e) Provides sample problems with verified solutions against which the computer program installation can be validated for each computer on which the program is installed.

Acquired safety software not developed under an approved QA program consistent with the documented QA program for the project shall be subject to a dedication activity to demonstrate that the computer program functions correctly due to its impact on NDC-3 to NDC-5 analyses.

Calculations, including computer-generated ones, should be documented in sufficient detail for a reviewer to determine that the design requirements have been correctly identified and implemented. A graded approach should be applied for the level of detail and rigor in the documentation.

10.3 Use of Experts and Peer Review for Site Characterization

Independent peer review of the site characterization carried out to implement Sections 3 through 8 above shall be performed by a panel of one or more subject matter experts. The independent reviewers shall be separate from those conducting the NDC-3 or greater analysis. The number of independent reviewers utilized shall depend on the complexity and size of the hazard analyses. NDC-1 and 2 analyses that utilize consensus standards, such as the IBC, do not require independent peer review where the design control requirements of the QAP are sufficient to ensure proper design.

11.0 REFERENCES

Executive Orders

EO 11988 (as amended by EO 13690), *Floodplain Management*, 1977.

EO 13690, *Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input*, 2015.

EO 13717, *Establishing a Federal Earthquake Risk Management Standard*, 2016.

Code of Federal Regulations

10 CFR Part 830, *Nuclear Safety Management*.

10 CFR Part 851, *Worker Safety and Health Program.*

29 CFR § 1910.109, *Explosives and Blasting Agents.*

29 CFR § 1910.1200, *Toxic and Hazardous Substances*.

DOE Directives

NE O 414.1, *Quality Assurance*, 2025.

NE O 420.1, *Facility Safety*, 2025.

NE O 458.1, *Radiation Protection of the Public and the Environment*, 2025.

DOE Guides

DOE G 414.1-4, *Safety Software for Use with 10 CFR 830 Subpart A, Quality Assurance Requirements.*

DOE Handbooks

DOE-HDBK-1216-2015, *Environmental Radiological Effluent Monitoring and Environmental Surveillance.*

DOE Technical Standards

NE-STD-1020-2025, *Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities*.

NE-STD-1027-2025, *Hazard Categorization of DOE Nuclear Facilities.*

DOE-STD-1212-2019, *Explosives Safety.*

DOE-STD-3009-2014, *Preparation of Nuclear Facility Documented Safety Analysis.*

Other DOE Documents

DOE/EH-0545, *Seismic Evaluation Procedure for Equipment in U.S. Department of Energy Facilities*, 1997.

American National Standards Institute/American Institute of Steel Construction

ANSI/AISC N690-12, *Specification for Safety-Related Steel Structures for Nuclear Facilities*, 2012.

ANSI/AISC N690-18, *Specification for Safety-Related Steel Structures for Nuclear Facilities*, 2018.

American National Standards Institute/American Nuclear Society

ANSI/ANS-2.3-2011 (R2021), *Estimating Tornado, Hurricane, and Extreme Straight-Line Wind Characteristics at Nuclear Facility Sites*, 2011.

ANSI/ANS-2.26-2004 (R2017), *Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design*, 2004.

ANSI/ANS-2.27-2020 (R2016), *Criteria for Investigation of Nuclear Facility Sites for Seismic Hazard Assessment*, 2008.

ANSI/ANS-2.29-2020, *Probabilistic Seismic Hazards Analysis*, 2020.

ANSI/ANS-2.34-2020, *Characterization and Probabilistic Analysis of Volcanic Hazards*, 2020.

ANSI/ANS-3.11-2015, *Determining Meteorological Information at Nuclear Facility Sites,* 2015.

American Society of Civil Engineers

ANSI/ASCE 1-82, *N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures*, 1988.

Manuals and Reports on Engineering Practice, No. 58, *Structural Analysis and Design of Nuclear Plant Facilities*, 1980.

Report of the ASCE Committee on Impactive and Impulsive Loads, Volume V, Civil Engineering and Nuclear Power, September 1980.

American Society of Mechanical Engineers

ASME NQA-1-2008 with NQA-1a-2009 addenda, *Quality Assurance Requirements for Nuclear Facility Applications*, 2009.

ASME QME-1-2012, *Qualification of Active Mechanical Equipment Used in Nuclear Facilities*, 2012.

National Institute of Standards and Technology Documents

NIST GCR 11-917-12, ICSSC RP-8, *Standards of Seismic Safety for Existing Federally Owned and Leased Buildings*, 2011.

NIST IR 5734, ICSSC RP-5, *ICSSC Guidance on Implementing Executive Order 12941 on Seismic Safety of Existing Federally Owned or Leased Buildings*, 1995.

NIST IR 8458e2022, ICSSC RP 10-22, *ICSSC Guidance on Standards of Seismic Safety for Existing Federally Owned and Leased Buildings*, 2022.

National Fire Protection Association

NFPA 780-2023, *Standard for the Installation of Lightning Protection Systems*, 2017.

Structural Engineering Institute of the American Society of Civil Engineers

ASCE 4-16, *Seismic Analysis of Safety-Related Nuclear Structures*, 2016.

ASCE/SEI 7-22, *Minimum Design Loads for Buildings and Other Structures*, 2022.

ASCE/SEI 41-13, *Seismic Evaluation and Retrofit of Existing Buildings*, 2013.

ASCE/SEI 43-19, *Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities,* 2019.

U.S. Nuclear Regulatory Commission Documents

NRC RIL2021-15, *Documentation Report for SSHAC Level 2: Site Response*, 2015.

NUREG-2117, *Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies*, Rev. 1, 2012.

NUREG/CR-6372, *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts*, 1997.

NUREG/CR-6728, *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-consistent Ground Motion Spectra Guidelines*, 2001.

NUREG/CR-7046 (PNNL-20091), *Design-Basis Flood Estimates for Site Characterization at Nuclear Power Plants in the United States of America*, 2011.

NUREG-0800, Section 2.4.10, Revision 3, *Flooding Protection Requirements*, 2007.

NUREG-0800, Section 2.5.5, Revision 4, *Stability of Slopes*, 2010.

NUREG-0800, Section 3.4.2, Revision 3, *Analysis Procedures*, 2007.

Regulatory Guide 1.117, *Protection Against Extreme Wind Events and Missiles for Nuclear Power Plants,* Revision 2, 2016.

Regulatory Guide 1.76, Rev. 1, *Design Basis Tornado and Tornado Missiles for Nuclear Power Plants*, 2007.

Regulatory Guide 1.102, *Flood Protection for Nuclear Power Plants*, 1976.

Regulatory Guide 1.208, *Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion*, 2006.

Regulatory Guide 1.221, *Design Basis Hurricane and Hurricane Missiles for Nuclear Power Plants*, 2011.

Other Documents

American Concrete Institute, ACI 349-13, *Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary*, 2014.

Conrads, T.J., *Volcano Ashfall Loads for the Hanford Site*, Westinghouse Hanford Company, WHC-SD-GN-ER-30038, Rev. 0, 1996.

Electric Power Research Institute, Technical Report 1012965, *Use of CAV in Determining Effects of Small Magnitude Earthquakes on Seismic Hazard Analyses*, 2005.

FEMA-2015-0006-0357, *Guidelines for Implementing Executive Order 11988, Floodplain Management and EO 13690 Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input*, 2015.

FEMA 547, *Techniques for the Seismic Rehabilitation of Existing Buildings*, 2006.

Hill, B.E., Aspinall, W.P., Connor, C.B., Komorowski, J.-C., and Nakada, S., *Recommendations for Assessing Volcanic Hazards at Sites of Nuclear Installations, in Volcanic and Tectonic Hazard Assessment for Nuclear Facilities*, C.B. Connor, N.A. Chapman, and L.J. Connor, eds., Cambridge University Press, 2009.

Hoblitt, R.P., and Scott, W.E., *Estimate of Tephra Accumulation Probabilities for the U.S. Department of Energy's Hanford Site*, Washington, U.S. Geological Survey Open-File Report 2011-1064, 2011.

IAEA (draft) Safety Guide DS405, *Volcanic Hazards in Site Evaluation for Nuclear Installations*.

IBC-2024, *International Building Code®*, International Code Council, 2024.

IEBC-2024, *International Existing Building Code®*, International Code Council, 2024.

Kennedy, Robert, *A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects, Nuclear Engineering and Design*, Volume 37, North Holland Publishing Company, 1976.

Mastin, L. G., Van Eaton, A., and Schwaiger, H. F., *A Probabilistic Assessment of Tephra-Fall Hazards at Hanford, Washington, from a Future Eruption of Mount St. Helens*, Washington, U.S. Geological Survey Open-File Report 2020-1133, 2020.

Mehta, K. C., McDonald, J. R., and Smith, D. A., *Procedures for Predicting Wind Damage to Buildings*, Journal of the Structural Division, ASCE, Vol. 107, No. 11, 2089-2096, 1981.

Newhall, C.G., and Hoblitt, R.P., *Constructing Event Trees for Volcanic Crises*, Bulletin of Volcanology, v. 64, pp. 3-20, 2002.

Newhall, C.G., and Self, S., *The Volcanic Explosivity (VEI): An Estimate of Explosive Magnitude for Historical Volcanism*, Journal of Geophysical Research, v.87, pp. 1231-1238, 1982.

Public Law 101-614 (as amended), *National Earthquake Hazards Reduction Program Reauthorization Act.*

Seismic Qualification Utility Group, *Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment*, Revision 3A, 1997.

U.S. Geological Survey, *Volcanic Ash and Gas Impacts & Mitigation.* http://volcanoes.usgs.gov/ash/build/index.html, referenced on March 16, 2011.