U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER™ iPWR DESIGN

2.4.6 TSUNAMI HAZARDS

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of issues related to hydrology

Secondary - None

I. AREAS OF REVIEW

In this section of the Design-Specific Review Standard (DSRS), the geophysical and hydraulic phenomena are reviewed to ensure that any potential hazards to the structures, systems, and components (SSCs) important to safety from the effects of tsunami hazards are considered in the plant design.

This section is part of Chapter 2 of the DSRS, which discusses the site characteristics that could affect the safe design and siting of the plant. The staff reviews information presented by the applicant for a design certification (DC), early site permit (ESP), or combined license (COL) concerning hydrologic setting of the site as it relates to SSCs Important to safety. This DSRS section applies to reviews performed for each of these types of applications. These reviews are based on information and analysis presented in the applicant's final safety analysis report (FSAR). The staff's review and findings are described in the appropriate section of the final safety evaluation report (FSER).

The staff's review of the FSAR covers the following specific areas:

1. Historical Tsunami Data. The staff reviews historical tsunami data, including paleotsunami mappings and interpretations, regional records and eyewitness reports, and more recently available tide gauge and real-time bottom pressure gauge data.

2. Design Basis Tsunami. The staff reviews the design basis tsunami[1] (DBT) that may pose hazards to the site. The staff also reviews tsunamigenic sources mechanisms, source parameters, propagation models, and near-shore inundation models. The staff's review of DBT will include the following topics:

   A. Potential tsunamigenic sources, both near and far field

[1] The DBT is defined as that tsunami for which the impact at the site is derived from the use of best available scientific information to arrive at a set of scenarios reasonably expected to affect the nuclear power plant site taking into account (a) appropriate consideration of the most severe of the natural phenomena that have been historically reported or determined from geological and physical data for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (b) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (c) the importance of the safety functions to be performed.

ADAMS Accession No. ML12221A028

B. Tsunamigenic source mechanisms including earthquakes, submarine and subaerial landslides, and volcanoes

C. Characteristics of tsunamigenic sources

i. Earthquake source parameters, including magnitude, focal depth, fault dimension and orientation, and displacement; volume and dynamics of landslides; volcanic explosions and resulting pyroclastic flows, caldera collapses and flank failures; etc.

ii. Efficiency of transfer of tsunamigenic source energy into wave energy

iii. Maximum initial displacement of water surface

D. Propagation of tsunami waves

i. Propagation in deep waters (linear wave dynamics)

ii. Propagation in shallow waters (nonlinear wave dynamics)

3. Tsunami Propagation Models

A. The staff reviews tsunami wave propagation models and model parameters used to simulate the tsunami wave propagation from the source towards the site.

B. The staff reviews input data, including bathymetry and topography data, used in tsunami wave propagation models.

4. Wave Travel Time, Runup, Inundation, and Drawdown. The staff reviews wave travel time. The staff also reviews extents and durations of wave runup and drawdown during the inundation and recession phases of the DBT event, respectively.

5. Static and Dynamic Hydraulic Forces. The staff reviews all plausible static and dynamic hydraulic force metrics (hydrostatic, buoyant, hydrodynamic drag, surge, wave-breaking), including the inundation and drawdown depths, current speed and direction, acceleration, inertial component, momentum flux, and water-borne debris that quantify the forces on any SSCs important to safety that may be exposed to the listed hazards from the tsunami waves.

6. Debris and Water-Borne Projectiles. The staff reviews the debris and water-borne projectiles that accompany tsunami currents and may impact SSCs important to safety.

7. Effects of Debris, Sediment Erosion and Deposition on Loss of Function of SSCs Important to Safety. The staff reviews the effects of debris, sediment erosion and deposition caused by tsunami waves that may result in blockage or loss of function of SSCs important to safety.

8. Consideration of Other Site-Related Evaluation Criteria. The staff reviews the potential effects of seismic (including the effects of possible land subsidence) and non-seismic information on the postulated design bases and how they relate to tsunami in the vicinity of the site and the site region.

9. Additional Information for Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52 Applications. The staff reviews additional information that will be presented depending on the type of application. For a COL application, the need for additional information depends on whether the application references an ESP, a DC, both, or neither. Information requirements are prescribed within the "Contents of Application" sections of the applicable subparts to 10 CFR Part 52.

Review Interfaces

Other DSRS and Standard Review Plan (SRP) sections interface with this section as follows:

1. Sections 2.4.0, 2.4.2 – 2.4.5 and 2.4.7 – 2.4.9 address the flood-producing phenomena individually and in combination to determine the design-basis flood.

2. The seismic design basis that includes seismically-induced land subsidence information is performed under SRP Section 2.5.1, "Basic Geologic and Seismic Information."

3. The analysis procedures that are utilized to transform the static and dynamic hydraulic forces (hydrodynamic forces, surge force, and impact forces from debris and projectiles) of the flood and tsunami into effective loads applied to seismic Category I structures are reviewed in DSRS 3.4.2, "Analysis Procedures."

4. The review to ensure that adverse environmental conditions, including those from loss of water due to drawdown during the receding tsunami waves, seiching induced by tsunami, or blockage from sedimentation, will not preclude the safety function of the ultimate heat sink is performed under DSRS Section 9.2.5, "Ultimate Heat Sink."

5. The organization responsible for the review of issues related to seismology provides information regarding the seismic displacement that may result in tsunami or tsunami-like waves.

6. For DC applications and COL applications referencing a DC rule or DC application, review of the site parameters in the Design Control Document (DCD) Tier 1 and Chapter 2 of the DCD Tier 2[2] submitted by the applicant is performed under SRP Section 2.0, "Site Characteristics and Site Parameters." Review of site characteristics and site-related design parameters in ESP applications or in COL applications referencing an ESP is also performed under SRP Section 2.0.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. 10 CFR Part 100, as it relates to identifying and evaluating hydrologic features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.20(c).

[2] Additional supporting information of prior DC rules may be found in DCD Tier 2 Section 14.3.

2. 10 CFR 100.23(d) sets forth the criteria to determine the siting factors for plant design bases with respect to seismically induced floods and water waves at the site.

3. 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2 as it relates to consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

4. 10 CFR 52.17(a)(1)(vi), for ESP applications, and 10 CFR 52.79(a)(1)(iii), for COL applications, as they relate to identifying hydrologic site characteristics with appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding areas and with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are set forth below. The DSRS is not a substitute for the NRC's regulations, and compliance with it is not required. Identifying the differences between this DSRS section and the design features, analytical techniques, and procedural measures proposed for the facility, and discussing how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria, is sufficient to meet the intent of 10 CFR 52.47(a)(9), "Contents of applications; technical information." The same approach may be used to meet the requirements of 10 CFR 52.17(a)(1)(xii) and 10 CFR 52.79(a)(41), for ESP and COL applications, respectively.

Appropriate sections of the following Regulatory Guides (RGs) are used by the staff for the identified acceptance criteria:

RG 1.27 describes the applicable ultimate heat sink capabilities.

RG 1.29 identifies seismic design bases for safety-related SSCs.

RG 1.59 (1977), as supplemented by best current practices, provides guidance for developing the flood design bases. RG 1.59 is currently being updated and will include guidance on tsunami hazard assessments.

RG 1.102 describes acceptable flood protection to prevent the SSCs important to safety from being adversely affected.

RG 1.206, Section C.I.2.4.6 provides general guidance for estimating flooding due to tsunami hazards.

JLD-ISG-2012-06 provides guidance for performing surge, seiche and tsunami hazard assessments for flooding, when necessary.

Historical Tsunami Data. The application should provide a complete description of historical tsunami data near the proposed plant site. This description should be sufficient to establish the history of tsunamis and tsunami-like waves in the vicinity of the site.

1. Design Basis Tsunami. The application should provide an assessment of the DBT for the proposed site. The DBT assessment should include a review of tsunamigenic sources from historical, geological, and physical data, both near and far field, relevant to the proposed plant site. If no tsunami hazard exists for the proposed site, it should be so stated with justification based on the history and location of the proposed site.

   The tsunamigenic sources in this review should include earthquakes, submarine and sub-aerial landslides, and volcanoes. The characteristics of tsunamigenic sources should be described including parameter values associated with the DBT. The results from numerical simulations of DBT waves towards the proposed site should be provided. This simulation should use shallow water wave approximation where appropriate, and use nonlinear wave dynamics where the approximation is not valid.

2. Tsunami Propagation Models. The application should provide a description of the tsunami wave propagation models used in the applicant's FSAR. The parameters used in the DBT wave propagation simulations should be listed and discussed with respect to their conservativeness. A discussion of all data used to input the tsunami wave propagation models should also be included.

3. Wave Travel Time, Runup, Inundation, and Drawdown. The application should provide the wave travel time, extents and durations of inundation and drawdown near the proposed site. The methods and models used to simulate wave propagation, inundation, and drawdown caused by the DBT should be described. The parameters used in the simulation of wave propagation, inundation, and drawdown should be discussed with respect to their conservativeness. The minimum wave travel time, maximum extents, and the longest durations of inundation and drawdown should be provided. These effects should be considered in establishing the design bases of the affected SSCs important to safety.

4. Static and Dynamic Hydraulic Forces. The application should provide a set of metrics that describes all plausible static and dynamic hydraulic forces caused by the DBT on the SSCs important to safety. This set should include the inundation and drawdown depths, current speed and direction, acceleration, inertial component, momentum flux, and water-borne debris near the proposed locations of SSCs important to safety. These effects should be considered in establishing the design bases of the affected SSCs important to safety.

5. Debris and Water-Borne Projectiles. The application should provide an assessment of the debris and water-borne projectiles that may accompany DBT currents. An assessment of the hazard posed by the debris and projectiles on SSCs important to safety should be provided. These effects should be considered in establishing the design bases of the affected SSCs important to safety.

6. Effects of Debris, Sediment Erosion and Deposition on Loss of Function of SSCs Important to Safety. The application should provide an assessment of the effects of debris, sediment erosion and deposition at the subsurface SSCs important to safety, dewatering systems related to SSCs important to safety, and/or near the proposed locations of SSCs important to safety. A description and an estimate of these effects on the design bases of SSCs important to safety should be provided. These effects should be considered in establishing the design bases of the affected SSCs important to safety.

7. Consideration of Other Site-Related Evaluation Criteria. The application should provide an evaluation of the potential effects of site-related proximity, seismic (including the effects of possible land subsidence), and non-seismic information as they affect tsunamis near the plant site and site regions. This assessment should be sufficient to demonstrate that the applicant's design bases appropriately account for these effects.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. Pursuant to GDC 2, nuclear power plant SSCs important to safety must be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their safety functions. The criterion further specifies that the design bases for these SSCs shall reflect the following:

   A. Appropriate consideration of the most severe natural phenomena historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and time period in which the historical data have been accumulated;

   B. Appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena; and

   C. The importance of the safety functions to be performed.

   The first specification was adopted in recognition of the relatively short history available for severe natural phenomena (e.g., tsunami) on the North American continent and, when based on probabilistic considerations only, the potential for underestimating the severity of such events. This problem can be avoided by using a deterministic approach to assess design basis events. Such an approach will account for the practical physical limitations of natural phenomena at a proposed site that contribute to the severity of a given event.

   This criterion is relevant to DSRS Section 2.4.6 in that it specifies the hydrologic phenomenon (i.e., tsunami) addressed in this section for the particular site. In general terms, it also specifies the level of conservatism that should be used to assess the severity of tsunami hazards for the purpose of determining the design bases for SSCs important to safety. This is a similar standard to that applied in reviewing ESP or COL applications for hydrologic site characteristics.

   For applications pursuant to 10 CFR Part 50, meeting the applicable requirements of GDC 2 provides a level of assurance that the design bases of SSCs important to safety will reflect appropriate consideration of the most severe hazards likely to occur as a result of tsunamis; the adequacy of these design bases will be evaluated pursuant to other DSRS sections.

   For applications pursuant to 10 CFR Part 52, meeting the applicable requirements of 10 CFR 52.17 and 10 CFR 52.79 that correspond to GDC 2 provides a level of assurance that the most severe hazards likely to occur as a result of tsunamis have

been identified; whether GDC 2 is met with respect to the adequacy of the associated design bases will be evaluated pursuant to other DSRS sections.

2. Section 100.20(c) of 10 CFR Part 100 requires that physical characteristics of a site (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor.

   To satisfy the hydrologic requirements of 10 CFR Part 100, the applicant's FSAR should contain a description of the hydrogeologic and seismic characteristics of the region and an analysis of the potential hazard due to tsunami. This description should be sufficient to assess the acceptability of the site and the potential for a tsunami to influence the design of plant SSCs important to safety.

   Meeting the requirements of Section 100.20(c) provides a level of assurance that physical characteristics of the site with respect to seismology and hydrology have been considered appropriately in determining the acceptability of the site; the adequacy of the associated plant design bases will be evaluated pursuant to other DSRS sections[3].

III. REVIEW PROCEDURES

The procedures outlined below are used to review ESP applications and COL applications that do not reference an ESP to determine whether data and analyses for the proposed site meet the acceptance criteria given in Subsection II of this DSRS section. As applicable, reviews of COLs include a determination on whether the content of technical specifications related to is acceptable and whether the technical specifications reflect consideration of any identified unique conditions.

These review procedures are based on identified DSRS acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

1. In accordance with 10 CFR 52.47(a)(8),(21), and (22), for new reactor license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues (USIs) and medium- and high-priority generic safety issues (GSIs) that are identified in the version of NUREG-0933 current on the date 6 months before application and that are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding FSER section.

2. Historical Tsunami Data. The staff reviews historical tsunami data, including paleotsunami data, to determine the vulnerability of a proposed site to this phenomenon. Historical data may help in establishing the frequency of occurrence and other useful indicators such as the maximum observed runup height.

3 As and when it becomes available, additional guidance related to tsunami hazard analysis is to be used

The National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Center (NGDC) collects and archives information on tsunami sources and effects to support tsunami modeling and engineering. The NGDC database contains historical as well as paleotsunami data. The NGDC data, relevant to the proposed plant site, should be used to describe the history of tsunamis at the site. Paleotsunami data should also be included in this description. Other sources of historical data, especially international sources that are relevant for proposed plant sites exposed to far-field trans-oceanic tsunamis, should also be investigated. The historical data and reference information can be found in NUREG/CR-6966[4].

The staff reviews the historical and paleotsunami data for their completeness and relevance to the proposed plant site.

3. Design Basis Tsunami. The staff reviews the DBT with respect to both far- and near-source mechanisms, characteristics of these source mechanisms, and simulation of the wave propagating towards the proposed plant site. The staff uses a deterministic screening approach that consists of a series of progressively refined methods that utilize increasingly detailed site-specific data to demonstrate whether the site is protected from the hazards of severe floods. This approach is described in the hierarchical hazard assessment (HHA) approach presented in NUREG/CR-7046. Multiple conceptual models should be established for conservative evaluation of tsunami propagation models. Methods for estimating the DBT are described in NUREG/CR-6966.

   Probabilistic tsunami hazard assessment (PTHA) combines deterministic hydrodynamic ocean wave and source generation models and probabilistic methods. The NRC will accept PTHA and deterministic approaches for tsunami hazard evaluations and continues to conduct cooperative research in this area with United States Geological Survey (USGS) and NOAA (Gonzalez et al., 2009; Geist and Parsons, 2006; ten Brink et al., 2009).

   A regional assessment of tsunamigenic sources should be carried out to determine the sources that may generate a DBT at the proposed plant site. The source mechanisms considered in this assessment should include earthquakes, submarine and subaerial landslides, and volcanoes. The characteristics of the sources that are used for the specification of the DBT should be conservative, e.g., supplemented by a larger regional or global earthquake size distribution to account for the limited period of historical records. The landslide sources should be characterized using the maximum volume parameter determined from seafloor mappings or geologic age dating of the historical landslides. A slope-stability analysis should be performed to assess the potential tsunami generation efficiency of the candidate landslides. The tsunamigenic source types caused by volcanic activity considered in the DBT assessment should include pyroclastic flows, submarine caldera collapse, explosions, and debris avalanches or flank failures.

   The staff reviews the initial displacement of the water surface that subsequently causes the radiating tsunami waves. The initial displacement of the water surface should be estimated conservatively.

   The staff reviews propagation of the DBT waves from the source towards the proposed site. If appropriate, the shallow water wave approximation should be used to simulate

[4] DBT was referred to as Probable Maximum Tsunami (PMT) in NUREG/CR 6966

propagation of the DBT waves in deep waters. The simulation of the propagation of the DBT waves in shallower waters, where the shallow water wave approximation is not valid, should use nonlinear wave dynamics approaches.

4. Tsunami Propagation Models. The staff reviews the computational models used in the DBT hazard analysis. Tsunami propagation models should be used, such as those used by NOAA that are published in peer-reviewed literature and are verified using extensive testing.

   The staff reviews the model parameters and the input data used to simulate the propagation of the DBT waves towards the site. The model parameters should be described and their conservative values should be chosen. All other data used for model input should be described and their respective sources noted. Usually bathymetry and topography data archived and maintained by NOAA/NGDC, the USGS, and the U.S. Army Corps of Engineers are sufficient.

5. Wave Travel Time, Runup, Inundation, and Drawdown. The staff reviews the wave travel time from the source to the plant site caused by the DBT. Conservative assumptions for choices of parameter values that affect the calculation should be made. The minimum travel time is used for implementation of emergency procedures required for adequate flood protection.

   NOAA tsunami warning center maintains a tsunami monitoring system in the Pacific Ocean. The staff also review the minimum response time (wave travel time from the monitoring station to the site) after a warning is issued by the tsunami warning center.

   The staff reviews the wave runup caused by the DBT. A conservative initial water surface elevation for the body of water under consideration, before the arrival of the tsunami waves, should be assumed, similar to that recommended for storm surges and seiches by ANSI/ANS-2.8-1992. For example, to estimate the highest tsunami wave runup at a coastal site, the 90th percentile of high tides may be used as the initial water surface elevation near the site; to estimate the lowest drawdown caused by receding tsunami waves at the same site, the 10th percentile of the low tides may be used as the initial water surface elevation. The initial water surface elevation should take into account future sea-level change based on the current understanding of sea level rise (SLR) processes and the scientific data used to arrive at that understanding.

   The staff reviews the extent of the inundation caused by the tsunami waves at the proposed plant site. The inundation may lead to flooding and should be considered in flooding design bases for the SSCs important to safety. The flooding due to the inundation caused by the tsunami waves may also necessitate flooding protection for some SSCs important to safety. The staff also reviews the duration of the inundation caused by the tsunami waves to estimate the time during which the SSCs important to safety may be affected.

   The staff reviews the effect of the drawdown caused by the tsunami waves and how it may affect the safety-related intakes, if they are used in the plant design and are exposed to the effects of the tsunami. The staff also reviews the duration of the drawdown caused by the tsunami waves to estimate the time during which a safety-related intake may be affected. The suggested criteria of RG 1.27 apply when the water supply comprises part of the ultimate heat sink.

It should be demonstrated that the extent and the duration of the inundation and the drawdown caused by the tsunami waves are adequately established for the purposes of the plant design bases.

6. Static and Dynamic Hydraulic Forces. The staff reviews all plausible static and dynamic hydraulic forces (hydrostatic, buoyant, hydrodynamic drag, surge, and wave-breaking) on the SSCs important to safety caused by the tsunami waves. Because the tsunami occurs as a train of waves, several incoming and receding wave cycles should be considered. Local geometry and bathymetry can significantly affect the height, velocity, and momentum flux near the locations of the SSCs important to safety. Criteria and methods of the Federal Emergency Management Agency (FEMA), as generally summarized in FEMA Coastal Construction Manual (FEMA 55), can be used as a standard to evaluate the applicant's estimate of forces caused by a tsunami. Particularly, surge forces caused by the leading edge of a tsunami impacting a structure and debris impact force (e.g., floating drift wood, lumber boats, automobiles, buildings) should be adequately considered that can be potentially a dominant cause of structural damage. Detailed analysis of debris and projectile impact forces structures important to safety should be reviewed in the DSRS 3.4.2 "Analysis Procedures." Conservative assumptions for parameter values that affect the calculation should be made. The suggested criteria of RG 1.27 apply when the water supply comprises part of the ultimate heat sink.

   It should be demonstrated that all plausible static and dynamic hydraulic forces caused by the tsunami waves are adequately established for the purposes of the plant design bases.

7. Debris and Water-Borne Projectiles. The staff reviews the likelihood of debris and water-borne projectiles carried along with the tsunami currents and their ability to cause damage to the SSCs important to safety. The suggested criteria of RG 1.27 apply when the water supply comprises part of the ultimate heat sink. It should be demonstrated that any possibility of damage to the SSCs important to safety from debris and water-borne projectiles is adequately established for the purposes of the plant design bases.

8. Effects of Debris, Sediment Erosion and Deposition on Loss of Function of SSCs Important to Safety. The staff reviews the debris and sediment deposition during the tsunami, as well as the erosion caused by the various turbulent forces and structural failures due to high velocity of flood waters, surge, and debris impact, and/or wave action during the tsunami and its effect on foundations of and subsurface SSCs important to safety, and dewatering system important to SSCs important to safety, if applicable, to ensure that these are adequately established for the purposes of the plant design bases. Any potential erosion and sediment deposition should not affect functioning of the exposed SSCs important to safety. The suggested criteria of RG 1.27 apply when the water supply comprises part of the ultimate heat sink.

9. Consideration of Other Site-Related Evaluation Criteria. Subpart B of 10 CFR Part 100 describes site-related proximity, seismic (including the effects of possible land subsidence), and non-seismic evaluation criteria for power reactor applications. The staff's review will include evaluation of pertinent information to determine if these criteria are appropriately used in postulation of worst-case tsunami scenarios.

10. Review Procedures Specific to 10 CFR Part 52 Application Types

A. ESP Reviews. Subpart A to 10 CFR Part 52 specifies the requirements and procedures applicable to the Commission's issuance of ESPs for approval of a proposed site. Information required for an ESP includes a description of the characteristics of the proposed site. For an ESP, the scope and level of detail for reviewing data parallel those used for a COL review.

In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the ESP at the COL stage. Accordingly, the reviewer should ensure that all physical attributes of the site that could affect the design basis of SSCs important to safety are reflected in the site characteristics, design parameters, or terms and conditions of the ESP. The reviewer verifies that:

B. Standard DC Reviews. Applications for DC do not contain general descriptions of site characteristics because this information is site-specific and will be addressed by the COL applicant. However, pursuant to 10 CFR 52.47(a)(1), a DC applicant must provide site parameters postulated for the design. Site parameters associated with this DSRS section are reviewed, as applicable, to verify that:

i. The postulated site parameters are representative of a reasonable number of sites that have been or may be considered for a COL application;

ii. The appropriate site parameters are included as Tier 1 information. This convention has been used by previous DC applicants. Additional guidance on site parameters is provided in SRP Section 2.0;

iii. Pertinent parameters are stated in a site parameters summary table; and

iv. The applicant has provided a basis for each of the site parameters.

C. COL Reviews. For a COL application referencing a certified standard design, the NRC staff reviews that application to ensure sufficient information was presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule. If there are site parameters associated with this DSRS section and if the above condition for these parameters has not been met (i.e. the actual site characteristics do not fall within the certified standard design site parameters), the COL applicant will need to demonstrate by some other means that the proposed facility is acceptable at the proposed site. This might be done by re-analyzing or designing the proposed facility.

For a COL application referencing an ESP, NRC staff reviews the application to ensure the applicant provided sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the ESP as applicable to this DSRS section. In accordance with 10 CFR 52.79(b)(2), should the design of the facility not fall within the site characteristics and design parameters, the application shall include a request for

a variance from the ESP that complies with the requirements of 10 CFR 52.39 and 10 CFR 52.93.

In addition, long-term environmental changes and changes to the region resulting from human or natural causes may have introduced changes to the site characteristics that could be relevant to the design basis. In the absence of certain circumstances, such as a compliance or adequate protection issue, 10 CFR 52.39 precludes the staff from imposing new site characteristics, design parameters, or terms and conditions on the ESP at the COL stage. Consequently, a COL application referencing an ESP need not include a re-investigation of the site characteristics that have previously been accepted in the referenced ESP. However, in accordance with 10 CFR 52.6, "Completeness and Accuracy of Information," the applicant or licensee is responsible for identifying changes of which it is aware, that would satisfy the criteria specified in 10 CFR 52.39. Information provided by the applicant in accordance with 10 CFR 52.6(b) will be addressed by the staff during the review of a COL application referencing an ESP or a DC.

For a COL application referencing either an ESP or DC or both, the staff should review the corresponding sections of the ESP and DC FSER to ensure that any ESP conditions, restrictions to the DC, or COL action items identified in the FSERs are appropriately handled in the COL application.

For a COL application referencing either an ESP or DC or both, the staff has issued additional guidance for review of COL items that cannot be resolved prior to issuance of the license in Interim Staff Guidance 015 (ISG-015). A COL applicant must provide all information in the COL application that is necessary for the staff to make the findings required to issue the license. Therefore, it may be necessary for the staff to partially close certain COL action or information items noted in an ESP or a DC, or both. The staff should identify the remaining portion of the COL items associated with information that is not necessary to issue the license as post-licensing commitments.

IV. EVALUATION FINDINGS

The review should document the staff's evaluation of site characteristics with regard to the relevant regulatory criteria. The evaluation should support the staff's conclusions as to whether the regulations are met. The reviewer should state what was done to evaluate the applicant's FSAR. The staff's evaluation may include verification that the applicant followed applicable regulatory guidance, performance of independent calculations, and/or validation of appropriate assumptions. The reviewer may state that certain information provided by the applicant was not considered essential to the staff's review and was not reviewed by the staff. While the reviewer may summarize or quote the information offered by the applicant in support of its application, the reviewer should clearly articulate the bases for the staff's conclusions.

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's FSER. The reviewer also states the bases for those conclusions.

1. COL Reviews

The following statements in the FSER should be preceded by a summary of the site characteristics and parameters used for the plant:

> As set forth above, the applicant has presented and substantiated information relative to the effects of tsunami hazards important to the design and siting of this plant. The staff has reviewed the available information provided and, for the reasons given above, concludes that the identification and consideration of the effects of tsunami hazards at the site and in the surrounding area are acceptable and meet the relevant requirements of 10 CFR Part 100.20(c) and [10 CFR Part 50, Appendix A, GDC 2] [or] 10 CFR 52.79]], with respect to determining the acceptability of the site.
>
> The staff finds that the applicant has considered the appropriate site phenomena for establishing the design bases for SSCs important to safety. The staff has generally accepted the methodologies used to determine the effects of tsunami hazards reflected in these site characteristics, as documented in FSERs for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing margin sufficient for the limited accuracy, quantity, and period of time in which the data have been accumulated. The staff concludes that the identified site characteristics meet the relevant requirement(s) of 10 CFR Part 100.10(c) [or 10 CFR Part 100.20(c)] and [10 CFR Part 50, Appendix A, GDC 2] [or] 10 CFR 52.79]], with respect to establishing the design basis for SSCs important to safety.

2. ESP Reviews

The following statements in the FSER should be preceded by a summary of the site characteristics and design parameters to be included in any ESP that might be issued for the proposed site:

> As set forth above, the applicant has presented and substantiated sufficient information pertaining to the effects of tsunami hazards at the proposed site. Section 2.4.6, "Tsunami Hazards," of the Design-Specific Review Standard for mPower™ Integral Pressurized Water Reactor (iPWR) Design, provides that the site FSAR should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the effects of tsunami hazards. Further, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the tsunami hazards, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. The staff has generally accepted the methodologies used to determine the severity of the phenomena reflected in these site characteristics, as documented in FSERs for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in site characteristics containing sufficient margin for the limited accuracy, quantity, and period of time in which the data have been accumulated. In view of the above, the site characteristics previously identified are acceptable for use in establishing the design bases for SSCs important to safety, as may be proposed in a COL application.
>
> Therefore, the staff concludes that the identification and consideration of the tsunami hazards site characteristics set forth above are acceptable and meet the requirements of 10 CFR 52.17(a)(1)(vi), 10 CFR 100.20(c), and 10 CFR 100.21(d).

In view of the above, the staff finds the applicant's proposed site characteristics related to tsunami hazards for inclusion in an ESP for the applicant's site, should one be issued, to be acceptable.

3. DC Reviews

The following statement in the FSER should be preceded by a list of the applicable site parameters used for the plant:

> The NRC staff acknowledges that the applicant has selected the site parameters referenced above for plant design inputs (a subset of which is included as Tier 1 information), and agrees that they are representative of a reasonable number of sites that have been or may be considered for a COL application. Tsunami hazards are site-specific and will be addressed by the COL applicant. This should include the provision of information sufficient to demonstrate that the design of the plant falls within the site parameters specified by the siting review.

V. IMPLEMENTATION

The staff will use this DSRS section in performing FSERs of mPower™-specific DC, COL, or ESP applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations.

Because of the numerous design differences between the mPower™ and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML102510405), to develop risk-informed licensing review plans for each of the small modular reactor (SMR) reviews including the associated pre-application activities, the staff has developed the content of this DSRS section as an alternative method for mPower™-specific DC, COL, or ESP applications submitted pursuant to 10 CFR Part 52 to comply with 10 CFR 52.47(a)(9), "Contents of applications; technical information."

This regulation states, in part, that the application must contain "an evaluation of the standard plant design against the SRP revision in effect 6 months before the docket date of the application." The content of this DSRS section has been accepted as an alternative method for complying with 10 CFR 52.47(a)(9) as long as the mPower™ DCD FSAR does not deviate significantly from the design assumptions made by the NRC staff while preparing this DSRS section. The application must identify and describe all differences between the standard plant design and this DSRS section, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria. If the design assumptions in the DC application deviate significantly from the DSRS, the staff will use the SRP as specified in 10 CFR 52.47 (a)(9). Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design assumptions. The same approach may be used to meet the requirements of 10 CFR 52.17 (a)(1)(xii) and 10 CFR 52.79 (a)(41), for ESP and COL applications, respectively.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 2, “Design Bases for Protection Against Natural Phenomena.”

2. 10 CFR Part 50, Appendix A, GDC 44, “Cooling Water.”

3. 10 CFR Part 52, “Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants.”

4. 10 CFR Part 100, “Reactor Site Criteria.”

5. ANSI/ANS-2.8-1992, “Determining Design Basis Flooding at Power Reactor Sites.” Historical Technical Reference.

6. B. F. Atwater, S. Musumi-Rokkaku, K. Satake, Y. Tsuji, K. Ueda, and D.K. Yamaguchi, “The Orphan Tsunami of 1700: Japanese Clues to a Parent Earthquake in North America,” the United States Geological Survey and the University of Washington Press, 2005.

7. B. W. Wilson, “Earthquake Occurrence and Effects in Ocean Areas (U),” Technical Report 69.027, U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, February 1969.

8. B. W. Wilson and A. Trum, “The Tsunami of the Alaskan Earthquake, 1964: Engineering Evaluation, ” Tech. Memo No. 25, Corps of Engineers Coastal Engineering Research Center (1968).

9. C. B. Vreugdenhil, “Numerical Methods for Shallow-Water Flow,” Kluwer Academic Publishers, Norwell, Mass., 1994.

10. C. L. Mader, “Numerical Simulation of Tsunamis,” Hawaii Institute of Geophysics and National Oceanic and Atmospheric Administration, February 1973.

11. C. L. Mader, “Numerical Modeling of Water Waves,” Second Edition, CRC Press, Boca Raton, Florida, 2004.

12. “Coastal Engineering Manual,” Report Number EM 1110-2-1100, U.S. Army Corps of Engineers, Coastal and Hydraulics Laboratory - Engineer Research and Development Center, Waterways Experiment Station - Vicksburg, Mississippi (2006).

13. “Coastal Construction Manual,” Report Number FEMA 55, Federal Emergency Management Agency, Jessup, MD, 2003.

14. Final Interim Staff Guidance ESP/DC/COL-ISG-015, "Post-Combined License Commitments." January 21, 2010. Accession Number: ML093561416.

15. Geist, E.L. and T. Parsons, 2006, “Probabilistic analysis of tsunami hazards,” *Natural Hazards* (2006) 37: 277-314.

16. Gonzalez, F.I., et al., 2009, Probabilistic tsunami hazard assessment at Seaside, Oregon, for near- and far-field seismic sources, *Journal of Geophysical Research*, 114,

C11023, doi:10.1029/2008JC005132)

17. J.C. Borrero, J. F. Dolan, and C. E. Synolakis, “Tsunamis Within the Eastern Santa Barbara Channel,” Geophysical Research Letters, Vol. 0, No. 0, Pages 0-0, M o, 2000, American Geophysical Union.

18. K. Satake, Ed., “Tsunamis: Case Studies and Recent Developments,” Springer, Dordrecht, The Netherlands, 2005.

19. Kammerer A., U. ten Brink, V. Titov, 2008, “Overview of the U.S. Nuclear Regulatory Commission Collaborative Research Program to Assess Tsunami Hazard for Nuclear Power Plants on the Atlantic and Gulf Coasts,” Proceedings of the 14th World Conference on Earthquake Engineering, Beijing China, October 2008.

20. Kammerer A., U. ten Brink, D. Twichell, E. Geist, J. Chaytor, J. Locat, H. Lee, B. Buczkowski, and M. Sansoucy, 2008, “Preliminary Results of the U.S. NRC Collaborative Research Program to Assess Tsunami Hazard for Nuclear Power Plants on the Atlantic and Gulf Coasts,” Proceedings of the 14th World Conference on Earthquake Engineering, Beijing China, October 2008.

21. National Oceanic and Atmospheric Administration, Nautical Charts.

22. National Oceanic and Atmospheric Administration (NOAA), 2007a, NOAA Technical Memorandum OAR PMEL-135, by Gonzalez, F.I., E. Bernard, U. Kanoglu, C.E. Synolakis, and V.V. Titov, “Standards, Criteria, and Procedures for NOAA Evaluation of Tsunami Numerical Models,” Pacific Marine Environmental Laboratory, Seattle, WA.

23. NOAA, 2007b, NOAA Technical Memorandum OAR PMEL-136, by Gonzalez, F.I., E. Bernard, P. Dunbar, E. Geist, B. Jaffe, U. Kanoglu, J. Locat, H. Mofjeld, A. Moore, C. Synolakis, and V. Titov, “Scientific and Technical Issues in Tsunami Hazard Assessment of Nuclear Power Plant Sites,” Pacific Marine Environmental Laboratory, Seattle, WA.

24. Prasad, Rajiv, “Tsunami Hazard Assessment at Nuclear Power Plant Sites in the United States of America,” NUREG/CR-6966, USNRC .

25. RG 1.27, “Ultimate Heat Sink for Nuclear Power Plants.”

26. RG 1.29, “Seismic Design Classification.”

27. RG 1.59, “Design Basis Floods for Nuclear Power Plants.”

28. RG 1.70, “Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants.”

29. RG 1.102, “Flood Protection for Nuclear Power Plants.”

30. RG 1.125, “Physical Models for Design and Operation of Hydraulic Structures and Systems for Nuclear Power Plants.”

31. RG 1.206, “Combined License Applications for Nuclear Power Plants.” (LWR Edition)

32. Ten Brink, U., et al., 2009, “Evaluation of Tsunami Sources with the Potential to Impact the U.S. Atlantic and Gulf Coasts: *USGS Administrative Report to the U.S. Nuclear Regulatory Commission*, U.S. Geological Survey.

33. Ten Brink, U. (Editor), 2009, Special Issue: “Tsunami hazard along the U.S. Atlantic coast,” *Marine Geology*, Volume 264, Issues 1-2.