

# Proposed - For Interim Use and Comment



## U.S. NUCLEAR REGULATORY COMMISSION **DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER™ iPWR DESIGN**

### 2.4.3 PROBABLE MAXIMUM FLOOD (PMF) ON STREAMS AND RIVERS

#### 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 hydrologic and hydraulic design basis is developed to ensure that any potential hazard to the structures, systems, and components (SSCs) important to safety from a PMF on streams and rivers are considered in 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 U.S. Nuclear Regulatory Commission (NRC) 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 they relate 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 safety evaluation report (SER).

The specific areas of review are as follows:

1. Design Bases for Flooding in Streams and Rivers
  - A. Applicable drainage area for flooding in streams and rivers adjacent to the site that may result in flooding at the site.
  - B. Probable maximum precipitation (PMP) over the applicable drainage area.
  - C. Precipitation losses over the applicable drainage area.
  - D. Runoff response characteristics of the applicable drainage area.
  - E. Accumulation of flood runoff through river channels and reservoirs to estimate the PMF hydrograph at the plant site and to determine flood water level at the site with coincident wind-generated waves during the PMF event.
  - F. Dynamic effects of flood on SSCs that are important to safety.

2. Consideration of Other Site-Related Evaluation Criteria. 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 floods in streams and rivers in the vicinity of the site and the site region.
3. Additional Information for Title 10 of the Code of Federal Regulations (10 CFR), Part 52 Applications. Additional information will be presented dependent on the type of application. For a COL application, the additional information is dependent 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 and 2.4.4 - 2.4.9 address the flood producing phenomena individually and in combination to determine the design-basis flood.
2. Flooding protection measures, including dynamic effects (hydrodynamic forces and impact forces from debris and projectiles), if required for SSCs important to safety, are reviewed under DSRS Section 2.4.10.
3. The seismic design basis that includes seismically-induced land subsidence information is performed under SRP Section 2.5.1, "Basic Geologic and Seismic Information."
4. The analysis procedures that are utilized to transform the static and dynamic hydraulic forces (hydrodynamic forces and impact forces from debris and projectiles) of the flood into effective loads applied to seismic Category I structures are reviewed in DSRS 3.4.2, "Analysis Procedures."
5. The effects of a failure of the circulating water system that may generate flooding of the SSCs important to safety is reviewed in DSRS 10.4.5, "Circulating Water System Review Responsibilities."
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<sup>1</sup> 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 NRC regulations:

---

<sup>1</sup> Additional supporting information of prior DC rules may be found in DCD Tier 2 Section 14.3.

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 100.10(c).
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 area 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 are used by the staff for the identified acceptance criteria:

- Regulatory Guide 1.27 describes the applicable ultimate heat sink capabilities.
  - Regulatory Guide 1.29 identifies seismic design bases for SSCs important to safety.
  - Regulatory Guide 1.59, as supplemented by current best practices, provides guidance for developing the flood design bases.
  - Regulatory Guide 1.102 describes acceptable flood protection to prevent the facilities important to safety from being adversely affected.
1. Design Bases for Flooding in Streams and Rivers. To meet the requirements of GDC 2, 10 CFR 52.17, and 10 CFR Part 100, estimates of the following characteristics are needed, and should be based on conservative assumptions of hydrometeorologic

characteristics in the drainage area: (a) the area of the watershed used to estimate flooding in streams and rivers, (b) the total depth of PMP and the PMP hyetograph, (c) the maximum PMF water surface elevation in streams and rivers with coincident wind-waves, and (d) hydraulic characteristics that describe dynamic effects of PMF on SSCs important to safety. If a potential hazard to SSCs important to safety exists, the applicant should document and justify the design bases of affected facilities.

2. Consideration of Other Site-Related Evaluation Criteria. To meet the requirements of GDC 2, 10 CFR 52.17 and 10 CFR Part 100 information about the potential effects of site-related proximity, seismic (including the effects of possible land subsidence), and non-seismic information as they relate to flooding in streams and rivers and local flooding adjacent to and on the plant site is needed.

### 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. Compliance with GDC 2 requires that nuclear power plant SSCs important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornados, hurricanes, floods, tsunamis, and seiches 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., floods) on the North American continent and, when based on probabilistic considerations only, the potential for underestimating the severity of such an event. 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 that contribute to the severity of a given event.

This criterion is applicable to DSRS Section 2.4.3 in that it specifies the hydrologic phenomenon (i.e., PMF) addressed in this section. In general terms, it also specifies the level of conservatism that should be used in assessing the severity of the PMF for the purpose of determining the design bases for the SSCs important to safety.

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 hydrologic site characteristics have been identified; whether GDC 2 is met with respect to the adequacy of the associated design bases is evaluated pursuant to other DSRS sections.

2. Section 10 CFR Part 100 requires that the physical characteristics of a site (including seismology, meteorology, geology, and hydrology) be taken into account when determining the acceptability of a site 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 hydrologic characteristics of the site and region and an analysis of the PMF. This description should be sufficient to assess the acceptability of the site and the potential for those characteristics to influence the design of the plant SSCs that are important to safety.

Meeting the requirements of 10 CFR Part 100 provides a level of assurance that the plant SSCs that are important to safety are designed to withstand hydrologic phenomena of severity up to and including the PMF.

### 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 hydrologic site characteristics is acceptable and whether the technical specifications reflect consideration of any identified unique conditions.

These review procedures are based on the 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 SER section.
2. Design Bases for Flooding in Streams and Rivers. The drainage area that contributes runoff to the location on the stream network adjacent to the plant site should be evaluated by delineating ridge lines on a topographic map. More recently, automated drainage network and contributing area delineation procedures have also become available that use digital elevation and digitized stream network data from the United States Geological Survey. The staff reviews the applicant's flood estimates using current standard methods. If a significant discrepancy exists in drainage areas between the two estimates, the staff will need the applicant to provide more data to support its estimate, or to accept the staff's estimate and re-analyze flooding of the streams and rivers.

The probable maximum flood adjacent to the plant site is based on estimates of probable maximum precipitation on the drainage area. The PMP is estimated for the drainage area using currently applicable National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) hydrometeorological reports (HMR). The rainfall-runoff response characterized by rainfall losses and overland flow mechanisms in the drainage area results in flooding that propagates downstream via the stream network. The staff may consult the U.S. Army Corps of Engineers (USACE) and other appropriate State and Federal agencies to determine the appropriate rainfall-runoff response functions and other watershed parameters. In its review of the PMF on streams and rivers, the staff may verify the applicant's estimate, perform its own independent analysis, or accept an estimate from a Federal or State agency that has the authority and responsibility to carry out these estimates. In its independent analysis, the staff should use currently accepted runoff generation and flood routing methods, such as those made available by the USACE. The staff should consider hydraulic characteristics such as mean and turbulent velocities and momentum fluxes that may assist in estimation of dynamic effects of the PMF on SSCs. Hydraulic characteristics to estimate dynamic effects of the flood waves include hydrodynamic forces and impact forces of waterborne debris and projectiles. If necessary, detailed analysis of impact forces of waterborne projectiles acting on SSCs should be reviewed in the DSRS 3.4.2 "Analysis Procedures". The staff will also determine whether appropriate and conservative rainfall-runoff conversion methods are applied in the estimation of runoff and streamflow. The staff's estimates are compared with the applicant's estimates to determine conformity to the acceptance criteria in Subsection II of this DSRS section.

3. Consideration of Permafrost Hydrology. For site located in the permafrost region, the staff will consider changes to flooding potential at the site as a result of freezing and thawing of the permafrost.
4. 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 should include evaluation of pertinent information to determine if these criteria are appropriately used in postulation of the worst-case flooding scenario at the proposed plant site and in the adjacent streams and rivers.
5. 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 NRC's review of an ESP application for approval of a proposed site. Information required in an ESP application includes a description of the site characteristics and design parameters of the proposed site. 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.

- B. Standard DC Reviews. DC applications 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 DSRS 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 redesigning 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 Final Safety Evaluation Report (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 against 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 SER. The reviewer also states the bases for those conclusions.

##### 1. COL Reviews

The following statements in the SER 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 probable maximum flooding on streams and rivers 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 probable maximum flooding on streams and rivers at the site and in the surrounding area are acceptable and meet the requirements of 10 CFR Part 50, Appendix A, GDC 2 and 10 CFR 100.20(c), as applicable], with respect to determining the acceptability of the site.

The staff finds that the applicant has considered the appropriate site phenomena in establishing the design bases for SSCs important to safety. The staff has generally accepted the methodologies used to determine the probable maximum flooding on

streams and rivers reflected in these design bases, as documented in SERs for previous licensing actions. Accordingly, the staff concludes that the use of these methodologies results in design bases 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 design bases meet the requirement(s) of 10 CFR Part 50, Appendix A, GDC 2 and 10 CFR 100.20(c), with respect to establishing the design basis for SSCs important to safety.

## 2. ESP Reviews

The following statements in the SER 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 ESP site:

As set forth above, the applicant has presented and substantiated sufficient information pertaining to the probable maximum flood on streams and rivers at the proposed site. Section 2.4.3, "Probable Maximum Flood (PMF) on Streams and Rivers," of the Design-Specific Review Standard for mPower™ Integral Pressurized Water Reactor (iPWR) Design, provides that the site FSAR report should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating the probable maximum flood on streams and rivers. Further, the applicant considered local flooding of the site drainage under local intense precipitation in establishing design-basis information pertaining to flooding, 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 SERs 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 probable maximum floods on streams and rivers 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 the probable maximum flood on streams and rivers for inclusion in an ESP for the applicant's site, should one be issued, acceptable.

## 3. DC Reviews

The following statement in the SER 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), but agrees that they are representative of a reasonable number of sites that have been or may be considered for a COL application. Probable maximum flood on streams and rivers and flooding of site drainage 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 safety evaluations 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 Accession (ADAMS) 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 Standard Review Plan (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

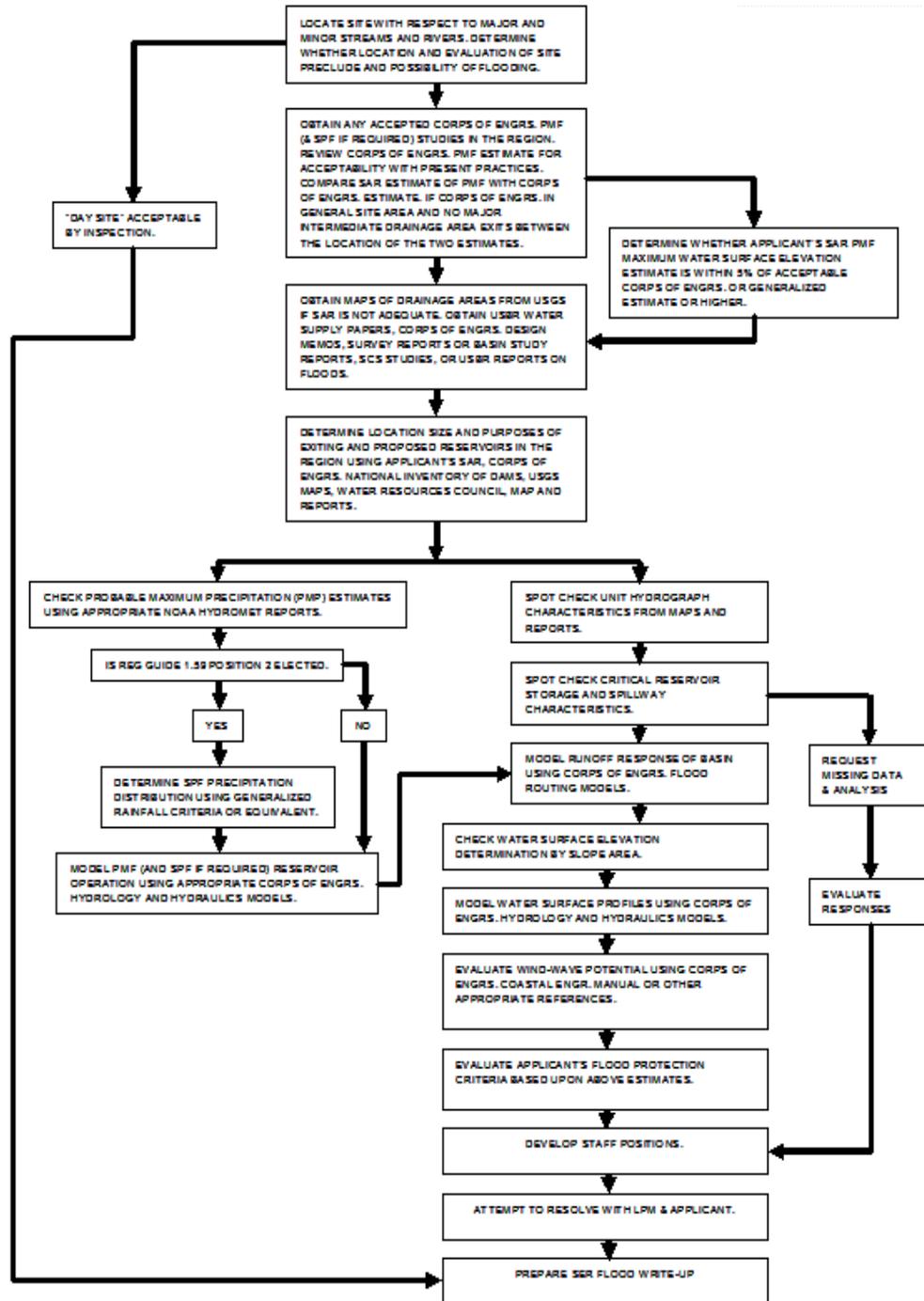
1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."
2. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."
3. 10 CFR Part 100, "Reactor Site Criteria."
4. ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites." Historical Technical Reference.
5. "Application of Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," Hydrometeorological Report No. 52, U.S. Department of Commerce

- National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, August 1982.
6. CHETN-III-70, "Estimating Irregular Wave Runup on Rough, Impermeable Slopes," ERDC/CHL, U.S. Army Corps of Engineers, July 2005.
  7. EM 1110-2-1405, "Flood Hydrograph Analysis and Computations," U.S. Army Corps of Engineers, August 31, 1959.
  8. EM 1110-2-1406, "Runoff from Snowmelt," U.S. Army Corps of Engineers, March 31, 1998.
  9. EM 1110-2-1408, "Routing of Floods Through River Channels," U.S. Army Corps of Engineers, March 1, 1960.
  10. EM 1110-2-1409, "Backwater Curves in River Channels," U.S. Army Corps of Engineers, December 7, 1959.
  11. EM 1110-2-1410, "Interior Drainage of Leveed Urban Areas: Hydrology," U.S. Army Corps of Engineers, May 3, 1965.
  12. EM 1110-2-1411, "Standard Project Flood Determinations," U.S. Army Corps of Engineers, March 26, 1952 (rev. March 1965).
  13. EM 1110-2-1416, "River Hydraulics," U.S. Army Corps of Engineers, October 15, 1993.
  14. EM 1110-2-1417, "Flood-Runoff Analysis," U.S. Army Corps of Engineers, August 31, 1994.
  15. EM 1110-2-1601, "Hydraulic Design of Flood Control Channels," U.S. Army Corps of Engineers, June 30, 1994.
  16. EM 1110-2-1603, "Hydraulic Design of Spillways," U.S. Army Corps of Engineers, March 31, 1965.
  17. ETL 1110-2-120, "Additional Guidance for Riprap Channel Protection," U.S. Army Corps of Engineers, May 1971.
  18. ETL 1110-2-221, "Wave Runup and Wind Setup on Reservoir Embankments," U.S. Army Corps of Engineers, November 1976.
  19. Final Interim Staff Guidance ESP/DC/COL-ISG-015, "Post-Combined License Commitments." January 21, 2010. Accession Number: ML093561416.
  20. "Handbook of Hydrology," David R. Maidment (ed.), McGraw-Hill Book Co., 1992.
  21. "Hydrology for Engineers," Ray K. Linsley, Jr., Max A. Kohler, and Joseph L. H. Paulhus, McGraw-Hill Book Co., Third Edition, 1982.
  22. "Meteorological Criteria for Extreme Floods for Four Basins in the Tennessee and Cumberland River Watersheds," Hydrometeorological Report No. 47, U.S. Department

of Commerce National Oceanic and Atmospheric Administration and Tennessee Valley Authority, May 1973.

23. "Meteorology of Important Rainstorms in the Colorado River and Great Basin Drainages," Hydrometeorological Report No. 50, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, December 1981.
24. "Probable Maximum and TVA Precipitation Estimates With Areal Distribution for Tennessee River Drainages Less Than 3,000 Mi<sup>2</sup> in Area," Hydrometeorological Report No. 56, U.S. Department of Commerce National Oceanic and Atmospheric Administration and Tennessee Valley Authority, October 1986.
25. "Probable Maximum Precipitation and Snowmelt Criteria for Southeast Alaska," Hydrometeorological Report No. 54, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, September 1983.
26. "Probable Maximum Precipitation Estimates, - United States Between the Continental Divide and the 103rd Meridian," Hydrometeorological Report No. 55A, U.S. Department of Commerce National Oceanic and Atmospheric Administration, (U.S. Department of Army Corps of Engineers and U.S. Department of Interior Bureau of Reclamation), June 1988.
27. "Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages," Hydrometeorological Report No. 49, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, Reprinted 1984.
28. "Probable Maximum Precipitation for California - Calculation Procedures," Hydrometeorological Report No. 58, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, October 1998.
29. "Probable Maximum Precipitation for California," Hydrometeorological Report No. 59, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, February 1999.
30. "Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," Hydrometeorological Report No. 51, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, June 1978.
31. "Probable Maximum Precipitation - Pacific Northwest States, Columbia River (including portions of Canada), Snake River and Pacific Coastal Drainages," Hydrometeorological Report No. 57, U.S. Department of Commerce National Oceanic and Atmospheric Administration, U.S. Department of Interior Bureau of Reclamation, and U.S. Department of Army Corps of Engineers, October 1994.
32. "Probable Maximum Precipitation and Snowmelt Criteria For Red River of the North Above Pembina, and Souris River Above Minot, North Dakota," Hydrometeorological

- Report No. 48, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, May 1973.
33. "Probable Maximum Precipitation in the Hawaiian Islands," Hydrometeorological Report No. 39, U.S. Department of Commerce Weather Bureau, May 1963.
  34. Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants."
  35. Regulatory Guide 1.29, "Seismic Design Classification."
  36. Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants."
  37. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."
  38. Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants."
  39. Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants." (LWR Edition)
  40. "Seasonal Variation of 10-Square-Mile Probable Maximum Precipitation Estimates, - United States East of the 105th Meridian," Hydrometeorological Report No. 53, U.S. Department of Commerce National Oceanic and Atmospheric Administration and U.S. Nuclear Regulatory Commission NUREG/CR-1486, April 1980.
  41. "Snow Hydrology: Summary Report of the Snow Investigations," U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon, 1956.
  42. Technical Bulletin No. 8, Sacramento District, "Generalized Snowmelt Runoff Frequencies," U.S. Army Corps of Engineers, September 1962.
  43. TM-37, "Riprap Stability on Earth Embankments Tested in Large and Small-Scale Wave Tanks," CERC, U.S. Army Corps of Engineers, June 1972.
  44. TP 78-2, "Reanalysis of Wave Runup on Structures and Beaches," CERC, U.S. Army Corps of Engineers, March 1978.
  45. Waterways Experiment Station, "Hydraulic Design Criteria," U.S. Army Corps of Engineers, continuously updated.



**Figure 2.4.3-1.** Standard Review Plan Section 2.4.3 Probable Maximum Flood (PMF) on Streams and Rivers

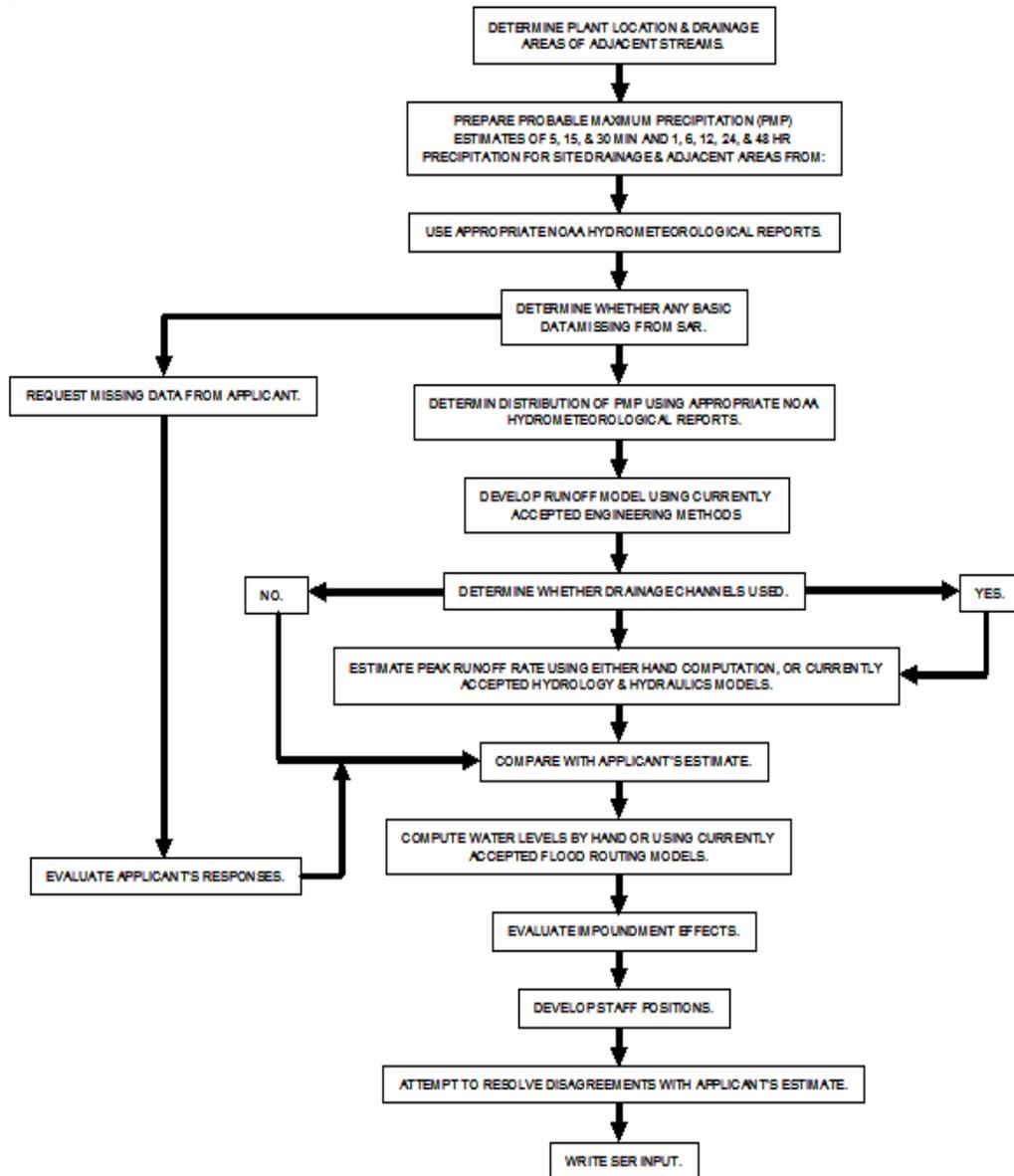


Figure 2.4.3-2. Standard Review Plan Section 2.4.3 Site Drainage and Adjacent Drainage