U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

2.4.6 PROBABLE MAXIMUM TSUNAMI FLOODING

REVIEW RESPONSIBILITIES

Primary - ~~Hydrologic & Geotechnical Engineering Branch (HGEB)~~Civil Engineering and Geosciences Branch (ECGB)[1]

Secondary - ~~Geosciences Branch (GB)~~None[2]

I. AREAS OF REVIEW

The geohydrological design basis of the plant (discussed in Regulatory Guide 1.59) is developed in this section of the safety analysis report (SAR) to determine the extent of plant protection required for tsunami flooding and drawdown (outlined in Regulatory Guide 1.102). The areas of review include the hydrologic characteristics of the maximum locally and distantly generated tsunami and the techniques, methodologies, and parameters, including the geoseismic parameters of the generators, used in the determination of the design basis tsunami.

Hydrologic analysis techniques~~,~~ (including tsunami formation, propagation and shoaling models~~,~~) and coincident water levels~~,~~ (including astronomical tide, storm surges and waves~~,~~)[3] are reviewed.

~~The Geosciences Branch (GB) as part of its secondary review responsibility will review geologic and seismic characteristics of potential tsunamic faults. Areas of review include earthquake magnitude, focal depth, source dimensions, fault orientation, and vertical displacement. GB will review the applicant's values of the parameters, discussed above, used to model tsunami. The values used may represent upper bounds of the parameters. If there is disagreement with the applicant's proposed values, GB will provide alternative values. GB will provide a written discussion of its review of the geologic and seismic characteristics of potential tsunami sources~~

~~to be included in the SER input for this section.~~The review will encompass the geologic and seismic characteristics of potential tsunamic faults, including the earthquake magnitude, focal depth, source dimensions, fault orientation, and vertical displacement. The applicant's values for parameters used to model tsunami, which may represent the upper bounds of the parameters, will be reviewed. If there is disagreement with the applicant's proposed values, the ECGB will provide alternative values.[4]

For a standard design certification applications, the maximum flood level (from all sources) and seismic parameters are specified in the site parameter envelope that must be met by the plant design.[5]

Review Interfaces[6]

The ECGB also reviews, under SRP Section 2.3.6 (proposed), the adequacy of the site parameter envelope specified in standard design certification applications. The ECGB also reviews, under SRP Section 2.4.2, the limiting flood level specified in the site parameter envelope for design certifications.[7]

II. ACCEPTANCE CRITERIA

Acceptance criteria for this SRP section relate to the following regulations:

1. General Design Criterion 2 (GDC 2) as it relates to structures, systems, and components important to safety being designed to withstand the effects of tsunami.

2. 10 CFR Part 100 as it relates to identifying and evaluating hydrologic features of the site.

3. 10 CFR Part 100, Appendix A, as it relates to investigating the tsunami potential at the site and determining the design bases for tsunami flooding.

To meet the requirements of GDC 2; 10 CFR Part 100; and 10 CFR Part 100, Appendix A, with respect to tsunami and the analysis thereof, the following specific criteria are used:

1. If it has been determined that tsunami estimates are necessary to identify flood or low water design bases, the analysis will be considered complete if the following areas are addressed and can be independently and comparably evaluated from the applicant's submission:

    a. All potential distant and local tsunami generators, including volcanoes and areas of potential landslides, are investigated and the most critical ones are selected.

    b. Conservative values of seismic characteristics (source dimensions, fault orientation, and vertical displacement) for the tsunami generators selected are used in the analysis.

c. All models used in the analysis are verified or have been previously approved by the staff. Regulatory Guide 1.125 provides guidance in the use of physical models of wave protection structures.

d. Bathymetric data are provided (or are readily obtainable).

e. Detailed descriptions of shoreline protection and safety-related facilities are provided for wave runup and drawdown estimates. Regulatory Guide 1.102 provides guidance on flood protection for nuclear power plants.

f. Ambient water levels, including tides, sea level anomalies, and wind waves, are estimated using NOAA and Corps of Engineers publications as described below.

g. If Regulatory Guide 1.59, Position 2, is adopted by the applicant, the design basis for tsunami protection of all safety-related facilities identified in Regulatory Guide 1.29 must be shown to be adequate in terms of the time required for implementation of any emergency procedures.

2. The applicant's estimates of tsunami runup and drawdown levels are acceptable if the estimates are no more than 5% less conservative than the staff's estimates. If the applicant's estimates are more than 5% less conservative (based on the difference between normal water levels and the maximum runup or drawdown levels) than the staff's, the applicant should fully document and justify its estimates or accept the staff's estimates.

3. This section of the SAR will also be acceptable if it states the criteria used to determine that tsunami flooding estimates are not necessary to identify the flood design basis (e.g., the site is not near a large body of water).

Technical Rationale[8]

The technical rationale for application of these acceptance criteria to reviewing probable maximum tsunami flooding of a nuclear power plant site is discussed in the following paragraphs:[9]

1. Compliance with GDC 2 requires that nuclear power plant structures, systems, and components important to safety 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 structures, systems, and components 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 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 that contribute to the severity of a given event.

This criterion is applicable to SRP Section 2.4.6 in that it specifies the hydrologic phenomenon (i.e., tsunami flooding) addressed in this section. In general terms, it also specifies the level of conservatism that must be used to assess the severity of the flood for the purpose of determining the design bases for structures, systems, and components important to safety.

Meeting the requirements of GDC 2 provides a level of assurance that structures, systems, and components important to safety have been designed to withstand the most severe flood likely to occur.[10]

2. Section 100.10(c) of 10 CFR Part 100 requires that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor.

10 CFR Part 100 is applicable to SRP Section 2.4.6 because it addresses the physical characteristics, including hydrology, considered by the Commission when determining the acceptability of the proposed site. To satisfy the hydrologic requirements of 10 CFR Part 100, the applicant's SAR must contain a description of the hydrologic characteristics of the coastal region in which the proposed site is located and an analysis of severe seismically induced waves. The description must be sufficient to assess the acceptability of the site and the potential for a tsunami to influence the design of plant structures, systems, and components important to safety.

Meeting this requirement provides a level of assurance that plant structures, systems, and components important to safety have been designed to withstand the effects of a locally or distantly generated tsunami.[11]

3. Appendix A to 10 CFR Part 100 requires that geologic and seismic factors be considered when determining suitability of the site and acceptability of the plant design. Paragraph IV(c) describes the investigation required to obtain geologic and seismic data necessary for evaluating seismically induced floods and water waves.

Appendix A is applicable to SRP Section 2.4.6 because it requires investigation of distantly and locally generated waves or tsunami that have affected or could affect a proposed site, including available evidence regarding the runup or drawdown associated

with historic tsunami in the same coastal region and local features of coastal topography that might modify runup or drawdown. More detailed guidance on the investigation of seismically induced flooding is provided in Regulatory Guide 1.70.

Meeting this requirement provides a level of assurance that plant structures, systems, and components important to safety have been designed to withstand the effects of a distantly or locally generated tsunami.[12]

III. REVIEW PROCEDURES

The review procedures are outlined in Figure 2.4.6-1. The references used are general geophysical, seismological, and hydrodynamic publications, such as published data by the National Oceanic and Atmospheric Administration (NOAA), and wave propagation models, such as those developed by NOAA, the Corps of Engineers' Waterways Experiment Station (WES), and Tetra Tech.

Section 2.4.6 of the applicant's SAR is reviewed to identify any missing data, information, or analysis necessary for the staff's evaluation of potential tsunami flooding. This section is evaluated when the applicant has responded to all the additional information requested. If the site is not near a large body of water with potential tsunami generators, the staff findings may be prepared a priori.

The ECGB staff ~~(with input from GB)~~[13] will review the potential tsunami sources analyzed by the applicant to ~~assure~~ ensure[14] that all locations capable of generating a tsunami of significant magnitude at the site have been considered. The ~~GB~~ECGB[15] staff will evaluate the geoseismic parameters of the tsunami generators, including fault location and orientation, and amplitude and areal extent of vertical displacement, to ~~assure~~ ensure that conservative values have been chosen.

An independent staff analysis, using one of the models listed in the references, may be performed. Staff estimates of tsunami levels are compared with the applicant's. The applicant must justify, to the staff's satisfaction, tsunami levels more than 5% less conservative than the staff's.

As an alternative, the staff may perform an independent evaluation of the applicant's model and its utilization. The model's theoretical basis, its inherent conservatism and applicability to the problem, will be evaluated (this can be done on a generic basis). The conservatism of the model's use, including the conservatism of all input parameters, will be evaluated.

Coincident ambient tide and wave conditions will be evaluated to ~~assure~~ ensure that they are of at least annual severity. Data from publications of NOAA, the Corps of Engineers, and other sources are used to substantiate these conditions chosen.

Criteria and methods of the Corps of Engineers as generally summarized in Reference ~~15~~ 16[16] are used as a standard to evaluate the applicant's estimate of coincident wind-generated wave action and runup.

Criteria and methods of the Corps of Engineers and other standard techniques are used to evaluate the potential for oscillation of waves at natural periodicity.

Criteria and methods of the Corps of Engineers (Ref. ~~15~~ 16) are used to evaluate the adequacy of protection from flooding, including the static and dynamic effects of broken, breaking, and nonbreaking coincident waves.

For an application referencing a certified standard design, the reviewer verifies that historical geohyrological data related to tsunamis are consistent with the flood levels specified in the site parameter envelope for the certified design.

Requirements and procedures governing issuance of early site permits for approval of proposed sites for nuclear power facilities are specified in 10 CFR Part 52. Information required for such a permit includes a description of the site's geohydrological characteristics. For this type of permit, the procedures above should be followed.[17]

For a standard design certification, an envelope of site-related hydrologic parameters is identified. These parameters should be representative of the most severe flooding or drawdown likely to occur as the result of a tsunami. The reviewer verifies that the site characteristics envelope meets the acceptance criteria given in subsection II of this SRP section.[18]

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[19]

IV. EVALUATION FINDINGS

For CP and early site permit[20] reviews, the findings will consist of a statement summarizing estimates of the maximum and minimum tsunami water levels, and static and dynamic effects of wave action. A statement of acceptability of the tsunami induced design basis in meeting the requirements of GDC 2; 10 CFR Part 100; and 10 CFR Part 100, Appendix A, will be made. If the tsunami conditions do not constitute a design basis, the findings will so indicate. For operating license (OL) reviews or reviews of plants proposed for a site with an early site permit[21], the findings will consist of the evaluation of any new information on tsunami potential, improvements in predictive models, acceptability of specific design bases, and the acceptability of design provisions.

A sample statement for a CP review follows:

> The staff concludes that the plant design is acceptable with respect to its ability to withstand the effects of tsunami. It therefore meets the tsunami design requirements of GDC 2; 10 CFR Part 100; and 10 CFR Part 100, Appendix A. This conclusion is based on the following analysis.

Analyses of tsunamic effects from local and distant generators were performed by the applicant at the staff's direction. The design tsunami results from a magnitude 8.7 earthquake in the Aleutian Trench. A finite difference numerical model was used to analyze tsunami generation and propagation to the continental shelf. Results of this computation were used in a near-shore model to calculate tsunami runup and drawdown. Including the effects of high and low tides of annual occurrence, the maximum tsunami runup and drawdown are estimated as ~~+24.5 feet~~ +7.5-m (+24-ft)[22] MLLW and ~~−13.4 feet~~ -4.1-m (-13.4-ft)[23] MLLW, respectively. Wind waves of annual severity were assumed coincident with the tsunami. Plant grade at elevation ~~+55 feet~~ +16.8-m (+55-ft)[24] MLLW is well above the tsunami flood level. The maximum wave runup, at the intake pumphouse, was estimated as ~~+31.2 feet~~ +31.2-m (+31.2-ft)[25] MLLW, which is ~~3.8 feet~~ +1.2 m (3.8 ft)[26] below the design flood level of ~~+35 feet~~ +10.7-m (+35-ft)[27] MLLW. The maximum drawdown at the location of the inshore intake was estimated as ~~-21.3 feet~~ -6.5-m (-21.3-ft)[28] MLLW. The intake is designed to be able to draw water down to ~~-30 feet~~ -9.1-m (-30-ft)[29] MLLW and will therefore not be affected by low water due to tsunami drawdown.

For an application referencing a certified plant design, the reviewer's findings should include a concluding statement similar to the following:

Historical data for the proposed site are consistent with the flood levels identified in the site parameter envelope specified in the certified plant design documents.[30]

For design certification reviews, the findings will also summarize, to the extent that the review is not discussed in other safety evaluation report sections, the staff's evaluation of inspections, tests, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements, and combined license action items that are relevant to this SRP section.[31]

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52. Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.

Implementation schedules for conformance of parts of the method discussed herein are contained in the referenced regulatory guides.

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."[32]

3. 10 CFR Part 100, "Reactor Site Criteria."

4. 10 CFR Part 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

5. Li-San Hwang, H. Lee Butler, and David J. Divorky, Tetra Tech, Inc., "Tsunami Model: Generation and Open-Sea Characteristics," Bulletin of the Seismological Society of America, Vol 62, No. 6, December 1972.

6. Li-San Hwang, D. Divorky, and A. Yuen, Tetra Tech, Inc., "Amchitka Tsunami Study," Report NV0-289-7, Nevada Operations Office, U.S. Atomic Energy Commission (1971).

7. Li-San Hwang and D. Divorky, Tetra Tech, Inc., "Rat Island Tsunami Model: Generation and Open-Sea Characteristics," Report NV0-289-10, Nevada Operations Office, U.S. Atomic Energy Commission (1971).

8. H. G. Loomis, "A Package Program for Time-Stepping Long Waves into Coastal Regions with Application to Haleiwa Harbor, Oahu," Hawaii Institute of Geophysics and National Oceanic and Atmospheric Administration (1972).

9. Li-San Hwang and D. Dovorky, "Tsunami Generation," Journal of Geophysical Research, Vol. 75, No. 33 (1970).

10. K. L. Heitner, "Additional Investigations on a Mathematical Model for Calculation of the Run-Up of Tsunamis," California Institute of Technology (1970).

11. R. L. Street, Robert K-C Chan, and J. E. Fromm, "Two Methods for the Computation of the Motion of Long Water Waves - A Review and Applications," NR 062-320, Technical Report 136, Office of Naval Research, distributed as a reprint from the Proc. 8th Symposium on Naval Hydrodynamics, August 1970.

12. 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.

13. C. L. Mader, "Numerical Simulation of Tsunamis," Hawaii Institute of Geophysics and National Oceanic and Atmospheric Administration, February 1973.

14. R. W. Preisendorfer, "Recent Tsunami Theory," Hawaii Institute of Geophysics and National Oceanic and Atmospheric Administration, August 1971.

15. National Oceanic and Atmospheric Administration, Nautical Charts.

16. "Shore Protection, Planning and Design," Technical Report 4, Third Edition, Corps of Engineers Coastal Engineering Research Center, Third Edition (1966); and "Shore Protection Manual" (1977).

17. 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).

18. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

19. Regulatory Guide 1.59, "Design Basis Floods for Nuclear Power Plants."

20. Regulatory Guide 1.102, "Flood Protection Requirements for Nuclear Power Plants."

21. Regulatory Guide 1.29, "Seismic Design Classification."

22. Regulatory Guide 1.125, "Physical Models for Design and Operation of" Hydraulic Structures and Systems for Nuclear Power Plants."

23. R. L. Wiegel, "Oceanographical Engineering," Prentice-Hall, Inc., Englewood Cliffs, NJ (1964).

24. J. R. Houston and A. W. Garcia, "Type 16 Flood Insurance Study: Tsunami Predictions for Pacific Coastal Communities," Technical Report H-74-3, U.S. Army Engineer Waterways Experiment Station (1974).

25. J. R. Houston, R. W. Whalen, A. W. Garcias and H. L. Butler, "Effect of Source Orientation and Location in the Aleutian Trench on Tsunami Amplitude Along the Pacific Coast of the Continental United States," Technical Report H-75-4, U.S. Army Engineer Waterways Experiment Station (1975).

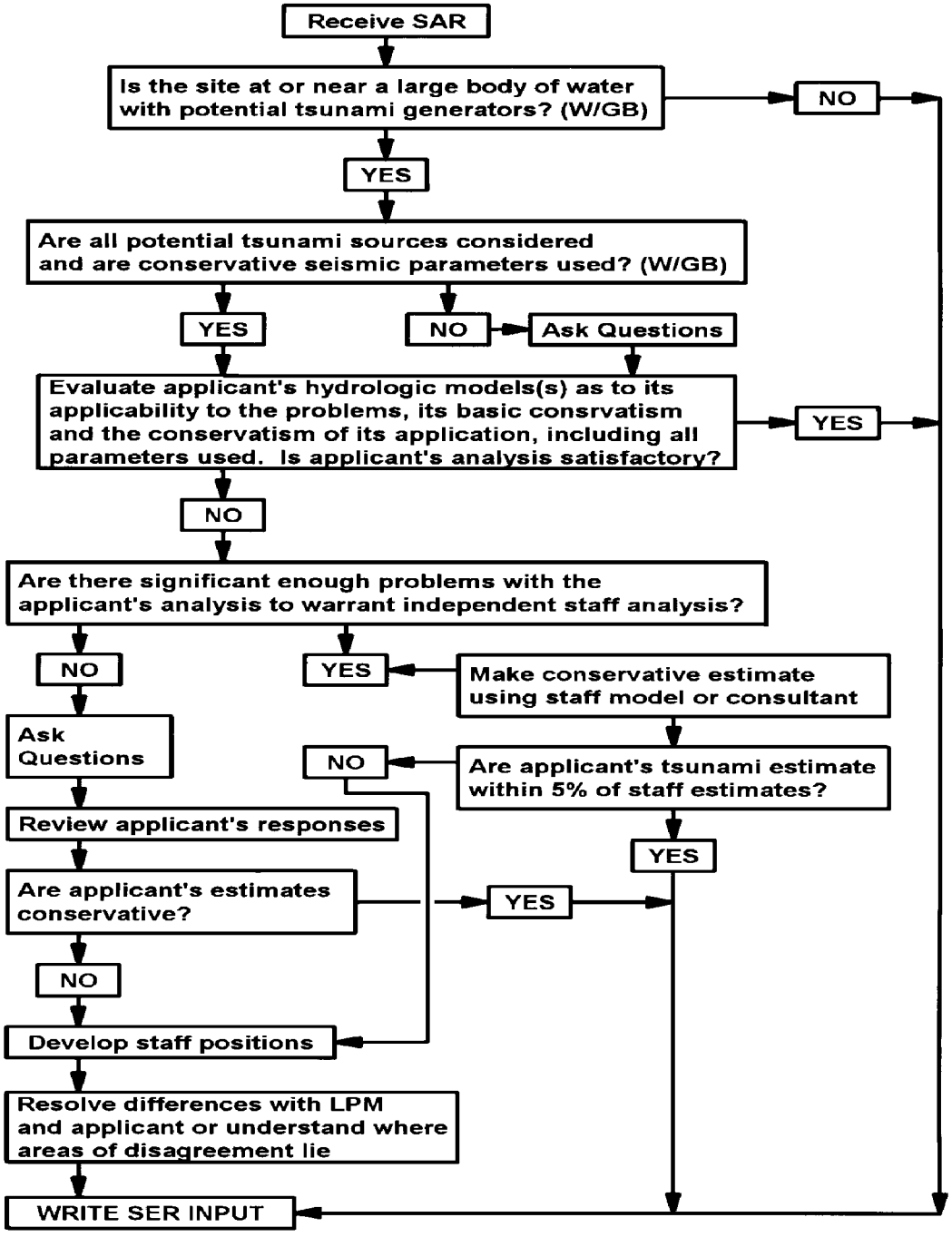
26. R. L. Wiegel, "Earthquake Engineering," Prentice-Hall, Inc., Englewood Cliffs, NJ (1970).

27. M. Brandsma, D. Divoky, and L. Hwang, "Tsunami Atlas for the Coasts of the United States," NUREG/CR-1106, USNRC (1979)

28. L. G. Hulman, W. S. Bivins, and M. H. Fliegel, "Tsunami Protection of Coastal Nuclear Power Plants in the United States," Journal of Marine Geodesy (1978).

Figure 2.4.6-1

REVIEW PROCEDURES



SRP Draft Section 2.4.6
Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB name and abbreviation	Changed PRB to Civil Engineering and Geosciences Branch (ECGB).
2.	Current SRB responsibilities	Changed to indicate the lack of an SRB for this section.
3.	Editorial	Deleted commas and added parentheses to improve clarity.
4.	Editorial	Revised paragraph describing SRB areas of review. ECGB is currently responsible for the entire review of this section, making a revision necessary.
5.	Integrated Impact No. 393	Noted site parameter envelope for standard design certification.
6.	SRP-UDP format item	Added "Review Interfaces" to AREAS OF REVIEW.
7.	Integrated Impact No. 393	Included review interfaces to new SRP Section 2.3.6 and to SRP Section 2.4.2 for review of DC site parameter envelope.
8.	Develop technical rationale	"Technical Rationale" added to ACCEPTANCE CRITERIA and presented in paragraph form.
9.	Develop technical rationale	Added lead-in sentence for "Technical Rationale."
10.	Develop technical rationale	Added technical rationale to describe the bases for referencing the GDC.
11.	Develop technical rationale	Added technical rationale for 10 CFR Part 100.
12.	Develop technical rationale	Added technical rationale for Appendix A to 10 CFR Part 100.
13.	Current PRB abbreviation	Reflects organizational change within NRR.
14.	Editorial	Changed "assure" to "ensure" (global change for this section).
15.	Current PRB abbreviation	Changed to PRB to ECGB.
16.	Editorial	Changed reference numbers to accommodate new Reference 2 (global change for this section).
17.	Integrated Impact No. 393	Added paragraphs to address early site review and applications referencing a certified design.
18.	SRP-UDP format item	Added paragraph to identify scope of standard design certification reviews and reference to the site characteristics envelope.
19.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.

Item	Source	Description
20.	Integrated Impact No. 393	Added reference to early site reviews.
21.	Integrated Impact No. 393	Added discussion of applications for plants proposed for a site with an early site permit.
22.	Conversion to SI units	Converted 24.5 ft to 7.5 m.
23.	Conversion to SI units	Converted –13.4 ft to –4.1 m.
24.	Conversion to SI units	Converted 55 ft to 16.8 m.
25.	Conversion to SI units	Converted 31.2 ft to 9.5 m.
26.	Conversion to SI units	Converted 3.8 ft to 1.2 m.
27.	Conversion to SI units	Converted 35 ft to 10.7 m.
28.	Conversion to SI units	Converted –21.3 ft to –6.5 m.
29.	Conversion to SI units	Converted –30 ft to –9.1 m.
30.	Integrated Impact No. 393	Added requirement for a statement regarding the site parameter envelope to EVALUATION FINDINGS.
31.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
32.	Integrated Impact No. 393	Added reference to 10 CFR Part 52.

SRP Draft Section 2.4.6
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
393	10 CFR Part 52 specifies that applications for design certifications must contain the site parameters postulated for the design, as well as an analysis and evaluation of the design in terms of such parameters. Integrated Impact No. 393 states that consideration should be given to (1) developing a new SRP section for review of the site parameter envelope,... and (2) revising the existing SRP sections, including SRP Section 2.4.6, for review of site-specific parameters to reflect the site parameter-related requirements of 10 CFR Part 52. Regarding consideration (1), action is proceeding on development of the new SRP section (see IPD-7.0 Form No. 2.3.1.) 2.3.6. Regarding (2), the revision of SRP Section 2.4.6 addresses the appropriate use of a site parameter envelope.	Subsection I, AREAS OF REVIEW, added final paragraph and REVIEW INTERFACES Subsection III, REVIEW PROCEDURES, added last two paragraphs Subsection IV, EVALUATION FINDINGS, first paragraph Subsection IV, EVALUATION FINDINGS, new finding Subsection VI, REFERENCES, Reference 2
1210	Revise the SRP to incorporate the new and revised requirements from proposed rulemaking 59 FR 52255.	No changes to SRP section, pending final action on the proposed rule.