



U.S. NUCLEAR REGULATORY COMMISSION  
**STANDARD REVIEW PLAN**

## 2.4.7 ICE EFFECTS

### REVIEW RESPONSIBILITIES

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

**Secondary** - None

#### I. AREAS OF REVIEW

Chapter 2 of the Standard Review Plan (SRP) discusses the site characteristics that could affect the safe design and siting of a plant. The staff reviews information presented by the applicant for a construction permit (CP), operating license (OL), design certification (DC), early site permit (ESP), or combined license (COL) concerning hydrological setting of the site as it relates to safety-related structures, systems, and components (SSC). This SRP section applies to reviews performed for each of these types of applications. The staff's review and findings are described in the appropriate section of the safety evaluation report (SER).

The hydrometeorological design basis is developed in this section of the applicant's safety analysis report (SAR) to ensure that safety-related facilities and water supply are not affected by ice-induced hazards.

Staff is responsible to provide site characteristics and other hydrometeorological parameters related to ice formation at or near the site to the organization responsible for review of the SSC to ascertain whether ice effects on potentially affected SSC are properly considered in the mechanical or structural design basis for the plant.

Revision 3 - March 2007

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### USNRC STANDARD REVIEW PLAN

This Standard Review Plan, NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC's regulations. The Standard Review Plan is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The standard review plan sections are numbered in accordance with corresponding sections in Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of Regulatory Guide 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by email to [NRR\\_SRP@nrc.gov](mailto:NRR_SRP@nrc.gov).

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The review covers the following specific areas:

1. Historical Ice Accumulation: The regional history and types of historical ice accumulations (i.e., ice jams, wind-driven ice ridges, floes, frazil ice formation, etc.).
2. High and Low Water Levels: The potential effects of ice-induced high or low flow levels on safety-related facilities and water supplies.
3. Ice Sheet Formation: The potential of a surface ice-sheet to reduce the volume of available liquid water in safety-related water reservoirs.
4. Ice-Induced Forces and Blockages: The potential for ice-produced forces on, or blockage of, safety-related facilities.
5. Consideration of Other Site-Related Evaluation Criteria: The potential effects of seismic and non-seismic information on the postulated worst-case icing scenario for the proposed plant site.
6. Additional Information for 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 SRP sections interface with this section as follows:

1. The identification of safety-related structures and equipment that should be protected against the effects of flooding is performed under SRP Section 3.4.1, "Flood Protection."
2. The review of the design of seismic Category I structures to design for the effects of flooding, including that which could result ice blockage, is performed under SRP Section 3.4.2, "Analysis Procedures."
3. The review to ensure that adverse environmental conditions, including freezing, will not preclude the safety function of the ultimate heat sink is performed under SRP Section 9.2.5, "Ultimate Heat Sink."
4. 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 Section 2.0.

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

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

## 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 hydrological features of the site. The requirements to consider physical site characteristics in site evaluations are specified in 10 CFR 100.10(c) for applications before January 10, 1997, and 10 CFR 100.20(c) for applications on or after January 10, 1997.
2. GDC 2, for CP and OL applications, 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.
3. 10 CFR 52.17(a)(vi), for ESP applications, and 10 CFR 52.79(a)(1)(iii), for COL applications, as they relate to the hydrologic characteristics of the proposed site 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.

### SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

Regulatory Guide 1.27 describes the applicable ultimate heat sink capabilities.

Regulatory Guide 1.29 identifies safety-related structures, systems, and components.

Regulatory Guide 1.59, as supplemented by best current practices, provides guidance for developing the hydrometeorological design bases.

Regulatory Guide 1.102 describes acceptable flood protection to prevent the safety-related facilities from being adversely affected.

1. Historical Ice Accumulation: The application should include a complete history of ice formation at and in the vicinity of the site. A thorough listing of types of ice formations (ice jams, ice dams, floes, ridges, frazil, etc.), locations and durations of these formations, and descriptions of hydrometeorological characteristics accompanying these formations should be provided that are sufficient to establish the history of ice-formation at and in the vicinity of the site.
2. High and Low Water Levels: The application should include estimates of water levels resulting from potential ice flooding or low flows. Flooding from collapse of an upstream

ice dam or an ice jam should be considered. Backwater effects from a downstream ice dam or an ice jam that may result in flooding at the proposed site should also be considered. The suggested criteria of Regulatory Guide 1.27 apply when the water supply comprises part of the ultimate heat sink.

3. Ice Sheet Formation: The application should include estimates of the most severe ice-sheet formation in water storage reservoirs. The reduction in liquid water storage capacity of water storage reservoirs due to the presence of the ice sheet should be estimated. The suggested criteria of Regulatory Guide 1.27 apply when the water supply comprises part of the ultimate heat sink.
4. Ice-induced Forces and Blockages: The application should provide estimates of the most severe ice-induced forces on safety-related SSC. The forces resulting from the most severe ice sheet interacting with safety-related SSC should be estimated. An assessment regarding formation of frazil ice at and in the vicinity of the site is needed. Blockages from frazil of safety-related intakes should be assessed. Ice blockage of rivers, streams, and estuaries, both upstream and downstream of the site, should be determined. The suggested criteria of Regulatory Guide 1.27 apply when the water supply comprises part of the ultimate heat sink.
5. Consideration of Other Site-Related Evaluation Criteria: The application should demonstrate that the potential effects of site-related proximity, seismic, and non-seismic information as they relate to worst-case icing scenarios adjacent to and on the plant site and site regions are appropriately take into account.

#### Technical Rationale

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

1. Pursuant to GDC 2, nuclear power plant SSC 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 SSC shall reflect the following:
  - A. Appropriate consideration of the most severe natural phenomena historically reported for the site and its 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 those 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 on the North American continent and, as a result, the potential for underestimating the severity of such events, based on probabilistic considerations only. 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 to contribute to the severity of a given event.

This criterion is relevant to this SRP section in that it addresses the potential effects of ice on the hydrological characteristics of the plant site. In general terms, it also specifies the amount of conservatism that should be used to determine the severity of icing phenomena for the purpose of assessing the adequacy of the design bases used or SSC important to safety. This is a similar standard as that applied in reviewing ESPs or COLs.

Meeting the requirements of GDC 2 provides assurance that SSC important to safety have been designed to withstand the most severe icing phenomena likely to occur.

2. Sections 100.10(c) and 100.20(c) of 10 CFR Part 100 require 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 hydrological requirements of 10 CFR Part 100, the applicant's SAR should contain a description of any icing phenomena with the potential to result in adverse effects to the intake structure or other safety-related facilities. Ice-related characteristics historically associated with the site and region should be described, and an analysis should be performed to determine the potential for flooding, low water, or ice damage to safety-related SSC. The analysis should be sufficient to evaluate the site's acceptability and to assess the potential for those characteristics to influence the design of the plant SSC important to safety.

Meeting this requirement provides assurance that SSC important to safety are designed to withstand the effects of potentially severe icing conditions.

### III. REVIEW PROCEDURES

The reviewer will select material from the procedures described below, as may be appropriate for a particular case.

The procedures outlined below are used to review CP applications, 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 SRP section. For reviews of OL applications, these procedures are used to verify that the data and analyses remain valid and that the facility's design specifications are consistent with these data. As applicable, reviews of OLs and 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 SRP 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. Historical Ice Accumulation: Publications of the National Oceanic and Atmospheric Administration (NOAA), the United States Geologic Survey (USGS), the U.S. Army Corps of Engineers (USACE), USACE Engineer Research and Development Center Cold Regions Research and Engineering Laboratory (CRREL), and other sources are used to identify the history and potential for ice formation in the region. Historical maximum depths of icing should be noted, as well as mass and velocity of any large floating ice bodies. The phrase "historical low water ice affected" or similar phrases in

streamflow records (USGS and State publications) will alert the reviewer to the potential for ice effects.

Applicable literature describing historical occurrences of icing in the region is reviewed to determine if icing protection should be considered in the design of safety-related facilities. If considered necessary, the most likely types of icing conditions (floating ice, river blockage by ice buildup, frazil ice, etc.) are listed, and the potential impact on plant design of each type is identified. Criteria of the USACE and others provide a means of assessing icing impact and methods of mitigating adverse effects. For each type of icing condition, preliminary independent conservative estimates of the "worst case" will be made by either statistical or deterministic techniques.

2. High and Low Water Levels: The regional ice dam and ice jam formation history (e.g., from the USACE historical ice jam database) should be described to enable an independent determination of the need for including ice effects in the design basis.

If the applicant's estimates of ice effects are comparable to the staff's preliminary bounding analysis, the staff should concur with the applicant's estimates. If the preliminary bounding analysis indicates the applicant's estimates of ice effects are not comparable to the staff's estimates, the staff's analysis should be repeated using more realistic techniques.

3. Ice Sheet Formation: Accumulated freezing degree-days data estimated from air temperatures available from CRREL may be analyzed to verify that only minimal ice sheet formation occurs on reservoirs even during severe winters. In such cases, further analysis may not be needed. If ice formation is not minimal, techniques for estimating ice sheet thickness on reservoirs such as those described in USACE publication EM 1110-2-1612, "Engineering and Design - Ice Engineering," can be used in combination with CRREL accumulated freezing degree-days data and conservative assumptions of the ice initiation date. The volume of liquid water available under the most severe ice sheet formation should be sufficient to meet safety-related water supply requirements.
4. Ice-Induced Forces and Blockages: If floating ice is prevalent, based on regional icing history, potential impact forces on the safety-related intakes should be considered in the design basis. The dynamic loading caused by floating ice should be included in the structural design basis.

If ice blockage of the river or estuary is possible, it should be demonstrated that the resulting water level in the vicinity of the site has been considered in establishing the flood (e.g., from collapse of an ice dam) and water supply design bases (e.g., low water downstream of ice jams). If this water level would adversely affect the intake structure, or other safety-related facilities, it should be demonstrated that an alternate safety-related water supply will not also be adversely affected.

If icing has not been severe, based on regional icing history, design considerations should be presented (e.g., return of a portion of low-grade heat to the intake) to ensure that icing or ice blockage of intake screens (e.g., due to frazil ice) and pumps will not adversely affect safety-related facilities and water supplies.

At sites or in site regions where more detailed analysis is needed to ascertain the most severe ice-induced hazard, the review verifies that the following icing potential site characteristics have been provided:

- A. maximum accumulated freezing degree-days (assists in design of SSC exposed to the effects of ice)
  - B. a determination of whether the site or the site region supports formation of frazil ice.
5. Consideration of Other Site-Related Evaluation Criteria: 10 CFR Part 100 describes site-related proximity, seismic, and non-seismic evaluation criteria for power reactor applications. Subpart A to 10 CFR Part 100 addresses the requirements for applications before January 10, 1997, and Subpart B is for applications on or after January 10, 1997. The staff's review should include evaluation of pertinent information to determine if these criteria are appropriately used in postulation of the worst-case icing scenario at the proposed plant site.
6. Review Procedures Specific to 10 CFR Part 52 Application Type
- A. Early Site Permit Reviews: Subpart A to 10 CFR Part 52 specifies the requirements and procedures applicable to the Commission'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 of review of data parallel that used for a CP 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 early site permit.
  - B. Standard Design Certification 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. The reviewer verifies 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. Combined License Reviews: For a COL application referencing a certified standard design, the NRC staff reviews that application to ensure that sufficient information is presented to demonstrate that the characteristics of the site fall within the site parameters specified in the DC rule. Should the actual site

characteristics 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 provides sufficient information to demonstrate that the design of the facility falls within the site characteristics and design parameters specified in the early site permit as applicable to this SRP 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 early site permit 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 early site permit conditions, restrictions to the DC, or COL action items identified in the FSERs are appropriately handled in the COL application.

#### 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 safety analysis report. 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 safety evaluation report. The reviewer also states the bases for those conclusions.



1. Construction Permit, Operating License, and Combined License Reviews

The following statements 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 ice effects 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 potential for ice flooding, ice blockage of water intakes, ice forces on structures, and the minimum low water levels (from upstream ice blockage) are acceptable and meet the requirements of [10 CFR Part 50, Appendix A, General Design Criterion 2 or 10 CFR 52.79, as applicable] and 10 CFR Part 100 [100.10(c) or 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 for establishing the design bases for SSCs important to safety. The staff has generally accepted the methodologies used to determine the potential for ice formation and blockage reflected in these site characteristics, as documented in safety evaluation reports 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 Requirement(s) of [10 CFR Part 50, Appendix A, General Design Criterion 2 or 10 CFR 52.79, as applicable] and 10 CFR 100.10(c) [or 10 CFR 100.20(c)], with respect to establishing the design basis for SSCs important to safety.

2. Early Site Permit Reviews

The following statements 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 identification and evaluation of ice effects at the proposed site. Section 2.4.7, "Ice Effects," of NUREG-0800, Standard Review Plan, provides that the site safety analysis report should address the requirements of 10 CFR Parts 52 and 100 as they relate to identifying and evaluating ice effects at the site. Further, the applicant considered the most severe natural phenomena that have been historically reported for the site and surrounding area while describing the hydrologic interface of the plant with the site, 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 safety evaluation reports 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 or CP application.

Therefore, the staff concludes that the identification and consideration of the site characteristics related to ice effects 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 ice effects for inclusion in an ESP for the applicant's site, should one be issued, to be acceptable.

### 3. Design Certification Reviews

The following statement 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 that they are representative of a reasonable number of sites that have been or may be considered for a COL application. Icing effects 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 SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

## VI. REFERENCES

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities."
2. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."
3. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."
4. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."
5. 10 CFR Part 100, "Reactor Site Criteria."
6. ANSI/ANS-2.8-1992, "Determining Design Basis Flooding at Power Reactor Sites" (1992). Historical Technical Reference.
7. "Engineering and Design - Ice Engineering," EM 1110-2-1612, U.S. Army Corps of Engineers, Washington, DC, 2002 or later edition.

8. Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants."
9. Regulatory Guide 1.29, "Seismic Design Classification."
10. Regulatory Guide 1.59, "Flood Design Basis for Nuclear Power Plants." Historical Technical Reference.
11. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)."
12. Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants."
13. Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants." (LWR Edition).

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**PAPERWORK REDUCTION ACT STATEMENT**

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50 and 10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.

**PUBLIC PROTECTION NOTIFICATION**

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

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