UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

September 25, 2012

Mr. R. W. Borchardt
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: DRAFT REGULATORY GUIDE DG-1290 (PROPOSED REVISION OF REGULATORY GUIDE 1.59), "DESIGN-BASIS FLOODS FOR NUCLEAR POWER PLANTS"

Dear Mr. Borchardt:

During the 597th meeting of the Advisory Committee on Reactor Safeguards, September 6-8, 2012, we completed our review of Draft Regulatory Guide DG-1290. DG-1290 is a proposed Revision 3 to Regulatory Guide RG-1.59, "Design-Basis Floods for Nuclear Power Plants." It has not yet been issued for public comments. Our Regulatory Policies and Practices Subcommittee reviewed DG-1290 during its meeting on July 10, 2012. During our meetings, we had discussions with representatives of the NRC staff and their consultants and the benefit of the documents referenced.

RECOMMENDATIONS

1. Draft Regulatory Guide DG-1290 should be issued for public comments after Recommendations 2, 3, and 4 are addressed.

2. The guidance in DG-1290 should provide clear and consistent definitions of a "design-basis flood" and of all phenomena that are characterized by the term "probable maximum." The guidance should clarify whether these analyzed conditions represent the maximum possible severity for each flood-causing mechanism. The guidance should make it clear that licensees should provide justification that the deterministically derived flood levels correspond to conditions that have a total expected frequency of less than 1×10^{-6} event per year, as specified for combined events in DG-1290, or they should develop suitable alternative analyses that provide this assurance.

3. The staff should revise Appendix H, Section H-2, to remove the implied need to evaluate the list of prescribed conditions. The guidance should emphasize the need to perform analyses for the applicable site-specific flood-causing mechanisms and to examine the sensitivity of the analysis results to variations in the combined event frequencies and possible dependencies among the conditions. It should provide more general examples of the types of combined conditions that should be evaluated, without reference to specific numerical values, assumed recurrence intervals, or logical combination rules.

4. The guidance for evaluation of the effects from dam failures should include coincident or dependent failures of downstream dams that may either drain or significantly reduce the plant's safety-related cooling water supply.

5. After RG 1.59, Revision 3, is issued, the staff should expedite the development of probabilistic methods to consistently evaluate exceedance frequencies for each flood-causing mechanism that is addressed in DG-1290. To the extent possible, those efforts should build on existing methods and guidance for the evaluation of other severe external hazards. The proposed methods should be applied to pilot plant sites which are exposed to multiple flooding hazards.

BACKGROUND

Draft Regulatory Guide DG-1290 is a proposed revision to RG 1.59, "Design-Basis Floods for Nuclear Power Plants." The current Revision 2 of RG 1.59 was issued in August 1977. An erratum was issued in July 1980 to update the probable maximum flood isolines in the Upper Ohio River Basin and to endorse revised methods in Appendix A for evaluating probable maximum floods and seismically induced floods for streams and coastal areas.

More data and significantly improved analytical methods for evaluating flood-causing mechanisms have become available over the last 30 years. Flooding analyses that are performed to support design certifications, early site permits, and combined license applications for new reactors require updated data and guidance that are consistent with current state-of-the-practice methods. In March 2012, the NRC issued letters under 10 CFR 50.54(f) which request all current licensees to provide information about their site-specific flooding hazards. Those letters refer to a pending update to RG 1.59 and to analytical methods that are described in NUREG/CR-7046, "Design Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America." These licensing activities have further focused attention on the outdated data and methods in RG 1.59, Revision 2, and the need for a timely update to that guidance.

DISCUSSION

The guidance in DG-1290 endorses deterministic methods for the identification and evaluation of external flooding hazards, most notably the approach that is described in NUREG/CR-7046. This revision to RG 1.59 is needed to support important regulatory activities that are associated with the licensing of new reactors and the implementation of key lessons learned from the Fukushima Dai-Ichi accident. Flooding analyses that are performed for these activities should benefit from the substantial advancements in meteorological, geotechnical, geohydrological, hydraulic, and structural analysis methods and their supporting data that have been made over the last 30 years. DG-1290 and its references provide a valuable compendium of that information and associated guidance for use in state-of-the-practice deterministic assessments.

The primary emphasis is on the use of deterministic methods. It is noted in the DG-1290 Introduction that:

The deterministic methods are replete with ambiguous statements like "[t]he design-basis flood is defined as the most severe flood conditions that can reasonably be anticipated to occur at a site." Such an approach for evaluating potentially severe flooding hazards is conceptually inconsistent with well-established probabilistic methods for the assessment of other extreme external hazards, such as very large earthquakes and hurricane winds. It is also not consistent with stated Commission policy that regulatory decisions should take maximum advantage of risk information, which includes an integrated probabilistic assessment of event frequencies, potential consequences, and associated uncertainties.

It is not practically feasible to integrate probabilistic flooding hazards analysis methods into RG 1.59 in a timely manner to support current regulatory needs. Therefore, DG-1290 should be issued for public comments after the recommendations that are discussed in the next three sections are addressed. The final section of this report discusses our recommendations for expedited inclusion of probabilistic methods in a subsequent revision of RG 1.59.

Relationship of "Probable Maximum" and Probabilistic Hazards Analysis

DG-1290 contains numerous passages that characterize design-basis flooding conditions as "the most severe flood conditions that can reasonably be anticipated to occur at a site" and "conditions that can reasonably be predicted to occur." However, the guidance also uses terms such as "most severe hazards" and "maximum credible" to characterize these flooding events and their contributing causes. In the discussion of analysis approaches, it is further noted that "probable maximum" or "maximum credible" events are "thought to have 'virtually no risk of exceedance."' These terms convey very different concepts about how to interpret the flooding events that are identified and evaluated according to the methods that are endorsed in this guidance.

The Glossary in Appendix I does not improve understanding of these concepts. For example, it contains a definition for the "design-basis flood" and several entries that briefly define a variety of "probable maximum" events, which are the conceptual bases for many of the flood-causing mechanisms and their analyses. The "design-basis flood" definition characterizes the flood as the consequence of "the most severe hazards." This definition seems to imply that the design-basis flood represents a physical upper bound for the flooding consequences, regardless of the event frequency. However, the definitions of "probable maximum" events range from events that are "thought to specify the physical limit of a natural event" to events that are the "most severe reasonably possible" or are "reasonably expected," considering available historical data and margins for the limitations of those data.

Contemporary assessments of potentially severe external hazards, such as large earthquakes, typically characterize those hazards by site-specific curves that display the best estimate of the hazard frequency as a function of its severity, with a corresponding evaluation of the uncertainties in those estimates. In some cases, fundamental physical considerations may constrain the maximum possible severity of a particular phenomenon. In other cases, it may be difficult to specify a maximum physical limit. The form and function of these hazard curves (also known as exceedance curves) are not influenced by such ambiguous concepts as "probable maximum," "maximum credible," "reasonably possible," "can reasonably be anticipated," etc.

When the results from the deterministic analyses that are performed according to the guidance in DG-1290 are used for regulatory decision making, it is important for site personnel, staff reviewers, NRC managers, and public stakeholders to consistently understand their meaning and their limitations. This is crucial to avoid misperceptions that the deterministically evaluated flood severity cannot be exceeded or that the expected flooding frequency is vanishingly small. DG-1290 provides clear guidance and methods for the computation of deterministic design-basis values. It also cites an exceedance frequency of $1x10^{-6}$ event per year as a metric for the assessment of these flooding scenarios. The guidance should make it clear that licensees should provide justification that the deterministically derived flood levels correspond to conditions that have a total expected frequency of less than $1x10^{-6}$ event per year, or they should develop suitable alternative analyses that provide this assurance.

Specification of Combined Event Scenarios

Appendix H, Section H-2, contains a list of prescribed conditions which define flooding scenarios that may result from combinations of precipitation; seismic failures of dams; floods along shorelines of streams, open bodies of water, and enclosed bodies of water; and tsunamis. The introduction to this section appropriately cautions that the list should not be used as a "cook book." However, the number of examples and their degree of specificity strongly imply that the depicted combinations define the scope of analyses that would be deemed necessary and sufficient to satisfy this element of the regulatory guidance.

The specified combinations are extracted from Appendix H of NUREG/CR-7046, where it is noted that:

"The combinations identified by ANS are thought to have an probability-of-exceedance of less than 1×10^{-6} (ANS 1992). Supporting information related to the probability-of-exceedance of combined events is provided by ANS (1992); however, rigorous statistical analyses have not been completed for these estimates."

In many cases, the specified scenarios represent stylized combinations of conditions that may not be applicable to a particular site. In other cases, the listed conditions may not include combinations of site-specific hazards that could exceed the nominal exceedance frequency of $1x10^{-6}$ event per year. For example, the design-basis earthquake exceedance frequency at many sites is typically on the order of 10^{-4} to 10^{-5} event per year. Thus, it may be necessary to consider the effects from much larger earthquakes to provide assurance that the frequency of floods that involve seismically induced damage is less than $1x10^{-6}$ event per year.

The staff should revise DG-1290 Appendix H, Section H-2, to remove the implied need to evaluate the list of prescribed conditions. The guidance should provide more general examples of the types of combined conditions that should be evaluated, without reference to specific numerical values, assumed recurrence intervals, or logical combination rules. It should also emphasize the need to perform these analyses for the applicable site-specific flood-causing mechanisms and to examine the sensitivity of the analysis results to variations in the combined event frequencies and possible dependencies among the conditions.

Failures of Downstream Dams

Appendix B, Section B-3.3, contains guidance for the evaluation of dams, reservoirs, and levees. It is noted that the information for these evaluations applies to “all upstream and downstream dams that could have a significant influence on floods or the plant’s safety-related water supply.” Subsequent guidance in this section focuses exclusively on failures of upstream dams or other water retention structures that are located above the plant grade elevation. Failures of these structures are evaluated for their potential to cause flooding (i.e., inundation) at the site.

Site-specific flood-causing mechanisms may also contribute to coincident or dependent failures of downstream dams or other water control structures that impound the plant's safety-related cooling water supply. The safety consequences from these events may not be evaluated appropriately if the analyses focus only on inundation of specific structures at the site. For example, the consequences from moderate site flooding combined with damage to the safety-related water retention structures could be more severe than the site inundation alone. The guidance for evaluation of the effects from dam failures should also include coincident or dependent failures of downstream dams that may either drain or significantly reduce the plant's safety-related cooling water supply.

Revision of RG 1.59 to Include Probabilistic Flooding Hazards Analysis

Well-established guidance exists for probabilistic assessments of other potentially severe hazards that may affect a nuclear power plant site. RG 1.208 contains extensive guidance for probabilistic assessments of the site-specific seismic hazard, including methods for evaluation of the uncertainties about that hazard. RG 1.76 and RG 1.221 contain guidance for probabilistic assessments of exceedance frequencies and consequential damage from high winds that are associated with tornadoes and hurricanes. RG 1.59 should be updated to provide corresponding guidance for state-of-the-practice probabilistic assessments of site-specific flooding hazards.

As noted above, the introduction to DG-1290 states that the proposed guidance is focused primarily on deterministic methods because “well-established probabilistic frameworks for assessing the site-specific extreme precipitation and flooding events of interest for design-basis determination are not widely used.” Other Federal agencies (most notably the Bureau of Reclamation, the US Army Corps of Engineers, and the Department of Energy) currently use probabilistic methods in their assessments of flooding hazards. We have not had an opportunity to review those methods or their applications and, therefore, we cannot comment on their technical scope or possible limitations. However, these methods should be examined for application or adaptation in probabilistic flooding hazards analyses for nuclear power plant sites. Methods that are used to extrapolate available hurricane data may also be applicable for estimating exceedance frequencies for severe storms that involve both high winds and extreme precipitation. Information from paleoflood studies may be used to derive exceedance frequencies for extreme flooding conditions, based on local and regional geologic evidence. It also seems feasible to apply the established methods for evaluating seismic hazards to examine potential sources of episodic events that may cause flooding from tsunamis.

It is not our intent to provide a comprehensive list of references for probabilistic flooding analysis methods or to endorse any specific methods for future application in the regulatory guidance. However, it is apparent to us that probabilistic methods have been developed and are used more widely than may be inferred by the discussion in DG-1290. For this revision of RG 1.59, it is not practically feasible for the staff to thoroughly examine the available probabilistic methods and extend them as necessary to support integrated guidance for the assessment of site-specific flooding hazards. However, after RG 1.59, Revision 3, is issued, the staff should expedite the development of probabilistic methods to consistently evaluate exceedance frequencies for each flood-causing mechanism that is addressed in DG-1290. To the extent possible, those efforts should build on existing methods and guidance for the evaluation of other severe external hazards. The proposed methods should be applied to pilot plant sites which are exposed to multiple flooding hazards. This will demonstrate how available data, analytic models, and guidance can be used in an integrated approach.

We look forward to continuing our dialogue with the staff to facilitate expeditious development and application of these probabilistic methods.

Sincerely,

/RA/

J. Sam Armijo
Chairman

REFERENCES

1. Draft Regulatory Guide DG-1290, "Design-Basis Floods for Nuclear Power Plants" (Proposed Revision of Regulatory Guide 1.59), June 2012 (ML12121A018).

2. Regulatory Guide 1.59, “Design-Basis Floods for Nuclear Power Plants,” Revision 2 with Errata, July 1980 (ML003740388).

3. “Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident,” March 12, 2012 (ML12053A340).

4. NUREG/CR – 7046, “Design-Basis Flood Estimation for Site Characterization at Nuclear Power Plants in the United States of America**,**” November 2011 (ML11321A195).

5. Draft NUREG/CR-7131, “Synthesis of Extreme Storm Rainfall and Probable Maximum Precipitation in the Southeastern US Pilot Region,” December 2011 (Unpublished).

6. Draft NUREG/CR-7132, “Application of Radar-Rainfall Estimates to Probable Maximum Precipitation in the Carolinas,” December 2011 (Unpublished).

7. Draft NUREG/CR-7133, “Review of Probable Maximum Precipitation Procedures and Databases Used to Develop Hydrometeorological Reports,” December 2011 (Unpublished).

8. NUREG/CR-7134, "The Estimation of Very-Low Probability Hurricane Storm Surges for Design and Licensing of Nuclear Power Plants in Coastal Areas," May 2012 (Unpublished).

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Letter to R.W. Borchardt, EDO, from J. Sam Armijo, ACRS Chairman, dated September 25, 2012

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