Technical Advisory Committee of the Nuclear Risk Research Center
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SUBJECT: INTERIM REPORT ON THE STATUS OF TSUNAMI RISK ASSESSMENT RESEARCH

Dear Dr. Apostolakis:

During the sixth meeting of the Technical Advisory Committee of the Nuclear Risk Research Center (NRRC), November 7-11, 2016, the NRRC staff provided an overview of the center's proposed research activities related to tsunami hazard and fragility assessments. The two presentations provided a high level description of the research strategy and the general methodology. The staff's stated purpose for these briefings was to obtain our feedback on potential gaps in the proposed analysis scope and approach. Our conclusions and recommendations are based only on the material provided in the referenced presentations and limited interactions with the staff during our meeting.

CONCLUSIONS AND RECOMMENDATIONS

1. The project's objective of developing an integrated and holistic understanding of the potential risk induced by tsunamis through investigating the phenomena that generate tsunamis, estimating the frequency of potentially damaging tsunamis, and evaluating the plant response to direct and indirect impacts of tsunamis is important and appropriate.

2. The proposed analysis scope for investigating the reliability of flood protection barriers (such as seawalls, water-tight doors, etc.) that may have been weakened by the tsunami-inducing seismic event is desirable. This is an area of research that is beyond the current state of practice. Since there is little, if any, previous work to build on, it is important that this task proceeds with a significant level of deliberation and consultation with structural experts to ensure the scope is well-defined, and it provides realistic and technically defensible results.

3. The graded analysis approach, which consists of a series of progressively more refined analyses that depend on the site-specific tsunami hazard severity, is

consistent with contemporary risk assessment practice. However, the team should reconsider how the screening criteria for the graded analyses are developed and applied to account for uncertainties in the tsunami hazard.

4. Based on the limited details provided in the presentation material and our discussions with the staff, we have questions about the following issues related to possible site-specific vulnerabilities.
   - Whether the failure probability of all potential flood propagation pathways will be evaluated consistently
   - Whether indirect consequential impacts from a tsunami event will be considered adequately

5. Until there is a better understanding of the potential site-specific risk from seismically-induced tsunamis, the scope of the initial research work and the probabilistic risk assessment (PRA) models should not try to account for the relative timing of the seismic and tsunami effects.

6. The team should determine how the combined effects from seismically-induced tsunamis will be represented and quantified in the PRA models. The methods to develop the composite hazard and to evaluate the structural and equipment fragilities for each source of loading should be compatible with the PRA modeling framework.

BACKGROUND

Tsunami waves may affect safety of a nuclear power plant by damaging structures, systems, and components (SSCs) needed for core decay heat removal, containment functions, and spent fuel cooling. All nuclear power plants that are potentially exposed to the tsunami hazard have installed barriers and features which are designed to protect those SSCs. Assessing whether these protection features adequately address all potential vulnerabilities and determining that they maintain the tsunami risk at an acceptable level are key components of a comprehensive risk management program. The NRRC staff is planning to conduct studies that develop a technical basis and provide analytical tools for a systematic and probabilistic assessment of the tsunami hazard.

DISCUSSION

In general, the presented material and our discussions with the NRRC staff indicated that the proposed studies provide a solid basis for evaluation of the tsunami risk. The strategy for developing a tsunami hazard PRA is generally consistent with the state-of-practice for PRA evaluations of other external hazards. The proposed methodology for assessing the risk from composite damage caused by a seismically-induced tsunami is beyond the state of practice. The following discussion and corresponding recommendations are provided to enhance the proposed studies.

Graded Approach to Scope of Analyses

The proposed methodology applies a graded approach to the evaluation of tsunami risk, depending on the frequency and severity of the site-specific tsunami hazard. The graded approach suggests that the most detailed assessments would be performed for sites that have the most challenging tsunami hazard, while more simplified conservative assessments are performed for sites at which the hazard is less severe. This approach is reasonable and consistent with general PRA practices.

The proposed screening criteria for application of this graded approach are based on the mean occurrence frequency of tsunami waves that may overtop the site seawall. Since there is substantial uncertainty in the tsunami hazard at any site, the mean value of the exceedance frequency may not be adequate for this type of screening process. This is especially true if the site-specific analyses indicate that there is a significant probability that damaging waves may occur more frequently than the nominal mean value screening criterion. Thus, more complete consideration of the uncertainty could affect decisions regarding the needed scope of the damage assessments. These considerations are potentially important for sites that are near the numerical screening boundaries between the successive evaluation categories.

The team should consider how the screening criteria are developed and applied to account for uncertainties in the tsunami hazard. For example, the criteria may more appropriately account for a certain confidence that the hazard will not exceed the specified severity, rather than reliance on only the mean exceedance frequency.

Potential Flood Propagation Pathways and Impact Analysis

The tsunami PRA methodology presentation and our discussions with the NRRC staff did not provide adequate assurance that the failure probability of all potential flood propagation pathways will be evaluated consistently. For example, flood propagation paths via failures of waterproof seals (e.g., randomly, or due to increased tsunami-induced back pressure) seem to have been dismissed without adequate technical justification. Additionally, it was not clear whether indirect consequential impacts from a tsunami event, such as plugging of cooling water intake screens or fouling of in-plant heat exchangers due to the introduction of large volumes of tsunami-generated debris (e.g., plastic bags, seaweed, oil from nearby industrial or storage facilities, etc.) will be considered adequately.

Treatment of Tsunami Arrival Time for Seismically-Caused Tsunamis

The proposed research contemplates developing a method and supporting models to explicitly account for the delay between the time that a seismic event affects a site and the tsunami waves reach the site. There is uncertainty in the timing of the tsunami arrival at the affected site, depending on the location of the earthquake source, its magnitude, site-specific bathymetry, etc. On the other hand, the duration of the seismic event is typically relatively short. The substantial effort needed to explicitly account for these timing considerations may not provide unique additional insights regarding the most important contributions to risk. In practice, PRA models for specific risk-significant scenarios are occasionally refined to account for timing information, if it is very important to their frequency or consequences. However,

those refinements are applied only after the scenario-specific risk contributors are identified and are well understood.

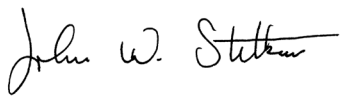
Based on these considerations, the initial research work in this area should not try to account for the relative timing of the seismic and tsunami effects. It is most important to first develop methods and models that can be used to derive the composite hazard, consistently evaluate the site-specific fragilities, and represent the combined seismic and tsunami damage for quantification in the PRA models.

Integration of Seismic and Tsunami Damage in PRA Models

This is a difficult task, and its solution will extend the current state-of-practice in PRA. It is a significant challenge to develop consistent methods to analyze the composite seismic and tsunami hazard, evaluate site-specific fragilities for the combined loads, and quantify the effects from the overall damage in the PRA models. Experience has shown that it is often useful to structure the supporting analyses for these complex problems by first understanding how the results will be used in the PRA. Therefore, that element of this research should receive early priority.

The team should determine how the combined effects from seismically-induced tsunamis will be represented and quantified in the PRA models. The methods to develop the composite seismic and tsunami hazard and to evaluate the structural and equipment fragilities for each source of loading should be compatible with the PRA modeling framework. During the meeting, we briefly discussed a general conceptual construct for these hazard and fragility assessments. We look forward to continuing our discussions with the NRRC staff as they develop and refine their methods and models for this important research topic.

Sincerely,



John W. Stetkar
Chairman

REFERENCES

1. "Strategy of Development of Tsunami PRA," NRRC Staff Presentation to NRRC Technical Advisory Committee, November 7, 2016, Proprietary.

2. "Development of PRA Methodology for Superposed Seismic and Tsunami Hazards," NRRC Staff Presentation to NRRC Technical Advisory Committee, November 7, 2016, Proprietary.