Technical Advisory Committee of the Nuclear Risk Research Center
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SUBJECT: OUTCOME OF HAMAOKA MODEL PLANT LEVEL 2 TSUNAMI PRA PROJECT

Dear Dr. Apostolakis:

During the 16th meeting of the Technical Advisory Committee of the Nuclear Risk Research Center (NRRC), May 23-27, 2022, we had a final briefing on the technical bases and results from the research project of a Level 1 and Level 2 PRA evaluation of the risk from tsunamis, using a model plant that is based on Hamaoka Unit 4.

CONCLUSIONS AND RECOMMENDATIONS

1. Completion of the Level 1 and Level 2 PRA research project to evaluate the tsunami risk for a model plant is a milestone achievement for the Japanese nuclear industry, and it has extended the methods and modeling tools that can be used to analyze risk in tsunami-prone areas worldwide.

2. The models, data, and supporting analyses should receive an independent and in-depth technical review.

3. A targeted sensitivity analysis should be performed to quantify the Level 1 and Level 2 models without the suppression chamber cooling and fission product scrubbing effects from the tsunami flood water in the reactor building

4. The research team should examine how timing considerations are typically modeled throughout a practical full-scope PRA before more detailed event scenario timing models are developed specifically for the tsunami analyses.

5. After resolution of the preceding recommendations, it should be possible to efficiently transform this research model into a technically sound, realistic, practical Level 1 and Level 2 PRA model for evaluating the risk from tsunamis at

Hamaoka Unit 4. The Hamaoka plant-specific PRA could then be used for risk-informed decision-making.

6. The NRRC should develop tsunami risk assessment guidance for use by the Japanese utilities and the standards committee.

BACKGROUND

The primary objective of this research project was to develop a technical basis for evaluating the risk from tsunamis, using enhanced analytical methods and an integrated Level 1 and Level 2 PRA model. We have received several briefings on this project throughout its evolution, including research results regarding the tsunami hazard analyses, fragility analyses, PRA models and accident analyses, and interim results for the frequencies of core damage and containment failure. Our November 27, 2016 letter report provided our conclusions and recommendations on supporting research for the preliminary models and analyses. During the present meeting, the NRRC research team reported the results from the Level 2 PRA source term evaluation and uncertainty analyses.

DISCUSSION

Completion of the Level 1 and Level 2 PRA research project to evaluate the tsunami risk for a model plant is a milestone achievement for the Japanese nuclear industry, and it has extended the methods and modeling tools that can be used to analyze risk in tsunami-prone areas worldwide. The level of analytical details in the model, including the systematic process used for evaluation of uncertainties and the extensive coverage of tsunami-induced risk scenarios, enables its use as a valuable risk management tool.

As with all pioneering research, there are important lessons to be learned from this initial application and potential enhancements that will further improve its technical adequacy and capabilities.

Independent Technical Review

To date, the models, data, and supporting analyses have been reviewed primarily by the project team as part of their normal research, development, and testing practices. The team was also advised by an expert committee, formed by the Ministry of Economics, Trade, and Industry (METI), the project sponsoring organization. We have provided individual member comments on specific issues during our periodic briefings, but we have not performed a review of the complete project and its results.

It is essential that a study of this technical complexity and importance should receive an independent and in-depth technical review. That review is needed to provide confidence in the technical quality of the methods, models, and results, so that they may be adapted for use in plant-specific PRAs at a variety of sites in Japan and worldwide.

The review should be comprehensive. However, special attention should be focused on analyses and models that were developed specifically during this project, such as the tsunami hazard analyses, fragility analyses for structures and equipment, selection of tsunami initiating events as a function of wave height at the control point, tsunami scenario event tree, flooding inundation models, integrated human reliability analyses, containment failure modes and locations, adaptations of MAAP models for suppression chamber external cooling, MAAP models for fission product releases and transportation in submerged and dry areas of the reactor building, etc.

Reactor Building Flooding Analyses

The PRA model evaluates multiple possible pathways for the tsunami flood water to enter the reactor building, depending on the wave height and the status of flood barriers. The consequential depth of water inside the building and the corresponding damage to equipment depend on the specific event scenario and the applied inundation models.

One objective of the Level 2 analyses in this study was to examine the following effects from the water in the reactor building:

- External cooling of the suppression chamber
- Scrubbing of fission products that are released into the flooded compartments

The research team has indicated that more detailed models are desirable to improve fidelity in all of the following analyses:

- Water flow into and distribution throughout the reactor building
- MAAP models for external cooling of the suppression chamber
- MAAP models for fission product releases into the flooded areas of the reactor building and transportation throughout the building
- Improved evaluation of decontamination factors for fission product scrubbing during releases into flooded compartments

The current study results indicate that the most important contributions to the source term for cesium involve accident scenarios with releases into the dry areas of the reactor building. However, those results account for the cooling and scrubbing effects that are discussed above. During our meetings with the project team, we could not determine the extent to which the source term and the overall risk are mitigated by those effects.

A targeted sensitivity analysis should be performed to quantify the Level 1 and Level 2 models without the suppression chamber cooling and fission product scrubbing effects from the water in the reactor building. The sensitivity analysis should retain the effects from equipment damage due to the reactor building flooding. However, the heat transfer from the suppression chamber into the reactor building water should be removed (e.g., heat transfer coefficient set to zero[1]), and the effects from fission product scrubbing through the reactor building water should be removed (e.g., decontamination factor set to zero).

A comparison between the results from the sensitivity analysis and the baseline study results (e.g., for core damage frequency and the cesium source term) will provide an estimate of the overall risk benefit that is afforded by the applied reactor building flooding models. It will also identify whether the most important risk benefits are from the suppression chamber cooling effect, the fission product scrubbing effect, or both. The team should then make a risk-informed decision regarding whether more detailed models are needed.

Treatment of Scenario Timing

The research team has discussed the need for more detailed treatment of the event scenario timing and dynamics. For example, for tsunamis that are generated by earthquakes, one potential element of the detailed scenario timing involves the responses of plant systems and personnel during the interval between arrival of the first seismic shock and arrival of the first tsunami wave. Another potential element of the detailed scenario timing involves the development of dynamic inundation models that determine the times at which specific equipment fails and personnel actions are needed, with corresponding effects on the thermal-hydraulic models for the event scenario progression.

Experience from numerous contemporary full-scope PRAs indicates that analysts typically make many simplifying assumptions which conservatively bound the functional effects from detailed timing considerations. For selected risk-significant scenarios, timing may be evaluated explicitly, but at a rather coarse level that is sufficient to account for the most important functional effects (e.g., timing models for loss of offsite power, failures of onsite emergency generators, and recovery of offsite power). More detailed treatment of event scenario timing for the tsunami analyses is justified if that treatment would have a significant effect on overall plant risk. Furthermore, treatment of potential mitigation actions and their timing should account for actual operating experience.

The research team should examine how timing considerations are typically modeled throughout a practical full-scope PRA before more detailed event scenario timing models are developed specifically for the tsunami analyses.

Transition to a Plant-Specific PRA

During our discussions with the project team, we were informed that the results from the model plant evaluation might be used as a reference to identify high-priority accident scenarios and to support risk-informed decisions for accident management guidance at Hamaoka Unit 4.

[1] The sensitivity analysis should remove credit for the heat transfer from the suppression chamber into the water in the reactor building. The analysis should account for the consequential effects from suppression chamber heatup on the conditional probability of core damage and scrubbing of fission products in the suppression chamber.

After resolution of the preceding recommendations, it should be possible to efficiently transform this research model into a technically sound, realistic, practical Level 1 and Level 2 PRA model for evaluating the risk from tsunamis at Hamaoka Unit 4. The Hamaoka plant-specific PRA could then be used for risk-informed decision-making. For example, an important initial risk-informed application could be confirmation of the effectiveness of the very significant prevention and mitigation measures already in place for tsunamis, as well as the optimization of accident management actions for response to severe tsunamis. The models could also be used to evaluate the potential risk benefits from proposed additional prevention or mitigation measures, or to identify conservatisms leading to overly burdensome constraints.

Guidance Development

Considering the fact that this pioneering work can be the foundation for an advanced and holistic analysis of the tsunami risk and is a major contribution to the international risk assessment community, the NRRC should develop detailed tsunami risk assessment guidance that can be used by the Japanese utilities and the standards committee.

Sincerely,

John W. Stetkar
Chairman

REFERENCES

1. "Outcome of Level 2 PRA on Hamaoka Tsunami PRA Project – Source Term Evaluation and Uncertainty Analysis," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 25, 2022, Proprietary.

2. "Tsunami Fragility," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 31, 2016, Proprietary.

3. "CRIEPI / NRRC's R&D," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 31, 2016, Proprietary.

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

5. "Determination of Scenario Tsunami Conditions for Fragility Assessment Based on Hazard Deaggregation," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 22, 2017, Proprietary.

6. "PTHA and TFA in Tsunami PRA," NRRC Staff Presentation to NRRC Technical Advisory Committee, November 8, 2017, Proprietary.

7. "Tsunami PRA Hazard and Fragility (Outdoor) Assessment (As a Study Applied to Hamaoka NPP)," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 23, 2018, Proprietary.

8. "Tsunami PRA Level 1 (Accident Sequence Evaluation) and Level 2 (Hamaoka Study)," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 23, 2018, Proprietary.

9. "Progress of Tsunami PRA Project," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 22, 2019, Proprietary.

10. "HRA Application Method in Hamaoka Tsunami PRA and the Effectiveness of HRA Improvement in PRA Results," NRRC Staff Presentation to NRRC Technical Advisory Committee, May 22, 2019, Proprietary.

11. Technical Advisory Committee of the Nuclear Risk Research Center, "Interim Report on the Status of Tsunami Risk Assessment Research," November 27, 2016.