Technical Advisory Committee of the Nuclear Risk Research Center
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SUBJECT: RESULTS OF IKATA SSHAC LEVEL 3 PROJECT AND PLAN FOR SSHAC-BASED PSHA DEVELOPMENT IN JAPAN

Dear Dr. Apostolakis:

This letter report provides our observations, conclusions, and recommendations from our review of the results of the Ikata Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 Project and plans for SSHAC-based Probabilistic Seismic Hazard Analysis (PSHA) development in Japan.

Due to the ongoing COVID pandemic, we could not meet with your team in our usual format to exchange information and discuss our comments and questions on these topics. In early October 2021, the Nuclear Risk Research Center (NRRC) seismic research team sent us the following materials:

- English translations of the Ikata SSHAC Level 3 Final Report and Executive Summary

- Review comments from Dr. Kevin Coppersmith (Special Advisor to the project) and Dr. Martin McCann (member of the Participatory Peer Review Panel)

- Presentations that summarize the technical content of the Ikata study and the NRRC's preliminary plans for future SSHAC-related activities

We reviewed these materials and prepared our individual comments and questions, as we would normally do before our meeting. We sent several of those individual member comments and questions to you for preliminary consideration by the SSHAC project team and the NRRC staff. We then held a 2-hour video conference in December 2021 to discuss selected comments and questions. The SSHAC team also provided detailed and thoughtful written responses to supplement our oral discussions. We deliberated on those discussions and the team's responses, and we developed the Committee's consensus observations, conclusions, and recommendations that are provided in this letter report.

As discussed later, completion of the Ikata SSHAC project and activities related to use of the SSHAC approach in Japan are some of the NRRC's most critical undertakings in its mission to expand the use of risk-informed decision-making (RIDM). The purpose of our review was to provide comments and observations on the Ikata SSHAC report, NRRC's plans to develop guidance for the use of SSHAC approaches by other utilities, plans for the development of regional SSHAC studies, and plans for specific studies to characterize local site response.

As we have often stated in our letter reports during the last two difficult years, our experience from this effort continues to reinforce the vital importance of the dynamic interactions during our face-to-face meetings. This is worth emphasizing again. We sincerely hope that we can return to our normal meetings in 2022.

CONCLUSIONS AND RECOMMENDATIONS

1. We congratulate and commend Shikoku Electric Power Company, the NRRC, and the entire SSHAC team for undertaking a complex, but essential, project and successfully completing it in accordance with the SSHAC guidance. This is a groundbreaking project that should help Japanese utilities to conduct comprehensive seismic risk evaluations, safety analyses, and RIDM applications.

2. The NRRC's planned activities for fiscal years 2022 through 2024 are timely to support the utilities' near-term needs. The NRRC should also evaluate the need for other focused research and studies to further support the utilities' PSHA plans.

3. We understand that NRRC plans to issue a PSHA Implementation Guide in March 2022, based on the Ikata SSHAC experience. We request a detailed briefing on the scope and technical contents of the Guide at the earliest opportunity. The Discussion section of this report outlines a few preliminary recommendations for the Guide, based on the available summary material and our discussions to date.

4. We understand that development of a Regional PSHA Study is planned for fiscal years 2022 through 2024. We request early and periodic briefings on the scope and specific technical activities for that study when the comprehensive planning is completed.

5. The NRRC research team should develop guidance and an example application for a SSHAC-based evaluation of local site response for a soft rock site. That guidance and application should be integrated with the Regional PSHA Study activities, and it should be completed before utilities begin to perform their updated site-specific PSHAs.

6. We understand that site-specific PSHA studies are planned to begin in fiscal year 2024 or 2025, using the information from the regional studies. We request a briefing on the scope and technical elements of those site-specific PSHA studies when the technical interface with the regional studies is determined.

BACKGROUND

The fundamental goal of the SSHAC process is to produce a probabilistic hazard analysis that captures the center, body, and range of technically defensible interpretations from the scientific community of seismic experts.

The Ikata SSHAC Level 3 PSHA study was sponsored by Shikoku Electric Power Company. The NRRC provided project management and technical support. The project Technical Integration teams were comprised of recognized experts from throughout the Japanese seismic technical community, including universities and private companies. Dr. Kevin Coppersmith, an internationally renowned expert from the United States, served as a Special Advisor to the project. Reviews were conducted by a separate Participatory Peer Review Panel, which included Japanese experts and Dr. Martin McCann from the United States. The study was conducted according to a SSHAC Level 3 assessment process, following contemporary guidance from the United States Nuclear Regulatory Commission, as implemented in numerous international SSHAC-based PSHA projects.

The completion of the SSHAC Level 3 project for the Ikata site is a major accomplishment, considering the importance of seismic issues in nuclear safety and public perception of the seismic risk. It is important to demonstrate and explicitly account for a credible and systematic consideration of uncertainties in the evaluation of a natural hazard that is inherently highly uncertain. The SSHAC methodology represents an internationally accepted practice that has been utilized for many years. Shikoku Electric Power Company and the NRRC are commended for carrying out this project for a complex seismotectonic environment, as well as in a different cultural and a different regulatory environment and in a reasonable schedule.

We recommended implementation of the SSHAC project for Ikata in our January 24, 2015 letter report. Since then, we have been briefed on the progress of the SSHAC project at almost every meeting. During our November 2016 meeting, NRRC also started to describe its plans for PSHA enhancements in Japan, based on the Ikata SSHAC project. We provided our recommendations on this aspect of the project in our November 27, 2016 letter report. The NRRC plans for SSHAC-based PSHA development in Japan are critical to gain acceptance by the Japanese utilities and to create a practical methodology suitable for the seismotectonic environment and business practices of Japan. The lessons learned from the Ikata project should provide important inputs to both technical and programmatic elements.

DISCUSSION

Completion of the Ikata SSHAC project is a very significant milestone. The next steps are to extend the use of SSHAC approaches by other utilities to provide a robust, state-of-practice analysis of the seismic hazard at each site. Those comprehensive hazard analyses will facilitate improved evaluations of the risk from seismic events, regulatory safety assessments, and site-specific RIDM applications.

Based on the summary information provided for our reviews and our discussions with the NRRC staff, we understand that the NRRC's plans for PSHA enhancement consist of the following three steps:

Step 1: Prepare a PSHA Implementation Guide based on the Ikata SSHAC study (to be completed in March 2022).

Step 2: Prepare a Regional PSHA Study and supporting technical evaluations which are broadly applicable to one or more regions in Japan (planned for fiscal years 2022 through 2024).

Step 3: Conduct site-specific PSHA evaluations, based on information from the regional studies (to begin in fiscal year 2024 or 2025).

We fully support these progressive activities to develop a comprehensive probabilistic assessment of the seismic hazard at each Japanese nuclear plant site.

The NRRC staff described some of the challenges that were encountered during the Ikata study and how they may affect the use of SSHAC approaches by other utilities. Two of the challenges include: (1) budgetary and time resources required for a site-specific study and (2) availability of expert resources, considering the academic and business environment in Japan. The NRRC's proposed activities are intended to address several elements of these challenges.

The following sections summarize our preliminary observations, comments, and recommendations for each major step of the NRRC plan, based on the information that we have received to date.

PSHA Implementation Guide

This near-term "guide" can also be viewed as a lessons-learned report from the Ikata SSHAC activities. We understand NRRC's desire to issue this guidance as soon as possible. It is very useful for all Japanese utilities to share the knowledge and experience from this landmark study. We understand that the working group that is preparing the Guide consists of subject matter experts, Technical Integration team members, a Participatory Peer Review Panel member, and members of the NRRC team who participated in the Ikata project. The lessons learned from the SSHAC project can be grouped into the following three general categories:

1. Procedural issues related uniquely to the Japanese academic and business environment.

2. Technical issues. These technical issues can be further divided into general technical issues that are common to all PSHA analyses and issues that are specific to an application of the SSHAC methodology.

3. Logistics and implementation issues.

Some of the adaptations and adjustments made by the Ikata project team provide valuable practical experience for ways to cope with procedural and logistical

challenges in implementing the SSHAC process in Japan. Consistent with our technical advisory role to the NRRC, we will focus more on the technical issues.

The Ikata SSHAC project team conducted comprehensive studies on several concepts that are different from the PSHAs that Japanese utilities have implemented so far. Examples include evaluations of a variety of international analysis methods and data, selection of a wide range of Ground Motion Prediction Equations (GMPEs), detailed study of site correction factors, and adoption of specific fault rupture models. As the NRRC research team noted during our discussions, these are important issues that should be brought to the attention of utilities before they update their PSHAs.

We understand that the Guide will address the need for training on the SSHAC methodology and process. We also understand that the participants in each SSHAC project will receive individual training when the project is implemented. However, it would be very useful for the Guide to provide a baseline training plan which can be referenced and adapted as necessary to suit the needs of an individual project. This will be a good way to transmit the experience and lessons learned from the Ikata project, and it will provide a consistent knowledge base when new experts implement the SSHAC process for the planned regional studies and site-specific analyses.

The Guide should also address some other broader generic issues that are important to understanding the technical basis and limitations of the PSHA results. Examples of these issues include insights into data collection, insights into sources of uncertainties, identification of dominating seismic sources, and additional investigations that could be undertaken for better characterization. This could lead to the development of joint programs by the utilities to further examine these issues that are common to all PSHAs.

The systematic and transparent consideration of uncertainties is one of the most important elements of the SSHAC process. To enhance the value of the Ikata experience and develop insights for the next phase, it is suggested that the Guide should provide a more detailed discussion of lessons learned with respect to uncertainties and issues encountered. It should also contain guidance for how to achieve an appropriate, technically-defensible balance between (1) the fundamental need for a comprehensive, integrated evaluation of epistemic and aleatory uncertainties in all elements of the analyses, and (2) the performance of resource-intensive, detailed analyses using specific analytical methods and models.

Determination of the site-specific seismic hazard is fundamental, but it is not the final step. The PSHA results are relevant only when they are used for integrated risk-informed decision-making. For example, in deterministic safety analyses, a comparison of the design-basis seismic spectra with the probabilistic hazard, including uncertainty, can be used to evaluate the robustness of structures, systems, and components against seismic loads over a range of earthquake recurrence intervals and to decide whether equipment modifications or operating procedure enhancements are needed. The PSHA results are also used in an integrated probabilistic risk assessment (PRA) that evaluates the risk of damage to the reactor core and spent fuel (Level 1) and consequential offsite releases (Level 2) from the entire spectrum of earthquake hazards, including explicit treatment of the uncertainty

in the risk. Results and insights from the PRA are key elements in site-specific and industry-wide risk-informed decision-making applications. It is very important that the PSHA should be conducted in a manner which produces results that can be integrated with the desired uses. Therefore, the Guide should include information about how the analyses are structured to produce results that can be used in RIDM applications.

Unfortunately, it is not practically feasible for us to review the draft PSHA Implementation Guide and to exchange technical information, comments, questions, and specific recommendations with the NRRC research team before the planned March 2022 issuance date. We request a detailed briefing on the scope and technical contents of the Guide at the earliest opportunity.

Regional PSHA Study

The NRRC's objective for a Regional PSHA Study is to develop common information and models that will support eventual performance of site-specific analyses. This approach is intended to improve technical consistency and efficiency, and overcome some of the challenges associated with completely independent site-specific studies. This is a practice that has been carried out in other countries, such as the United States and Spain. The Regional Study also provides a consistent treatment of common elements, such as seismic sources and GMPEs, which may be applicable to several sites. Based on our preliminary discussions, we understand that, in addition to GMPEs and treatment of regional seismic sources (e.g., subduction type and other common areal sources), the study will also evaluate other generally applicable issues, such as validation of fault rupture models.

We understand that the SSHAC approach for the use of GMPEs and characterization of the associated uncertainties differs from the current Japanese practice, which relies primarily on GMPEs proposed by individual researchers using different databases. Along with the planned Regional Study, the NRRC is undertaking additional studies of some specific issues, such as treatment of GMPEs using standardized databases similar to that done in recent projects (e.g., for the Central and Eastern United States) and development of enhanced site correction factors (e.g., for site-specific corrections of GMPEs and local amplification). We agree that these two very important elements should be addressed soon.

We understand that there are other elements of the integrated methodology (e.g., fault rupture modeling) that can benefit from additional studies, but cannot be included in the 2022 - 2024 time frame. We suggest that the NRRC carefully evaluate these issues in the seismic research plans, considering the utilities' needs and schedules for their next PSHA updates. Of particular importance are those elements of the analyses which can have a systematic impact on characterization of uncertainties. Examples include development of earthquake catalogs utilizing short recorded history, incorporation of applicable alternate models rather than focusing on fewer models with emphasis on precise calculations, and use of nominal applied uncertainty distributions in lieu of direct quantification of uncertainties through the respective analytical models. Activities related to these issues and planned studies will require interactions with the utilities and external experts, and a dialogue with them should be initiated early.

The Regional PSHA Study and the development of companion guidance for integrated SSHAC-based site response analyses are very important. We understand that our current information is very preliminary and that more comprehensive planning is ongoing. We request early and periodic briefings on the detailed plans for the Regional Study, how the Regional Study will be utilized in the next phase of the analyses, and the results of outreach and communications with utility stakeholders.

Site-Specific PSHA Evaluations

We understand that site-specific PSHA evaluations based on the Regional Study will begin in approximately fiscal year 2024 or 2025 and continue beyond. The studies will include elements such as characterization of site-specific seismic sources, site corrections of regional GMPEs, site amplification, logic tree modeling, etc.

The three major elements of a site-specific PHSA include:

(1) Characterization of seismic sources,

(2) Characterization of ground motion (transmission of motion from each source to the bedrock, or reference rock, at the site), and

(3) Characterization of local site response (transmission of motion from the reference bedrock to the site structural foundations).

The local site conditions can have an important effect on the spectral frequencies and magnitudes of the accelerations that are transmitted to the plant structures. The uncertainties in the local site response are as significant as uncertainties in the other elements of the PSHA. Furthermore, the uncertainties in the local site response models must be evaluated consistently and integrated carefully with the uncertainties in the ground motion models that link the seismic sources to the site. For example, the abstract in a recent U.S. Nuclear Regulatory Commission Research Information Letter (RIL 2021-15) notes the following:

> *"…The SSHAC process has been consistently applied to the seismic source characterization (SSC) and ground motion characterization (GMC) components of PSHAs performed for critical facilities for more than 15 years. However, because site response analyses (SRA) have often been conducted outside of the SSHAC process it has not benefitted from the systematic evaluation of alternative data, models, and methods within a structured and logical framework….This report documents work sponsored by the NRC that applied the SSHAC process for systematically identifying and propagating epistemic uncertainties in the SRA as has been previously applied to the SSC and GMC analyses. The process was tested at two example sites, the resulting epistemic uncertainty in elements of the SRA at both sites were found to be as large or larger than those of the SSC and GMC models. This finding supports the rationale for implementing a structured process such as SSHAC to capture and document the uncertainties in the SRA."*

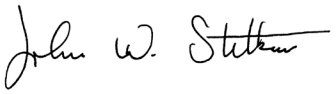
The report also documents the efficacy of alternative methods for incorporating the results of the SRA into the final PSHA hazard calculations.

The Ikata site is a hard rock site. Therefore, it was not necessary to address the issue of site amplification in the Ikata SSHAC study. In our letter report of November 27, 2016, we suggested that the NRRC consider a SSHAC project at a site with softer rock conditions. We understand the reasons why this was not practically feasible. We agree that it is important to proceed with development of the PSHA Implementation Guide and the Regional PSHA Study in a timely manner. However, we recommend that a study which demonstrates a SSHAC-based site response methodology and integrated treatment of uncertainties for a soft rock site should be undertaken in coordination with the Regional Study. The methodology, guidance, and an example application should be completed before utilities begin to perform their updated site-specific PSHAs.

We fully endorse the planned approach to extend the regional studies to site-specific PSHAs. However, it is not clear how this will be accomplished. For example, we do not know if NRRC plans to conduct example studies that demonstrate the general methods, or whether the plans include a complete PSHA evaluation for a selected site (in cooperation with a utility). We request briefings on the scope and technical elements of the site-specific PSHA studies, including the development of methods to conduct the local site response analyses, when the technical interface with the regional studies is determined.

The systematic development of site-specific SSHAC-based PHSAs is a critical element of an integrated understanding of the seismic risk at each Japanese nuclear power plant. That knowledge is essential to support a comprehensive process of risk-informed decision-making. We look forward to our continuing interactions with the NRRC seismic research team to review interim plans, draft guidance, and research results for these topics in a timely manner.

Sincerely,



John W. Stetkar
Chairman

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