Seismic Reevaluation of Nuclear Facilities in Taiwan

Development of the Hazard Input Document for Taiwan Using SSHAC Level 3 Methodology

Project Plan

Version 1

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National Center for Research on Earthquake Engineering

National Applied Research Laboratories

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LIST OF ACRONYMS

AEC	Atomic Energy Council
ANS	American Nuclear Society
ANSI	American National Standards Institute
CBR	Center, Body and Range
CEUS	Central and Eastern United States
CFR	Code of Federal Regulations
DCPP	Diablo Canyon Power Plant
EPRI	Electric Power Research Institute
GIS	Geographic Information Systems
GMC	Ground Motion Characterization
GMPE	Ground Motion Prediction Equation
GMRS	Ground Motion Response Spectrum
GPS	Global Positioning System
HCT	Hazard Calculation Team
HID	Hazard Input Document
INER	Institute of Nuclear Energy Research
ITC	Informed Technical Community
NCREE	National Center for Research on Earthquake Engineering
NGA	Next Generation of Attenuation Relationships
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NTTF	Near-Term Task Force
NUREG	Nuclear Regulation
PEs	Proponent Experts
PMO	Project Manager Office
PPRP	Participatory Peer Review Panel

PSHA	Probabilistic Seismic Hazard Analysis
PTI	Project Technical Integrator
QA	Quality Assurance
REs	Resource Experts
RG	Regulatory Guide
SSC	Seismic Source Characterization
SSCs	Structures, Systems, and Components
SSHAC	Senior Seismic Hazard Analysis Committee
SWUS	Southwestern United States
TDI	Technical Defensible Interpretation
TI	Technical Integrator
TPC	Taiwan Power Company

INTRODUCTION

In response to the 50.54(f) letter issued in March, 2012, an updated probabilistic seismic hazard analysis (PSHA) based on a Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 process (Budnitz et al., 1997; NRC 2012, NUREG 2117) is required to be conducted for all operating nuclear power plants in the United States. In Taiwan, the Atomic Energy Council (AEC) requested Taiwan Power Company (TPC) to reevaluate seismic hazard and review the seismic design basis of nuclear facilities in Taiwan based on the suggestions in NTTF 2.1: Seismic. As the result, TPC launched the "Seismic Reevaluation of Nuclear Facilities" Project executed by the National Center for Research on Earthquake Engineering (NCREE). A seismic hazard analysis will be performed for four nuclear power plants assigned by the Taiwan Power Company (TPC) by developing the Seismic Source Characterization (SSC) model and the Ground Motion Characterization (GMC) model as basic inputs to a site-specific probabilistic seismic hazard analysis (PSHA). SSC describes the future earthquake potential (e.g., magnitudes, locations and rates), and GMC describes the distribution of the ground motion as a function of magnitude, style of faulting, source-to-site geometry and site condition. For the seismic hazard analysis, both of these models will be developed following the guidelines of the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 process (Budnitz et al., 1997; NRC, 2012). The SSC model developed in this study is majorly specific to the region of the study sites with a 320-kilometer radius. The GMC model for the rock ground motions applicable to the study sites will be developed in this study in parallel. The GMC logic tree model will incorporate relevant empirical ground motion models as well as results from numerical simulations. The PSHA calculations and the development of surface response spectra considering site-specific site amplification are not part of this project and will be performed subsequent to the SSC and GMC SSHAC Level 3 studies by another project. The hazard results of four study sites evaluated by using the SSC and GMC models developed in this study will meet the requirements of SSHAC Level 3 methodology.

The objective of this study is to develop SSC and GMC models that capture the center, body and range (CBR) of the technically defensible interpretations (TDI) with SSHAC Level 3

methodology as described in NUREG 2117 (NRC, 2012) for use in PSHA for the study sites. TDI are defined as the development, assessment, and weighting of the scientifically justifiable and defensible interpretations of earth science and geotechnical data by appropriate experts in these fields using a structured process of evaluation and integration with full access to all available data. The purpose of this Project Plan is to describe how the SSHAC Level 3 process will be applied to develop the SSC and GMC models for the study sites.

DESCRIPTION OF SSHAC METHODOLOGY

In 1997, the Senior Seismic Hazard Analysis Committee (SSHAC) published NUREG/CR-6372 (Budnitz et al., 1997) that detailed a methodology for capturing the epistemic uncertainty in input parameters for PSHAs. Factors motivating the development of this methodology were the observations that: (1) different PSHA studies (e.g., EPRI, 1988; Bernreuter et al., 1989) developed significantly different estimates of the mean seismic hazard for nuclear facilities; and (2) the primary reason for the difference in hazard estimates was that the SSCs and GMCs did not adequately characterize the epistemic uncertainty within those characterizations. Recognizing the importance of characterizing epistemic uncertainty, the SSHAC spent approximately four years developing a methodology for characterizing epistemic uncertainties in SSCs and GMCs. Since publication of the original SSHAC methodology, there have been additional publications that have elaborated on the guidance and how it should be applied (e.g., Hanks et al., 2009, Coppersmith et al., 2010; NRC, 2012). The following summary of the SSHAC methodology and this Project Plan are consistent with these publications.

The stated goal of the SSHAC guidelines is to provide a methodology for developing SSC and GMC that "…represent the center, the body, and the range of technical interpretations that the larger informed technical community would have if they were to conduct the study" (Budnitz et al., 1997, p. 21). The terminology "center, body, and range" refers to the complete characterization of uncertainty. For simplicity, consider the single parameter of the maximum earthquake magnitude for a fault. In this case, "center" can be thought of as the median of the maximum magnitude, "range" can be thought of as the extreme upper and lower estimates of

the maximum magnitude limits, and "body" can be thought of as the shape of the distribution of potential maximum magnitudes within that range (e.g., symmetric or skewed distributions).

A SSHAC Level 3 process is a formal, structured process for developing SSCs and GMCs, and has been identified in NRC regulatory guidance (RG 1.208, NRC, 2007) as an acceptable process for use in performing PSHA for nuclear sites. The SSHAC process provides guidelines for how all aspects of the SSC and GMC development should be conducted, including: (a) identification of significant issues and data; (b) identification and solicitation of expert opinions and alternative models; (c) evaluation of the available data, expert opinions and alternative models; (d) integration of the information into SSC and GMC models that incorporate the range of technically defensible interpretations; (e) documentation of the model development; and (f) participatory peer review of the technical results and process. The procedure of SSHAC Level 3 methodology is shown in Figure 1. As described within the SSHAC guidelines (Budnitz et al, 1997; Hanks et al., 2009; Coppersmith et al., 2010; NRC 2012), the goal of following a SSHAC process is to provide reasonable regulatory assurance that the center, body and range (CBR) of the technically defensible interpretations (TDI) in the SSC models and GMC models have been adequately captured. Following the content of this study will be introduced according to SSHAC process including selection of SSHAC level, organization, participants, work plan, key study tasks and schedule of this study.

SELECTION OF SSHAC LEVEL

The SSHAC methodology defines four different levels of study that can be conducted to achieve the goal of capturing the CBR of the TDI. The four study levels, Level 1 through Level 4, are distinguished by an increasing level of sophistication, resources, and participation by technical experts. According to ANSI/ANS-2.29-2008 and given the technical complexity of seismic sources and recent identification of the Shanchiao fault and Hengchun fault in the nuclear power plant site vicinity, a SSHAC Level 3 or 4 study should be selected to evaluate and integrate all of the available data, methods, and alternative models. However, NUREG 2117 (NRC, 2012) explicitly states, "From the regulatory perspective of the NRC, there is no essential difference between Level 3 and Level 4 studies, and throughout

these guidelines they are considered as parallel and equally valid options." In addition, NRC NTTF 2.1 requested that a SSHAC Level 3 process be performed for existing nuclear power plants in the United States. As per NTTF 2.1, all existing nuclear power plant sites, including California, went through SSHAC Level 3 accordingly. In view of the above considerations, it is determined that a Level 3 study is an appropriate SSHAC level for the seismic hazard analysis of nuclear facilities in Taiwan.

PROJECT ORGANIZATION

The project organization for the Taiwan SSHAC Level 3 study is shown in Figure 2. As described by Budnitz et al. (1997) and Hanks et al. (2009), specific roles and responsibilities of individuals within a SSHAC process must be clearly defined because the guided interaction between the different roles allows for the center, body, and range of the SSC and GMC to be robustly characterized. For the Taiwan SSHAC Level 3 study, the roles listed below will be explicitly designated and documented. Members of the project team (TI Team and PPRP) were selected based on the following criteria:

(1) Past experience on the Probability Seismic Hazard Analysis;

(2) Knowledge of data, methods and technical approaches;

(3) Foreign participant prior with SSHAC Level 3 experience;

In addition, there is a goal identified by the NRC (2012) to involve younger scientists on the TI team. This capacity-building goal aims to build up the number of people with experience with the SSHAC process within the scientific community in general and within the owner organization specifically, and to provide a legacy for future SSHAC projects. The justification for the selection of the TI team and PPRP members given these criteria is provided below within the descriptions of the project roles. For those members of the project team without prior experience or knowledge of the probability seismic hazard analysis, and with no prior SSHAC experience, the Project Plan provides for bringing all members of the project team to a common level of understanding of the technical data as well as explicit training in the SSHAC process. Specific roles of the Taiwan SSHAC Level 3 Project Team and members are described below. More detail information about the selection criteria and introduction for the members of each team are described in Appendix A.

Project Sponsor – TPC is the Project Sponsor for the Taiwan SSHAC Level 3 project. The project sponsor provides financial support and "owns" the results of the study in the sense of property ownership.

Project Manager Office – The project will be coordinated under the direction of the Project Management Office, Director Kuo-Chun Chang, Prof. Wen-Yen Chang, and Dr. Chiun-Lin Wu. In addition, NCREE has invited Dr. Yi-Ben Tsai, Prof. Yeong-Tein Yeh and Prof. Cheng-Hong Chen as consultants for their valuable experience and knowledge in the earthquake engineering and the earth science area which will bring about extensive support for the Project.

Project Technical Integrator (PTI) – PTI is a technical expert with knowledge of the SSHAC process and both the GMC and SSC studies. The PTI is responsible for ensuring coordination and compatibility between the GMC and SSC studies and for providing oversight of the overall Taiwan SSHAC Level 3 process. Because the separate components of a SSC model and GMC model are combined in the hazard calculation, it is important that the interfaces between the SSC and GMC models are addressed. This integration between the SSC and GMC studies will be accomplished by having Prof. Chin-Hsiung Loh, Dr. Norm Abrahamson and Prof. Cheng-Horng Lin served as the Project Technical Integrators, attending all workshops and working meetings of this project.

Participatory Peer Review Panel (PPRP) – PPRP is a panel of experts with SSHAC methodology and/or PSHA experience that provide participatory peer review of the SSHAC methodology implementation process and technical judgments of the TI Team. PPRP assures that the range of TDI is captured and documented through proper implementation of the SSHAC process. Members of PPRP will attend all of the formal workshops and are encouraged to participate in field reviews and selected working meetings of the TI Teams.

Opportunities to participate in field reviews and working meetings will be identified, as needed, in collaborative discussions between the project leadership (Project Manager, PTI and TI Lead) and PPRP. Members of PPRP are Dr. William Lettis, President of Lettis Consultants International, Inc. (Chair), Dr. Yousef Bozorgnia, Professor of University of California, Berkeley, Dr. Sheng-Taur Mau, Professor of California State University, Northridge (Retired), and Dr. Kuo-Fong Ma, Professor of National Central University. Dr. Lettis provides expertise and experience with the SSHAC Level 3 process, and knowledge of methods and technical approaches used in seismic source characterization. Dr. Bozorgnia provides experience with the SSHAC Level 3 process and expertise in ground motion prediction equation with relevance to ground motion characterization. Dr. Mau provides expertise with earthquake engineering and seismic zonation for PSHA. Dr. Ma has familiarity with the seismic and tectonic setting of Taiwan and ground motion simulation technique. The composition of PPRP thus includes individuals with prior SSHAC Level 3 experience as well as capturing the breadth of technical requirements for the project.

Technical Integrator Team (TI Team) – TI Team consists of Evaluator Experts with PSHA and/or SSC&GMC experience that are responsible for conducting the evaluation and integration process and development of the SSC and GMC logic tree models. TI Team also will have a staff of Evaluator Experts that are not officially part of the TI Team but will assist the team during the data evaluation of the project. Although the TI staff will assist with the data evaluation, it is the exclusive role of the TI Team to perform the integration and model-building part of the study and ultimately to take intellectual responsibility for the results of the study. As such, the TI Team is solely responsible for ensuring: (1) that the various data, models, and methods proposed by the larger technical community and relevant to the hazard analysis are considered in the evaluation; and (2) that the final SSC and GMC models represent the CBR of the TDI.

For the SSC TI Team of Taiwan SSHAC Level 3 project, Dr. Bor-Shouh Huang, Researcher of the Institute of Earthquake Sciences of Academia Sinica, will be the SSC TI Team Lead. Dr. Huang provides expertise with the seismology, geophysics, geosciences and seismic source characterization. SSC TI Team members are Dr. Chin-Hsun Yeh, Researcher of the National Center for Research on Earthquake Engineering, Dr. Chin-Tung Cheng, Deputy Manager of Sinotech Engineering Consultant, Inc., Dr. Tien-Shun Lin, Associate Professor of the National Central University, and Mr. Kevin Clahan, Principal Engineering Geologist of Lettis Consultants International. Dr. Yeh provides probability seismic hazard and risk analysis expertise. Dr. Cheng provides probability seismic hazard analysis and seismic source characterization expertise. Dr. Lin provides expertise of characterizing on-shore and off-shore faults. Mr. Clahan provides SSHAC experience, engineering geology, geologic, seismic hazard assessments and paleo-seismology expertise.

For the GMC TI Team of Taiwan SSHAC Level 3 project, Dr. Kuo-Liang Wen, Division Leader of the National Center for Research on Earthquake Engineering and Professor of National Central University, will be the GMC TI Team Lead. Dr. Wen provides expertise with the ground motion characterization, soil amplification and site response. GMC TI Team members are Dr. Yin-Nan Huang, Associate Professor of National Taiwan University, Dr. Po-Shen Lin, Researcher of Sinotech Engineering Consultant, Inc., Dr. Hung-Chie Chiu, Researcher of Institute of Earthquake Sciences of Academia Sinica, and Dr. Brian Chiou, Senior Geologist. Dr. Huang provides probability seismic hazard and risk analysis expertise. Dr. Lin provides the ground motion prediction equation expertise. Dr. Chiu provides ground motion characterization expertise and signal processing expertise. Dr. Chiou provides valuable SSHAC experience and expertise on ground motion prediction equation and near-fault directivity.

Evaluator Expert (EE) – EE is an expert with PSHA experience capable of evaluating the relative credibility of multiple alternative hypotheses to explain observations. All members of the TI Team will be EEs. EEs use their professional judgment to objectively quantify epistemic uncertainty based on evaluations of the data, knowledge, and alternative models presented by the Resource and Proponent Experts. In addition, a support staff of selected EEs will assist the TI Team in their evaluation of certain datasets and proponent models. Members of the TI staff have individual knowledge of data, interpretations, and, thus, are valuable contributors to the TI Team evaluation process. However, they will not participate in the integration and model-building part of the process.

Resource Expert (RE) – RE is an expert with a specialized knowledge of a particular data set, interpretation, or hypothesis, who can present this information without a proponent bias. REs generally are invited to one or more workshops and/or may be contacted outside of the workshop environment by the TI Team to present and discuss their specialized knowledge regarding the strengths and weaknesses of alternative models and data sets. For the Taiwan SSHAC Level 3 project, REs will be identified as needed throughout the study.

Proponent Expert (PE) – In contrast to the unbiased RE, a PE is an expert who advocates a particular hypothesis or technical position. The PE's opinion may range from mainstream to extreme (outlier) views. PEs generally are invited to one or more workshops and/or may be contacted outside of the workshop environment by the TI Team to present and discuss their position. For the Taiwan SSHAC Level 3 project, PEs will be identified as needed throughout the project.

Hazard Calculation Team (HCT) – Hazard Calculation Team is responsible for performing the PSHA calculations. Hazard Calculation Team is incorporated

into all phases of the study (e.g., evaluation, integration) because they can provide: (a) valuable insight into how to represent uncertainty within different parameters; and (b) sensitivity feedback with respect to what parameters have the most impact to the hazard calculations. For the Taiwan SSHAC Level 3 study, support staff from the National Center for Research on Earthquake Engineering (NCREE), Sinotech Engineering Consultant, Inc. and the Institute of Nuclear Energy Research (INER) will be the member of Hazard Calculation Team.

Database Management Team (DMT) – A comprehensive seismic source database and ground motion database will be established for the project. For the Taiwan SSHAC Level 3 study, support staff working in the National Center for Research on Earthquake Engineering (NCREE) will be the member of Database Management Team.

Observers – Observers are not explicitly defined within the SSHAC guidance (Budnitz et al., 1997), but are discussed in the implementation guidelines (NRC, 2012, NUREG 2117). Observers may include sponsors, regulators, public representatives, or other stakeholders. Outside observers do not participate in any aspect of the SSHAC process (e.g., evaluation, integration, peer review, documentation), but they may be invited to observe some workshops depending on the specific needs of the project sponsor. During the workshop, time for observer comment will be accommodated at the end of each day and at the conclusion of each workshop.

WORK PLAN AND KEY STUDY TASKS

For the Taiwan SSHAC Level 3 project, the SSHAC Level 3 study will involve four components: (1) evaluation, (2) integration, (3) participatory peer review, and (4) documentation. Evaluation refers to the process of compiling and evaluating relevant data, alternative models/concepts, and alternative interpretations of the TDI. Integration refers to

the assessment process where the various datasets, models, and interpretations are combined into a representation of the CBR of the TDI for the SSC and GMC. Participatory peer review refers to review of the evaluation and integration process by a peer review panel capable of providing feedback, during the project, on technical aspects of the project and whether the SSHAC Level 3 process was followed appropriately. By providing feedback during the project, the TI team can make necessary corrections before the project is complete. Documentation refers to the data summary and evaluation tables and final reports produced by the project that document the technical results (i.e., the SSC and GMC logic tree model), how they were reached, and how the SSHAC Level 3 process was implemented.

This SSHAC Level 3 study will be conducted using a series of formal workshops, working meetings and internal work. Given the extensive amount of new data and information that will be developed and collected throughout the project, the process of evaluation followed by integration and model development will be repeated several times. The project schedule is shown in Figure 3.

1. SSHAC Process Components

The process of evaluation, integration, documentation, and peer review will occur in a series of workshops, working meetings, and internal work. These process components are described below:

i. Evaluation

The consideration of the complete set of data, models and methods proposed by the larger technical community that is relevant to the hazard at study sites. The process of evaluation includes, but not limit to, the: (a) identification of hazard-significant issues; (b) compilation of relevant data, models, and interpretations (e.g., published research papers, geologic, geophysical and seismic data); and (c) evaluation of the data, models and interpretations with respect to their impact on the SSC and GMC models. The overall goal of the evaluation process is to compile and evaluate all of the data that are relevant to SSC and GMC. The project database will include relevant seismic, geologic

and geophysical data and will be updated progressively as new information becomes available. The data evaluation process will be led by the TI Team, who will be assisted by the TI Team staff and Resource and Proponent Experts. Many of the interactions between the Experts and the TI Team occur at official project workshops, but various Experts may also be called upon by the TI Team as needed in other settings (e.g., working meetings). Through sensitivity analyses, those parts of the SSC and GMC logic tree that are most significant to hazard will be the focus for evaluation and update. Those parts of the logic tree model that are not significant to hazard will be reviewed and updated to reflect the current state of scientific knowledge, as appropriate, but will not be the focus of detailed evaluation or further refinement. The PPRP will be involved in the evaluation process through attending workshops, reviewing interim project documentation, and participating in field reviews and/or working meetings, as needed.

ii. Integration

Representing the CBR of the TDI in light of the evaluation process (i.e., informed by the assessment of existing data, models and methods). Following the evaluation process, the TI Team will integrate the relevant data, models, and interpretations to develop SSC and GMC logic tree model that captures the CBR of the TDI. The process of integration commonly includes: (a) development of a version of the SSC and GMC logic tree model; (b) hazard sensitivity analyses to document the impact of model parameters on the seismic hazard at the frequencies of interest; (c) feedback from the Resource Experts, Proponent Experts, and PPRP members on the logic tree model and hazard sensitivity; and (d) development of the next version of the SSC and GMC logic tree. This process is iterated until a final SSC and GMC logic tree model is developed.

For the SSC and GMC models, we anticipate three iterations of the logic tree (versions SSC and GMC model V0 to V2) before development of the final

logic tree model (SSC and GMC model V3). Initial versions of the SSC and GMC logic tree model will capture the CBR of the TDI as best understanding by the TI Team at the time, and/or will be designed as "sensitivity" logic trees to focus on what logic tree parameters are most sensitive to hazard. The final logic tree model (SSC and GMC model V3) will be finalized following review and feedback from the PPRP.

The SSC and GMC TI Team will lead the integration process; the Hazard Analysts will conduct the iterative hazard sensitivity analyses. The REs and PEs will be less active in this process, but they can be called upon request by the TI Teams as needed to provide clarification, resolve new issues, and provide feedback on the preliminary logic tree models. The majority of the integration process will occur through informal working meetings and internal work. The workshops are designed to present the models and sensitivity results, and to collect feedback. PPRP will be involved in the integration process through attending workshops, reviewing interim project documentations and attending selected working meetings, as needed.

iii. Participatory Peer Review

Participatory peer review is an integral component of a SSHAC Level 3 study. The overall goals of this review will be to ensure that the SSHAC process is adequately followed and that the technical results adequately characterize the CBR of the TDI. The review is participatory in that it will be a continuous process throughout the study, and not a singular review that occurs at the end of the study. As such, PPRP will be kept abreast of project development through a combination of attending workshops, reviewing interim project documents and attending selected field reviews and/or working meetings, as needed. The TI team will have the opportunity to address PPRP comments and make modifications during the project.

iv. Documentation

Documentation also is an integral component of a SSHAC Level 3 study in that it provides a record of the final technical results, how they were reached, and how the SSHAC Level 3 process was implemented. In addition, the documentation provides the basis for review by any pertinent regulatory officials, if needed. Documentation of the Taiwan SSHAC Level 3 project also will provide the basis for future PSHA updates for Taiwan. Documentation for the study will include workshop summaries and presentations (including videotapes of workshops), PPRP letter reports and TI Team responses, summary tables that describe the contents of the project such as the SSC geospatial database and the reference library, GMC database, source-specific source evaluation sheets, the SSC logic tree models and the GMC logic tree models, including the model Hazard Input Document (HID), and draft and final reports including PPRP comments.

At the end of the project, final report, PPRP final letters, presentations from Workshops, Workshop summaries minutes, Working Meetings material and reference documents will be made publicly available. Project participants will have access to such repository throughout the project; critical reference material will be available prior to each Workshop to allow adequate time for PPRP to review. If documentation for a specific model is not provided in a timely manner, the model might be down weighted in the subsequent evaluation process.

2. Key Study Tasks

The key study tasks of Taiwan SSHAC Level 3 project include:

i. Prepare Draft Project Plan and Initial Sensitivity Analysis

The initial task for the project was to prepare the draft Project Plan and Workshop 0 (the Kick-off Meeting). Preparation for Workshop 0 included reviewing the hazard report of four nuclear power plants, conducting sensitivity analyses using the initial SSC and GMC models, holding planning meeting (Pre-Kickoff Meeting) and

establishing contractual relationships with PPRP, the TI Team and staff and the Hazard Analysts. This task was completed in August 2015.

ii. Hold Workshop 0 (Kick-off Meeting)

Workshop 0 (the Kick-off meeting) took place on August 18-19, 2015 and was attended by the PTI, the SSC TI Team and staff, the GMC TI Team and staff, PPRP, and the Hazard Analysts. The meeting objectives were to: (a) present and explain the project content, organization and schedule, (b) present the hazard reports of four nuclear power plants; (c) present the preliminary sensitivity analysis to identify key parameters and features most significant to hazard at the site; (d) identify REs and PEs that will be used in the study to address the significant parameters and features; and (e) identify key interface issues (SSC, GMC, and site response). The outcomes of Workshop 0 included revisions to the draft Project Plan and the identification of the initial set of REs for Workshop 1. The PPRP provided a letter documenting their observations and comments on the draft Project Plan. This task was completed in August 2015.

iii. Develop Project Database

The SSC project geospatial database will serve as a repository for all project-related geospatial data. The elements of the geospatial database will include seismic, geologic, geophysical, and geographic information such as: georeferenced geologic and geomorphic maps and associated GIS files, LiDAR and topographic survey data, aerial imagery, geographic boundary layers, earthquake catalogs, magnetic and gravity data, and geotechnical borehole data, fault trench data, geologic sampling locations, etc. A catalog detailing the individual geospatial database components will be compiled in Microsoft Excel. The catalog will include a brief description of the data set, data type, date, file path, author, and version information.

The references and datasets considered by the SSC TI Team for conducting the SSC logic tree models will be compiled in a reference library. A record of the library contents and how they were considered by the SSC TI Team will be provided by data

summary tables and source evaluation sheets. The data summary tables will be compiled from a reference database designed with Microsoft Access and maintained by the SSC TI Team staffs. The data summary tables are an output of the reference database that provide a record of what documents and datasets were reviewed and considered by the SSC TI Team for input in the SSC logic tree model. The source evaluation sheets are separate outputs that include compiled information from the reference database and considered as the record that describes the basis for each branch value and weight in the SSC logic trees, starting with SSC model V2 and going through the final SSC model V3.

The GMC project database will involve several strong motion networks and the ground motion databases including Taiwan Strong Motion Instrumentation Program network (TSMIP) of Center Weather Bureau (CWB), and the Institute of Earth Sciences (IES), Strong Motion Accelerographic Network (SMA) of IES, Strong Motion Array in Taiwan phase I and phase II (SMART-I and SMART-II) of IES, seismic data of nuclear power plant sites in Taiwan, Next Generation Attenuation Relationships for Western U.S. (NGA-West 2) database of Pacific Earthquake Engineering Research Center (PEER) and simulated ground motions etc.

The project database will be available at the working meetings and workshops for querying, review and analysis. The project SSC geospatial database and GMC ground motion database developed for this study will become part of the SSHAC documentation. All of the relevant database content that contributes to the final SSC and GMC models (either directly or indirectly by informing the evaluation and integration process) will be described within the final SSHAC documentation.

iv. Hold Working Meetings

Working meetings will take place on an approximately quarterly basis and will provide an opportunity for the TI Team to identify and review topics of relevance to the SSC and GMC issues for the study sites, develop the structure and content of the SSC and GMC logic tree models, and plan workshops. The working meetings involve

the TI Team, appropriate members of the TI Team staff and one of the Hazard Analysts. Members of PPRP are invited to attend and observe the working meetings.

v. Hold Workshops

Each workshop will have an opening session to present results of the sensitivity analysis, followed by presentations from Resource and/or Proponent Experts. The Expert presentations will be organized into themes, with several presentations on a common topic, issue, proponent model or data set, followed by a discussion session to fully query each speaker regarding their data, interpretation, or proponent model. A summary session will be provided at the conclusion session of each day. All workshop materials and presentations will be documented and made publicly available.

Workshop #1

Objective

The goal of WS1 is to discuss issues significant to hazard, identify available data to address the significant issues, and identify gaps in data or knowledge that can be obtained to reduce epistemic uncertainty related to the significant issues.

Preparation

Based on the sensitivity analysis performed for Workshop 0, key parameters of the SSC and GMC models that were identified as significant to hazard were noted, and data availability, gaps and needs to address those hazard-significant parameters were considered during the selection of REs to present at Workshop 1. Prior to Workshop 1, REs were identified and a list was provided to the PPRP for their review. The PPRP was provided the opportunity to identify additional REs for consideration and/or significant issues or topics to be covered at the workshop. The REs were contacted prior to the workshop and provided with a specific request for information, data or discussion topics as described in task 4.

Prior to the workshop, letters will be sent to the selected REs identifying directed topics and issues that they should prepare to address at the meeting. The letters help

focus the workshop discussion on key issues related to a particular data set, including quality and resolution of data, expected use of data, uncertainty or limitations in the data or interpretations, etc.

Process

Workshop 1 will last for five days and be attended by PTI, the SSC TI Team and staff, the GMC TI Team and staff, PPRP, the Hazard Analysts, and the Resource Experts (REs). REs will be asked to discuss specific data sets and to assist in identifying available data to address significant issues. The REs will be asked to present data in oral sessions and/or to participate in interactive discussion sessions with the TI Teams and other REs. The presentations and following discussion inform the TI Teams of the available data and evaluations and interpretations of the data. In addition, data needs identified during the course of Workshop 1 are to be compiled by the TI Teams and to be used to help define the scope of further research studies. Digital video files of the workshop and electronic files of presentation materials will be posted on project website and made publically available following the meeting.

PPRP will attend Workshop 1 as observers, and provide verbal comments at the end of each day and at the conclusion of the workshop. The day following the five-day workshop, PPRP will caucus for a half-day meeting to review the workshop proceedings. During this meeting, PPRP will prepare written comments and feedback to PTI and the TI Teams. PTI and the TI Team Leads will provide written responses to the PPRP comments. Following the workshop and PPRP meeting, the proceedings of the workshop will be documented in a brief workshop summary for distribution to the Project Sponsor and PPRP. The workshop summary and PPRP letter will be publicly available and become part of the final documentation of the Taiwan SSHAC Level 3 project.

Topics and Issues

- SSHAC training for project participants.
- Summarize project overview and objectives.

- Review of SSHAC procedures and workshop ground rules.
- Presentation of sensitivity analyses on SSC and GMC logic tree version V0 models.
- Presentations of new collected data and information.
- Review the available models.
- Interactive discussion with Resource Experts (selected presentations).
- Exploration of key data, data uncertainties, and appropriate use and limitations of the data interpretations.
- Identification of additional data gaps, data needs, and/or analyses.
- Identify scenarios to be implemented in the numerical ground motion simulations.

Workshop #2

Objective

The primary goal of Workshop 2 is to use the PEs to explore the center, body, and range of TDI for the SSC and GMC, with a focus on those parameters of the logic trees in SSC and GMC model V1 that are most significant to hazard.

Preparation

SSC and GMC TI Team will evaluate the data, information, and interpretations provided by the REs, and additional information collected from the ongoing field and research programs through a series of working meetings and internal work between working meetings. The project geospatial database and reference database are to be updated and utilized during the working meetings. Primary objectives are to identify the range of potential alternative interpretations or models resulting from the evaluation of available data, and to identify PEs to discuss and defend these alternative interpretations or models. The SSC and GMC TI Teams will compile and evaluate additional relevant data identified in Workshop 1, consider the range of alternative interpretations of these data, and develop sensitivity logic trees that constitute SSC and GMC logic tree model V1. The primary purpose for this initial updated model is to perform sensitivity analyses to identify those models and/or

interpretations of the data that are most significant to hazard. The Hazard Analyst will perform the sensitivity analysis. The sensitivity analyses will be used to (1) assist the SSC and GMC TI Teams in their evaluation of the data, and (2) identify potential PEs for invitation to Workshop 2. Working meetings of the TI Teams include presentations of hazard sensitivity results by the Hazard Analysts. One or more members of PPRP will attend the working meetings as observers. Prior to Workshop 2, PEs will be identified for PPRP to review. The PEs will be contacted prior to the workshop and provided with a specific request for discussion topics as described in Task 6.

Process

Workshop 2 will last for five days and be attended by PTI, the TI Teams and staff, PPRP, the Hazard Analysts, and the Proponent Experts (PEs). In the case for the PEs to identify other alternative models or technical issues not captured in the V1 logic trees, these alternative models or technical issues will be indicated during the Workshop for future evaluation by the TI Team and will be considered for inclusion in later versions of the SSC and GMC logic tree models, as appropriate. The workshop will provide a forum to explore alternate interpretations of data and alternative hypotheses derived from the data in a series of presentations and structured dialog between various PEs and the TI Teams. The information gained from these interactions will, combined with information within the project geospatial database and reference database, form the basis for defining the center, body, and range of the TDI and be used to update the SSC and GMC model V1. Workshop 2 also will be used to identify additional data gaps, data needs, and/or analyses that may be performed to further evaluate alternative models or key model parameters and uncertainties. Digital video files of the workshop and electronic files of presentation materials will be posted on the project website and be made publicly available following the meeting.

PPRP will attend Workshop 2 as observers, and provided verbal comments at the end of each day and at the conclusion of the workshop. Following the three-day workshop,

the PPRP caucused to review the workshop proceedings. The PPRP prepared written comments and feedback to the Project Sponsor, PTI and TI Team. The PTI and TI Team Lead provided written responses to the PPRP comments. Following the workshop, the proceedings will be documented in a brief workshop summary for distribution to the Project Sponsor and members of the PPRP. The Workshop summary and PPRP letter will be publically available and become part of the final documentation of the Taiwan SSHAC Level 3 project.

Topics and Issues

- Summarize project overview and objectives.
- Review of SSHAC procedures and workshop ground rules.
- Presentation of sensitivity analyses on the SSC and GMC logic tree version V1 models.
- Presentations of new collected data and information.
- Present the proponent models and discuss their strengths and weaknesses through interactive discussion with the Proponent Experts and Resource Experts.
- Evaluate the proponent models with comparisons to data, as appropriate.
- Exploration of key parameters, data or model uncertainties, and alternative models.
- Identification of additional data gaps, data needs, and/or analyses.

Workshop 3

Objective

The primary goal of Workshop 3 will be for the TI Teams to integrate information into models that represent the CBR of TDI.

Preparation

Following Workshop 2, a series of meetings and internal work will be performed to evaluate the available data and range of alternative proponent models. The SSC and GMC TI Teams will evaluate the data presented at Workshop 2 and integrate the

information into logic trees that constitute the SSC and GMC model V2. Formal RE and PE presentations based on newly available data will be provided at working meetings, where possible. These presentations at working meetings will be provided as part of the final documentation of the Taiwan SSHAC Level 3 project. The basis for the SSC and GMC model V2 characterizations will be documented and provided to PPRP prior to Workshop 3 so that PPRP will be able to fully evaluate the SSC and GMC model V2 before the workshop.

Process

Workshop 3 will last five days and be attended by PTI, the TI Teams and staff, PPRP, the Hazard Analysts, and the selected REs and PEs that are identified by the TI Teams, as needed. The first part of Workshop 3 will be allocated to select PE presentations based on data or analyses performed following Workshop 2. Following the selection of the PE presentations, the main activities of Workshop 3 will begin. In contrast to Workshops 1 and 2, PPRP will be the active participants in Workshop 3 to fully query the model parameters, level of documentation, uncertainty, and rationale in developing the model.

During Workshop 3, the SSC and GMC model V2 logic trees will be presented to PPRP and the selected REs and PEs, as needed. The workshop provides an opportunity for the REs, PEs, and PPRP to review and challenge the TI teams' evaluations and the technical justifications used to develop the structure of the SSC and GMC logic trees and weights on branches of the logic trees (e.g., whether any significant interpretations are missing, how the TI Teams have integrated the alternative models and data uncertainties, etc.). The TI Teams will use this feedback in developing the final version of the SSC and GMC logic trees.

At Workshop 3, the Hazard Analysts will present the results of hazard sensitivity analyses to the TI Teams and PPRP to provide the TI Teams with feedback about the implications of the SSC and GMC logic trees on hazard. REs, PEs, and PPRP will

also use the hazard sensitivity results to focus the discussion on the technical issues and parameters that have the greatest effect on the hazard at the study sites.

The proceedings of Workshop 3 will be documented in a brief workshop summary report for distribution to the Project Sponsor and members of PPRP, and PPRP will submit a letter to the Project Sponsor, PTI, and TI Team Leads documenting their observations of the workshop. PTI and the TI Team Leads will provide written responses to the PPRP comments. The workshop summary and PPRP letter will be made publicly available and become part of the final documentation of the Taiwan SSHAC Level 3 project.

Topics and Issues

- SSC and GMC model V2 logic tree.
- Preliminary hazard calculations of study sites and sensitivity analysis of SSC and GMC model V2 logic tree to identify hazard-significant issues and parameters.
- Review and challenge of the TI Team logic tree.
- Identification of shortcomings of the logic tree.
- Identification of key models and parameters requiring further evaluation.
- Identification of additional analyses to better constrain logic trees.

vi. Hazard Sensitivity Analysis

The developed SSC and GMC models will focus on the epistemic uncertainties in the SSC and GMC parameters that have significant impacts on the hazard. Hazard sensitivity studies will be used throughout the project with the evaluation effort focused on those issues most significant to hazard at the study site. The sensitivity analyses will be performed using preliminary SSC and GMC models and will require close integration of the SSC and GMC studies. Although all aspects of the SSC and GMC logic tree models will be considered and discussed based on current scientific understanding and concepts, the intent of the sensitivity analyses will be to inform the SSHAC participants of those issues of greatest significance to the hazard results and

to focus further evaluation and integration of data and information on characterizing the uncertainty in these key model parameters.

vii. Develop final SSC and GMC Models

Following Workshop 3, the TI Teams will revise the SSC and GMC model V2 logic trees in response to the PPRP comments, Expert comments, and any additional information that is collected or discovered as part of the SSHAC process.

The model developed during this stage will be the SSC and GMC logic tree model V3. To develop the model, the TI Team will hold a series of Working Meetings to discuss significant issues that were raised by PPRP and/or experts on the SSC and GMC model V2 logic trees. The TI Team may also utilize REs and PEs, as necessary, to further refine alternate interpretations within the characterizations. As part of model finalization, the TI Team will prepare the draft SSC and GMC technical report. The SSC model V3 logic trees will be transferred to the Hazard Analysts through a Hazard Input Document (HID) for a series of sensitivity analyses, during which the model may be simplified into a more "hazard informed" logic tree that eliminates non-significant branches.

viii. Prepare Documentation

This task includes development of the final documentation of the Taiwan SSHAC Level 3 project. This documentation includes the final technical report and final HID, and finalization of the supporting materials, including: workshop and Expert presentation documentation, data summary tables and source evaluation sheets, and project database contents. The final draft report will be provided to PPRP for their review. It is anticipated that the technical content of the SSC and GMC logic tree model V3 will not change following the final briefing meeting and the submittal of the final HID under Task 9, and that review of the final draft technical report by PPRP following submittal of the final HID will be focused on the model documentation, not model content. Upon completion of their review, the TI Team will respond to PPRP comments and finalize the report. The PPRP will review the response to comments

and Final Report, and provide a letter to the Project Sponsor, PTI, and TI Team Lead documenting their evaluation of the report and the project's compliance with the SSHAC Level 3 process. This letter will be included in an appendix of the Final Report.

ix. Hold Final Meeting

The SSC and GMC logic tree model V3 and the supporting documentation will be provided to PPRP prior to final meeting so that the PPRP will be able to review the technical content of the SSC model. The final meeting will include presentation of the final draft SSC and GMC model V3 and hazard results to PPRP. The meeting will be attended by the Project Sponsor, PTI, the TI Team and staff, PPRP, and the Hazard Analysts. The goals of the final briefing meeting are for the TI Team and Hazard Analysts to present to PPRP: (1) a review of the SSHAC Level 3 process that was used to develop the final logic trees; (2) the final draft SSC and GMC V3 model including how the PPRP, PE, and RE comments from workshop 3 were addressed; and (3) the final hazard feedback (model V3 hazard results) at the study sites from the combination of the final draft SSC and GMC model developed during this study. The intent of these presentations is to provide the PPRP with a clear representation of how the TI Team integrated the CBR of the TDI into the SSC and GMC model and how these characterizations impact seismic hazard. The dialogue and interaction with the PPRP will be used to help refine the final SSC and GMC model and the final project documentation of the Taiwan SSHAC Level 3 project. The proceedings of the final meeting will be documented in a brief summary for distribution to the Project Sponsor and members of the PPRP, and the PPRP will submit a letter to the Project Sponsor, PTI, and TI Team Lead documenting their observations of the final briefing meeting. The meeting summary and PPRP letter will become part of the documentation of the Taiwan SSHAC Level 3 project.

Following the final briefing meeting, the SSC and GMC logic tree model V3 will be finalized and a final HID will be provided to the Hazard Analysts. The final SSC and GMC model V3 will be implemented to calculate the final hazard. The site response

will be incorporated as part of the development of the GMRS. Concurrent with this activity, the final draft SSC and GMC technical report will be prepared that will incorporate the results of the final briefing meeting.

PROJECT SCHEDULE

The schedule for completing the Taiwan SSHAC Level 3 project is presented in Figure 3. The project commenced with Workshop 0 (Kickoff Meeting) in August, 2015 and is targeted for completion in December, 2018 of a 3½ -year duration. Workshops are anticipated to be held at 6 to 7-month intervals throughout the project.

As described above, the goal of following the SSHAC Level 3 methodology is to have reasonable assurance that epistemic uncertainties in both SSC and GMC logic trees to be adequately captured for use in PSHA of study sites. Accurately capturing these uncertainties is essential for developing an SSC and GMC model that will: (1) be accepted by the AEC, and (2) provide a robust characterization of the hazard at the study sites. This goal is accomplished by following the formal SSHAC process of data collection, evaluation, integration, participatory peer review and documentation. While the process is formal, in that the required process steps are defined within the SSHAC documentation (Budnitz et al., 1997), the process is very dynamic. For example, the discovery of new data can trigger additional evaluation steps, and attempts to integrate unexpected alternative models identified and/or supported by experts can slow the integration process. Comments by the PPRP and experts can trigger the need for unexpected analysis and revisions to the SSC and GMC. All of these dynamic events are part of the SSHAC process, and the unexpected work they trigger needs to be conducted to ensure that the uncertainties in SSC and GMC are appropriately characterized.

The schedule for the Taiwan SSHAC Level 3 project in Figure 3 considers the development of data, model and possible requests or need to develop information to address specific SSC and GMC parameters and uncertainties. However, because of possible unexpected events, we view the schedule as dynamic. Task durations and start dates will be adjusted throughout the

course of the project to accommodate these unexpected events to the extent possible, but the target completion date for December, 2018 will be maintained in order to comply with the TPC schedule.

Beyond capturing the CBR of the TDI given the currently available data, this study will also integrate new data with the objective of reducing the epistemic (i.e., non-random) uncertainties. Planned data collection studies include onshore and offshore field investigations performed by TPC and other researchers. The new data collected only before Workshop #2 will be fully evaluated and integrated into the SSC and GMC models.

QUALITY ASSURANCE

Quality Assurance for development of the SSC and GMC models is the SSHAC process itself and the participatory peer review. As stated in NUREG 2117 (NRC, 2012) "participatory peer review is a fundamental element in ensuring the quality of the resulting PSHA product." … "Hence, following the guidance contained in these documents for either a Level 3 or 4 assessment, NUREG/CR-6372, ANSI/ANS-2.29-2008 and ANSI/ANS-2.27-2008 will result in a study that satisfies the intent of national quality standards." The participatory peer review is comparable to and, in many areas, much more thorough and comprehensive than the standard Independent Technical Review (ITR) of the QA procedures. Thus, the SSHAC process will meet the requirements of the QA procedures.

The hazard calculations and site response analysis for the development of GMRS are not part of this project. Implementation of the final SSC and GMC models into hazard inputs, however, will be required to follow the QA procedure. The translation of the SSC and GMC models into PSHA inputs will be documented in Hazard Input Documents (HIDs) which will be part of the QA documentation.

References

ANSI/ANS-2.27-2008 (2008). "Criteria for Investigations of Nuclear Facility Sites for Seismic Hazard Assessments," *American Nuclear Society*, La Grange Park, Illinois.

ANSI/ANS-2.29-2008 (2008). "Probabilistic Seismic Hazards Analysis," *American Nuclear Society*, La Grange Park, Illinois.

Bernreuter, D.L., Savy, J.B., Mensing, R.W., Chen, J.C., and Davis, B.C., 1989, Seismic hazard characterization of 69 nuclear plant sites east of the Rocky Mountains, NUREG/CR-5250, Volumes 1-8, U.S. Nuclear Regulatory Commission, Washington D.C.

Budnitz, R.J., Apostolakis, G., Boore, D.M., Cluff, L.S., Coppersmith, K.J., Cornell, C.A., and Morris, P.A., 1997, Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts: Washington, D.C., US Nuclear Regulatory Commission, NUREG/CR-6372, p. 278

Coppersmith, K.J., Bommer, J.J., Kammerer, A.M., and Ake, J., 2010, Implementation guidance for SSHAC Level 3 and 4 processes; 10th International Probabilistic Safety and Management Conference, Seattle, Washington, June 7-11, 2010

EPRI, 1988, Seismic hazard methodology for the central and eastern United States, EPRI NP-4726A, Revision 1, Volumes 1-11, Electric Power Research Institute, Palo Alto, California

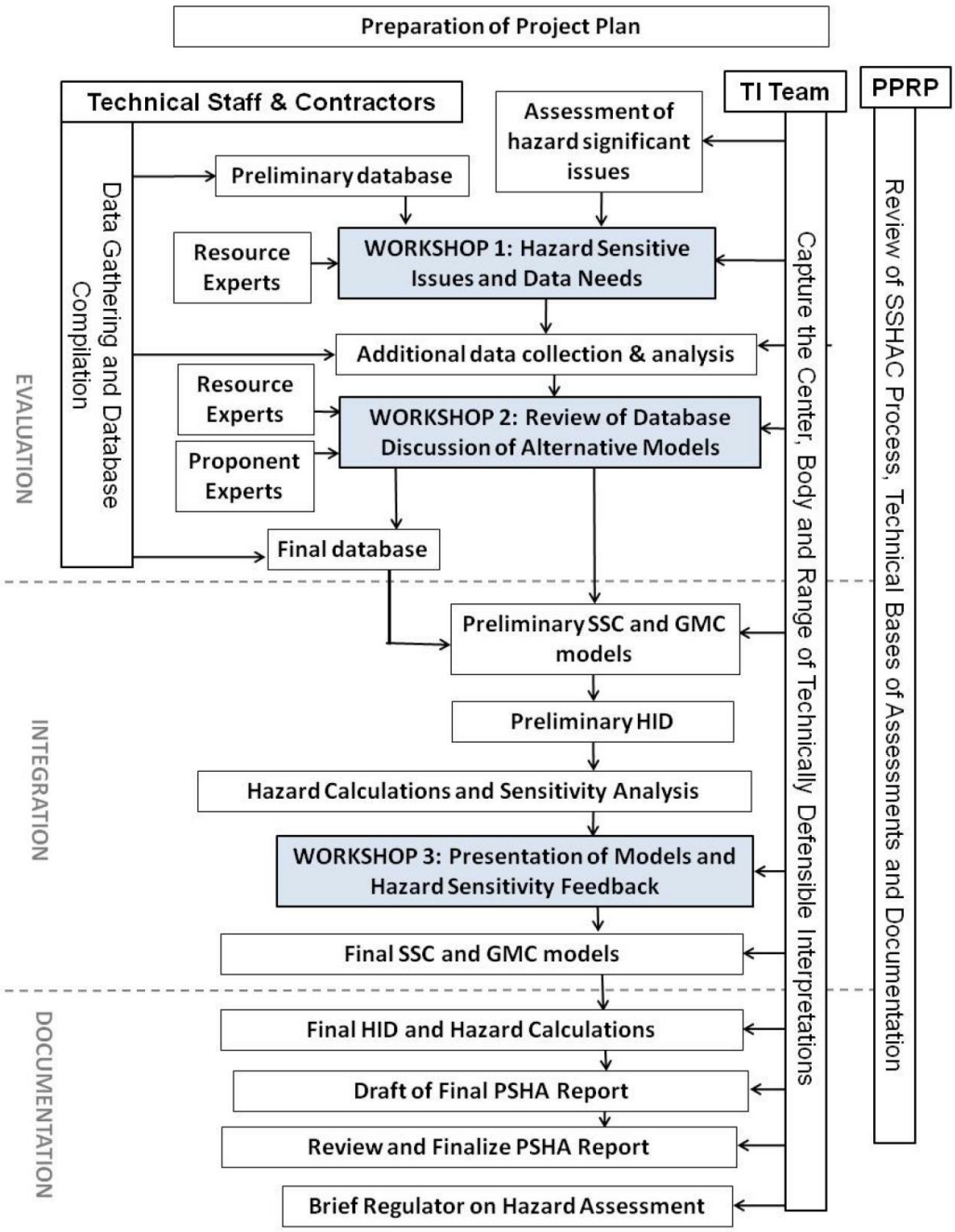
Hanks, T.C., Abrahamson, N.A., Boore, D.M., Coppersmith, K.J., and Knepprath, N.E., 2009, Implementation of the SSHAC Guidelines for Level 3 and 4 PSHAs—Experience Gained from Actual Applications, U.S. Geological Survey, Open File Report 2009-1093, p. 66

U.S. NRC, 2007, Reg. Guide 1.208: A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion, US Nuclear Regulatory Commission, p. 53.

U.S. NRC, 2012, Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies: Washington D.C., US Nuclear Regulatory Commission, NUREG 2117.

U.S. NRC 2012. 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, 10 CFR

50.54(f) letter, U.S. Nuclear Regulatory Commission, Washington D.C., March 12, 2012.



Note: For a Level 4, the TI team can be substituted with the TFI and evaluator experts. The beginning of the project occurs at the top of the diagram, and time progresses toward the bottom. The activities associated with evaluation, integration, and documentation are shown.

Figure 1. Procedure of SSHAC Level 3 Methodology (NUREG-2117, 2012)

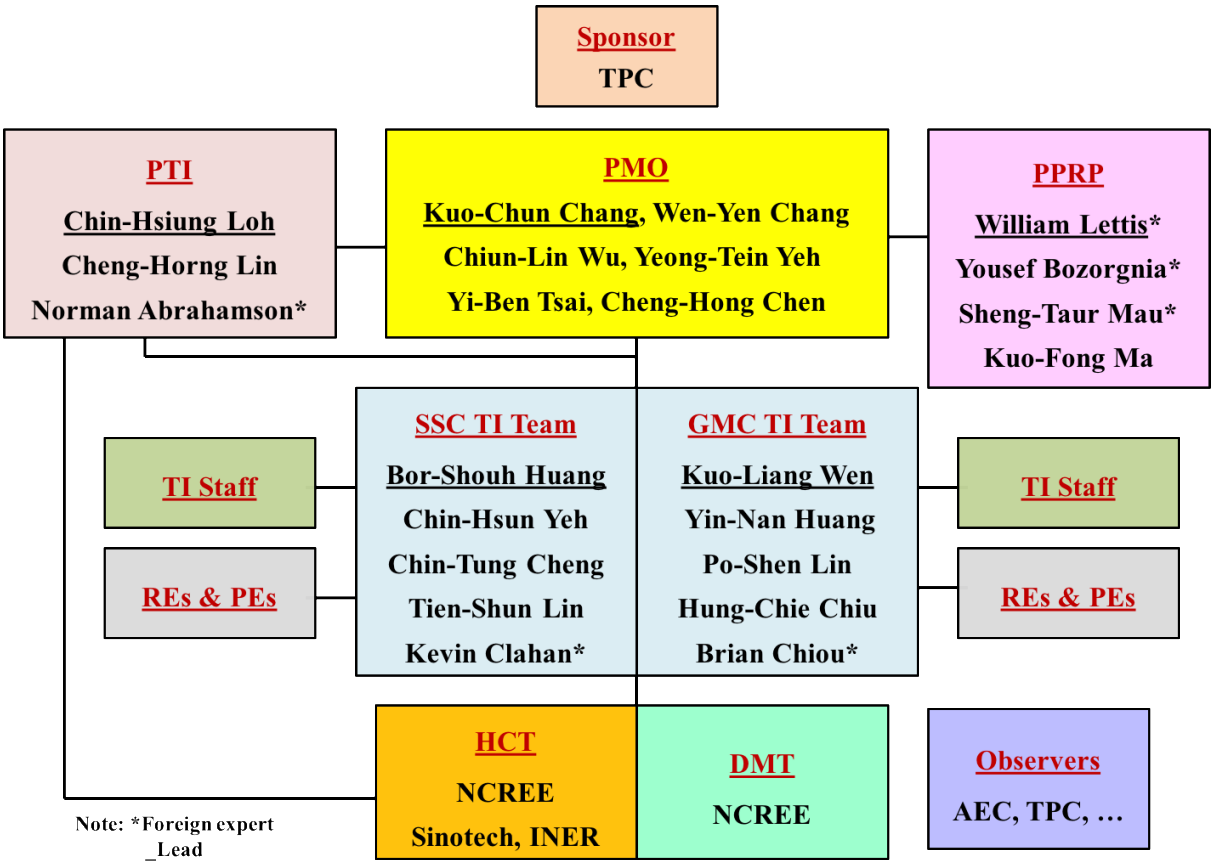


Figure 2. Taiwan SSHAC Level 3 Project Organization Chart

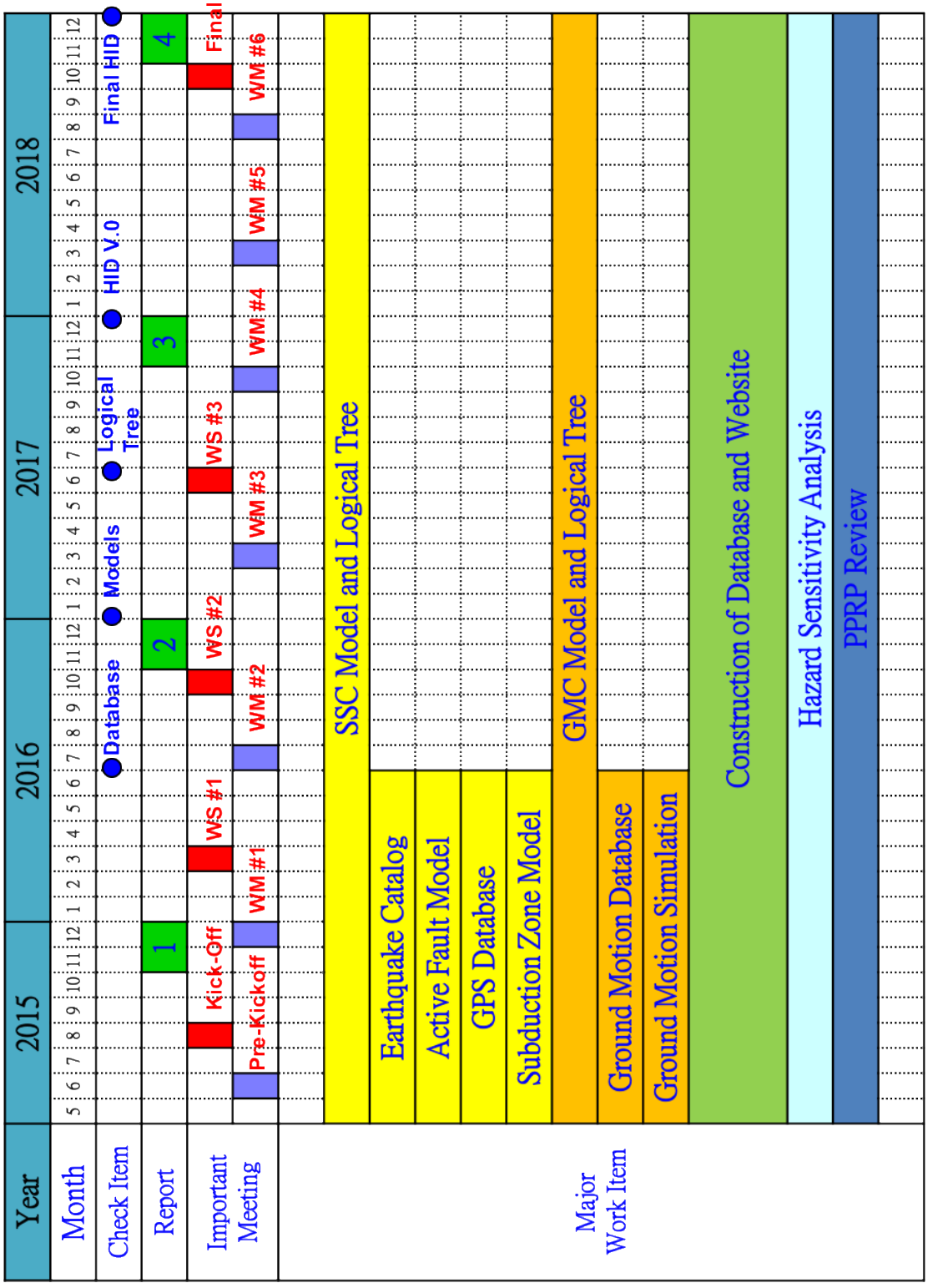


Figure 3: Taiwan SSHAC Level 3 Project Schedule

Appendix A - Expertise and Selection Criteria for Project Participants

This appendix describes the expertise and selection criteria of PTI, TI teams members, PPRP members and the Hazard Calculation Team. For this project, there is a goal identified by the NRC NUREG-2117(2012) to involve younger scientists from Taiwan on the organization to help build up the number of native people with experience with the SSHAC process for future project.

1. Project Technical Integrator (PTI)

The PTI role is effectively that of overall technical leader of the project. The PTI team was headed by Chin-Hsiung Loh, who was assisted by Cheng-Horng Lin and Norman Abrahamson. A three person PTI was selected for this project. The roles and responsibilities of the PTI are given in Table A-1 and the selection criteria are given in Table A-2.

Chin-Hsiung Loh, PhD, is a Professor in the Department of Civil Engineering at National Taiwan University, Taiwan. Prof. Loh is a recognized expert in earthquake engineering and seismic hazard. He has over 30 years of experience in hazard analysis and ground motion evaluation for design and review of site-critical facilities. Prof. Loh has served as a project staff member for the 1984 seismic hazard studies at NPP No.2 in Taiwan, and was the Principal Investigator for the 1989, 1987, 1993, and 2004 seismic hazard studies at NPPs No.1, No.3, No.4, and No.4 in Taiwan, respectively. He has worked on many other seismic hazard and design ground motion studies for railway system, oil storage vessel and large building in Taiwan. Prof. Loh was selected as the PTI lead because of his extensive knowledge on seismic hazard assessment and interface issues between SSC, GMC and hazard calculations.

Cheng-Horng Lin, PhD, is a Research Fellow in the Institute of Earth Sciences at Academia Sinica, Taiwan. Dr. Lin is a recognized expert in volcano observations, tectonophysics, and seismology. He has more than 15 years of experience in conducting investigations in the field of volcanic activity with expertise in Tatun volcanic area and submarine volcanoes in

northern Taiwan. Dr. Lin was the member of the Taiwan Volcano Observatory (TVO) and Taiwan Earthquake Model (TEM) of Taiwan Earthquake Research Center (TEC). Dr. Lin was selected as a PTI member to provide knowledgeable information on volcanic source zones impact to ground motion hazard.

Norman Abrahamson, PhD, is a Chief Scientist of Geosciences Department with Pacific Gas & Electric Company, California. Dr. Abrahamson is an internationally recognized expert in seismic hazard and ground motion with 30 years of experience in the practical application of engineering seismology. He was one of the GMPE developers in the 2008 NGA project and 2014 NGA-west2 project. He has also good communication skills to be the interface between the earth sciences and earthquake engineering. Dr. Abrahamson has extensive experience with SSHAC studies having served as the Technical Facilitator/ Integrator for the 1996-1998 Yucca Mountain and 2001-2004 Swiss SSHAC level 4 GMCs. He has also served as the TI lead for the 2008-2011 BC Hydro and 2011-2015 SWUS SSHAC level 3 GMCs, the TI co-lead for the NGA-east SSHAC level 3 GMC, and TI team member for the Blue Castle SSHAC level 3 GMC.

Table A-1. Roles and Responsibilities of PTI

1	Preparation of Project Plan with PMO and TI leads.
2	Ensuring coordination and compatibility between GMC and SSC studies.
3	Conduct of overall technical direction of the project, development of the logic-trees, and the execution of the PSHA calculations with TI leads.
4	Finding and assuring participation of suitable Resource Experts and Proponent Experts with TI leads.
5	Attendance at kick-off meeting, each workshop, selected working meetings, and final meeting.
6	Review of development of the logic-trees, the execution of the PSHA calculations, project plan, SSC and GMC models, project reports and hazard input document to ensure that the project documentation is complete and comprehensive.
7	Response to Project Manager, PPRP and Sponsor comments and questions.

Table A-2. Attributes / Selection Criteria of PTI

1	Past experience on SSC and/or GMC studies in Taiwan region.
2	Experience in the conduct of PSHA studies.
3	Project management skills to ensure technical products are high-quality and delivered in a timely manner.
4	Willingness to commit time and effort to the project.
5	A thorough understanding of the SSHAC goals and processes.
6	Strong communication skills to work with the technical evaluators.
7	Experience and familiarity with PSHA implementation guidelines and regulatory compliance.

2. SSC Technical Integrator (SSC TI)

TI plays the most important role in the project. A five person SSC TI team was selected for this project, headed by Bor-Shouh Huang with the team members: Chin-Hsun Yeh, Tien-Shun Lin, Chin-Tung Cheng and Kevin Clahan. The roles and responsibilities of the TI lead and the TI team members are given in Table A-3 and Table A-4, respectively.

Bor-Shouh Huang, PhD, is a Research Fellow in the Institute of Earth Sciences at Academia Sinica, Taiwan. Dr. Huang is a recognized expert in seismology and seismic source evaluation. He has over 20 years of experience in the field of focal mechanisms and rupture processes for specific earthquakes, and seismogenic structure evaluations. He is also knowledgeable on historical and instrumental earthquakes, active fault geometries, and seismic wave propagation in Taiwan. Dr. Huang has served on the 2008-2009 Taiwan Integrated Geodynamics Research (TAIGER) Project cooperated by Taiwan and the U.S. to image the crustal and upper mantle structures of the Taiwan mountain belt and its surrounding seas for the purposes of understanding the mountain building processes, plate boundary dynamics, seismogenic mechanisms and marine geohazards. Prof. Huang has also served as a member of review panels for the offshore geological survey and active faults investigation for nuclear power plants in Taiwan.

Chin-Hsun Yeh, PhD, is a Research Fellow in the Earthquake Disaster Simulation Division of National Center for Research on Earthquake Engineering, Taiwan. Dr. Yeh has extensive experience in the field of seismic hazard and risk assessment. During his professional career, Dr. Yeh has applied his research training to seismic safety analysis, focusing on assessing earthquake hazard for large engineered facilities such as bridges and pipelines and developing strategies for reducing earthquake vulnerabilities. Dr. Yeh was one of the developers in the Taiwan Earthquake Loss Estimation System (TELES), which has been applied to earthquake warning systems, disaster resistance strategies, and risk management for government institutes and private enterprises to build up effective strategies against earthquakes.

Tien-Shun Lin, PhD, is an Associate Professor in the Department of Earth Sciences at National Central University, Taiwan. Prof. Lin has been a petroleum geologist at Chinese Petroleum Corporation, Taiwan. He has extensive experience in the field of geology, geodynamics, sedimentology, stratigraphy, and petroleum geology. Prof. Lin has involved in several projects about geological survey, including marine geological mapping around Taiwan, geological and geophysical data collection and analysis offshore northeast and southwest Taiwan, and assessment on the reuse and geosequestration of carbon dioxide. Prof. Lin is also knowledgeable in tectonics and the distribution and geometry of faults in Taiwan region.

Chin-Tung Cheng, PhD, is a Senior Researcher with Sinotech Engineering Consultants, Inc., Taiwan. Dr. Cheng is a recognized expert in seismic hazard analysis, geographic information system, active fault and seismogenic structure evaluation. He was involved in several projects related to reservoir and electric power plant's seismic safety evaluation in Taiwan, including Tseng-Wen and Pao-Shan Reservoirs, Chung-Yue hydraulic power plant, and Kao-Yuan and Tung-Hsiao natural gas power plants. Dr. Cheng has also experience with probabilistic seismic hazard analysis and seismic source characteristic in Taiwan such as active fault potential evaluation, near fault offset model for the NPPs, and NPP's geological investigation and hazard analysis data compiling.

Kevin Clahan is a Principal Engineering Geologist with Lettis Consultants International, Inc., California. Mr. Clahan has over 25 years of experience in fields of engineering geology, geologic and seismic hazard assessments. He has also experience with the Probabilistic Fault Displacement Hazard Analysis (PFDHA) study of the Hengchun fault in southern Taiwan, and the review of structural characteristics offshore of northeastern Taiwan. Mr. Clahan has previous experience with the SSHAC studies in the TI team for the PVNGS SSHAC Level 3 SSC. He performed the study as part of a SSHAC Level 2 evaluation of seismic hazards for the North Anna nuclear site, and he is also directing a SSHAC level 2 study for the Clinch River site.

Table A-3. Roles and Responsibilities of the TI Leads

1	Preparation of Project Plan with PMO and PTI.
2	Conduct of overall technical direction of the project, development of the logic-trees, and the execution of the PSHA calculations with PTI.
3	Finding and assuring participation of suitable Resource Experts and Proponent Experts with PTI.
4	Leading the evaluation and integration activities of the TI team.
5	Running workshops and working meeting with PTI.
6	Review of development of the logic-trees, the execution of the PSHA calculations, project plan, SSC and GMC models, project reports, and hazard input document to ensure that the project documentation is complete and comprehensive.
7	Willingness to commit time and effort to the project.
8	Response to Project Manager, PPRP, and Sponsor comments and questions.

Table A-4. Roles and Responsibilities of the TI Team Members

1	Development of SSC / GMC models (including uncertainties) that represent the center, body and range of technically defensible interpretations.
2	Evaluation of applicable data, models, and methods, and Identification of important issues and applicable data.
3	Providing complete and clear justifications of the technical bases for all elements of

	the model including the reasons for excluding or down-weighting any data, models or methods.
4	Interaction with proponent and resource experts.
6	Attendance at kick-off meeting, each workshop, selected working meetings, and final meeting.
7	Preparation of project documentation and report.

3. GMC Technical Integrator (GMC TI)

TI plays the most important role in the project. A five person GMC TI team was selected for this project, headed by Kuo-Liang Wen with the team members: Yin-Nan Huang, Hung- Chie Chiu, Po-Shen Lin and Brian Chiou. The roles and responsibilities of the TI lead and the TI team members are given in Table A-3 and Table A-4, respectively.

Kuo-Liang Wen, PhD, is a Professor in the Department of Earth Sciences at National Central University, Taiwan. Prof. Wen is a recognized expert in ground motion and seismic hazard. He has over 30 years experience with site-effect analysis and ground motion evaluation. He has also good communication skills to be the interface between the earth sciences and earthquake engineering. Prof. Wen has served as a Principal Investigator for the 2004 seismic hazard studies at NPP No.4 in Taiwan. He was also involved in the several projects related to NPP's seismic safety evaluation for active faults, seismic monitoring, and seismic hazard in Taiwan, including Lotung Large Scale Seismic Test (LSST) jointed by the TPC and the EPRI, seismic safety re-evaluation for reissuing the operating license, seismic site-effect and seismic reaction research, seismic monitoring networks of the regions near the NPPs.

Yin-Nan Huang, PhD, is an Associate Professor in the Department of Civil Engineering at National Taiwan University, Taiwan. Prof. Huang is knowledgeable with respect to the application of design ground motion studies. He has previous experience with the 2006-2007 Project 07 - Reassessment of Seismic Design Procedures having advised the USGS on the development of seismic design maps for the United States, and his work was focus on

developing the technical basis for amending the probabilistic and deterministic analysis procedures used to establish seismic demands on structures.

Hung-Chie Chiu, PhD, is a Research Fellow in the Institute of Earth Sciences at Academia Sinica, Taiwan. Dr. Chiu is an established expert in the field of seismology, ground motion evaluation, and seismic site response. He is also knowledgeable on analysis of strong-motion array data in Taiwan and site response evaluation using H/V ratio. With over 20 years of experience in both strong-motion data processing and seismic wave propagation, Dr. Chiu has a strong background of the GMC studies for this project.

Po-Shen Lin, PhD, is a Senior Researcher of Sinotech Engineering Consultants, Inc. Dr. Lin is a recognized expert in seismic hazard, ground motion and active fault evaluation. He has experience with projects related in Taiwan PSHA and GMPE, focusing on ground motion database, GMPE development of crustal and subduction zones (Lin et al., 2011; Lin and Lee, 2008), σ value analysis in single station, and ground motion on hanging wall and footwall of faults. He also developed earthquake database and different types of GMPEs.

Brian Chiou, PhD, is a Senior Seismologist. Dr. Chiou is a recognized expert in ground motion and seismic hazard. He was one of the GMPE developers in the 2008 NGA project and 2014 NGA-west2 project. For this project, his key expertise is in evaluation and adjustment of NGA-west2 and others proponent GMPEs for use in Taiwan. Dr. Chiou has previous experience with the SSHAC studies having been a Resource Expert for the 2008-2011 BC Hydro and 2011-2013 Blue Castle SSHAC level 3 GMC studies. He has also served as a PPRP member for the 2012-2014 Hanford and 2011-2015 SWUS SSHAC level 3 GMC studies.

4. Participatory Peer Review Panel (PPRP)

PPRP is a key and indispensable role of both technical and process review in the project. A four person PPRP was selected for this project, headed by William Lettis with the team members: Yousef Bozorgnia, Sheng-Taur Mau and Kuo-Fong Ma. The roles and

responsibilities of the PPRP are given in Table A-5 and the selection criteria are given in Table A-6.

William Lettis, PhD, is a Senior Principal Geologist and President of Lettis Consultants International, Inc., California. Dr. Lettis is a recognized expert in SSHAC level 3 process and PSHA. He has over 30 years of experience in performing regional and site investigations to assess geologic and seismic hazards. Dr. Lettis has also extensive experience with the SSHAC process. He has served as a TI team member for the 2008-2011 CEUS SSC SSHAC level 3 study and as the TI team lead for the DCPP SSC SSHAC level 3 study. In addition, Dr. Lettis has served as a PPRP member for the 2012-2014 Hanford SSHAC level 3 SSC and GMC studies, and was a Project TI member for the 2011-2013 Blue Castle SSHAC level 3 SSC and GMC studies. He was selected as the PPRP chair because of his extensive knowledge on seismic hazard, his strong communication skills, and his availability to commit the required time to work with the PPRP members to achieve a consensus and complete reporting on schedule.

Yousef Bozorgnia, PhD, is a Professor in the Department of Civil and Environmental Engineering and Executive Director in the Pacific Earthquake Engineering Research Center at UC Berkeley, California. Prof. Bozorgnia is a recognized expert in ground motion and seismic hazard. He has over 30 years of experience in developing empirically based GMPEs. He was one of the GMPE developers in the 2008 NGA project and the 2014 NGA-west2 project. Prof. Bozorgnia has previous experience with the SSHAC studies as the Project Manager for the 2010-2014 NGA-east SSHAC level 3 GMC study, and was a Proponent Expert in the 2012-2014 Hanford and 2011-2015 SWUS SSHAC level 3 GMCs.

Sheng-Taur Mau, PhD, was a Professor in Department of Civil Engineering at California State University, Northridge. Prof. Mau is a recognized expert in earthquake engineering, seismic hazard and risk analysis. His experience in nuclear project in Taiwan includes seismic risk analysis of Lan-Yu waste material storage siting and review of seismic design of nuclear power plant No.1 and No.2. Prof. Mau has pioneered approaches to executing probabilistic seismic hazard assessment for Taiwan region and applied the PSHA results to establish

seismic zoning and design parameters for the 1974 Taiwan Building Code. Prof. Mau was selected as a PPRP member to provide his extensive experience of the seismic hazard and risk in Taiwan to assure the integrity of the SSC and GMC studies.

Kuo-Fong Ma, PhD, is a Professor in the Department of Earth Science at National Central University, Taiwan. Prof. Ma is a recognized expert in seismology, source mechanics, and numerical simulation. She has over 20 years of experience in 3-D velocity structure beneath Taiwan and dynamic rupture simulation. Her work has involved the application of these methods to earthquake hazards, including fault characterization and site response. Prof. Ma has participated in the 1999 Taiwan Meinong Reservoir Seismic Assessment Project, the 2004 Taiwan Chelungpu-fault Drilling Project (TCDP), and the 2008-2009 Taiwan Integrated Geodynamics Research (TAIGER) Project. Prof. Ma is serving as the Director of the Taiwan Earthquake Research Center (TEC), and a member of the Taiwan Earthquake Model (TEM) Working Group. Prof. Ma was selected as a PPRP member to provide a link between the seismic source and the ground motion characterization issues for this project.

Table A-5. Roles and Responsibilities of PPRP

1	Providing a technical review of all SSC, GMC and hazard issues for capturing the CBR of the TDI.
2	Providing a process review of the SSHAC level 3 PSHA study.
3	Review of project plan, workshop participants list, workshop agenda, workshop proceedings, SSC and GMC models, project reports and hazard input document.
4	Issue of consensus review report (after review comments are adequately addressed).
5	Attendance at kick-off meeting, each workshop, selected working meetings and final meeting.
6	Direct challenge of evaluators' assessment at Workshop#3.

Table A-6. Attributes / Selection Criteria of PPRP

1	Past experience on SSC and GMC studies in Taiwan region.
2	Working knowledge of PSHA.

3	Willingness to commit time and effort to the project.
4	A thorough understanding of the SSHAC goals and processes.
5	Past experience with SSHAC level 3 studies.

5. Hazard Calculation Team (HCT)

The selection criteria of HCT is to have working knowledge of PSHA program and executing experience of PSHA project for site-critical facilities in Taiwan. A three utilities HCT was selected for this project as follows: National Center for Research on Earthquake Engineering, Sinotech Engineeering Consultants, Inc. and the Institution of Nuclear Energy Research.

National Center for Research on Earthquake Engineering (NCREE) dedicates in application and research of seismic hazard with over 20 years of extensive experience in PSHA, including empirical models studies, computing program development and engineering design application. NCREE has developed GMPEs using crustal earthquakes of Taiwan in 2011 (NCREE 2011). NCREE has also executed several projects related to seismic hazard evaluation for critical facilities in Taiwan, such as nuclear power plant, airport MRT System, harbors and high-voltage electrical substation.

Sinotech Engineering Consultants, Inc. (Sinotech) has over 15 years of experience in probabilistic seismic hazard analysis and seismic hazard evaluation including nuclear power plants, reservoirs, and hydraulic and natural gas power plants in Taiwan. Sinotech has established ground motion database of subduction zone in Taiwan for the 2008-2011 BC Hydro SSHAC level 3 project. For the research and development in the field of PSHA, Sinotech has developed GMPEs of both crustal and subduction zones, revised PSHA program and performed data processing of strong ground motion records.

Institute of Nuclear Energy Research (INER) is the sole national research institute to promote nuclear application safety in Taiwan. INER has practical experience with seismic hazard analysis to assist Atomic Energy Council regarding safety-related decisions. Near five years, INER has involved several projects related to PSHA for nuclear power plants and offshore

wind power farms in Taiwan. In addition, INER has working knowledge of EZ-FRISK program to provide cross validation with Haz43b program applied by other HCT utilities.

Table A-7. Roles and Responsibilities of HCT

1	Responsible for hazard calculations and sensitivity analyses.
2	Providing feedback to PTI and the TI team, and answering questions on the distributions used for the PSHA computation.
3	Identifying key contributors to uncertainty.
4	Attendance at kick-off meeting, each workshop, selected working meetings, and final meeting.

Table A-8. Attributes / Selection Criteria of HCT

1	Technical expertise with hazard computation and analysis.
2	Working knowledge of PSHA programs.
3	Experience and familiarity with requirement of performing hazard analysis.

PPRP LETTER APPROVING PROJECT PLAN

December 10, 2015

Chiun-lin Wu, PhD
Executive Secretary, Project Management Office
National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhai Rd.
Taipei City, 10668, Taiwan

Dear Dr. Wu

The Participatory Peer Review Panel (PPRP) has reviewed Version 1 of the Project Plan (dated October 30, 2015) for the Seismic Reevaluation of Nuclear Facilities in Taiwan, Development of the Hazard Input Document Using SSHAC Level 3 Methodology. The Project Plan document is well prepared, explains the SSHAC Level 3 guidelines well, and provides a framework for successful implementation of those guidelines. It is responsive to earlier PPRP's recommendations, as detailed in our memoranda following the Kickoff Meeting dated August 21, 2015. The Plan includes a Technical Integration (TI) team that brings the project an appropriate balance between experts with both Taiwanese and International experience, and includes high-level expertise in both seismic source and ground motion characterization.

The PPRP believes that the Project Plan has the elements required for meeting the SSHAC Level 3 objectives. We thank the project team for its efforts in developing the plan and look forward to its implementation.

Sincerely,

William Lettis
Chair, PPRP

Yousef Bozorgnia
Member, PPRP

Kuo-Fong Ma
Member, PPRP

Sheng-Taur Mau
Member, PPRP