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September 18, 2009 Via e-mail

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Dear Mr. Salomone:

Reference: *Central and Eastern United States Seismic Source Characterization for Nuclear Facilities:* Participatory Peer Review Report on Workshop No. 3.

This letter constitutes the report of the PPRP[1] on Workshop No. 3 ("WS-3") for the referenced project. The *Feedback* workshop was held August 25–26, 2009, at EPRI headquarters in Palo Alto, California. Following guidance described in the Project Implementation Plan for the PPRP[2], and consistent with the expectations of the SSHAC process[3], the PPRP participated in WS-3 in order to be informed and to review both procedural and technical aspects of the workshop.

Seven members of the PPRP (J. P. Ake, W. J. Arabasz, W. J. Hinze, A. M. Kammerer, D. P. Moore, M. D. Petersen, and J. C. Stepp) attended WS-3 and were able to fully observe all aspects of the workshop. The Panel's eighth member (J. K. Kimball) was unable to attend the workshop because of an unavoidable conflict but was provided with electronic copies of all presentations made at WS-3 together with other workshop materials to enable his participation in this review.

**General Observations**

The Project Manager and TI Team Leader worked together very effectively, executing their respective roles, and the TI team members were well prepared and effective in their respective contributions, all of which resulted in a successful workshop. The Panel commends the continuing effective leadership of the Project Manager and TI Team Leader and the professional preparation of the TI team members that were displayed in this workshop. We observed that the workshop accomplished the stated goals established for this important milestone of the CEUS SSC assessment.

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[1] Acronyms are explained in the Appendix.
[2] *Implementation of the PPRP's Participation in the CEUS SSC Project*: Written statement communicated by J. Carl Stepp to L. Salomone and the TI Team on June 16, 2008.
[3] Budnitz, R. J., G. Apostolakis, D. M. Boore, L. S. Cluff, K. J. Coppersmith, C. A. Cornell, and P. A. Morris, 1997. *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts.* NUREG/CR-6372, Washington, DC, U.S. Nuclear Regulatory Commission.

WS-3 imposed a deadline for completing work tasks such as compilation of the seismicity catalog, the completion of a first-stage seismic source model for the CEUS termed "the SSC sensitivity model," and hazard sensitivity analyses based on the SSC sensitivity model. As such, WS-3 in effect was the TI Team's first opportunity to review and discuss its initial integrated evaluations of the range of the larger technical community's interpretations, although considering still incomplete data. The Panel recognizes that all of the evaluations reviewed in WS-3 constitute just a starting point for the TI Team to progressively build a seismic source model for the CEUS.

We observed that the informative presentations made by the TI Team Leader at the beginning and end of Day 2 effectively focused the Team's discussion on important evaluations remaining to be done going forward to support the SSC assessment. At the beginning of Day 2, Dr. Coppersmith summarized key conclusions he had extracted from the diverse feedback discussions during Day 1, and at the end of Day 2 he facilitated a lively discussion that actively engaged the TI Team in identifying additional feedback they required from the hazard analysts to effectively complete their SSC assessment. We found these discussions to be very informative and we consider them to have significant value for tracking how the TI Team is progressing with its implementation of the SSHAC guidelines.

**Specific Comments and Recommendations**

Provided below are comments and recommendations for consideration and follow-up action by the TI Team. The comments are not ranked in order of priority. Because the PPRP will not have another scheduled opportunity to comment on the CEUS SSC Project for a number of months, some of our comments extend beyond the content of WS-3.

1. *The Principal SSHAC Goal for a PSHA:* We appreciate Dr. Coppersmith's informative presentation of the background and context of the principal SSHAC goal for a PSHA: ***"to represent the center, the body, and the range of technical interpretations that the larger technical community would have if they were to conduct the study."*** His description of the historical context of the treatment of uncertainties in seismic regulation practice illustrates the critical importance to safety decision making of proper treatment of uncertainty, which formed the basis for the SSHAC's evolution of this important goal as well as the process that the SSHAC defined for achieving it. The SSHAC assessment process defines roles for participants as well as process activities that when properly implemented provide reasonable assurance that the goal for a PSHA established by the SSHAC is achieved. Based on Dr. Coppersmith's presentation and the follow-on discussions during the workshop, we concur that the assessment process activities being implemented for the CEUS SSC Project satisfy the SSHAC guidance. <u>We recommend that this important presentation be developed in the form of a white paper suitable for inclusion as a section in the project final report and that the white paper be distributed among the project participants, including the PPRP and sponsor technical representatives, for early review.</u>

2. *USGS Open-File Report on Maximum Magnitude:* Although briefly mentioned during the workshop, it was not clear to us how the soon-to-be issued USGS Open-File Report on estimation of maximum magnitude for seismic sources in the CEUS will be considered by the TI Team. We recommend that the report be considered as part of the information base for assessment of the CEUS SSC model.

3. *CEUS Earthquake Catalog:* The development and attendant analyses of the updated CEUS Earthquake Catalog are important contributions of the CEUS SSC Project that could potentially have high value for use in future PSHAs. The work summarized by Dr. Youngs on the catalog reflects a tremendous amount of work and represents a significant advancement in this important hazard data base. In order to be assured of the catalog's continuing high value, arrangements should be made to continually maintain this consensus catalog, and the analyses should be periodically updated as warranted by the addition of new data. Because multiple agencies and organizations will use the SSC Model, we recommend that the Project suggest a plan for keeping the CEUS Earthquake Catalog current into the future as a companion product for use of the SSC Model.

4. *Comments on Smoothing*:

   - We recognize that the concept of smoothing of seismicity is attractive from the standpoint of honoring the general location of past seismicity as well as allowing the TI Team a method to incorporate the uncertainty in the location of historical events. However, there needs to be careful consideration given to smoothing applied on a very small scale, especially in the "*b*-value". There are certainly implicit tectonic and/or structural assumptions associated with having the *b*-value changing over small distances. We believe a physical rationale should be supplied to support the Team's implementation of this approach. The examples shown at WS-3 utilized several different smoothing approaches but all were applied across very large regions or the entire CEUS. The use of a constant approach across the entire region may not be appropriate. It is not clear to us at this time whether that is the approach being planned by the TI team.

   - The smoothing methodologies discussed in the workshop are not described in any detail in the HID. It is not clear to us where the full documentation of the alternative smoothing procedures will appear. However, enough detail must be included in the HID to allow an experienced analyst to reasonably perform the hazard calculations for any point in the CEUS.

   - We consider the alternative procedures for smoothing seismicity that were presented and discussed during the workshop to be valuable tools for the TI Team to use to express uncertainty in its tectonic-based assessments of the spatial variation of seismicity. Accordingly, we recommend that the use of these tools (i.e., the choice of smoothing method, the use of anisotropic kernels, priors on parameters, and so on) be justified in terms of the Team's evaluations of tectonic processes governing earthquake occurrence.

5. *Independent Check*. The PPRP encourages the Project and the TI Team to perform the necessary independent checks of the analyses completed as part of developing the CEUS Earthquake Catalog and the Alternative Smoothing Procedures to ensure that this computational work is of the highest quality. It would be sufficient for the PPRP that this checking be performed using the TI Team participants so long as the "checker" is independent of the original work performed.

6. *Data Summary Table and Data Evaluation Table:* The **Data Summary Table** appears to be a highly valuable means of documenting the current range of the larger technical community's technical interpretations. We believe that the **Data Evaluation Table** also is an important part of the documentation of the CEUS SSC assessment that can serve the important need for transparent documentation of the TI Team's evaluations supporting its assessments of the center and body of uncertainty in the larger technical community's technical interpretations. The **Data Evaluation Table** also is potentially useful as a record of lessons learned and as such will be valuable in considering the need for and planning future investigations of the CEUS. This includes not only the utility of the various data most important in the SSC assessment, but also the nature and quality of data which imposed limitations on their use in identification and characterization of the seismic source zones. A summary of the various documents, their contents, and relationships would likely prove helpful and increase clarity for future implementation of the SSC Model. We recommend that the Project and TI Teams give careful consideration to these important potential uses of the **Data Evaluation Table** as the assessment goes forward.

7. *Sensitivity studies:* We consider the sensitivity studies to be highly valuable for providing insights and gaining understanding of the sensitivity of PSHA at a specific site to various elements of the SSC model. Additional sensitivity studies at a range of distances from the sources of frequent large earthquakes could add value for future use of the SSC model. However, we recommend that the sensitivity studies not be used to justify devoting a reduced effort to assessing any fundamental element of the SSC model. (See also Comment 11.)

8. *Lack of Consideration of Focal Depths:* There was a lack of discussion of earthquake focal depths in the workshop presentation on the updated CEUS seismicity catalog. This omission should be rectified. Because focal depth is a potentially important contributor to our knowledge of seismic hazards, useful in characterizing and defining the limits of seismic source zones, and helpful in assessing potential ground motion, we recommend that greater consideration be made of this parameter in the CEUS SSC.

9. *Plan for use of gravity and magnetic data.* Gravity and magnetic anomaly data and a variety of maps processed from these data are important in mapping largely hidden geological structures of the CEUS that may be useful in identifying seismic source zones and their geographic boundaries. We note that the contract for preparing the gravity anomaly data and associated maps has been let to the University of Oklahoma, but the contract has not been executed for preparing and processing the magnetic anomaly data. Furthermore, the Expanded Schedule for the CEUS project (7/14/09) set the completion date for both of these contracts as October 30, 2009, which we

learned at WS-3 has now been delayed until December 31, 2009. Despite the lack of the products from these contracts, the work of the TI team including the identification and delimiting of source zones must continue. As a result, we recommend that after December 31, 2009, once the new data sets and maps are available, a thorough review be conducted of decisions on identification and bounding of source zones that were reached prior to the availability of the gravity and magnetic anomaly data and related maps. This review may lead to modification of previous decisions.

10. *Preliminary Seismic Source Zones:* The seismic source zones used for the sensitivity evaluations and discussions during WS-3 are still tentative, but a cursory review of these zones raises several concerns:

- Where the evidence for the identified seismic source zones and their geographic limits are not described in referenced publications, we recommend that a comprehensive description be provided for the basis underlying the assessments of the source zones and their boundaries.

- It is unclear why certain regions were selected as "zones of elevated seismicity." What is their role? Why was the Clarendon-Linden region identified but not southeastern New York, the Niagara Peninsula, and other CEUS regions of above-normal seismicity in the historical record? We recommend that definitive criteria be cited for the selection of elevated seismicity zones.

- Earlier at Workshop No. 2, a scheduled presentation by Nano Seeber on seismicity and faulting in Ohio, Pennsylvania, New York State, and New York City was canceled and no similar presentation on this topic was made. Has anything been done to fill this void in the consideration and treatment of alternative interpretations? For example, a 2008 paper by Sykes and others[4] suggests an alternative view of seismicity in the New York City area that has not been cited in the Data Summary Table. We recommend that the list of alternative interpretations be updated to include those pertaining to the region that was to be discussed by Dr. Seeber at WS-2.

- There may be an inconsistency in the way that "extended zones" are used in the identification of seismic source zones. The area of the extended zone with normal faulting associated with the Iapetan Rift Margin is moved hundreds of kilometers west into the stable craton from the mapped rift margin. However, the limits of the seismic source zone associated with Iapetan (Cambrian) rifting in the midcontinent, including the New Madrid Rift Zone and its extensions, appear to be limited to mapped grabens without consideration of a bordering extended zone. Of particular note is the lack of an extended zone associated with the Grayville graben in southern Indiana. The "wide" interpretation of the seismic source zones is a step in the correct direction, but without further documentation on the factors defining the boundaries of this interpretation, it is difficult to determine if the broader extended zone is being captured in this interpretation. We recommend

[4] Sykes, L. R., Armbruster, J. G., Kim, W.-K., and Seeber, L., 2008, Observations and tectonic setting of historic and instrumentally located earthquakes in the greater New York City-Philadelphia area: *Bulletin of the Seismological Society of America*, v. 98, no. 4, pp. 1696–1719.

that the TI Team consider the possibility of an "extended zone" marginal to midcontinent seismic source zones.

11. *Pruning the Logic Tree and Need for Complete, Clear Documentation*. The use of an initial sensitivity model to inform evaluations to support the final model assessments is a sound and efficient approach. However, care must be taken to fully and clearly document the results of the sensitivity study, particularly as it impacts development of the final model and particularly in cases where alternative branches are removed. In a SSHAC level-3 study, the degree of credibility that the technical community grants the final model may be based heavily on the clarity and completeness of documentation and the ability of the technical community to understand the basis of assessments made by the TI team. In addition, robust documentation can more easily allow for the incorporation of new data and site-specific information into the model. In fact, specific guidance on how new or site-specific data should be evaluated could prove very valuable to the practitioner.

    The final model must represent the range of legitimate interpretations of the informed technical community in a scientifically defensible way. While some pruning of the tree based on the sensitivity study is desirable, we recommend that the sensitivity study not be used to trim branches that represented significant concepts or alternate hypotheses, even if the inclusion of alternate branches does not impact hazard. Some computational efficiencies could possibly be gained for the future hazard analyst if the study provides specific guidance as to the distance from the more significant sources at which the source no longer impacts hazard, and can be trimmed from the model.

12. *Evaluation and Assessment of Time-Dependent and In-vs.-Out-of-Cluster Models.* The approach to evaluating and assessing the time-dependent and in-vs.-out-of-cluster models need to be better explained. The time-dependent models require an aperiodicity parameter for use in the Brownian-Passage-Time calculations. Previous working groups in California determined a range of potential aperiodicity (or COV) parameters based on examining recurrence data with the associated uncertainties. It appears that the CEUS-SSC model may adopt this same range of parameters that was used in California. Since this is such an important parameter in determining the hazard, there should be some justification in the documentation regarding this choice considering the very different tectonic process that appears to be operative. The cluster models also need some further clarification. Sometimes the cluster models allow for activity in other nearby regions (migration of activity) when the primary source turns off and sometime they don't. In addition, different cluster-model weights for the Cheraw and Meers faults have been applied. It would be important to understand the basis for these weights and all other weights associated with these temporal models.

13. *Sanity Check for Seismic Sources Defined by Paleoliquefaction:* We recommend that the TI Team make a sanity check for those seismic sources defined by paleoliquefaction—that is, whether the source boundaries make sense, given the assumed magnitude versus area (or length) using relationships between magnitude and the maximum distance to liquefaction. For example, the magnitude-versus-area

relationship for the CEUS results in an assumed rupture length of ~21 km for M = 6.7. For the currently defined Charleston source options, can ruptures at the far ends of the source (e.g., the southeastern or northwestern corners of the large zone shown on Figure 15 in the HID) explain the observed paleoliquefaction at the opposite end of the source? The TI Team may need to factor in how they are modeling the recurrence of the source relative to the paleoliquefaction—but they need to make sure that the sources for the paleoliquefaction regions do not become too large when considering how rupture length is being modeled relative to paleoliquefaction.

14. *Integration with Ground-Motion Prediction Equations*. During the workshop there was discussion of the impact of the choice of ground-motion prediction equations on hazard results, particularly for sites in areas such as the Gulf region where the initiating seismic sources may be in other types of seismic-wave attenuation domains. It may be beneficial to consider recommendations to the practitioner with regard to the ground-motion prediction equations when different seismic-wave-propagation domains are involved in the PSHA.

15. *Need for Uniform Rigor in Assessing Rate-Information Inputs.* Examination of the SSC Sensitivity Model shows an apparent unevenness in rigor applied to assessing rate-information inputs in terms of significant figures and assessed distributions. This stands in contrast to the systematic rigor applied, say, to recurrence modeling. Because of the fundamental importance of rate information to hazard, we recommend careful uniform attention to the assessment of rate inputs. Such assessments should meet the basic expectations of a normative expert in a PSHA if one were overseeing the assessments.

16. *PPRP Observers in Remaining Working Meetings*. Under the CEUS SSC Project Expanded Schedule (dated July 14, 2009), the next face-to-face meeting of the PPRP with the TI Team will be in March 2010. Because this will be at a relatively late stage of shaping a near-final (albeit still "preliminary") SSC model, we recommend that the Project Manager facilitate participation of at least two PPRP members as observers in the TI Team's Working Meeting #6 (October 20–21, 2009) and Working Meeting #7 (January 12–13, 2010).

Do not hesitate to contact us if you wish to discuss any of our observations, comments, or recommendations.

Sincerely,

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Copy: PPRP Members
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# APPENDIX

## Acronyms

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| CEUS | Central and Eastern United States |
| COV | Coefficient of Variation |
| EPRI | Electric Power Research Institute |
| HID | Hazard Input Document |
| PPRP | Participatory Peer Review Panel |
| PSHA | Probabilistic Seismic Hazard Analysis |
| SSC | Seismic Source Characterization |
| SSHAC | Senior Seismic Hazard Analysis Committee |
| TI | Technical Integrator |
| USGS | U.S. Geological Survey |