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EPRI (2004,2006) Ground Motion Model (GMM) Review Project

Nuclear Regulatory Commission (NRC)
Public Meeting
January 23, 2013

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GOALS FOR BRIEFING

- To provide an overview and current status of the EPRI GMM Review Project
- To briefly review recent developments and technical advancements that have occurred since the public meeting on October 18, 2013
- To review the project schedule and present the tasks that will occur to complete the project
- To present and discuss the preliminary updated EPRI (2004, 2006) GMM

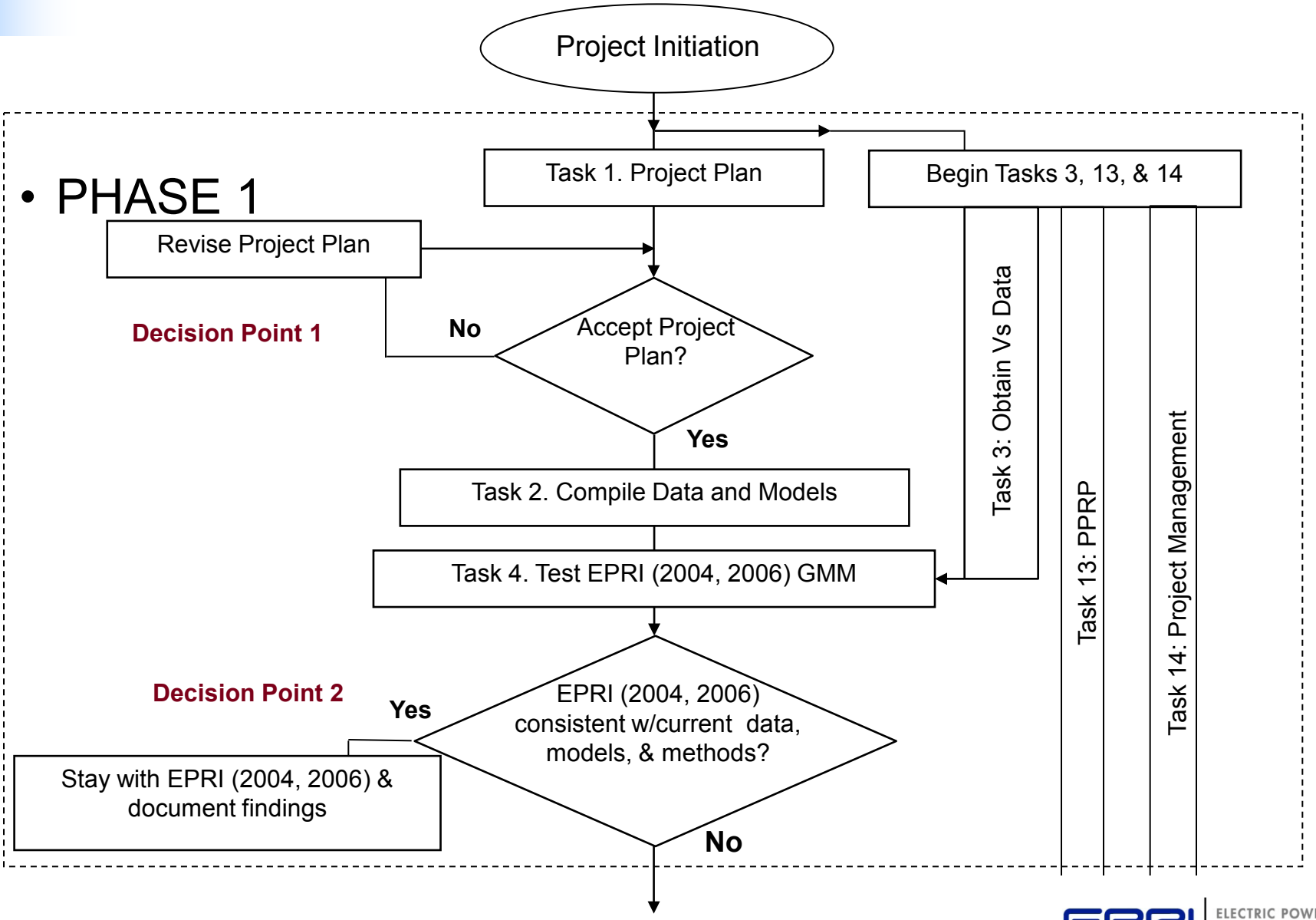
EPRI (2004, 2006) GROUND-MOTION MODEL (GMM) REVIEW PROJECT EXPECTATIONS

- Meet Schedule for GMRS Calculations and Provide Informed Response to NRC March 12, 2012 Request for Information
- Increase Accuracy of Input to Calculate GMRS At Existing Nuclear Power Plants
- Engagement of all Stakeholders
- Transparency
- Eliminate Delays

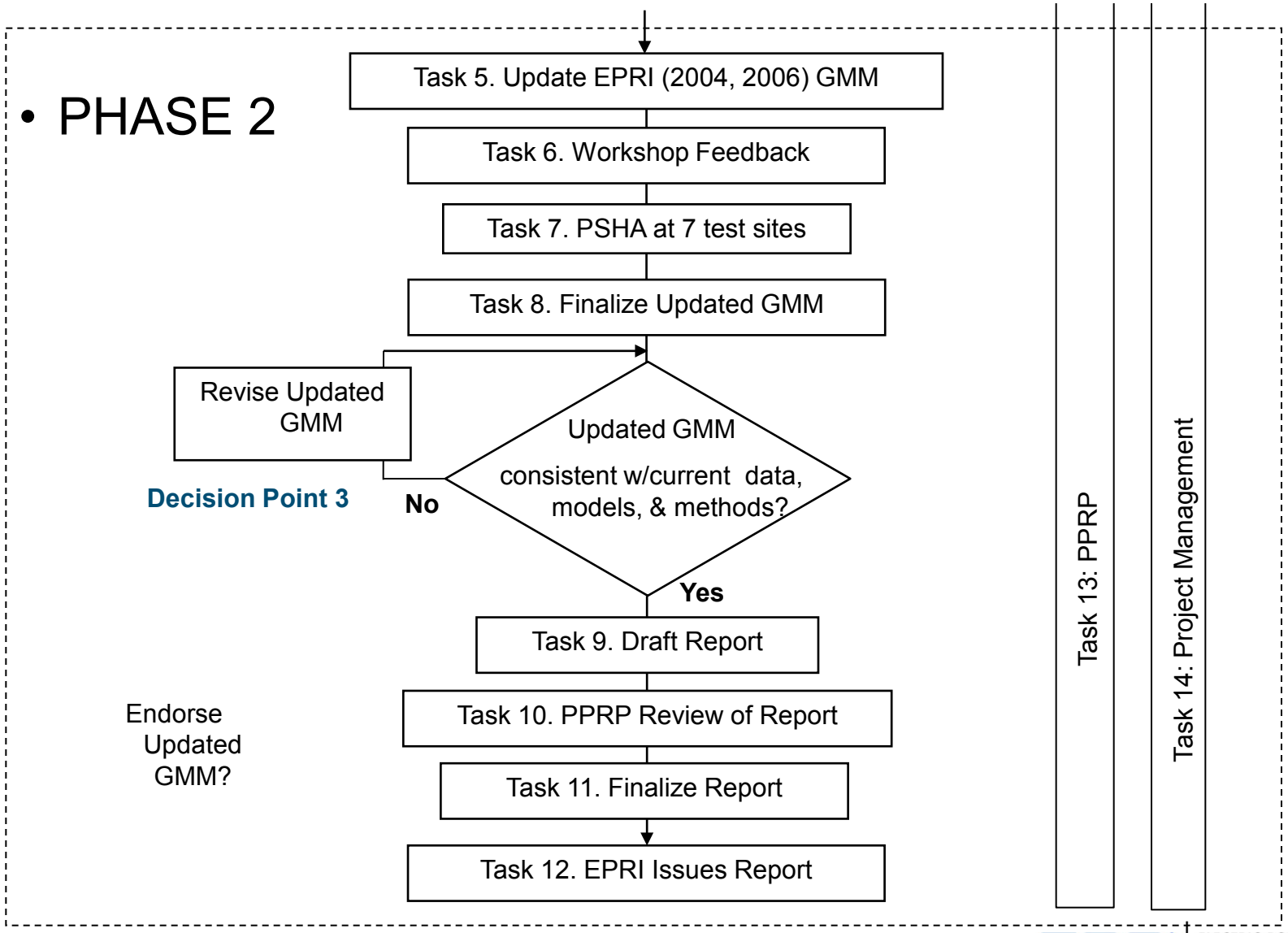
- Reduce Time to Achieve Project Goals

- Carry Out Properly and Document SSHAC Activities of Evaluation and Integration

REVIEW: Project Plan: FLOW CHART



REVIEW: Project Plan: Flow Chart (continued)



SSHAC ASSESSMENT PROCESS

- The fundamental goal of a SSHAC process is to carry out properly and document completely the activities of evaluation and integration, defined as:
  - Evaluation: The consideration of the complete set of data, models and methods proposed by the larger technical community that are relevant to the hazard analysis.
  - Integration: Representing the center, body, and range of technically defensible interpretations in light of the evaluation process informed by the assessment of existing data, models, and methods.

SSHAC Level 2 Assessment Process

- Steps (attributes) for Implementing a SSHAC Level 2 Study:
  - **Step 1:** Project Manager Identifies and Engages Peer Reviewers
  - **Step 2:** Technical Integrator (TI) Identifies Available Information and Design Analyses and Information Retrieval Methods
  - **Step 3:** TI Perform Analyses, Accumulate Information Relevant to Issue and Develop Representation of Community Distribution
  - **Step 4:** TI Perform Data Diagnostics and Respond to Peer Reviews – On-going peer review would occur after Steps 2, 3, and 4.
  - **Step 5:** Document Process and Results

Assessment Process Used for the EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project

- Assessment Process Used for the EPRI GMM Study included a structured, systematic and unbiased evaluation of the range of defensible technical interpretations from the larger technical community

- Followed guidance in NUREG-2117 to *update* not *replace* the EPRI (2004, 2006) GMM by maintaining the conceptual framework of the EPRI (2004, 2006) GMM

- The steps prescribed in the SSHAC Level 2 assessment process were performed in addition to implementing the following enhancements:
  - The Project Manager identified four professionals to serve as the TI Team rather than one professional serving as a Technical Integrator (TI)
  - Four professionals identified as a *Participatory* Peer Review Panel
  - *Participatory* peer review of technical findings and process during the entire study
  - A PPRP Closure Briefing is scheduled for February 13, 2013
  - A workshop was held on October 17, 2012 to enhance interaction with the technical community
  - A preliminary GMM was developed prior to the Feedback Workshop
  - A Hazard Input Document (HID) provided input to seismic hazard calculations
  - Development of draft and final report that included documentation of the SSHAC process, technical bases, and results

Executive Overview

- The EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project demonstrates that a SSHAC Level 2 assessment of a SSHAC Level 3 study is feasible by maintaining the conceptual framework of the SSHAC Level 3 study
- Each of the prescribed steps in the SSHAC Level 2 guidelines were followed in addition to enhancements performed for the EPRI (2004, 2006) GMM Review Project
- The value of the Updated EPRI (2004, 2006) GMM has been enhanced by the participation of key stakeholders from industry, government and academia
  - Productive Cooperation of PEER and Members of the NGA-East Project
  - Productive Cooperation of USGS and Members of the USGS National Seismic Hazard Mapping Project
- EPRI GMM Study Uses a Hazard Input Document (HID) to provide basic elements of the Updated GMM for seismic hazard calculations

Executive Overview (continued)

- Guidance for Future Applications of Updated EPRI (2004, 2006) GMM Provided:
  - Recommended Distance Limitations of Ground-Motion Models
  - Updated Gulf Region Boundaries Provided
  - Information on How to Select model for Mid-Continent Region or Gulf Region based on Path
- The Center, Body, Range of Views of the Larger Technical Community have been captured and represented in the Updated (EPRI (2004, 2006) GMM
- Sensitivity Analysis Was Performed to Evaluate Proponent Positions Regarding the Weight for Small Magnitude Earthquakes
- EPRI GMM Study Updates But Does Not Replace the EPRI (2004, 2006) GMM. The Updated EPRI (2004, 2006) GMM Will Be Suitable for Use Until Completion of the NGA-East Project. The NGA-East Project Ground-Motion Prediction Equations (GMPEs) Will Replace the Updated EPRI (2004, 2006) GMM When Available

EPRI (2004) GMM

Cluster	Model Type	Models
1	Single Corner Stochastic (0.275/0.351)	~~Hwang and Huo (1997)~~ ~~Silva et al (2002) - SC-CS~~ Silva et al (2002) - SC-CS-Sat Silva et al (2002) - SC-VS Toro et al (1997) Frankel et al (1996)
2	Double Corner Stochastic (0.312/0.399)	~~Atkinson and Boore (1995)~~ ~~Silva et al (2002) DC~~ Silva et al (2002) DC - Sat
3	Hybrid (0.196/0.250)	~~Abrahamon & Silva (2002)~~ ~~Atkinson (2001) & Sadigh et al (1997)~~ ~~Campbell (2003)~~
4	Finite Source /Greens Function (0.217/0.000)	Somerville et al. (2001)

Basis for Recommendation to Proceed to Update the EPRI (2004, 2006) Ground-Motion Model

- Seven (7) of the thirteen (13) developers of the ground motion prediction equations (GMPEs) used in the EPRI (2004, 2006) GMM recommended that their GMPEs be replaced.
- There are three new GMPEs developed by ground motion experts during the past ten (10) years.
- Eighty percent (80%) of the earthquake records in a new ground motion database are from earthquakes that occurred after the development of the EPRI (2004) GMM.
- The EPRI (2004, 2006) GMM over-predicts ground motions at some magnitude-distance-frequency ranges important to nuclear power plant (NPP) probabilistic seismic hazard assessments (PSHAs).

PHASE 1 CONCLUSION

- It is appropriate to update the existing EPRI (2004, 2006) GMM to incorporate current data, models and methods before it is used to calculate GMRS at existing nuclear power plant sites. The updated EPRI (2004, 2006) GMM should be the “appropriate” EPRI (2004, 2006) GMM referred to in the NRC RFI 50.54 (f) letter dated March 12, 2012.

Phase 2
Task 5 - Update EPRI (2004, 2006) Ground-Motion (GMM) Model
Results

EPRI (2004) GMM

Cluster	Model Type	Models
1	Single Corner Stochastic (0.275/0.351)	~~Hwang and Huo (1997)~~ ~~Silva et al (2002) - SC-CS~~ Silva et al (2002) - SC-CS-Sat Silva et al (2002) - SC-VS Toro et al (1997) Frankel et al (1996)
2	Double Corner Stochastic (0.312/0.399)	~~Atkinson and Boore (1995)~~ ~~Silva et al (2002) DC~~ Silva et al (2002) DC - Sat
3	Hybrid (0.196/0.250)	~~Abrahamon & Silva (2002)~~ ~~Atkinson (2001) & Sadigh et al (1997)~~ ~~Campbell (2003)~~
4	Finite Source /Greens Function (0.217/0.000)	Somerville et al. (2001)

New Clusters & Weights

Cluster	Model Type	Models
1	Single Corner Brune Source (0.11/0.127)	Silva et al (2002) - SC-CS-Sat* Silva et al (2002) - SC-VS* Toro et al (1997) Frankel et al (1996) * Treated as one model for calculation of weights
2	Complex/Empirical ~R^{-1} Geometrical spreading (0.27/0.310)	Silva et al (2002) DC – Sat A08’
3	Complex/Empirical ~$R^{-1.3}$ Geometrical spreading (0.49/0.563)	AB06’ PZT11
4	Finite Source /Green’s Function (0.14/0)	Somerville et al. (2001); slightly different models for rifted and non-rifted (not used for distributed seismicity sources with large contribution from **M** < 6)

EPRI (1993, 2004) Map of Gulf Region

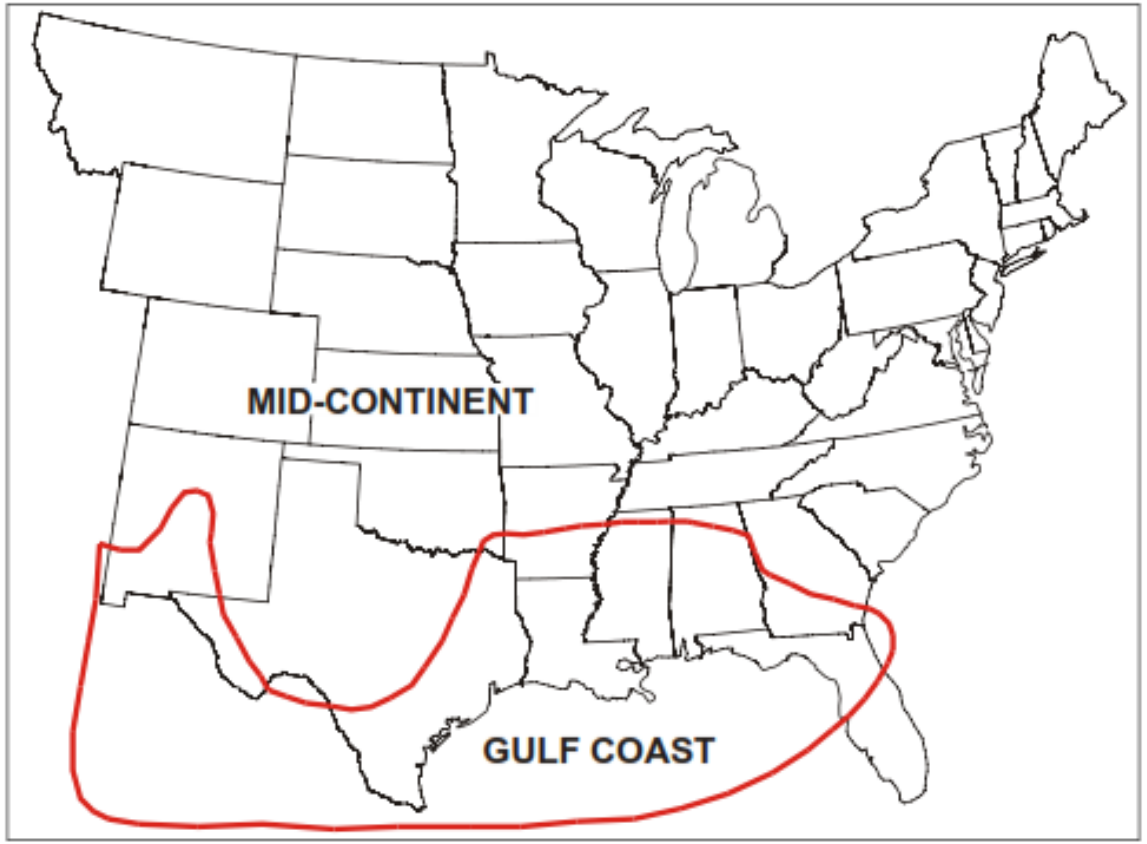
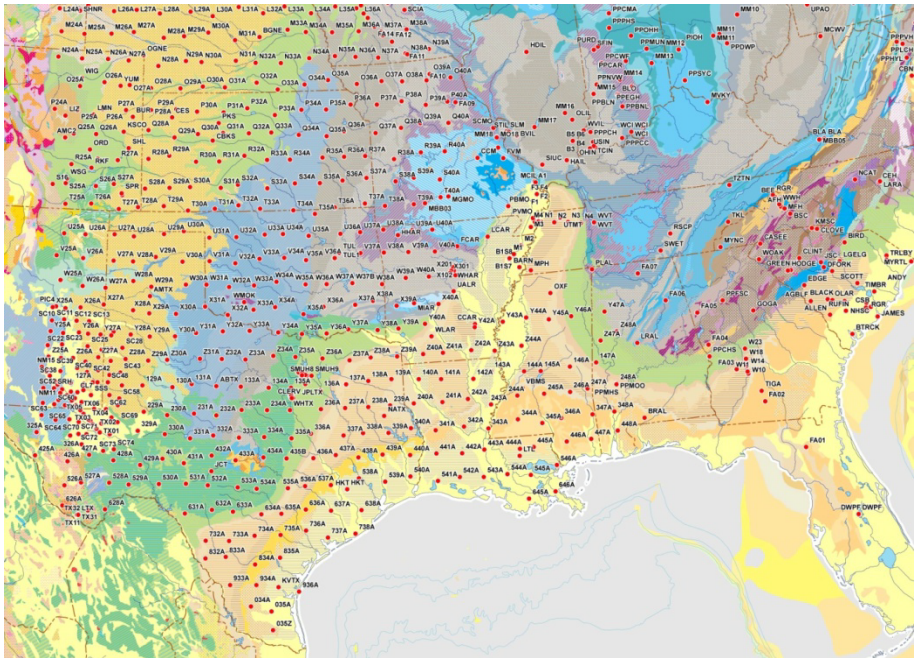
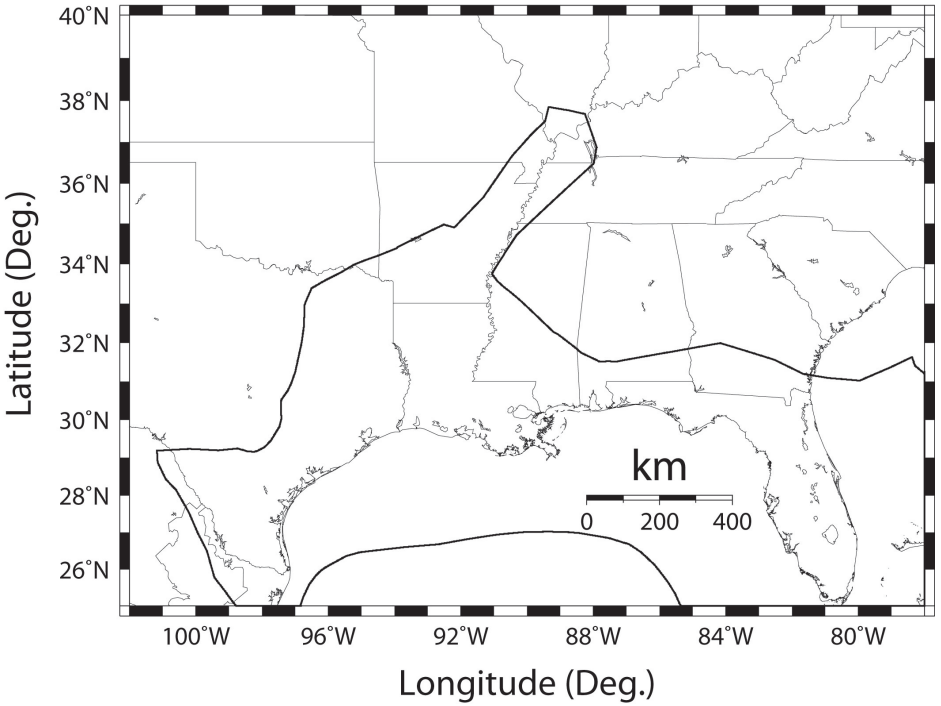


Figure 3-2
Mid-Continent and Gulf Coast Regions of the CEUS (EPRI, 1993)

Revised Gulf Region



Geologic map showing the locations of EARTHSCOPE Transportable Array stations installed as of April, 2011, as well as other regional broadband stations.



Gulf Coast region used for attenuation study.

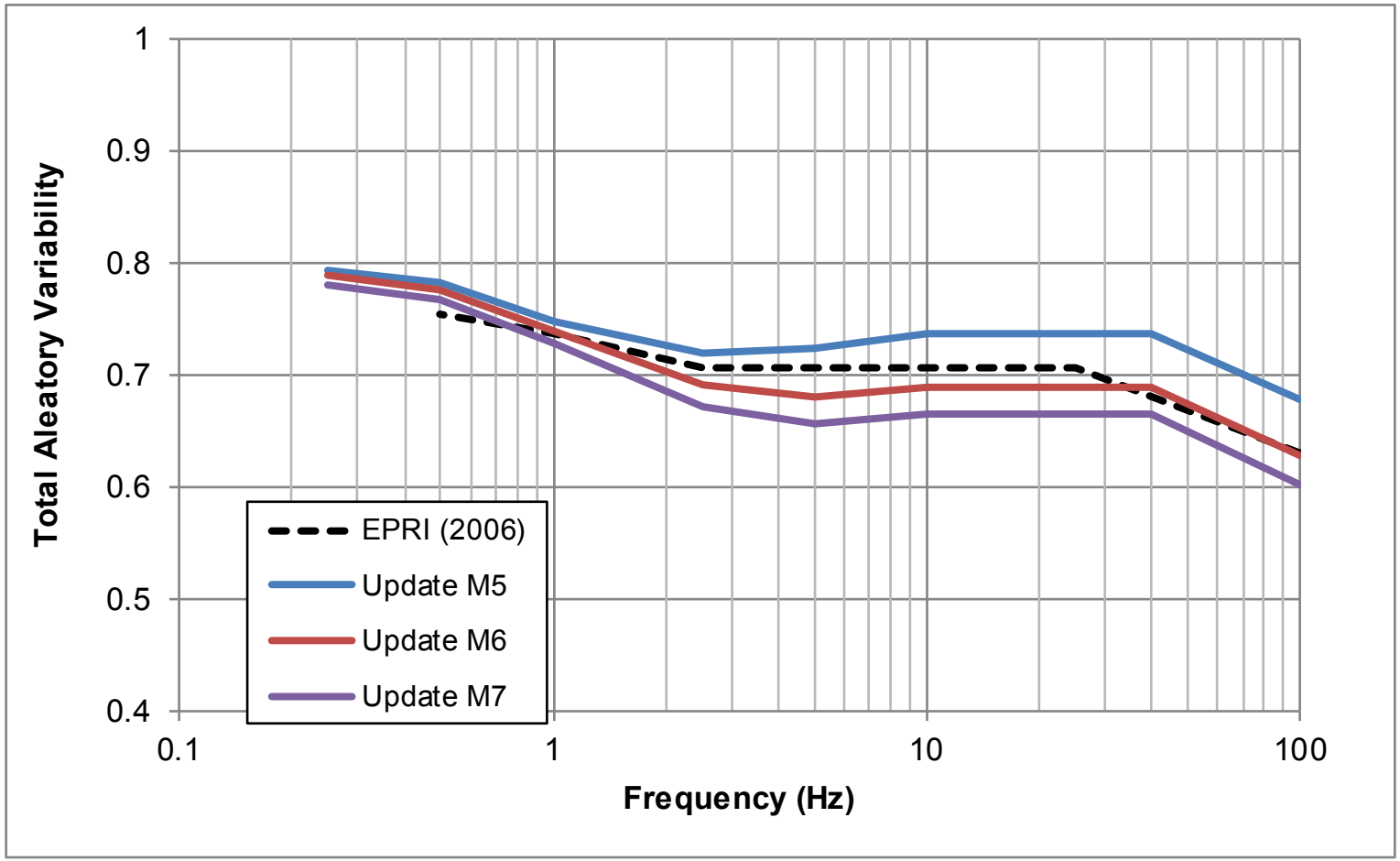
Update to EPRI (2006) Aleatory Variability Model

- Results of interviews with experts did not indicate a need to change the conclusions of EPRI (2006) with regard to differences between CENA and WNA aleatory variability

- Repeated analysis using final published values of aleatory variability from NGA West 1 (2008) papers for 4 models which provided both inter-event and intra-event aleatory components

- Revisited final aleatory model based on preliminary results from NGA West 2

Frequency - and Magnitude - Dependent Portion of the Aleatory Uncertainty



STATUS and TARGET DATES (PHASE 1)

- Task 1: **Completed** and Posted Project Plan on June 18, 2012;
- Task 2: Reviewed Ground-Motion Database, Reviewed New CEUS Ground Motion Prediction Equations (GMPEs), and Conducted Resource Expert and Proponent Interviews **(Completed)**;
- Task 3: Obtained Shear Wave Velocity Measurements at 33 Recording Stations **(Completed)**;
  - Received Shear Wave Velocity Profiles for 25 additional Seismic Recording Stations **(Completed)**
- Task 4: Tested the EPRI (2004, 2006) Ground Motion Model (GMM) **(Completed)**;
  - PPRP agreement with the recommendation to update the EPRI (2004,2006) Ground-Motion Model **(Completed August 2012)**
  - EPRI Letter to NRC documenting decision to update the EPRI (2004,2006) Ground-Motion Model **(Completed August 2012)**

STATUS and TARGET DATES (Phase 2)

- Task 5: Updating the EPRI (2004, 2006) Ground-Motion Model – Preliminary Updated GMM for Mid-Continent and Gulf Regions to Hazard Analyst **(Completed)**
- Task 6: Held Feedback Workshop on October 17, 2012 **(Completed)**
- Task 7: Calculation of Preliminary Seismic Hazard Curves at Seven (7) Test Sites (February 13, 2013):
- Task 8: Finalize Updated EPRI (2004, 2006) Ground-Motion Model (February 13, 2013)
  - Final Closure Briefing PPRP Report (February 27, 2013)
  - Final NRC Letter with Acceptance to Use Updated GMM (February 27, 2013)

STATUS and TARGET DATES (PHASE 2) (continued)

- Task 9: Document EPRI (2004, 2006) GMM Review Project in Draft Report (March 13, 2013)

- Task 10: Receive comments from PPRP and NRC (April 10, 2013)
  - Receive PPRP Final Report (April 24, 2013)

- Task 11-12: Document EPRI (2004, 2006) GMM Review Project in Final Report (May 2013)

EPRI (2004, 2006) GMM Review Project: Review Tools to Reach Closure

Updated EPRI (2004, 2006) GMM

- PPRP and Observer Key Issues Identified During Five (5) Working Meetings and Documented in Working Meeting Highlights
- Five (5) Project and Observer Conference Calls
- Five (5) NRC Public Meetings
- PPRP Workshop Report Underlined Statements
- January 2013 Intermediate Document Providing the Updated GMM and Accompanying Text

EPRI (2004, 2006) GMM Review Project

- Draft Report: March 13, 2013
- Final Report: May 2013

What's Next

- Pre-Closure Briefing Project Conference Call – February 1, 2013 (tentative)
- PPRP Closure Briefing – Approval for Updated EPRI (2004, 2006) GMM: February 13, 2013
- Draft Closure Briefing PPRP Report and Draft NRC Letter with Acceptance to Use Updated EPRI (2004, 2006) GMM (February 20, 2013)
- Final Closure Briefing PPRP Report and Final NRC Letter Documenting Acceptance of Updated EPRI (2004, 2006) GMM (February 27, 2013)
- **Draft** EPRI (2004, 2006) GMM Review Project Report (March 13, 2013)
- Receive PPRP and Observer Comments (April 10, 2013)
- PPRP Final Report (April 24, 2013)
- **Final** EPRI (2004, 2006) GMM Review Project Report (May 2013)

SSHAC-Required Documentation

REVIEW: OVERVIEW

Background:

- The EPRI (2004, 2006) Ground Motion Model (GMM) Review Project will provide industry information necessary specifically for an informed response to the NRC Request for Information (RFI) to Title 10 of the Code of Federal Regulation 50.54(f) Recommendation 2.1 of the Near-Term Task Force (NTTF) Review of Insights from the Fukushima Dai-Ichi Accident dated March 12, 2012.
- The project will provide information for developing site-specific ground motion response spectra (GMRS) for existing nuclear power plant sites and other seismic regulatory issues pending completion of the NGA-East Ground Motion Model.
- The industry position is to review and, if necessary, update the EPRI (2004, 2006) GMM: This position is prudent in light of guidance in NUREG-2117 (2012), input from ground motion experts and seismologists contacted from October 2011 to March 2012 and new data, models and methods that have become available since the SSHAC Level 3 EPRI (2004) workshops were held in 2002.

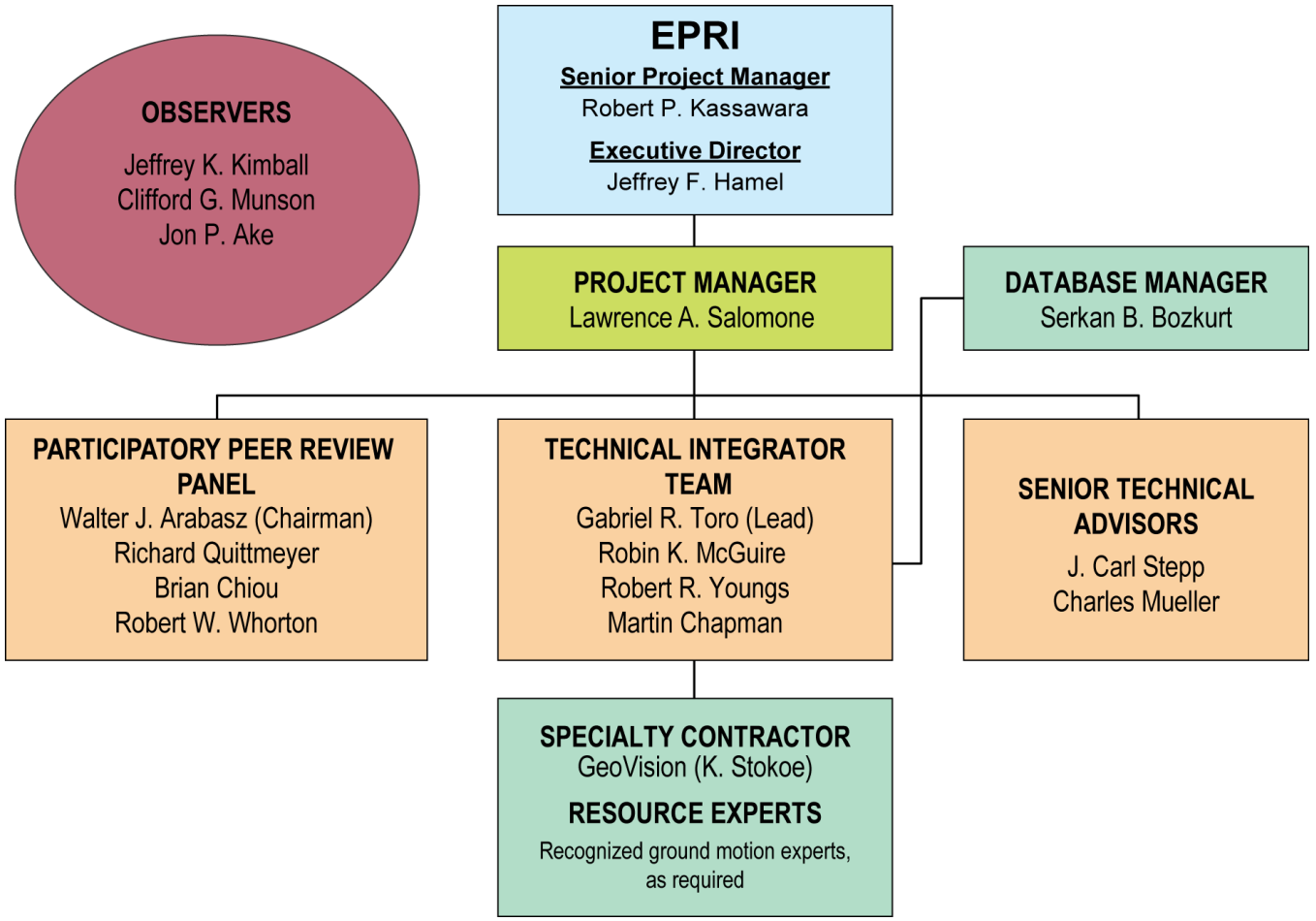
Purposes:

- Review and Update, if appropriate, the EPRI (2004, 2006) GMM for the need of calculating GMRS for existing nuclear power plant sites in response to the NRC RFI of the NTTF recommendation for seismic using an approach that can be accepted by the NRC
- Increase the accuracy of input to compute ground motion response spectra (GMRS) required in NTTF Recommendation 2.1 for seismic

REVIEW: INDUSTRY DUE DILIGENCE

Contact Type	Date	Participants
Conference Call	November 8, 2011	G. Atkinson, J. Bailess, J. Hamel, R. Kassawara, K. Keithline, J. Marrone, S. McDuffie, R. McGuire, M. Petersen, L. Salomone, J.C. Stepp, G. Toro, B. Youngs,
Interviews	October 26, 2011	N. Abrahamson
	November 2, 2011	M. McCann
	November 3, 2011	W. Silva
Meeting	November 30, 2011	A. Frankel, C. Goulet, R. McGuire, M. Moschetti, C. Mueller, M. Petersen, S. Rezaeian, L. Salomone, J.C. Stepp, G. Toro,
Conference Call –Project "Kickoff" Call	March 8, 2012	N. Abrahamson, J. Ake, W. Arabasz, S. Bozkurt, M. Chapman, J. Hamel, R. Kassawara, J. Kimball, R. McGuire, C. Mueller, C. Munson, R. Quittmeyer, L. Salomone, J.C. Stepp,

Organizational Chart



REVIEW: Task 2 - Literature Reviews

- **Reviewed References:**

- Table A-1 Atkinson, 2004a
- Table A-2 Atkinson, 2004b
- Table A-3 Campbell, 2004
- Table A-4 Tavakoli and Pezeshk, 2005
- Table A-5 Atkinson-Boore, 2006
- Table A-6 Douglas et al, 2006
- Table A-7 Sonley and Atkinson, 2006
- Table A-8 Atkinson et al, 2007
- Table A-9 Kanth and Iyengar, 2007
- Table A-10 Atkinson, 2008
- Table A-11 Atkinson and Morrison, 2009
- Table A-12 Campbell, 2009
- Table A-13 Somerville et al, 2009
- Table A-14 Atkinson and Kraeva, 2010
- Table A-15 Boore et al. 2010
- Table A-16 Zandieh and Pezeshk, 2010
- Table A-17 Atkinson-Boore, 2011
- Table A-18 Atkinson et al, 2011
- Table A-19 Boatwright and Seekins, 2011
- Table A-20 Pezeshk et al, 2011
- Table A-21 Atkinson, 2012
- Table A-22 Boore, 2012
- Table A-23 Atkinson and Wald, 2007

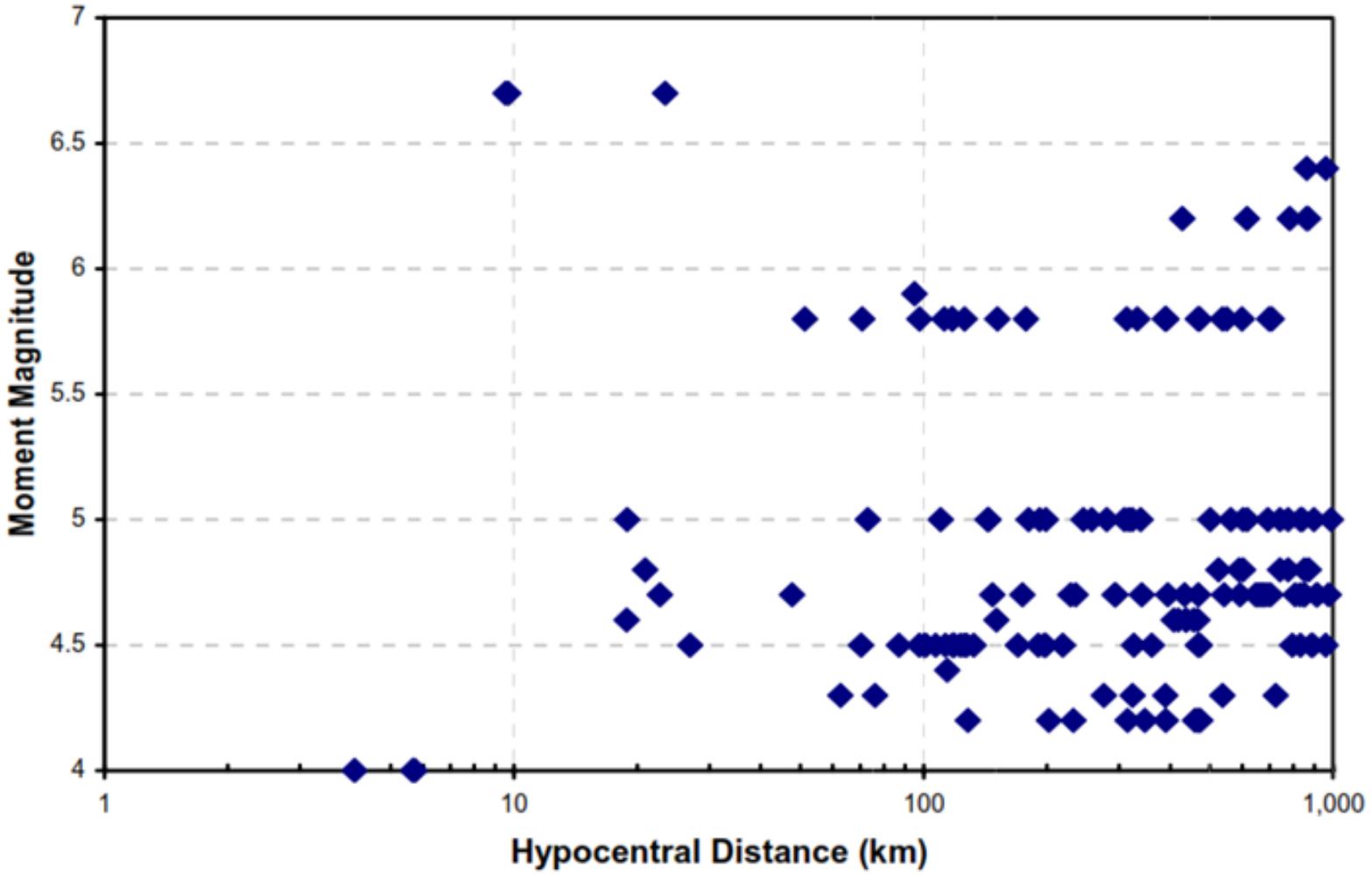
REVIEW: Task 2 - Interviews

- N. Abrahamson; Completed June 21, 2012
- G. Atkinson; Completed July 6, 2012
- J. Boatwright; Completed October 4, 2012
- D. Boore; Completed June 26, 2012
- K. Campbell; Completed June 20, 2012
- C. Cramer; Completed July 3, 2012
- A. Frankel; Completed July 31, 2012
- B. Herrmann; Completed September 11, 2012
- S. Pezeshk; Completed June 26, 2012
- W. Silva; Completed July 17, 2012
- P. Somerville; Completed July 9, 2012

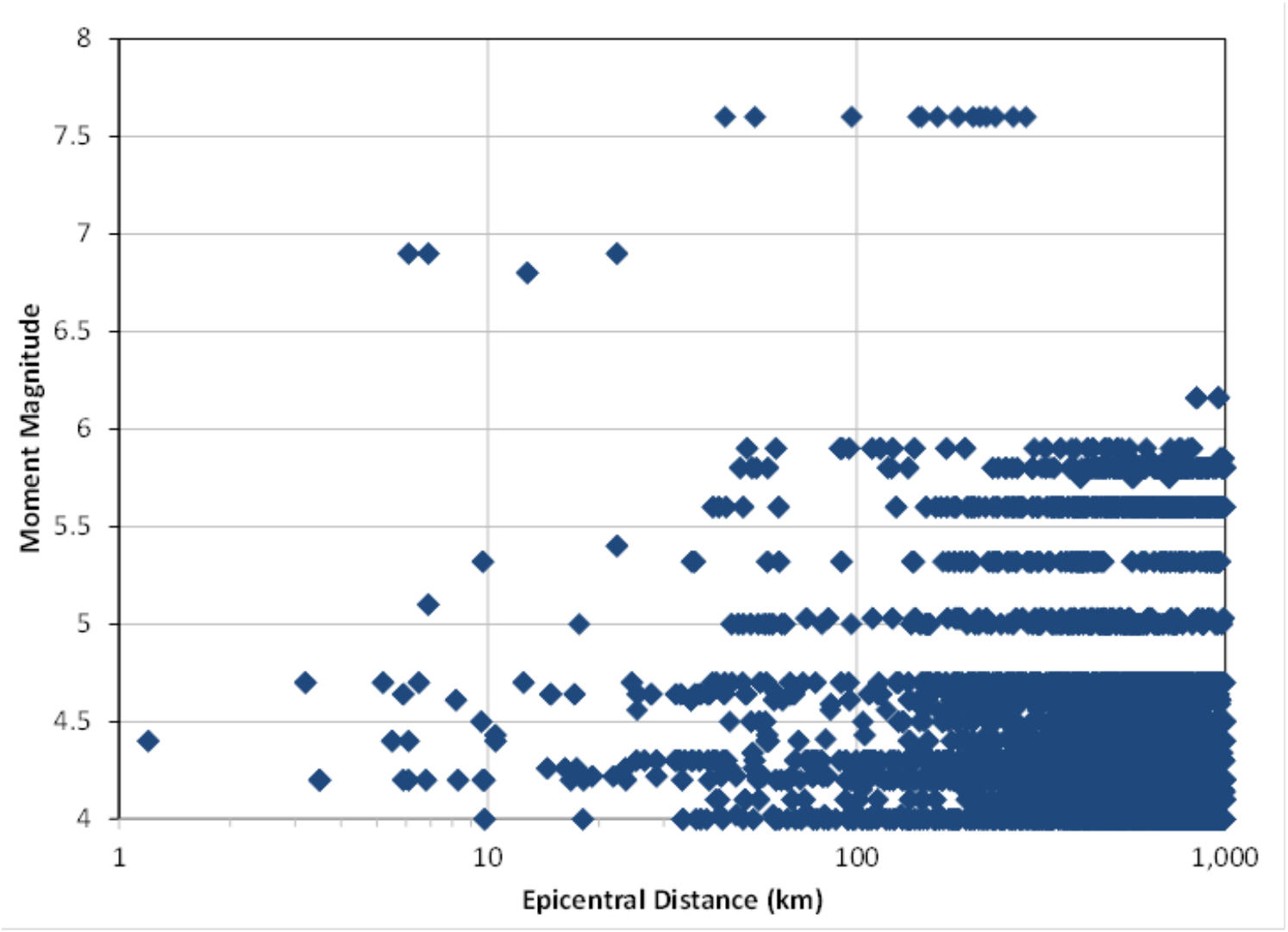
REVIEW: NGA-EAST DATABASE

- Data and metadata from earthquakes in CENA including some recent earthquakes:
  - M4 and greater with any records within 1000km
  - M2.5 to M4 with five or more recordings within 100km
- Number of records is nearly 28,000
- Each record has a flag indicating its quality
- Includes notable earthquakes not in EPRI (2004) study:
  - 2008 M5.3 Mt. Carmel, IL
  - 2010 M5.0 Val des Bois, Quebec
  - 2011 M5.8 Mineral VA earthquake (about 300 recordings) and one M4.5 aftershock
  - 2011 M5.6 Sparks Oklahoma
- Eighty Percent (80%) of the records are from earthquakes that occurred since 2004

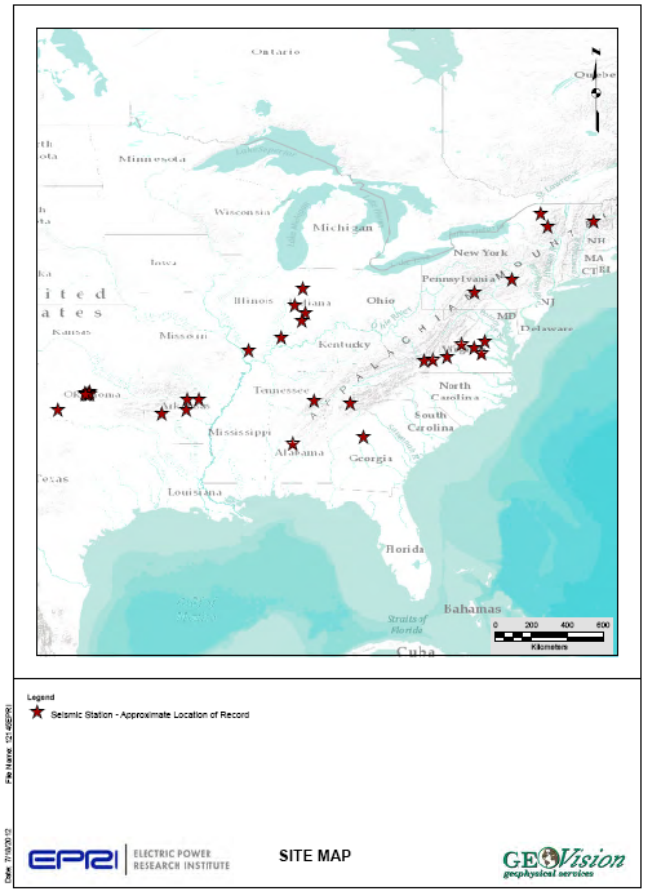
REVIEW: EPRI (2004) GMM: MAGNITUDE-DISTANCE PLOT



REVIEW: MAGNITUDE-DISTANCE PLOT – NGA-EAST



Task 3: Shear Wave Velocity Measurements Site Map



TASK 3: SHEAR WAVE VELOCITY MEASUREMENT GENERAL OBSERVATIONS

- Shear wave velocity for hard rock sites are, in general, below the reference rock velocity of 2800 m/s; Some recording stations had shear wave velocities at about the reference rock velocity at depths greater than 30 m (e.g. PN.PPBLN - Indiana and US.WMOK - Oklahoma).
- Velocity inversions occurred at some sites; Shear Wave Velocity of Layer 1 in the profile can be higher than Layer 2.
- Information on the depth of seismograph emplacement were obtained for the recording stations.
- The geology at the recording stations can be highly variable; Lateral velocity variation is an important issue at many sites; Future investigations may require more testing arrays.
- Different array locations, anisotropy and depth of water table assumed can cause differences when making shear wave velocity measurements.

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