ELECTRIC POWER RESEARCH INSTITUTE

July 23, 2013

TO: Recipients of EPRI Product 3002000717, EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project

Subject: Errata Sheet for EPRI Technical Report *EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project*, Product 3002000717

Dear Recipient of 3002000717,

Please note that the referenced report had some changes to the subject pages.

- The text in the last paragraph of the acknowledgments on Page VI;
- The text on Section 7.3.1.1, Step 3, page 7-13, has been revised to eliminate confusion;
- Equation 7.6.2-2 in the text on page 7-36 has been revised to be consistent with the Hazard Input Document (HID).

The last paragraph in the acknowledgments should read as follows:

> EPRI would also like to acknowledge the Participatory Peer Review Panel (W. Arabasz – Chairman, B. Chiou, R. Quittmeyer, and R. Whorton), who reviewed the technical and process aspects of the project, and GEOVision, Inc., with The University of Texas, who conducted the shear-wave-velocity measurements at seismic recording stations. The ground-motion experts and seismologists, listed in Table 2.1-1, who participated in the due diligence review of the EPRI (2004, 2006) Ground-Motion Model, in interviews conducted by the TI Team (Appendix C), and in the October 17, 2012, workshop (Table 2.2.6-1) are also acknowledged. The value of the Updated EPRI (2004, 2006) GMM has been enhanced through productive cooperation from the Pacific Earthquake Engineering Research (PEER) Center, members of the NGA-East Project, the U.S. Geological Survey (USGS). EPRI thanks Albert Kottke for providing and revising his IRVT software. Some of the analyses and graphics contained in this report were prepared using R (R Development Core Team, 2012). EPRI thanks R. Chambers, G. Moore, and N. Sutherland of AMEC Environment & Infrastructure, Inc., for their assistance with the preparation of the report.

On page 7-13, Step 3 the last two bullets in the bulleted list that summarize the approach for the calculation of parameter kappa should be removed, as profiles with V_{S30}<500 m/s were not used.

On page 7-36, Equation 7.6.2-2 should read as follows:

PALO ALTO OFFICE
3420 Hillview Avenue, Palo Alto, CA 94304-1338 USA • 650.855.2000 • Customer Service 800.313.3774 • www.epri.com

$$\begin{aligned}\ln(PSA) = {} & C_1 + C_2\mathbf{M} + C_3\mathbf{M}^2 + C_4\mathbf{M}^3 + \\ & \left[C_5 + C_6 \times \min(\mathbf{M}, C_{14}) \ + C_7 \times \max(\mathbf{M} - C_{14}, 0)\right] \times \ln(R') + \\ & \left[C_8 + C_9 \times \min(\mathbf{M}, C_{14}) \ + C_{10} \times \max(\mathbf{M} - C_{14}, 0)\right] \times R'\end{aligned} \qquad (7.6.2\text{-}2)$$

$$R' = R_{JB} + \exp\{C_{11} + C_{12} \times \min(\mathbf{M}, C_{14}) + C_{13} \times \max(\mathbf{M} - C_{14}, 0)\}$$

The revisions are noted on an errata sheet which has been added to the report. The electronic version of the errata sheet can be viewed at:

http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002000717.

Sincerely,
EPRI Technical Publishing

Lettis Consultants International, Inc.
1981 N. Broadway, Suite 330
Walnut Creek, CA 94596

Database Manager
Bozkurt, S.B.

This report describes research sponsored by EPRI.

EPRI would also like to acknowledge the Participatory Peer Review Panel (W. Arabasz – Chairman, B. Chiou, R. Quittmeyer, and R. Whorton), who reviewed the technical and process aspects of the project, and GEOVision, Inc., with The University of Texas, who conducted the shear-wave-velocity measurements at seismic recording stations. The ground-motion experts and seismologists, listed in Table 2.1-1, who participated in the due diligence review of the EPRI (2004, 2006) Ground-Motion Model, in interviews conducted by the TI Team (Appendix C), and in the October 17, 2012, workshop (Table 2.2.6-1) are also acknowledged. The value of the Updated EPRI (2004, 2006) GMM has been enhanced through productive cooperation from the Pacific Earthquake Engineering Research (PEER) Center, members of the NGA-East Project, the U.S. Geological Survey (USGS). EPRI thanks Albert Kottke for providing and revising his IRVT software. Some of the analyses and graphics contained in this report were prepared using R (R Development Core Team, 2012). EPRI thanks R. Chambers, G. Moore, and N. Sutherland of AMEC Environment & Infrastructure, Inc., for their assistance with the preparation of the report.

.

This publication is a corporate document that should be cited in the literature in the following manner:
EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project. EPRI, Palo Alto, CA: 2013. 3002000717.

$$V_S(z) = \exp\{\theta \ln[V_S(z)(\text{template high})] + (1-\theta)\ln[V_S(z)(\text{template low})]\} \quad (7.3.1\text{-}2)$$

3. Splice the interpolated profile to the measured profile.

In some instances, the templates were offset vertically in order to obtain profiles that are consistent with the local geology.

Figures 7.3.1.1-2 and 7.3.1.1-3 illustrate this process for station ET.SWET in Tennessee. Figure 7.3.1.1-2 depicts the profile measured by The University of Texas. Figure 7.3.1.1-3 depicts the top 1,000 m of the extended profile that is used for the calculation of amplification factors, as well as the template profiles.

The density ρ(z) is less variable than V_S. For depths at which no density information is available, the approach recommended by Boore (2007) for the estimation of density as a function of V_S is used.

For parameter kappa, this project used the approach recommended in the EPRI SPID (EPRI, 2013b[4]), as follows:

- For rock (V_{S30} > 500 m/s) with at least 1,000 m of firm sedimentary rock (i.e., material between 500 and 2,000 m/s), use the Silva et al. (1998) equation for kappa as a function of V_{S30}, which (after conversion to natural logarithms and m/s) takes the form $\ln[\kappa(\text{s})] = 3.9575 - 1.093\ln[V_{S30}(\text{m/s})]$. This equation is close to the equation obtained by Van Houtte et al. (2011) using a much larger data set.
- For thinner rock, use 0.006 s plus the kappa associated with Q = 40 (calculated over the thickness of deposits with V_S < 2,000 m/s).

Uncertainty in these parameters is specified as follows (also based on the recommendations of EPRI, 2013b):

- Uncertainty in V_S is characterized by a logarithmic standard deviation of 0.35 over the entire profile. This factor accounts both for uncertainty in velocity and uncertainty in the approach for the calculation of amplification factors. V_S is randomized using a two-point distribution and full depth-wise correlation, resulting in two profiles with V_S (z) equal to exp(–0.35) and exp(+0.35) times the base-case V_S (z).[5] The base-case profile is also run in the calculations,

---

[4] Soil stations (V_{S30}< 500 m/s) are not considered in the analytical approach, but it is important to make a clarification regarding their kappa values for Gulf-Coast sites. Although the EPRI SPID (EPRI, 2013) specifies a maximum kappa of 0.04 s for soils, the analysis of Gulf Coast recordings at deep-soil stations presented in Section 7.11.1.1 indicates values of kappa greater than 0.04 s. There is no inconsistency between those results and the SPID value because all the stations considered in other sections of this chapter are outside the Gulf Coast.

[5] The uncertainty in both ln(Vs) and ln(kappa) is characterized by means of discrete distributions, each consisting of two equally weighted masses located at_base-case±1σ. This commonly used two-point approximation preserves the mean and standard deviation of each distribution being represented, and of linear functions thereof. The symmetry of the high and low curves relative to the base-case curves on Figures 7.3.2-1 through 7.3.2-6 indicates that the amplification is roughly linear in ln(Vs) and ln(kappa), thereby confirming the validity of these approximations. The

were used for PGA. Shown on each plot are the motions predicted by the component GMPEs and the resulting weighted median motion. Plots are provided for **M** 5, 6, 7, and 8.

The mean values of ln(PSA) and ln(PGA) for Clusters 1, 2, and 3 were then fit with algebraic forms. The GMPE for Cluster 4 was left unchanged from EPRI (2004), because only a single model, the SEL model, is in the cluster. Two forms were used for the other clusters. The values of ln(PSA) and ln(PGA) for Clusters 1 and 3 were fit with the following form:

$$
\begin{aligned}
\ln(PSA) &= C_1 + C_2\mathbf{M} + C_3\mathbf{M}^2 + (C_4 + C_5\mathbf{M}) \times R_1 + \\
&\quad (C_6 + C_7\mathbf{M}) \times R_2 + (C_8 + C_9\mathbf{M}) \times R_3 + (C_{10} + C_{11}\mathbf{M}) \times R' \\
R' &= \sqrt{R_{JB}^2 + \{\exp(C_{12} + C_{13}\mathbf{M})\}^2} \\
R_1 &= \min[\ln(R'), \ln(C_{14})] \\
R_2 &= \max\{\min[\ln(R'/C_{14}), \ln(C_{15}/C_{14})], 0\} \\
R_2 &= \max\{\ln(R'/C_{15}), 0\}
\end{aligned}
\tag{7.6.2-1}
$$

This form has the flexibility to represent the tri-linear distance attenuation shapes with distance breakpoints at C_{14} and C_{15}.

The values of ln(PSA) and ln(PGA) for Cluster 2 were fit with the following form:

$$
\begin{aligned}
\ln(PSA) &= C_1 + C_2\mathbf{M} + C_3\mathbf{M}^2 + C_4\mathbf{M}^3 + \\
&\quad [C_5 + C_6 \times \min(\mathbf{M}, C_{14}) + C_7 \times \max(\mathbf{M} - C_{14}, 0)] \times \ln(R') + \\
&\quad [C_8 + C_9 \times \min(\mathbf{M}, C_{14}) + C_{10} \times \max(\mathbf{M} - C_{14}, 0)] \times R'
\end{aligned}
\tag{7.6.2-2}
$$

$$
R' = R_{JB} + \exp\{C_{11} + C_{12} \times \min(\mathbf{M}, C_{14}) + C_{13} \times \max(\mathbf{M} - C_{14}, 0)\}
$$

This form was needed to capture a break in magnitude scaling that occurs at magnitude C_{14}.

Figures 7.6.2-4, 7.6.2-5, and 7.6.2-6 show the fits of the above forms to the values of ln(PSA) and ln(PGA) for Clusters 1, 2, and 3, respectively. As can be seen, the functional forms provide a close match to the median ground-motion values. The resulting coefficients are provided in Appendix G.

7.7 Overall Epistemic Uncertainty for Each Cluster and Calculation of High and Low GMMs for the Midcontinent

EPRI (2004) represented the epistemic uncertainty in the median ground motions for the individual clusters by three alternative models that define a discrete distribution for median ground motions. Utilizing the discrete distribution suggested by Keefer and Bodily (1983), models were defined for the median (50th percentile) with weight 0.63, and for the 5th and 95th percentiles, each with weight 0.185. The 5th and 95th percentiles were set at ±1.645 standard deviations from the median (mean log) model, consistent with the normal distribution. The