



Q01: What is the purpose of your Supplemental Testimony?

A01: A4NR agreed with PG&E that it would provide a specific ratemaking recommendation in evidence after reviewing additional data responses from PG&E that were received after the July 14, 2015 submittal of its Prepared Testimony. This Supplemental Testimony provides that recommendation and reflects upon those data responses.

Q02: What is A4NR's ratemaking recommendation?

A02: A4NR recommends that the Commission disallow recovery of the \$4.56 million recorded in the DCSSBA as costs incurred in 2014 for the AB 1632 Seismic Studies. PG&E's refusal to interact with the IPRP as required by D.12-09-008 and D.10-08-003, as well as its failure to submit to IPRP review prior to publishing its final report, prevent the Commission from finding that these costs were reasonably incurred. A4NR also recommends disallowance of the \$0.90 million recorded in the DCSSBA as costs incurred in 2014 for Project Management of the Long-Term Seismic Program. PG&E's failure to provide for timely IPRP review of the AB 1632 Seismic Studies, and obtain the IPRP's assurance that the AB 1632 Seismic Studies were properly incorporated into PG&E's SSHAC report as intended by D.12-09-008, prevents the Commission from finding that these Project Management costs were reasonably incurred.

Q03: What role did PG&E's post-July 14, 2015 data responses play in A4NR's recommendation?

A03: PG&E's data responses strongly reinforce A4NR's conclusion that key analyses that deserved painstaking review were kept from the IPRP. A4NR requested the deterministic

ground motion spectra plots (and associated  $10^{-6}$  and  $10^{-7}$  plots) described in A4NR-00660 for joint ruptures on the following linked faults: (i) Hosgri linked to faults up to Mendocino Triple Junction; (ii) Los Osos linked to Hosgri; (iii) San Luis Bay linked to Hosgri; and (iv) Shoreline linked to Hosgri.<sup>1</sup> Despite the assurances in A4NR-00660, which was written by Geosciences Director Klimczak in the midst of PG&E's IPRP information blackout period, these deterministic joint rupture analyses never made it into the CCCSIP report.

Q04: Since each of the deterministic joint rupture plots purports to show ground motion well below the 1977 Hosgri spectrum, what significance does A4NR attach to them?

A04: The methodologies used to calculate these plots should have been discussed with the IPRP. In explaining how it had derived an M8 assumption for each joint rupture,<sup>2</sup> PG&E went further and described the role "saturation" plays in its results:

*The differences in the spectral accelerations at the DCPD site would be negligible between a M8.0 and a M8.5. This is because of the short-distance large-magnitude scaling known as "magnitude saturation" in ground motion studies. It is accepted within the scientific community, and both empirical observations and numerical simulations validate, that there is not an increase in high-frequency (> 2 Hz) ground shaking levels for close in sites to shallow crustal earthquakes for magnitudes above about magnitude 6.5 (M6.5).*

Q05: Why is that statement significant?

A05: It effectively immunizes Diablo Canyon from high-frequency ground shaking from earthquakes above M6.5 on close-in faults like Hosgri, Shoreline, San Luis Bay, and Los Osos,

---

<sup>1</sup> PG&E's response "ERRA-2014-PGE-Compliance\_DR\_A4NR\_004-Q01", along with the four spectral plots PG&E attached to it, is included in Appendix as Exhibit 1.

<sup>2</sup> PG&E's response "ERRA-2014-PGE-Compliance\_DR\_A4NR\_005-Q01" is included in Appendix as Exhibit 2.

not to mention their joint ruptures, and materially underestimates the hazard from near-source, long-period motions associated with large earthquakes.

Q06: But if this “*saturation*” effect is real, what is the problem?

A06: After consulting with Dr. Blakeslee, A4NR sees several. The magnitude saturation assumption depends upon data extrapolation using far-field earthquakes, because there simply is not much recorded data from large earthquakes in the near-field (although there are some very large accelerations which have been observed in the extreme near-field). The catalog of near-field data that measures the magnitude saturation observationally is small, with a large standard deviation, while using a numerical simulations approach to estimate the effect misses the influence of starting phases, stopping phases, heterogeneous stress drops, and asperities. And the question of shaking duration needs to be factored in. Put another way: shaking for 10 seconds above a prescribed level is very different from shaking for 60 seconds above the same level. In each case the peak acceleration may only be 0.4g but the damage is significantly greater when the duration of shaking is longer. A structure can literally shake itself to pieces over the longer duration of rupture produced by a long (e.g., 300 km) fault vs. a shorter fault (e.g., 60 km).

Q07: Can you elaborate on the hazard associated with near-source, long-period motions?

A07: Dr. Thomas Heaton, Director of the Earthquake Engineering Research Laboratory at the California Institute of Technology (with dual CalTech faculty appointments as a Professor of Geophysics and a Professor of Civil Engineering), expressed written concerns after PG&E’s second SSHAC workshop on ground motion characterization:

If low frequency motions are a concern (sloshing of storage pools?), then whatever systems are affected are almost certainly not linear systems for very large motions. This means that modal analysis is not appropriate. **It is important for the design engineers to directly communicate with scientists about what types of ground motion time histories are plausible.** I would strongly discourage the use of “spectrum compatible motions” to simulate non-linear long-period dynamics.

The spatial distribution of slip is the key parameter that determines the nature of near-source long-period ground motion. For example, two earthquakes of identical magnitude can have very different average slips. Furthermore the maximum slip can be much larger than the average slip. However, when considering low-probability long-period motion, it's critically important to characterize the statistical features of slip on segments of a fault that are close to the site. The current analysis does this problem by characterizing the source with moment magnitude, which is an averaging parameter for an earthquake. Variability is handled by assuming that long-period motions are log-normally distributed about the mean appropriate for the magnitude. However, I am not aware of any evidence that shows that the slip at a point is log-normally distributed about the mean. Instead, I would guess that we are looking at a power law distribution (Pareto). For a variety of reasons, I would argue that these slip distributions are approximately fractal in nature. Unfortunately, power law distributions are very hard to deal with when using standard statistical analysis. **It may be more appropriate to simply say that PSHA is not well suited for this problem. The key issue is to design structures that are robust with respect to long-period ground motions.** (Please see Yamada, M., A. Olsen, and T. Heaton 2009, Statistical features of short- and long-period near-source ground motions, Bull. Seism. Soc. Am., 99: 3264 - 3274)<sup>3</sup>

Q08: Did Professor Heaton's post-Workshop #2 comments express any view about magnitude saturation in near-source, short-period motions?

A08: Yes, as follows:

When it comes to high-frequency near-source shaking, the evidence is good that observations are compatible with the hypothesis that  $pga$ 's saturate with magnitude and that they are approximately log-normally distributed about  $\frac{1}{2} g$  with a standard deviation of a factor of about 2. You argue that this variability can be decomposed into separate site and source variabilities; this seems to be convincing and I fully support this approach. **However, I am concerned about using a log-normal distribution to catch the tails of the distribution. In particular, I am concerned that we have now seen several**

---

<sup>3</sup> Southwestern United States Ground Motion Characterization SSHAC Level 3 Workshop #2 Proceedings, Appendix B, pp. B-1 – B-2.

**examples of near-source peak accelerations whose time histories are asymmetric about their zero line** (see Yamada, M., J. Mori, and T. Heaton, 2008, *The slapdown phase in high acceleration records of large earthquakes*, *Seismological Research Letters*; 80: 559 – 564). It has been hypothesized that this may be an example of ‘slap down,’ a phenomenon that was well studied by the nuclear explosion test community. Slap down is clearly a nonlinear phenomenon and I would expect its statistics to be independent of the log-normal distribution that are [sic] used to characterize most of the data. It’s very difficult to put an upper limit on slap down accelerations. There are many examples of objects that have been launched through the air in violent shaking from past earthquakes. Slap-down seems to be a plausible phenomenon in the near source of earthquakes. <sup>4</sup> (emphases added)

Q09: To what extent do Professor Heaton’s concerns reflect a preference for using peak ground displacement (“PGD”) rather than peak ground acceleration (“PGA”) as a measure of intensity for long-period ground motions associated with large earthquakes?

A09: The 2009 research paper referenced in Professor Heaton’s post-Workshop #2 comments observed,

*Generally speaking, the energy in ground motions from smaller, more frequent earthquakes is mostly from the short-period content, whereas the energy in ground motions from larger, less frequent earthquakes is primarily in the long-period content.*<sup>5</sup>

The paper pointed out a fundamental divergence between the two methodologies:

*As mentioned previously, PGA is known to saturate at magnitudes greater than 6, and the logarithm of PGD is known to increase linearly with respect to magnitude. Thus, there is essentially no correlation between these two intensity measures for near-source ground motions from large events.*<sup>6</sup>

\*\*\*

---

<sup>4</sup> *Id.*

<sup>5</sup> Masumi Yamada, Anna H. Olsen, Thomas H. Heaton, “Statistical Features of Short-Period and Long-Period Near-Source Ground Motions,” *Bulletin of the Seismological Society of America*, Vol. 99, No. 6, December 2009, pp. 3264 – 3274, 3264.

<sup>6</sup> *Id.*, p. 3267.

*Knowing the magnitude does not help predict the PGA because PGA saturates with magnitude, but knowing the magnitude helps to predict PGD because the logarithm of PGD is proportional to the magnitude.*<sup>7</sup>

Q10: Why does A4NR think it essential that PG&E discuss the deterministic joint rupture analyses with the IPRP before deciding to exclude them from the CCCSIP report?

A10: Because relegating consideration of joint ruptures to a probabilistic review greatly obscures catastrophic potential and tends to preclude the evaluation of mitigation options. In PG&E's memorable phrase from the ongoing controversy about DCNPP's licensed seismic design basis, the "*probability is so small that it would mask in PRA space any probability of an issue occurring.*"<sup>8</sup>

Q11: Does that conclude your testimony?

A11: Yes, it does.

---

<sup>7</sup> *Id.*, p. 3271.

<sup>8</sup> GRC2014-Ph-I\_DR\_A4NR\_001-Q02Supp01Atch20 unnumbered p. 2 is included in Appendix as Exhibit 3. PRA is an acronym for probabilistic risk analysis.

# Appendix

- Exhibit 1**      **ERRA-2014-PGE Compliance\_DR\_A4NR\_004-Q01**
- Exhibit 2**      **ERRA-2014-PGE-Compliance\_DR\_A4NR\_005-Q01**
- Exhibit 3**      **GRC2014-Ph-I\_DR\_A4NR\_001-Q02Supp01Atch20**



# **Exhibit 1**

**ERRA-2014-PGE Compliance\_DR\_A4NR\_004-Q01**

**PACIFIC GAS AND ELECTRIC COMPANY**  
**2014 Energy Resource Recovery Account Compliance Review**  
**Application 15-02-023**  
**Data Response**

PG&E Data Request No.:	A4NR_004-01		
PG&E File Name:	ERRA-2014-PGE-Compliance_DR_A4NR_004-Q01		
Request Date:	July 7, 2015	Requester DR No.:	004
Date Sent:	July 31, 2015	Requesting Party:	Alliance for Nuclear Responsibility
PG&E Witness:	Kent Ferre	Requester:	John Geesman

**QUESTION 1**

32. Regarding the three-page document A4NR-00660 previously provided to A4NR by PG&E:
- (a) Please identify the author of this document.
  - (b) Did PG&E develop the “deterministic ground motion spectra plots” mentioned in paragraph 4.c. on page 2 of the document for any of the following linked faults?
    - (i) Hosgri linked to faults up to Mendocino Triple Junction.
    - (ii) Los Osos linked to Hosgri.
    - (iii) San Luis Bay linked to Hosgri.
    - (iv) Shoreline linked to Hosgri.
  - (c) If the response to Question (b) above is negative for any of the linked faults identified, please explain why such work was not performed.
  - (d) If the response to Question (b) above is affirmative, please provide copies of such “plots” as well as all documents and electronically stored information which analyze or discuss such “plots.”
  - (e) Did PG&E perform the “hybrid approach” described in paragraph 4.c.v.2. on page 2 of the document (i.e., deterministic plots based on magnitudes at 10-6 annual recurrence rate) for the linked faults identified above in Question (b)?
  - (f) If the response to Question (e) above is negative for any of the linked faults identified, please explain why such work was not performed.
  - (g) If the response to Question (e) above is affirmative, please provide copies of such “plots” as well as all documents and electronically stored information which analyze or discuss such “plots.”
  - (h) Did PG&E perform the “hybrid approach” described in paragraph 4.c.v.2.b on page 3 of the document (i.e., deterministic plots based on magnitudes at 10-7 annual recurrence rate) for the linked faults identified above in Question (b)?

- (i) If the response to Question (h) above is negative for any of the linked faults identified, please explain why such work was not performed.
- (j) If the response to Question (h) above is affirmative, please provide copies of such “plots” as well as all documents and electronically stored information which analyze or discuss such “plots.”
- (k) Please provide copies of the “plots” described in paragraph 4.e.i. on page 3 of the document (i.e., M8 earthquakes on the Hosgri, SLB, Los Osos, and Shoreline Faults) as well as all documents and electronically stored information which analyze or discuss such “plots.”
- (l) Please provide copies of the evaluations identified in paragraph 4.e.ii. on page 3 of the document.
- (m) Regarding the evaluations identified in paragraph 4.e.ii. on page 3 of the document, please explain why “(i)t was decided to only evaluate the ‘critical’ SSCs in any frequencies of exceedance range to show they can perform their safety functions.”

## **ANSWER 1**

PG&E responds as follow:

- a) Richard Klimczak, retired Director of Geosciences.
- b) Yes. PG&E developed 84<sup>th</sup> percentile, deterministic plots for all the linked fault scenarios. The magnitudes are all M8 and spectra are provided for both the turbine building (TB) site and the power block (PB) site.
- c) Not applicable.
- d) PG&E objects to this data request as overbroad and burdensome.  
Notwithstanding this objection, PG&E responds as follows:  
Attachments 1 and 2 to this response provide the deterministic ground motion spectra plots referred to in PG&E’s response to subpart b) of this data request. They are for the PB site and the TB site, respectively.
- e) Yes. PG&E developed 84<sup>th</sup> percentile deterministic spectra using the hybrid approach for the TB site. The plots are based on magnitudes at 10-6 annual recurrence rate. The magnitude recurrence curves used for the analysis were based on the Wells and Coppersmith magnitude-distribution scaling, and the Wooddell et al upper bound model.
- f) Not applicable.
- g) PG&E objects to this data request as overbroad and burdensome.  
Notwithstanding this objection, PG&E responds as follows:  
Attachment 3 to this response provides the deterministic ground motion spectra plots referred to in PG&E’s response to subpart e) of this data request.

h) Yes. PG&E developed 84<sup>th</sup> percentile deterministic spectra using the hybrid approach. The plots are based on magnitudes at 10-7 annual recurrence rate. The spectra are provided for the TB site. The magnitude recurrence curves used for the analysis were based on the Wells and Coppersmith magnitude-distribution scaling, and the Wooddell et al upper bound model.

i) Not applicable.

j) PG&E objects to this data request as overbroad and burdensome. Notwithstanding this objection, PG&E responds as follows:

Attachment 4 to this response provides the deterministic ground motion spectra plots referred to in PG&E's response to subpart h) of this data request.

k) PG&E objects to this data request as overbroad and burdensome. Notwithstanding this objection, PG&E responds as follows:

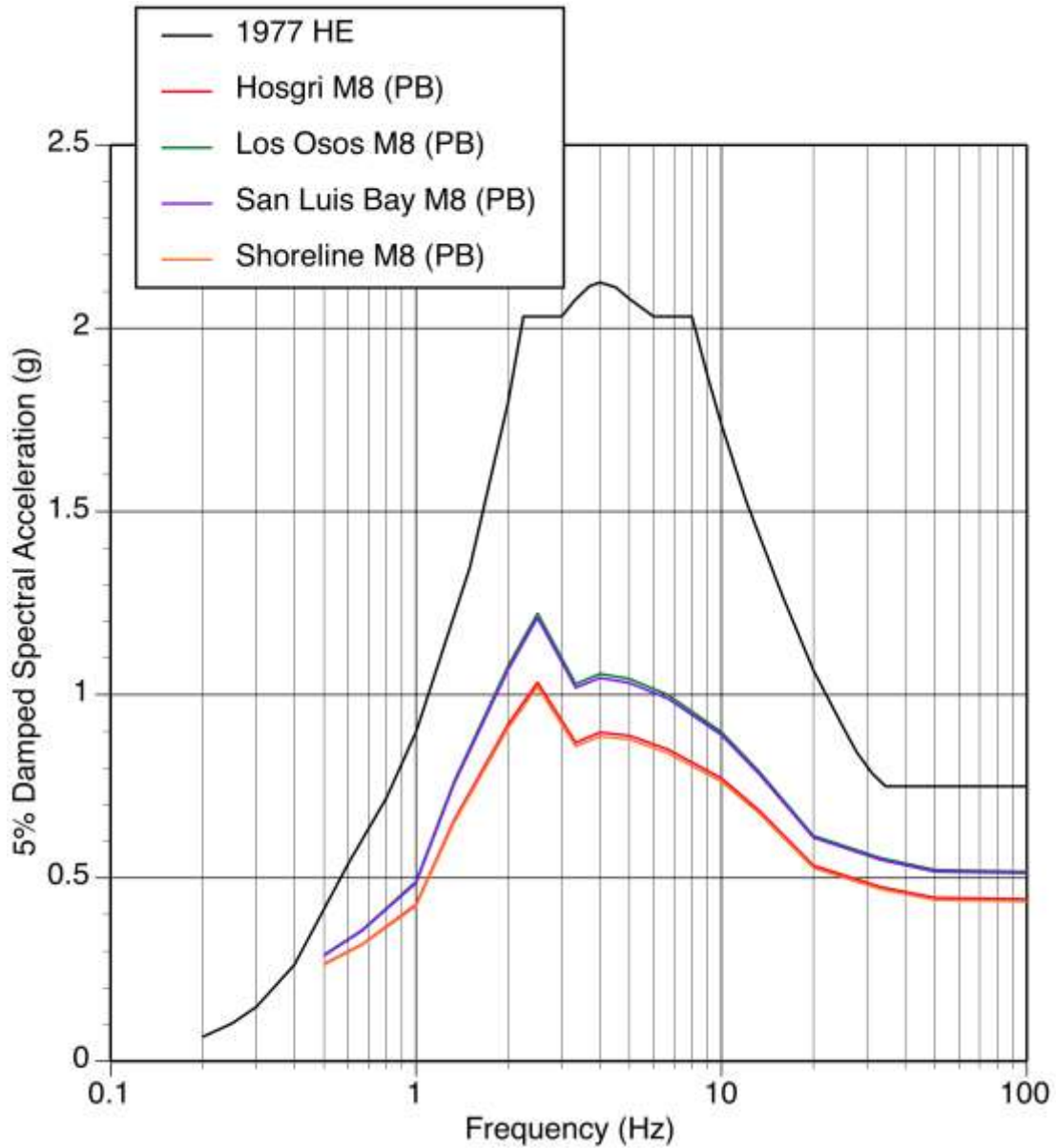
Attachments 1 and 2 to this response provide the deterministic ground motion spectra plots that are responsive to this subpart of this data request.

l) PG&E objects to this data request insofar as it seeks information that is beyond the scope of this proceeding. "SSC" studies are not part of the studies whose costs are recovered in the Diablo Canyon Seismic Studies balancing account (DCSSBA). Notwithstanding this objection, PG&E responds as follows:

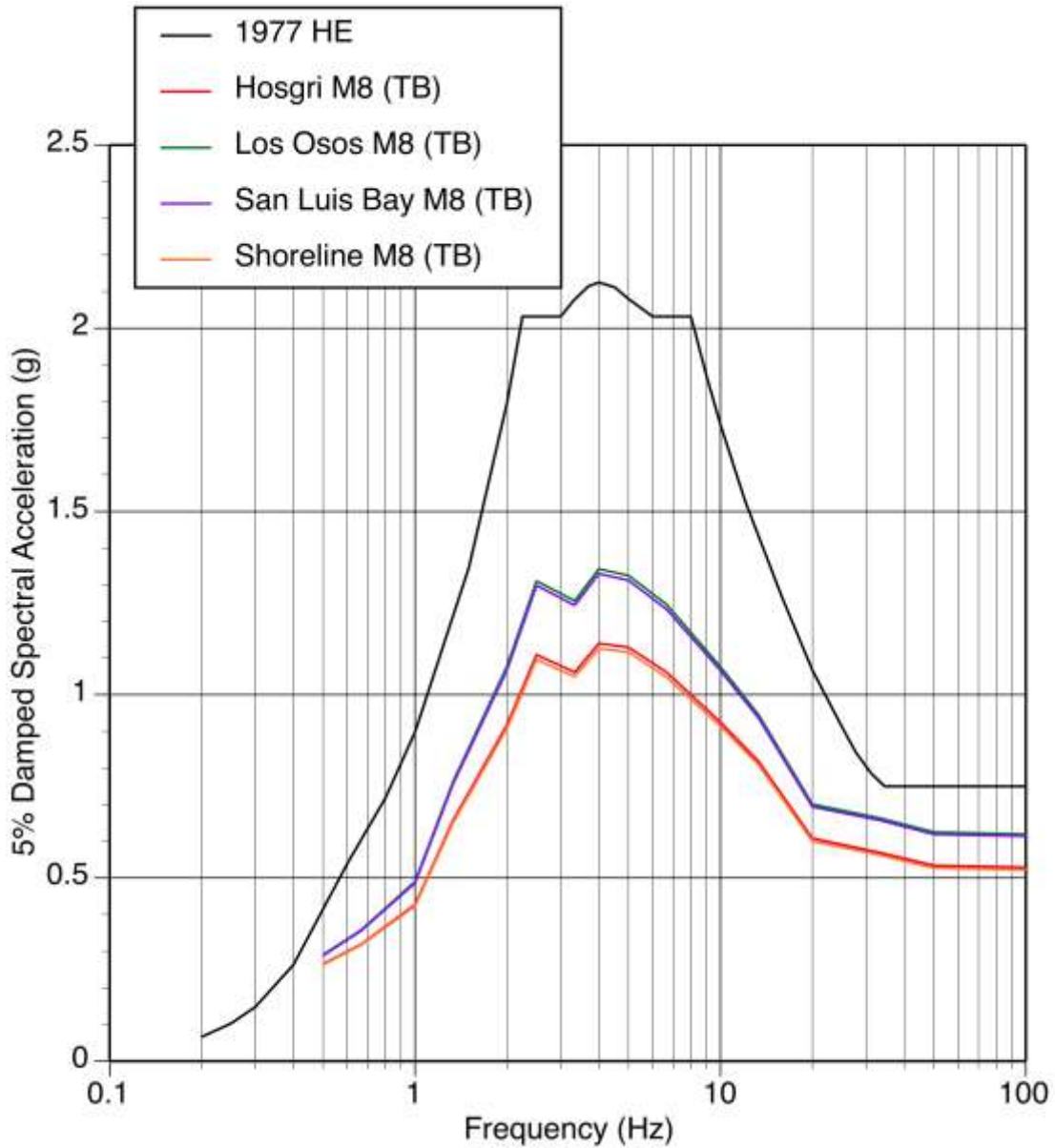
Evaluations done compared the deterministic plots to the 1977 Hosgri Earthquake response spectrum. These comparisons are included in each of the attachments to this data response. Since the safety critical structures, systems, and components (SSCs) are designed to withstand (with margin) ground shaking level defined by the 1977 Hosgri Earthquake response spectrum, and since the plots provided in response to this data request all fall below the 1977 Hosgri Earthquake response spectrum curve, the SSCs can withstand shaking from the M8 earthquakes whose spectra are provided in response to this data request.

m) PG&E objects to this data request insofar as it seeks information that is beyond the scope of this proceeding. "SSC" studies are not part of the studies whose costs are recovered in the DCSSBA. Notwithstanding this objection, PG&E responds as follows:

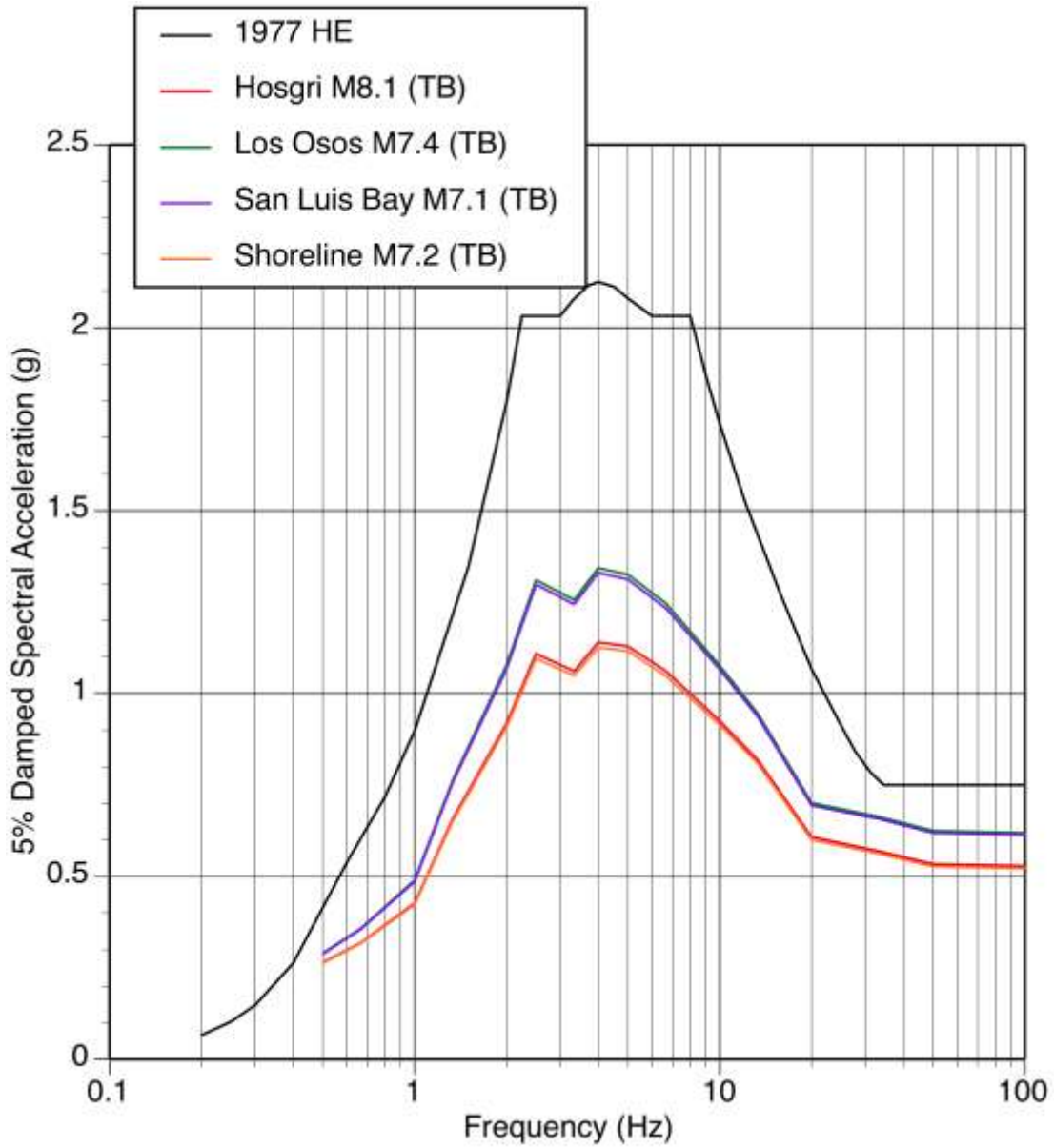
Non-safety critical SSCs were not evaluated because they are not required to function to safely shut down the plant.



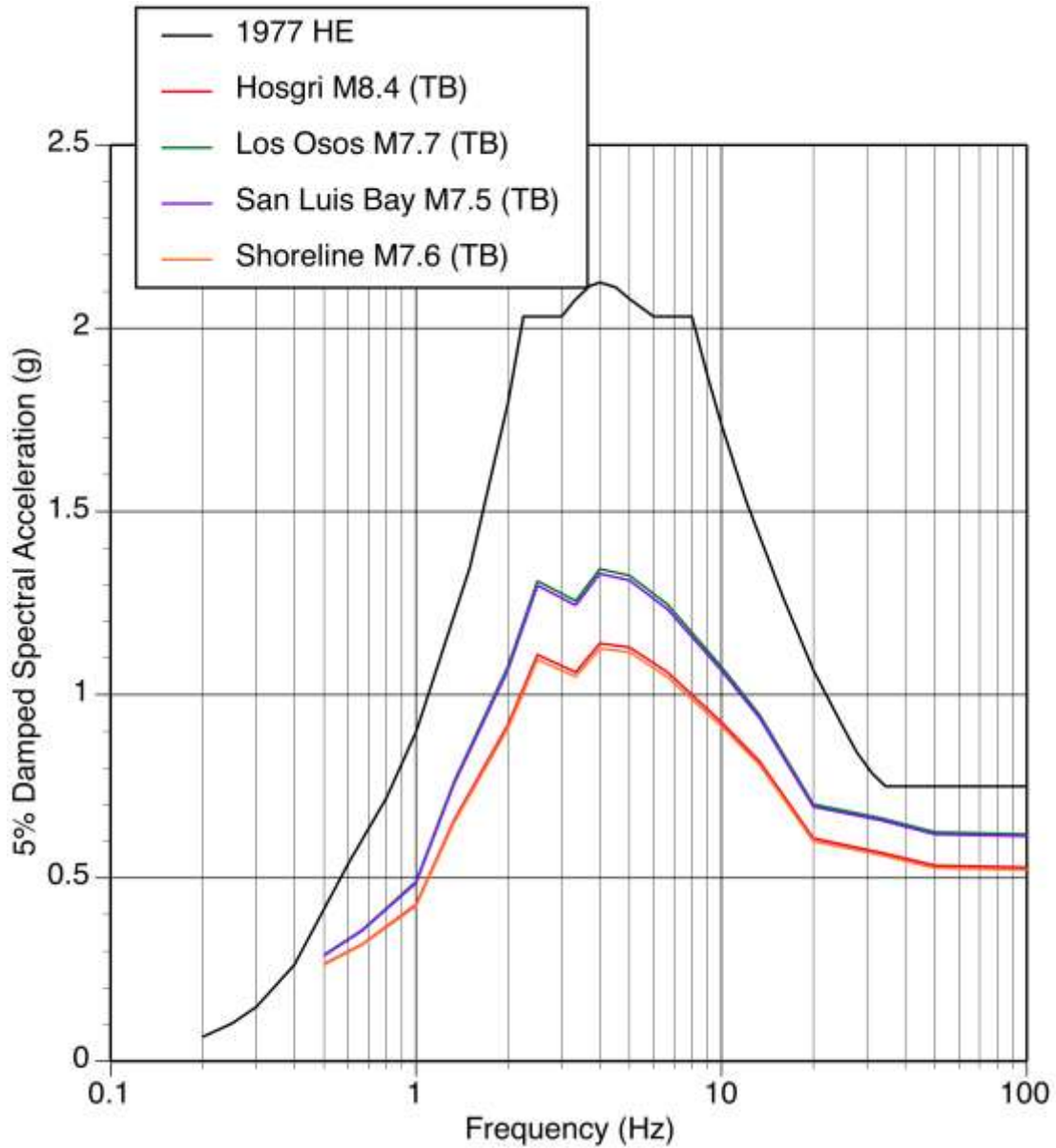
Deterministic 84<sup>th</sup> percentile spectra for the power block foundation level assuming a magnitude 8 earthquake on each source.



Deterministic 84<sup>th</sup> percentile spectra for the turbine building foundation level assuming a magnitude 8 earthquake on each source.



Deterministic 84<sup>th</sup> percentile spectra for the turbine building foundation level using the magnitude for a 1E-6/yr rate of occurrence.



Deterministic 84<sup>th</sup> percentile spectra for the turbine building foundation level using the magnitude for a 1E-7/yr rate of occurrence.



## **Exhibit 2**

**ERRA-2014-PGE-Compliance\_DR\_A4NR\_005-Q01**

**PACIFIC GAS AND ELECTRIC COMPANY  
2014 Energy Resource Recovery Account Compliance Review  
Application 15-02-023  
Data Response**

PG&E Data Request No.:	A4NR_005-01		
PG&E File Name:	ERRA-2014-PGE-Compliance_DR_A4NR_005-Q01		
Request Date:	August 4, 2015	Requester DR No.:	005
Date Sent:	August 12, 2015	Requesting Party:	Alliance for Nuclear Responsibility
PG&E Witness:	Kent Ferre	Requester:	John Geesman

**QUESTION 1**

33. Please describe the methodology, or explain the rationale, used by PG&E to assign a magnitude 8 earthquake to calculate the “deterministic ground motion spectra plots” mentioned in paragraph 4.c. on page 2 of A4NR-00660 for joint ruptures on each of the following linked faults:
- (i) Hosgri linked to faults up to Mendocino Triple Junction.
  - (ii) Los Osos linked to Hosgri.
  - (iii) San Luis Bay linked to Hosgri.
  - (iv) Shoreline Linked To Hosgri.

**ANSWER 1**

The magnitudes are based on established magnitude scaling methods (e.g., Hanks and Bakun). For each of the four cases listed above, the linkage assumed the rupture extended to the Mendocino Triple Junction for a magnitude M8. Note that in the Senior Seismic Hazard Analysis Committee (SSHAC) Seismic Source Characterization (SSC) model, the magnitude was conservatively increased to M8.5. Deterministic plots were not rerun for magnitude M8.5.

The differences in the spectral accelerations at the DCPD site would be negligible between a M8.0 and a M8.5. This is because of the short-distance large-magnitude scaling known as “magnitude saturation” in ground motion studies. It is accepted within the scientific community, and both empirical observations and numerical simulations validate, that there is not an increase in high-frequency (> 2 Hz) ground shaking levels for close in sites to shallow crustal earthquakes for magnitudes above about magnitude 6.5 (M6.5).

## **Exhibit 3**

**GRC2014-Ph-I\_DR\_A4NR\_001-Q02Supp01Atch20**

This still leaves us with reconciling the Shoreline to the DDE/HOSGRI in accordance with the methodology used for establishing the spectra the DDE/HOSGRI. The April 8, 2009 letter appears to be saying that they our basing their statement that we meet the design and licensing basis on our statements to that end. If we have misrepresented our design and licensing basis requirements or have compared to non-D&LB (like LTSP) then this introduces new station vulnerability to additional violations regarding the completeness and accuracy of our communications

[REDACTED]  
Regulatory Services Manager  
Diablo Canyon Power Plant

---

**From:** Bemis, Paul R  
**Sent:** Friday, October 01, 2010 9:54 AM  
**To:** Klimczak, Richard  
**Cc:** [REDACTED]; Cluff, Lloyd; Grozan, [REDACTED]; Nimick, Jan; Sharp, Loren; [REDACTED]; Westcott, Susan; [REDACTED]; Fledderman, Jude  
**Subject:** RE: Benioff and Smith Paper (1967)

Rich,  
I will look over the material. I agree that we should not have to revisit DE and DDE with each new study or informational finding. The only reason this was an issue this time was because Hosgri probability is so small that it would mask in PRA space any probability of an issue occurring. [REDACTED] wants to confirm that we meet our licensing basis which is not, to my knowledge, PRA rather it is deterministic. We should consider in the future if PGE/DCPP desires committing to the Guide 199, but this would require a LAR to change the licensing basis. If most plants use this now we should have no problem obtaining this change.

I do feel if this information bears up to critical review it should also convince NRC a violation on the operability previously performed is not an issue.

Paul

*Paul Bemis*  
**Office: 805-545-6495**  
**Cell: 805-305-5013**  
***pnb9@pge.com***

---

**From:** Klimczak, Richard  
**Sent:** Friday, October 01, 2010 7:06 AM  
**To:** Bemis, Paul R  
**Cc:** [REDACTED]; Cluff, Lloyd; Grozan, Thomas C; [REDACTED]; Nimick, Jan; Sharp, Loren; [REDACTED]; Westcott, Susan; [REDACTED]  
**Subject:** RE: Benioff and Smith Paper (1967)

Paul,