Ronald B. Clary
General Manager
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SCE&G®
A SCANA COMPANY

March 12, 2009
NND-09-0047

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

ATTN: Document Control Desk

Subject: Virgil C. Summer Nuclear Station (VCSNS) Units 2 and 3 Combined License Application (COLA) - Docket Numbers 52-027 and 52-028 Response to NRC Request for Additional Information (RAI) Letter No. 030

Reference: Letter from Ravindra G. Joshi (NRC) to Alfred M. Paglia (SCE&G), Request for Additional Information Letter No. 030 Related to SRP Section 2.5.2 for the Virgil C. Summer Nuclear Station Units 2 and 3 Combined License Application, dated February 10, 2009.

The enclosure to this letter provides the South Carolina Electric & Gas Company (SCE&G) response to the RAI items included in the above referenced letter. The enclosure also identifies any associated changes that will be incorporated in a future revision of the VCSNS Units 2 and 3 COLA.

The responses to NRC RAI Numbers 02.05.02-6, 02.05.02-15, 02.05.02-18 and 02.05.02-19 are still under development and review by SCE&G. The final responses to those RAIs are expected be provided to the NRC by March 31, 2009.

Should you have any questions, please contact Mr. Al Paglia by telephone at (803) 345-4191, or by email at apaglia@scana.com.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 12th day of March, 2009.

Sincerely,

Ronald B Clary

Ronald B. Clary
General Manager
New Nuclear Deployment

JMG/RBC/jg

D083
NRO

Enclosure

c (without attachment):

- Luis A. Reyes
- Ravindra G. Joshi
- John Zieler
- Stephen A. Byrne
- Ronald B. Clary
- Bill McCall
- Kenneth J. Browne
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NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-4

FSAR Section 2.5.2.1.2 describes the applicant's update of the EPRI seismicity catalog for the period 1985 to the present. FSAR Table 2.5.2-202 lists the parameters (including latitude, longitude, time, and magnitude) of the updated portion of the seismicity catalog. Please clarify whether or not the values for Smb (in Equation 2.5.2-3) were derived from the EPRI seismicity catalog or the updated seismicity catalog. Please also provide electronic versions of both the EPRI seismicity catalog and the updated seismicity catalog (relevant portions).

VCSNS RESPONSE:

Based on an examination of the EPRI-SOG catalog, σ_{mb} (Smb) values can be associated with each of the various size measures from which Emb values were determined. For example, for an earthquake with a published mb determined from instrumental data, a σ_{mb} (Smb) of 0.1 was specified. These same size-measure-specific values for σ_{mb} (Smb) were similarly adopted for each earthquake in the updated catalog.

Electronic copies of the EPRI-SOG seismicity catalog [**EPRI_EQ_Catalog_PH-IIc(VCS_only).xls**] and the updated seismicity [**Table3.xls**], as given in FSAR Table 2.5.2-202 [earthquakes from 1985 to August 2006 with Rmb $\geq$ 3.0 or $I_0 \geq$ IV(4)] within the study region of 30°N to 38°N, 77°W to 89°W are appended.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-5

The Advanced National Seismic System (ANSS) catalog covers the site region and includes the regional South East U.S. Seismic Network (SEUSSN) catalog. Please explain why the ANSS catalog was not used as the preferred catalog instead of the SEUSSN catalog, which is the preferred catalog in the FSAR.

VCSNS RESPONSE:

Both the Southeastern US Seismic Network [SEUSSN] and Advanced National Seismic System [ANSS] catalogs were used for the temporal update [1985 to present] of the EPRI (1988) seismicity catalog. The SEUSSN, which has coverage over the entire project region [30°N to 38°N, 77°W to 89°W] is, according to the ANSS web page at http://www.ncedc.org/anss/cnss-detail.html, the "authoratative" source used to compile the national ANSS seismicity catalog in this region and was preferred. The ANSS catalog was used as an alternate source in the FSAR catalog compilation. Earthquakes from other near seismic networks, as incorporated in the ANSS catalog but that were not included in the SEUSSN catalog, were also incorporated into the regional seismicity update.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-7

FSAR Section 2.5.2.1.3 discusses the reservoir-induced seismicity associated with Monticello Reservoir. An initial surge of reservoir-induced seismicity was associated with the initial filling of the reservoir in 1977 but subsequent intervals of increased seismicity have also occurred in succeeding years. Please explain whether the reservoir seismicity correlates with changes in water impound levels. Did the recent upsurge in seismicity starting in 1996 correlate with any change in the water level?

VCSNS RESPONSE:

Beyond the initial occurrence of Reservoir Induced Seismicity (RIS) which was associated with the initial filling of Monticello Reservoir in 1977-78, there has been no correlation between RIS activity and changes in water level within the impoundment, including the increase in activity in 1996.

Dr. Pradeep Talwani at the University of South Carolina is a prominent researcher of RIS in the southeastern United States and has evaluated the RIS activity at Monticello Reservoir since 1977, including pre-impoundment activity for the period 1974-77. SCE&G has interactively worked with Dr. Talwani since the mid-1970s and provided data on daily water fluctuations of Monticello Reservoir and Parr Reservoir, rainfall data, etc. After approximately 30 years of study, SCE&G is not aware that Dr. Talwani has ever been able to conclusively correlate water level changes in Monticello Reservoir, rainfall data, or flood conditions in Parr Reservoir to any specific increases in RIS activity.

Additionally, the fluctuation of water level in Monticello Reservoir is limited to a maximum change of 4.5' per day based on FERC operating license controls that establish the upper water level at 425' MSL and the lower water level of 420.5' MSL. Therefore, based on over 30 years of observations, it has been concluded that this relatively small change in water level in Monticello Reservoir has an insignificant affect on RIS activity.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-8

Section 2.5.2.1.3 (page 2.5.2-5) of the FSAR explains that Unit 1 was required to have a margin of safety by design for a magnitude 5.0 event from the reservoir-induced seismicity. Please confirm if this is also the case for Units 2 and 3.

Also, the reservoir-induced seismicity events do not appear to be included in the updated seismicity catalog. The staff is concerned that ground motion from events of this size could be removed from the design process by the cumulative absolute velocity filter, but could still involve large accelerations.
Please address the staff's concerns

VCSNS RESPONSE:

1. The magnitude 5.0 event (as described in FSAR Section 2.5.2.1.3) was suggested by expert opinion during the ACRS hearings for Unit 1 to be an upper bound estimate of the largest earthquake that could potentially occur as a result of RIS activity due to the impoundment of Monticello Reservoir. In NUREG-0717, Section 2.5.3, "Maximum Earthquake Associated with Reservoir Impoundment at Monticello Reservoir", (February 1981), the NRC staff chose a magnitude 4.5 earthquake as the largest reservoir induced event likely to occur. This postulated event was subsequently characterized by the Applicant as a magnitude 4.5 earthquake of normal tectonic depth anchored to a zero period acceleration (ZPA) of 0.22g. In NUREG-0717, Supplement 4 (August 1982), the NRC staff found the Applicant's characterization of this earthquake to be conservative. Although this earthquake exceeded the Unit 1 SSE design response spectrum at frequencies generally above 10 Hz, it was subsequently shown to have an insignificant impact on plant components required for safe shutdown. These results were documented and submitted to NRC in the following reports, which satisfied the Unit 1 Operating License Condition 2.C(25):

   - Seismic Confirmatory Program, Virgil C. Summer Nuclear Station Unit 1, OL No. NPF-12, February 1983
   - Seismic Confirmatory Program Equipment Margin Study, Virgil C. Summer Nuclear Station Unit 1, OL No. NPF-12, November 1983

   This postulated RIS earthquake was evaluated solely for Unit 1 and is not a design requirement for Units 2 and 3. Additionally, the Westinghouse AP1000

Certified Seismic Design Response Spectra (CSDRS), anchored to a ZPA of 0.30g, easily bounds this postulated RIS event.

2. The Monticello Reservoir RIS events which have occurred since late 1977 have all been small, with the largest earthquakes of magnitude 2.8 occurring in 1978 and 1979. Since the updated seismicity catalog only considered earthquakes of magnitude 3.0 and larger, none of the RIS events would be included. The magnitude 5.0 event discussed in FSAR Section 2.5.2.1.3 was only a postulated event for engineering design considerations as part of the ACRS evaluations for Unit 1.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-9

In FSAR Section 2.5.2.1 (page 2.5.2-8), the applicant states that smaller earthquakes were modeled using an exponential magnitude distribution. Please clarify whether or not this magnitude distribution is the Gutenberg-Richter magnitude frequency relation and please make the corresponding correction in the statement. If a relation other than the Gutenberg-Richter relation was used, please provide the details for the relation and justify the relation based on observations.

VCSNS RESPONSE:

The magnitude distribution of smaller (between 5 and 6.7) earthquakes for the Charleston seismic source referred to in FSAR Section 2.5.2.2.1 is the Gutenberg-Richter relation. As formally used in the PSHA analysis, a truncated exponential form of the Gutenberg-Richter magnitude distribution, $\log_{10}N(m) = a - bm$, is used in which

$$N(m) = \nu_{m_{min}} [1 - k + ke^{-\beta(m - m_{min})}] \qquad m_{min} \le m \le m_{max}$$

where

$$\beta = b \ln 10,\ \nu_{m_{min}} = 10^{a}\ 10^{-bm_{min}},\ \text{and } k = [1 - e^{-\beta(m_{max} - m_{min})}]^{-1}$$

A good reference further discussing the characterization of magnitude distribution for seismic hazard analysis is McGuire (2004).

Reference:

McGuire, Robin K. (2004), “Seismic Hazard and Risk Analysis,” Monograph MNO-10, Earthquake Engineering Research Institute.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

The last paragraph of FSAR Subsection 2.5.2.2.1 will be revised as follows in a future revision to the COLA:

Except for the Charleston seismic source, no new geological, geophysical, or seismological information in the literature published since the EPRI NP-6395-D source model suggests that these sources should be modified. Each EST's characterization of the Charleston seismic source was replaced by four alternative source geometries. For each source zone geometry, large earthquake occurrences (**M** 6.7 to 7.5) were modeled with a range of mean recurrence rates, and smaller earthquakes (mb 5 to 6.7) were modeled with ~~an~~ a Gutenberg-Richter exponential magnitude distribution, with rates and b-values determined from historical seismicity. Also, all surrounding sources for each team were redrawn so that the new Charleston source geometries were accurately represented as a "hole" in the surrounding source, and seismic activity rates and b-values were recalculated for the modified surrounding sources, based on historical seismicity. Further details and the results of sensitivity analyses performed on the modified seismic sources are presented in Subsection 2.5.2.4.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-10

FSAR Section 2.5.2.2.1.5 describes the source zones developed by the Weston Geophysical team for the EPRI PSHA. On page 2.5.2-16, the FSAR states, "The largest Mmax assigned by the Weston Geophysical team to these combination zones is mb 6.6 (**M** 6.5)." However, in FSAR Table 2.5.2-207 (page 2.5.2-69), the Mmax for combination zone C33 is listed as mb 7.2 at 10 percent weight. Please address the discrepancy between the text and the table.

VCSNS RESPONSE:

The discrepancy between FSAR Table 2.5.2-207 and FSAR Section 2.5.2.2.1.5 is the result of a typographical error. This error has no effect on downstream analyses performed for the Virgil C. Summer Nuclear Station Units 2 and 3 COLA. FSAR Table 2.5.2-207 correctly states the M_{max} distributions for Weston Geophysical's combination zones. FSAR Section 2.5.2.2.1.5 incorrectly states the largest M_{max} value assigned by Weston Geophysical to their combination zones. As such, FSAR Section 2.5.2.2.1.5 will be revised to correctly state the M_{max} upper-bound for Weston Geophysical combination zones is m_b 7.2 (**M** 7.5).

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

FSAR Section 2.5.2.2.1.5, last paragraph, page 2.5.2-16 should be revised as follows:

- Nine Combination Zones: (103–23–24 [C19]; 104–22 [C20]; 104–25 [C21]; 104–22–26 [C23]; 104–22–25 [C24]; 104–28BCDE–22 [C26]; 104–28BCDE–22–25 [C27]; 26–25 [C33]; and 104–28BE–25 [C35]). Weston Geophysical specified a number of combination seismic source zones, nine of which are primary sources for the Units 2 and 3 site. The largest M_{max} assigned by the Weston Geophysical team to these combination zones is m_b 6.6 (**M** 6.5)~~.~~, with the exception of C33, which has an upper-bound magnitude of m_b 7.2 (**M** 7.5).

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-11

In FSAR Section 2.5.2.4.1 (page 2.5.2-35), the applicant stated that it used the 1989 EPRI study as the starting point for probabilistic seismic hazard calculations. The FSAR states that "differences in hazard are also small for the median hazard, except at large ground motions (peak ground acceleration greater than or equal to 0.7 g), where differences of 20% and +30% are seen." Please provide an explanation for the relatively large difference in seismic hazard of +20% to +30% between the 1989 EPRI analysis and the recent one done using Risk Engineering, Inc.'s FRISK88 software for the median hazard at large ground motions.

VCSNS RESPONSE:

The good agreement between the current hazard calculations and the 1989 EPRI study for mean and 85% hazard, for peak ground acceleration amplitudes between 0.05g and 1g, indicates that the seismic sources from the 1989 EPRI study have been accurately modeled. The good agreement between median hazard for peak ground accelerations amplitudes between 0.05g and 0.5g also supports this conclusion. The larger difference between median hazards for peak ground acceleration amplitudes of 0.7g and 1g indicates that the current estimates of median hazard exceed those from the 1989 EPRI study by 20% to 30%. This means that the current calculations are slightly more conservative than the 1989 EPRI study for these amplitudes and for median hazards. One possible explanation for the difference is that the 1989 EPRI study used an integration step size corresponding to approximately 5 km, whereas the current hazard calculations use an integration step size corresponding to approximately 2.5 km, which is more accurate. SCE&G believes that the assumptions made in the current calculations correctly reflect the interpretations of the EPRI teams regarding their seismic sources, and use calculational parameters (e.g. integration step size) that provide accurate hazard results. Thus, the current calculations accurately reflect the hazard, given the inputs, from the 1989 EPRI study.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-12

FSAR Section 2.5.2.4.5 (page 2.5.2-40) states that the applicant used the results of Abrahamson and Bommer (2006) to characterize aleatory uncertainties. Please discuss the effect of using the Abrahamson and Bommer (2006) uncertainties on the calculated hazard, as well as the differences between Abrahamson and Bommer (2006) and the EPRI (2004) study. Please also explain how the seismic hazard curves and the UHRS would change if the EPRI (2004) aleatory uncertainties had been used rather than those in Abrahamson and Bommer (2006).

VCSNS RESPONSE:

The Abrahamson and Bommer (2006) ground motion aleatory uncertainties were used in the VCSNS FSAR because the original EPRI (2004) aleatory uncertainties were thought to be too large. Abrahamson and Bommer (2006, page 7-2) state: "The EPRI (2004) ground motion models were based on the JB distance metric and a significant increase in the standard deviation for JB distances less than 20 km was included in all of the sigma models developed in that study. The empirical ground motion data evaluated in this study do not support a large increase in the standard deviation at short distances, but some increase may be justified. Three alternative models of the additional contribution to the standard deviation at short distances are developed.....Note that most of the weight is given to the model with zero increase."

In addition to the short distance effect, two other effects were studied by Abrahamson and Bommer (2006). First, they found that the inter-event variability used by EPRI (2004) was conservative and adopted a different inter-event variability model. Second, Abrahamson and Bommer (2006) adopted an intra-event variability based on empirical data from the western US, rather than using modeling methods as in EPRI (2004). Both effects resulted in lower aleatory uncertainties.

Lower aleatory uncertainties in the ground motion equations will result in lower seismic hazard curves. For example, Figure RAI-12A (a reproduction of Figure 2-10 from Abrahamson and Bommer, 2006) shows peak ground acceleration seismic hazard curves for a site in southern California with a range of aleatory uncertainties in the ground motion equation. If the EPRI (2004) aleatory uncertainties had been used in the VCSNS seismic hazard analysis, the seismic hazard curves and UHRS for the Summer site would have been higher.

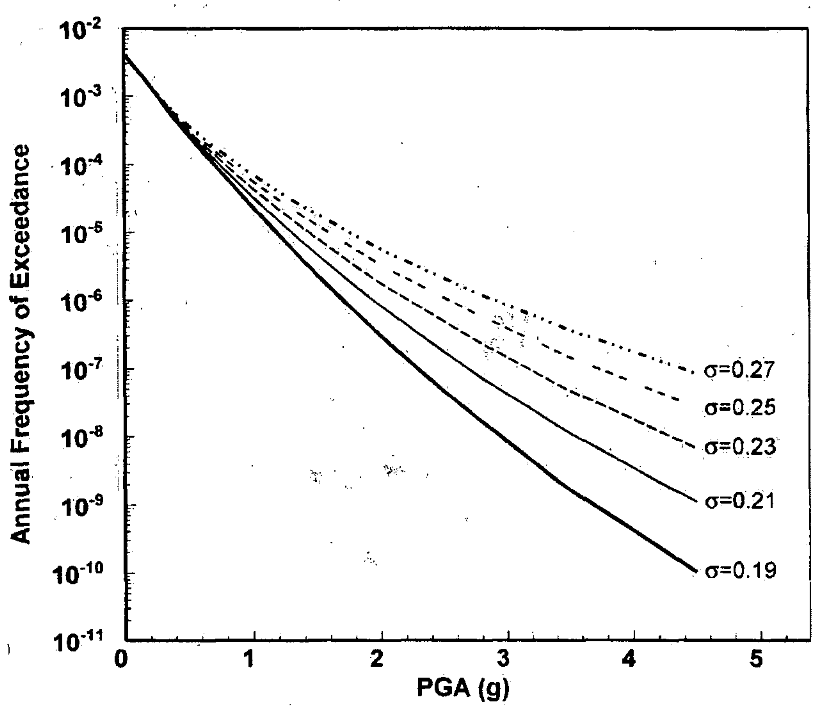

Figure RAI-12A. Peak ground acceleration hazard curves for a site in southern California illustrating sensitivity to aleatory standard deviation (log 10 units). Reproduction of Figure 2-10 of Abrahamson and Bommer (2006).

Reference:

Abrahamson, N., and J. Bommer (2006). *Program on Technology Innovation: Truncation of the Lognormal Distribution and Value of the Standard Deviation for Ground Motion Models in the Central and Eastern United States,* Elec. Power Res. Inst., Palo Alto, CA, Rept. 1014381, August.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-13

In FSAR Section 2.5.2.4.5 (page 2.5.2-40), the applicant stated that it used the EPRI (2004) ground motion equations in its updated PSHA. However, the EPRI ground motion report contains many equations that are arranged in "clusters." Please provide more detail regarding how the applicant used the various equations from the EPRI ground motion report to compute the site hazard, including the weights that the applicant applied for the specific equations, if multiple equations were used in the analysis.

VCSNS RESPONSE:

The EPRI (2004) ground motion equations consist of four clusters, each of which has a high, medium, and low estimate. Figure RAI-13A shows that for general area sources, only the first 3 clusters are used in the analysis. Figure RAI-13A indicates the weights on the nine equations used for general area sources. For non-general sources, Figure RAI-13B shows that all four clusters are used in the analysis, and Figure RAI-13B indicates the weights on the 12 equations used for non-general sources. When both general area sources and non-general sources are used in a hazard analysis, the nine equations shown in Figure RAI-13A and the 12 equations shown in Figure RAI-13B are used in a specific set of combinations, and these combinations (and their weights) are shown in Figure RAI-13C. Thus both the number of equations and their weights depend on the specific types of sources that are used for a seismic hazard analysis. The seismic hazard analysis for the Summer site used the weights given in EPRI (2004) for all clusters and all equations within a cluster.

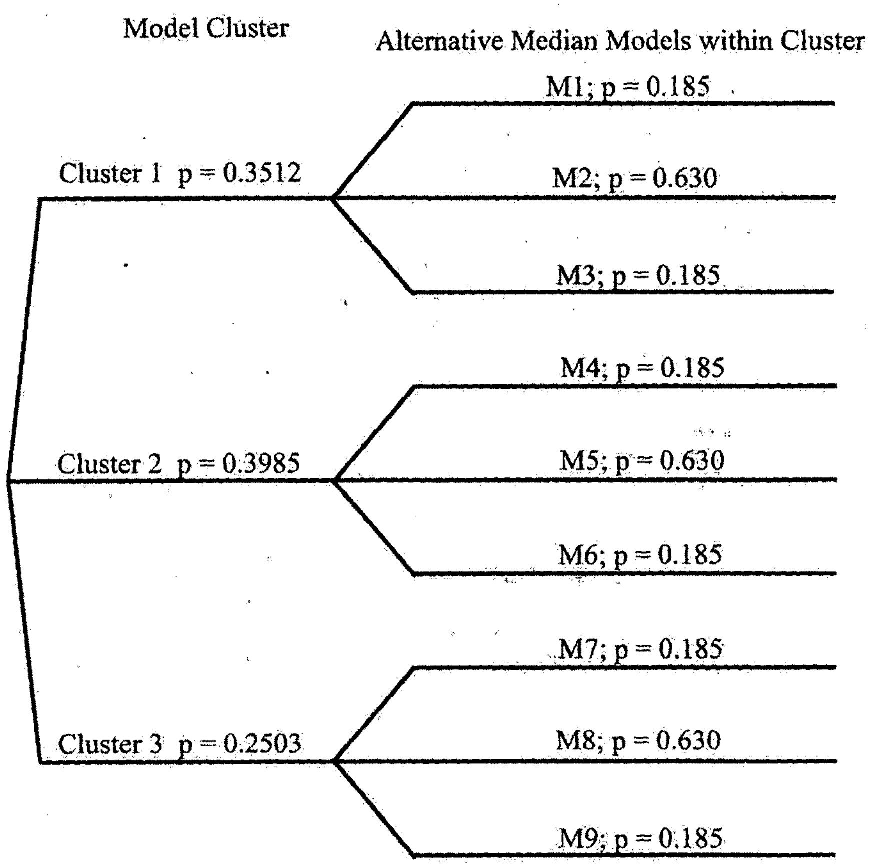

Figure RAI-13A. Ground motion model clusters, individual models, and weights recommended for general area sources (reproduced from Figure 5-2 of EPRI, 2004).

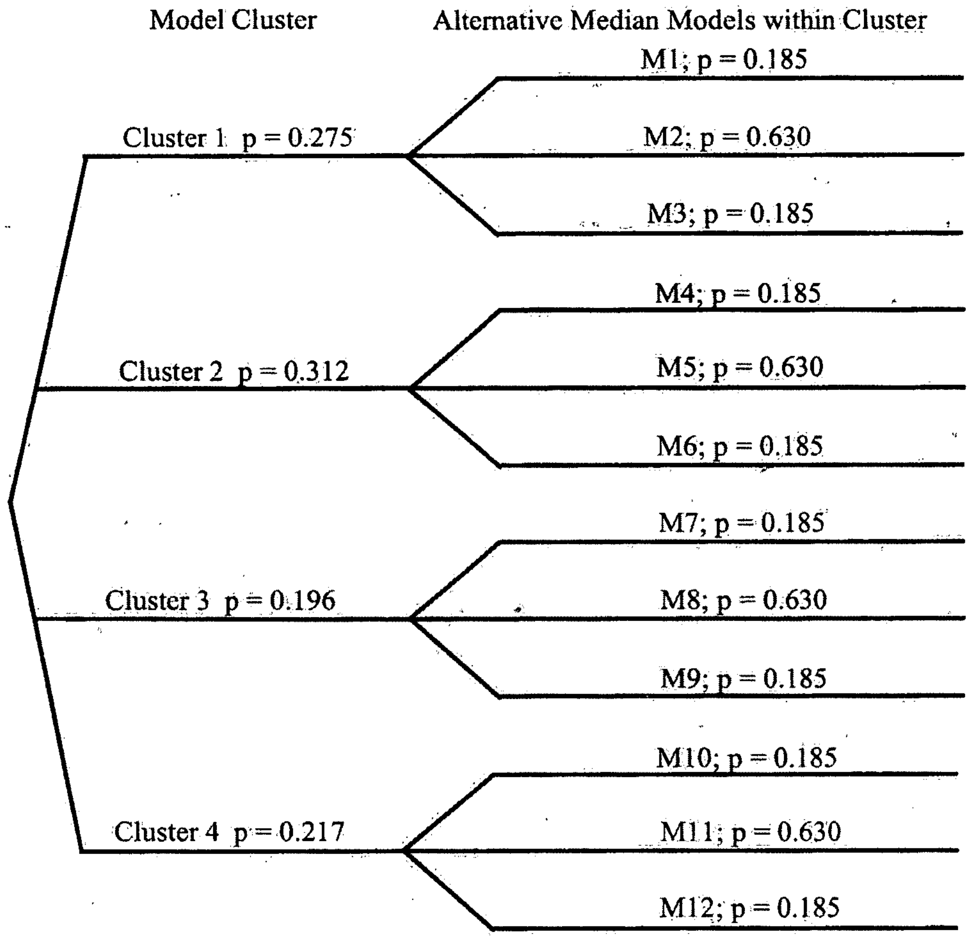

Figure RAI-13B. Ground motion model clusters, individual models, and weights recommended for non-general sources (reproduced from Figure 5-3 of EPRI, 2004).

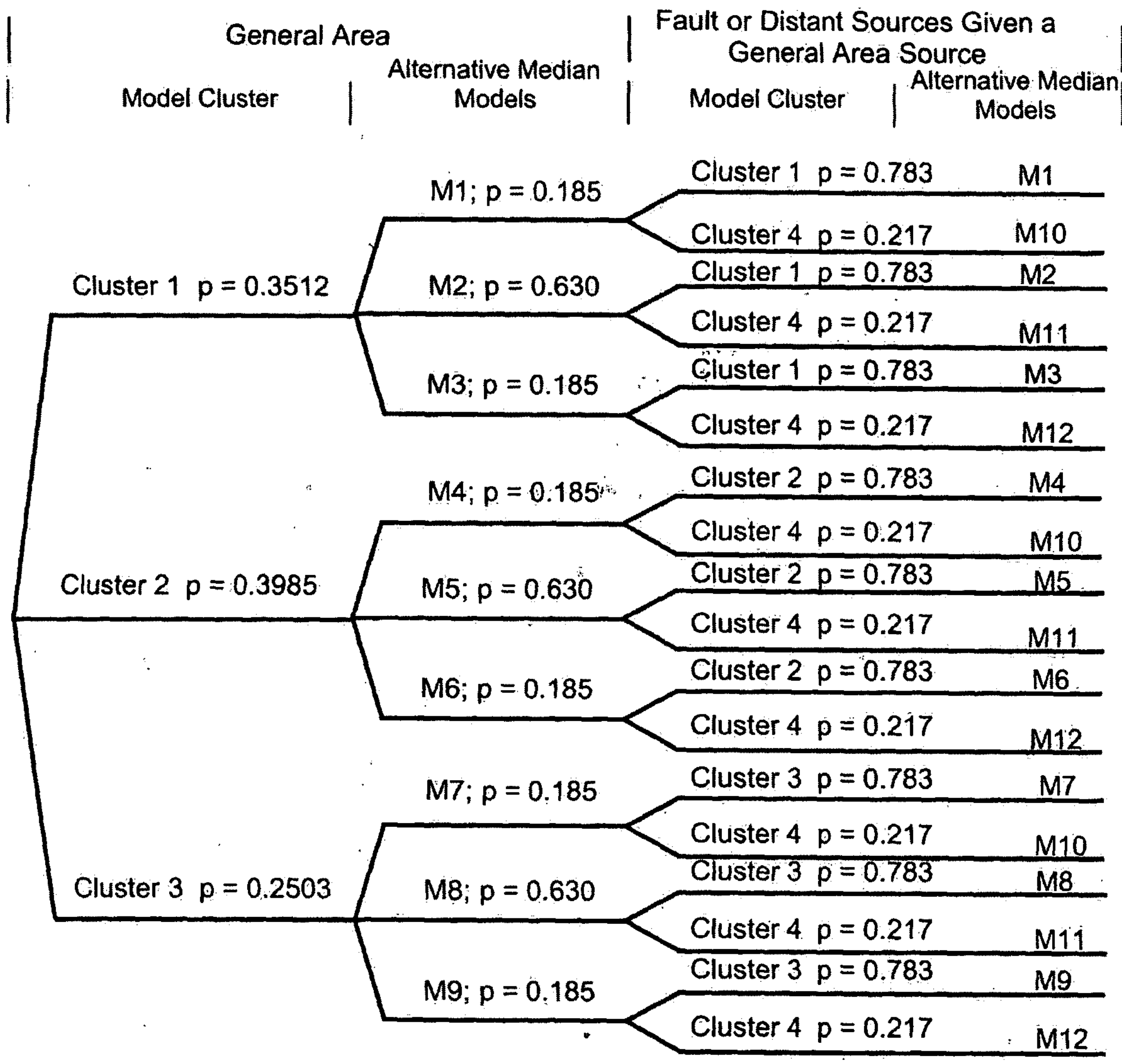

Figure RAI-13C. Ground motion model clusters, individual models, and weights recommended when multiple source types are used for hazard calculations (reproduced from Figure 5-4 of EPRI, 2004).

Reference:

EPRI (2004). *CEUS Ground Motion Project Final Report*, Elec. Power Res. Inst, Palo Alto, CA, Rept. 1009684, December.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-14

NUREG-0800 states that use of the EPRI ground motion models (2004) "is acceptable as long as an adequate investigation has been carried out to provide reasonable assurance that there are no significant updates or new models that may impact on the results of the PSHA." Section 2.5.2.4.5 of the FSAR does not discuss any new ground motion models. However, at least two new ground motion prediction models for the CEUS have been published in peer-reviewed literature since 2004: (1) "Empirical-stochastic ground-motion prediction for eastern North America" by Tavakoli and Pezeshk (Bulletin of the Seismological Society of America, 2005, v.95[6], 2,283-2,296) and (2) "Earthquake ground-motion prediction equations for eastern North America" by Atkinson and Boore (Bulletin of the Seismological Society of America, 2006, v.96[6], 2,181-2,205). In addition to these specific models, the latest version of the US National Seismic Hazard maps (Petersen and others, 2008) computes ground motions from a weighted combination of a number of ground-motion prediction equations. As such, these ground motions can be considered another ground-motion model. Please provide justification for not considering these new ground-motion prediction models.

VCSNS RESPONSE:

Figure RAI-14A plots ground motion amplitudes for 1 Hz spectral acceleration for **M**=7 earthquakes vs distance for the 12 equations used from EPRI (2004), and for the Tavakoli and Pezishk (2005) and Atkinson and Boore (2006) references. At all distances, the range of the 12 EPRI (2004) models encompasses the ground motions predicted by the other two references.

Figure RAI-14B shows a similar plot of ground motion amplitudes for 10 Hz spectral acceleration for **M**=5.7. At all distances, the range of the 12 EPRI (2004) models encompasses the ground motions predicted by the other two references, except for distances between about 50 and 90 km, where the Atkinson and Boore (2006) equation falls below the range of the 12 EPRI (2004) models.

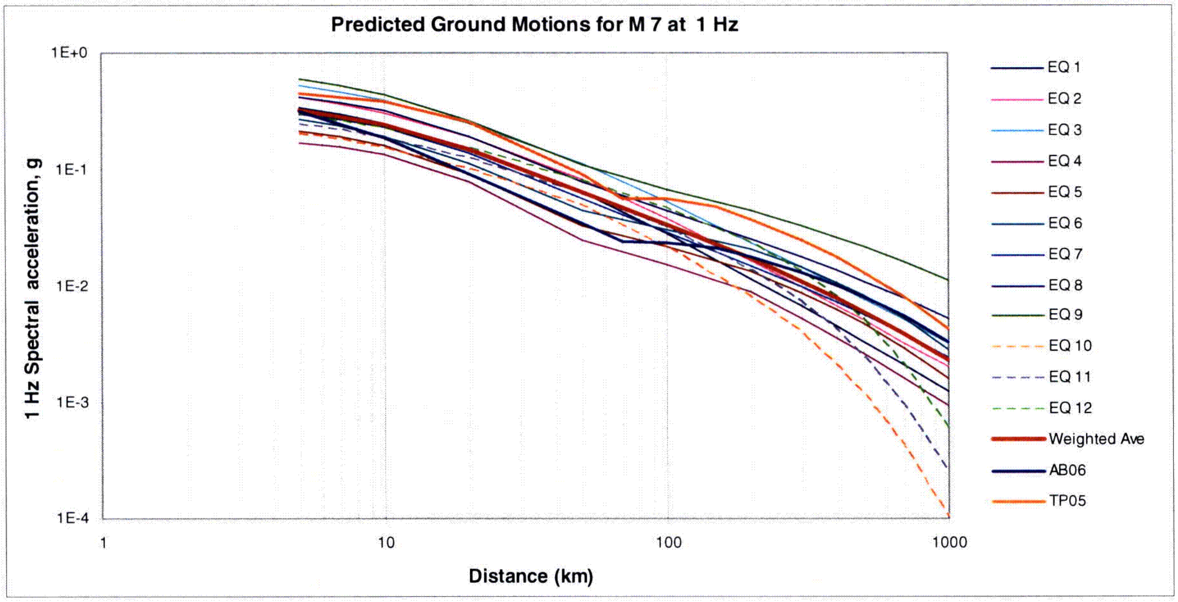

Figure RAI-14A. 1 Hz spectral accelerations predicted for M=7 for the EPRI (2004) models and for the Atkinson and Boore (2006) and Tavakoli and Pezeshk (2005) references.

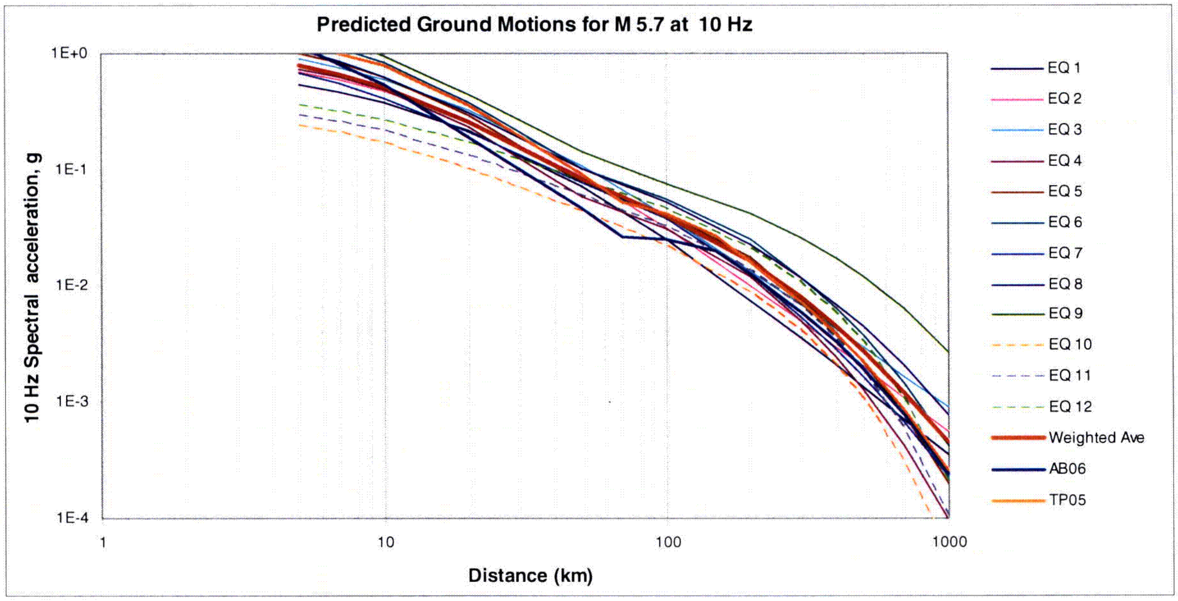

Figure RAI-14B. 10 Hz spectral accelerations predicted for M=5.7 for the EPRI (2004) models and for the Atkinson and Boore (2006) and Tavakoli and Pezeshk (2005) references.

The ground motion models used in the 2008 USGS National Seismic Hazard maps include equations from the following nine references.

Atkinson and Boore (1995)
Atkinson and Boore (2006)

Frankel et al. (1996)
Toro et al. (1997)
Toro (2002)
Campbell (2003)
Somerville (2001)
Silva et al. (2002)
Tavakoli and Pezeshk (2005)

Among these nine, the Atkinson and Boore (1995), Toro et al (1997), Campbell (2003), Frankel et al. (1996), Somerville (2001), and Silva et al (2002) equations were considered in the EPRI (2004) study that was used in the seismic hazard calculations for the Summer site. The Toro (2002) reference is an update of the Toro et al (1997) reference for close distances to large magnitude earthquakes. The Atkinson and Boore (2006) and Tavakoli and Pezeshk (2005) references are evaluated above and are encompassed by the range of EPRI (2004) ground motion equations. Thus the weighting of the nine equations in the Peterson et al. (2008) study does not constitute an independent ground motion model, but involves a weighting of many of the equations used in the EPRI (2004) study, and includes some models (e.g. Frankel, et al., 1996) that have not undergone peer review. The two more recent equations, published since the EPRI (2004) study, are consistent with the EPRI (2004) study. Thus the EPRI (2004) ground motion equations are considered representative of those used by the Peterson et al. (2008) study. Further, the EPRI (2004) study consisted of a SSHAC level 3 study (Senior Seismic Hazard Analysis Committee, 1997) to derive appropriate ground motion models for the central and eastern US, and this the EPRI (2004) study has a level of credibility appropriate for seismic hazard calculations for nuclear facilities. In addition, Drs. Atkinson, Campbell, Silva, Somerville, and Toro participated as experts in the EPRI (2004) study.

References:

Atkinson, G.M. and D.M. Boore (1995). "Ground motion relations for eastern North America," *Bull. Seism. Soc. Am.*, 85, 17-30.

Atkinson, G.M. and D.M. Boore (2006). "Earthquake ground motion prediction equations for eastern North America," *Bull. Seism. Soc. Am.*, 96, 2181-2205.

Campbell K.W. (2003). "Prediction of strong ground motion using the hybrid empirical model and its use in the development of ground-motion (attenuation) relations in eastern North America," *Bull. Seism. Soc. Am.*, 93, 1012-1033.

Frankel, A., et al (2006). *National Seismic Hazard Maps—Documentation*, U. S. Geological Survey Open-file Report 96-532, 110p.

Senior Seismic Hazard Analysis Committee (1997). *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts,"* US Nuclear Regulatory Commission Report, NUREG/CR-6372, April 1997.

Somerville et. al. (2001). "Ground motion attenuation relationships for the central and eastern United States—Final Report, June 30, 2001 report to the US Geological Survey for award 99HQGR0098, 38p.

Silva, W., N. Gregor and R. Darragh (2002). "Development of hard rock attenuation relations for central and eastern North America," Pacific Engineering and Analysis Report, http://www.pacificengineering.org/CEUS/Development%20of%20Regional%20Hard_ABC.pdf

Tavakoli, B., and Pezeshk, S. (2005). "Empirical-Stochastic ground-motion prediction for eastern North America," *Bull. Seism. Soc. Am.,* 95, 2283-2296.

Toro, G.R., Abrahamson, N.A., and J.F. Schneider (1997). "A model of strong ground motions from earthquakes in central and eastern North America—Best estimates and uncertainties," *Seism. Res. Ltrs.*, 68, 41-57

Toro, G.R. (2002). "Modification of the Toro et al. (1997) attenuation relations for large magnitudes and short distances," Risk Engineering, Inc. Report, http://www.riskeng.com/PDF/atten_toro_extended.pdf

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-16

FSAR Section 2.5.2.4.5 on page 2.5.2-41 contains the following statement: "The ground motions for frequencies other than 100 Hz are assumed to be correlated with the ground motions at 100 Hz, so that the filtering is consistent from frequency to frequency." Please clarify whether the above statement is referring to structural frequencies rather than ground motion frequencies. In addition, please provide a justification for the assumption included in the above statement.

VCSNS RESPONSE:

The quoted statement refers to frequencies in the ground motion response spectrum used to determine the uniform hazard response spectrum (UHRS) at the site. The statement is made in the context of the application of the Cumulative Absolute Velocity (CAV) filter, wherein the deviation of ground motion amplitude at each spectral frequency (from its logarithmic mean value) is correlated to the deviation of ground motion amplitude at a different spectral frequency (from its logarithmic mean value). The correlation model is given in Equations 3-2 and 3-3 of Hardy et al. (2006). The correlation is specified between values of spectral acceleration and peak ground acceleration (PGA), which is equivalent to spectral acceleration at a frequency of 100 Hz. The CAV model is an overall model of the damageability of earthquake ground motions that is consistent across all spectral frequencies. As a result, seismic hazard curves for different spectral frequencies have the same horizontal asymptote, because they reflect the same frequency of occurrence of damaging earthquakes in the region.

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None

NRC RAI Letter No. 030 Dated February 10, 2009

SRP Section: 2.5.2 – Vibratory Ground Motion

Question from Geosciences and Geotechnical Engineering Branch 2 (RGS2)

NRC RAI Number: 02.05.02-17

FSAR Section 2.5.2.4.7 (page 2.5.2-43) describes the vertical spectra that were obtained by multiplying the horizontal spectra by a frequency-dependent, but magnitude and distance-independent, scaling factor. However, some studies (for example, Bozorgnia and Campbell, 2004) have found that the vertical-to-horizontal ratio can depend strongly on distance (and to a lesser extent, magnitude). Please explain how these different dependencies would impact the modeled ground motions at the VCSNS site.

In addition, recent data show that the 14 June 2008 M 6.9 Iwate-Miyagi earthquake in Japan produced a vertical ground motion of greater than 3.8 g at the surface and 0.68 g at 260 m depth (Aoi, S. and others, 2008, Trampoline effect in extreme ground motion: Science, v.322, p. 727). This vertical ground motion is much higher than its horizontal components at the surface and about equal at depth of the basement rock over a wide range of frequencies. How do these documented observations affect the modeled ground motions at the VCSNS site?

VCSNS RESPONSE:

The V/H ratios used in FSAR Section 2.5.2.4.7 are those presented in Chapter 4 NUREG/CR-6728 for rock sites in the central and eastern US. This reference acknowledges the dependence of V/H on distance and magnitude: "*With the dramatic increase in strong motion data since the development of these design specifications in the 1970's* [i.e., the simple V/H implied from Reg Guide 1.60], *the conclusion that the vertical and average horizontal ground motions vary in stable and predictable ways with magnitude, distance, and site condition has become increasingly compelling.*" Further extensive discussion on vertical motions is presented in Appendix J of this NUREG.

The V/H ratios presented in NUREG/CR-6728 are a function of ranges of expected horizontal peak acceleration, which are a "*reasonable accommodation of magnitude and distance dependency*". Therefore the V/H ratios used in FSAR Section 2.5.2.4.7 effectively incorporate magnitude and distance dependency through their dependency on peak acceleration.

The recorded observation of nearly 4g vertical motion at the ground surface during the June 2008 earthquake in Japan is under active investigation not only by seismologists, but also geotechnical engineers [see 2008 American Geophysical Union Annual

Meeting, Session on "Earthquake Strong Motions"; Kayen and others, 2008]. Aoi and others (2008) describe the observed peak ground motions for this event:

- Vertical motions recorded at the ground surface were highly asymmetrical – the upward vertical peak motion was ~3.9g, while the largest downward motion was only ~1.7g;

- Horizontal motions at the ground surface appeared normally symmetrical with a peak acceleration of ~1.4g; and

- Both vertical and horizontal motions at a depth of 260 meters were more conventionally symmetrical time histories with peak accelerations of ~1.0g and ~0.7g for the horizontal and vertical motions, respectively.

In reviewing recordings of other large [peak vector sum of all three components greater than gravity] Japanese earthquakes, Aoi and others (2008) indicate that a few showed some degree of vertical asymmetry, but not to the obvious extent as the 2008 event, which also had notably greater ground motions than the other large Japanese events.

Aoi and others (2008) also comment on the horizontal surface-to-downhole Fourier spectral ratios – roughly representing soil amplification factors – for the main 2008 event as compared to the smaller amplitude aftershocks. Typical soil nonlinearity effects are observed for the horizontal motions – that is, the soil amplification is generally less for the main event than that for the average of the smaller amplitude aftershocks, and the peak of the soil amplification for the main event is at a lower frequency than that for the aftershocks. For the vertical motions, the soil amplification for the main event is also smaller than that for the average of the aftershocks, but at a notably lesser degree than that for the horizontal motions. Also, the frequency of the peak of vertical soil amplification of the main event is not significantly different than the frequency of the peak of the average of the aftershocks. That is, typical nonlinear effects are much less in evidence for the vertical motions.

Aoi and others (2008) propose a new model of soil's nonlinear behavior. "*We hypothesize that, when dilatational strains become large enough during strong downgoing acceleration, the bulk tensile strength of the near-surface material is reached, so that soil and rocks lose their cohesion through the development of tensile cracks and apertures.*" Basically, the downward-directed ground motion [relative to the earth] is so great that the soil particles lose contact with each other, become airborne, and virtually fall back downward in a free-fall state at the acceleration of gravity [or less], much as a person on a trampoline.

For the purposes of the design ground motions presented in FSAR Section 2.5.2, 1) the seismic setting of the Summer site is notably different than the setting of the Japanese earthquake, and such high ground motions associated with near-source effects of large earthquakes are not expected at the site, at the regulatory annual hazard levels considered for the FSAR; and 2) the Summer site is a rock site, not a soil site. Therefore, it is concluded, that neither the observed ground motions nor the implied V/H ratios from the 2008 Japanese earthquake are applicable to the Summer site.

References:

Risk Engineering, Inc., *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines*, U.S. Nuclear Regulatory Commission Report NUREG/CR-6728, October 2001.

Aoi, S., T. Kunugi, and H. Fujiwara (2008). *Trampoline Effect in Extreme Ground Motion*. Science, Vol. 322. no. 5902, 31 October 2008: pp. 727 – 730.

Kayen, R., B. Cox, J. Johansson, C. Steele, P. Somerville, K. Konagai, Y. Zhao, H. Tanaka. (2008). Geoengineering and Seismological Aspects of the Iwate Miyagi-Nairiku, Japan Earthquake of June 14, 2008. Geo-engineering Extreme Events Reconnaissance Web Report 2008, GEER Association Report No. GEER-014, September 12, 2008, v. 1.1. [http://research.eerc.berkeley.edu/projects/GEER/GEER_Post%20EQ%20Reports/Japan_2008/Cover_Japan2008.html]

This response is PLANT SPECIFIC.

ASSOCIATED VCSNS COLA REVISIONS:

No COLA changes have been identified as a result of this response.

ASSOCIATED ATTACHMENTS:

None