PMHarrisCOL PEmails

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Sent: Thursday, July 31, 2008 12:24 PM
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Subject: RE: Harris_USGS_RAIs
Attachments: Harris RAIs 1Aug08.doc

Alice,

Attached are our RAIs, slightly revised as discussed at the conference yesterday. The revisions include: adding one sentence and deleting another in RAI 2.5.1-22, addition of Tish's list of suggestions for improving the figures as RAI 2.5.1-25, rewriting of RAI 2.5.1-2, and addition of missing RAI 2.5.2-16, which increases the following RAI numbers in section 2.5.2 by one.

I have turned this document in for USGS approval and I don't expect the text to change. Please let us know if you need anything else.

Steve Personius and I will be in the field 4-26 Aug, but I should be reading email every few days. My cell is 303-709-4276, although there is rarely cell coverage near the trenches.

Cheers,

alan

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Think before you print

Hearing Identifier: ShearonHarris_COL_Public
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Mail Envelope Properties (000501c8f329$e3d07f80$ab717e80$)

Subject: RE: Harris_USGS_RAIs
Sent Date: 7/31/2008 12:24:21 PM
Received Date: 7/31/2008 12:24:38 PM
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Files	**Size**	**Date & Time**
MESSAGE	926	7/31/2008 12:24:38 PM
Harris RAIs 1Aug08.doc	186944	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

Interagency Agreement No. NRC-07-001
JCN No. Q-4151
Task Order No. 3, Review of the Harris Project Application for Combined Operating License in the Areas Relating to Geology and Seismology
TAC No. RX0227
Harris Nuclear Power Plant Units 2 and 3

SSAR RAIs, Submitted by USGS, 1 August, 2008, for Harris, North Carolina site

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Section 2.5.1: Basic Geologic and Seismic Information

RAI 2.5.1-1

FSAR 2.5.1.1.3.1.1.4 (p. 2.5-24) Please provide additional information about dating of Precambrian and Paleozoic rocks. What techniques were used and what were the results?

RAI 2.5.1-2

FSAR 2.5.1.1.3.2.1 (p. 2.5-27) Please provide additional information about the field relations and geochronology leading to the age estimate of the Mars Hill terrane.

RAI 2.5.1-3

FSAR 2.5.1.1.4.2.1 (p. 2.5-33) The applicant describes movement on the Nutbush Creek and Hollister faults as occurring between 312 Ma and 285 Ma, and 251 Ma and 292 Ma, respectively. Clarify whether these faults formed during the Late Proterozoic to Early Paleozoic and were reactivated during the Late Paleozoic, or if they formed during the Late Paleozoic.

RAI 2.5.1-4

FSAR 2.5.1.1.4.2.5 (p. 2.5-37) In the New Jersey-New York area, numerous small and moderate earthquakes have occurred within a broad zone along the southeastern flank of the Newark Basin and several of these earthquakes have been associated with northwest-oriented Mesozoic faults (Seeber and Armbruster, 1989, Annals of the New York Academy of Science, v. 558, p. 21-39). These authors note that similar levels of seismic activity are not associated with the Gettysburg and other Mesozoic basins and attribute this to nonstationary temporal behavior of seismicity. Please discuss the relevance of these findings in the northeastern U.S. for the HAR site region.

RAI 2.5.1-5

FSAR 2.5.1.1.4.2.5.1 (p. 2.5-38) Please provide additional information about the probable sand dikes found at two sites in the Central Virginia seismic zone. What are the characteristics of the features and on what basis are they interpreted as earthquake-induced liquefaction features? How are their ages determined, where do they occur, and what are their spatial relation to faults in the area?

RAI 2.5.1-6

FSAR 2.5.1.1.4.2.5.1 (p. 2.5-38, 2.5-39) Please describe the topographic expression and trenching investigations of the LiDAR lineament identified by Wieczorek et al (2004; Reference 2.5.1-260) in greater detail. What evidence suggests Pleistocene or Holocene movement on this fault? In what ways were the trenching results "equivocal"? Does evidence from the trench suggest fault movement as young as Holocene?

RAI 2.5.1-7

FSAR 2.5.1.1.4.2.5.3 (p. 2.5-39) Please describe the Georgetown liquefaction features (type and size) and their significance in more detail. How old are the features, what is the uncertainty of the age estimates, and how do these compare with the age estimates of liquefaction features near Charleston? Could any of the features have formed during the 1886 earthquake? What is the basis for the interpretation that the features near Georgetown formed as a result of a local earthquake?

RAI 2.5.1-8

FSAR 2.5.1.1.4.2.5.4 (p. 2.5-39, 2.5-40) How young could the terrace deposits that constrain the age of the Pembroke faults be? Please explain in more detail why the faults are not considered to be a potential seismic source.

RAI 2.5.1-9

FSAR 2.5.1.1.4.2.5.5 (p. 2.5-40, 2.5-41) Apparently based largely on the evaluation of Wheeler (2005; Reference 2.5.1-259), the applicant states that the southern segment of the postulated East Coast fault system (ECFS) is considered to be a possible source of repeated large-magnitude earthquakes. A conclusion from the Vogtle ESP stating that the ECFS-S has a relatively low likelihood of producing Charleston-type earthquakes is then cited. Please summarize in much greater detail why this possible seismic source was judged to have a "low likelihood"; include an explanation of what "low likelihood" means.

RAI 2.5.1-10

FSAR 2.5.1.1.4.2.5.5 (p. 2.5-41, 2.5-42, 2.5-43) The discussion and evaluation of the evidence for recent movement on the three segments of the East Coast fault system (ECFS) is difficult to follow, is not detailed enough to be convincing, and lacks figures that show alternative explanations for key features attributed by Marple and Talwani (2000; Reference 2.5.1-243) to tectonic uplift. A more detailed discussion with a stronger paragraph organization, like that in NUREG-1835, is needed to clearly explain the evaluation of these potential seismic sources. In paragraphs on pages 2.5-41 and 2.5-42 some statements are made without listing or explaining the evidence for them and without appropriate references. Phrases such as "any significant geomorphic changes", "it does not seem warranted based on review of the data," and "performed in this study suggest that the postulated ECFS-C may not exist, or has very low probability of activity if it does exist." are especially vague.

(a) Please discuss the different types of evidence used to infer late Quaternary movement on each of the three segments of the fault system and the possible alternative explanations for such evidence.

(b) Evaluate how each of the previously summarized types of evidence has been used along each of the three fault segments to argue for recent movement of that segment. Evaluate the arguments for each segment separately drawing on the earlier summary of the different types of evidence. NUREG-1835's evaluation and conclusions about the ECFS-N should be summarized in this section. Because of its proximity to the Harris site, the discussion for the central segment of the ECFS (ECFS-C) should be more extensive than for the other segments. The evaluation of the ECFS-N in NUREG-1835 is a good example of what is needed for the ECFS-C.

(c) Provide a discussion of how the new LiDAR data mentioned on page 2.5-45 affects the evaluation of features used as evidence for the ECFS.

(d) Considering the regional tectonic setting, provide a more detailed evaluation of the high rates of uplift for parts of the ECFS suggested by Marple and Talwani (2000; Reference 2.5.1-243).

RAI 2.5.1-11

FSAR 2.5.1.1.4.2.5.5 and FSAR 2.5.1.1.4.2.5.6 (p. 2.5-42, 2.5-45, 2.5-46) Stream profiles derived from the new LiDAR data (Figure 2.5.1-220) are described as showing "no consistent vertical anomalies in the modern drainage." However, the scale of the profiles of Figure 2.5.1-220 is too small to show whether or not any anomalies might be present. The new profiles are not explained or labeled well enough to understand the arguments in the text.

(a) Please expand the discussion of Figures 2.5.1-219 and 2.5.1-220 and accompanying ideas in the text and explain their significance in terms of both the ECFS and Weem's fall lines. NUREG-1835's evaluation and conclusions about Weem's (1998; Reference 2.5.1-273) fall lines should be summarized in this section.

(b) Describe the resolution, quality, and areal extent of the LiDAR imagery used to construct the stream profiles. Explain in more detail how points used to construct the profiles were measured from the imagery.

(c) Use figures to compare the lack of anomalies in the new data with the anomalies shown by Marple and Talwani (2000; Reference 2.5.1-243) and Weems (1998; Reference 2.5.1-273). Where lithologic or structural differences in bedrock units are important in interpreting the stream profiles, attempt to show or summarize lithologies on the new figures.

RAI 2.5.1-12

FSAR 2.5.1.1.4.2.5.1 (p. 2.5-43) Explain in greater detail the paleoliquefaction reconnaissance by Amick et al. (1990a; Reference 2.5.1-270) and the Quaternary terrace mapping project by Owens et al. (1989; Reference 2.5.1-271). For the Amick et al. (1990a; Reference 2.5.1-270) study, what areas were searched, how were those areas selected, and how well known is the liquefaction susceptibility of sediment in those areas? For the Owens et al. (1989; Reference 2.5.1-271) study, at what level of detail and over how large an area were cutbank exposures examined? Does sediment susceptible to liquefaction occur along the Cape Fear River? To what degree do these two studies preclude large earthquakes near the Harris site?

RAI 2.5.1-13

FSAR 2.5.1.1.4.2.6.1 (p. 2.5-47) Underlying solution collapse and slumps are given as alternative interpretations for the origin of the Pembroke faults. Describe in more detail the supporting evidence for these nontectonic interpretations?

RAI 2.5.1-14

FSAR 2.5.1.1.4.2.6.2 (p. 2.5-49) Please describe and explain in much greater detail the "detailed geologic studies" in the region of the Eastern Tennessee seismic zone and the "no concrete evidence" found. Why were the two sites that "warrant further study" not investigated?

RAI 2.5.1-15

FSAR 2.5.1.1.4.3 (p. 2.5-51) Please summarize the applicant's "independent evaluation" of the ECFS at a level of detail similar to that in the evaluation of the ECFS-N in NUREG-1835. Include discussion of the 3D seismicity analysis and the reflection data referred to.

RAI 2.5.1-16

FSAR 2.5.1.1.4.3 (p. 2.5-51, 2.5-52) Please discuss the errors associated with earthquake locations in the Ashley River area and provide figures of cross-sectional views of the microseismicity in relation to the local faults.

RAI 2.5.1-17

FSAR 2.5.1.1.4.3 (p. 2.5-54, 2.5-58, 2.5-60) Please include the findings of Talwani and Cox, (1985, Science, v. 229, no. 4711, p. 379-381.) in the discussions of paleoliquefaction features in the Charleston, SC area.

RAI 2.5.1-18

FSAR 2.5.1.1.4.3 (p. 2.5-55) The applicant states that negative evidence from Obermeier et al. (2001; Reference 2.5.1-302) and Amick et al. ((1990b; Reference 2.5.1-300; with the lone exception of a liquefaction feature north of the South Carolina-North Carolina border) strongly suggests that the seismic source that produced the 1886 Charleston earthquake and large prehistoric earthquakes is localized in the Charleston meizoseismal area.

(a) Please describe in more detail the "lone" liquefaction feature north of the border?

(b) How extensive was the search of the coastal plain in northeastern South Carolina and southeastern North Carolina? How many kilometers of rivers and ditches were examined for liquefaction features?

(c) How do the Georgetown liquefaction features compare in age and size to the features in Charleston?

(d) What magnitude earthquake centered in the MPSSZ would be required to induce liquefaction at the Georgetown liquefaction sites?

RAI 2.5.1-19

FSAR 2.5.1.1.4.3 (p. 2.5-55) Please describe the study by Talwani and Schaeffer (2001; Reference 2.5.1-301) in more detail.

(a) What ages constrain the times of the paleoearthquakes identified by these authors and what are the uncertainties on the ages?

(b) What evidence is there of the magnitude of these earthquakes and how reliable are the magnitude estimates?

(c) Please discuss changes in sea level during the Holocene and how these changes may have influenced earthquake-induce liquefaction and the completeness of the paleoearthquake record in this area?

RAI 2.5.1-20

FSAR 2.5.1.1.4.3 (p. 2.5-56) Please describe in more detail the geotechnical study of the 1886 Charleston earthquake by Martin and Clough (1994; Reference 2.5.1-310). How many sites were tested and where are the sites located? Were the back-calculated ground motions for the earthquake calculated on the basis of soil properties of the liquefaction features or on the source layer that liquefied? If the latter, how did they determine which subsurface layer liquefied? Why was the Ishihara relation used and is it applicable in South Carolina?

RAI 2.5.1-21

FSAR 2.5.1.1.4.3 (p. 2.5-58) Please briefly describe the method by which Leon (2003; Reference 2.5.1-317) and Leon et al. (2005; Reference 2.5.1-318) take into account the effect of sediment age on liquefaction potential.

RAI 2.5.1-22

FSAR 2.5.1.1.4.3 (p. 2.5-59, 2.5-60) Please discuss whether or not the size distribution of similar-age liquefaction features in South Carolina was considered in the interpretation of source area and magnitude of paleoearthquakes. Also discuss how earthquake recurrence estimates would be effected if regional correlations between related but scattered areas of liquefaction features are not recognized.

RAI 2.5.1-23

FSAR 2.5.1.2.2 (p. 2.5-68) Please provide more details about the "possible Pliocene or Pleistocene faulting" approximately 23 km from the HAR site. What evidence, if any, constrains the age of the gravels?

RAI 2.5.1-24

FSAR 2.5.1.2.4.1.1 (p. 2.5-84) Please describe "no information unfavorable to the plant site." in more detail. Explain what the modeling showed. A figure might help show the results of the modeling.

RAI 2.5.1-25

General suggestions to improve figures in Section 2.5.1
(The most important suggestions, which would increase the clarity of the accompanying text, are underlined.)

Figure 2.5.1-204 and Figure 2.5.1-205: Legends appear to be missing.
Figure 2.5.1-206: Location map needed to show how cross-sections relate to maps A, B, and C.
Figure 2.5.1-207: Enlarge map, font size, and symbol size.
Figure 2.5.1-208: Spell out CP&L. Fill in blank portions of the table. Enlarge font size of reference list.
Figure 2.5.1-210: Better differentiate patterns for E. Triassic and Norian units. Increase font size of lettering and symbol size on map and in legend.
Figure 2.5.1-211: Enlarge map, font size, and symbol size.
Figure 2.5.1-212: Reference Figure 2.5.1-211 for locations of cross-sections; enlarge font size; make font size consistent for all faults.
Figure 2.5.1-214: Lettering for "Central Piedmont Suture" is cut off.
Figure 2.5.1-215: Label Chatham fault zone on cross-section.
Figure 2.5.1-217: Enlarge map, font size, and symbol size.
Figure 2.5.1-219: Difficult to read lettering for cross-sections. Use different color, perhaps black. Increase font size and symbol size on map and in legend.
Figure 2.5.1-220: Increase font size on profiles and in legend.
Figure 2.5.1-221: Enlarge map. Increase font size of lettering and symbol size on map and in legend.
Figure 2.5.1-222: Increase font size of text and symbol size on map and in legend. Indicate locations of Bluffton, Georgetown, and Myrtle Beach.
Figure 2.5.1-224: Increase font size of place names, legend, scale, and caption.
Figure 2.5.1-227: Enlarge map and especially font size of text.
Figure 2.5.1-228: Increase font size of scale and legend.
Figure 2.5.1-229: Use different color for Eastern Piedmont fault system, Clingman and Ocoee lineaments that are easier to differentiate from magnetic anomaly colors.

Figure 2.5.1-230, Figure 2.5.1-231, Figure 2.5.1-232: Enlarge font size of legend and labeling on map of locations and geologic units.
Figure 2.5.1-235: Enlarge font size of legend and labeling on map of Harris fault and geologic units.
Figure 2.5.1-237, Figure 2.5.1-238: Increase font size of scale and legend.
Figure 2.5.1-239: Increase font size of scale and legend and labeling on map of locations and geologic units. Also label A-A' and B-B' with darker lettering.
Figure 2.5.1-240: Indicate location of HAR site and that location of resistivity lines are shown on Figure 2.5.1-239.
Figure 2.5.1-241: Increase font size of profile and legend. Explain why seismic profile is not included.

Section 2.5.2: Vibratory Ground Motion

RAI 2.5.2-1

FSAR 2.5.2.1.2 (p. 2.5-108, 2.5-111) Eleven earthquakes with magnitude m_b 4.9 or larger are listed within 320 km of the HAR site. All eleven of these occurred in the 100-year period 1817 to 1916. Zero events are listed for the subsequent period of 92 years, from 1917 to 2008. Discounting one of the listed events as an aftershock of the Charleston 1886 mainshock, the mean rate of presumably independent events is 0.1/year for the first period. The probability of observing zero $m_b \geq 4.9$ earthquakes within the region of interest in a 92-year period, based on a standard Poisson model (independent occurrences in time and space), with mean lambda = 0.1*92=9.2, is

$$Pr[0]=9.2^{0}e^{-9.2}/0!=0.0001.$$

Another way of looking at this pattern is to find the Poisson rate that maximizes the likelihood of recording 10 or more $m_b \geq 4.9$ eqs. in a hundred year period followed by 0 in the following 100-year period (for ease of calculation the 92-year period has been stretched to 100). This rate is about 4.32 per hundred years, and gives a probability of 0.0132 for observing 10 or more, or zero. The probability of recording 10 then zero as reported in the FSAR (allowing the 8-year extrapolation of zero) should then be 0.0132^2 or about 1/5600, from the maximum-likelihood approach.

(a) Do these low probabilities (from first or second method above) imply that there is a lower probability of detection than the assessed probability of detection of 1 listed in Table 2.5.2-208 for the later time period, or are other explanations available? If other explanations exist, please provide them with assessments of their pertinence.

(b) How does the answer to (a) bear upon seismic-hazard estimates for the HAR site?

RAI 2.5.2-2

FSAR 2.5.2.1.2 (p. 2.5-114, 2.5-115) The locations of several historical mb 4.9 and larger earthquakes appear to be significantly different in the HAR earthquake catalog as compared to the EPRI-SOG catalog. Please more completely justify these relocations; i.e., why the location as given in either the NCEER-91 or the USGS National Hazard Mapping catalog is preferred over the EPRI-SOG location. Specific events of concern are:

> (a) The EPRI-SOG location for the January 8, 1817 earthquake places it approximately 100 kilometers northwest of the Harris site; i.e., about halfway between the southwestern-most felt location (Milledgeville, Georgia) and the northeastern-most felt location (Baltimore, Maryland) as reported in the FSAR. Yet the FSAR prefers a location near Charleston, SC as given in the USGS National Hazard Mapping catalog (Reference 2.5.2-207?). The USGS catalog itself references Stover and Coffman (1993), USGS Professional Paper 1527 as the source for this event. Do you know why Stover and Coffman assign a location near Charleston, SC?
>
> (b) The April 29, 1852 earthquake was felt at Buckingham and Wytheville, Virginia – not South Carolina. Correct this description.
>
> (c) Is the location of the 2:45 PM October 22, 1886 earthquake in South Carolina in the HAR catalog the same as in the EPRI-SOG catalog? Where was the maximum intensity VII reported? Since it is located ~120 km inland from Summerville, do you consider an aftershock of 1886 or as a triggered event outside the aftershock zone in the HAR catalog?
>
> (d) Reference 2.5.2-206 credits M. Chapman (pers. comm.) as the source for moving the February 21, 1916 earthquake further west (away from the HAR site). Yet the Southeastern U.S. Earthquake Catalog (http://www.geol.vt.edu/outreach/vtso/anonftp/catalog/susn2006cat.txt) maintained by the Virginia Tech Seismological Laboratory (of which M. Chapman is the Director) lists this event as occurring at 35.5N, 82.5W; i.e., the same as in the EPRI-SOG and NCEER-91 catalogs. Please explain this discrepancy.

RAI 2.5.2-3

FSAR 2.5.2.2.1 Several seismic sources cannot be found or seen clearly on figures. The Eastern Basement (Source 17) or Alternate Eastern Basement Background (Source 217) from the Law Engineering Team cannot be found on Figure 2.5.2-205. The Appalachian Crust (Source 49) from the Rondout Associates Team cannot be found on Figure 2.5.2-206. In addition, Source 26 (South Carolina Seismic Zone) cannot be seen clearly.

RAI 2.5.2-4

FSAR 2.5.2.4.1.1.1 (p. 2.5-125) The applicant states that the Charleston 1886 source width was set at a depth of 20 km. In standard English usage, “width” is a 1-dimensional quantity whereas “a depth of 20 km” is a point estimate, 0 dimensional. Please reword this sentence to clarify what was done to model the Charleston source geometry and its significance to seismic hazard at the HAR site. What is the modeled width or thickness of the seismogenic source zone? What is the significance of assuming vertical dipping rather than, say, 60 degree dipping, virtual faults?

RAI 2.5.2-5

FSAR 2.5.2.4.1.1.2 (p. 2.5-126) A postulated East Coast Fault System (green outlined area according to figure caption) cannot be seen on Figure 2.5.2-214.

RAI 2.5.2-6

FSAR 2.5.2.4.1.3 (p. 2.5-135) The last paragraph of this section notes that the maximum magnitude distributions were modified for several sources. Please specifically note these modified magnitude distributions on the appropriate tables (Table 2.5.2-203 and 2.5.2-205).

RAI 2.5.2-7

FSAR 2.5.2.4.2.1 (p. 2.5-136, 2.5-137) The median ground motions for the Atkinson and Boore (2006) model are at the 95% level of the EPRI (2004) cluster 2 model for 1 Hz Spectral Acceleration at distances of ~300 kilometers (i.e., approximate distance of the Charleston source area). In addition, another new eastern North America ground motion model (Tavakoli and Pezeshk, BSSA, 2005, v.95[6], 2283-2296) is not considered here. Given the large contribution of the Charleston source to the seismic hazard at the Harris site, what would be the impact of using either the Atkinson and Boore (2006) or Tavakoli and Pezeshk (2005) relationship instead of EPRI (2004) cluster 2?

RAI 2.5.2-8

FSAR 2.5.2.4.2.1 (p. 2.5-137) The applicant states that, “The rift version of the cluster 4 model was used for the Charleston sources.” What are the other versions of the cluster 4 model and why was the “rift” version chosen?

RAI 2.5.2-9

FSAR 2.5.2.4.2.2 (p. 2.5-138) What are the actual values for the aleatory variability used in conducting the PSHA (i.e., from the EPRI 2006 study)?

RAI 2.5.2-10

FSAR 2.5.2.4.3 (p. 2.5-139) Please explain the statements in the last paragraph before FSAR 2.5.2.4.3.1 in more detail. Were the new ground motion models (i.e., EPRI 2004 and associated aleatory variability EPRI 2006) used in the sensitivity analysis? Or were previously defined ground motion models used (i.e., EPRI 1989)?

RAI 2.5.2-11

FSAR 2.5.2.4.3 (2.5-139 through 2.5-146) uses a method of computing response spectral values based on correlations with the spectral value at a specified frequency for a given magnitude and distance, which are those of the Design Earthquake (DE). The correlations are based on an empirical study by Baker and Cornell (Reference. 2.5.2-257). The data for this study were earthquakes within 100 km of stiff-soil sites, from tectonically active environments, and with moment magnitude greater than 5.5 (Baker and Cornell, p. 216). The controlling earthquakes, in contrast, are all from tectonically stable areas, sometimes less than M5.5, or if greater than M5.5, at distances greater than 200 km, recorded at a generic hard-rock site according to the PSHA. That is, there is no overlap between data of the empirical study of Baker and Cornell and the DEs in the application presented in FSAR 2.5.2.5.4.3.

(a) Please explain if the reasoning for assuming the correlations of epsilon between frequencies estimated by Baker and Cornell (Reference. 2.5.2-257), or Baker and Jayaram (Reference. 2.5.2-258), should also apply to the DEs at the HAR2 and HAR3 sites. Some reasons to expect differences from Baker and Cornell's findings, for example, are the absence of soil resonant frequencies at a generic rock site, the likelihood of much higher average source stress drop in the stable tectonic environment, and many different features of propagation of seismic waves in the two environments. One such example of the latter difference is the dominance or at least importance of the Lg phase from the Charleston SC sources (with distance of 200 to 300 km), a source which is frequently chosen as the DE in FSAR 2.5.2.5.4.3. This phase is probably negligible for most or all of the PEER data used by Baker and Cornell.

(b) If justification of the use of the Baker and Cornell (Reference. 2.5.2-257) correlation coefficients is difficult for the FSAR, what is the effect of using a higher correlation coefficient among spectral periods than Baker and Cornell found for WUS and other tectonically active regional sources?

RAI 2.5.2-12

FSAR 2.5.2.5 (p. 2.5-152) The HAR sites are underlain by sediments and sedimentary rock of the Deep River basin. See Figure 2.5.1-241, Figure 2.5.3-207 and others for details of basin geometry. Please provide justification for excluding three-dimensional, long- and short-period basin effects on ground motion from seismic waves interacting with the Deep River Basin structure.

RAI 2.5.2-13

RAIs 2.5.2.5.1.4 (p. 2.5-156) This section on "Shear Modulus and Damping" describes an additional kappa reduction of 0.0002 second for the scattering effects due to randomization of the velocity profiles. Is this value based on research or experimental results (in which case a reference is needed), or based on the applicant's judgment? Has the applicant conducted any test of the scattering effects on Q?

RAI 2.5.2-14

FSAR 2.5.2.5.3.4 (p. 2.5-162, 2.5-163) uses an EPRI-devised scheme which incorporates CAV to determine the sources to consider when computing the RE and DE spectra at HAR 2 and HAR 3 of FSAR 2.5.2.6. Figures 2.5.2-295 through 2.5.2-301 show that in all cases the sets of sources associated with the method are considerably different than sources from the method which includes all potential sources with $m_b \geq 5.0$. This is because the rates of significant events differ by more than a factor of thirty (30) when using both methods for all spectral frequencies considered (100 Hz or PGA to 0.5 Hz).

(a) Please show a graph or graphs in magnitude, distance space which portray the 5%, 50%, and 95% probability that a source with this magnitude and distance will not be included in the PSHA when the CAV filter is applied.

(b) What is the probability that a m_b 4.9 earthquake within 5 km of the HAR2 (or HAR3) site will not be included in the PSHA when the CAV filter is applied?

(c) What is the minimum distance and maximum magnitude that are excluded from the PSHA with at least 50% probability when the CAV filter is applied to determine the RE and DE spectra?

(d) Please list the CEUS or Eastern North American strong-motion seismograms that are available to support the answers of a, b, and c above. These should be seismograms collected on rock sites with amplification properties that are substantially the same as those of HAR2 and HAR3, or if different, explain what adjustments were made to these seismograms to make them appear similar to those that would be collected at a site with near-surface properties like those of HAR2 and HAR3.

RAI 2.5.2-15

FSAR 2.5.2.4.4.2 (p. 2.5-`148) on the computation of UHS for Generic CEUS Rock and Identification of Controlling Earthquakes uses one procedure for determining the dominating or controlling earthquakes while FSAR 2.5.2.5.3.4 (p. 2.5-162) uses another which incorporates CAV to determine the sources to consider when computing the rock spectra at HAR 2 and HAR 3. Figures 2.5.2-295 to 2.5.2-301 show that in all cases the sets of sources associated with the two methods are considerably different, because the rates of significant events differ by more than a factor of twenty (20) when using both methods for all spectral frequencies considered (100 Hz or PGA to 0.5 Hz).

(a) Please deaggregate the hazard which is used to produce the GMRS of FSAR 2.5.2.6, that is, the rock hazard that uses CAV filtering to eliminate earthquake sources that the applicant believes are not relevant to well-designed nuclear power plants.

(b) Please show the deaggregation graphs for 1 Hz, 2.5 Hz, 5 Hz, and 10 Hz (and other frequencies if desired) using CAV filtering and exhibit the results using just one magnitude (moment magnitude or body-wave magnitude) on the magnitude axis, and specify which magnitude is used in these graphs. Please show these graphs for the 10**-4 and 10**-5 PE, and other PEs if desired.

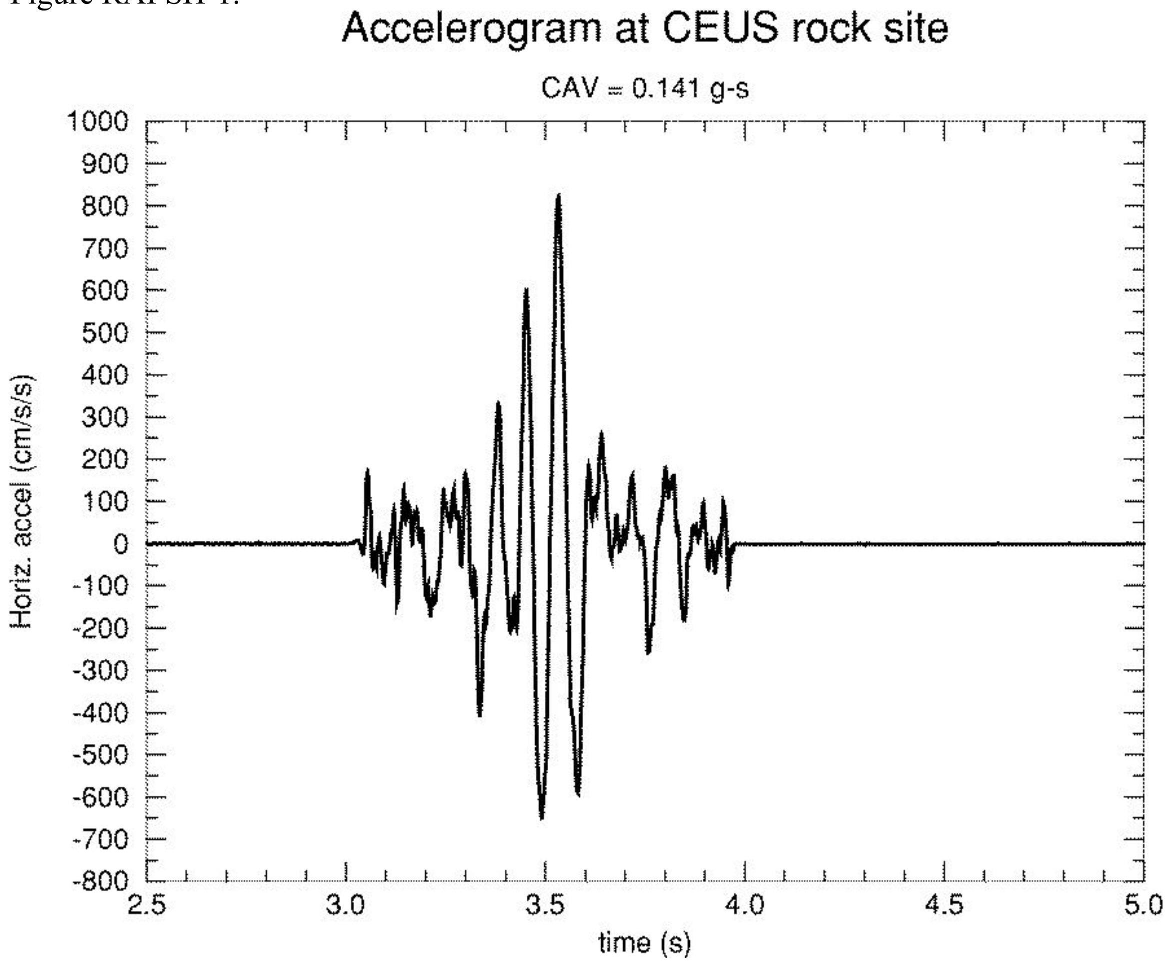
RAI 2.5.2-16

FSAR 2.5.2.5.1.4 (p. 2.5-156) The applicant should explain the justification for the use of the equivalent linear code SHAKE for nonlinear soil response. This code overdamps high frequencies compared to true nonlinear codes such as DESRA.

RAI 2.5.2-17

FSAR 2.5.2.5.3.4 (p. 2.5-163) uses a method which incorporates CAV to determine the sources to consider when computing the rock spectra at HAR 2 and HAR 3. Figures 2.5.2-299 illustrates the 10-hz mean hazard curves with and without CAV. The 10**-5 PE 10-hz mean SA with CAV is about 0.9 times the mean SA without CAV according to Table 2.5.2-221, and is about 0.75 times the mean SA without CAV at 10**-4 PE. The below synthetic seismogram represents the motion from a nearby small, but high stress-drop, earthquake. Its CAV is 0.141 g-s and therefore this source would be omitted from consideration when computing the GMRS by virtue of CAV filtering. Nevertheless, its 10-hz 5% damped pseudo spectral acceleration is 1.96 *g*, about six times the GMRS 10-hz 5% damped pseudo spectral acceleration of Table 2.5.2-222 (p 2.5-192). Please justify

the omission of sources with CAV less than 0.16 g when such sources may produce high-frequency spectral ordinates many times in excess of the GMRS spectra and greater than the high-frequency portion of the RE, DE and other spectra to be used in seismic-resistant design at HAR2 and HAR3.
Figure RAI SH-1.



RAI 2.5.2-18

FSAR 2.5.2.5.3.4 (p. 2.5-163) uses an EPRI-devised scheme which incorporates CAV to determine the sources to consider when computing the RE and DE spectra at HAR 2 and HAR 3 of FSAR 2.5.2.6 (p. 2.5-164). Figures 2.5.2-295 to 2.5.2-301 show that in all cases the sets of sources associated with the method are considerably different than sources from the method which includes all potential sources with $m_b \geq 5.0$, because the rates of significant events differ by more than a factor of thirty (30) when using both methods for all spectral frequencies considered (100 Hz or PGA to 0.5 Hz). The mean rate of the Charleston SC mainshock is about 1 event per 550 years, which in decimal notation is 0.001818, or $1.8 \cdot 10^{-3}$. The low ground-motion mean hazard with CAV asymptote in Figures 2.5.2-295, 2.5.2-296, and 2.5.2-297 is about $3 \cdot 10^{-4}$. This means that CAV filtering must remove most or all contributions of the Charleston SC mainshock at the HAR site for long period motion, 0.5 Hz to 2.5 Hz, shown in those three figures.

(a) Please reconcile the fact that the hazard graphs of Figures 2.5.2-295 and 2.5.2-296 must exclude all or most of the Charleston mainshock contribution as irrelevant because of its low CAV with the deaggregation results of Figures 2.5.2-243, 2.5.2-244, 2.5.2-245, and 2.5.2-246 that indicate that the Charleston mainshock is the controlling event at a wide range of PEs for the long-period combination (1 and 2.5 Hz).

(b) Please provide a complete set of deaggregation graphs that use the PSHA hazard analysis with CAV filtering ON and describe the controlling earthquakes that result from this analysis.

(c) Please provide a list of strong motion records for M7+ earthquakes with source and propagation characteristics similar to those expected at HAR and at Charleston-like distances that support the rejection of this source by CAV filtering.

(d) In view of the total understanding available, not just CAV-based, is or is not the Charleston SC mainshock a controlling event at the HAR site for relatively long-period ground motion?

RAI 2.5.2-19

FSAR 2.5.2.5.3.4 (p. 2.5-163) The applicant states that, "The model results indicate that earthquakes of magnitude less than M 4 have very little probability of producing a CAV greater than 0.16 g-seconds (Reference 2.5.2-271). The magnitude conversions used in the PSHA convert a m_b of 4.0 into M magnitudes that are less than 4.0." This is relevant to FSAR 2.5.2.4.1.3 (p. 2.5-134) which provides the formulae for magnitude conversions.

(a) Eq 2.5.2-5: In Johnston (1996), this equation was originally given by:
$\text{Log}(M_o) = 18.28 + 0.679 * m_b + 0.077 * mb^2$,
from which it is easy to get a M (m_b) relationship different from Eq 2.5.2-5, as used by the applicant. Here the question is that if Eq 2.5.2-5 was used to convert m_b to M, then the applicant may have omitted events of magnitude m_b between 3.9 and 4.4 by applying the CAV filter. Fortunately, as described in the original reference (Johnston, 1996), the Eq 2.5.2-5 used for the HAR site was really meant to convert M (m_{LG}) (The m_{LG} is sometimes referred to as m_{b_LG}.). In any case, to avoid confusion in the magnitude scales used, the applicant should provide a brief description of why the magnitude m_{LG} is cited as m_b.

(b) In the original form of Eq 2.5.2-4 in Atkinson and Boore (1995), the Nuttli magnitude m_N was used. For the same reason as described in (a), the applicant should provide a brief description of why the m_N is cited as m_b for the HAR site.

RAI 2.5.2-20

FSAR 2.5.2.6, Table 2.5.2-221 (Effect of CAV on surface spectra, p. 2.5-191) The ratios of CAV/no-CAV > 1.0 were given for PE of 10**(-6) at frequencies of 10-, 25- , and 100-Hz. Please explain why the corresponding surface UHRS for the GMRS profiles (Figs. 2.5.2-302 and 2.5.2-303) produced higher amplitudes in spectral acceleration with CAV filtering. Was this due to possible interpolation and numerical truncation errors or to some other causes?

Section 2.5.3: Surface Faulting

RAI 2.5.3-1

FSAR 2.5.3.2 (p. 2.5-197) The applicant states that the County LiDAR data has a grid size of 6 m (20 ft). Please estimate the minimum width and height of geomorphic features (scarps, etc.) that can be observed with data of this resolution.

RAI 2.5.3-2

FSAR 2.5.3.1.4 (p. 2.5-197) Given the occurrence of earthquake-induced liquefaction features in northeastern South Carolina and a possible liquefaction feature near Myrtle Beach, North Carolina, please explain why a reconnaissance for similar features was not conducted in the North Carolina coastal plain?

RAI 2.5.3-3

FSAR 2.5.3.2 (p. 2.5-199) Please explain what criteria were used to interpret fault capability from aerial photographs and satellite imagery and clarify whether or not these interpretations were checked in the field. Please provide a figure that shows how the new LiDAR lineaments compare with the old lineaments identified with SLAR and ERTS imagery.

RAI 2.5.3-4

FSAR 2.5.3.2.1.1 (p. 2.5-200-201) Please provide additional detail about the assessment of the age of most recent movement on the Jonesboro fault.

(a) What does “little to no geomorphic expression” of the Jonesboro fault mean?

(b) What are the “observations and conclusions cited in the HNP FSAR”? How were the previous conclusions confirmed by the most recent investigations near the site?

(c) Were lineament and field studies conducted in areas where potential evidence of Quaternary deformation, or lack thereof, would be most easily observed, such as in stream terrace deposits?

(d) The applicant states that they found no existing sites where the fault is exposed. Were subsurface methods (trenching, boreholes, shallow geophysics) commonly employed in fault investigations used to confirm a lack of deformation in Quaternary deposits that lie across the unexposed trace of the Jonesboro fault?

(e) The applicant states that the exposures with evidence of post-Cretaceous deformation along the Jonesboro fault near Stanford described by Prowell (1983; Reference 2.5.3-213) no longer exist. Please describe this evidence in more detail and explain whether or not it is evidence of Pleistocene or younger movement on the fault.

RAI 2.5.3-5

FSAR 2.5.3.2.1.2 (p. 2.5-203) Where is the similar location with comparable depths of oxidation, how is depth of oxidation related to saprolite formation, and how was the age of saprolite formation estimated? Explain in more detail why the diabase has not been disturbed in more than 500,000 years.

RAI 2.5.3-6

FSAR 2.5.3.2.1.6 (p. 2.5-205) Where are the faults of Parker and Prowell (1979; 1983; References 2.5.3-215 and 2.5.3-213) for which no evidence of recent movement was found by the NCGS and what kinds of evidence were used to draw these conclusions (What does the phrase “not strong evidence” mean?)? At what, if any, sites did LiDAR lineaments coincide with these previously identified faults? Explain “geomorphic evidence of recent faulting” in more detail. Were subsurface methods (trenching, boreholes, shallow geophysics) commonly employed in fault investigations used to confirm a lack of deformation in Quaternary deposits that lie across the unexposed traces of these faults?

RAI 2.5.3-7

FSAR 2.5.3.2.2 (p. 2.5-207) Please explain in more detail, or more clearly, the probable origins of the FPL lineament, the eastward extension of the Harris fault lineament, and the north-south lineaments nearest the HAR2, HAR3, and HNP1 on the east and west. In each case, what is the origin of features that are being mapped as lineaments?