From: Laurel Bauer
To: "Vogtle_NonPublic_Emails" <Vogtle_NonPublic_Emails@nrc.gov>
Date: 11/26/2007 10:33:14 AM
Subject: Fwd: USGS review of Vogtle DSER

>>> Russell L Wheeler <wheeler@usgs.gov> 10/22/2007 4:41 PM >>>
Laurel-

Attached in three formats is the final version of our review of the Vogtle DSER. It is the same as the draft of 18 Sept., except that Chuck's seismology review has been added, the first two sections of the TLR are reworked, and there are a handful of minor editing changes that do not affect any substance. Please forward this to anyone who should have been copied but whom I left out.

Thanks,
Rus

Rus Wheeler
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Email Number: 7497

Mail Envelope Properties (474AA0F1.HQGWDO01.TWGWPO04.100.16B3769.1.9B7D.1)

Subject: Fwd: USGS review of Vogtle DSER
Creation Date: 11/26/2007 10:33:14 AM
From: Laurel Bauer

Created By: LMB1@nrc.gov

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Post Office	Route
TWGWPO04.HQGWDO01	nrc.gov

Files	Size	Date & Time
MESSAGE	827	11/26/2007 10:33:14 AM
VogtleDSERReview.doc	78336	11/26/2007 10:33:21 AM
VogtleDSERReview.rtf	429714	11/26/2007 10:33:21 AM
VogtleDSERReview.pdf	59363	11/26/2007 10:33:21 AM

Options
Priority: Standard
Reply Requested: No
Return Notification: None
None

Concealed Subject: No
Security: Standard

Technical Letter Report to U.S. Nuclear Regulatory Commission
JSN J-3332, Task Order 1, Task number 6, TAC number MD3009/01675/001
Mechanical and Civil Engineering Branch, Division of Engineering, Office of Nuclear Reactor Regulation

Review of Draft SER

ESP Application for the Vogtle Electric Generating Plant
Applicant: Southern Nuclear Operating Co.
Submitted by Russell L. Wheeler and Charles S. Mueller, USGS, 22 October, 2007

Introduction

This report contains the U.S. Geological Survey's (USGS's) review of the draft SER (DSER) written by Nuclear Regulatory Commission (NRC) staff. The review was restricted to sections 2.5.1-2.5.3 of the DSER, which deal with geology, seismology, and surface faulting, respectively.

Summary of Work Performed

The review is in three parts, each of which addresses one of the evaluated DSER sections 2.5.1-2.5.3. Each part consists of comments that are keyed to individual numbered subsections or pages of the DSER.

The review concentrates on geological and seismological matters that are likely to influence hazard computations. Wheeler reviewed the Technical Evaluation sections 2.5.1.3, 2.5.3.3, and parts of 2.5.2.3. Mueller reviewed all of section 2.5.2. Both addressed the Open Items. Accordingly, this report consists of Wheeler's comments, with Mueller's comments inserted between lines of asterisks at the end of the comments on section 2.5.2.

Evaluation

2.5 Geology, Seismology, and Geotechnical Engineering

2.5.1 Basic Geologic and Seismic Information

At several places the DSER cites Wheeler (2005), Wheeler (1996), or both. Wheeler did publish abstracts and papers in these years, but the texts surrounding the DSER citations suggest that the cited years might be incorrect. Possibly some of the citations refer to papers published in 1995 or 2006. Please verify the years given in the citations.

RAI 2.5.1-16 does not appear to be mentioned in the DSER. The RAI deals with the Steel Creek fault on the Savannah River site. The response to the RAI provided the requested information that indicates the fault is not capable.

2.5.1.1.1 Regional Geologic Description

Seismic Sources Defined by Regional Seismicity: In referring to the Eastern Tennessee Seismic Zone, the DSER states that "the zone exhibits no geologic evidence of prehistoric earthquakes larger than any historical event that has occurred within the zone." Whether or not the seismic zone exhibits such evidence is unknown because no paleoseismologist has searched the zone thoroughly for geologic evidence of large prehistoric earthquakes. It is true that no such geologic evidence in known, but that is a different statement than the one in the DSER.

Seismic Sources Defined by Regional Seismicity: The magnitudes of the New Madrid earthquakes of 1811-1812 are given as M7.1-M7.5. The statement is unclear because the magnitude scale and the source of these values are not specified. Usage of M in section 2.5.2 suggests that it stands for moment magnitude **M** or Mw. If so, this should be stated at the start of each pertinent section of the SER to avoid confusion. This is particularly the case in the CEUS, where smaller earthquakes are still characterized by body-wave magnitudes m_b or m_{bLg}.

Additionally, of the three current estimates of the three very large New Madrid magnitudes, none is clearly preferred: Hough and others (2000, J. Geophys. Res.) obtained Mw 7.0-7.5, Bakun and Hopper (2004, Bull. Seism. Soc. Am.) calculated Mw 7.5-7.8, and Johnston (1996, Geophys. J. Internat.) computed Mw 7.8-8.1. Each of these estimates has associated uncertainties. However, none is obviously the source of the stated "M7.1-M7.5".

2.5.1.3.2 Regional Tectonic Description

Paleozoic Tectonic Structures: Concerning the Augusta and Modoc fault zones, the DSER notes that "the observed mineralization of some brittle fabrics exposed at the surface … cannot form under modern-day geologic and hydrothermal conditions", as one argument that the fault zones' brittle fabrics are older than Quaternary. Actually, the mineralization could form in the site region today, and perhaps it is forming, but only at depths of several kilometers.

The key points are (1) the site region has been tectonically quiescent for tens of millions of years, (2) in such a stable tectonic environment, uplift and erosion are slow, (3) the mineral assemblages that form the brittle fabrics form at depths of several kilometers, and (4) probably the brittle fabrics that are now exposed at the surface formed several million years ago and took until now to make the long journey up to ground level. Therefore, those fabrics are too old to represent faulting that could impact hazard assessments.

Tertiary Tectonic Structures: Crone and Wheeler (2000, USGS OFR 00-260) do not mention the Yamacraw arch. The SSAR lists it with the Cape Fear arch but does not mention the Yamacraw arch again, beyond asserting that there is no evidence that it is active (SSAR p. 2.5.1-37 and -38). The SSAR correctly cites Crone and Wheeler (2000) as classifying the Cape Fear arch as Class C. Thus, the statement in the DSER that "based on Crone and Wheeler (2000), the applicant concluded that these features do not exhibit any evidence for Quaternary faulting" is incorrect because it should not apply to the Yamacraw arch. The applicant appears to be correct in dismissing the Yamacraw arch: literature searches with GeoRef, Google Scholar, and Google found no suggestions that the arch is active.

The DSER does not list any Open Items for section 2.5.1.

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Figure 2.5.2-1 is missing and the caption does not list the SSAR figure from which it might have been reproduced. Is 2.5.2-1 a modification of SSAR figure 2.5.1-12?

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Post-EPRI Seismic Source Characterization Studies: Open Item 2.5-2: I accepted the response to RAI 2.5.2-7, in which the applicant explained the decision not to use results of the TIP study in designing the PSHA. However, NRC investigated the matter more thoroughly and I agree with their decision to make it an Open Item.

Open Item 2.5-3: We raised some of the same objections to low Mmax values for the Eastern Tennessee Seismic Zone in our reply to the RAI responses. NRC has delved more deeply into the matter and their decision to make it an Open Item is a sound one. DSER Figure 2.5.2-11 suggests that higher Mmax values might increase the hazard very slightly at 10^{-4}, would make little or no difference at 10^{-5}, and might actually decrease the hazard at lower annual probabilities.

Updated EPRI Seismic Sources: Open Item 2.5-4: I originally had some of the same reservations about the RAI response that justified the use of a SSHAC Level 2 study. Since then, the NRC has investigated the matter more thoroughly. I agree with their decision to make it an Open Item pending resolution of the remaining questions.

Open Item 2.5-5: the Open Item correctly requests evidence that precludes large prehistoric earthquakes more than 50 km inland from the coast. In our reply to RAI response 2.5.2-8, we noted that the liquefaction record of an 1886-sized prehistoric earthquake would be uniquely identified by abundant, very large liquefaction craters or sand blows over an area the size of the 1886 meizoseismal area. The most direct and conclusive way to rule out that such an earthquake had occurred would be to examine numerous liquefiable deposits, which are spaced closely enough to reveal very large liquefaction features if they had been produced since formation of the deposits. Only S.F. Obermeier has done enough fieldwork in inland South Carolina to have made such observations. Only a quotation or letter from him could document such a search, could document the lack of abundant very large liquefaction features over a sufficiently large area, and could provide the evidence requested in the Open Item.

The DSER accepts the applicant's treatment of the 5 k.y. chronology of large earthquakes at Charleston. One question remains: whether the treatment is conservative, as stated in the applicant's response to RAI 2.5.2-12. The following example illustrates the question. The Charleston paleoseismic record is accepted as complete for the last 2 k.y., but it is of unknown completeness for 2-5 ka. The 2 k.y.-record yields a mean recurrence interval of 548 years and was assigned a weight of 0.8. The application assumed that the 5 k.y.-record is also complete and assigned it a weight of 0.2. The assumption of a complete 5-k.y. record yields a mean recurrence interval of 958 years for the last 5 k.y. The probability-weighted average of the two recurrence intervals is 630 years.

However, the record might be incomplete for 2-5 k.y. The response explains that the SSAR does not consider this possibility because the resulting recurrence interval would be very similar to the 548 years from 0-2 ka. The degree of similarity remains unclear. If the mean recurrence interval were the same during 2-5 ka as during 0-2 ka, it would be 548 years. The true completeness during 2-5 ka is unknown, so the 0.2 weight assigned to this part of the record can be split between one branch that assumes completeness, and a second branch that assumes incompleteness. For the branch that assumes incompleteness, assume that the true but unknown recurrence interval is 548 years during 2-5 ka, the same as during 0-2 ka. The standard treatment for weighting alternatives in the absence of evidence favoring either one is to assign equal weights. That treatment would assign the first branch a weight of 0.1; as already noted, this branch has a mean recurrence interval 958 years. The second branch would also be assigned a weight of 0.1; as assumed, this branch has a mean recurrence interval of 548 years. Therefore, the logic tree would have three branches with recurrence intervals of 548 years (weight 0.8), 958 years (0.1), and 248 years (0.1). The probability-weighted mean recurrence interval would be 589 years.

Does the difference between recurrence intervals of 630 years and 589 years matter? If not, then no additional explanation is needed and the DSER should remain unchanged on this point.

****

Comments on DSER Section 2.5.2 and Open Items 2.5-6 – 2.5-9
Reviewer: Charles Mueller, USGS
Date: 22 October 2007

Page	Comment
2-172	You might want to mention that modeled finite faults are confined inside the source zones in the Applicant's model - this obviously matters for sites near the boundaries, and might be important at Vogtle.
2-173	In the first paragraph it's not obvious to me what "default to the existing EPRI background zones" means – clarify?
2-173	Prose suggestion: add "using the original and updated catalogs" after "assessed seismicity rates for two sources in the site region". Also, the paragraph organization seems a bit choppy here. You might simplify by just saying original seismicity rates are the same or slightly conservative relative to the new catalog...?
2-173	Prose suggestion that might help the reader understand the EPRI ground motion models better: "... applicant combined nine estimates of median ground motion (three model cluster types, each with three alternate medians) with ..." and "... applicant combined 12 estimates of median ground motion (four model cluster types, each with three alternate medians) with four estimates of aleatory uncertainty, resulting in 48 combinations. These combinations represent epistemic uncertainty in the ground motion estimates."
2-174	It might be worth mentioning that the largest tabulated difference in the validation tests was 11.7% (85-percentile PGA, 100 cm/s^2 PGA), and that reasons for the differences are not discussed in the SSAR. [These differences have always seemed a bit high to me, but it may not be easy to exactly reproduce an old analysis.]
2-174	On p. 2.5.2-37 of the SSAR the Applicant states the the analysis was done "following the guidelines of RG 1.165, modified for use in calculating SSE spectra using a performance-based procedure." The phrase after the comma is important, and you might want to work it into the DSER.
2-174	The Charleston earthquake dominates the high- and low-frequency 10^-4 deaggregations (SSAR Figs. 2.5.2-22 and 23) and the lo-freq 10^-5 and lo-freq 10^-6 (Figs. 25 and 27). But local earthquakes contribute strongly for hi-freq 10^-5 (Fig. 24) and dominate for hi-freq 10^-6 (Fig. 26). There is no "similarity", at least for the last two. [Maybe these kinds of comments belong below under "Technical Evaluation...]

2-175 As above, since Charleston dominates for hi-freq 10^-4 and local eqs dominate for hi-freq 10^-6, there must be a reason other than "similarity" why "the Applicant selected a single Mbar and Dbar for each frequency range". [Charleston is not used to develop the high-freq spectra, even though it dominates the HF hazard at 10^-4. It's not clear to me what "controlling earthquake" means in this case, and the Applicant skates around this problem in the SSAR (e.g., top of p. 2.5.2-44). It's almost as if they are determined to find one HF and one LF controlling eq to simplify the analysis, but they don't say this explicitly. RG 1.165 doesn't help, because it specifies only one reference probability. I'm not sure if there's other guidance on this...]

2-175 Table 2.5.2-3 lists numbers like 39358", "39359", etc. where it should list "10^-4", "10^-5", etc. [I'm on a Mac; Rus sees the same problem on a PC.]

2-176 Wording in the first sentence in the "Site Response Model" section is confusing: (to paraphrase) a 1049-foot soil profile consists of 86 feet of Barnwell Group.

2-176 I get an underscore rather than a degree symbol on the Mac ("the Pen Branch fault dips to the southeast...")

2-176 Do you mean SSAR Figure 2.5.4-7 (last paragraph)?

2-177 The last paragraph before "Site Response Input Time Histories" seems like mostly a repeat of the previous paragraph.

2-177 As above, there is no "similarity of the calculated Mbar and Dbar values for the three hazard levels" for the HF case.

2-182 Equations 1 & 2 are not reproduced in my copy.

2-182 Section "Vertical GMRS", first paragraph: listed LF and HF controlling eqs are the same.

2-186 Middle of the page, end of the sentence beginning "Although some of the EPRI (misspelled) ESTs ...": the weighted mean Mmax value is missing.

2-186 Bottom of the page: "the Dames & Moore EST gave fairly low weights to some of its seismic source zones." Do you mean gave low weights to larger Mmax values? Reading further, I see that you probably wrote what you meant, but I wonder if you are adding confusion by bringing probability of activity into a discussion about Mmax.

2-187 I note that the USGS PSHAs are not explicitly mentioned as possible new information in the Mmax discussion (recognizing that they are based on Johnston's work). Just wondering if this is intentional...

2-194 Describe the other six curves in the figure?

2-213 I assume that "hazard curves for the six EPRI ESTs" refers to the updated models with geometry accommodating the UCSS, not the EPRI/SOG curves?

2-215 See comments above about lack of "similarity" of Mbar and Dbar in the high-frequency 10^-4, 10^-5, and 10^-6 deaggregations.

2-221 Do you mean RAI 2.5-19? Is there any response from the Applicant?

Comments on Open Items:

Open Item 2.5-6

I, too, struggled with the soil-response methodology as it was described in the SSAR. Simply as an exercise in calculation, I multiplied the hard rock spectral accelerations in Tbl 2.5.2-21 and the amp factors from Tbl 2.5.2-20 (average EPRI & SRS) for the high- and low-frequency ranges (I did not know how to do this for the envelope-transition range). I was able to reproduce some of the soil motions listed in Tbl 2.5.2-21 accurately, but not others (certainly not to three significant figures) - so I am missing something. I note that the hard-rock motions used to develop the amp factors (Tbl 2.5.2-20) are systematically greater then the hard rock motions used to compute the final soil motions (Tbl 2.5.2-21). Given nonlinear response of the soil this seems non-conservative, but, again, I am probably missing something. I have not seen the Applicant's response to RAI 2.5.2-19, so I can't directly comment on its adequacy, but I agree that the original description of the methodology in the SSAR was poor.

Open Item 2.5-7

I have used SHAKE as a black box, but I don't have any experience comparing fully-linear and equivalent-linear codes; I don't have the expertise to comment on the Open Item.

Open Item 2.5-8

I agree with the Staff that it's a good idea to request the hazard curves.

Open Item 2.5-9

I assume that the Lee (2001) and NUREG/CR-6728 studies are the only existing guidelines. By asking the Applicant to justify their use, is the Staff implicitly asking for a new site-specific V/H modeling study for the Vogtle site? Little would be gained from such an exercise in terms of known first-order differences in seismological structure between the SRS and Vogtle sites. The first-order regional feature is a section of young, low-Vs sediments above high-Vs bedrock, and, to my knowledge, the structure is not much different at Vogtle than at SRS. Shear waves "see" this contrast more than compressional waves, and the corresponding shear-wave resonance accounts for the V/H dip in the Lee spectrum near 0.4 Hz. Small velocity or depth differences will not change this story to first order; changing assumptions about Q or Vs in the sediments might have more effect, but these parameters are poorly-known, and unlikely to be much different at the two sites. How the Lee spectrum is enveloped is a separate question, and I agree that it is reasonable to ask the Applicant to justify the use of an envelope that falls below the peaks in the spectrum.

****

2.5.3 Surface Faulting

2.5.3.3.9 Potential for Nontectonic Deformation

The DSER, in discussing the response to RAI 2.5.3-2, states that "the applicant also stated that clastic dikes developed during a weathering event that is older than Late Pleistocene (i.e., greater than 10,000 years ago)." It is unclear whether 10,000 years refers to the minimum age of the weathering event or to the end of the Late Pleistocene.

Late Pleistocene time was 130-10 ka. Therefore, if “10,000 years ago” refers to the weathering event then the sentence is in error and should be corrected. If it refers to the end of the Late Pleistocene then the parenthetical expression should be reworded to avoid confusion. Later in the DSER, the same confusion arises from the phrase “earlier than Late Pleistocene (i.e., greater than 10,000 years in age)” in the second paragraph following numbered point 4.

Open Item 2.5-10: We asked the same question on the timing and origin of injection sand dikes in their reply to the RAI responses. I agree with making the question an Open Item.

Technical Letter Report to U.S. Nuclear Regulatory Commission
JSN J-3332, Task Order 1, Task number 6, TAC number MD3009/01675/001
Mechanical and Civil Engineering Branch, Division of Engineering, Office of Nuclear Reactor Regulation

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Does the difference between recurrence intervals of 630 years and 589 years matter? If not, then no additional explanation is needed and the DSER should remain unchanged on this point.

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Comments on DSER Section 2.5.2 and Open Items 2.5-6 – 2.5-9
Reviewer: Charles Mueller, USGS
Date: 22 October 2007

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Comments on Open Items:

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2.5.3 Surface Faulting

2.5.3.3.9 Potential for Nontectonic Deformation

The DSER, in discussing the response to RAI 2.5.3-2, states that "the applicant also stated that clastic dikes developed during a weathering event that is older than Late Pleistocene (i.e., greater than 10,000 years ago)." It is unclear whether 10,000 years refers to the minimum age of the weathering event or to the end of the Late Pleistocene.

Late Pleistocene time was 130-10 ka. Therefore, if “10,000 years ago” refers to the weathering event then the sentence is in error and should be corrected. If it refers to the end of the Late Pleistocene then the parenthetical expression should be reworded to avoid confusion. Later in the DSER, the same confusion arises from the phrase “earlier than Late Pleistocene (i.e., greater than 10,000 years in age)” in the second paragraph following numbered point 4.

Open Item 2.5-10: We asked the same question on the timing and origin of injection sand dikes in their reply to the RAI responses. I agree with making the question an Open Item.

science for a changing world

Technical Letter Report to U.S. Nuclear Regulatory Commission
JSN J-3332, Task Order 1, Task number 6, TAC number MD3009/01675/001
Mechanical and Civil Engineering Branch, Division of Engineering, Office of Nuclear Reactor Regulation

Review of Draft SER

ESP Application for the Vogtle Electric Generating Plant
Applicant: Southern Nuclear Operating Co.
Submitted by Russell L. Wheeler and Charles S. Mueller, USGS, 22 October, 2007

Introduction

This report contains the U.S. Geological Survey's (USGS's) review of the draft SER (DSER) written by Nuclear Regulatory Commission (NRC) staff. The review was restricted to sections 2.5.1-2.5.3 of the DSER, which deal with geology, seismology, and surface faulting, respectively.

Summary of Work Performed

The review is in three parts, each of which addresses one of the evaluated DSER sections 2.5.1-2.5.3. Each part consists of comments that are keyed to individual numbered subsections or pages of the DSER.

The review concentrates on geological and seismological matters that are likely to influence hazard computations. Wheeler reviewed the Technical Evaluation sections 2.5.1.3, 2.5.3.3, and parts of 2.5.2.3. Mueller reviewed all of section 2.5.2. Both addressed the Open Items. Accordingly, this report consists of Wheeler's comments, with Mueller's comments inserted between lines of asterisks at the end of the comments on section 2.5.2.

Evaluation

2.5 Geology, Seismology, and Geotechnical Engineering

2.5.1 Basic Geologic and Seismic Information

At several places the DSER cites Wheeler (2005), Wheeler (1996), or both. Wheeler did publish abstracts and papers in these years, but the texts surrounding the DSER citations suggest that the cited years might be incorrect. Possibly some of the citations refer to papers published in 1995 or 2006. Please verify the years given in the citations.

RAI 2.5.1-16 does not appear to be mentioned in the DSER. The RAI deals with the Steel Creek fault on the Savannah River site. The response to the RAI provided the requested information that indicates the fault is not capable.

2.5.1.1.1 Regional Geologic Description

Seismic Sources Defined by Regional Seismicity: In referring to the Eastern Tennessee Seismic Zone, the DSER states that "the zone exhibits no geologic evidence of prehistoric earthquakes larger than any historical event that has occurred within the zone." Whether or not the seismic zone exhibits such evidence is unknown because no paleoseismologist has searched the zone thoroughly for geologic evidence of large prehistoric earthquakes. It is true that no such geologic evidence in known, but that is a different statement than the one in the DSER.

Seismic Sources Defined by Regional Seismicity: The magnitudes of the New Madrid earthquakes of 1811-1812 are given as M7.1-M7.5. The statement is unclear because the magnitude scale and the source of these values are not specified. Usage of M in section 2.5.2 suggests that it stands for moment magnitude **M** or Mw. If so, this should be stated at the start of each pertinent section of the SER to avoid confusion. This is particularly the case in the CEUS, where smaller earthquakes are still characterized by body-wave magnitudes m_b or m_{bLg}.

Additionally, of the three current estimates of the three very large New Madrid magnitudes, none is clearly preferred: Hough and others (2000, J. Geophys. Res.) obtained Mw 7.0-7.5, Bakun and Hopper (2004, Bull. Seism. Soc. Am.) calculated Mw 7.5-7.8, and Johnston (1996, Geophys. J. Internat.) computed Mw 7.8-8.1. Each of these estimates has associated uncertainties. However, none is obviously the source of the stated "M7.1-M7.5".

2.5.1.3.2 Regional Tectonic Description

Paleozoic Tectonic Structures: Concerning the Augusta and Modoc fault zones, the DSER notes that "the observed mineralization of some brittle fabrics exposed at the surface … cannot form under modern-day geologic and hydrothermal conditions", as one argument that the fault zones' brittle fabrics are older than Quaternary. Actually, the mineralization could form in the site region today, and perhaps it is forming, but only at depths of several kilometers.

The key points are (1) the site region has been tectonically quiescent for tens of millions of years, (2) in such a stable tectonic environment, uplift and erosion are slow, (3) the mineral assemblages that form the brittle fabrics form at depths of several kilometers, and (4) probably the brittle fabrics that are now exposed at the surface formed several million years ago and took until now to make the long journey up to ground level. Therefore, those fabrics are too old to represent faulting that could impact hazard assessments.

Tertiary Tectonic Structures: Crone and Wheeler (2000, USGS OFR 00-260) do not mention the Yamacraw arch. The SSAR lists it with the Cape Fear arch but does not mention the Yamacraw arch again, beyond asserting that there is no evidence that it is active (SSAR p. 2.5.1-37 and -38). The SSAR correctly cites Crone and Wheeler (2000) as classifying the Cape Fear arch as Class C. Thus, the statement in the DSER that "based on Crone and Wheeler (2000), the applicant concluded that these features do not exhibit any evidence for Quaternary faulting" is incorrect because it should not apply to the Yamacraw arch. The applicant appears to be correct in dismissing the Yamacraw arch: literature searches with GeoRef, Google Scholar, and Google found no suggestions that the arch is active.

The DSER does not list any Open Items for section 2.5.1.

2.5.2 Vibratory Ground Motion

2.5.2.1 Technical Information in the Application

Figure 2.5.2-1 is missing and the caption does not list the SSAR figure from which it might have been reproduced. Is 2.5.2-1 a modification of SSAR figure 2.5.1-12?

2.5.2.3.2 Geologic and Tectonic Characteristics of the Site and Region

Summary of EPRI Source Zones: The DSER states the weighted mean of the EPRI EST's values of Mmax. The value of the weighted mean is not printed. Should it be Mw 6.0?

The caption of Figure 2.5.2-10 does not explain the magnitudes and plus-minus values shown in the figure. What about adding the following, or something like it? "The value of Mmax shown above each histogram is the USGS's preferred value for an early draft of their 2007 national seismic-hazard maps. The +/- 0.2 values are early estimates of uncertainties. They have since been replaced with logic trees that extend 0.2 units above the preferred values shown here and 0.4 units below, with highest probabilities being assigned to the preferred values." If this addition gets too far afield for the needs of the DSER, then the Mmax and +/- 0.2 values and the blue and red leader lines could just be deleted.

Open Item 2.5-1: We made the same two objections to low weights on high values of Mmax in our reply to the RAI responses, and agree with making both objections an Open Item.

Post-EPRI Seismic Source Characterization Studies: Open Item 2.5-2: I accepted the response to RAI 2.5.2-7, in which the applicant explained the decision not to use results of the TIP study in designing the PSHA. However, NRC investigated the matter more thoroughly and I agree with their decision to make it an Open Item.

Open Item 2.5-3: We raised some of the same objections to low Mmax values for the Eastern Tennessee Seismic Zone in our reply to the RAI responses. NRC has delved more deeply into the matter and their decision to make it an Open Item is a sound one. DSER Figure 2.5.2-11 suggests that higher Mmax values might increase the hazard very slightly at 10^{-4}, would make little or no difference at 10^{-5}, and might actually decrease the hazard at lower annual probabilities.

Updated EPRI Seismic Sources: Open Item 2.5-4: I originally had some of the same reservations about the RAI response that justified the use of a SSHAC Level 2 study. Since then, the NRC has investigated the matter more thoroughly. I agree with their decision to make it an Open Item pending resolution of the remaining questions.

Open Item 2.5-5: the Open Item correctly requests evidence that precludes large prehistoric earthquakes more than 50 km inland from the coast. In our reply to RAI response 2.5.2-8, we noted that the liquefaction record of an 1886-sized prehistoric earthquake would be uniquely identified by abundant, very large liquefaction craters or sand blows over an area the size of the 1886 meizoseismal area. The most direct and conclusive way to rule out that such an earthquake had occurred would be to examine numerous liquefiable deposits, which are spaced closely enough to reveal very large liquefaction features if they had been produced since formation of the deposits. Only S.F. Obermeier has done enough fieldwork in inland South Carolina to have made such observations. Only a quotation or letter from him could document such a search, could document the lack of abundant very large liquefaction features over a sufficiently large area, and could provide the evidence requested in the Open Item.

The DSER accepts the applicant's treatment of the 5 k.y. chronology of large earthquakes at Charleston. One question remains: whether the treatment is conservative, as stated in the applicant's response to RAI 2.5.2-12. The following example illustrates the question. The Charleston paleoseismic record is accepted as complete for the last 2 k.y., but it is of unknown completeness for 2-5 ka. The 2 k.y.-record yields a mean recurrence interval of 548 years and was assigned a weight of 0.8. The application assumed that the 5 k.y.-record is also complete and assigned it a weight of 0.2. The assumption of a complete 5-k.y. record yields a mean recurrence interval of 958 years for the last 5 k.y. The probability-weighted average of the two recurrence intervals is 630 years.

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