## LeeRAIsPEm Resource

**From:** Brian Hughes
**Sent:** Wednesday, December 03, 2008 10:40 AM
**To:** LeeRAIsPEm Resource
**Subject:** RAI LETTER NO. 055 RELATED TO SRP 02.05.02 FOR THE WILLIAM STATES LEE III UNITS 1 AND 2 COL
**Attachments:** LEE-RAI-LTR-055.doc

Brian Hughes
Project Manager
NRO/DNRL/NWE1
US NRC
301-415-6582

**Hearing Identifier:** Lee_COL_RAI
**Email Number:** 63

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**Subject:** RAI LETTER NO. 055 RELATED TO SRP 02.05.02 FOR THE WILLIAM STATES LEE III UNITS 1 AND 2 COL
**Sent Date:** 12/3/2008 10:40:28 AM
**Received Date:** 12/3/2008 10:40:51 AM
**From:** Brian Hughes

**Created By:** Brian.Hughes@nrc.gov

**Recipients:**
"LeeRAIsPEm Resource" <LeeRAIsPEm.Resource@nrc.gov>
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December 3, 2008

Mr. Peter S. Hastings, P.E.
Licensing Manager, Nuclear Plant Development
Duke Energy
526 South Church Street
Charlotte, NC 28201-1006

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 055 RELATED TO SRP 02.05.02 FOR THE WILLIAM STATES LEE III UNITS 1 AND 2 COMBINED LICENSE APPLICATION

Dear Mr. Hastings:

By letter dated December 12, 2007, as supplemented by letters dated January 28, 2008, February 6, 2008 and February 8, 2008, Duke Energy submitted its application to the U. S. Nuclear Regulatory Commission (NRC) for a combined license (COL) for two AP1000 advance passive pressurized water reactors pursuant to 10 CFR Part 52. The NRC staff is performing a detailed review of this application to enable the staff to reach a conclusion on the safety of the proposed application.

The NRC staff has identified that additional information is needed to continue portions of the review. The staff's request for additional information (RAI) is contained in the enclosure to this letter.

To support the review schedule, you are requested to respond within 30 days of the date of this letter. If changes are needed to the final safety analysis report, the staff requests that the RAI response include the proposed wording changes.

If you have any questions or comments concerning this matter, you may contact me at 301-415-6582.

Sincerely,

/**RA**/

Brian Hughes, Senior Project Manager
AP1000 Projects Branch 1
Division of New Reactor Licensing
Office of New Reactors

Docket Nos. 52-018
52-019

Enclosure:
Request for Additional Information

CC: see next page

If you have any questions or comments concerning this matter, you may contact me at 301-415-6582.

Sincerely,

/**RA**/

Brian Hughes, Senior Project Manager
AP1000 Projects Branch 1
Division of New Reactor Licensing
Office of New Reactors

Docket Nos. 52-018
52-019

eRAI Tracking No. 1244

Enclosure:
Request for Additional Information

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*Approval captured electronically in the electronic RAI system.

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Request for Additional Information No. 1244

12/3/2008

William States Lee III, Units 1 and 2
Duke Energy Carolinas, LLC
Docket No. 52-018 and 52-019
SRP Section: 02.05.02 - Vibratory Ground Motion
Application Section: 2.5.2

QUESTIONS for Geosciences and Geotechnical Engineering Branch 2 (RGS2)

02.05.02-6

On April 30, 2008, you submitted a letter to the NRC along with an enclosed report that details the methodology used to develop the horizontal and vertical site-specific hazard consistent UHRS at the Lee Unit 1 site. The purpose of this report is to supplement information presented in FSAR Section 2.5.2.7 “Development of FIRS for Unit 1”.

Please reference this report in the appropriate subsection in your next FSAR Revision.

02.05.02-7

In Section 2.1 of Enclosure 1 (submitted April 30, 2008), the following statement is made regarding RVT durations:

> For both applications, i.e. estimating spectral accelerations and peak particle velocities as well as peak shear-strains, durations are taken as the inverse of the source corner frequency (Boore, 1983) with a distance dependent term to accommodate the increase in duration due to wave scattering (Herrmann, 1985).

The duration inverse to the source corner frequency corresponds to the duration of one wave (e.g., S-). The correction of Herrmann (1985)

$$T = 1/fc + 0.05R$$

is supposed to take into account an increase in duration due to the appearance of surface waves. The above formula (used by the applicant and shown in Table 2 of Enclosure 1) is relatively simplistic and does not take into account the source depth or additional factors. In addition, strong motion records include P-waves that usually have more high frequency content than S- and surface waves.

a.) Please provide examples and/or references that demonstrate an adequate comparison of duration of actual strong-motion time histories with those modeled by Boore (1983) method with Herrmann (1985) correction.

There are also limitations on the low-frequency portion of the spectra. Boore and Joyner (1984) specifically addressed the issue of duration for calculation of response spectra when period of oscillator is longer than the duration of record (i.e. reaction of SDF can be longer than the duration used).

b.) Please provide more information on calculation of the low frequency part of the response spectra that can potentially be affected by non-adequate duration.

02.05.02-8

Table 2 of Enclosure 1 (submitted April 30, 2008), relating to FSAR Figure 2.5.2-221, lists the point-source model parameters and durations used in developing site-specific V/H ratios.

Please provide more information on this table. Specifically, please explain why parameters are identical at 1.50 and 1.25 PGA.

02.05.02-9

Paragraph 2 of Section 2.1.1 of the Enclosure 1 report, describes the process for integrating the PSD. The following statement is made regarding the integration range used for the Lee Unit 1 site:

> To integrate the PSD, numerical integration is performed rather than analytical integration, as the PSD includes site response in addition to FAS of the simple point-source model. Because the PSD is reasonably smooth, a simple and rapid Simpson's three-point scheme is implemented but with a very dense sampling to fully accommodate the presence of peaks and troughs. Typically (e.g. Lee Nuclear Station Unit 1) 25,000 points are used from 0.007 Hz (about 150 sec) to 150 Hz. The wide integration rate is to ensure inclusion of potential high- and low-frequency amplification. Additionally, the RMS is sensitive to the integration over low-frequency so it is prudent to extend its range to at-least an order of magnitude below the lowest frequency of interest, 0.1 Hz for nuclear applications (e.g. Lee Nuclear Station Unit 1).

Data used in strong motion seismology are based on records obtained using film (mostly SMA-1) or digital (SSA-2, Etna, and others) accelerographs. Older-style film instruments had typical flat frequency response characteristics from DC to 20-25 Hz. The new generation digital accelerometers have flat frequency response characteristics that range from DC to either ~50 or ~100 Hz. The sampling rate of strong motion records used by the USGS or CGS networks (the main sources for strong motion data in the U.S.) is 200 samples/sec. Combining those parameters limits the reliable frequency response of existing data to 100 Hz at the most, for the high-frequency end.

Almost all existing data are processed with the low-frequency cut-off filter of 0.1 Hz or higher (10 second period or lower). Usually it is a 4-pole Butterworth filter. The most recent PEER NGA database contains a very limited number of data confident up to 10 sec, with most data confident up to 5 sec-period (0.2 Hz).

As a result, the confident frequency response of strong motion data in current databases varies from 0.2 to 25 Hz (typical for film instruments) to 0.1 to 100 Hz (typical for digital instruments). The frequency band used by the applicant is much beyond those limits: 0.007 to 150 Hz.

Please clarify what procedures are used to extend the frequency band to such values. How are you confident that results from frequencies 0.007 to 150 Hz (well beyond the confidence level of strong-motion recordings) are reliable and not contaminated by noise? If your response is based on theoretical results, please provide information on constrains at both low and high frequency ends of the spectrum, and validation of your model at both low- and high-frequency ends beyond the empirical data.

02.05.02-10

Paragraph 1 of Section 2.1.2 of the Enclosure 1 report states that for application to transfer functions differences in response spectra due to different corrections at low-frequency are cancelled through taking ratios.

Please clarify why corrections to the duration of the time series (time domain) can be cancelled by taking ratios (frequency domain). Please clarify if response (not Fourier) spectral ratios are used.

02.05.02-11

Paragraph 2 of Section 2.1.2 of the Enclosure 1 report states the following:

> In typical WNA and CENA, source durations scale with magnitude (M) such that for M 5, 6, and 7, durations are approximately 1, 3, and 9 seconds respectively. As a result, corrections only become important for oscillator periods below 1,3, or 9 seconds, depending on the magnitude used in generating the transfer functions.

The correction elongates duration of the time history, therefore the correction is important for oscillator periods longer than the ground motion duration. Please provide additional information to justify your statement. Maybe it is just a typo?

02.05.02-12

Paragraph 3 of Section 2.1.2 of the Enclosure 1 report states the following regarding figure 1 of the report:

> Figure 1 shows an example comparison using 30 time histories from a finite fault simulation reflecting randomly selected model parameters (e.g. slip model, nucleation point, shear-wave velocity profiles etc.)

Figure 1 of the report shows only response spectra, not time series. Please provide example comparisons of simulated records with actual earthquake time series from appropriate magnitude and distances in order to demonstrate reliability of method.

02.05.02-13

Paragraph 3 of Section 2.2 of the Enclosure 1 report states the following:

> The vertically propagating shear-wave approach cannot successfully model amplitudes to arbitrary long periods at deep soil sites at large source distances, as this formulation does not consider horizontally propagating surface waves. It is not clear, however, under what circumstances (profile depth, source size and distance, and structural frequency) the 1D vertically propagating shear-wave model would result in unconservative motions. Validation exercises consisting of modeling recorded motions using the 1D approximation at deep soil sites in tectonically active regions suggest the simple model performs well in terms of spectral amplitudes to periods of at least several seconds (EPRI, 1993; Silva et al., 1997; Hartzell et al., 1999), periods long enough to accommodate nuclear facilities.

You state that validation exercises were performed. You also state that it is not clear under what circumstances the 1D vertically propagating shear-wave model would produce unconservative results. These statements appear contradictory. Please provide specific information on the limitations of applying the 1D approximation in Approach 3.

02.05.02-14

The last sentence in paragraph 3 of Section 2.2 in the Enclosure 1 report says:

> The stacking (averaging) of responses necessary to achieve stability over multiple input time histories (all matched to the same control motion spectrum) renders the time domain (SHAKE) approach difficult to properly develop fully probabilistic response spectra.

It is not clear if you are discussing Approach 2B, although it appears that you are. However, Approach 2B is shown to work well with a large enough number of realizations (60). It is also transparent. Please clarify the approach being discussed.

02.05.02-15

Paragraph 5 of Section 2.2 (Enclosure 1 report) discusses the potential for double-counting of variability when developing amplification factors using a time domain procedure. The additional variability (frequency-to-frequency and record-to-record variability in the computed soil response due to time history propagation) reflects a double-counting since this is intrinsically included in the ground motion prediction equations (GRMPEs) used to develop the reference PSHA. This conclusion may be a true for the western U.S. where the GRMPEs are based almost entirely on recorded data that does contain this variability. However, it is not clear if this is true for CEUS GRMPEs that are based almost entirely on simulations using point-source models, RVT, and fixed values of kappa. Please provide clarification on this point.

02.05.02-16

Paragraph 1 of Section 2.2.1 “Amplification Factors” of the Enclosure 1 report needs further clarification. Paragraph 1 states the following:

> The correlation and layering model prevents unconservative profile realizations with uncorrelated velocity fluctuations over depth resulting in increased effective overall damping due to wave scattering at impedance boundaries (scattering kappa). This condition is exacerbated at high loading levels due to nonlinearity, concentrating shear strain in low velocity layers. As a check on this possibility it is important to compare the median response spectrum over multiple realizations with that from a single analysis with base-case properties, at low (linear) loading levels. If the median spectrum falls below that computed using the base-case dynamic material properties at high frequency by more than about 5%, a significant amount of scattering kappa has been added in the velocity randomization, resulting in an overall larger kappa value than desired and uncoservative high-frequency motions at low loading levels. This should be then compensated by appropriately lowering the kappa value in the control motions, another advantage of using a point-source model to generate control motions as it is not an unambiguous endeavor to adjust control motions developed from attenuation relations of spectral shapes (NUREG/GR-6728) for lower (or larger) kappa values.

a.) In the above discussion you suggest lowering the kappa value in the control motions to compensate for the shortcomings of the randomization. Please specify what kappa value was used and the quantitative rationale for using this value. Also, please provide references.

b.) You suggest the correlation and layering model as a means to prevent unconservative profile realizations. You then discuss a means of checking for unconservative realizations in the profile. The process of checking for unconservative profiles is different from the process of preventing the unconservative profiles. Please provide a description of the preventative aspects of the model rather than just the secondary check for unconservative realizations in the profile.

c.) Please discuss any physical reason why profiles with significant “scattering kappa” should not exist in the real world. If there are physical limitations, then does the correlation and layering model generate unrealistic profiles? If there are no physical limitations, then are the motions only being modified so as to be conservative?

d.) Please explain if the results are consistently conservative. If the strains within the layers change with the modification of the control motion, then the site amplification will occur at different frequencies. This change in the frequency of amplification may result in conservatism at some frequencies, and unconservatism at other frequencies.

e.) If the correlation and layering model generates problematic profiles, then the correction should be made to the layering model, not the motion. How is the kappa adjusted? Is it specific for each site realization? In the calculation of the spectral ratio, is the ratio between the “corrected” surface and the “uncorrected” bedrock, or the “corrected” surface and the “corrected” bedrock?

02.05.02-17

Paragraph 3 of Section 2.2.1 of the Enclosure 1 report discusses perturbation tapering at the ends of the modulus reduction and damping curves in order to preserve the shape of the base-case curves.
Please clarify the following:
a) what causes these perturbations,
b) what type of tapering was used and the length of the tapering windows.

02.05.02-18

Paragraph 3 of Section 2.2.1 (Enclosure 1 report) states the following:

> Empirical sigma values, based on laboratory test of materials of the same general type (e.g. gravely sands) such that the $G/G_{max}$ and hysteretic damping curves would be applied over depth ranges which boring logs or laboratory index property tests indicate are appropriate, are 0.15 ($\sigma_{ln}$) and 0.30 ($\sigma_{ln}$) for modulus reduction and hysteretic damping respectively.

Please provide a reference for this assumption.

02.05.02-19

The last sentence of Paragraph 1, Section 2.2.2 (Enclosure 1 report) suggests the development of amplification factors using both single and double-corner models and combining results with the same weights used in the development of the reference PSHA. This will require a detailed assessment of the different sub-models used in the development of the reference PSHA (assuming use of the 2004 EPRI GMPE where the weights for single and double-corner models vary for source types (i.e. general area sources vs. non-general area sources)). Please provide a discussion of how this GMPE deaggregation would be performed.

02.05.02-20

Section 2.2.2 “Control Motions” of the Enclosure 1 report does not specifically describe the methods applied to the Lee site. Please describe what models were used, whether point-source, single- or double- corner, or a combination. Please describe the weighting factors used for the Lee COLA site.

02.05.02-21

Paragraph 2 of Section 2.2.2 “Control Motions” of the Enclosure 1 report states that “Use of the point-source models is computationally efficient as it avoids intermediate step of spectral matching to the empirical spectra, which are not well constrained for all M at distances exceeding about 100 km.”

Please clarify that computational effectiveness of using point-source model instead of empirical spectra does not compromise the reliability of results.

02.05.02-22

Section 2.2.2.1 of the Enclosure 1 report discusses spectral shape effects. Please clarify if the shape of the control motion spectrum discussed in this section is applicable to the Lee site where Vs is approximately 9300 ft/sec overlaid by ~20 ft of concrete with Vs of 7500 ft/sec. Please provide additional information in regards to the nonlinear model used and how it is constrained in the linear portion as applicable at the Lee site.

02.05.02-23

Paragraph 3 of Section 2.2.2.1 of the Enclosure 1 report discusses Figure 3 of the report. The figure shows an example of median and ± 1 sigma estimates of amplification factors computed for a deep soil site in the CENA. The figure is used to illustrate the effects of control motion loading level on amplification factors. Based on the figure:

- At frequencies higher than 2 Hz amplification decreases as loading levels increase
- Deamplification reaches 0.2 at about 30 Hz.

According to empirical attenuation relations available through 1997, the minimum amplification is observed at about 0.5. You chose to implement the 0.5 minimum value instead of the minimum value (0.2) shown in figure 3 of the report.

You explained the difference between the empirical and model results as possibly being the result of using equivalent-linear approximation with a single value of S-wave velocity and damping at all frequencies. However, it seems that using a fully non-linear model can result in even larger deamplification. Please provide more explanation about these differences and possibly the need to modify the model.

02.05.02-24

The discussion on Approach 3 in Section 3.1 of the Enclosure 1 report states that frequency dependent amplification factors, accounting for non-linearity in soil response, characterize site-specific amplification. Please provide additional information and justification for the nonlinear model that you used.

02.05.02-25

The last paragraph of the Approach 3 discussion in Section 3.1 (Enclosure 1 report) describes two ways to implement Approach 3.

a.) Please explain why both methods of Approach 3 implementation double count site aleatory variability.

b.) Please explain the rationale for why corrections for the site component aleatory variability result in a 5-10% reduction in motion.

02.05.02-26

Paragraph 5 of Section 2.2 (Enclosure 1 report) asserts that using an RVT approach properly neglects the frequency-to-frequency and record-to-record variability and avoids double-counting of these variabilities in computed site response (relative to the time-domain approach). This statement seems to be at odds with the following conclusion from Section 3.1 which describes the two methods for implementation of Approach 3:

> Both implementations result in very similar site-specific hazards (Cramer, 2003) and both will tend to double count site aleatory variability, once in the suite of transfer function realizations and again in the aleatory variability about each median attenuation relation.

Please provide a discussion that clarifies this inconsistency.

02.05.02-27

Section 3.4.1 “Optimum Number of Realizations” of the Enclosure 1 report cites a paper by Bazzuro and Cornell (2004) which suggests that as few as 10 realizations are enough to satisfy the Approach 3 application. However, you state that Table 3 (from the report) suggests that in order to improve the accuracy in aleatory variability to 10%, 130 realizations are required at the 90% confidence level. Please provide further explanation as to why such differences exist in the number of suggested realizations, 10 by Bazzuro and Cornell to 130 as stated in your report.

02.05.02-28

Paragraph 2 of Section 3.4.1 (Enclosure 1 report) states the following:

> Clearly, for application of fully probabilistic approaches to developing site-specific hazard, the number of realizations should be case specific and determined with preliminary analysis.

Please provide further explanation for justifying your recommendation and explain how “case specific” realizations apply specifically to the Lee site. Does it also mean that 130 realization recommended before may not be enough in certain cases?

02.05.02-29

Table 2 of the Enclosure 1 report, which relates to FSAR Table 2.5.2-221, shows ranges of amplitude, magnitude and distance. Please provide additional discussion of how these ranges are developed. In particular, please explain the relationship between Table 2 of the report and the deaggregation results shown on report Figure 16 and in section 4.1 in a more transparent fashion. Why Table 2 reflects only magnitude 5.1?

02.05.02-30

Paragraph 2 of Section 2.2.2.1 (Enclosure 1 report) discusses the magnitude dependency of amplification factors and the guideline for discretization of reference disaggregation to ~one-half magnitude unit. This is consistent with the results shown in report Figure 16. However, the magnitude used in Table 2 is M 5.1 which is not consistent with report Figure 16. Please provide a discussion of the basis for M 5.1 vs. M 5.25. Also, the last sentence in this paragraph discusses the use of the mode vs. mean ("Use of the mode is clearly more appropriate than the mean, even though there is rarely a single peak over magnitude."). Please provide a discussion and rationale for this conclusion and outline how the situation with multiple nearly equal modes in the disaggregation results will be handled in the development of amplification factors using Approach 3.

02.05.02-31

Paragraph 4 of Section 4.2.1 "Site-Specific V/H Ratios" (Enclosure 1 report) discusses validation exercises relating to the 1989 Loma Prieta and 1992 Northridge earthquakes. The Northridge earthquake occurred in 1994. The Landers earthquake occurred in 1992. Please specify which earthquake is actually being discussed.

02.05.02-32

Paragraph 5 of Section 4.2.1 "Site-Specific V/H Ratios" (Enclosure 1 report) states that a hard rock kappa value of 0.0003 seconds is used for the vertical analyses. Please provide justification for using this value, including any references.

02.05.02-33

Paragraph 1 of Section 4.2.2 "Empirical V/H Ratios" (Enclosure 1 report) states the following:

> The relative weights listed in table 4 reflect the assumed appropriateness of WNA soft rock empirical V/H ratios for Unit 1.

a.) Please provide rational for using soft rock V/H ratios from WNA for Unit 1?

b.) Most sites in California are characterized by much lower S-wave velocities. Please clarify what soft rock means in terms of shear-wave velocity. Is it ~760 m/sec (B-C boundary)?

02.05.02-34

In Table 4 of the Enclosure 1 report, the weight assignments are not clear. Nonlinearity is cited in a number of places through the report. In mean time, there is a number of different nonlinear models. Please provide graphs showing dependency of site amplification on PGA, and for a few SAs. Please provide similar graphs showing dependencies upon shear-wave velocity in order to better understand the model. Please clarify consistency of the model with known seismological data on nonlinearity which was not observed for accelerations less than 0.2g.