December 8, 2008

Mr. Thomas L. Williamson
Manager, GGNS COLA Project
Entergy Nuclear
1340 Echelon Parkway
Jackson, MS 39213

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 26 RELATED TO SRP SECTIONS 2.5.1-2.5.5 FOR THE GRAND GULF COMBINED LICENSE APPLICATION

Dear Mr. Williamson:

By letter dated February 27, 2008, Entergy Operations Incorporated (EOI) submitted for approval a combined license application pursuant to 10 CFR Part 52. The U. S. Nuclear Regulatory Commission (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 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, I can be reached at 301-415-2890 or by e-mail at Andrea.Johnson@nrc.gov.

Sincerely,

/RA/

Andrea M. Johnson, Project Manager
ESBWR/ABWR Projects Branch 1
Division of New Reactor Licensing
Office of New Reactors

Docket No. 052-0024

Enclosure:
Request for Additional Information

December 8, 2008

Mr. Thomas L. Williamson
Manager, GGNS COLA Project
Entergy Nuclear
1340 Echelon Parkway
Jackson, MS 39213

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 26 RELATED TO SRP SECTIONS 2.5.1-2.5.5 FOR THE GRAND GULF COMBINED LICENSE APPLICATION

Dear Mr. Williamson:

By letter dated February 27, 2008, Entergy Operations Incorporated (EOI) submitted for approval a combined license application pursuant to 10 CFR Part 52. The U. S. Nuclear Regulatory Commission (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.

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Sincerely,
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Andrea M. Johnson, Project Manager
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Docket No. 052-0024
Enclosure:
Request for Additional Information

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NAME	YLi	CMunson	AJohnson	MCarpentier	AJohnson
DATE	11/18/2008	11/19/2008	11/19/2008	11/24/2008	12/05/08

***Approval captured electronically in the electronic RAI system.**

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Grand Gulf, Unit 3 COLA
Entergy Operations, Inc.
Docket No. 52-024
SRP Sections: 02.05.01 - 02.05.05
Application Sections: 2.5.1 – 2.5.5

QUESTIONS for Geosciences and Geotechnical Engineering Branch 2 (RGS2)

02.05.01-1

Section 2.5.1.2.3 describes the subsurface stratigraphy at the Unit 3 site. FSAR Table 2.5.1-201 indicates that the ace deposits defined during Unit 1 investigation include both Lower Loess and Upland Alluvium. However, in the Lower Loess description (page 12), FSAR states that "comparison of GGNS boring logs with Unit 1 FSAR borehole logs suggests that the Lower Loess may be discontinuous in the GGNS site vicinity and laterally restricted a the GGNS site between the Mississippi River bluff and west of Unit 1." The combined average thickness for these two layers is about 50 feet. Please explain the discrepancy between the table and the text description, and explain why these two layers only exist beneath the Unit 3, and what kind of contacts between these layers and the surrounding stratigraphic layers.

02.05.01-2

Please explain the differences between the profiles shown in Figures 2.5-1-217 (FSAR) and 2.5-31 (SSAR) in terms of layer thickness and control borings. In addition, please explain why some of the boring logs were included in constructing the SSAR site geological profiles but not included in the FSAR profiles, for example, B -16 on Figure 2.5-77 and Figure 2.5-31 (SSAR), but not on Figure 2.5.1-217 (FSAR).

02.05.02-1

FSAR Section 2.5.2.4.3 explains the updates of the maximum magnitude (Mmax) for the EPRI seismic source zone covering part of the Gulf of Mexico. Provide a description of the procedure you used to revise the EPRI SOG source parameters. In particular, describe the level of the SSHAC process and provide documentation on the different expert opinions and how the Technical Integrator reached a consensus.

02.05.02-2

Paleoliquefaction features in southeastern Arkansas and northeastern Louisiana indicate that potential new seismogenic sources may exist (e.g., Al-Shukri et al, 2005; Cox et al., 2004; Cox, personal communication; Tuttle et al., 2006 as noted in your application). Please explain if those new sources will potentially impact the seismic hazard at the site, including their impact on the EPRI-SOG seismic source models.

Enclosure

02.05.02-3

In the last 15 years, there is wider recognition that seismicity migrates within crustal zones over periods of thousands to tens of thousands of years (e.g., Nelson et al., 1999; Schweig and Ellis, 1994; Coppersmith, 1988). Please explain how this might apply to seismic hazard estimate for the site region.

References:

"Quaternary grabens in southernmost Illinois — Deformation near an active intraplate seismic zone," Tectonophysics, Volume 305, pp. 381-397, Nelson, W.J., Denny, F.B., Follmer, L.R., and Masters, J.M., 1999.

"Temporal and spatial clustering of earthquake activity in the central and eastern United States," Seismological Research Letters, Volume 59, pp. 299-304, Coppersmith, K.J., 1999.

"Reconciling short recurrence intervals with minor deformation in the New Madrid seismic zone," Science, Volume 264, pp. 1308-1311, Schweig, E.S., and Ellis, M.A.,1994.

02.05.02-4

In calculating site response SSAR uses laboratory soil dynamic test results on damping ratio and modulus reduction curves. In contrast, for the site response calculation in the FSAR, you used another set of soil dynamic curves which were based on the ratio of laboratory (at in-situ confining pressure) -to-field shear wave velocities. Please explain what caused the change and justify why this empirical correction can correct sample disturbance.

02.05.02-5

The FSAR discussed the change introduced since the SSAR was released and states that the GMRS for Unit 3 was developed in accordance with RG1.208 using an updated seismic source model and revised ground motion attenuation information. RG 1.208 specifies the performance based approach, which estimates GMRS by scaling 10^{-4} mean UHRS by a Design factor based on the hazard curve slope between 10^{-4} and 10^{-5}. However, the staff did not find the calculation of DF in the FSAR. Please provide the corresponding description and calculation.

02.05.02-6

You stated in Section 2.1 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra), "*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. 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). Please provide more information on calculation of the low frequency part of the response spectra that can potentially be affected by non-adequate duration.

02.05.02-7

Table 2 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) lists point-source model parameters and durations used in developing rock motion input for ground motion analysis for the Grand Gulf site response analysis. Please explain how these data are developed, specifically, delta sigma, T source, and T path. In addition, please explain how to treat magnitude 6-7 earthquakes using a point source model at close source-to-site distances.

02.05.02-8

Paragraph 1 of Section 2.1.2 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) 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. Please clarify if response (not Fourier) spectral ratios are used.

02.05.02-9

Paragraph 5 of Section 2.2 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) discusses the potential for double-counting of variability when developing amplification factors using a time domain procedure. The additional variability (frequency-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 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.

02.05.02-10

Paragraph 1 of Section 2.2.1 in the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) “Amplification Factors” 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 unconservative 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 suggested 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 suggested the correlation and layering model as a means to prevent unconservative profile realizations. You then discussed 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?

02.05.02-11

Paragraph 3 of Section 2.2.1 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) 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.

02.05.02-12

Paragraph 3 of Section 2.2.1 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) 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 (σ_{ln}) and 0.30 (σ_{ln}) for modulus reduction and hysteretic damping respectively.

Please provide a reference for this assumption.

02.05.02-13

Paragraph 2 of Section 2.2.2 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) 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.

02.05.02-14

The last paragraph of the Approach 3 discussion in Section 3.1 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) 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.

02.05.02-15

Section 3.4.1 “Optimum Number of Realizations” of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) cites 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.

02.05.02-16

Paragraph 2 of Section 3.4.1 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) 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 justify your recommendation and explain how “case specific” realizations apply specifically to the GGNS site. Does it also mean that 130 realization recommended before may not be enough in certain cases?

02.05.02-17

The last sentence in the paragraph 2 of Section 2.2.2.1 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) 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.

02.05.02-18

Paragraph 5 of Section 4.1.1 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) “Site-Specific V/H Ratios” states that a hard rock kappa value of 0.002 seconds is used for the vertical analyses. Please provide justification for using this value, including any references.

02.05.02-19

Paragraph 1 of Section 4.2.2 of the Supplemental Report (Entergy Letter No. CNRO-2008-00020, Supplemental Information Regarding Methodology Used to Develop Horizontal and Vertical Site-Specific Hazard Consistent Uniform Hazard Response Spectra) “Empirical V/H Ratios” states the following:

“The relative weights between WNA soft rock and deep firm soil were based on judgment regarding overall stiffness between WNA soft rock and soil sites and the four embedment profiles.

a.) Please provide rational for the judgment on the relative weights.

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?

02.05.02-20

Please deaggregrate seismic hazard at different exceedance levels with respect to epsilon (ε) values. In addition, please explain why the controlling earthquakes obtained during the COL application are different from the EPRI SOG controlling earthquakes (NUREG 6606) and which controlling earthquake you used as a high frequency controlling earthquake.

02.05.03-1

Please explain the “correction” that was made to the following statement on FSAR page 102 (Section 2.5.3.3) in comparison to SSAR, “[t]wo salt diapirs, the Bruinsburg salt dome and the Galloway salt dome, are within approximately 8.5 miles to the southwest and northeast of the site, respectively (Figure 2.5-9).”

02.05.04-1

FSAR Section 2.5.4.1.1 “Surface and Subsurface Subsidence and Unrelieved Bedrock Stresses” states that operation of industrial radial makeup water wells on the east shoreline of the Mississippi River has caused no subsidence or adverse impacts to the stability of the strata below the Unit 3 power-block area. Please provide the information or evidence that this conclusion is based on.

02.05.04-2

Section 2.5.4.1.7 “Rock and Soil Stability with Respect to Mineralogy, Water Content, Creep, and Seismic Response” indicates that the bluff on the western and northern sides of the site shows evidence of surficial soil creep. FSAR Figure 2.5.1-202 shows that the colluvium (Qc) accumulated at the base of the bluff, which may indicate loess slope instability. Please estimate the slope creep rate and explain how this creeping would potentially impact the lateral stability of the facility against seismic motions. Also, explain if you are planning on implementing a long term in-situ (real-time) monitoring program to monitor the geological stability of the bluff.

02.05.04-3

Section 2.5.4.2.2.1.2 “Upper Loess,” discusses the potential collapse of the Upper Loess. Considering the potential for high water level at the site, possibly caused by the maximum flood water level or extreme rainfall, please provide detailed information on (1) how the variability of effective stress of the loess was considered in analyzing the bluff slope stability and the soil-structure interaction when the loess becomes saturated; and (2) the impact of the backfill to the integrity of the surrounding loess and to the ground water level due to the potential change in hydraulic conductivity.

02.05.04-4

FSAR Tables 2.5.4-203 and 2.5.1-203 summarize the geologic and engineering properties of the subsurface materials beneath Unit 3 site based on sample inspection, CPT and laboratory test results. Subsections 2.5.4.2.2.1.2, 2.5.4.2.2.1.3, 2.5.4.2.2.1.4, and 2.5.4.2.2.1.5 also provide some soil parameters. Please explain the difference between the values listed in the tables and presented in the text, such as internal friction angle, undrained shear strength, and SPT N-values.

02.05.04-5

Please explain why the permeability values provided in FSAR Table 2.5.1-203 are different from those provided in FSAR Section 2.4.12.2.4, “Hydrogeologic Properties of Subsurface Materials.” Please provide clarification on the determination of the permeability and its use in the design and analyses.

02.05.04-6

Section 2.5.4.2.1.3.5 “Resonant Column and Torsional Shear” indicates that the ratio of lab/field shear wave velocities should ideally be unity, but ratios as low as 0.61 were observed (as shown in Table 2.5.1-206 of the application). Please explain the potential impact of the differences between the lab and field shear wave velocity measurements on the site response calculations and how they were accounted for in the site dynamic property evaluations. In addition, Subsection 2.5.4.2.2.2 “Dynamic Material Properties,” states repeatedly that “assumed K_0 values (the coefficient of earth pressure at rest) may have been too low,” and “the damping ratio and modulus reduction curves in Figures 2.5.4-207 and 2.5.4-208 are very likely minimum values.” Please justify these statements regarding both K_0 values and soil degradation curves.

02.05.04-7

Because the ESBWR DCD uses the Metric system and the FSAR frequently uses the English system, but occasionally the Metric system, the staff noticed that some converted values deviate from the commonly accepted accuracy by a significant margin, for example, converting 14.9 m to 45.1 ft (on page 126), and 3030 ft to 1000 m (on page 148). Please check the unit conversion throughout Section 2.5.4 and 2.5.5, including converting the dimensions of the foundation and thickness of the base mat on page 154 and others.

02.05.04-8

Section 2.5.4.4.2 states that SASW survey data was analyzed using WinSASW software. RG 1.206, 2.5.2.5 "Seismic Wave Transmission Characteristics of the Site" specifies the application needs to "[d]escribe the methods used to determine these properties, including the variability in each of these properties and the methods used to model the variability" when determining site subsurface material properties that include seismic compressional and shear wave velocities. Please provide details on the model used in WinSASW, or justify why such details are not necessary.

02.05.04-9

Subsection 2.5.4.5.1.4 "Vertical Limits of Excavation – FWSC" states that the excavation "to a depth of about 48.5 ft (elevation 85 ft) below site grade" "stops above the highest modeled perched water level measured." Since the observed ground water elevation varies from between 74 and 75 ft to between 80 and 83 ft within the excavation area of the FWSC, as indicated in Subsection 2.5.4.6.1, please clarify the vertical limit of excavation of the FWSC**.**

02.05.04-10

In Section 2.5.4.5.3 "Backfill," and FSAR Table 2.4.1-2 of Part 10, "ITAAC For Backfill Under Category I Structures," you did not specify the inspections, tests, or analyses that will be used to ensure that the properties of the selected backfill meet the ESBWR DCD Tier I requirements, and you only committed to meeting the minimum density values, but did not provide other specific criteria. FSAR section 2.5.4.10.1 "Soil Property Determination" listed specific values for total unit weight, internal friction angle, and static modulus (E) used in bearing capacity analysis, but those values were assumed, not based on site investigation. Please justify how the parameters selected ensure that static and dynamic properties of the backfill soil will meet or exceed: (1) site parameter requirements of the ESBWR DCD, e.g. the minimum shear wave velocity of 1000 ft/s as listed in Tier I document; and (2) soil property parameters used in the site seismic response and liquefaction potential analyses, bearing capacity, settlement and earth pressure estimates.

02.05.04-11

Section 2.5.4.6.3 "Construction Dewatering" indicates that the dewatering analysis was performed using the United States Geological Survey's Modular Groundwater Flow (USGS MODFLOW) numerical model. Since the USGS MODFLOW model uses a network of grid cells for finite difference simulation, the followings items are vital to achieve a meaningful evaluation:

- Modeling objective is clearly specified,
- A conceptual model that is verified by providing a grid map to show a two or three - dimensional modeling; boundary conditions; distribution of the hydro-conductivity for different layers and soils; and other conditions, such as dewatering wells included in simulation, etc.
- Conceptual model calibration by groundwater gradient before the model simulation.

Please provide more details on how the aforementioned factors were considered and what input, including the boundary condition, was used in the dewatering analysis.

02.05.04-12

In subsection 2.5.4.7.1 “Calculation of Dynamic Soil Property Profiles,” you stated that “[t]he P-S suspension velocity and SASW data sets were then combined geometrically (with equal weighting) to arrive at a profile mean Vs.” And then “after calculating the combined mean Vs by profile, the Poisson's ratio data set generated from the analysis of suspension velocity data was used to extrapolate the profile mean Vp, in essence adjusting the Vp values to reflect aggregation of SASW into the profile mean Vs.” Please explain: (1) how the data from two different field measurements were combined with equal weights; and (2) why extrapolated Poisson ratios determined from P-S test can be used to adjust the Vp values when SASW data was used, and how reliable the extrapolated values are.

02.05.04-13

Subsection 2.5.4.7.2 “Evaluation of Modulus Reduction and Damping Values from RCTS Data,” states that “Two sets of damping ratio and modulus reduction curves were considered in the analysis to develop the GMRS and FIRS.” Section 2.5.2.4.2.1.1 “Horizontal Amplification Factors” provides a description of the two sets. The first set is “based on similarities between the EPRI cohensionless soil curves with dynamic laboratory test data” and the second set “reflects an empirical correction for sample disturbance based on the ratio of laboratory (at in-situ confining stress) – to-field shear-wave velocities.” Laboratory test results are affected by many factors, such as the disturbance of the sample during sample collection, transportation and testing process, deviation of soil stress from laboratory to field conditions, as well as the variability of soil properties in the field. Please provide additional information to justify the empirical correction used in the analysis, including a discussion of whether using the ratio of lab-to-field shear wave velocity can realistically refine the data from laboratory tests, or whether it may produce additional uncertainty.

02.05.04-14

Subsection 2.5.4.10.2 “Bearing Capacity” provides the calculated ultimate bearing capacity using conventional methods, and compares the calculated bearing capacity with both the static and dynamic bearing capacities requirement by the ESBWR DCD. Since the conventional method is commonly used in foundation bearing capacity analysis under the normal shear failure assumption, for nuclear power plant structures, especially for the nuclear island, bearing capacity should be estimated “particularly due to overturning forces,” as stated in ESBWR DCD Tier 2, Section 3.8.5.4 “Design and Analysis Procedures.” Please clarify if and how the overturning forces, and their effect on the foundation, were considered in the foundation allowable bearing capacity analysis.

02.05.04-15

Section 2.5.4.10.3 “Settlement” indicates that the boring logs show that sporadic lenses of firm clay are present in the UCA below the subgrade level in the RB/FB mat footprint, as well as in the CB footprint, with cumulative thickness from about 3 ft. to about 7 ft. You also state that SPT N-values recorded in the field within these clay lenses generally ranged from about 10 to 57 blows/ft. Considering the existence of clay lenses and the variation of the strength as indicated by the SPT N-values and the Atterberg index results for UCA and UCOA soils, please clarify whether and how these conditions were considered in your settlement evaluation.

02.05.04-16

Subsection 2.5.4.10.6 “Static Lateral Earth Pressures and Hydrostatic Pressure” indicates that you calculated the at-rest lateral earth pressure coefficient for the in-place loess using the procedure outlined in Reference 2.5.4-253, which resulted in values of Ko ranging from 0.55 to 1.46. You also stated that in general, “the largest Ko values were calculated for the loess near the ground surface, with Ko values decreasing with depth.” Since the calculated Ko values are based on internal friction angle (Phi) and overconsolidation ratio (OCR), please provide additional justification for the values given in Table 2.5.4-203, in consideration of your statement that Ko values decrease with depth. In addition, the Phi and OCR values listed in Table 2.5.4-203 are different from those listed in Table 2.5.1-203. Please clarify the difference between the two tables and justify the OCR and Phi values used in the Ko calculation.

02.05.04-17

Section 2.5.4.10.3 “Foundation Sliding” states that sliding potential “for the deeply-embedded mat foundations for the RB/FB and CB mat foundations was analyzed, assuming that the resistance to sliding is provided by shear resistance along the base of the mat, and if necessary, from passive soil resistance in front of the mat in the direction of sliding." Please provide more details regarding the determination of the friction coefficient at the soil and structure interface.

02.05.04-18

FSAR Section 2.5.4.2.1.1 indicates that 175 samples were recovered from all stratigraphic unit of engineering interest. Considering that the dynamic response of the power-block structures may be impacted by soil properties extending to significant depths and that RG 1.206 specifies that the applicant “should provide a detailed and quantitative discussion of the criteria used to determine that the samples were properly taken and tested in sufficient manner to define all critical soil parameters for the site,” please justify whether the samples were undisturbed and of sufficient quantity to be used in determining more than index properties. Also justify whether the depths where the samples were extracted are sufficient to account for the soil dynamic properties at the site.

02.05.04-19

Section 2.5.4.2.1.3.5 indicates that in-situ confining pressures (Ko) were estimated for each test specimen. Table 2.5.4-202 indicates that these values were “assumed.” Please clarify how these values were estimated and explain the assumptions as well as the potential impact on subsequent calculations, including the site response calculation.

02.05.04-20

Section 2.5.4.2.2 “Material Engineering Properties” presents information on static testing of soils for strength evaluations and indicates the cohesion/friction angle results from the triaxial test series, as well as the shear strength derived from approximate correlations with CPT data. There are few triaxial test series that were performed for several stratigraphic units under the power-block area. For example, only one CU test series for the lower loess soil and two CU test series for Upland Complex Alluvium - the load bearing layer, were performed. RG 1.206 states that the applicant “should provide summary tables and plots that show the important test results,” and “should explain how the developed data are used in the safety analysis, how the test data are enveloped by the design, and why the design envelope is conservative. Values of the parameters used in the analyses should be presented." Please (1) explain how you captured the uncertainty and variability in soil properties determination, especially the soil shear strength parameters, based on limited data, and (2) confirm whether appropriate parameters were used in the stability evaluation for the load bearing layers, as well as the stability of the facilities and nearby slopes.

02.05.04-21

Figures 2.5.4-215 and 2.5.4-217 in Section 2.5.4.5.2.1 "Excavation Support - RB/FB and CB" show a conceptual design for a tied-back soldier pile wall. The section also states that analysis of the tied-back soldier pile wall system shows that the system has a top lateral deflection (toward the excavation) of less than 1 inch. Please (1) provide details on how the tied-back soldier pile wall system analysis was performed; and (2) explain whether possible reduced lateral support strength to the anchors of the Tied-Back Solder Pile walls due to the saturation of the loess (caused by heavy rain fall or rising ground water level) is a concern.

02.05.04-22

Section 2.5.4.8.3 "SPT-Based Liquefaction Assessment" states that "[e]valuated variations in groundwater table do not significantly affect the analysis results, but higher groundwater scenarios result in a slight increase in the number of SPT test points that fall within the liquefiable zone," and it concludes that "liquefaction is more or less independent to the groundwater level." With the consideration of the potential high water table, and that (1) ground water level change can significantly change the degree of saturation of soil, and therefore, the soil's effective stress, therefore, change the soil's liquefaction potential; and (2) the SPT data selection protocol was not based on the grain size distribution and plasticity, and the variation of test data has a potentially large impact on the evaluation of liquefaction potential, please provide more details on the simplified approach used for the liquefaction analysis, especially for the Upland Complex Alluvium that is a load bearing layer and generally classified as poorly graded sand, in consideration of the maximum water level scenario.

02.05.04-23

In Subsection 2.5.4.10.3 "Settlement," you state an "equivalent elastic modulus for all of the soil layers located within the depth of influence of the mat foundation is used." Please specify the depth of influence, provide details on how the variation of soil properties was considered in this "equivalent elastic modulus" determination, and justify the values that were used in the calculation.

02.05.04-24

As described in Section 2.5.4.10.3 "Settlement" of the FSAR Rev. 1, a Finite Element analysis program (SIGMA/W) was used as the primary method for the settlement analysis for RB/FB and the CB, but two other methods were also used. Please provide (1) an explanation of the model used in the analysis; major assumptions; input parameters and how the parameters were determined; (2) a comparison of the results from all three methods; (3) a comparison between the analysis results with what was actually observed for the Unit 1 foundation; and (4) a justification of whether a long term settlement monitoring plan is needed because predicted total settlements for the CB mat foundation shown in

Table 2.5.4-215 exceed the criteria of DCD Table 2.0-1 for settlement. In addition, please provide a plot of the finite element mesh generated during the analysis; boundary conditions; and displays of the results: scalar variables in the form of isosurfaces or isolines (e.g., components of stress and strain fields and their invariants, displacements – settlements and rebounds), distribution of internal forces and vectors of deformation.

02.05.05-1

Section 2.5.5 “Stability of Slopes” states that "[e]xisting natural ground surface inclinations of these bluffs are relatively steep, but do not show evidence of past large scale instability or potentially unstable conditions as described in Section 2.5.4.1." Also, Subsection 2.5.5.2 “Design Criteria and Analyses,” states that "the slope stability modeling program GALENA was used to calculate FOSs and to predict potential failure planes." The analysis results shown in Table 2.5.5-203 indicate that the Factors of Safety (FOSs) are less than 1, or close to 1, in the areas near the edges of the bluffs, which indicates that the bluff may be potentially unstable. Please clarify: (1) how the potential failure planes were outlined, (2) what model the GALENA program uses in slope stability analysis, and (3) what inputs were used for the slope stability analysis.

02.05.05-2

Section 2.5.5.1.1 “General Discussion” states that "[n]o slope instability, erosional, or incipient slope failure features were observed on this transitional cut slope, which will be removed in the final grading for Unit 3 and be replaced with a retaining wall as indicated in Figure 2.4.1-201." However, no exact locations of the proposed retaining walls were specified in the Figure. Please provide an updated Figure to outline the locations of the proposed retaining walls.

02.05.05-3

Section 2.5.5.1.1 “General Discussion” states that "[p]otential failures of the bluff slopes do not impact lateral capacity of the soils to support Unit 3 structures. The relatively large distances of the slope to the Unit 3 power block facility preclude an impact on the lateral stability." Since the possible flooding from local intense precipitation will result in a water level at 132.94 ft above msl (Table 2.0-202 of the FSAR), for the case of saturated soils please (1) verify that your slope stability analyses and the conclusions for the COL site are justified and (2) provide an evaluation of the impact of potential slope failure to the integrity of safety related structures in terms of lateral stability (in Section 2.5.4) and SSI (3.7.1).