Progress Energy

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U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-0001

LEVY NUCLEAR PLANT, UNITS 1 AND 2
DOCKET NOS. 52-029 AND 52-030
SUPPLEMENT 2 TO RESPONSE TO NRC RAI LETTER 108 – IMPLEMENTATION OF FUKUSHIMA NEAR-TERM TASK FORCE RECOMMENDATIONS

References:

1. Letter from Mark Tonacci (NRC) to John Elnitsky (PEF), dated March 15, 2012, "Request for Additional Information Letter No. 108 Concerning Implementation of Fukushima Near-Term Task Force Recommendations."
2. Letter from John Elnitsky (PEF) to Nuclear Regulatory Commission (NRC), dated April 12, 2012, "30-Day Response to NRC RAI Letter 108 – Implementation of Fukushima Near-Term Task Force Recommendations," Serial: NPD-NRC-2012-012.
3. Letter from John Elnitsky (PEF) to Nuclear Regulatory Commission (NRC), dated April 25, 2012, "Response to NRC RAI Letter 108 – Implementation of Fukushima Near-Term Task Force Recommendations," Serial: NPD-NRC-2012-014.
4. Letter from John Elnitsky (PEF) to Nuclear Regulatory Commission (NRC), dated June 19, 2012, "Supplement 1 to Response to NRC RAI Letter 108 – Implementation of Fukushima Near-Term Task Force Recommendations," Serial: NPD-NRC-2012-019.

Ladies and Gentlemen:

Progress Energy Florida, Inc. (PEF) hereby submits a supplemental response to the Nuclear Regulatory Commission's (NRC) request for additional information (RAI) provided in Reference 1.

A response addressing one of the four NRC actions identified in the RAI is contained in the enclosure. The enclosure also identifies associated changes made in Revision 5 of the Levy Nuclear Plant Units 1 and 2 application.

If you have any further questions, or need additional information, please contact Bob Kitchen at (919) 546-6992, or me at (704) 382-9248.

Progress Energy Florida, Inc.
P.O. Box 14042
St. Petersburg, FL 33733

D094
NRO

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

Executed on August 1, 2012.

Sincerely,

Christopher M. Fallon

Christopher M. Fallon
Vice President
Nuclear Development

Enclosure/Attachments

cc : U.S. NRC Region II, Regional Administrator (without Attachments)
Mr. Donald Habib, U.S. NRC Project Manager (without Attachments)

Levy Nuclear Plant Units 1 and 2 (LNP)
Supplement 2 to Response to NRC Request for Additional Information Letter No. 108 Related to Implementation of Fukushima Near Term Task Force Recommendations, Dated 3/15/2012

NRC RAI #	Progress Energy RAI #	Progress Energy Response
01.05-1	L-0998	Response enclosed – see following pages
01.05-1	L-0999	April 25, 2012; NPD-NRC-2012-014
01.05-1	L-1000	April 25, 2012; NPD-NRC-2012-014
01.05-1	L-1002	June 19, 2012; NPD-NRC-2012-019

NRC Letter No.: LNP-RAI-LTR-108

NRC Letter Date: March 15, 2012

NRC Review of Final Safety Analysis Report

NRC RAI NUMBER: 01.05-1

Text of NRC RAI:

Subject: Request for Additional Information Letter No. 108 Concerning Implementation of Fukushima Near-term Task Force (NTTF) Recommendations

Bullet 1
Evaluate the seismic hazards at your site against current NRC requirements and guidance, and, if necessary, update the design basis and structures systems and components important to safety to protect against the updated hazards (seismic portion only - of detailed Recommendation 2.1 - Enclosure 7 of SECY-12-0025).

PGN RAI ID #: L-0998

PGN Response to NRC RAI:

Sensitivity evaluations were performed to develop LNP site hard rock seismic hazard, finished grade 10^{-5} Uniform Hazard Response Spectra (UHRS), Ground Motion Response Spectra (GMRS), finished grade Performance Based Surface Response Spectra (PBSRS), and Foundation Interface Response Spectra (FIRS) (EL +11 ft.) using the Central and Eastern United States Seismic Source Characterization (CEUS SSC) (NUREG 2115) methodology and the modified cumulative absolute velocity filter (CAV) (NRC SECY-2012-0025 Enclosure 7 – Attachment 1 to Seismic Enclosure 1). The LNP site hard rock seismic hazard, finished grade 10^{-5} UHRS, GMRS, finished grade PBSRS, and FIRS (EL +11 ft.) using the CEUS SSC model were compared to the corresponding hazard and response spectra using the updated Electric Power Research Institute Seismic Owners Group (EPRI-SOG) methodology. The updated EPRI-SOG methodology included the updated EPRI-SOG earthquake catalog through end of 2006 and use of the Updated Charleston Seismic Source (UCSS). It was concluded that the site specific designs (liquefaction evaluations, Soil Structure Interaction (SSI) analysis, and the evaluations for seismic interaction between the Annex Building, Turbine Building, and Radwaste Building with the nuclear island [NI]) for the CEUS SSC methodology ground motions are bounded by that for the updated EPRI-SOG methodology currently presented in the FSAR. Similarly, the Seismic Margin Assessments for the standard plant components, site liquefaction potential, adjacent buildings' seismic interaction with the nuclear island, and the RCC bridging mat capacity for the CEUS SSC methodology ground motions are bounded by that for the updated EPRI-SOG methodology currently presented in the FSAR.

Also included in this response are sensitivity evaluations for impact on site specific RCC Bridging Mat design; Seismic II/I interaction between the Nuclear Island (NI) and the adjacent Turbine Building, Annex Building, and the Radwaste Building; and Floor Response Spectra at six key AP1000 locations when Regulatory Guide 1.60 spectral shape (scaled to 0.1 g horizontal and 0.0695g vertical) is applied as the FIRS.

Sensitivity Evaluations for CEUS SSC

The CEUS SSC methodology, verification of the CEUS SSC methodology implementation, the LNP site hard rock seismic hazard, finished grade 10^{-5} UHRS, GMRS, finished grade PBSRS, FIRS (EL +11 ft.), and their comparison to the corresponding LNP site seismic hazards and amplified ground motions (to meet 10 CFR Part 50 Appendix S requirements) using the updated EPRI-SOG model currently presented in the FSAR are presented in the new FSAR Subsection 2.5.2.7 included in Attachment C to this RAI response.

Comparisons between the scaled GMRS, PBSRS, and FIRS developed using the updated EPRI-SOG model with full CAV and the corresponding spectra developed using the CEUS SSC model with modified CAV are shown on Figures 2.5.2-355, 2.5.2-357, and 2.5.2-358 respectively. These comparisons show that the PBSRS and FIRS based on the CEUS SSC model with modified CAV are enveloped by the corresponding spectra developed using the updated EPRI-SOG model with full CAV. The GMRS based on the CEUS SSC model with modified CAV is also nearly enveloped by the scaled GMRS based on the updated EPRI-SOG model with full CAV, with the maximum exceedance being 4 percent near 1 Hz. Thus, it is concluded that the site specific ground motions developed using the updated EPRI-SOG model with full CAV presented in Subsection 2.5.2.6 are appropriate for use as the design basis for the LNP site.

The topics presented in the new FSAR Subsection 2.5.2.7 are as follows:

Scaled GMRS

For site specific evaluations and design (liquefaction evaluations, seismic interaction of the Annex, Turbine, and Radwaste Building with the NI, Soil Structure Interaction analysis of the NI, and the design of the RCC bridging mat), scaled PBSRS and scaled FIRS (EL +11 ft.) are used. The scale factor of 1.212 was used so that the FIRS has a zero period acceleration of 0.1g as required by 10 CFR Part 50 Appendix S. To be consistent with the site specific evaluations and design, the GMRS was also scaled by the 1.212 factor. The scaled horizontal and vertical GMRS are presented in Figure 2.5.2-296. The scaled GMRS represents the licensing basis GMRS for the LNP site.

The scaled horizontal and vertical GMRS are compared to the Westinghouse Certified Seismic Design Response Spectra (CSDRS) on Figure 2.5.2-296. The site scaled GMRS are enveloped by the CSDRS.

Site Liquefaction Evaluations

Earthquake-induced cyclic stresses within soils considered for liquefaction analysis were computed from the site response analyses used to develop the site amplification functions for the PBSRS profiles described in Subsection 2.5.2.5. The site response analyses were performed using 60 randomized soil profiles representing each PBSRS shear wave velocity profile and 30 acceleration time histories representing each deaggregation earthquake (DE) listed in Table 2.5.2-225. In each individual site response analysis effective cyclic shear strains and iterated shear modulus were computed for each layer of the profile. The effective cyclic shear stress for each layer was then taken as the product of the effective cyclic shear strain and the iterated shear modulus. The results of the 180 analyses (60 randomized profiles times three deaggregation earthquakes) were then used to compute a weighted mean effective cyclic shear stress for each layer within each of the three PBSRS soil profiles and for the 10^{-4} and 10^{-5} exceedance level input motions. The weights used were the relative weights assigned to the DEs that are listed in Table 2.5.2-225.

The results of the site response analyses were used to produce peak ground acceleration (PGA) seismic hazard results at the finished graded elevation computed without CAV for the 10^{-4} and 10^{-5} exceedance levels. These values were used to compute a performance based PGA at the finished grade elevation using Equations 2.5.2-215 through 2.5.2-217. The resulting acceleration value is 0.118g. The corresponding PGA at the base of the excavation (-24 ft. NAVD88) is 0.071g. These values along with the site class and the value of F_a based on the International Building Code (2006) are shown in Table 2.5.4.8-201.

The development of the cyclic shear stress complies with the guidance in Regulatory Position 3.3.2 of Regulatory Guide 1.198 because an ensemble of time histories was used that represent the earthquakes contributing to the hazard at the LNP site. The development of the ensemble of time histories is described in Subsection 2.5.2.5.2. The time histories used to represent the DE were taken from NUREG/CR-6728 (Reference 2.5.2-263). The weighted mean magnitude for the earthquake time histories representing the high frequency (HF) 10^{-4} and 10^{-5} DEs are 6.8 and 6.1, respectively. Thus, these time histories also satisfy the acceptance criteria in SRP Section 2.5.2 in that weighted mean magnitudes for the ensembles of time histories exceed magnitude 6. The associated number of equivalent cycles of loading was estimated using the relationship between earthquake magnitude and number of loading cycles provided in Reference 2.5.4.8-203. The m_b magnitudes listed in Table 2.5.2-225 for the HF DEs were converted to moment magnitudes using the relationships given in Subsection 2.5.2.4.2.3 and the resulting average moment magnitude was used to estimate the number of cycles for each DE using Figure 12 in Reference 2.5.4.8-203. The resulting weighted mean values are 9.4 cycles and 6.5 cycles for the HF 10^{-4} and 10^{-5} hazard levels, respectively.

The soils under the Nuclear Island will be excavated and backfilled with RCC; therefore, no liquefaction potential exists under the Nuclear Island foundation. For design basis evaluations of liquefaction potential of soils under the adjacent Annex, Turbine and Radwaste Buildings, earthquake-induced cyclic stresses in the soil column were based on ground motions computed for the PBSRS profile using the updated EPRI-SOG model. The associated PGA at the finished grade elevation is 0.118g (Table 2.5.4.8-201) and is based on the surface hazard curves computed without CAV. The PGA at the finished grade elevation computed without CAV using the CEUS SSC model is 0.091g. As the computed equivalent cyclic shear stresses are proportional to the PGA at the finished grade, the equivalent cyclic shear stresses based on the CEUS SSC model would be lower than those computed based on the updated EPRI-SOG model. Therefore, the liquefaction evaluations based on the updated EPRI-SOG LNP ground motions bound those from the CEUS SSC ground motions.

Soil Structure Interaction Analysis

The scaled updated EPRI-SOG scaled FIRS (EL +11 ft.) was the input ground motion for the LNP site specific SSI analysis. As shown in Figure 2.5.2-358 the horizontal and vertical CEUS SSC FIRS (EL +11 ft.) is enveloped by the corresponding updated EPRI-SOG scaled FIRS (EL +11 ft.). Thus, the conclusions of the LNP site specific SSI analysis that the LNP floor response spectra (FRS) at the six key locations are bounded by the CSDRS FRS and the maximum bearing pressure is less than the 24 ksf design value are also valid for the LNP site ground motions based on the CEUS SSC model.

Seismic Interaction between the Adjacent Buildings with the Nuclear Island

The updated EPRI-SOG scaled finished grade PBSRS was used to show that there is no interaction between the adjacent Annex, Turbine, and Radwaste Buildings with the NI. As shown in Figure 2.5.2-357, the CEUS SSC finished grade horizontal and vertical PBSRS are enveloped by the updated EPRI-SOG scaled finished grade PBSRS. Thus, the conclusions that there is no interaction between the adjacent Annex, Turbine, and Radwaste Building with the NI are valid for the LNP site ground motions based on the CEUS SSC model.

The computed probable maximum relative displacement during SSE between the NI and the Annex Building foundation mat, between the NI and the Turbine Building foundation mat, and between the NI and the Radwaste Building foundation mat are less than 2.5 cm (1 in.) when the Regulatory Guide 1.60 spectra anchored at peak ground acceleration of 0.1g is applied at the foundation elevation of the Annex Building, Turbine, and the Radwaste Building foundations respectively as shown in Table 3.7-206. Figure 3.7-226 shows the conceptual design detail for the interface between the Nuclear Island (NI) and the drilled shaft supported foundation mat of the Annex Building. This design detail provides a 5.0 cm (2 in.) gap between the Annex Building foundation and the NI consistent with DCD Subsection 3.8.5.1. Thus, no seismic interaction between the Annex Building, Turbine Building, and the Radwaste Building Foundations and the NI is expected.

Sensitivity Evaluations for Regulatory Guide 1.60 Spectra FIRS

The Regulatory Guide 1.60 Foundation Input Response Spectra (FIRS) is anchored at peak ground accelerations for the scaled site-specific FIRS in Table 2.5.2-236 (0.1g horizontal and 0.0695g vertical). The scaled site-specific FIRS was developed using the updated EPRI-SOG methodology and scaled to meet 10 CFR Part 50 Appendix S requirements. Tables 3.7-203 and 3.7-204 present the 5% damped site specific FIRS, the 5% damped Regulatory Guide 1.60 FIRS, and the ratio of the Regulatory Guide FIRS and the site specific FIRS at various frequencies for horizontal and vertical spectra respectively.

Sensitivity evaluations were performed to assess whether the FRS at the six key locations using the Regulatory Guide 1.60 FIRS instead of the scaled site-specific FIRS remains bounded by the Certified Seismic Design Response Spectra (CSDRS) FRS. The sensitivity evaluations were performed using conservative simplified methodology by scaling the entire site specific FRS by the ratio of the Regulatory Guide 1.60 FIRS and the scaled site specific FIRS at the predominant response frequency at the node/direction. The predominant response frequency was determined from the peaks in the site specific FRS at each of the six nodes in the X, Y, and Z directions. The site specific FRS at the six nodes in the X, Y, and Z directions are shown in Figures 3.7-214, 3.7-215, 3.7-216, 3.7-217, 3.7-218, and 3.7-219. For this evaluation the lowest predominant response frequency is used because it will yield a larger scaling factor and is thus conservative. Table 3.7-205 presents the predominant response frequencies at the six key nodes in the X, Y, and Z directions, the ratio of the Regulatory Guide 1.60 FIRS and the scaled site specific FIRS at the predominant response frequency (scaling factor), and the minimum margin for site specific FRS with respect to the CSDRS FRS when the whole site specific FRS is scaled by the scaling factor for the predominant response frequency for the node and direction. Because the scaling factors to develop the Regulatory Guide 1.60 FRS are always smaller than the available margin with respect to the CSDRS FRS, the response to Regulatory Guide 1.60 FRS will be bounded by the CSDRS FRS. In addition, because the Regulatory Guide 1.60 spectra has only a small frequency content above 20 Hz. and no frequency content above 33 Hz., the Regulatory Guide 1.60 FRS peaks in the high frequency range (>20 Hz.) will be lower than that obtained by the simple scaling used, thus providing additional margin with respect to the CSDRS FRS.

As stated in Subsections 2.5.4.5.4 and 2.5.4.10.1.1, the conceptual design of the RCC bridging mat is based on a bearing pressure of 8.9 kips per square foot [ksf] for static loading and 24.0 ksf for dynamic loading. The static bearing pressure is based on DCD Tier 1 Table 5.0.1. The dynamic bearing pressure is the maximum subgrade pressure at the AP1000 basemat that results from the generic AP1000 analysis for soft rock sites. For the subsurface rock bearing capacity calculations, the RCC self weight was included as an additional bearing pressure load of 5.16 ksf. The buoyancy effects due to the hydrostatic pressure acting at the bottom of the RCC were considered in this analysis. A base shear load of 136,000 kips based on the AP1000 generic analysis was applied at the top of the RCC bridging mat. Because the AP1000 generic analyses are based on the CSDRS (0.3g Regulatory Guide 1.60 spectra enhanced in the high frequency region), the RCC design is conservative for the Regulatory Guide 1.60 FIRS.

Seismic Margin Analysis

As shown in Figures 2.5.2-355 and 2.5.2-357, both the CEUS SSC GMRS and the PBSRS are enveloped by the AP1000 CSDRS. As stated above, the CEUS SSC LNP site specific floor response spectra (FRS) at the six key locations are bounded by the CSDRS FRS and the maximum bearing pressure is less than the 24 ksf design value. Thus, LNP site unique foundation conditions and CEUS SSC ground motions do not lower the High Confidence Low Probability of Failure (HCLPF) values calculated for the certified design.

For site specific seismic margins evaluation presented in Subsection 19.55.6.3 liquefaction potential of soils under the adjacent Annex, Turbine and Radwaste Buildings, earthquake-induced cyclic stresses in the soil column, based on ground motions consistent with the updated EPRI-SOG finished grade 10^{-5} UHRS, were used. As shown in Figures 3.7-228 and 3.7-229, 1.67*GMRS and 1.67*PBSRS developed using the CEUS SSC methodology and modified CAV filter are enveloped by the updated EPRI-SOG finished grade 10^{-5} UHRS. Furthermore, the PGA for the 10^{-5} PBSRS profile surface motions computed without CAV using the CEUS SSC model are lower than those computed using the updated EPRI-SOG model. Thus, the HCLPF capacity for liquefaction potential of soil under the Annex, Turbine, and Radwaste Buildings exceeds the 1.67*GMRS goal for the plant level HCLPF for the CEUS SSC ground motions.

To calculate the HCLPF capacity for seismic interaction between the Annex, Turbine, and Radwaste Buildings and the NI, the Annex, Turbine, and Radwaste Buildings displacements relative to the NI were calculated using the updated EPRI-SOG finished grade 10^{-5} UHRS. As shown in Figures 3.7-228 and 3.7-229, 1.67*GMRS and 1.67*PBSRS developed using the CEUS SSC methodology and modified CAV filter are enveloped by the updated EPRI-SOG finished grade 10^{-5} UHRS. Thus, HCLPF capacity for no seismic interaction between the Annex, Turbine, and Radwaste Bulding and the NI exceeds the 1.67*GMRS goal for the plant level HCLPF for the CEUS SSC ground motions.

The HCLPF capacity of the RCC mat was calculated as 0.30g using the conservative deterministic failure margin (CDFM) methodology of FSAR Reference 19.55.7-201. The peak ground acceleration for the CEUS SSC GMRS is 0.073. Thus, the HCLPF capacity of the RCC bridging mat exceeds the overall plant HCLPF acceptance criteria of 1.67*GMRS using the CEUS SSC methodology and modified CAV filter.

Associated LNP COL Application Revisions:

<u>FSAR Text Revisions</u>

FSAR text revisions are shown in revision mode in the attached markup for:

- Subsection 2.5.0 (Attachment B)
- Subsection 2.5.2 (Attachment C)
- Subsection 2.5.4 (Attachment E)
- Subsection 2.5.7 (Attachment F)
- Subsection 3.7 (Attachment G)
- Subsection 19.55 (Attachment H)

<u>FSAR Chapter 2 Revised Tables</u>

- Revised Table 2.0-201: Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics (Attachment A)

- Revised Table 2.5.4.8-201: Summary of Peak Ground Acceleration Used for Liquefaction Analysis (Attachment E)
- Revised Table 2.5.2-226: LNP Site GMRS Scaled by 1.212 consistent with Reactor Foundation Elevation SCOR FIRS Scaled to 0.1g Horizontal Peak Ground Acceleration (Attachment C)

FSAR Subsection 2.5.2 New Tables (Attachment C)

- Table 2.5.2-232: Comparison of Ground Motions Computed from Mean Hazard Curves for the NUREG-2115 Seven Demonstration Sites
- Table 2.5.2-233: Comparison of Reference and Deaggregation Earthquakes Based on Updated EPRI-SOG and CEUS SSC Models
- Table 2.5.2-234: Comparison of Updated EPRI-SOG Scaled GMRS with CAV and CEUS GMRS with Modified CAV
- Table 2.5.2-235: Comparison of Updated EPRI-SOG Scaled PBSRS with CAV and CEUS PBSRS with Modified CAV
- Table 2.5.2-236: Comparison of Updated EPRI-SOG Scaled Reactor Building FIRS with CAV and CEUS SSC Reactor Building FIRS with Modified CAV

FSAR Subsection 2.5.2 Revised Figures (Attachment D)

- Revised Figure 2.5.2-294: Horizontal 10^{-5} UHRS, GMRS, and Scaled GMRS Based on CAV for the LNP Site
- Revised Figure 2.5.2-296: Horizontal and Vertical Scaled GMRS for the LNP Site

FSAR Subsection 2.5.2 New Figures (Attachment D)

- Figure 2.5.2-312: CEUS SSC Model Master Logic Tree
- Figure 2.5.2-313: Location of RLME Sources in the CEUS SSC Model
- Figure 2.5.2-314: CEUS SSC Model Logic Tree for the Mmax Source Zones
- Figure 2.5.2-315: CEUS SSC Mmax Source Zones - Narrow Interpretation
- Figure 2.5.2-316: CEUS SSC Mmax Source Zones - Wide Interpretation
- Figure 2.5.2-317: CEUS SSC Model Logic Tree for Seismotectonic Source Zones
- Figure 2.5.2-318: CEUS SSC Seismotectonic Source Zones - Narrow Interpretation, Separate Reelfoot and Rough Creek
- Figure 2.5.2-319: CEUS SSC Seismotectonic Source Zones - Narrow Interpretation, Combined Reelfoot and Rough Creek
- Figure 2.5.2-320: CEUS SSC Seismotectonic Source Zones - Wide Interpretation, Separate Reelfoot and Rough Creek
- Figure 2.5.2-321: CEUS SSC Seismotectonic Source Zones - Wide Interpretation, Combined Reelfoot and Rough Creek
- Figure 2.5.2-322: CEUS SSC Model Logic Tree for the Charleston RLME Source
- Figure 2.5.2-323: Alternative Geometries for the Charleston Source

- Figure 2.5.2-324: Location of Seven Demonstration Sites Used in NUREG-2115
- Figure 2.5.2-325: Comparison of Hazard Computed in this Study to Results in NUREG-2115 for the Central Illinois Demonstration Site
- Figure 2.5.2-326: Comparison of Hazard Computed in this Study to Results in NUREG-2115 for the Chattanooga Demonstration Site
- Figure 2.5.2-327: Comparison of Hazard Computed in this Study to Results in NUREG-2115 for the Houston Demonstration Site
- Figure 2.5.2-328: Comparison of Hazard Computed in this Study to Results in NUREG-2115 for the Jackson Demonstration Site
- Figure 2.5.2-329: Comparison of Hazard Computed in this Study to Results in NUREG-2115 for the Manchester Demonstration Site
- Figure 2.5.2-330: Comparison of Hazard Computed in this Study to Results in NUREG-2115 for the Savannah Demonstration Site
- Figure 2.5.2-331: Comparison of Hazard Computed in this Study to Results in NUREG-2115 for the Topeka Demonstration Site
- Figure 2.5.2-332: 0.5 Hz Spectral Acceleration Hazard for the LNP Site Computed Using Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-333: 1 Hz Spectral Acceleration Hazard for the LNP Site Computed Using Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-334: 2.5 Hz Spectral Acceleration Hazard for the LNP Site Computed Using Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-335: 5 Hz Spectral Acceleration Hazard for the LNP Site Computed Using Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-336: 10 Hz Spectral Acceleration Hazard for the LNP Site Computed Using Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-337: 25 Hz Spectral Acceleration Hazard for the LNP Site Computed Using Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-338: 100 Hz Spectral Acceleration Hazard for the LNP Site Computed Using Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-339: Contribution of the Different Source Types to the Total Mean Hazard at the LNP Site
- Figure 2.5.2-340: Comparison of Hard Rock UHRS based on Updated EPRI-SOG CEUS SSC Models
- Figure 2.5.2-341: Deaggregation of Mean 10^{-3} Hazard from CEUS SSC Model
- Figure 2.5.2-342: Deaggregation of Mean 10^{-4} Hazard from CEUS SSC Model
- Figure 2.5.2-343: Deaggregation of Mean 10^{-5} Hazard from CEUS SSC Model
- Figure 2.5.2-344: Deaggregation of Mean 10^{-6} Hazard from CEUS SSC Model
- Figure 2.5.2-345: Mean 0.5 Hz Spectral Acceleration Hazard with CAV for Updated EPRI-SOG and CEUS Models

- Figure 2.5.2-346: Mean 1 Hz Spectral Acceleration Hazard with CAV for Updated EPRI-SOG and CEUS Models
- Figure 2.5.2-347: Mean 2.5 Hz Spectral Acceleration Hazard with CAV for Updated EPRI-SOG and CEUS Models
- Figure 2.5.2-348: Mean 5 Hz Spectral Acceleration Hazard with CAV for Updated EPRI-SOG and CEUS Models
- Figure 2.5.2-349: Mean 10 Hz Spectral Acceleration Hazard with CAV for Updated EPRI-SOG and CEUS Models
- Figure 2.5.2-350: Mean 25 Hz Spectral Acceleration Hazard with CAV for Updated EPRI-SOG and CEUS Models
- Figure 2.5.2-351: Mean 100 Hz Spectral Acceleration Hazard with CAV for Updated EPRI-SOG and CEUS Models
- Figure 2.5.2-352: GMRS Elevation Horizontal UHRS Based on Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-353: PBSRS Elevation Horizontal UHRS Based on Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-354: Development of Horizontal GMRS Based on the CEUS SSC Model with Modified CAV
- Figure 2.5.2-355: Comparison of GMRS Based on Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-356: Development of Horizontal PBSRS Based on the CEUS SSC Model with Modified CAV
- Figure 2.5.2-357: Comparison of PBSRS Based on the Updated EPRI-SOG and CEUS SSC Models
- Figure 2.5.2-358: Comparison of Reactor Building FIRS Based on the Updated EPRI-SOG and CEUS SSC Models

FSAR Subsection 3.7 New Figures (Attachment G)

- Figure 3.7-228: Comparison of the horizontal 10^{-5} UHRS using the Updated EPRI-SOG model with 1.67 x the GMRS using the CEUS SSC model with modified CAV
- Figure 3.7-229: Comparison of the horizontal 10^{-5} UHRS using the Updated EPRI-SOG model with 1.67 x the PBSRS using the CEUS SSC model with modified CAV

FSAR Subsection 3.7 New Tables (Attachment G)

- Table 3.7-203: Ratio of Horizontal RG 1.60 FIRS and Site Specific (SS) FIRS
- Table 3.7-204: Ratio of Vertical RG 1.60 FIRS and Site Specific (SS) FIRS
- Table 3.7-205: Predominant Frequencies, Scale Factors for Regulatory Guide 1.60 FIRS, and CSDRS FRS Margin
- Table 3.7-206: Probable Maximum Relative Displacements between the Nuclear Island (NI) and Adjacent Buildings

FSAR Subsection 19.55 Revised Table (Attachment H)

Revised Table 19.55-201: HCLPF Capacities for LNP Site Specific Design Features

Attachments:

Attachment A: Revised Subsection 2.0 Table

Attachment B: Revised Subsection 2.5.0 Text

Attachment C: Revised Subsection 2.5.2 Text and Tables and New Subsection 2.5.2 Tables

Attachment D: Revised Subsection 2.5.2 Figures and New Subsection 2.5.2 Figures

Attachment E: Revised Subsection 2.5.4 Text and Table

Attachment F: Revised Subsection 2.5.7 Text

Attachment G: Revised Subsection 3.7 Text and and New Subsection 3.7 Tables and Figures

Attachment H: Revised Subsection 19.55 Text and Table

Attachment A

Revised Subsection 2.0 Table

[10 pages following this cover page]

LNP SUP 2.0-1

Table 2.0-201 (Sheet 1 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters	LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
Air Temperature				
Maximum Safety [a]	115°F dry bulb / 86.1°F coincident wet bulb	105.1°F dry bulb / 78.7°F coincident wet bulb (Tallahassee); 104.4°F dry bulb / 82.3°F coincident wet bulb (Jacksonville). Values are 100-year return estimates of 2-hour duration, 0% exceedance values.	FSAR Subsection 2.3.1.2.7	Yes
	86.1°F wet bulb (non-coincident) [h]	85.5°F wet bulb (non-coincident) (Tampa, 100-year return estimate of 2-hour duration, 0% exceedance values).	FSAR Subsection 2.3.1.2.7	Yes
Minimum Safety [a]	-40°F	3°F (Tallahassee,100-year return period)	FSAR Subsection 2.3.1.2.7	Yes
Maximum Normal [b]	101°F dry bulb / 80.1°F coincident wet bulb	95°F dry bulb / 78°F coincident wet bulb (Jacksonville)	FSAR Subsection 2.3.1.2.7	Yes
	80.1°F wet bulb (non-coincident) [c]	80°F wet bulb (non-coincident) (Tampa).	FSAR Subsection 2.3.1.2.7	Yes
Minimum Normal [b]	-10°F	24°F (Tallahassee)	FSAR Subsection 2.3.1.2.7	Yes
Wind Speed				
Operating Basis	145 mph (3-second gust); importance factor 1.15 (safety), 1.0 (non-safety); exposure C; topographic factor 1.0	120 mph (3-second gust, 50-year recurrence)(importance factor 1.0 [non-safety]; exposure C; topographic factor 1.0) 128 mph (3-second gust, 100-year recurrence)(importance factor 1.15 [safety]; exposure C; topographic factor 1.0).	FSAR Subsection 2.3.1.2.2	Yes
Tornado	300 mph	300 mph	FSAR Subsection 2.3.1.2.2	Yes
	Maximum pressure differential of 2 lb/in^2	2 lb/in^2	FSAR Subsection 2.3.1.2.2	Yes

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Table 2.0-201 (Sheet 2 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters	LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
Seismic				
CSDRS	CSDRS free field peak ground acceleration of 0.30 g with modified Regulatory Guide 1.60 response spectra (see Figures 5.0-1 and 5.0-2.). The SSE is now referred to as CSDRS. Seismic input is defined at finished grade except for sites where the nuclear island is founded on hard rock. If the site-specific spectra exceed the response spectra in Figures 5.0-1 and 5.0-2 at any frequency, or if soil conditions are outside the range evaluated for AP1000 design certification, a site-specific evaluation can be performed. This evaluation will consist of a site-specific dynamic analysis and generation of in-structure response spectra at key locations to be compared with the floor response spectra of the certified design at 5 percent damping. The site is acceptable if the floor response spectra from the site-specific evaluation do not exceed the AP1000 spectra for each of the locations or the exceedances are justified. The HRHF envelope response spectra are shown in Figure 5.0-3 and Figure 5.0-4 defined at the foundation level for 5 percent damping. The HRHF envelope response spectra provide an alternative set of spectra for evaluation of site-specific GMRS. A site is acceptable if its site-specific GMRS falls within the AP1000 HRHF envelope response spectra. Evaluation of a site for application of the HRHF envelope response spectra includes consideration of the limitation on shear wave velocity identified for use of the HRHF envelope response spectra. This limitation is defined by a shear wave velocity at the bottom of the basemat equal to or higher than 7,500 ft/sec, while maintaining a shear wave velocity equal to or above 8,000 ft/sec at the lower depths. [(d)]	For updated EPRI-SOG scaled GMRS ~~P~~peak ground accelerations: 0.084~~69~~ g horizontal 0.062~~51~~ g vertical For CEUS SSC GMRS peak ground accelerations: 0.073 g horizontal ~~defined at 100 Hz.~~ 0.054 g vertical GMRS peak ground acceleration defined at 100 Hz. Ground Response Spectra: At LNP 1 and LNP 2: The horizontal and vertical updated EPRI-SOG scaled GMRS and CEUS SSC GMRS are bounded by the horizontal and vertical CSDRS (Figure 2.5.2-355~~296~~).	FSAR Subsections 2.5.2.6, 2.5.2.7, and 3.7	Yes

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Table 2.0-201 (Sheet 3 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters	LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
Fault Displacement Potential	No potential fault displacement considered beneath the seismic Category I and seismic Category II structures and immediate surrounding area. The immediate surrounding area includes the effective soil supporting media associated with the seismic Category I and seismic Category II structures.	The potential for tectonic deformation at the LNP site is negligible.	FSAR Subsection 2.5.3.8	Yes
Soil				
Average Allowable Static Bearing Capacity	The allowable bearing capacity, including a factor of safety appropriate for the design load combination, shall be greater than or equal to the average bearing demand of 8,900 lb/ft^2 over the footprint of the nuclear island at its excavation depth.	Allowable Static Bearing Capacity for LNP 1 and LNP 2: 108,000 psf	FSAR Subsection 2.5.4.10.1.2	Yes
Dynamic Bearing Capacity for Normal Plus SSE	The allowable bearing capacity, including a factor of safety appropriate for the design load combination, shall be greater than or equal to the maximum bearing demand of 35,000 lb/ft^2 at the edge of the nuclear island at its excavation depth, or Site-specific analyses demonstrate factor of safety appropriate for normal plus safe shutdown earthquake loads.	Allowable Dynamic Bearing Capacity for LNP 1 and LNP 2: 108,000 psf	FSAR Subsection 2.5.4.10.1.2	Yes
Shear Wave Velocity	Greater than or equal to 1,000 ft/sec based on minimum low-strain soil properties over the footprint of the nuclear island at its excavation depth.	Materials below nuclear island subgrades have V_S greater than 1000 ft/sec.	FSAR Subsection 2.5.4.4.2	Yes

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Table 2.0-201 (Sheet 4 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters	LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
Lateral Variability	Soils supporting the nuclear island should not have extreme variations in subgrade stiffness. This may be demonstrated by one of the following: 1. Soils supporting the nuclear island are uniform in accordance with Regulatory Guide 1.132 if the geologic and stratigraphic features at depths less than 120 feet below grade can be correlated from one boring or sounding location to the next with relatively smooth variations in thickness or properties of the geologic units, or 2. Site specific assessment of subsurface conditions demonstrates that the bearing pressures below the nuclear island do not exceed 120% of those from the generic analyses of the nuclear island at a uniform site, or 3. Site specific analysis of the nuclear island basemat demonstrates that the site specific demand is within the capacity of the basemat. As an example of sites that are considered uniform, the variation of shear wave velocity in the material below the foundation to a depth of 120 feet below finished grade within the nuclear island footprint and 40 feet beyond the boundaries of the nuclear island footprint meets the criteria in the case outlined below:	The nuclear islands will be founded on a 10.7 m (35 ft.) thick roller compacted concrete (RCC) bridging mat, overlaying the Avon Park Formation. Average V_s is greater than 2500 ft/sec for every layer below the nuclear island. LNP 1: Dip is approximately 2 degrees. Beneath the RCC bridging mat, one geologic unit is uniformly present to depths beyond 120 ft. below grade. This is consistent across all boreholes within the nuclear island footprint. Properties, particularly shear wave velocity, can vary within the geologic unit, but they vary smoothly and by less than 15 percent between boreholes. Because of the presence of the 10.7 m (35 ft.) thick RCC bridging mat, and the relative uniformity of the geologic unit below the RCC bridging mat, the site specific demand is within the capacity of the AP1000 basemat.	FSAR Subsection 2.5.4.10.3 FSAR Subsection 2.5.4.4.2.1.1 FSAR Subsection 2.5.4.4.2.1.2	Yes

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Table 2.0-201 (Sheet 5 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters	LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
	Case 1: For a layer with a low strain shear wave velocity greater than or equal to 2500 feet per second, the layer should have approximately uniform thickness, should have a dip not greater than 20 degrees, and should have less than 20 percent variation in the shear wave velocity from the average velocity in any layer.	LNP 2: Dip is approximately 2 degrees. Beneath the RCC bridging mat, one geologic unit is uniformly present to depths beyond 120 ft. below grade. This is consistent across all boreholes within the nuclear island footprint. Properties, particularly shear wave velocity, can vary within the geologic unit, but they vary smoothly and by less than approximately 20 percent between boreholes. Because of the presence of the 10.7 m (35 ft.) thick RCC bridging mat, and the relative uniformity of the geologic unit below the RCC bridging mat, the site specific demand is within the capacity of the AP1000 basemat.		
Liquefaction Potential	No liquefaction considered beneath the seismic Category I and seismic Category II structures and immediate surrounding area. The immediate surrounding area includes the effective soil supporting media associated with the seismic Category I and seismic Category II structures.	Material beneath and adjacent to the nuclear island will be non-liquefiable. Some of the material in the passive resistance wedge, adjacent to the nuclear island, will be removed and replaced. Roller Compacted Concrete is used to support the nuclear island and is a zero-slump concrete with high flyash content, compacted by vibratory rollers. This material is non-liquefiable. Surface soils adjacent to the nuclear island will be removed or improved. Adjacent structures are supported on deep foundations.	FSAR Subsection 2.5.4.8	Yes

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Table 2.0-201 (Sheet 6 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters		LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
Minimum Soil Angle of Internal Friction	The minimum soil angle of internal friction is greater than or equal to 35 degrees below the footprint of nuclear island at its excavation depth. If the minimum soil angle of internal friction is below 35 degrees, a site-specific analysis shall be performed using the site-specific soil properties to demonstrate stability.		Not applicable: Soils beneath the foundation for the nuclear islands will be excavated and replaced with RCC. A waterproofing membrane will be located between the RCC and the mudmat, meeting AP1000 DCD requirements of ≥0.55 static coefficient of friction.	Not applicable	Not applicable
Limits Of Acceptable Settlement Without Additional Evaluation [i]	Differential Across Nuclear Island Foundation Mat	0.5 in. in 50 ft.	<0.25 in. in 50 ft. (projected)	FSAR Subsection 2.5.4.10.3	Yes (projected)
	Total for Nuclear Island Foundation Mat	6 in.	< 1 in. (projected)		
	Differential Between Nuclear Island and Turbine Building [j]	3 in.	< 1 in. (projected)		
	Differential Between Nuclear Island and Other Buildings [j]	3 in.	< 1 in. (projected)		
Missiles					
Tornado	4000-lb. automobile at 105 mph horizontal, 74 mph vertical		4000-lb. automobile at 105 mph horizontal, 74 mph vertical	DCD Subsection 3.5.1.4	Yes
	275-lb., 8-in. shell at 105 mph horizontal, 74 mph vertical		275-lb., 8-in. shell at 105 mph horizontal, 74 mph vertical	DCD Section 3.5	Yes
	1-in.-diameter steel ball at 105 mph in the most damaging direction		1-in.-diameter steel ball at 105 mph in the most damaging direction	APP-GW-GLR-02 0, "Wind and Tornado Site Interface Criteria," Westinghouse [e]	Yes

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Table 2.0-201 (Sheet 7 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters	LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
Flood Level	Less than plant elevation 100 ft.	DCD plant elevation of 100 ft. = 51 ft. NAVD88 or 52 ft. NGVD29 (nominal plant grade floor elevation)	FSAR Subsection 2.4.1.1	Yes
		The maximum water elevation in Lake Rousseau from a PMF is 29.7 ft. NAVD88.	FSAR Subsection 2.4.3.5	
		The maximum water surface elevation in the lower Withlacoochee River associated with a postulated failure of the Inglis Dam during a PMF is 24.65 ft. NGVD29.	FSAR Subsection 2.4.3.6	
		The maximum total (surge and wave action) water elevation from a PMH is 49.78 ft. NAVD88 or 50.78 ft. NGVD29.	FSAR Subsection 2.4.5.4.9	
Groundwater Level	Less than plant elevation 98 ft.	DCD groundwater elevation of 98 ft. = 49 ft. NAVD88 or 50 ft. NGVD29.	FSAR Subsection 2.4.12.5	Yes
		Surficial monitoring wells MW-15S (LNP 1) and MW-13S (LNP 2) recorded groundwater elevations (March, June, September, and December 2007), which ranged from 37.88 to 42.05 ft. NAVD88 and 37.66 to 41.94 ft. NAVD88, respectively.		

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Table 2.0-201 (Sheet 8 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

	AP 1000 DCD Site Parameters	LNP Site Characteristics	LNP Site Characteristic Reference	Bounding Yes/No
Plant Grade Elevation	Less than plant elevation 100 ft., except for portion at a higher elevation adjacent to the annex building	The nominal plant grade floor elevation is 51 ft. NAVD88 or 52 ft. NGVD29, which corresponds to AP1000 elevation of 100 ft. The actual plant grade will be lower and will vary to accommodate site grading, drainage, and local site flooding. Therefore, DCD plant elevation of 100 ft. = 51 ft. NAVD88 or 52 ft. NGVD29.	FSAR Subsection 2.4.1.1	Yes
Precipitation				
Rain	20.7 in./hr [1-hr 1-mi^2 PMP]	19.6 in./hr	FSAR Subsection 2.4.2.3	Yes
Snow / Ice	75 lb/ft^2 on ground with exposure factor of 1.0 and important factor of 1.2 (safety) and 1.0 (non-safety)	The 50-year recurrent Ground Snow Load for all monitoring stations is zero; therefore, estimations of the weight of snowpack are not necessary for the LNP site.	FSAR Subsection 2.3.1.2.3	Yes
Atmospheric Dispersion Values X/Q (f)				
Site Boundary (0-2 hours)	≤ 5.1 x 10^{-4} sec/m^3	5.08 x 10^{-4} sec/m^3	Table 2.3.4-201	Yes
Site Boundary (annual average)	≤ 2.0 x 10^{-5} sec/m^3	1.90 x 10^{-5} sec/m^3	Table 2.3.4-201	Yes
Low population zone boundary				Yes
0-8 hours	≤ 2.2 x 10^{-4} sec/m^3	9.70 x 10^{-5} sec/m^3	Table 2.3.4-201	Yes
8-24 hours	≤ 1.6 x 10^{-4} sec/m^3	7.19 x 10^{-5} sec/m^3	Table 2.3.4-201	Yes
24-96 hours	≤ 1.0 x 10^{-4} sec/m^3	3.75 x 10^{-5} sec/m^3	Table 2.3.4-201	Yes
96-720 hours	≤ 8.0 x 10^{-5} sec/m^3	1.48 x 10^{-6} sec/m^3	Table 2.3.4-201	Yes
Population Distribution				
Exclusion area (site)[(g)]	0.5 miles	The minimum distance from the effluent release boundary to the exclusion area boundary is 1340 m (4396 ft. or 0.83 mi.), except for LNP 1's ESE sector which has a minimum distance of 1247 m (4091 ft. or 0.77 mi.).	FSAR Subsection 2.1.1.2	Yes

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Table 2.0-201 (Sheet 9 of 9)
Comparison of AP1000 DCD Site Parameters and LNP Site Characteristics

Notes:
a) Maximum and minimum safety values are based on historical data and exclude peaks of less than 2 hours duration.

b) The maximum normal value is the 1-percent seasonal exceedance temperature. The minimum normal value is the 99-percent seasonal exceedance temperature. The minimum temperature is for the months of December, January, and February in the northern hemisphere. The maximum temperature is for the months of June through September in the northern hemisphere. The 1-percent seasonal exceedance is approximately equivalent to the annual 0.4-percent exceedance. The 99-percent seasonal exceedance is approximately equivalent to the annual 99.6-percent exceedance.

c) The non-coincident wet bulb temperature is applicable to the cooling tower only.

d) With ground response spectra as given in Figures 3.7.1-1 and 3.7.1-2 of the AP1000 DCD.

e) Per APP-GW-GLR-020, the kinetic energies of the missiles discussed in DCD Section 3.5 are greater than the kinetic energies of the missiles discussed in Regulatory Guide 1.76 and result in more conservative design.

f) For AP1000, the terms "site boundary" and "exclusion area boundary" are used interchangeably. Thus, the X/Q values specified for the site boundary applies whenever a discussion refers to the exclusion area boundary.

g) Exclusion area (site) for the LNP is defined as two overlapping circles centered on the reactor building of each unit. The radius of each circle is 1340 m (4396 ft.). The overall shape of the LNP exclusion area boundary is defined by the outermost boundary of each unit's circle. The EAB for LNP 1 was modified in the east-southeast direction. Atmospheric dilution factor (Chi/Q) calculations support the modification of the EAB to follow the property line in the east-southeast sector.

h) The containment pressure response analysis is based on a conservative set of dry-bulb and wet-bulb temperatures. These results envelop any conditions where the dry-bulb temperature is 115°F or less and wet-bulb temperature of less than or equal to 86.1°F.

i) Additional evaluation may include evaluation of the impact of the elevated estimated settlement values on the critical components of the AP1000, determining a construction sequence to control the predicted settlement behavior, or developing an active settlement monitoring system throughout the entire construction sequence, as well as a long-term (plant operation) plan.

j) Differential settlement is measured at center of Nuclear Island and center of adjacent structures.

°F = degrees Fahrenheit
CEUS SSC = Central and Eastern United States Seismic Source Characterization
CSDRS = certified seismic design spectra
EPRI-SOG = Electric Power Research Institute Seismic Owners Group
FIRS = foundation input response spectrum
~~ft. = foot~~
~~ft/sec = feet per second~~
~~g = unit of measure of acceleration of gravity~~
GMRS = ground motion response spectrum
ft. = foot
ft/sec = feet per second
g = unit of measure of acceleration of gravity
in. = inch
lb. = pound
lb/ft^2 = pound per square foot
lb/in^2 = pound per square inch
lb/m^2 = pound per square meter
m = meter
mph = miles per hour
~~NAVD88 = North American Vertical Datum of 1988~~
NAVD88 = North American Vertical Datum of 1988
NGVD29 = National Geodetic Vertical Datum of 1929
PMF = probable maximum flood
PMH = probably maximum hurricane
PMP = probable maximum precipitation
RCC = roller compacted concrete
sec/m^3 = seconds per cubic meter
SSE = safe shutdown earthquake
V_S = shear wave velocity

HRHF = hard rock high frequency
Hz = hertz

~~NGVD29 = National Geodetic Vertical Datum of 1929~~

Attachment B

Revised Subsection 2.5.0 Text

[13 pages following this cover page]

2.5 GEOLOGY, SEISMOLOGY, AND GEOTECHNICAL ENGINEERING

This section of the referenced DCD is incorporated by reference with the following departures and/or supplements.

STD DEP 1.1-1

This section is numbered to follow Regulatory Guide 1.206. The COL information items in DCD Subsections 2.5.1, 2.5.2, 2.5.3, 2.5.4, and 2.5.5 are addressed in FSAR Subsection 2.5.6.

LNP SUP 2.5-1

This section of the Final Safety Analysis Report (FSAR) presents information on the geology, seismology, and geotechnical engineering characteristics of the region, vicinity, and area of the Levy Nuclear Plant Units 1 and 2 (LNP) site. This section was developed in accordance with requirements outlined in Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)." Additional regulatory and technical guidance considered during preparation of FSAR Section 2.5 are discussed within each subsection.

FSAR Subsection 2.5.0 provides a summary of information presented in detail in FSAR Subsections 2.5.1, 2.5.2, 2.5.3, 2.5.4, and 2.5.5. Combined License Information items are summarized in FSAR Subsection 2.5.6, and references are in FSAR Subsection 2.5.7.

The vertical datum used for the COLA subsurface investigation and for the LNP construction site is the North American Vertical Datum 1988 (NAVD88). The vertical datum for references cited in this FSAR is per the cited reference, which include, above mean sea level (amsl), mean sea level (msl), NAVD88, or National Geodetic Vertical Datum 1929 (NGVD29).

2.5.0 SUMMARY

2.5.0.1 Basic Geologic and Seismic Information

2.5.0.1.1 Regional Geology

The LNP site is located on the west coast of the Floridian plateau or platform, a recently emergent part of the south-central North American Plate that separates the Gulf of Mexico from the Atlantic Ocean. Basement rocks underlying the Florida platform include Precambrian – Cambrian igneous rocks, Ordovician – Devonian sedimentary rocks, and Triassic – Jurassic volcanic rocks. Paleozoic basement rocks had a Gondwana origin, and were joined to the North American Plate in the final stages of development of the Appalachian Mountains in the Late Carboniferous to Early Permian. The igneous and sedimentary basement rocks originated from the African Plate but remained attached to the North American Plate when rifting that resulted in opening of the present Atlantic Ocean occurred in the Middle Triassic to Early Jurassic.

A thick sequence of mid-Jurassic to Holocene sediments unconformably overlies the basement rocks. From Middle Jurassic to Middle Oligocene, carbonate sedimentation was widespread along the Florida platform. This depositional regime changed in response to sea-level fluctuations and uplift and erosion in the Appalachian highlands. Starting in the mid-Oligocene and continuing into the Holocene, deposition of siliciclastic-bearing carbonates and siliciclastic sediments dominated the Florida platform. This thick sequence of unconsolidated to semiconsolidated sedimentary rocks comprises the Coastal Plain physiographic province.

The south-central United States is a passive continental margin with no relative differential motion (i.e., angular velocity) between the Gulf of Mexico and the North American continental plate. The LNP site lies within a stable continental region that is characterized by low earthquake activity and low stress. The site lies within a compressive midplate stress province characterized by reverse and strike-slip faulting. Reverse focal mechanisms for earthquakes that appear to have originated in the basement in the abyssal plain region of the Gulf of Mexico west of the site region are consistent with an east-northeastward-directed compressive stress environment.

The LNP site is located near the northeastern margin of the Gulf of Mexico basin (also referred to as the Gulf Coast basin or Gulf basin) that includes the present Gulf of Mexico and adjacent rift basins. Tectonic features in the site region reflect the cumulative deformation of tectonic events throughout the Late Proterozoic to Early Paleozoic, Paleozoic, Mesozoic, and Cenozoic eras. Cenozoic faults have been postulated by numerous authors in various parts of the study region, including the site area, based on apparent displacements inferred from limited outcrops and subsurface data from widely spaced boreholes and wells. The existence of many of these structures is controversial and not well supported by available data. None of these structures is judged to be a capable tectonic source.

The Electric Power Research Institute and Seismic Owners Group (EPRI-SOG) seismic hazard analysis for the nearby Crystal River Unit No. 3 Nuclear Generating Plant (CR3) site identified the Charleston seismic zone, the source of a large, geologically recent earthquake, as a significant seismic source at a distance of approximately 500 kilometers (km) (300 miles [mi.]). Updated information regarding the location, magnitude, and recurrence of this more distant, but significant, seismic source was incorporated into the updated seismic hazard analysis for the LNP site.

2.5.0.1.2 Site Geology

The LNP site, located within southern Levy County, lies approximately 16 km (10 mi.) west of the Gulf of Mexico and approximately 12.8 km (8 mi.) north of the Withlacoochee River. The site area, located within the Gulf Coastal Lowlands geomorphic province, is characterized by both depositional and erosional features. Broad plains underlain by a series of late Tertiary and Quaternary surfaces and shorelines are pitted with karstic depressions within the limestone at or near the present land surface in the site area. The LNP site is located within the Limestone Shelf and Hammocks subzone, a zone that is characterized as a karstic, erosional limestone plain overlain by sand dunes, ridges, and coast-parallel paleoshore sand belts associated with the Pleistocene-age marine terraces.

The oldest rocks penetrated within the site area are Paleozoic shales and quartzite pebble sands that are intruded by Triassic diabase. Overlying these sediments is a thick section of Cretaceous and Cenozoic carbonates (limestone and dolomite) that are overlain by undifferentiated Pleistocene- to Holocene-age surficial sands, clayey sands, and alluvium. Stratigraphy of the LNP site location is known from the Robinson No. 1 well located approximately 500 meters (m) (1640 feet [ft.]) north of the LNP site and from over 118 geotechnical borings that were drilled as part of the Combined License Application (COLA) study.

Hydrostratigraphic units of the Floridan aquifer system carbonate depositional sequence in west-central Florida include an Upper Floridan aquifer, which typically contains fresh potable water, and a Lower Floridan aquifer. The Upper Floridan aquifer commonly is separated physically and hydraulically from the underlying Lower Floridan aquifer by sequences of lower permeability evaporite rock units known as the Middle Confining Unit (MCU), which act as an aquitard. The geotechnical boring program at the LNP site results showed that the first carbonate rock units encountered below the surficial aquifer deposits are deposits of the middle Eocene age Avon Park Formation. To the maximum investigated depth of 152 m (500 ft.), neither the MCU nor the Lower Floridan aquifer units were encountered.

The Quaternary deposits (designated unit S1) encountered in the LNP site borings generally consist of gray silty sands. The subrounded to rounded sand grains and sorting indicate that the sands likely were deposited in a nearshore beach or dune environment, possibly during the transgression and regression of the high sea level stand that formed the underlying marine terrace platform, which is interpreted to be middle to early Pleistocene in age (>340,000 years). There may be a component of younger eolian sand deposited during subsequent sea level fluctuations and locally derived fluvial deposits. In some boreholes, thicker section of the S1 deposits consist of gray sand intermixed or interbedded with medium brown sand and grayish black clay and sandy clay layers. These deposits are interpreted to represent infills of sand and marsh deposits into paleosinks. Some of the infill material in the deeper paleosinks may be Tertiary as well as Quaternary in age.

The Avon Park Formation is a carbonate mud-dominated peritidal sequence, pervasively dolomitized in places and not dolomitized in others, and contains some intergranular and interbedded evaporites in its lower part. Fossils are mostly benthic forms showing limited faunal diversity. Seagrass beds are well preserved at certain horizons. The lower portion of the Avon Park Formation consists of lower permeability evaporite deposits, which act as an aquitard separating the Upper Floridan aquifer within the Avon Park Formation from the Lower Floridan aquifer within the Oldsmar Limestone.

The LNP site stratigraphy and surface morphology are consistent with expected characteristics of a developed, older (paleo) karst landscape mantled by several meters of sand (i.e., a mantled epikarst subsurface). Although there are no recognized sinkholes in the State of Florida sinkhole database or the SDII Global Corporation's much larger, private database (Reference 2.5.1-328) within 2 km (1.28 mi.) of the LNP site and no sinkholes at the land surface were observed during site investigations and reconnaissance within the LNP site, the presence of a few voids at depths identified in some borings suggests that paleo sinks such as those developed on the barren mature epikarst surface are locally present at the site.

Based on the review and updating of the geological, seismological, geophysical, and geotechnical data for the LNP site, nothing was identified that would preclude the safe operation of the facilities. The only geologic hazard identified in the LNP site area is potential surface deformation related to carbonate dissolution and slow cover subsidence related to the occurrence of karst. Karst features encountered below the nuclear islands at the LNP site are determined to be associated with near-vertical to vertical fractures and subhorizontal bedding planes, and vary in size from a few centimeters to approximately 1.5 m (5 ft.). Karst-related solution zones and/or infilled zones that exist in the subsurface beneath the LNP foundation will be addressed through appropriate design considerations in the LNP foundation conceptual design, as described in FSAR Subsection 2.5.4.

2.5.0.2 Vibratory Ground Motion

The selected starting point for developing the site-specific ground motion assessments for the LNP site was the Probabilistic Seismic Hazard Analysis (PSHA) conducted by the EPRI-SOG in the 1980s. Following guidance in the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.208, the adequacy of the EPRI-SOG hazard results was evaluated in light of new data and interpretations and evolving knowledge pertaining to seismic hazard evaluation in the central and eastern United States (CEUS). PSHA sensitivity analyses were conducted to test the effect of the new information on the seismic hazard. Using these results, a~~n updated~~ PSHA analysis was performed using an updated EPRI-SOG seismic source model.~~;~~ T~~t~~he results of that analysis we~~a~~re ~~have been~~ used to develop the site-specific design ground motions. The site-specific ground motions were scaled upward to meet 10 Code of Federal Regulations (CFR) Part 50 Appendix S requirements.~~uniform hazard response spectra (UHRS) and the identification of the controlling earthquakes~~.

Sensitivity evaluations were performed using ~~the~~ the CEUS Seismic Source Characterization (SSC) seismic source model (~~Reference 2.5.2-284~~NUREG-2115) and the modified cumulative absolute velocity filter (CAV) (NRC Office of the Secretary [SECY]-20~~20~~12-0025 Enclosure 7 – Attachment 1 to Seismic Enclosure 1) to show that the site--specific ground response spectra obtained using the CEUS SSC model are bounded by those using the updated EPRI-SOG model~~methodology~~ scaled to meet 10 CFR Part 50 Appendix S requirements. The CEUS SSC sensitivity evaluations are described in Subsection 2.5.2.7.

2.5.0.2.1 Seismicity

For this study, an updated earthquake catalog was created that includes additional historical and instrumental events through December 2006. Only 15 earthquakes larger than body-wave magnitude (m_b) 3.0 have occurred within the LNP site region. The largest event, an m_b 4.3 earthquake, occurred at a distance of 76.6 km (47.6 mi.) from the LNP site and is the only event within 80 km (50 mi.) of the site.

Seismicity that is occurring beyond the site region also was considered. The occurrence of two moderate earthquakes in the Gulf of Mexico in 2006 has implications to the evaluation of seismicity parameters for the Gulf Coast basin source zones that include the LNP site.

2.5.0.2.2 Geologic Structures and Seismic Source Models

In the review of seismic source characterization models developed for post-EPRI-SOG seismic hazard analyses, and comparison of the updated earthquake catalog to the EPRI-SOG evaluation, one additional specific seismic source was identified and evaluated: repeated large-magnitude earthquakes in the vicinity of Charleston, South Carolina.

The EPRI-SOG seismic source models in the vicinity of Charleston, South Carolina, were updated in 2006 by the Southern Nuclear Company (SNC), in support of the Vogtle Early Site Permit Application, to incorporate new information on the possible source of future large earthquakes similar to the 1886 Charleston earthquake; new assessments of the size of the 1886 earthquake; and new information on the occurrence rate for large earthquakes in the vicinity of Charleston, South Carolina. The result was the development of an updated Charleston seismic source (UCSS).

2.5.0.2.3 Correlation of Earthquake Activity with Seismic Sources

Comparison of the updated earthquake catalog to the EPRI-SOG earthquake catalog and EPRI-SOG sources yields the following conclusions:

- In addition to those included in the EPRI-SOG characterizations, the updated earthquake catalog does not show a pattern of seismicity within the site region different from that exhibited by earthquakes in the EPRI-SOG catalog that would suggest a new seismic source.

- The updated earthquake catalog shows similar spatial distribution of earthquakes to that shown by the EPRI-SOG catalog, suggesting that no significant revisions to the geometry of seismic sources defined in the EPRI-SOG characterization is required based on seismicity patterns.

- The updated catalog does not show any earthquakes within the site region that can be associated with a known geologic structure.

- The largest earthquake known to have occurred in southeastern United States, the 1886 Charleston earthquake, likely reactivated a structure within the basement rock, but cannot be definitely associated with any of the major identified basement structures. Alternative source locations, maximum magnitudes, and recurrence for repeated large-magnitude, Charleston-type earthquakes are incorporated into the PSHA.

- The updated catalog includes two earthquakes that are larger in magnitude than some of the upper- and/or lower-bound values used by EPRI-SOG teams to characterize the maximum magnitude (M_{max}) distribution of source zones within which these earthquakes occurred. These earthquakes are the February 10, 2006, Emb[a] 4.9 earthquake, and the September 10, 2006, Emb 6.0 earthquake. Revisions to some of the EPRI earth science teams (EST) M_{max} distributions for background source zones to account for these events were incorporated into the updated PSHA.

- The February 10, 2006, Emb 4.9 earthquake, which does not exhibit typical source characteristics of a tectonic earthquake, has been potentially associated with specific geologic structures near the edge of the continental shelf. The September 10, 2006, Emb 6.0 earthquake, which has a tectonic signature, has not been tied to any unique geologic structure. This event occurred near the transition between oceanic and thin transitional crust, in extended basement crust having northwest-trending normal faults that are favorably oriented for reactivation in the present tectonic regime.

- The updated earthquake catalog adds a few earthquakes in the time period covered by the EPRI-SOG catalog (principally prior to 1910). The effect of these additional events on estimated seismicity rates was assessed.

2.5.0.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquakes

The review of new geological, geophysical, and seismological information, the review of seismic source characterization models developed for post-EPRI-SOG seismic hazard analyses, and a review of the updated earthquake catalog to the EPRI-SOG evaluation have been used to develop an updated seismic hazard model for the LNP site. The EPRI-SOG source models have been modified as follows:

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[a] Emb — Expected estimate of body wave magnitude. Emb values assigned to the 2006 earthquakes in the STP 3 & 4 COLA differ slightly from the LNP catalog due to different versions of magnitude conversion relationships used in the two studies.

- The UCSS developed by SNC has been included to account for new information regarding the location, size, and occurrence of repeated large-magnitude earthquakes in the vicinity of Charleston, South Carolina.

- Two moderate earthquakes have occurred within the Gulf of Mexico since the EPRI-SOG 1986 study. The magnitudes of these events exceed the upper and/or lower bound of the M_{max} distributions originally proposed by some of the EPRI ESTs for large areal source zones that encompass large portions of the Gulf Coastal Plain and the Gulf of Mexico. The M_{max} distributions have been revised for five of the six EPRI EST source zones to account for these earthquakes in the hazard calculations.

- An additional earthquake catalog completeness zone in the Gulf of Mexico has been added to incorporate the contribution of offshore seismicity into the hazard analysis for the LNP site.

The following PSHA model adjustments were studied as part of PSHA sensitivity tests for the LNP site based on this new information:

- Selection of the appropriate set of seismic sources for each EPRI-SOG EST using the updated EPRI ground motion models that will be used to compute the PSHA for the LNP site.

- Sensitivity to new data relative to the occurrence of large earthquakes in the Charleston, South Carolina, region.

- Sensitivity to the updated maximum magnitude distributions for seismic sources extending into the Gulf of Mexico.

- Sensitivity to the updated seismicity parameters for seismic sources extending into the Gulf of Mexico.

The PSHA for the LNP site was conducted using the updated EPRI-SOG seismic sources combined with the UCSS source. Earthquake ground motions were modeled using the median ground motion models developed by EPRI in 2004 and the ground motion aleatory variability models developed by EPRI in 2006.

PSHA calculations were performed for response spectral accelerations at the seven structural frequencies provided in the EPRI 2004 ground motion model: 0.5, 1.0, 2.5, 5, 10, 25, and 100 hertz (Hz) (peak ground acceleration [PGA]). The UCSS produces comparable hazard or somewhat larger hazard than that obtained from the updated EPRI-SOG sources for 10-Hz motions, and dominates the hazard for 1-Hz motions

The mean hazard results were interpolated to obtain UHRS for generic CEUS hard rock conditions for mean annual frequencies of exceedance of 10^{-4}, 10^{-5}, and 10^{-6}.

Deaggregation was conducted to identify the controlling earthquakes for two frequency bands: (1) the average of the 5-Hz and 10-Hz hazard results representing the high-frequency (HF) range, and (2) the average of the 1-Hz and 2.5-Hz hazard results representing the low-frequency (LF) range. The HF deaggregation shows a progression from domination of the hazard by large, distant earthquakes at a mean exceedance frequency of 10^{-3} to dominance by nearby small-magnitude earthquakes at a mean exceedance frequency of 10^{-6}. The LF deaggregation indicates that the distant large-magnitude earthquakes dominate the hazard at all four levels of exceedance frequency.

Site response Approach 2B, defined in NUREG/CR-6728, was used to assess site amplification. In this method, the response spectra of the controlling earthquakes (termed reference earthquakes [RE] in NUREG/CR-6728) are multiplied by mean site amplification function to develop hazard consistent response spectra at the reference location. The mean site amplification functions are computed for a range of earthquake magnitude-distance pairs that represent distribution of earthquakes contributing to the hazard. These are termed deaggregation earthquakes (DEs), and three are defined for both the high-frequency and low-frequency ranges. Smooth response spectra were developed for each DE.

2.5.0.2.5 Seismic Wave Transmission Characteristics of the Site

Site response analyses were conducted to evaluate the effect of the sedimentary rocks on the generic CEUS hard rock ground motions. The intent of these analyses is to develop ground motions at the surface that are consistent with the hazard levels defined for the generic rock conditions.

Shear (V_S) and compression (V_P) wave velocity data were obtained at the LNP site. A combination of suspension logging and downhole velocity surveys were used to measure shear-wave velocities to a depth of approximately 152 m (500 ft.). Measurements were conducted in or near 18 borings, 9 at the site of each LNP unit. Interpreted shear-wave velocity models for each boring was based on interpretations of the velocity data and comparisons to boring log lithology and a suite of other geophysical logging survey data. The shear-wave velocity data show a generally consistent pattern at the two units. Velocity information that was available for other wells in the site vicinity was used to estimate shear-wave velocity for the deeper part of the section down to and including the Paleozoic units underlying the site location.

The ground motion response spectra (GMRS) were calculated at an elevation of 11 m (36 ft.) in the North American Vertical Datum of 1988 (NAVD88) at the top of the calcareous silt (unit S2) (undifferentiated Tertiary unit, interpreted as weathered rock). The materials that are included in the site response analysis to develop the GMRS consist of approximately 18.3 m (60 ft.) of partly to moderately calcareous silts (units S2 and S3) above unweathered sedimentary rocks. To account for the potential of nonlinear behavior in the calcareous silt units (weathered rock), two alternative sets of modulus reduction and damping relationships were used.

Site response calculations were performed for four initial profiles. Analyses were preformed using two sets of modulus reduction and damping relationships and the best estimate value for κ. For each analysis, 60 randomized profiles were generated and the mean site amplification (response spectrum for surface motion divided by response spectrum for input motion) was computed.

Based on sensitivity analyses, two profiles (one for each unit) were selected for calculation of the site amplification. The envelope of the site amplification computed from the two profiles was used to develop surface motion.

The site response analyses profiles for the design grade case were developed by adding a layer of engineered fill to the GMRS profiles to bring the top elevation up to 15.5 m (51 ft.) NAVD88. The analyses were performed for a wide range of engineered fill properties.

2.5.0.2.6 Ground Motion Response Spectra

The final assessment of the surface UHRS was based on PSHA calculations that use ~~cumulative absolute velocity (~~CAV~~)~~ filtering in place of a fixed minimum magnitude. These UHRS were used to develop the GMRS.

The horizontal GMRS for the LNP site were developed using the performance-based approach defined in NRC Regulatory Guide 1.208 (based on UHRS developed using CAV filtering). The computed GMRS corresponds to the minimum of 0.45 times the 10^{-5} UH~~S~~RS. The vertical GMRS were developed by multiplying the horizontal GMRS by vertical/horizontal spectral ratios derived from the ratios recommended for western United States (WUS) rock and CEUS hard rock in NUREG/CR-6728. ~~A~~The final step was to scale the GMRS upward by a factor of 1.212 to meet~~an~~ the requirement of a minimum peak horizontal acceleration of 0.1 gravity acceleration (g) for the foundation input response spectra (FIRS) at the reactor foundation level. The horizontal and vertical site scaled GMRS are enveloped by the Westinghouse Certified Seismic Design Response Spectra (CSDRS).

Performance-based surface response spectra (PBSRS) and associated soil column outcropping response (SCOR) ~~foundation input response spectra (~~FIRS~~)~~ were developed using the site response analysis of profiles that extended to the design grade elevation. These spectra were scaled upward by a factor of 1.212 to meet the requirement of a minimum peak horizontal acceleration of 0.1 ~~gravity acceleration (~~g~~)~~ for the FIRS at the reactor foundation level. These spectra are used to develop inputs for soil structure interaction (SSI) analyses. The scaled PBSRS are also enveloped by the Westinghouse CSDRS. Design grade (elevation 15.5 -m [51 ft.]) SSI input response spectra were also developed. Three SSI input soil profiles were developed from the randomized soil profiles used to compute the PBSRS. These profiles accommodate the variability in the in-situ materials and the anticipated range in fill properties.

2.5.0.3 Surface Faulting

The evaluation of the potential for surface deformation at Levy Nuclear Plant Unit 1 and 2 (LNP 1 and LNP 2) considered both tectonic and nontectonic origins. Investigations performed to evaluate the potential for surface fault rupture at LNP 1 and LNP 2, as well as the surrounding LNP site area, included compilation and review of existing data and literature, lineament analyses, discussions with current researchers in the area, field reconnaissance, geomorphic analyses, and review of seismicity data. Results of the surface faulting study indicate that there is no evidence for Quaternary tectonic surface faulting or fold deformation at the LNP site, and no capable tectonic sources have been identified within 40 km (25 mi.) of the site.

The LNP site is located on a marine terrace that is estimated to be older than 340,000 years, possibly of early Pleistocene to late Pliocene age. There is no geomorphic evidence to suggest that the bedrock surface (marine plantation surface) underlying the Quaternary terrace cover deposits in the site location has been displaced or deformed by tectonic faulting. The nearly horizontal terrace surface generally exhibits only minor relief related to karst development. There are no pronounced lineaments across the site location that suggest the presence of a through going fault or major fracture system.

The potential for nontectonic deformation at the site from phenomenon other than karst-related collapse or subsidence is negligible.

The LNP site area is situated in an area that could potentially have karst feature development (see FSAR Subsection 2.5.1). An assessment of aerial photos and site investigation was conducted to identify key features associated with solution subsidence activity. Although evidence of solution activity was encountered in some of the boreholes advanced as part of this COLA, findings from the soils and rock borings, along with geophysical testing, did not indicate the presence of major solution features that would have a significant impact on the safety of a nuclear plant with a properly designed foundation.

2.5.0.4 Stability and Uniformity of Subsurface Materials and Foundations

Surface geologic deposits observed at LNP 1 and LNP 2 consist of undifferentiated Quaternary age fluvial and marine terrace sediments, primarily silty fine sands. The sands overlie the Avon Park Formation, a shallow marine carbonate rock unit of mid-Eocene age, characterized as cream to brown or tan, poorly indurated to well-indurated, variably fossiliferous limestone, interbedded in places with tan to brown, very poorly to well-indurated, fossiliferous, vuggy dolostones. Carbonized plant remains are common in the rock sequence in the form of thin, poorly indurated laminae and cyclic interbeds.

The depth of undifferentiated Quaternary (unit S1) and Tertiary (units S2 and S3) sediments varies. The top of rock (unweathered Avon Park Formation) occurs at an approximate elevation of -7.3 m (-24 ft.) NAVD88 at the LNP site, with undulations due to the erosional nature of the surface. The reactor islands of LNP 1 and LNP 2 will be founded at basemat elevation +3.5 m (+11.5 ft.) NAVD88. Therefore, the Avon Park Formation rock is below the bottom of the basemat of each nuclear island. The Avon Park Formation rock has a weighted mean dip of 2 degrees at both LNP 1 and LNP 2 within the subsurface investigation depth, i.e. 152 m (500 ft.).

A subsurface investigation program, consisting of geotechnical boreholes, geophysical surveys, in situ testing, and laboratory testing, was performed from January 2007 through January 2008 in accordance with Regulatory Guide 1.132 and Regulatory Guide 1.138. A total of 118 boreholes were advanced, including 10 initial phase boreholes, 90 main phase boreholes, and 18 supplemental boreholes. The depth of these boreholes ranged from less than 30 m (100 ft.) to nearly 152 m (500 ft.) below the ground surface (bgs) with at least 19 at each nuclear island with depths of more than 61 m (200 ft.). Geophysical survey methods were conducted in representative boreholes. These survey methods included suspension P-S velocity logging, downhole shear-wave logging, acoustic televiewer surveys, and non-seismic borehole geophysical surveys, including natural gamma logging, gamma-gamma logging, neutron-neutron logging, and induction logging. In addition, pressuremeter testing (PMT) was performed at various depths in one borehole at each LNP site. A total of 213 special-care rock core samples were laboratory tested for unconfined compressive strength (UCS) and other index tests. Forty two special-care rock core samples were laboratory tested for split tensile strength and other index tests. Nine special-care rock core samples were used for triaxial compressive strength tests in laboratory. Numerous soil samples were tested for index properties.

Engineering properties of subsurface materials were characterized from the site investigation activities. Two of the key properties are summarized as follows:

- The average shear-wave velocity (V_S) from all suspension P-S velocity logging at LNP 1 varied from 760 to 1680 meters per second (m/sec) (2500 to 5500 ft/sec) below the top of rock. At LNP 2, the average V_S varied from 760 to 1520 m/sec (2500 to 5000 ft/sec) below the top of rock. Three and four rock layers were defined for engineering analysis based on shear-wave velocity at LNP 1 and LNP 2, respectively.

- The average UCS from laboratory tests on intact rock core samples of the rock layers varied from 4.8 to 25.5 megaPascals (MPa) (700 to 3700 pounds per square inch [psi]) at LNP 1 and varied from 4.8 to 20 MPa (700 to 2900 psi) at LNP 2. UCS results range from 0.9 to 127.3 MPa (131 to 18458 psi) among all samples tested from the LNP site.

The nuclear island building floor elevation for LNP 1 and LNP 2 is elevation +15.5 m (+51 ft.) NAVD88. The ground surface elevation immediately outside of the reactor islands will be at elevation +15.5 m (+51 ft.) NAVD88, except where required to be lower due to water control. The surrounding grade will be lower to accommodate site grading, drainage, and local site flooding requirements. The current ground surface varies approximately from +12.3 to +13.2 m (+40.3 to +43.2 ft.) NAVD88 at LNP 1, and from +12.1 to +13.4 m (+39.8 to +43.9 ft.)

NAVD88 at LNP 2. Therefore, site fill of approximately +1.8 to +3.0 m (+6 to +10 ft.) will be required to raise the grade.

The nuclear island basemat will be founded at elevation +3.5 m (+11.5 ft.) NAVD88 on an 11 m (35 ft.) roller compacted concrete (RCC) bridging mat. A waterproof geomembrane will be placed on the RCC and topped with a 15-centimeter (cm) (6-inch [in.]) mudmat, as described in the DCD (Subsection 3.4.1.1.1), prior to placement of the nuclear island basemat. Excavation for construction of the RCC bridging mat and nuclear island is facilitated by permeation grouting and a perimeter diaphragm wall. Grouting from the ground surface will provide a barrier over a 23 m (75 ft.) zone of the Avon Park Formation below the planned RCC. The diaphragm wall will be keyed into the grouted limestone formation and provide a side barrier for excavation dewatering. Grouting reduces gross porosity and permeability to facilitate dewatering but also reduces long-term groundwater flow to minimize potential solution impact.

Groundwater dewatering flow rates were calculated as summarized in FSAR Subsection 2.5.4.6.2. It is anticipated that groundwater inflow during construction can be managed by six submersible pumps (each with 378 liters per minute [lpm] [100 gallons per minute [gpm]] capacity) installed in wells located around the inside perimeter of the diaphragm wall and pumps placed in sumps within the excavation. Although highly unlikely, a second round of drilling and pressure grouting in localized zones could be implemented at specific locations to help seal areas where groundwater is seeping through the engineered barriers.

The factors of safety (FS) for static and dynamic bearing capacity were analyzed for safety-related structures. Conservative methodology was used to estimate bearing capacity as summarized in FSAR Subsection 2.5.4.10.1. Static and dynamic FS were greater than 3.0 and 2.0 for both LNP 1 and LNP 2. The nuclear island foundations have no potential for liquefaction because these foundations consist of RCC, dental concrete, grouted rock, and rock. Some material adjacent to the nuclear island will be replaced or improved due to potential liquefaction, or detailed analysis for nuclear island sliding will demonstrate an adequate margin of safety without credit for passive wedge resistance. The LNP 1 and LNP 2 Annex Buildings (seismic Category II structures) will be founded on deep foundations (4000-psi concrete drilled shafts) that are socketed into the Avon Park Formation. The downdrag load on the deep foundation due to the potential liquefaction of soils will be also resisted by the rock socket in the Avon Park Formation.

Total and differential settlements of safety-related structures were estimated based on elastic compression rock mass from average elastic moduli established by suspension P-S velocity logging surveys at LNP 1 and LNP 2. Total settlements at each LNP site are estimated to be within acceptable settlement criteria for the Westinghouse AP1000 Reactor (AP1000) nuclear islands. The differential settlement (distortion) slopes are estimated to be less than 0.00083 (or 1/1200), which is within the acceptable range for the AP1000 under both LNP 1 and LNP 2.

- Adjacent nonsafety-related structures will be founded on deep foundations (4000-psi concrete drilled shafts) that are socketed into the Avon Park Formation. Preliminary settlement analyses indicate that these structures will exhibit very little total settlement (less than 25 millimeters (mm) [1 in.]), and therefore any potential for differential settlement is negligible.

2.5.0.5 Stability of Slopes

The site grade at the LNP site will be constructed at approximately 15.5 m (51 ft.) NAVD88, with minor variations to allow drainage for an area of about 370 m by 390 m (1210 ft. by 1280 ft.) around the nuclear island. No permanent slopes will be present at the site that could adversely affect safety-related structures.

The AP1000 does not utilize safety-related dams or embankments, and there are no existing upstream or downstream dams that could affect the LNP site safety-related facilities.

2.5.1 BASIC GEOLOGIC AND SEISMIC INFORMATION

LNP COL 2.5-1

This subsection presents information on the geologic and seismologic setting of the LNP site. Appendix C, "Investigations to Characterize Site Geology, Seismology, and Geophysics," of the NRC Regulatory Guide 1.208 "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" provides additional guidance on geological, seismological, and geophysical investigations that should be conducted to develop an up-to-date, site-specific earth science database that supports site characterization and a site-specific probabilistic seismic hazard analysis (PSHA). FSAR Subsection 2.5.1 presents geologic and seismologic information, as outlined in the NRC Regulatory Guide 1.208, about the site region (within a 320 km [200 mi. radius) including site vicinity (within a 40 km [25 mi.] radius), site area (within an 8 km [5 mi.] radius), and site location (within a 1 km [0.6 mi.] radius).

Several sources of information were used to develop the information summarized in this subsection. The Final Safety Analysis Report for the Crystal River Unit No. 3 Nuclear Generating Plant (CR3) (Reference 2.5.1-201), which is located approximately 18 km (11 mi.) southwest of the LNP site, provided a limited amount of information applicable to the LNP analysis. A more comprehensive database was developed for the LNP site that incorporates reports, maps, and articles published by state and federal agencies and professional/academic journals, remote sensing imagery, aerial photographs, and digital elevation model data. Additional unpublished information and data also were obtained through communications with individual researchers and personnel at universities, the Florida Geological Survey (FGS), and Southwest Florida Water Management District (SWFWMD).

The emphasis was placed on identifying new information that would suggest significant differences from the information used to develop the Electric Power

Attachment C

Revised Subsection 2.5.2 Text and Tables and New Subsection 2.5.2 Tables

[89 pages following this cover page]

2.5.2 VIBRATORY GROUND MOTION

LNP COL 2.5-2

This subsection provides a detailed description of vibratory ground motion assessments that were carried out for LNP 1 and LNP 2. The subsection begins with a review of the approaches outlined in NRC Regulatory Guide 1.208 for conducting the vibratory ground motion studies. Following this review of the regulatory framework used for the project, results of the seismic hazard evaluation are documented and the site-specific scaled GMRS for horizontal and vertical motions are developed. ~~In addition, s~~Sensitivity evaluations were also performed for the CEUS SSC source model (~~Reference 2.5.2-284~~NUREG-2115) and the modified CAV filter (SECY-2012-0025 Enclosure 7 – Attachment 1 to Seismic Enclosure 1) to show that the site-specific groundg response spectra (PBSRS and FIRS [EL~~(elevationEL~~ +11 ft.]~~)~~) obtained using the CEUS SSC model are bounded by those obtained using the updated EPRI-SOG model scaled to meet 10 CFR Part 50 Appendix S requirements. The updated EPRI-SOG methodology included the updated EPRI-SOG earthquake catalog through the end of 2006, and use of the ~~Updated Charleston Seismic Source (~~UCSS~~)~~. The CEUS SSC sensitivity evaluations are described in Subsection 2.5.2.7.

The NRC Regulatory Guide (RG) 1.208 provides guidance on methods acceptable to the NRC to satisfy the requirements of the seismic and geologic regulation, 10 ~~Code of Federal Regulations (~~CFR~~)~~ 100.23, for assessing the appropriate safe shutdown earthquake (SSE) ground motion levels for new nuclear power plants. Regulatory Guide 1.208 states that the PSHA conducted by the EPRI-SOG in the 1980s (References 2.5.2-201 and 2.5.2-202) has been used for studies in the past. The EPRI-SOG study involved a comprehensive compilation of geological, geophysical, and seismological data; evaluations of the scientific knowledge concerning earthquake sources, maximum earthquakes, and earthquake rates in the CEUS by six multidisciplinary teams of experts in geology, seismology, and geophysics; and separately, development of state-of-knowledge earthquake ground motion modeling, including epistemic and aleatory uncertainties.[c] The uncertainty in characterizing the frequency and maximum magnitude of potential future earthquakes associated with these sources and the ground motion that may be produced was assessed and explicitly incorporated in the seismic hazard model.

c. Epistemic uncertainty is uncertainty attributable to incomplete knowledge about a phenomenon that affects the ability to model it. Epistemic uncertainty is reflected in a range of viable models, model parameters, multiple expert interpretations, and statistical confidence. In principle, epistemic uncertainty can be reduced by the accumulation of additional information. Aleatory uncertainty (often called aleatory variability or randomness) is uncertainty inherent in a nondeterministic (stochastic, random) phenomenon. Aleatory uncertainty is accounted for by modeling the phenomenon in terms of a probability model. In principle, aleatory uncertainty cannot be reduced by the accumulation of more data or additional information.

Regulatory Guide 1.208 further specifies that the adequacy of the EPRI-SOG hazard results must be evaluated in light of new data and interpretations and evolving knowledge pertaining to seismic hazard evaluation in the CEUS. The following steps describe a procedure acceptable to the NRC staff for performing a PSHA.

1. Perform regional and site geological, seismological, and geophysical investigation in accordance with Regulatory Position 1 and Appendix C to RG 1.208.

2. Perform an evaluation of seismic sources, in accordance with Appendix C to RG 1.208, to determine whether they are consistent with the site-specific data gathered in Regulatory Positon 3.1 or if they require updating. If potentially significant differences are identified, perform sensitivity analyses to assess whether those differences have a significant effect on site hazard.

3. If Step 2 indicates that there are significant differences in site hazard, then the PSHA for the site is revised by either updating the previous calculations or, if necessary, performing a new PSHA. If not, the previous EPRI-SOG results may be used to assess the appropriate SSE ground motions.

Regulatory Guide 1.208 provides guidance on performance goal-based methods acceptable to the NRC to satisfy the requirements of the seismic and geologic regulation, 10 CFR 100.23, for assessing the appropriate site-specific performance goal-based ground motions for new nuclear power plants. Specifically, the performance-based approach described in American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) Standard 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities" may be used to define site-specific performance goal-based GMRS at the ground surface based on mean hazard results (Reference 2.5.2-203). The development of mean seismic hazard results is to be based on a site-specific PSHA combined with site-specific site amplification analyses. The procedures to be used to perform the PSHA and site amplification studies are in Regulatory Guide 1.208. Regulatory Guide 1.208 also provides guidance on an alternative approach for addressing the lower-bound magnitude used in the PSHA based on the likelihood that earthquakes of various sizes can produce potentially damaging ground motions. The ground motion measure used to correlate with the threshold of potential damage is ~~cumulative absolute velocity (~~CAV~~)~~. The alternative approach using the CAV filter is used to develop the final scaled GMRS for LNP 1 and LNP 2.

This subsection discusses the following aspects of vibratory ground motion:

- Seismicity (FSAR Subsection 2.5.2.1)

- Geologic and Tectonic Characteristics of the Site and Region (FSAR Subsection 2.5.2.2)

- Correlation of Earthquake Activity with Seismic Sources (FSAR Subsection 2.5.2.3)
- Probabilistic Seismic Hazard Analysis and Controlling Earthquake (FSAR Subsection 2.5.2.4)
- Seismic Wave Transmission Characteristics of the Site (FSAR Subsection 2.5.2.5)
- Ground Motion Response Spectra (FSAR Subsection 2.5.2.6)
- Sensitivity Evaluations for the CEUS SSC model (FSAR Subsection 2.5.2.7)

2.5.2.1 Seismicity

An important component in developing a seismic hazard model for the LNP site is the seismic history of the region. The selected starting point for developing the site-specific PSHA for the LNP site is the EPRI-SOG (Reference 2.5.2-201) seismic hazard model for the CEUS. The data used to assess earthquake occurrence rates for the seismic sources in the EPRI-SOG model were those in the earthquake catalog.

The first step in the three-step process for evaluating the adequacy of this model for the assessment of seismic hazards at the LNP site involved an assessment of the effect of recent information on the characterization of the seismicity of the southeastern United States. The development of an updated earthquake catalog for the project region is described in FSAR Subsection 2.5.2.1.1. Information on significant earthquakes is provided in FSAR Subsection 2.5.2.1.2. In addition to the discussion of significant earthquakes within the site region, this subsection also discusses recent earthquakes in Gulf of Mexico that postdate the EPRI-SOG catalog. Although these events fall outside the 320-km (200-mi.) radius site region, they occurred within some of the EPRI-SOG background seismic source zones that include the LNP site and thus have implications for assessment of maximum magnitudes in these source zones as discussed in FSAR Subsection 2.5.2.4.1.2. In addition, further assessment of catalog completeness and earthquake recurrence parameters for the offshore region were required as discussed in FSAR Subsections 2.5.2.4.1.3 and 2.5.2.4.1.4.

2.5.2.1.1 Earthquake Catalog

Earthquake occurrence rates for the seismic sources developed in the EPRI-SOG study were based on the EPRI-SOG CEUS earthquake catalog that was developed for the time period of 1627 through February 1985. The EPRI-SOG catalog has gone through two significant revisions. Seeber and Armbruster (Reference 2.5.2-204) conducted a thorough review of the catalog, revising the magnitude estimates and locations of many events, removing some events as non-earthquakes and adding others. The revised earthquake catalog is denoted as the National Center for Earthquake Engineering Research (NCEER)-91 catalog (Reference 2.5.2-205). Subsequently, Mueller et al.

reviewed the NCEER-91 catalog along with additional information and developed a catalog of independent[d] earthquakes for use in the U.S. Geological Survey's National Seismic Hazard Mapping Program (Reference 2.5.2-206). The most recent version of this catalog, which is referred to as the USGS 2002 CEUS catalog, is obtainable from the USGS National Seismic Hazard Mapping Project website (Reference 2.5.2-207).

The USGS 2002 CEUS catalog was further updated as part of studies for the Tennessee Valley Authority (TVA) Bellefonte site (Reference 2.5.2-208). The updated catalog incorporated new information on location and magnitude of historical earthquakes and included 174 newly identified historical earthquakes, principally from studies by Metzger, Metzger et al., and Munsey (References 2.5.2-209, 2.5.2-210, and 2.5.2-211). Details of the development of the Bellefonte Geotechnical, Geological, and Seismological (GG&S) earthquake catalog are provided in TVA (Reference 2.5.2-208).

The catalog for the LNP site consists of the Bellefonte GG&S earthquake catalog extended to 23°N and to 107°W, and through December 2006 using the listing of additional earthquakes from the EPRI-SOG catalog and recent earthquakes obtained from the following sources:

- Advanced National Seismic System (ANSS) website (References 2.5.2-208 and 2.5.2-212).

- USGS National Earthquake Information Center website (Reference 2.5.2-213).

- Southeastern U.S. Seismic Network website operated by Virginia Tech Seismological Observatory (Reference 2.5.2-214).

- International Seismological Center Bulletin (Reference 2.5.2-215).

Figure 2.5.2-201 shows the spatial distribution of earthquakes in the project earthquake catalog. Figure 2.5.2-202 shows the locations of earthquakes within 320 km (200 mi.) of the LNP site. Note that only one earthquake in the project catalog has occurred within 80 km (50 mi.) of the LNP site. The earthquakes are color coded on Figures 2.5.2-201 and 2.5.2-202 to indicate those events included in the EPRI-SOG earthquake catalog for the time period of 1758 to 1985, historical events added to the EPRI-SOG catalog, and those events that occurred after the EPRI-SOG catalog (1985 to 2006). The added historical earthquakes and the earthquakes occurring since the EPRI-SOG study have similar spatial

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d. The PSHA formulation used in this study assumes that the temporal occurrence of earthquakes conforms to a Poisson process, implying independence between the times of occurrence of earthquakes. Thus it is necessary to remove dependent events (such as foreshocks and aftershocks) from the earthquake catalog before estimating earthquake frequency rates.

distributions as the earthquakes contained in the EPRI-SOG catalog, and no new concentrations of seismicity are apparent in the updated catalog.

Appendix 2AA lists the earthquakes in the updated catalog that have occurred within 320 km (200 mi.) of the LNP site. The list consists of 15 events of $m_b \geq 3$ that occurred between 1826 and January 1, 2007. The size distribution of these earthquakes consists of 13 events of magnitude $3 \leq m_b < 4$; and 2 events of magnitude $4 \leq m_b < 4.5$. Estimates of the Modified Mercalli Intensity (MMI) and strong motion records are not available for these earthquakes.

In addition to these events, earthquakes that occurred in the Gulf of Mexico at greater distance from the LNP site were considered. In all, there are 17 additional earthquakes of $m_b \geq 3$ recorded from 1963 to January 1, 2007; 11 events of magnitude $3 \leq m_b < 4$; 5 events of magnitude $4 \leq m_b < 5$; and 1 event of magnitude $5 \leq m_b \leq 6$, which occurred at nearly 500 km (310 mi.) from the LNP site. Estimates of the MMI and strong motion records are not available for these earthquakes.

Focal depths are either not determined (set equal to 0) or fixed (set to 5, 10, 15, or 33 km) for most of the earthquakes. Only five events have listed depths greater than 10 km. The earthquakes do not show any correlation between depth and magnitude.

The body-wave magnitude scale, m_b, was used as the uniform magnitude scale in the original EPRI-SOG earthquake catalog and is the magnitude scale used in the catalog developed for the LNP study. Estimated seismic moments are provided for the catalog in Appendix 2AA. The values listed were estimated by first estimating moment magnitude using the three relationships described in FSAR Subsection 2.5.2.4, then computing seismic moment from each moment magnitude estimate using the Hanks and Kanamori relationship, and finally, averaging the results (Reference 2.5.2-216).

2.5.2.1.2 Significant Earthquakes

2.5.2.1.2.1 Significant Earthquakes in the Site Region (320 km [200 mi.] Radius)

Seismicity within 320 km (200 mi.) of the LNP site is sparse and minor; earthquake magnitudes do not exceed m_b 4.3. The locations of the earthquakes listed in the catalog developed for the LNP study are shown on Figure 2.5.2-202. The largest earthquake (m_b 4.3) is described as follows:

This earthquake occurred on January 13, 1879, near St. Augustine in the northeast part of Florida. Shaking caused by this event knocked plaster from walls and articles from shelves in St. Augustine and Daytona Beach. The shock was felt throughout northern and central Florida and at Savannah, Georgia (Reference 2.5.2-217).

Although located outside the site region, the 1886 Charleston, South Carolina, earthquake is the largest event known in the southeastern United States. The Charleston earthquake occurred on September 1, 1886 (August 31 local time), about 500 km (about 300 mi.) north of the LNP site. This earthquake was felt throughout northern Florida, particularly on the eastern coast. Several aftershocks were felt in Jacksonville, Florida (Reference 2.5.2-217).

This earthquake was one of the largest historic shocks in eastern North America and the most damaging earthquake to occur in the Southeast United States (Reference 2.5.2-218). The maximum intensity has been estimated at MMI X. The first shock was followed by a strong aftershock 8 minutes later, followed by six additional shocks during the next 24 hours. In Charleston an estimated 60 persons were killed and many more were injured. Damage was extensive; many buildings were totally destroyed and only a few escaped serious damage. Cities within a radius of 160 km also experienced damage, including Columbia, South Carolina, and Augusta and Savannah, Georgia. The total area affected by the earthquake included distant points in the United States such as New York City, Boston, and Milwaukee, plus Havana, Cuba, Bermuda, and Ontario, Canada (Reference 2.5.2-219).

2.5.2.1.2.2 Recent Gulf of Mexico Earthquakes

One earthquake having a body-wave magnitude of approximately 6 (Emb 6.0) and two smaller events occurred in the northern Gulf of Mexico during 2006 (Figure 2.5.2-203). A summary of the reported magnitudes for these and earlier events and distances from the LNP site is provided in Table 2.5.2-201. An unusual m_b 4.2, M_s 5.3 earthquake occurred off the coast of Louisiana, approximately 240 km (384 mi.) south of New Orleans on February 10, 2006 (References 2.5.2-220 and 2.5.2-221). This earthquake was the largest to occur in the Gulf of Mexico since the **M** 5 (Emb 4.9) earthquake of July 24, 1978 (Reference 2.5.2-222), which represents the best-recorded earthquake in the region prior to the February 10, 2006, event (Reference 2.5.2-221). Two previous earthquakes in 1994 (m_b 4.2, according to the National Earthquake Information Center [NEIC]) and 2000 (m_b 4.2, M_S 4.3; according to NEIC) also occurred in the same area (within an error of ~50 km) of the February 10, 2006, event (Figure 2.5.2-203). Following the February 2006 event, another unusual event with source characteristics similar to the February event occurred on April 18, 2006, less than 100 km (30 mi.) offshore of the tip of Louisiana's Birdfoot Delta. This earthquake, which was not detected or located by the USGS (NEIC) using traditional P-wave[e] arrivals, generated surface waves of an amplitude typical for a shallow event of approximately **M** 4.6 (Reference 2.5.2-220). A larger **M** 5.8-5.9, m_b 5.9, earthquake occurred on September 10, 2006, approximately 419 km (260 mi.) west-southwest from Clearwater, Florida, (Reference 2.5.2-223) in an abyssal plain environment. This earthquake, which was felt in parts of Florida,

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e. P-wave —a body wave that can pass through all the layers of the earth, the fastest of all seismic waves; also known as a compressional wave; longitudinal wave; primary wave.

Georgia, Alabama, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas, as well as in the Bahamas and the Yucatan Peninsula, Mexico, did not generate a significant tsunami (References 2.5.2-223 and 2.5.2-224). Felt reports at Crystal River, Florida, were intensity IV (Reference 2.5.2-223).

The earthquake size measure used in the EPRI-SOG seismic source characterization is expected body wave magnitude, Emb. The EPRI-SOG methodology for obtaining Emb was to use the reported m_b if available. If no m_b value was reported, then Emb was assessed using conversions from other size measures. As indicated in Table 2.5.2-201, the estimate of m_b based on conversion from M_s is 5.6. For the LNP site evaluation a conservative value of Emb 4.9 is used, which is obtained by averaging the converted M_s value with the reported m_b of 4.2 for the February 10 earthquake. The September 10, 2006, earthquake had a reported m_b of 5.9 and a reported moment magnitude of **M** 5.8 to 5.9. Conversion of the moment magnitude to body wave magnitude using the relationships presented in FSAR Section 2.5.2.4.2.3 yields an average estimated m_b of 6.1. For the LNP site evaluation a slightly conservative value of Emb 6.0 is used, which is obtained by averaging the reported m_b and the value converted from **M** 5.8-5.9. The South Texas Project (STP) 3 & 4 FSAR reports an Emb of 6.1 for the September 10 earthquake, which is based solely on conversions from **M** 5.8.

The source characteristics of the largest events recorded in the Gulf of Mexico, the 1978 and recent 2006 events, are quite different suggesting that different types of triggering mechanisms may give rise to earthquakes in this region. In contrast to the unusual February and April 2006 earthquakes, which did not provide good teleseismic waveforms, the faulting geometry and size of both the 1978 and September 2006 earthquakes were well constrained by standard centroid-moment-tensor (CMT) analysis (Reference 2.5.2-221). As described below, the source characteristics of the February and April 2006 events are best explained as being gravity-driven displacements on a shallow, low-angle detachment surface within or at the base of a thick sedimentary wedge; the 1978 and September 2006 earthquakes, which occurred within basement rock at depths of greater than 15 km (9.3 mi.), have source characteristics more typical of tectonic events.

Frohlich (Reference 2.5.2-222) concluded based on the focal depth (15 km [9.3 mi.]) and reverse-faulting focal mechanism that the 1978 earthquake occurred within the basement and that typical of other intraplate events the event probably occurred along relatively inactive structural trends that may represent zones of weakness in the crust. Frohlich postulated that the event may have been related to stresses associated with the downwarping of the lithosphere caused by accumulation of sediments from the Mississippi River (Reference 2.5.2-222). Different focal mechanisms are reported for this event. Frohlich (Reference 2.5.2-222) shows a reverse faulting mechanism on an east-northeast trend, whereas the global CMT catalog solution shows a reverse faulting mechanism on a northwest trend (Reference 2.5.2-225).

The September 10 earthquake, which had a deep hypocenter (22 km [13.6 mi.] per USGS solution and 31.7 km [19.6 mi.] per Harvard solution [Reference 2.5.2-223]), is recognized as a typical tectonic event (Reference 2.5.2-226). The U.S. Geological Survey did not associate this earthquake with a specific causative fault. The September earthquake occurred near the transition between oceanic crust and thin transitional crust as shown by Sawyer et al. (Reference 2.5.2-227) in an area where there are a number of northwest-trending basement faults and structures (Reference 2.5.2-228), as well as an interpreted northwest-trending regional basement structure that is inferred to have been related to rifting and opening of the Gulf of Mexico in the Mesozoic (Reference 2.5.2-229).

In contrast to the 1978 and September 2006 earthquakes, the February 10 earthquake is notable for the unusual characteristics of the teleseismic waveforms it generated (Reference 2.5.2-221). In particular, the teleseismic seismograms are depleted in high-frequency energy, and are not fit well by traditional double-couple source models typical of tectonic faulting mechanisms. A moment-tensor source can be used to model the surface waves generated by the February 10, 2006, earthquake if the earthquake centroid is placed within a few miles of the earth's surface in a medium with a very low shear modulus. The seismograms are fit well by a single-force source (that is, a model of sliding on a shallow, sub-horizontal surface). The depth of the source for the February 10 event was likely less than 6 to 8 km (3.7 to 5 mi.) The best explanation for the mechanism for the February 10, 2006, earthquake and the similar event on April 18, 2006, is that of a gravity-driven displacement occurring on a low-angle detachment surface within the sedimentary wedge. (Reference 2.5.2-221)

Peel (Reference 2.5.2-230) describes the structural context of the February earthquake and reviews possible seismogenic processes that could operate within the region. He refers to the February event, which is located within the Green Canyon Block 344, as the GC344 event. The location of this event is close to a major down-to-the-northwest basement step, corresponding to a downdip change in basement character. Peel (Reference 2.5.2-230) notes that this boundary also corresponds to a change in character of the regional magnetic pattern; and it is probably the boundary between stretched continental crust (updip) and stretched basinal crust, possibly oceanic in character (downdip). The location of the GC344 event also overlies the boundary between autochthonous and allochthonous deep salt, which appears to correspond to the basement boundary. The autochthonous deep salt is overlain in turn by a thick section of Jurassic to Upper Miocene cover sediment that has moved a distance of about 5 to 10 km (3 to 6 mi.) towards the south-southeast, as a result of gravity spreading of the whole margin. Southwards movement and folding of this sediment package occurred during the Paleogene and Miocene, and there appears to have been no further movement since the early Pliocene. Since that time, southwards movement appears to be concentrated at a higher level within the Sigsbee Salt Nappe, a major allochthonous salt canopy spread out over the folded unit. Spreading of this salt unit began during the middle Miocene, reached a peak during the late Miocene and Early Pliocene, and continues to the present day.

As reported by Peel (Reference 2.5.2-230), seismic imaging shows that the Sigsbee Salt Nappe contains large recumbent folds and a major basal shear zone. The salt nappe was dominantly emplaced by large-scale glacier-like flow from the north-northwest, with a minor component of local vertical feeding through diaper throats. On top of the Sigsbee salt is a sediment package (carapace) of Upper Miocene, Pliocene, and Pleistocene sediments that is dominated by salt withdrawal basins and salt walls. Some of the salt withdrawal basins have subsided all the way to the base of the Sigsbee Nappe, forming significant sediment-on-sediment contact areas known as welds. Peel (Reference 2.5.2-230) observes that a likely welded area can be mapped close to GC344, and concludes that the most likely mechanism for the earthquake was movement on the base of the Sigsbee Salt, with faulting occurring where a suprasalt basin is grinding against the base of the salt weld. The probable seismic expression of this mechanism would be low-angle faulting at a depth of about 8 to 10 km (5 to 6 mi.) subsea. The predicted movement is likely to be generally southwards, but a wide range of movement direction (± 90 degrees) is possible due to partitioning of movement of the Sigsbee Nappe.

Angell and Hitchcock (Reference 2.5.2-231) invoke a possible model of fault characteristics that could contribute to seismic rupture of a growth fault in which areas of both stick-slip and creep modes of displacement coexist on a single fault surface. They note that these conditions might occur along a fault plane where salt has been evacuated and the result is a sediment-sediment contact at the base of the growth fault.

Gangopadhyay and Sen (Reference 2.5.2-226) suggest a mechanism for earthquakes in the Gulf of Mexico that involves stress concentration resulting from the contrast in mechanical properties between salt and surrounding sediments driven by tectonic loading. The results of modeling suggest that some locations of relatively high shear stress correlate well with the spatial distribution of seismicity in the northern Gulf of Mexico, thereby suggesting a possible causal association.

2.5.2.2 Geologic and Tectonic Characteristics of the Site and Region

As outlined previously, Regulatory Guide 1.208, specifies that recent information should be reviewed to evaluate if this information indicates significant differences from the previous seismic hazard. FSAR Subsection 2.5.1 presents a summary of available geological, seismological, and geophysical data for the site region (320 km [200 mi.] radius), site vicinity (40 km [25 mi.] radius), and site area (8 km [5 mi.] radius) that provides the basis for evaluating seismic sources that contribute to the seismic hazard to the LNP site. This subsection presents a description of the seismic source characterizations from the EPRI-SOG evaluation (Reference 2.5.2-201) (FSAR Subsection 2.5.2.2.1), followed by a summary of general approaches and interpretations of seismic sources used in more recent seismic hazard studies (FSAR Subsection 2.5.2.2.2). FSAR Subsections 2.5.2.3 and 2.5.2.4 present evaluations of the new information relative to the EPRI-SOG seismic source evaluations (Reference 2.5.2-201).

2.5.2.2.1 EPRI-SOG Source Evaluations

During the 1980s, the Seismic Owners Group (SOG) conducted a comprehensive seismic hazard methodology development program at EPRI. The SOG program emphasized earth science assessments of alternative explanations of earthquakes in the CEUS, with a particular emphasis on a systematic understanding and expression of uncertainties. Seismic sources and associated interpretations necessary for hazard calculations at any nuclear power plant site in the CEUS were developed. Six earth science teams (EST) provided input interpretations: Bechtel Group, Dames & Moore, Law Engineering, Rondout Associates, Weston Geophysical, and Woodward-Clyde Consultants. Each team produced a report (Volumes 5 through 10 of EPRI-SOG) that provided descriptions of how the seismic sources were identified and defined. (Reference 2.5.2-201)

The seismic source characterizations developed by the EPRI-SOG ESTs were used to conduct PSHAs for nuclear power plant sites in the CEUS that were reported in EPRI (Reference 2.5.2-202). Included in that set of plant sites was the Crystal River Unit 3 (CR3) located within the Crystal River Energy Complex (CREC) located about 15.5 km (9.6 mi.) from the LNP site. The EPRI-SOG PSHA seismic source characterization for the CR3 (Reference 2.5.2-202), thus was judged to be an appropriate initial starting point in the assessment of the seismic hazard for the LNP site.

The calculations performed by EPRI (Reference 2.5.2-202) for each site excluded the seismic sources defined by each EPRI-SOG EST that, in combination, contributed less than one percent to the total hazard computed from all sources defined by that EST. The EPRI selection of the seismic sources that are significant to assessing the seismic hazard at a site was based on calculations made with the ground motion models presented in EPRI-SOG (References 2.5.2-202 and 2.5.2-201). Since that time, there have been advances in the characterization of earthquake ground motions for CEUS earthquakes. These advances are described in FSAR Subsection 2.5.2.4.2. Because the potential contribution of a seismic source to the hazard at a site is dependent in part on the ground motion model used to compute the hazard, the identification of the significant EPRI-SOG seismic sources for the LNP site was assessed using updated ground motion models. Tables 2.5.2-202, 2.5.2-203, 2.5.2-204, 2.5.2-205, 2.5.2-206, and 2.5.2-207 list the seismic sources for each of the six EPRI-SOG teams that were found to contribute in aggregate 99 percent of the hazard at the LNP site. FSAR Subsection 2.5.2.4.3.1 presents the hazard contribution of the individual EPRI-SOG seismic sources. These seismic sources are shown on Figures 2.5.2-204, 2.5.2-205, 2.5.2-206, 2.5.2-207, 2.5.2-208, and 2.5.2-209 and are described in FSAR Subsections 2.5.2.2.1.1, 2.5.2.2.1.2, 2.5.2.2.1.3, 2.5.2.2.1.4, 2.5.2.2.1.5, and 2.5.2.2.1.6. Many of the seismic sources described by the EPRI-SOG teams are so described in FSAR Subsection 2.5.1.1.4.4, including the zones associated with the 1886 Charleston earthquake.

2.5.2.2.1.1 Bechtel Team Seismic Sources

Five seismic sources defined by the Bechtel team (Reference 2.5.2-232) are included in the PSHA calculations for the LNP site (Figure 2.5.2-204). These sources are listed in Table 2.5.2-202 and are described below.

- Charleston Area (Source H) and Charleston Faults (Source N3): These two seismic source zones (Reference 2.5.2-232) are located in the vicinity of Charleston, South Carolina. No specific information on these sources is provided by the Bechtel team other than that they represent possible source locations for the 1886 Charleston earthquake and may contain an active fault (Reference 2.5.2-232).

- Atlantic Coastal Region (Source BZ4): This background source zone is a large area that encompasses the Eastern Mesozoic basins (Source 13), Charleston (Source H), and a source derived from three separate model sources in the Charleston, South Carolina, area (Source N3) (Reference 2.5.2-232).

- Gulf Coast Region (Source BZ1): The LNP site lies within the Gulf Coast region (Source BZ1). This zone is a large background source that extends from the continental shelf off eastern Florida to the western coastal plain of Texas and encompasses the majority of the site region. This background source zone was defined based on geopotential (gravity and magnetic anomaly data) and seismic data. (Reference 2.5.2-232)

- Southern Appalachians Region (Source BZ5): This background source zone encompasses a large area of the southern Appalachians to the north of the site region. The zone includes the Eastern Mesozoic basins (Source 13); Rosman fault (Source 15); Belair fault (Source 16); Stafford fault (Source 17); Giles County feature (Source 19); Lebanon geopolitical trend (Source 23); Bristol block trends (Source 24); a segment of the New York – Alabama lineament (Source 25); central Virginia (Source E); southeast Appalachians (Source F); and northwest South Carolina (Source G). Some of these sources are associated with moderate earthquakes (Reference 2.5.2-232).

2.5.2.2.1.2 Dames & Moore Team Seismic Sources

Six seismic sources defined by the Dames & Moore team (Reference 2.5.2-233) are included in the PSHA calculation for the LNP site (Figure 2.5.2-205). These sources are listed in Table 2.5.2-203 and are described below.

- Southern Cratonic Margin (default) (Source 41): This source zone contains deformed Grenvillian basement overlain by late Precambrian metamorphosed clastic sediment and associated mafic intrusive and extrusive rocks. The Southern Cratonic Margin default zone encompasses a large region of continental margin deformed during Mesozoic and Cenozoic rifting and includes many Triassic basins and border faults. This source is a default zone for the Newark-Gettysburg basin, Ramapo fault zone, and other Mesozoic/Cenozoic basins (Sources 42, 43, 46, respectively, which are considered mutually exclusive with the default zone, Source 41). This source zone contains seismicity in a diffuse pattern throughout the zone. (Reference 2.5.2-233)

- Southern Appalachian Mobile Belt (default) (Source 53): This default source contains crustal rocks that are younger than Grenvillian or Avalonian that have undergone multiple periods of crustal divergence and convergence. It contains several Triassic basins. Much of the seismicity associated with the zone is diffuse throughout the zone. Included within this default zone is the Charleston Mesozoic Rift (Source 52), which may have some association with seismicity in the Charleston, South Carolina, area. (Reference 2.5.2-233)

- Charleston (Source 54): This source is a zone around the Charleston region that contains recurring seismic activity. The zone includes tectonic features described in the literature as possible sources of the 1886 Charleston, South Carolina, earthquake. These features are the Woodstock fault, Ashley River fault, Cooke fault, and the Helena Banks fault. (Reference 2.5.2-233)

- Charleston Mesozoic Rift (Source 52): This source zone is in the northern part of the site region and encompasses a large area around the Charleston, South Carolina, area. This Mesozoic rift source may have some association with seismicity in the area of Charleston (Reference 2.5.2-233).

- Southern Coastal Margin (Source 20): The LNP site lies within the Southern Coastal Margin, which extends from the continental shelf off eastern Florida, along the Texas coastal plain, and into Mexico. This source zone encompasses the majority of the site region. This source zone was defined based on its fairly low, diffuse seismicity. The zone represents the down warping miogeosynclinal wedge of sediment that accumulated within the Gulf Coast Basin since the Cretaceous. (Reference 2.5.2-233)

- Paleozoic (Appalachian) Fold Belt (Source 4): This zone is located to the north of the site region and consists of a major segment of a folded mountain belt, the Appalachians from New York to Alabama. Two configurations of this zone are considered: the fold belt and the fold belt with kinks (Sources 4A, 4B, 4C, and 4D) (Reference 2.5.2-233).

2.5.2.2.1.3 Law Engineering Team

Eight seismic sources defined by the Law Engineering team (Reference 2.5.2-234) are included in the PSHA calculations for the LNP site (Figure 2.5.2-206). These sources are listed in Table 2.5.2-204 and described briefly below.

- Eastern Basement (Source 17): This zone encompasses a large area of buried (sub-decollement) Precambrian-Cambrian normal faults (Reference

2.5.2-234). The zone includes the Giles County, Virginia – East Tennessee Seismic Zone, the Pennsylvania Aulacogen, and the Scranton Gravity High tectonic features, all of which are related to the same deformational phase (Reference 2.5.2-234).

- Eastern Basement Background (Source 217): This background seismic zone is characterized by a negative Bouguer gravity field and a pattern of magnetic anomalies. The zone is inferred to overlie the Precambrian continental margin of North America (Reference 2.5.2-234).

- Reactivated Normal Faults (Source 22): This zone is known as the Wentworth Hypothesis – Reactivated Eastern Seaboard Normal Faults seismic source zone (Reference 2.5.2-234). The zone was defined based on the hypothesis that seismicity throughout the Eastern Seaboard region may be associated with faults reactivated in the current compressive stress regime. Those faults interpreted to have the highest potential for reactivation originally formed as normal faults during the Mesozoic era (Reference 2.5.2-234).

- Charleston (Source 35): This source zone was defined by the Law Engineering team based on the pattern of seismicity and "because the various tectonic features related by hypothesis to the zone cannot explain why Charleston might continue to exhibit seismicity higher than its surrounding area" (Reference 2.5.2-234). The Law Engineering team also defined three seismic source zones based on tectonic features that could allow a large earthquake to recur at Charleston; however, such an event would not be restricted to the Charleston area. Accordingly, the Charleston seismic zone (Source 35) was defined. (Reference 2.5.2-234)

- Mesozoic Basins (Source 8): Buried East Coast Mesozoic basins are recognized as potential seismic sources by the Law Engineering team (Reference 2.5.2-234). The Mesozoic Basins are northeast-trending elongated troughs of late Triassic to early Jurassic age that are bounded on one or both sides by high-angle faults. These faults are favorably oriented to be reactivated, similar to the faults described above in the Reactivated Normal Fault zone (Source 22) (Reference 2.5.2-234).

- Southern Coastal Block (Source 126): The LNP site lies within the Southern Coastal Block (Source 126). This background seismic source zone is assumed to represent an area of similar crustal structure at seismogenic depths. The southern boundary of this zone was defined based on broad wavelength magnetic anomalies that extend from the southeast Texas-Mexico border to the continental shelf offshore Florida; the northern boundary was defined by the Paleozoic edge of the North American craton. (Reference 2.5.2-234)

- Eastern Piedmont (Source 107): This background seismic source is located to the north of the site region. It is characterized by a positive Bouguer gravity field and a pattern of magnetic anomalies. The region is believed to be a crustal block that lies to the east of the relict North American continental margin (Reference 2.5.2-234).

- Brunswick (Source 108): This background seismic source has a basement terrane with a distinctive geophysical pattern that contrasts with the patterns of the Eastern Piedmont province to the northwest and the Southern Coastal Block (Source 126) to the south. The basement rock may represent a zone of Triassic and/or Jurassic crustal extension formed during the early stages of the opening of the Atlantic Ocean (Reference 2.5.2-234).

2.5.2.2.1.4 Rondout Associates Team

Five seismic sources defined by the Rondout Associates team (Reference 2.5.2-235) are included in the PSHA calculation for the LNP site (Figure 2.5.2-207). These sources are listed in Table 2.5.2-205 and described briefly below.

- Charleston (Source 24): The Charleston seismic zone includes the Ashley River fault and Woodstock fault (Reference 2.5.2-235).

- Southern Appalachians (Source 25): This seismic source zone is defined based on deep-seated seismicity in basement rocks below the regional decollement. The seismicity may be associated with faults inferred from the aeromagnetic anomalies associated with the New York – Alabama lineament (Source 13) (Reference 2.5.2-235).

- South Carolina Zone (Source 26): This seismic zone parallels and encompasses northwest, cross-cutting fracture zones mapped on the detailed aeromagnetic map of South Carolina. Seismicity is associated with this zone. (Reference 2.5.2-235)

- Appalachian Crust (Source 49): The LNP site lies within the Appalachian Crust seismic zone. The crust of this background zone was formed after the Precambrian and the basement is a complex accretionary terrane. The zone may not have a uniform seismic potential (Reference 2.5.2-235).

- Gulf Coast to Bahamas Fracture Zone (Source 51): This source zone was defined separately because of differences in the orientation of the stress regime between the Paleozoic crust within the zone and the Appalachian crust of roughly the same age to the east and northeast (Reference 2.5.2-235).

2.5.2.2.1.5 Weston Geophysical Team

Six seismic sources defined by the Weston team (Reference 2.5.2-236) are included in the PSHA for the LNP site (Figure 2.5.2-208). These sources are listed in Table 2.5.2-206 and described briefly below.

- New York – Alabama – Clingman Block (Source 24): This seismic source is a linear block of seismicity within the Southern Appalachian zone (Source 103). Relatively accurate hypocenters for seismicity in the block suggest that these earthquakes originate well below a detachment structure previously assumed to be seismogenic (Reference 2.5.2-236).

- Charleston (Source 25): Several tectonic features are included in this seismic domain, and it is assumed by the Weston team that future seismicity in the east will be localized along one or more of these features identified for the Charleston, South Carolina, region. These tectonic features are: the Woodstock, Ashley River, Helena Banks, and Cooke faults; the northwest extension of an offshore fracture zone; and a zone of decollement (Reference 2.5.2-236). This zone is part of the Southern Coastal Plain background (Source 104).

- South Carolina Zone (Source 26): This zone is also part of the Southern Coastal Plain background (Source 104) (Reference 2.5.2-236).

- Southern Appalachian (Source 103): This background zone is located to the north of the site region and includes the Inner Piedmont, Blue Ridge, and Valley and Ridge physiographic belts of the southern Appalachians. The New York – Alabama – Clingman lineaments block seismic zone (Source 24) is within this background zone (Reference 2.5.2-236).

- Southern Coastal Plain Background (Source 104): This south coastal plain background seismicity zone adjoins the Southern Appalachian background (Source 103). The zone incorporates several additional seismic sources, including the Charleston, South Carolina, seismic zone (Source 25) and the South Carolina seismic zone (Source 26) (Reference 2.5.2-236).

- Gulf Coast Background (Source 107): The majority of the site region is within this background source zone. This source zone was defined as an independent background source that does not contain any other seismic source regions. This zone extends from Texas to Florida (Reference 2.5.2-236).

2.5.2.2.1.6 Woodward-Clyde Consultants Team

Four seismic sources defined by the Woodward-Clyde Consultants team (Reference 2.5.2-237) are included in the PSHA for the LNP site (Figure 2.5.2-209). These sources are listed in Table 2.5.2-207 and described briefly below.

- Greater South Carolina (Sources 29, 29A, and 29B): This source zone pertains to seismicity located in South Carolina, Georgia, and western North Carolina (Reference 2.5.2-237). An isostatic gravity high trends northeast along the Appalachians, but in the area of central South Carolina a saddle or gap is observed in the gravity high. A northwest-trending zone of seismicity extends from the coast into western North Carolina; this zone includes the area of the 1886 Charleston earthquake and many smaller magnitude events. The expression within the isostatic gravity data of the saddle suggests that it is crustal in scale; varying crustal thickness in the area may be a potential stress concentrator (Reference 2.5.2-237). Alternative source zone designations that are mutually exclusive (Sources 29, 29A, and 29B) are used for the hazard calculations.

- Charleston (Source 30): The only tectonic features assessed to have significant seismic potential in the local Charleston area are the Ashley River and Woodstock faults (Reference 2.5.2-237). The existence of these faults is based primarily on seismological evidence, as recent microseismic activity is located along and in large part defines these faults. The correlation of these faults with the 1886 Charleston earthquake is based primarily on isoseismal patterns (Reference 2.5.2-237).

- Blue Ridge Zone and Alternative (Sources 31 and 31A): This source zone extends from the southern to the central Appalachians. Two alternative configurations are defined (Reference 2.5.2-237). The basis for the source zone is an inferred block of distinctive crust associated with an isostatic gravity low. The alternative interpretation of this zone is based on three sub-zones of seismicity (Reference 2.5.2-237).

- Crystal River Background (Source B36): The LNP site lies within a large background zone that encompasses most of the state of Florida. This source is a background zone defined as a rectangular area (2 degrees by 2 degrees) surrounding the CR3 site and is not based on any geological, geophysical, or seismological features. Because the CR3 site is located only 18 km (11 mi.) from the LNP site, the Crystal River Background Source was used for the LNP site without modification of its geometry.

2.5.2.2.2 Post-EPRI Seismic Source Characterizations

Seismic hazard studies conducted in the LNP site region since completion of the 1986 - 1988 EPRI-SOG study are described in the following subsections (Reference 2.5.2-201).

2.5.2.2.2.1 Lawrence Livermore National Laboratory Trial Implementation Program Source Evaluations

A decade after the completion of the EPRI-SOG (Reference 2.5.2-201) evaluation, Lawrence Livermore National Laboratory (LLNL) (Reference 2.5.2-238) conducted a Trial Implementation Program (TIP) of the Senior Seismic Hazard Analysis Committee (SSHAC) guidance for a Level IV analysis (Reference 2.5.2-239). The LLNL TIP project focused on issues related to the development of seismic zonation and earthquake recurrence models. Participants in the project included a Technical/Facilitator/Integrator team, a panel of five expert evaluators, and expert proponents and presenters. Preliminary implementations for two sites in the southeastern United States (the

Vogtle site in Georgia, which is affected by the issue of the Charleston earthquake, and the Watts Bar site in Tennessee, which is close to the East Tennessee seismic zone [ETSZ]) were completed as part of the TIP study. Although focused primarily on process, the LLNL TIP study provided assessments for some of the seismic sources significant to the LNP site region, in particular the source for repeated large-magnitude, Charleston-type events and source zones for background events.

Seismic source models were developed for each of the five experts. Through discussions at workshops, one-on-one interviews, and white papers, a set of common sources was identified as the basic building block for all the sources and alternative sources. The general boundaries of these common sources are shown on Figure 2.5.2-210. This minimum set of zones was then used to create the composite model of seismic sources that represented the range of feasible sources. These sources included five basic alternative zones for both the East Tennessee and Charleston sources, three for the South Carolina – Georgia seismic zone, and alternative zones for background earthquakes for both the East Tennessee and Charleston regions.

Table 2.5.2-208 provides a description of the minimum set zones. A complete description of the logic tree representation of the experts' interpretations for the Charleston and ETSZ and maximum magnitude distributions for alternative source zones is presented in Savy et al. (Reference 2.5.2-238).

2.5.2.2.2.2 USGS Earthquake Hazard Mapping Source Characterization Model

As part of the 2002 USGS National Seismic Hazard Mapping Program, updated seismic hazard maps for the conterminous United States were produced in 2002 (Reference 2.5.2-240). Input for revising the source characterization used in the 1996 hazard maps was provided by researchers through a series of regional workshops (Reference 2.5.2-241). Key issues that were addressed in the updated source characterization included new information regarding the location, size, and recurrence of repeated large-magnitude earthquakes in the Charleston and New Madrid source regions. Although the USGS program does not use formal expert elicitation and full uncertainty quantification, the resulting seismic hazard model provides information on the current understanding of the seismic potential of the study region and the catalog of recorded earthquakes.

The USGS seismic source model developed by the USGS are shown on Figure 2.5.2-211 (Reference 2.5.2-206).The general approach used by the USGS for modeling distributed seismicity in the CEUS is based on gridded, spatially smoothed seismicity in large background zones.

Two broad regions are defined with different maximum magnitudes in the USGS model: an extended margin zone (maximum magnitude [M_{max}] = **M** 7.5) and a craton zone (M_{max} = **M** 7.0). In addition, the USGS source model includes an East Tennessee regional source zone, alternative fault-line sources for repeated large-magnitude earthquakes in the New Madrid Seismic Zone, and alternative zones for a Charleston seismic source zone (Figure 2.5.2-211). The maximum magnitude probability distribution assigned to the New Madrid fault sources is **M** 7.3 (0.15), **M** 7.5 (0.2), **M** 7.7 (0.5), and **M** 8.0 (0.15). For the Charleston source the maximum magnitude probability distribution used was **M** 6.8 (0.2), **M** 7.1 (0.2), **M** 7.3 (0.45), and **M** 7.5 (0.15). The USGS model uses a mean recurrence time of 500 years and 550 years for repeated large-magnitude earthquakes in the New Madrid and Charleston regions, respectively, and assumes a time-independent model.

2.5.2.2.2.3 South Carolina Department of Transportation Seismic Hazard Map Study for Bridges and Highways

A probabilistic seismic hazard mapping project was completed in 2002 for the South Carolina Department of Transportation (SCDOT) as part of a program to develop seismic design specifications for highway bridges (Reference 2.5.2-242). The approach used in the SCDOT study is similar to that used by the USGS to develop the 2002 national seismic hazard maps. The SCDOT study uses a logic tree approach. It includes alternative source configurations as well as a smoothed seismicity approach for earthquakes in the magnitude range (5.0 < **M** < 7.0); alternative source models and maximum magnitudes for larger, repeated Charleston-type earthquakes (7.0 < **M** < 7.5) in the coastal areas of South Carolina; and alternative ground motion prediction models adopted by the USGS for the 2002 hazard maps. Alternative source areas defined for noncharacteristic earthquakes are shown on Figure 2.5.2-212.

The SCDOT source characterization for characteristic (i.e., repeated large-magnitude) Charleston-type earthquakes employs a combination of line and area sources and uses a slightly different M_{max} range (**M** 7.1 – 7.5) than the USGS 2002 characterization (Figure 2.5.2-211). Three equally weighted source zones defined for this study include (1) a fault zone consisting of three parallel faults that model a combined Woodstock and Ashley River fault scenario; (2) a larger Coastal South Carolina zone that includes most of the paleoliquefaction sites; and (3) a southern zone of river anomalies (postulated East Coast fault system) source zone. The magnitude distribution and weights used for M_{max} are **M** 7.1 (0.2), **M** 7.3 (0.6), and **M** 7.5 (0.2). The paleoliquefaction-based recurrence interval used in the SCDOT study is a mean recurrence interval of 550 years.

The LNP site lies within Source Area 9 as defined in the SCDOT study. This zone has not experienced sufficient seismicity to permit calculation of a recurrence model. The SCDOT study defined the recurrence model for this zone based on the seismicity rate per unit area defined for the adjacent Source Area 6. The geographic area of this Source Area 9 is defined to include transitional crust. The SCDOT study defines two alternative source zone configurations for the Piedmont and Coastal Plain region (Source Area 6), which also lie within the LNP site region. One configuration includes a zone of more concentrated seismicity in the South Carolina Coastal Plain (Source Area 7) and a localized zone in Charleston (Source Area 8). Recognizing that the borders between these zones are not well defined, an alternative configuration (Source Area 19) that includes South Carolina and adjacent parts of surrounding states was modeled using smoothed seismicity (Figure 2.5.2-212). A maximum magnitude of **M** 7.0 was used for all of the noncharacteristic source zones.

2.5.2.2.2.4 Updated PSHA for the Vogtle Plant Site

Southern Nuclear Company (SNC) updated the EPRI-SOG seismic source models in the vicinity of Charleston, South Carolina, to incorporate new information on the possible source of future large earthquakes similar to the 1886 Charleston earthquake, new assessments of the size of the 1886 earthquake, and new information on the occurrence rate for large earthquakes in the vicinity of Charleston, South Carolina (Reference 2.5.2-243). The result was the development of an updated Charleston seismic source (UCSS). The UCSS consists of the four alternative geometries for the seismic source, (shown on Figure 2.5.2-213) and the seismic source logic tree (Figure 2.5.2-214) that defines the weights assigned to the alternative geometries and the characterization of the size and frequency of large earthquakes associated with the source.

The UCSS model was used to define the location, size, and frequency of earthquakes similar to the 1886 earthquake. The occurrence of smaller earthquakes was modeled following the approaches developed in EPRI-SOG (Reference 2.5.2-201). The spatial distribution of earthquakes was modeled using the spatial smoothing approach developed in EPRI-SOG. SNC (Reference 2.5.2-243) integrated the UCSS into the EPRI-SOG seismic source characterization by replacing each EST's Charleston-specific source with the UCSS and modifying the remaining source geometries to accommodate the UCSS geometries. The frequency of earthquakes in these modified sources was modeled using the truncated exponential distribution and was based on analysis of the earthquake catalog.

2.5.2.2.2.5 FSAR South Texas Units 3 and 4 COLA

The South Texas Project (STP) Nuclear Operating Company (STPNOC) updated the EPRI-SOG seismic source parameters for Gulf of Mexico source zones as part of a recent COLA for the proposed STP Units 3 & 4 site near Bay City, Texas. The STP 3 & 4 FSAR incorporated contributions from seismic sources in the Gulf of Mexico that had not been included in the original EPRI methodology and updated the maximum magnitude probability distributions of Gulf of Mexico source zones based on the occurrence of two moderate earthquakes in the Gulf of Mexico (Reference 2.5.2-244)

2.5.2.3 Correlation of Earthquake Activity with Seismic Sources

Regulatory Guide 1.208 indicates that the earthquake activity should be correlated with seismic sources. The principal database for assessing earthquake recurrence is the historical and instrumental earthquake record. An updated catalog of independent historical and instrumental earthquakes covering the LNP site region was developed (see discussion in FSAR Subsection 2.5.2.1.1).

The distribution of earthquake epicenters from the EPRI (pre-1985) catalog, the more recent (post-1985) instrumental events, and updated historical earthquakes for the site region with respect to the EPRI-SOG sources are shown on Figures 2.5.2-204, 2.5.2-205, 2.5.2-206, 2.5.2-207, 2.5.2-208, and 2.5.2-209. Comparison of the updated earthquake catalog to the EPRI-SOG earthquake catalog and EPRI-SOG sources yields the following conclusions:

- The updated earthquake catalog does not show a pattern of seismicity within the site region different from that exhibited by earthquakes in the EPRI-SOG catalog that would suggest a new seismic source, in addition to those included in the EPRI-SOG characterizations.

- The updated earthquake catalog shows similar spatial distribution of earthquakes to that shown by the EPRI-SOG catalog, suggesting that no significant revisions to the geometry of seismic sources defined in the EPRI-SOG characterization is required based on seismicity patterns.

- The updated catalog does not show any earthquakes within the site region that can be associated with a known geologic structure.

- The closest principal source of seismic activity is the Charleston, South Carolina, area, which lies at a distance of greater than 430 km (267 mi.). Concentrations of seismicity in the vicinity of Charleston were recognized and considered by the EPRI-SOG teams, as discussed in FSAR Subsection 2.5.2.2.1.

- The largest historical earthquake in the southeastern United States, the 1886 Charleston earthquake, likely reactivated a structure within the basement rock, but cannot be definitely associated with any of the major identified basement structures (FSAR Subsection 2.5.1.1.4.4). Paleoliquefaction studies indicate that repeated large-magnitude earthquakes have occurred in the epicentral region of the 1886 Charleston earthquake (see discussion in FSAR Subsection 2.5.1.1.4.4). Alternative source locations, maximum magnitudes, and recurrence for repeated large-magnitude, Charleston-type earthquakes are discussed in FSAR Subsection 2.5.2.4.1.

- The updated catalog includes two earthquakes that are larger in magnitude than some of the upper- and/or lower-bound values used by EPRI-SOG teams to characterize the M_{max} distribution of source zones within which these earthquakes occurred. These earthquakes are the February 10, 2006, surface-wave magnitude (M_s) 5.3, body-wave magnitude (m_b) 4.2 earthquake (Emb 4.9), and the September 10, 2006, moment magnitude (**M**) 5.8-5.9, m_b 5.9, earthquake (Emb 6.0). These events require revisions to some of the ESTs' M_{max} distributions for background source zones, as described in FSAR Subsection 2.5.2.4.1.2.

- As discussed above in FSAR Subsection 2.5.2.1.2.2, the February 10, 2006, m_b 4.2, M_s 5.3 earthquake, which does not exhibit typical source characteristics of a tectonic earthquake, has been potentially associated with specific geologic structures near the edge of the continental shelf.

- The September 10, 2006, m_b 5.9, **M** 5.8-5.9 earthquake, which has a tectonic signature, has not been tied to any unique geologic structure. This event occurred near the transition between oceanic and thin transitional crust, in extended basement crust having northwest-trending normal faults that are favorably oriented for reactivation in the present tectonic regime (see discussion in FSAR Subsection 2.5.1.1.4.5).

- The February 10, 2006, m_b 4.2, M_s 5.3 earthquake has been proposed to be the result of a gravity-driven displacement on a shallow, low-angle detachment surface within or at the base of a thick sedimentary wedge (Reference 2.5.2-221), possibly related to a sediment-sediment contact (weld) at the base of a growth fault at the edge of the continental shelf (References 2.5.2-230 and 2.5.2-231). The smaller-magnitude April 18, 2006, earthquake that exhibits similar source characteristics is also attributed to similar gravity-driven processes. This event was neither detected nor located by the USGS (NEIC) and thus is not included in the updated earthquake catalog. This hypothesis suggests a potential association between seismicity in the Gulf of Mexico and normal growth faults at the edge of the continental shelf; however, no other events within the updated catalog have been attributed to such mechanisms. The edge of the continental shelf generally is encompassed by the various EST areal source zones for the Gulf of Mexico and environs, and as such, increases in M_{max} to account for the February 10, 2006 earthquake, as well as the September 10, 2006, m_b 5.9, **M** 5.8-5.9 earthquake adequately account for any potential association between earthquakes within the Gulf of Mexico and normal faults along the edge of the continental shelf. (Reference 2.5.2-244).

- The updated earthquake catalog adds a few earthquakes in the time period covered by the EPRI-SOG catalog (principally prior to 1910). The effect of these additional events on estimated seismicity rates is assessed in FSAR Subsection 2.5.2.4.1.3.

2.5.2.4 Probabilistic Seismic Hazard Analysis and Controlling Earthquake

This subsection describes the PSHA conducted for the LNP site. Following the procedures outlined in Appendix E, Section E.3, of Regulatory Guide 1.208, FSAR Subsections 2.5.2.4.1 and 2.5.2.4.2 discuss new information on seismic source characterization and ground motion characterization, respectively, that is potentially significant relative to the EPRI-SOG (Reference 2.5.2-201) seismic hazard model. FSAR Subsection 2.5.2.4.3 presents the results of PSHA sensitivity analyses used to test the effect of the new information on the seismic hazard. Using these results, an updated PSHA analysis was performed, as described in FSAR Subsection 2.5.2.4.4. The results of that analysis are used for the development of uniform hazard response and identification of the controlling earthquakes (FSAR Subsection 2.5.2.4.4.2). The initial PSHA presented in this subsection utilizes a minimum magnitude for hazard integration of m_b 5.0, consistent with the original PSHA calculations performed by EPRI (Reference 2.5.2-202). The purpose of these calculations is to develop the controlling earthquakes for use in the site response analyses. The final PSHA to develop the GMRS is conducted using the CAV approach presented in Regulatory Guide 1.208. This calculation is described in FSAR Subsection 2.5.2.6.2.

2.5.2.4.1 New Information Relative to Seismic Sources

This subsection describes potential updates to the EPRI-SOG seismic source model. Seismic source characterization data and information that could affect the predicted level of seismic hazard include the following:

- Identification of possible additional seismic sources in the site region.
- Changes in the characterization of the rate of earthquake occurrence for one or more seismic sources.
- Changes in the characterization of the maximum magnitude for seismic sources.

Based on the review of new geological, geophysical, and seismological information that is summarized in FSAR Subsection 2.5.1, the review of seismic source characterization models developed for post-EPRI-SOG seismic hazard analyses (FSAR Subsection 2.5.2.2.2), and a comparison of the updated earthquake catalog to the EPRI-SOG evaluation (FSAR Subsection 2.5.2.3), the EPRI-SOG source models have been modified for the LNP 1 and LNP 2 COLA as follows:

- A UCSS developed by SNC (Reference 2.5.2-243) has been included to account for new information regarding the location, size, and occurrence of repeated large-magnitude earthquakes in the vicinity of Charleston, South Carolina.
- Two moderate earthquakes have occurred within the Gulf of Mexico since the EPRI-SOG 1986 - 1988 study. The magnitudes of these events exceed the upper and/or lower bound of the maximum magnitude (M_{max}) distributions originally proposed by some of the EPRI ESTs for large areal source zones that encompass large portions of the Gulf Coastal Plain and the Gulf of Mexico. Following the updated characterization initially developed by NuStart for the Grand Gulf Nuclear Station Unit 3 COLA (Reference 2.5.2-245) and implemented by STPNOC for the STP 3 & 4 COLA (Reference 2.5.2-244) M_{max} distributions have been revised for five of the six EPRI EST source zones to account for these earthquakes in the hazard calculations.
- An additional earthquake catalog completeness zone in the Gulf of Mexico has been added to incorporate the contribution of offshore seismicity into the hazard analysis for the LNP site.

2.5.2.4.1.1 Updated Charleston Seismic Source

The seismic source model for repeated large-magnitude, Charleston-type earthquakes is taken directly from the UCSS presented in SNC (Reference 2.5.2-243). The source for repeated large earthquakes at Charleston is modeled by the four alternatives shown on Figure 2.5.2-213. Earthquakes are modeled to occur as extended ruptures on closely spaced vertical faults oriented parallel to the long dimension of each source (Reference 2.5.2-243). The fault width was set at a depth of 20 km and rupture dimensions are modeled using an empirical relationship between rupture size and magnitude developed by Wells and Coppersmith (Reference 2.5.2-246).

SNC characterizes the occurrence of the repeated large earthquakes at Charleston by a characteristic earthquake model with the size and frequency of the characteristic earthquake defined by the parameters in the logic tree shown on Figure 2.5.2-214 (Reference 2.5.2-243).

The concept of a characteristic earthquake occurrence model was implemented in this study using the model developed by Youngs and Coppersmith, as modified by Youngs et al. (References 2.5.2-247 and 2.5.2-248). The magnitudes listed on Figure 2.5.2-214 are considered to represent the size of the expected maximum earthquake rupture for a repeated Charleston-type event. The size of the next characteristic earthquake is assumed to vary randomly about the expected value following a uniform distribution over a range of ±¼ magnitude units. This range represents the aleatory variability in the size of individual repeated large-magnitude, Charleston-type earthquakes. The alternative magnitude values listed in the logic tree represent epistemic uncertainty in the expected size of that earthquake.

SNC fully integrated the UCSS into the EPRI-SOG seismic source characterizations by modifying the geometry of the Charleston seismic sources defined by the EPRI-SOG ESTs (Reference 2.5.2-243). However, these sources are typically over 400 km (250 mi.) from the LNP site (Tables 2.5.2-202, 2.5.2-203, 2.5.2-204, 2.5.2-205, 2.5.2-206, and 2.5.2-207). Thus the details of their geometry, as it relates to the occurrence of smaller earthquakes, are not important to the hazard assessment for the LNP site. Accordingly, a simpler approach was adopted for incorporating the updated Charleston seismic source into the PSHA for the LNP site. The seismic source geometries shown on Figure 2.5.2-213 were used to model only the occurrence of repeated large-magnitude earthquakes in the vicinity of Charleston. The occurrence of all other earthquakes in the Charleston region was modeled using the EPRI-SOG seismic source interpretations (Reference 2.5.2-201). To eliminate double counting of the occurrence of large earthquakes near Charleston, the maximum magnitude distributions for the EPRI-SOG seismic sources related specifically to Charleston were limited to a maximum value of m_b 6.6, which is at the lower edge of the range of magnitudes for the repeated large earthquakes associated with the UCSS model. The EPRI-SOG Charleston seismic sources are indicated in Tables 2.5.2-202, 2.5.2-203, 2.5.2-204, 2.5.2-205, 2.5.2-206, and 2.5.2-207, and the modified maximum magnitude distributions are listed in the right-hand column of the tables. FSAR Subsection 2.5.2.4.3.3 provides further details.

2.5.2.4.1.2 New Maximum Magnitude Information

Geological and seismological data published since the 1986 EPRI seismic source model are summarized and discussed in FSAR Subsections 2.5.1 and 2.5.2.1, respectively. Based on a review of these data and the updated source characterizations implemented in the STP 3 & 4 COLA (Reference 2.5.2-244), the maximum magnitude distributions for some of the EPRI ESTs source zones that extend into the Gulf of Mexico and contain the LNP site (referred to as the Gulf Coastal Source Zones [GCSZ]) are revised. A comparison of the maximum magnitude distributions of EPRI EST characterizations of GCSZs and modifications for the STP 3 & 4 COLA is provided in Table 2.5.2-209.

The maximum magnitude distributions for some of the GCSZs were updated in the STP 3 & 4 COLA (Reference 2.5.2-244) based on the occurrence of two earthquakes that occurred after the development of the EPRI 1986 source model. The STP 3 & 4 COLA updated the maximum magnitude distribution for a particular GCSZ only when two conditions are met: (1) one or both of the 2006 moderate-magnitude earthquakes cannot be determined to have occurred outside the source zone with reasonable certainty, and (2) the observed Emb magnitude for the largest earthquake in the zone is greater than the minimum m_b magnitude of the EPRI 1986 source model maximum magnitude distribution. These criteria resulted in updates to five of the six EST GCSZs maximum magnitude distributions (Table 2.5.2-209).

The updated maximum magnitude distributions were developed by applying the maximum magnitude methodology developed by each EST to that EST's sources that contained one or both of the 2006 earthquakes. The STP 3 & 4 COLA used an Emb of 5.5 for the February 10, 2006 earthquake based on conversion from the reported M_s magnitude and an Emb of 6.1 for the September 10, 2006 earthquake based on conversions from the reported moment of magnitude. As discussed in FSAR Subsection 2.5.2.1.2.2 and indicated in Table 2.5.2-201, the reported m_b values for these two earthquakes are 4.2 and 5.9, respectively. Inclusion of the reported m_b values in the assessment of Emb results in values of 4.9 and 6.0 for the February 10 and September 10 earthquakes, respectively (Table 2.5.2-201). Use of these values to update the maximum magnitude distributions for the GCSZ would lead to small differences in the updated maximum magnitude distributions. Overall, the changes in the maximum magnitude distributions would be small and the values listed in Table 2.5.2-209 are slightly conservative compared to those that would be developed using Emb values of 4.9 and 6.0 for the February 10, 2006, and September 10, 2006, earthquakes, respectively. Therefore, the values listed in Table 2.5.2-209 were used in the updated PSHA calculation for the LNP site.

The maximum magnitude distributions for several other source zones were modified to account for the occurrence of another Emb 5.0 earthquake not associated with the GOM within their boundaries. These sources are Dames &

Moore source 52 (Table 2.5.2-203), Law Engineering sources 107 and 108 (Table 2.5.2-204), Rondout source 49 (Table 2.5.2-205), and Woodward-Clyde Consultants source B38 (Table 2.5.2-207).

2.5.2.4.1.3 Earthquake Occurrence Rates within EPRI-SOG Completeness Regions

FSAR Subsection 2.5.2.1.1 describes the development of an updated earthquake catalog for the LNP site region. This updated catalog includes modifications to the EPRI-SOG catalog by subsequent researchers, the addition of earthquakes that have occurred after completion of the EPRI-SOG seismic source characterization studies (post-March 1985), and the identification of additional earthquakes in the time period covered by the EPRI-SOG evaluation for the project region (1758 to March 1985). The effect of the new catalog information was assessed by evaluating the effect of the new data on earthquake magnitude estimates and on earthquake recurrence estimates within the 320 km (200 mi.) region around the LNP site.

The earthquake recurrence rates computed in the EPRI-SOG evaluation included a correction to remove bias introduced by uncertainty in the magnitude estimates for individual earthquakes (Reference 2.5.2-201). The bias adjustment was implemented by defining an adjusted magnitude estimate for each earthquake, m_b*, and then computing the earthquake recurrence parameters by maximum likelihood using earthquake counts in terms of m_b*. The adjusted magnitude is defined by the relationship

$$m_b{}^* = m_b - \beta\sigma^2_{m_b|m_b\ instrumental} / 2$$ Equation 2.5.2-201

when m_b is based on instrumentally recorded m_b magnitudes and by the relationship

$$m_b{}^* = m_b + \beta\sigma^2_{m_b|X} / 2$$ Equation 2.5.2-202

when m_b is based on other size measures X, such as maximum intensity, I_0, or felt area (Reference 2.5.2-201). The change in sign in the correction term from negative in Equation 2.5.2-201 to positive in Equation 2.5.2-202 reflects the effects of the uncertainty in the conversion from size measure X to m_b. Parameter β is the Gutenberg-Richter *b*-value in natural log units. Values of the adjusted magnitude m_b* were computed for the earthquakes in the updated catalog using the assessed uncertainties in the magnitude estimates and a value of β equal to 0.95 × ln(10) based on the global *b*-value of 0.95 assigned to the CEUS by Frankel et al. (References 2.5.2-240 and 2.5.2-241). Values of $\sigma_{m_b|X}$ range from 0.55 for m_b estimated from maximum intensity, to 0.3 to 0.5 for m_b estimated from various other magnitude scales or felt area (Reference 2.5.2-201). The value of $\sigma_{m_b|m_b instrumental}$ is typically set at 0.1

The EPRI-SOG procedure for computing earthquake recurrence rates was based on a methodology that incorporated data from both the period of complete catalog reporting and the period of incomplete catalog reporting (Reference 2.5.2-201). For the period of incomplete reporting, a probability of detection, P^D, was defined that represented the probability that the occurrence of an earthquake would ultimately be recorded in the earthquake catalog for the region. The CEUS was subdivided into 13 "completeness" regions that represented different histories of earthquake recording. (Reference 2.5.2-201) Figure 2.5.2-215 shows the three completeness regions (2, 3, and 13) that cover the area within 320 km (200 mi.) of the LNP site. Note that the EPRI-SOG catalog contained only a few events in the Gulf of Mexico and no completeness region was defined for this area. The assessment of catalog completeness for the Gulf of Mexico and the incorporation of recent seismicity in that area is discussed in FSAR Subsection 2.5.2.4.1.4.

The total time span of the EPRI-SOG catalog was then divided into six time intervals. Then using the observed seismicity and information on population density and the history of earthquake reporting across the CEUS, the probability of detection was estimated for each time interval within each completeness region for six magnitude intervals. Earthquake recurrence estimates were then made using the "equivalent period of completeness," TE, for each completeness region and all of the recorded earthquakes within the usable portion of the catalog. The equivalent period of completeness is computed by the expression

$$T_{ij}^{E} = \sum_{k} T_{k} \times P_{ijk}^{D} \qquad \text{Equation 2.5.2-203}$$

where P_{ijk}^{D} is the probability of detection for completeness region *i*, magnitude interval *j*, and time period *k* of length T_k (Reference 2.5.2-201). The estimated values of the probability of detection for all of the completeness regions are given in EPRI-SOG (Reference 2.5.2-201).

The updated earthquake catalog includes newly identified earthquakes for the time period covered by the EPRI-SOG catalog, reassessment of the sizes of previously identified events, and earthquakes that have occurred after completion of the EPRI-SOG evaluation. The event counts for the EPRI-SOG and updated catalogs are given in Table 2.5.2-210, where "Update-EPRI AS" indicates the updated catalog without the events flagged as aftershocks in the EPRI-SOG catalog. For the region within 320 km (200 mi.) of the LNP site, the difference in the number of earthquakes in the EPRI-SOG and updated catalog for the time up to 1985 is very small. The impact of the change in the number of events in particular time interval on the probability of detection within the EPRI-SOG completeness zones was approximately estimated by multiplying the value of P^D reported in EPRI-SOG (1986 - 1988) by the ratio of the earthquake count from the updated earthquake catalog to the earthquake count from the EPRI-SOG catalog, with a maximum value of 1.0 for the updated value of P^D. These assessments are presented in Table 2.5.2-210 for completeness regions 2 and

13. Completeness region 3 does not contain any earthquakes with 320 km (200 mi.) of the LNP site.

The effect of the updated earthquake catalog on earthquake occurrence rates was assessed by computing earthquake recurrence parameters for the portions of the EPRI-SOG completeness regions that lie within 320 km (200 mi.) of the LNP site. The truncated exponential recurrence model was fit to the seismicity data using maximum likelihood. Earthquake recurrence parameters were computed using the EPRI-SOG catalog and equivalent periods of completeness and using the updated catalog and the updated equivalent periods of completeness. It was assumed that the probability of detection for all magnitudes is unity for the time period of March 1985 to January 1, 2007. The resulting earthquake recurrence rates for the portion of completeness region 13 with 320 km (200 mi.) of the LNP site are compared on Figure 2.5.2-216. The data labeled "Updated (all events)" includes earthquakes that were flagged as aftershocks in the EPRI-SOG catalog, and the data labeled "Update (no EPRI-SOG aftershocks)" have these events removed before calculating the recurrence parameters. Two sets of calculations were performed, one using unconstrained likelihood and one in which a prior of 1.0 was imposed on the *b*-value. EPRI-SOG (Reference 2.5.2-201) used the approach of applying a prior distribution for the *b*-value in the maximum likelihood estimation (MLE) of seismicity parameters. The use of the prior on *b*-value stabilized the estimate of seismicity parameters in areas with only a few earthquakes. For both sets of analyses (with and without a prior on *b*-value), the rates computed with the updated catalogs are lower than those obtained using the original EPRI-SOG catalog. Calculations were not performed for completeness in region 2 because the event count did not change, and region 3 does not have any events within 320 km (200 mi.) of the LNP site.

Based on comparisons shown on Figure 2.5.2-216, the earthquake occurrence rate parameters developed in the EPRI-SOG evaluation adequately represent the seismicity rates within 320 km (200 mi.) of the Levy site within the EPRI-SOG completeness regions. The impact of the seismicity in the Gulf of Mexico is assessed in FSAR Subsection 2.5.2.4.1.4.

2.5.2.4.1.4 Evaluation of Catalog Completeness within the Gulf of Mexico

The original EPRI completeness regions do not cover the Gulf of Mexico region. As a consequence, the earthquake recurrence parameters in that area had not been computed in the EPRI-SOG (Reference 2.5.2-201) study (Figure 2.5.2-215). Improved seismic networks have increased the detection of events in the Gulf of Mexico and the occurrence of the two moderate events discussed above in FSAR Subsection 2.5.2.1.1 indicates that seismicity in this area needs to be considered a potential contributor to the seismic hazard at the LNP site.

A new catalog completeness region covering the Gulf of Mexico has been created for this purpose. The region is bounded to the north by EPRI-SOG (Reference 2.5.2-201) completeness regions 2 and 3; to the east by region 13; and it extends south to latitude 24°N. The extent of this region is shown on

Figure 2.5.2-201 and its relationship to the EPRI-SOG EST seismic sources is shown on Figures 2.5.2-204, 2.5.2-205, 2.5.2-206, 2.5.2-207, 2.5.2-208, and 2.5.2-209.

The probabilities of detection for the new Gulf of Mexico completeness region were estimated adopting the same procedure used in the EPRI-SOG study (Reference 2.5.2-201). The methodology employs a matrix of probability of detection of earthquakes for selected time and magnitude intervals. A time interval ranging from 1984 through 2006 was added to the intervals used in the EPRI-SOG (Reference 2.5.2-201) assessment to include the most recent earthquakes in the analysis.

The probabilities of detection for the Gulf of Mexico region were evaluated using the EPRI-SOG software package EQPARAM under the same conditions applied in the EPRI-SOG study (Reference 2.5.2-201), namely

- No spatial smoothing of parameter a.
- Medium smoothing of parameter b.
- Moderate smoothing of the probability of detection.
- Monotonicity in m_b and time interval.
- Probability of detection fixed to 1 for certain m_b and time intervals.

In addition, the probability of detection is not computed for the time intervals prior to 1950 because no events are reported prior to that date. Table 2.5.2-211 shows the assessed probabilities of detection for this region. These values were used to compute the earthquake occurrence parameters for the EPRI-SOG EST source zones that include portions of the Gulf of Mexico.

2.5.2.4.2 New Information Relative to Earthquake Ground Motions

2.5.2.4.2.1 Models for Median Ground Motions

The EPRI (Reference 2.5.2-202) calculation of seismic hazard characterized epistemic uncertainty in median (mean log) earthquake ground motions by using three strong-motion attenuation relationships: McGuire et al. (Reference 2.5.2-249), Boore and Atkinson (Reference 2.5.2-250), and Nuttli (Reference 2.5.2-251) combined with the response spectral relationships of Newmark and Hall (Reference 2.5.2-252). These relationships were based to a large extent on modeling earthquake ground motions using simplified physical models of earthquake sources and wave propagation.

Estimating earthquake ground motions in the CEUS has been the focus of considerable research since completion of the EPRI-SOG studies. The research has produced a number of ground motion attenuation relationships. EPRI completed a study in 2004 to update methods used to characterize the estimation of strong ground motion in the CEUS for application in PSHA for nuclear facilities (Reference 2.5.2-253). This study was conducted following the SSHAC guidelines for a Level III analysis (Reference 2.5.2-239). SSHAC provided guidance on the appropriate methods to use for quantifying uncertainty in evaluations of seismic hazard (Reference 2.5.2-239). In a SSHAC Level III analysis, the responsibility for developing the quantitative description of the uncertainty distribution for the quantity of interest lies with an individual or team designated the Technical Integrator. The Technical Integrator is guided by a panel of experts whose role is to provide information, advice, and review. In the EPRI study, a panel of six ground motion experts was assembled (Reference 2.5.2-253). During a series of workshops, the experts provided advice on the available CEUS ground motion attenuation relationships that were considered appropriate for estimating strong ground motion in the CEUS. The experts also provided information on the appropriate criteria for evaluating the available ground motion models. The Technical Integrator then used this information to develop a composite representation of the current scientific understanding of ground motion attenuation in the CEUS.

The EPRI study recommended four alternative sets of median ground motion models (termed model clusters) to represent alternative modeling approaches for defining the median ground motions as a function of earthquake magnitude and source-to-site distance (Reference 2.5.2-253). Three of these ground motion clusters are appropriate for use in assessing the hazard from moderate-sized local earthquakes occurring randomly in source zones, and all four are to be used for assessing the hazard from sources whose hazard contribution is from large-magnitude earthquakes.

EPRI (Reference 2.5.2-253) proposed the logic tree structure to be used with these models that is shown on the left-hand side of Figure 2.5.2-217. The first (leftmost) level of the logic tree shown in the figure provides the weights assigned to the three median cluster models appropriate for local sources. The second level addresses the appropriate ground motion cluster median model to use for large-magnitude distant earthquake sources. For the LNP site, these sources are Charleston-related sources (those defined in both the EPRI-SOG model, listed in Tables 2.5.2-202, 2.5.2-203, 2.5.2-204, 2.5.2-205, 2.5.2-206, and 2.5.2-207, and the UCSS model, for repeated large-magnitude earthquakes). Two alternatives are provided: to use the cluster model used for the local sources or to use the cluster 4 model. The effect of this logic structure on the PSHA is that by following the branch for cluster 1 at the first node, two options are available: (1) use the cluster 1 model for the large-magnitude sources, and (2) use cluster 4 for the large-magnitude sources and cluster 1 for all other sources. This same logic is repeated for the branches for clusters 2 and 3. The rift version of the cluster 4 model was used for the Charleston sources.

EPRI provided estimates of the epistemic uncertainty in the median ground motion model for each cluster (Reference 2.5.2-253). As shown by the third level of the logic tree (Figure 2.5.2-217), the uncertainty in each cluster median model is modeled by a three-point discrete distribution with ground motion relationships for the 5th, 50th, and 95th percentiles of the epistemic uncertainty in the median attenuation relationship for each ground motion cluster.

The EPRI (Reference 2.5.2-253) ground motion median models for clusters 1 and 2 were based in large part on the CEUS ground motion models developed by Silva et al. (Reference 2.5.2-254) and Atkinson and Boore (Reference 2.5.2-255), respectively. Silva et al. (Reference 2.5.2-256) and Atkinson and Boore (Reference 2.5.2-257) have since developed updated versions of their models. These newer models are compared to the EPRI (Reference 2.5.2-253) models on Figure 2.5.2-218.

- The two plots on the left compare the EPRI (Reference 2.5.2-253) 5th percentile, 50th percentile, and 95th percentile 10-Hz and 1-Hz median models for ground motion cluster 1 with the three single-corner stochastic models developed by Silva et al. (Reference 2.5.2-256). The updated models all fall well within the range of the EPRI (Reference 2.5.2-253) models.

- The two plots on the right compare the EPRI (Reference 2.5.2-253) 5th percentile, 50th percentile, and 95th percentile 10-Hz and 1-Hz median models for ground motion cluster 2 with the model developed by Atkinson and Boore (Reference 2.5.2-257). The Atkinson and Boore (Reference 2.5.2-257) model uses rupture distance as the distance measure, while the EPRI (Reference 2.5.2-253) cluster 2 models use Joyner-Boore distance. The comparisons shown on Figure 2.5.2-218 were made assuming that the top of rupture for the **M** 5 earthquake is at a depth of 4 km (2.5 mi.), based on a mean point-source depth of 6 km (3.7 mi.) (Reference 2.5.2-254). The median ground motions produced by the updated Atkinson and Boore (Reference 2.5.2-257) model fall within the range of the EPRI (Reference 2.5.2-253) cluster 2 medians except for distances less than about 7 km (4.3 mi.) for large-magnitude earthquakes.

As presented in FSAR Subsection 2.5.2.4.4, large-magnitude earthquakes at very small distances are not a significant contributor to the hazard. On the basis of the comparisons shown on Figure 2.5.2-218, it is concluded that the EPRI (Reference 2.5.2-253) median ground motion models are appropriate for use in computing the hazard for the LNP site.

2.5.2.4.2.2 Models for Ground Motion Aleatory Variability

The EPRI (Reference 2.5.2-253) study also provided a characterization of the aleatory variability in CEUS ground motions based on an assessment of information available at the time. More recently, EPRI conducted a study focused in part on evaluating the appropriate aleatory variability for CEUS ground motions (Reference 2.5.2-258). The thrust of the study was to identify reasons why the aleatory variability for CEUS motions may be different than that observed for the large empirical database of strong ground motion in the western United States and other tectonically active regions, and then evaluate the extent to which these reasons are supported by empirical data. The result of the EPRI study was a recommended model for aleatory variability for CEUS ground motions (Reference 2.5.2-258).

The EPRI (Reference 2.5.2-258) model for aleatory variability in CEUS ground motions is represented by the fourth and fifth levels of the ground motion logic tree shown on Figure 2.5.2-217. The fourth level of the logic tree addresses the overall aleatory model. Two alternatives were defined: (1) model 1A is based on WUS aleatory variability with an additional component of intra-event variability for CEUS earthquakes and (2) Model 1B is unmodified WUS aleatory variability. Model 1A was favored based on the available data.

The EPRI included an additional component of aleatory variability to account for variability in source depth at small source-to-site distances when the Joyner-Boore distance measure is used for ground motion models based on point-source numerical simulations (Reference 2.5.2-253). EPRI (Reference 2.5.2-258) evaluated the empirical evidence for additional aleatory variability at small Joyner-Boore distances and concluded that the adjustments proposed by EPRI (Reference 2.5.2-253) were not supported by empirical data. Instead, three alternatives were recommended:

1. Model 2A — no adjustment.
2. Model 2B — an additional 0.12 standard error in the natural log of ground motion amplitude.
3. Model 2C — an additional 0.23 standard error.

The additional standard error is to be combined with model 1A or 1B as the sum of variances to produce the final standard error for Joyner-Boore distances less than or equal to 10 km. A log-linear decrease in the additional standard error is to be applied over the distance range of 10 to 20 km, with no additional adjustment for distances greater than 20 km. These alternative models define the fifth level of the logic tree shown on Figure 2.5.2-217. These additional standard error models are applied to the EPRI median models that use the Joyner-Boore distance measure (clusters 1, 2, and 4) (Reference 2.5.2-253).

2.5.2.4.2.3 Conversion from Body Wave to Moment Magnitude

The last level of the ground motion logic tree shown on Figure 2.5.2-217 addresses the relationship between body-wave magnitude, m_b, and moment magnitude, **M**. This conversion is required because the EPRI (Reference 2.5.2-253, Reference 2.5.2-258) ground motion models are defined in terms of **M**, whereas the EPRI-SOG recurrence rates are defined in terms of m_b. The epistemic uncertainty in the conversion between m_b and **M** was addressed by using the three m_b-**M** relationships.

(1) By Atkinson and Boore (Reference 2.5.2-255):

$$\mathbf{M} = -0.39 + 0.98 m_b \qquad \text{for } m_b \leq 5.5$$

Equation 2.5.2-204

$$\mathbf{M} = 2.715 - 0.277 m_b + 0.127 m_b^2 \quad \text{for } m_b > 5.5$$

(2) By Johnston (Reference 2.5.2-259):

$$\mathbf{M} = 1.14 + 0.24 m_b + 0.0933 m_b^2$$

Equation 2.5.2-205

(3) By EPRI (Reference 2.5.2-260):

$$m_b = -10.23 + 6.105\mathbf{M} - 0.7632\mathbf{M}^2 + 0.03436\mathbf{M}^3$$

Equation 2.5.2-206

These three models are assigned equal weight, as the models are all credible.

2.5.2.4.3 PSHA Sensitivity Analysis

This subsection describes the sensitivity studies that were carried out to address any need for changes in the EPRI-SOG PSHA model used in EPRI (Reference 2.5.2-202). Based on the assessments in FSAR Subsection 2.5.2.4, and consistent with the requirements of Regulatory Guide 1.208, the following PSHA model adjustments were studied as part of PSHA sensitivity tests for the LNP site:

- Selection of appropriate set of seismic sources for each EPRI-SOG EST.
- Sensitivity to new data relative to the occurrence of large earthquakes in the Charleston, South Carolina, region.
- Sensitivity to the updated maximum magnitude distributions for seismic sources extending into the Gulf of Mexico.
- Sensitivity to the updated seismicity parameters for seismic sources extending into the Gulf of Mexico.

Sensitivity analyses were not conducted to address the effect of the updated ground motions models developed by EPRI (References 2.5.2-253 and 2.5.2-258) because these have become the standard set of models for the assessment of seismic hazards for proposed new power plants.

As discussed above in FSAR Subsection 2.5.2.2.1, the specific subset of EPRI-SOG seismic sources to include for each EPRI-SOG EST was assessed using updated ground motion models. The selection of the appropriate set is based on the contribution of individual sources to the total hazard at the site. The assessment of the contribution of more distant sources will be affected by the level of hazard contributed by the local sources. FSAR Subsection 2.5.2.4.1.2 presents revised maximum magnitude distributions for sources that extend into the Gulf of Mexico and FSAR Subsection 2.5.2.4.1.4 discusses updated calculation of seismicity parameters for an extension of the EPRI-SOG catalog completeness regions into the Gulf of Mexico. Both of these updates to the EPRI-SOG seismic source characterization are expected to be implemented in the PSHA for the LNP site. Therefore, these modifications were made prior to the assessment of the appropriate set of EPRI-SOG seismic sources.

2.5.2.4.3.1 Selection of EPRI-SOG Seismic Sources

The specific subset of EPRI-SOG seismic sources to include for each EST was assessed using the updated EPRI ground motion models that will be used to compute the PSHA for the LNP site (References 2.5.2-253 and 2.5.2-258). The sources examined included those within 320 km (200 mi.) of the site and those at larger distances with somewhat higher rates of seismicity, such as sources in the vicinity of Charleston, South Carolina, and eastern Tennessee. These calculations were performed for each individual team. Seismic sources were added until additional sources produced less than a 1 percent increase in the frequency of exceedance in the 10^{-4} to 10^{-5} range. The source contributions were tested for 10-Hz and 1-Hz ground motions. The calculations were performed using the preferred set of ground motion models for each ground motion cluster (i.e., the highest weighted path through the logic tree for each ground motion cluster). This corresponds to use of the 50[th] percentile cluster median model and aleatory variability models 1A and 2A. A single m_b-$\mathbf{M}$ conversion relationship was used (Reference 2.5.2-255). The modification to the maximum magnitude distributions and seismic parameters for Gulf of Mexico seismic sources discussed in FSAR Subsection 2.5.2.4.1.2 and FSAR Subsection 2.5.2.4.1.4 were applied to the Gulf of Mexico seismic sources as part of this assessment.

EPRI (Reference 2.5.2-253) provided ground motion models for two regions of the CEUS, the mid-continent region that covered most of CEUS, and the Gulf Coast Region. The Gulf Coast Region was originally defined by EPRI (Reference 2.5.2-260) as an area with a higher rate of ground motion attenuation than the remaining portion of the CEUS. This region is shown in relationship to the EPRI-SOG EST sources on Figures 2.5.2-204, 2.5.2-205, 2.5.2-206, 2.5.2-207, 2.5.2-208, and 2.5.2-209. The Gulf Coast ground motion models were used for those sources where the travel path is primarily thought the Gulf Coast region and the Mid-continent model was used for those sources where a substantial portion of the travel path is through the Mid-continent region. The use of these two models for specific sources is indicated in Tables 2.5.2-202, 2.5.2-203, 2.5.2-204, 2.5.2-205, 2.5.2-206, and 2.5.2-207. Note that various crustal regions defined in EPRI (Reference 2.5.2-260) did not include the southern half of the Florida peninsula, apparently due to lack of data for this portion of the CEUS. It is assumed in this analysis that the southern half of Florida should be included along with the northern half in the Gulf Coast Region for the purpose of selection of the appropriate EPRI (2004) (Reference 2.5.2-260) ground motion models.

2.5.2.4.3.1.1 Bechtel Team's Seismic Sources

Figure 2.5.2-219 shows the mean hazard curves computed for the Bechtel team's sources listed in Table 2.5.2-202. The Gulf Coast model ground motion was applied only to Source BZ1. This source is the largest contributor to the hazard at the LNP site from the Bechtel source model.

2.5.2.4.3.1.2 Dames & Moore Team's Seismic Sources

Figure 2.5.2-220 shows the mean hazard curves computed for the Dames & Moore team's sources listed in Table 2.5.2-203. The implementation of the seismic source model for the Dames & Moore team followed the approach used in the HAR COLA (Reference 2.5.2-261) in that Sources 41 and 53 were considered to be active in some form with probability 1.0. Source 53 interacts with Sources 52 and 54. As originally defined, Source 53 overlays both of these sources. For this analysis, modified versions of Source 53 were developed that excluded the region occupied by Source 54, which has a P* = 1, and when Source 52 is active, only occupied the region north of Sources 52 and 54.

The Gulf Coast ground motion model was applied only to Source 20. This source is the largest contributor to the hazard at the LNP site from the Dames & Moore source model.

2.5.2.4.3.1.3 Law Engineering Team's Seismic Sources

Figure 2.5.2-221 shows the mean hazard curves computed for the Law Engineering team's sources listed in Table 2.5.2-204. The Gulf Coast ground motion model was applies to Source 126 and the southern part of Source 8. Source 126 is the largest contributor to the hazard at the LNP site from the Law Engineering source model.

2.5.2.4.3.1.4 Rondout Associates Team's Seismic Sources

Figure 2.5.2-222 shows the mean hazard curves computed for the Rondout Associates team sources listed in Table 2.5.2-205. The Gulf Coast ground motion model was applies to Sources 51, 13, and the southern part of Source 49. Source 49 is the largest contributor to the hazard at the LNP site from the Rondout Associates source model.

2.5.2.4.3.1.5 Weston Geophysical Team's Seismic Sources

Figure 2.5.2-223 shows the mean hazard curves computed for the Weston Geophysical team's sources listed in Table 2.5.2-206. The Gulf Coast ground motion model was applies to Source 107. Source 107 is the largest contributor to the hazard at the LNP site from the Weston Geophysical source model.

The Weston Geophysical Teams Source 103 includes a number of alternative geometries depending on whether or not sources within the boundary are considered active. These alternatives were tested and it was found that the combination of Source 24 active within the boundary of Source 103 produced slightly higher hazard than the other cases. This combination was used in the updated hazard analysis. The hazard curve for Source 103 shown on Figure 2.5.2-224 includes the contribution of Source 24.

2.5.2.4.3.1.6 Woodward-Clyde Consultants Team's Seismic Sources

Figure 2.5.2-224 shows the mean hazard curves computed for the Woodward-Clyde Consultants team's sources listed in Table 2.5.2-207. The Gulf Coast ground motion model was applies to Source B36. This source is the largest contributor to the hazard at the LNP site from the Woodward-Clyde Consultants source model.

The two alternative geometries for Source 31 were tested. It was found that they produced very similar hazard, with Alternative 31 producing slightly higher hazard than Alternative 31A. In order to simplify the model, only the Alternative 31 is shown on Figure 2.5.2-224 and this alternative was used in the updated seismic hazard analysis.

2.5.2.4.3.2 PSHA Sensitivity to Revisions of the EPRI-SOG Sources

FSAR Subsection 2.5.2.4.1.2 discusses modifications to the maximum magnitude distributions for EPRI-SOG seismic sources that extend into the Gulf of Mexico and encompass the location of one or both of the moderate magnitude earthquakes that occurred in 2006. The effect of these modified maximum magnitude distributions on the hazard from the EPRI-SOG seismic sources is shown on Figure 2.5.2-225. The modified maximum magnitude distributions primarily affect the source zones in which the LNP site is located and the result is an appreciable increase in the hazard.

FSAR Subsection 2.5.2.4.1.4 presents an updated assessment of catalog completeness and seismicity parameters for the region in the Gulf of Mexico that was not included in the original EPRI-SOG calculation of seismicity parameters. The affect of including the updated seismicity rates for these sources is also shown on Figure 2.5.2-225. The result is a small increase in the hazard from sources that extend into the Gulf of Mexico in the vicinity of the site.

In summary, the modifications to the maximum magnitude distributions to account for the occurrence of the 2006 Gulf of Mexico earthquakes and to incorporate Gulf of Mexico seismicity lead to a combined appreciable increase in the hazard at the LNP site from the updated EPRI-SOG seismic sources, and these modifications are incorporated into the updated PSHA for the LNP site. The limitation on the maximum magnitude distribution for EPRI-SOG Charleston-specific seismic sources is considered to be appropriate to prevent double counting of the occurrence of large-magnitude earthquakes near Charleston and is also incorporated into the updated PSHA for the LNP site.

2.5.2.4.3.3 Additional Seismic Sources

The second set of sensitivity analyses test the effect of incorporating sources of repeated large-magnitude earthquakes at Charleston. That portion of the UCSS model that defines a source for repeated large earthquakes near Charleston was implemented (Reference 2.5.2-230). The main features of this model are described in FSAR Subsection 2.5.2.4.1.1. The four alternative source geometries shown on Figure 2.5.2-213 were modeled by a series of closely spaced vertical faults parallel to the long axis of the source. Earthquakes were modeled as extended ruptures on these faults using the relationship between magnitude and rupture area defined by Wells and Coppersmith for all slip types (Reference 2.5.2-246). The epistemic uncertainty in the expected magnitude of the repeated large earthquakes occurring on this source was modeled by the weighted alternatives in the UCSS logic tree shown on Figure 2.5.2-214. The aleatory variability in the magnitude of individual earthquakes is assumed to vary randomly about the expected value following a uniform distribution over a range of ±¼ magnitude units.

The lognormal distributions for the uncertainty in the recurrence interval of the repeated earthquakes defined on Figure 2.5.2-214 were modeled by the 5-point discrete approximation to a continuous distribution developed by Miller and Rice (Reference 2.5.2-262). The discrete recurrence interval values, the associated weights, and the resulting equivalent annual frequencies are listed in Table 2.5.2-212.

Figure 2.5.2-225 compares the hazard computed from the UCSS model with that obtained from the updated EPRI-SOG model described in FSAR Subsection 2.5.2.4.3.1. The UCSS source produces exceedance frequencies for 10-Hz motions that are larger than those produced by the updated EPRI-SOG sources for exceedance frequencies in the range of 10^{-3} to 10^{-5}. For 1-Hz motions, the hazard produced by the UCSS model exceeds by a large margin the hazard produced by the updated EPRI-SOG sources for exceedance frequencies less than 10^{-3}. These results indicate that the UCSS in a major contributor to the hazard and it was incorporated into the updated PSHA for the LNP site.

As discussed in FSAR Subsection 2.5.2.4.1.1, the UCSS is used to model the occurrence of repeated large magnitude earthquakes near Charleston. To prevent double counting of the occurrence of these events, the maximum magnitude distributions of Charleston-specific sources defined by the EPRI-SOG ESTs were limited to a maximum of m_b 6.6. Figure 2.5.2-225 shows the effect of this modification on the computed hazard from the EPRI-SOG seismic sources. The modification results in a slight decrease in the 10-Hz spectral acceleration hazard and a small decrease in the 1-Hz spectral acceleration hazard. These small decreases are more that made up for by the addition of the contribution from the UCSS.