UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 22, 2015

Mr. Scott Batson
Vice President, Oconee Nuclear Station
Duke Energy Corporation
7800 Rochester Highway
Seneca, SC 29672-0752

SUBJECT: OCONEE NUCLEAR STATION, UNITS 1, 2, AND 3 - STAFF ASSESSMENT OF INFORMATION PROVIDED PURSUANT TO TITLE 10 OF THE *CODE OF FEDERAL REGULATIONS* PART 50, SECTION 50.54(f), SEISMIC HAZARD REEVALUATIONS FOR RECOMMENDATION 2.1 OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT (TAC NOS. MF3736, MF3737, AND MF3738)

Dear Mr. Batson:

On March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a request for information pursuant to Title 10 of the *Code of Federal Regulations*, Part 50, Section 50.54(f) (hereafter referred to as the 50.54(f) letter). The purpose of that request was to gather information concerning, in part, seismic hazards at each operating reactor site and to enable the NRC staff, using present-day NRC requirements and guidance, to determine whether licenses should be modified, suspended, or revoked.

By letter dated March 31, 2014, Duke Energy Carolinas, LLC (Duke, the licensee) responded to this request for Oconee Nuclear Station, Units 1, 2, and 3 (Oconee).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for Oconee and, as documented in the enclosed staff assessment, determined that the licensee provided sufficient information in response to Enclosure 1, Items (1) – (3), (5), (7) and comparison portion of Item (4) of the 50.54(f) letter. Further, the staff concludes that the licensee's reevaluated seismic hazard is suitable for other actions associated with Near-Term Task Force Recommendation 2.1, "Seismic".

Contigent upon the NRC's review and acceptance of the Duke's expedited seismic evaluation process, and seismic risk evaluation including the high frequency and spent fuel pool evaluations (i.e., Items (4), (6), (8), and (9)) for Oconee, the Seismic Hazard Evaluation identified in Enclosure 1 of the 50.54(f) letter will be completed.

If you have any questions, please contact me at (301) 415-1617 or at Frankie.Vega@nrc.gov.

Sincerely,

Frankie G. Vega, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-269, 50-270, and 50-287

Enclosure:
Staff Assessment of Seismic
Hazard Evaluation and Screening Report

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STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO SEISMIC HAZARD AND SCREENING REPORT

OCONEE NUCLEAR STATION, UNIT NOS. 1, 2, AND 3

DOCKET NOS. 50-269, 50-270, 50-287

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC or Commission) issued a request for information to all power reactor licensees and holders of construction permits in active or deferred status, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.54(f) "Conditions of license" (hereafter referred to as the "50.54(f) letter"). The request was and other regulatory actions were issued in connection with implementing lessons-learned from the 2011 accident at the Fukushima Dai-ichi nuclear power plant, as documented in the "Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident" (NRC, 2011b).[1] In particular, the NRC Near-Term Task Force (NTTF) Recommendation 2.1, and subsequent Staff Requirements Memoranda (SRM) associated with Commission Papers SECY-11-0124 (NRC, 2011c) and SECY-11-0137 (NRC, 2011d), instructed the NRC staff to issue requests for information to licensees pursuant to 10 CFR 50.54(f).

Enclosure 1 to the 50.54(f) letter requests that addressees perform a reevaluation of the seismic hazards at their sites using present-day NRC requirements and guidance to develop a ground motion response spectrum (GMRS).

The required response section of Enclosure 1 requests that each addressee provide the following information:

(1) Site-specific hazard curves (common fractiles and mean) over a range of spectral frequencies and annual exceedance frequencies,

(2) Site-specific, performance-based GMRS developed from the new site-specific seismic hazard curves at the control point elevation,

(3) Safe Shutdown Earthquake (SSE) ground motion values including specification of the control point elevation,

(4) Comparison of the GMRS and SSE. A high-frequency evaluation (if necessary),

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[1] Issued as an enclosure to Commission Paper SECY-11-0093 (NRC, 2011a).

(5) Additional information such as insights from NTTF Recommendation 2.3 walkdown and estimates of plant seismic capacity developed from previous risk assessments to inform NRC screening and prioritization,

(6) Interim evaluation and actions taken or planned to address the higher seismic hazard relative to the design basis, as appropriate, prior to completion of the risk evaluation (if necessary),

(7) Statement if a seismic risk evaluation is necessary,

(8) Seismic risk evaluation (if necessary), and

(9) Spent fuel pool (SFP) evaluation (if necessary).

Present-day NRC requirements and guidance with respect to characterizing seismic hazards use a probabilistic approach in order to develop a risk-informed performance-based GMRS for the site. Regulatory Guide (RG) 1.208, A Performance-based Approach to Define the Site-Specific Earthquake Ground Motion (NRC, 2007), describes this approach. As described in the 50.54(f) letter, if the reevaluated seismic hazard, as characterized by the GMRS, is not bounded by the current plant design-basis SSE, further seismic risk evaluation of the plant is merited.

By letter dated November 27, 2012 (Keithline, 2012), the Nuclear Energy Institute (NEI) submitted Electric Power Research Institute (EPRI) report “Seismic Evaluation Guidance: Screening, Prioritization, and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1 Seismic" (EPRI, 2012), hereafter called the SPID. The SPID supplements the 50.54(f) letter with guidance necessary to perform seismic reevaluations and report the results to the NRC in a manner that will address the Requested Information Items in Enclosure 1 of the 50.54(f) letter. By letter dated February 15, 2013 (NRC, 2013b), the staff endorsed the SPID.

The required response section of Enclosure 1 to the 50.54(f) letter specifies that Central and Eastern United States (CEUS) licensees provide their Seismic Hazard and Screening Report (SHSR) by 1.5 years after issuance of the 50.54(f) letter. However, in order to complete its update of the EPRI seismic ground motion models (GMM) for the CEUS (EPRI, 2013), industry proposed a six-month extension to March 31, 2014, for submitting the SHSR. Industry also proposed that licensees perform an expedited assessment, referred to as the Augmented Approach, for addressing the requested interim evaluation (Item (6) above), which would use a simplified assessment to demonstrate that certain key pieces of plant equipment for core cooling and containment functions, given a loss of all alternating current power, would be able to withstand a seismic hazard up to two times the design basis. Attachment 2 to the April 9, 2013, letter (Pietrangelo, 2013) provides a revised schedule for plants needing to perform (1) the Augmented Approach by implementing the Expedited Seismic Evaluation Process (ESEP) and (2) a seismic risk evaluation. By letter dated May 7, 2013 (NRC, 2013), the NRC determined that the modified schedule was acceptable and by letter dated August 28, 2013 (NRC, 2013c), the NRC determined that the updated GMM (EPRI, 2013) is an acceptable GMM for use by CEUS plants in developing a plant-specific GMRS.

By letter dated April 9, 2013 (Pietrangelo, 2013), industry committed to following the SPID to develop the SHSR for existing nuclear power plants. By letter dated September 11, 2013

(Waldrep, 2013), Duke Energy Carolinas, LLC (Duke, the licensee) submitted at least partial site response information for Oconee Nuclear Station (Oconee), Units 1, 2, and 3. By letter dated March 31, 2014 (Batson, 2014a), the licensee submitted its SHSR for Oconee.

2.0 REGULATORY BACKGROUND

The structures, systems, and components (SSCs) important to safety in operating nuclear power plants are designed either in accordance with, or meet the intent of Appendix A to 10 CFR Part 50, General Design Criteria (GDC) 2: "Design Bases for Protection Against Natural Phenomena;" and Appendix A to 10 CFR Part 100, "Reactor Site Criteria." The GDC 2 states that SSCs important to safety at nuclear power plants shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

For initial licensing, each licensee was required to develop and maintain design bases that, as defined by 10 CFR 50.2, identify the specific functions that an SSC of a facility must perform, and the specific values or ranges of values chosen for controlling parameters as reference bounds for the design. The design bases for the SSCs reflect appropriate consideration of the most severe natural phenomena that had been historically reported for the site and surrounding area. The design bases also considered limited accuracy, quantity, and period of time in which the historical data have been accumulated.

The seismic design bases for currently operating nuclear power plants were either developed in accordance with, or meet the intent of GDC 2 and 10 CFR Part 100, Appendix A. Although the regulatory requirements in Appendix A to 10 CFR Part 100 are fundamentally deterministic, the NRC process for determining the seismic design-basis ground motions for new reactor applications after January 10, 1997, as described in 10 CFR 100.23, requires that uncertainties be addressed through an appropriate analysis such as a probabilistic seismic hazard analysis (PSHA).

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. On March 12, 2012, the NRC staff issued requests for licensees to reevaluate the seismic hazards at their sites using present-day NRC requirements and guidance, and identify actions planned to address plant-specific vulnerabilities associated with the updated seismic hazards.

Attachment 1 to Enclosure 1 of the 50.54(f) letter describes an acceptable approach for performing the seismic hazard reevaluation for plants located in the CEUS. Licensees are expected to use the CEUS Seismic Source Characterization (CEUS-SSC) model in NUREG-2115 (NRC, 2012b) along with the appropriate EPRI (2004, 2006) ground motion models. The SPID provides further guidance regarding the appropriate use of GMMs for the CEUS. Specifically, Section 2.3 of the SPID recommends the use of the updated GMM (EPRI, 2013) and, as such, licensees used the NRC-endorsed updated EPRI GMM instead of the older EPRI (2004, 2006) GMM to develop PSHA base rock hazard curves. Finally, Attachment 1 requested that licensees conduct an evaluation of the local site response in order to develop site-specific hazard curves and GMRS for comparison with the plant SSE.

2.1 Screening Evaluation Results

By letter dated March 31, 2014 (Batson, 2014a), Duke provided the SHSR for Oconee, Units 1, 2, and 3. The licensee's SHSR indicates that the site GMRS exceeds the SSE for Oconee over the frequency range of 1 to 10 Hertz (Hz). As such, Oconee screens in to perform a plant seismic risk evaluation. A SFP evaluation will also be performed. The GMRS also exceeds the SSE at frequencies above 10 Hz. The licensee indicated that the risk evaluation would address the high frequency exceedance.

On May 9, 2014 (NRC, 2014), the staff issued a letter providing the outcome of its 30-day screening and prioritization evaluation. As indicated in the letter, the staff confirmed the licensee's screening results. The licensee's GMRS, as well as the confirmatory GMRS developed by the staff, exceed the SSE for Oconee, Units 1, 2, and 3 over the frequency range of approximately 2 to 100 Hz. Therefore, a seismic risk evaluation, SFP evaluation, and a high-frequency confirmation are merited for Oconee, Units 1, 2, and 3.

3.0 TECHNICAL EVALUATION

The NRC staff evaluated the licensee's submittal to determine if the provided information responded appropriately to Enclosure 1 of the 50.54(f) letter with respect to characterizing the reevaluated seismic hazard.

3.1 Plant Seismic Design-Basis

Enclosure 1 of the 50.54(f) letter requests the licensee provide the SSE ground motion values, as well as the specification of the control point elevation(s) for comparison to the GMRS. For operating reactors licensed before 1997, the SSE is the plant licensing basis earthquake and is characterized by 1) a peak ground acceleration (PGA) value which anchors the response spectra at high frequencies (typically at 20 to 30 Hz for the existing fleet of nuclear power plants; 2) a response spectrum shape which depicts the amplified response at all frequencies below the PGA; and 3) a control point where the SSE is defined.

In Section 3.1 of its SHSR, the licensee described its seismic design bases for Oconee. The licensee stated that the SSE for Oconee is based on a postulated intensity VI earthquake 11 miles from the site along the Brevard fault zone. Based on this earthquake, the response spectral shape is anchored at a PGA of 0.10 g (10 percent of the acceleration due to earth's gravity) with a Housner-type spectrum.

The licensee specified that the SSE control point is located at the top of the rock at a mean sea level (MSL) elevation of 753 ft [229.6 m]. In the absence of a control point definition in the Updated Final Safety Analysis Report (UFSAR), the licensee relied on the guidance provided in Section 2.4.2 of the SPID to define the control point.

3.2 Probabilistic Seismic Hazard Analysis

In Section 2.2 of its SHSR, the licensee stated that, in accordance with the 50.54(f) letter and the SPID, it performed a PSHA using the CEUS-SSC model and the updated EPRI GMM for the CEUS (EPRI, 2013). For its PSHA, the licensee used a minimum moment magnitude (M_w) of 5.0 as specified in the 50.54(f) letter. The licensee further stated that it included CEUS-SSC background sources out to a distance of 400 miles [640 km] and included the Charleston, Commerce, Eastern Rift Fault segments, Marianna, New Madrid Fault system, and Wabash Valley repeated large magnitude earthquake (RLME) sources, which lie within 620 miles [1,000 km] of the site. The RLME sources are those source areas or faults for which more than one large magnitude ($M_w >= 6.5$) earthquake has occurred in the historical or paleo-earthquake (geologic evidence for prehistoric seismicity) record. The licensee used the mid-continent version of the updated EPRI GMM (EPRI, 2013) for each of the CEUS-SSC sources.

Rather than implement the CEUS-SSC model as published for its PSHA, the licensee stated in its SHSR that it performed a site-specific review of the CEUS-SSC seismic catalog with regard to two issues: (1) identification of additional reservoir induced seismicity (RIS) earthquakes in the southeastern U.S. and (2) locations of earthquakes in South Carolina near the time of the 1886 Charleston, SC earthquake sequence. The purpose of the licensee's review was to determine if the magnitude recurrence parameters for the southeastern U.S., as determined in the CEUS-SSC model, needed to be adjusted.

Concerning the first issue, the licensee noted that in developing the CEUS-SSC catalog, earthquakes identified as RIS were removed from the final earthquake catalog. Taking into consideration the proximity of each earthquake to a reservoir, timing of the earthquake versus the filling of the reservoir, magnitude of the earthquake, and proximity to a nuclear power plant, the licensee further evaluated the CEUS-SSC seismic catalog to determine if there were additional RIS earthquakes that had not been previously identified in the CEUS-SSC seismic catalog. As a result of its review, the licensee identified and removed an additional 30 earthquakes from the CEUS-SSC catalog that it considered to be RIS.

Concerning the second issue, the licensee noted that in developing the CEUS-SSC catalog earthquakes identified as aftershocks of the large Charleston, South Carolina 1886 main shock were removed from the final catalog. Prior to using the CEUS-SSC source model, the licensee evaluated 20 earthquakes in the CEUS-SSC catalog located at a sufficient distance from Charleston to not be identified as aftershocks of the 1886 main event. Of these 20 earthquakes, the licensee identified several that it considered to be duplicates, mislocated, or to have incorrect magnitudes and therefore, they were modified as appropriate.

After reviewing the licensee's CEUS-SSC catalog changes, the NRC staff issued an request for additional ifnromation (RAI). In its RAI, the NRC staff noted that Enclosure 1 to the 50.54(f) letter states that regional and local refinements of the CEUS-SSC are not necessary for this evaluation, and that Section 2 of the SPID states that the use of the CEUS-SSC model as published is appropriate. The NRC staff further noted that Section 6 of NUREG-2117 (NRC, 2012c) recommends that viable regional probabilistic hazard studies, such as the CEUS-SSC, should be updated with at least a Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 study. As such, the NRC staff requested that the licensee either provide the SSHAC Level 2 study supporting the licensee's changes to the CEUS-SSC catalog or re-perform the PSHA for Oconee using the CEUS-SSC model as published. In response to the RAI, by letter dated November 12, 2014 (Batson, 2014b), the licensee stated that it would perform a SSHAC Level 2 study to ensure that the modified CEUS-SSC catalog represents the center, body, and range of technically defensible interpretations.

By letter dated April 28, 2015 (Gatlin, 2015), the licensee submitted its SSHAC Level 2 study on the topics of RIS and the Charleston earthquake locations. The SSHAC study developed the technical basis for the removal of RIS and the relocation of earthquakes located near the Charleston RLME source near the time of the 1886 earthquake sequence. In addition, the SSHAC study included the technical comments provided by two independent reviewers and the authors' response to and resolution of the technical comments. Finally, the SSHAC study included a closure letter from the independent reviewers confirming that the technical comments had been resolved and the SSHAC level 2 process was followed.

The NRC staff reviewed the SSHAC Level 2 study, the reviewer comments, and the comments' resolution. The NRC staff's review focused on the technical bases for the removal of events near the plant sites identified as RIS and the relocation of seismicity near Charleston. On the issue of RIS, the NRC staff notes that a substantial effort was made to remove RIS from the CEUS-SSC catalog, however, the potential that some RIS remains in the published catalog cannot be ruled out. The issue of induced seismicity, and its effect on hazard, is on of importance to the broader seismic hazard community. Based on the NRC staff's review of the SSHAC Level 2 study and the recent literature related to RIS, the NRC staff finds that the licensee's removal of additional RIS from the catalog on a site-specific basis for the limited purpose of responding to Recommendation 2.1, to be acceptable. The magnitudes of the 30 earthquakes identified as RIS and removed from the catalog range from **M** 2.32 – 3.64. Earthquakes of this size have a limited impact on the calculation of recurrence parameters for the CEUS-SSC model but the removal of a large number of small events in a concentrated area may impact the overall hazard for a nearby site.

On the issue of relocating earthquakes potentially associated with the Charleston earthquake sequence, the NRC staff reviewed the SSHAC Level 2 study and the technical comments made by the reviewers. The location of historical seismicity is made difficult by the lack of instrumental data, requiring that scientists rely on historical reports of felt motions, most often recorded in contemporaneous newspaper accounts. The staff notes that significant effort went into locating events near Charleston during the CEUS-SSC study using the most up to date methods and available reports at the time of the study. The licensee's technical judgement is based on additional reviews of historical newspaper accounts and evidence that some earthquake times may have been misinterpreted in the original catalog. The NRC staff agrees that additional review of earthquake locations, times, and magnitudes is warranted when new information is made available (i.e. additional historical data becomes available), but notes that locating historical seismicity remains a subject of intense debate within the broader technical community.

Overall, the NRC staff finds that the licensee followed applicable guidance in conducting a SSHAC Level 2 study when modifying the CEUS-SSC catalog for its site-specific PSHA. However, because the issues addressed by the study are subjects of significant discussion within the broader scientific community, the staff regards the site-specific modifications conducted by the licensee to be applicable to only the licensee's response to the 50.54(f) request for information. As such, the staff does not consider these site specific refinements to the hazard inputs of the CEUS-SSC model to constitute an official update of the CEUS-SSC model. In order for these changes to the model to be considered as an official update, all of the stakeholders of the CEUS-SSC would need to agree on their merits.

As part of its confirmatory analysis of the licensee's GMRS, the staff performed its own PSHA calculations for base rock conditions at the Oconee site. As input, the staff used the CEUS-SSC model as documented in NUREG-2115 (NRC, 2012b) along with the updated EPRI GMM

(EPRI, 2013). Consistent with the guidance provided in the SPID, the staff included all CEUS-SSC background seismic sources within a 310 mi [500 km] radius of the Oconee site. In addition, the staff included all of the RLME sources falling within a 620 mi [1,000 km] radius of the site. For each of the CEUS-SSC sources used in the PSHA, the staff used the mid-continent version of the updated EPRI GMM (EPRI, 2013). The staff used the resulting base rock seismic hazard curves together with a confirmatory site response analysis, described in the next section, to develop control point seismic hazard curves and a GMRS for comparison with the licensee's results.

As part of its RAI response, the licensee provided base rock hazard curves in order to show the impact of its refinements to the CEUS-SSC seismicity catalog. Figure 3.2-1 of this assessment shows the licensee's base rock hazard curves along the staff's base rock hazard curves. As shown in Figure 3.2-1 of this assessment, the impact of the licensee's changes to the hazard inputs have a very minor impact on the hazard for the Oconee site.

Based on review of the SHSR, the NRC staff concludes that the licensee appropriately followed the guidance provided in the SPID for selecting the PSHA input models and parameters for the site. This includes the licensee's use and implementation of the CEUS-SSC model and the updated EPRI GMM.

3.3 Site Response Evaluation

After completing PSHA calculations for reference rock site conditions, Attachment 1 to Enclosure 1 of the 50.54(f) letter requests that the licensee provide a GMRS developed from the site-specific seismic hazard curves at the control point elevation. In addition, the 50.54(f) letter specifies that the subsurface site response model, for both soil and rock sites, should extend to sufficient depth to reach the generic or reference rock conditions as defined in the GMMs used in the PSHA. To develop site-specific hazard curves at the control point elevation, Attachment 1 requests that licensees perform a site response analysis.

Detailed site response analyses were not typically performed for many of older the operating plants; therefore, Appendix B of the SPID provides detailed guidance on the development of site-specific amplification factors (including the treatment of uncertainty) for sites that do not have detailed, measured soil and rock parameters to extensive depths.

The purpose of the site response analysis is to determine the site amplification that will occur as a result of bedrock ground motions propagating upwards through the soil/rock column to the surface. The critical parameters that determine what frequencies of ground motion are affected by the upward propagation of bedrock motions are the layering of soil and/or soft rock, the thicknesses of these layers, the shear-wave velocities and low-strain damping of the layers, and the degree to which the shear modulus and damping change with increasing input bedrock amplitude.

3.3.1 Site Base Case Profiles

The licensee provides detailed site profile descriptions in Sections 2.3.1 and 2.3.2 of its SHSR based on original siting investigations, described in the UFSAR (Duke, 2013), and recent borings and geophysical measurements performed by the licensee for a Main Steam Isolation Valve (MSIV) project. The licensee states that the Oconee site is underlain by approximately 20 to 30 ft [6.1 to 9.1 m] of residual soils overlying about 65 ft [19.8 m] of partially weathered rock grading into metamorphic igneous rocks. The licensee provides a brief description of the subsurface materials in terms of geologic units and thicknesses in its SHSR.

Geophysical investigations performed by the licensee for its MSIV Project measured compressional (P) and shear (S) wave velocities of the rock in two boreholes near the reactor building using the suspension P-S logging method. The best estimate seismic shear wave velocity for the approximately 67 ft [20.4 m] of rock from the control point to the assumed base rock depth of 110 ft [33.5 m] is 8,265 feet per second (fps) [2,519 meters per sec].

To characterize the subsurface geology, the licensee developed three site base case profiles. The licensee's middle, or best estimate profile was developed using measured the shear-wave velocity of 8,265 fps [2,519 m/sec] from the MSIV project and assumed to be constant over the 67 ft [20.4 m] of firm rock. The licensee developed upper and lower base case profiles using a natural log standard deviation of 0.20. As such, the lower velocity profile has a constant S-wave velocity of 6,612 fps [2,015 m/sec] and since the S-wave velocity for the upper velocity profile exceeds the assumed base rock velocity of 9,285 fps [2,830 m/sec], the licensee concluded that the upper profile should be considered as hard base rock. Figure 3.3-1 of this assessment shows the licensee's three shear-wave velocity base case profiles.

In Section 2.3.2.1 of its SHSR, the licensee assumed that the rock material over the entire profile of 67 ft [20.4 m] could be modeled as either linear or non-linear. To model the potential non-linear behavior of the rock the licensee used the generic EPRI shear modulus reduction and hysteretic damping curves over the entire profile. To model the linear behavior of the rock over the profile, the licensee used the low strain damping values (approximately 3 percent) from the EPRI rock curves for each of the rock layers. The licensee weighed these alternative material behaviors equally, assigning 50 percent to each case.

The licensee also considered the impact of kappa, or small strain damping, on site response. Kappa is measured in units of seconds (sec), and is the damping contributed by both intrinsic hysteretic damping as well as scattering due to wave propagation in heterogeneous material. For Oconee, a site with about 67 ft [20.4 m] of firm rock over the assumed base rock material, the licensee used the low strain damping values from the EPRI rock curves (approximately 3 percent) over the 67 ft [20.4 m] to calculate a kappa value for each of the three base case profiles. The licensee also added an additional kappa of 0.006 sec to account for the damping in the underlying base rock material. Total profile kappa values for the best estimate, upper, and lower base case velocity profiles are 0.0065, 0.0060, and 0.0067 sec, respectively.

To account for randomness in material properties across the plant site, the licensee stated that it randomized its base case shear-wave velocity profiles in accordance with Appendix B of the SPID. In addition, the licensee randomized the depth to bedrock by ±13 ft [±4.1 m], which corresponds to 20 percent of the total profile thickness. The licensee stated that this randomization did not represent the actual uncertainty in the depth to bedrock, but was used to broaden the spectral peaks.

3.3.2 Site Response Method and Results

In Section 2.3.4 of its SHSR, the licensee states that it followed the guidance in Appendix B of the SPID to develop input ground motions for the site response analysis and, in Section 2.3.5, the licensee describes its implementation of the random vibration theory (RVT) approach to perform its site response calculations. Finally, Section 2.3.6 of the SHSR shows the resulting amplification functions and associated uncertainties for two of the eleven input loading levels for the base case profile and EPRI rock shear modulus and damping curves.

In order to develop probabilistic site-specific control point hazard curves, as requested in Requested Information Item 1 of the 50.54(f) letter, the licensee used Method 3, described in Appendix B-6.0 of the SPID. The licensee's use of Method 3 involved computing the site-specific control point elevation hazard curves for a broad range of spectral accelerations by combining the site-specific bedrock hazard curves, determined from the initial PSHA (Section 3.2), and the amplification functions and their associated uncertainties, determined from the site response analysis.

3.3.3 Staff Confirmatory Analysis

To confirm the licensee's site response analysis, the staff performed its own site response calculations for the Oconee site. The staff independently developed a shear-wave velocity profile, damping values, and modeled the potential nonlinear behavior of the rock using measurements and geologic information provided in the Oconee UFSAR (Duke, 2013), the licensee's description of the MSIV Project in the SHSR, and Appendix B of the SPID. For its site response calculations, the staff employed the RVT approach and developed input ground motions in accordance with Appendix B of the SPID.

The licensee used the latest geotechnical exploration data to establish the shear wave velocity profile for the site, which was based on three boreholes with shear wave velocity measurements (P-S logging) at the distance between 19.5 and 28 ft [5.9 to 8.5 m] to the edge of the three reactor units. Because the site profile established based on some recent obtained and site-specific data and is fairly well characterized, the NRC staff used the same input velocity profiles as those provided by the licensee. Figure 3.3-1 of this staff assessment shows the velocity profiles used by the licensee and the staff.

Similar to the approach used by the licensee, the NRC staff assumed both linear and non-linear behavior beneath the site in response to the range of input loading motions. The NRC staff used two soil models: one is the generic EPRI rock shear modulus and damping curves to model the non-linear behavior of the rock , and the other is the linear model (with very small damping) to model the linear behavior of the rock. The NRC staff used these two alternative models (non-linear and linear) over the upper 20 ft [6.1 m] of the site profile, giving each equal weight. Below a depth of 20 ft [6.1 m], the NRC staff assumed linear behavior for the rock with a damping value of 0.3 percent.

According to the SPID, a typical kappa value for the basement rock in the CEUS is about 0.006 sec. Because the Oconee site is essentially a hard rock site with a high shear wave velocity very similar to the CEUS basement rock, the NRC staff used 0.006 second (sec) as the base kappa value for the site. To model the uncertainty in the kappa value, the staff used a natural log standard deviation value of about 0.15 to obtain lower and upper kappa values of 0.005 sec and 0.007 sec.

Figure 3.3-2 of this assessment shows a comparison of the staff's and licensee's median site amplification functions and uncertainties (±1 standard deviation) for 2 of the 11 input loading levels. Due to the use of very low damping values and modeling of the rock behavior as essentially linear for the range of input loading levels, the NRC staff's confirmatory amplification factors are essentially one for the entire frequency range. The licensee's amplification functions are also flat over the entire frequency range for the two loading levels shown in the SHSR.

Overall, the licensee's approach to modeling the subsurface rock properties and their uncertainty, results in very similar amplification factors as those developed by the staff. In addition, as shown in Figure 3.3-3 of this assessment, the NRC staff's and licensee's control point seismic hazard curves are very similar.

In summary, the NRC staff concludes that the licensee's site response was conducted using present-day guidance and methodology, including the NRC-endorsed SPID. The NRC staff performed independent calculations, which confirmed that the licensee's amplification factors and control point hazard curves adequately characterize the site response, including the uncertainty associated with the subsurface material properties, for the Oconee site.

3.4 Ground Motion Response Spectra

In Section 2.4 of its SHSR, the licensee stated that it used the control point hazard curves, described in SHSR Section 2.3.7, to develop the 10^{-4} and 10^{-5} (mean annual frequency of exceedance) uniform hazard response spectra (UHRS) and then computed the GMRS using the criteria in RG 1.208.

The NRC staff independently calculated the 10^{-4} and 10^{-5} UHRS using the results of its confirmatory PSHA and site response analyses, as described in Sections 3.2 and 3.3 of this staff assessment, respectively. Figure 3.4-1 of this assessment shows a comparison of the GMRS determined by the licensee to that determined by the NRC staff.

The NRC staff confirms that the licensee used the present-day guidance and methodology outlined in RG 1.208 and the SPID to calculate the horizontal GMRS, as requested in the 50.54(f) letter. The NRC staff performed both a PSHA and site response confirmatory analysis and achieved results consistent with the licensee's horizontal GMRS. As such, the NRC staff concludes that the GMRS determined by the licensee adequately characterizes the reevaluated hazard for the Oconee site. Therefore, this GMRS is suitable for use in subsequent evaluations and confirmations, as needed, for the response to the 50.54(f) letter.

4.0 CONCLUSION

The NRC staff reviewed the information provided by the licensee for the reevaluated seismic hazard for the Oconee site. Based on its review, the NRC staff concludes that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance, it appropriately characterized the site given the information available, and met the intent of the guidance for determining the reevaluated seismic hazard. Based upon the preceding analysis, the NRC staff concludes that the licensee provided an acceptable response to Requested Information Items (1) through (3), (5), (7), and the comparison portion to Item (4) identified in Enclosure 1 of the 50.54(f) letter. Further, the licensee's reevaluated seismic hazard is acceptable to address other actions associated with NTTF Recommendation 2.1: “Seismic”.

Additionally, as described above, the staff finds that the licensee followed applicable guidance in conducting a SSHAC Level 2 study when modifying the CEUS-SSC catalog for its site-specific PSHA. However, because the issues addressed by the study are subjects of significant discussion within the broader scientific community, the NRC staff regards the site-specific modifications conducted by the licensee to be applicable to only the licensee's response to the 50.54(f) request for information.

In reaching this determination, the NRC staff confirmed the licensee's conclusion that the licensee's GMRS for the Oconee site exceeds the SSE over the frequency range of approximately 2 to 100 Hz. As such, a seismic risk evaluation, SFP evaluation, and high frequency confirmation are merited. The licensee indicated that it would perform the high frequency confirmation as part of its seismic risk evaluation. The NRC review and acceptance of Duke's seismic risk evaluation with the high frequency confirmation, and also an interim ESEP evaluation and SFP evaluation (i.e., Items (4), (6), (8), and (9)) for Oconee will complete the Seismic Hazard Evaluation in Enclosure 1 of the 50.54(f) letter.

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Figure 3.2-1 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Oconee Site. RAI Response Curves are Licensee Curves Developed using the Currently Endorsed CEUS-SSC (NUREG-2115**) for the Oconee Site**

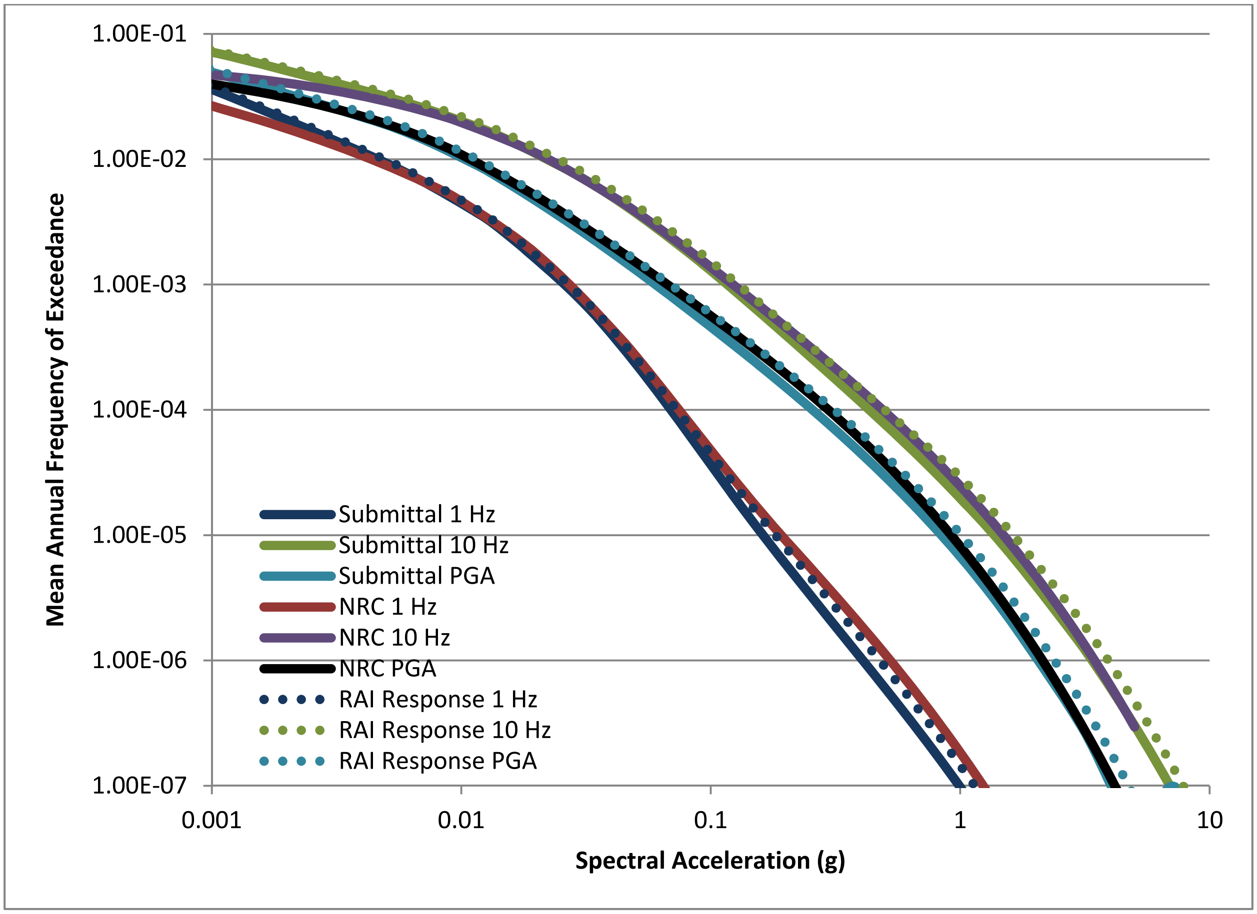


Figure 3.3-1 Plot of Staff's and Licensee's Base Case Shear-Wave Velocity Profiles for the Oconee site

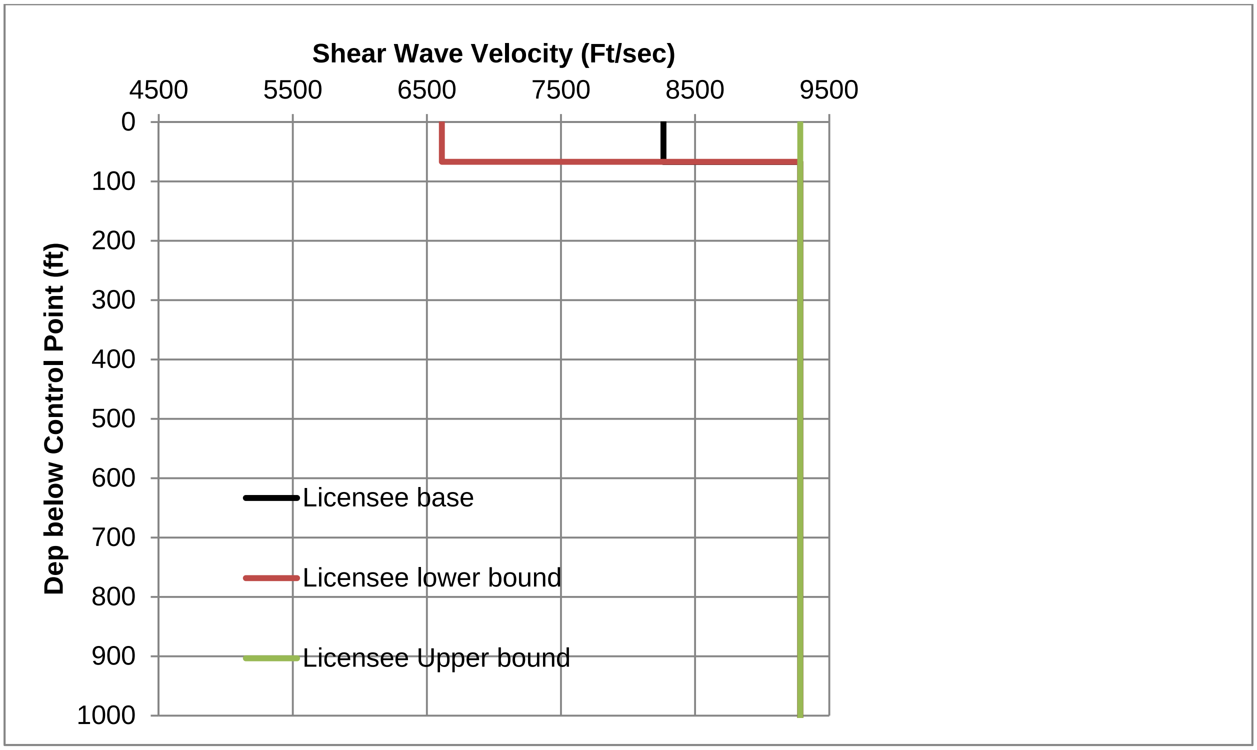


Figure 3.3- 2 Plot Comparing the Staff's and the License's Median Amplification Functions and Uncertainties for two input loading levels for the Oconee site

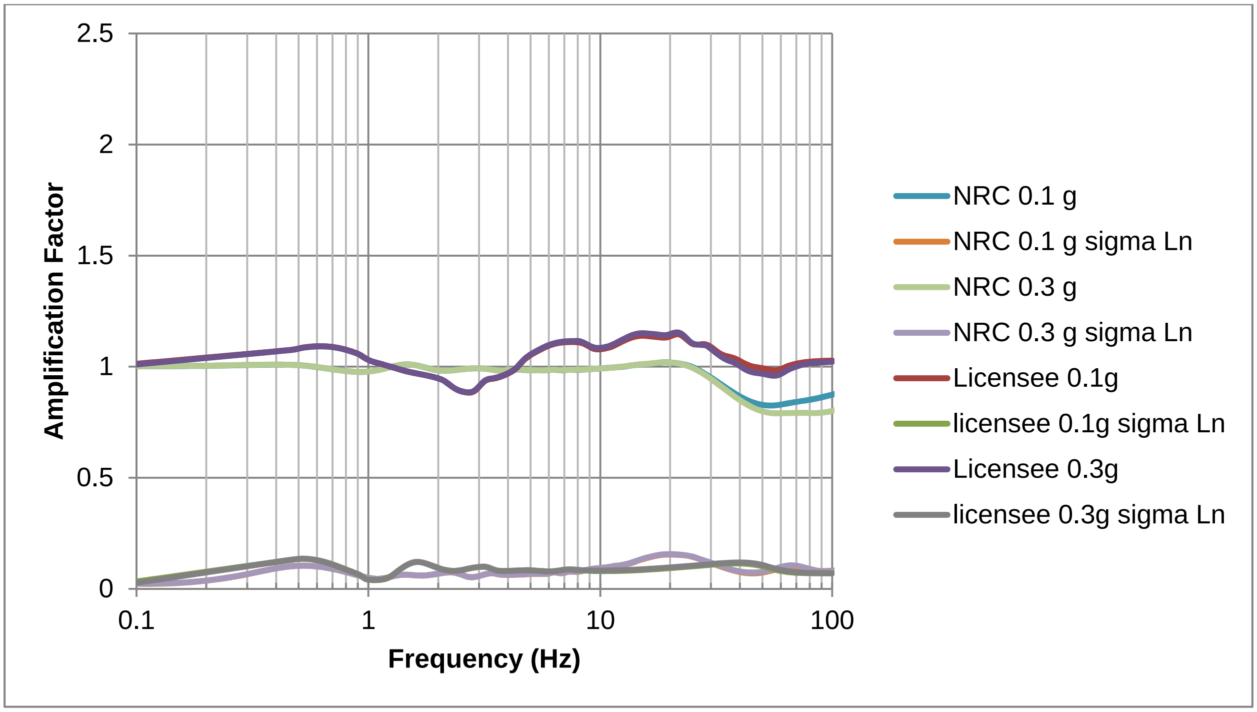


Figure 3.3-3 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Oconee site

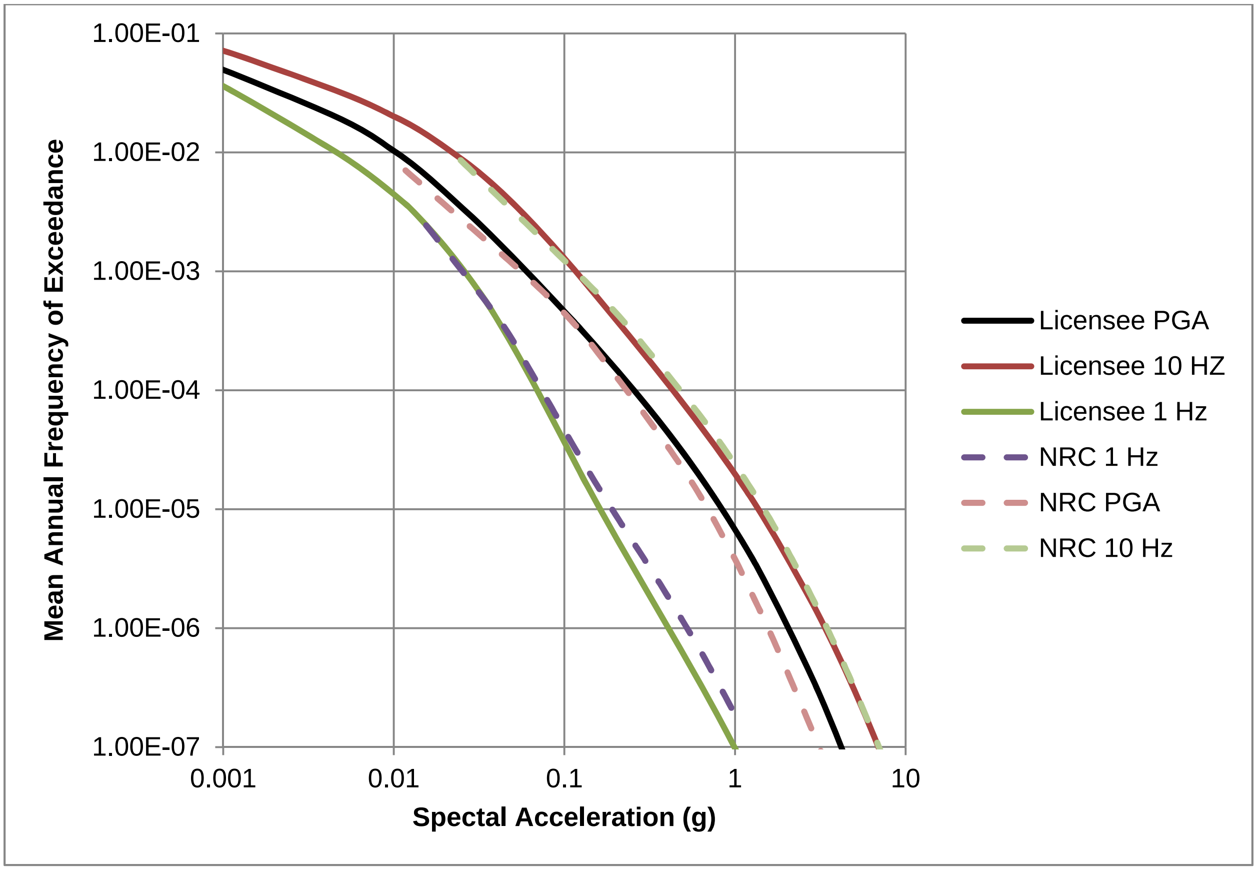
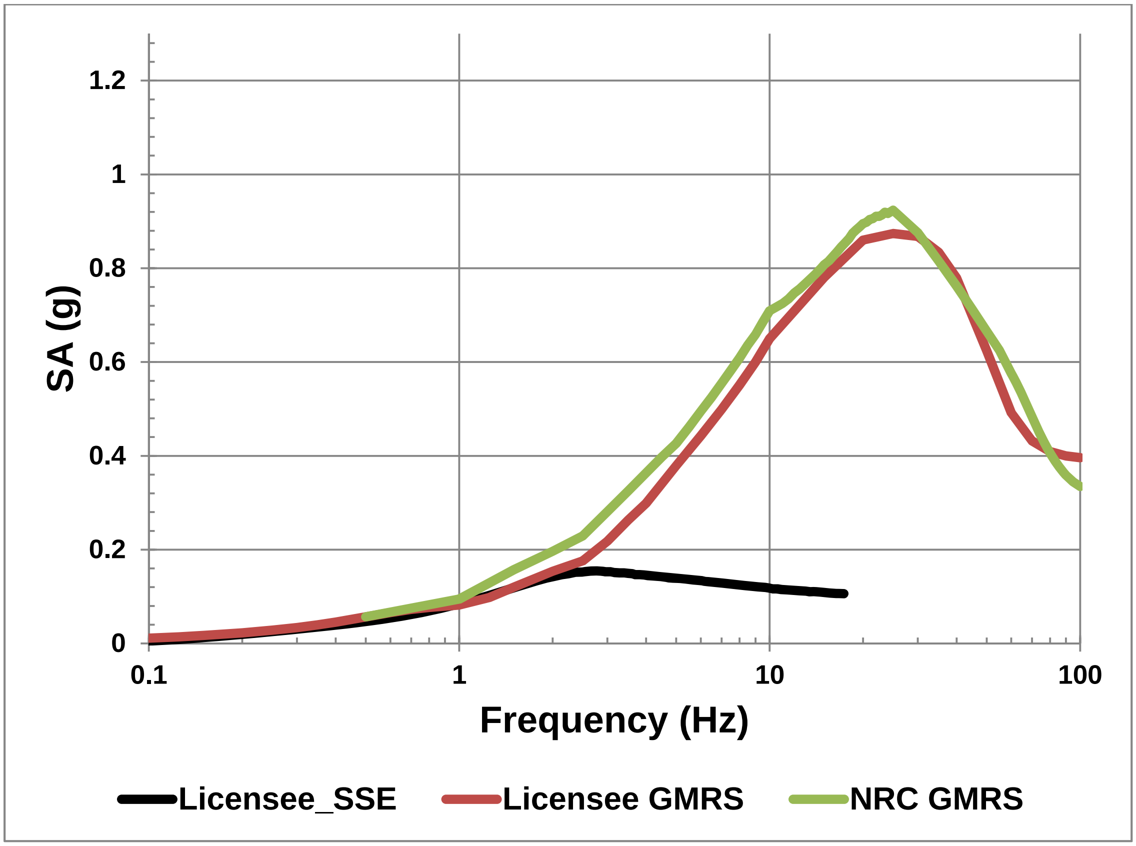


Figure 3.4-1 Comparison of the Staff's GMRS with Licensee's GMRS and the SSE for the Oconee site



If you have any questions, please contact me at (301) 415-1617 or at Frankie.Vega@nrc.gov.

Sincerely,

/RA/

Frankie G. Vega, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-269, 50-270, and 50-287

Enclosure:
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Hazard Evaluation and Screening Report

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