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

February 18, 2016

Mr. Robert Braun
President and CNO
PSEG Nuclear LLC-N09
P. O. Box 236
Hancocks Bridge, NJ 08038

SUBJECT: SALEM NUCLEAR GENERATING STATION, UNITS 1 AND 2 - 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 (CAC NOS. MF3922 AND MF3923)

Dear Mr. Braun:

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 28, 2014, PSEG Nuclear LLC (PSEG, the licensee), responded to this request for Salem Nuclear Generating Station, Units 1 and 2 (Salem).

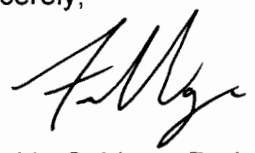
The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for Salem and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to Enclosure 1, Items (1) – (3), (5) - (8) and the comparison portion of Item (4) of the 50.54(f) letter. Further, the NRC staff concludes that the licensee's reevaluated seismic hazard is suitable for other actions associated with Near-Term Task Force Recommendation 2.1, "Seismic".

As indicated in the NRC letter dated October 27, 2015 (ADAMS Accession No. ML15194A015), PSEG is requested to submit a spent fuel pool evaluation and either a full-scope Individual Plant Examination of External Events (IPEEE) relay chatter review or a High Frequency (HF) confirmation. In choosing one of the two options, PSEG should consider that a relay chatter study will continue to be needed for the IPEEE submittal to meet the Screening, Prioritization, and Implementation Details (SPID) acceptance criteria. Meeting the SPID criteria will be necessary if PSEG plans to rely on the IPEEE results in its mitigation strategies assessment with respect to the reevaluated hazard.

Contingent upon the NRC staff's review and acceptance of PSEG's HF confirmation (Item 4) or the full-scope IPEEE relay chatter review and spent fuel pool evaluation (Item (9)) for Salem, 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
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Office of Nuclear Reactor Regulation

Docket Nos. 50-272 and 50-311

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

SALEM NUCLEAR GENERATING STATION, UNITS 1 AND 2

DOCKET NOS. 50-272 AND 50-311

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 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 (HF) 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 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 and (2) a seismic risk evaluation. By letter dated May 7, 2013 (NRC, 2013a), 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 GMMs for use by CEUS plants in developing a plant-specific GMRS.

By letter dated April 9, 2013 (Pietrangelo, 2013), industry committed to follow the SPID to develop the SHSR for existing nuclear power plants. By letter dated September 10, 2013 (Perry, 2013), PSEG Nuclear LLC (PSEG, the licensee) submitted at least partial site response information for Salem Nuclear Generating Station, Units 1 and 2 (Salem). By letter dated March 28, 2014 (Perry, 2014), the licensee submitted its SHSR for Salem.

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 described 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) GMMs. The SPID provided further guidance regarding the appropriate use of GMMs for the CEUS. Specifically, Section 2.3 of the SPID recommended 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 28, 2014 (Perry, 2014), the licensee provided the Salem SHSR. The licensee's SHSR indicates that the site GMRS exceeds the site SSE for a portion of the frequency range between 1 to 10 Hertz (Hz). However, the licensee indicated that over the frequency range of 1 to 10 Hz, the GMRS is bounded by either the site SSE or the site Individual Plant Examination of External Events (IPEEE) plant-level high confidence of low probability of failure (HCLPF) spectrum (IHS). Following the guidance in Section 3.3 of the SPID, the licensee provided an evaluation of its IPEEE program in order to use the IHS as the plant seismic capacity for the screening comparison with the GMRS. For frequencies above 10 Hz, the IHS also bounds the licensee's site GMRS. However, the full scope IPEEE detailed review of relay chatter required in SPID Section 3.3.1 has not been completed by the licensee. Therefore, the licensee stated that it will complete the relay chatter review consistent with NEI letter to NRC dated October 3, 2013 (Keithline, 2013), on the same schedule as the HF confirmation as proposed in the NEI letter dated April 9, 2013 (Pietrangelo, 2013), and accepted in NRC's letter dated May 7, 2013 (NRC, 2013a). The licensee stated that the HF confirmation per the SPID Section 3.4 will be performed only if the relay chatter review is not successful in demonstrating relay adequacy based on the GMRS.

On May 9, 2014 (NRC, 2014a), the NRC staff issued a letter providing the outcome of its 30- day, preliminary, screening and prioritization evaluation. In the letter, the NRC staff characterized the Salem site as conditionally screened-in, because additional information was needed to support a screening decision based on the licensee's implementation of the IPEEE screening criteria in the SPID. On October 3, 2014 (NRC, 2014b), the NRC staff issued a letter providing the outcome of its final seismic screening and prioritization results. Based on its evaluation of the SHSR, and the licensee's original IPEEE submittal,the NRC staff confirmed that the licensee met the IPEEE adequacy criteria in the SPID provided that a IPEEE relay chatter review is successfully completed. The NRC staff confirmed that the licensee's GMRS, as well as the staff's confirmatory GMRS, is bounded by the SSE or IHS for Salem over the frequency range of 1 to 10 Hz, and therefore, a plant seismic risk evaluation is not warranted for Salem. Additionally, in the frequency range above 10 Hz, the GMRS exceeds the SSE and is bounded by the IHS. As such, to satisfy the IPEEE adequacy criteria an IPEEE relay chatter review is merited.

This initial screening decision was contigent on the licensee's successful completion of the IPEEE relay chatter review, in accordance with the IPEEE program screening criteria in the SPID. As stated in the October 27, 2015 (NRC, 2015), letter, the NRC revised this initial screening determination. Based on the NRC staff's comparison of the GMRS to the SSE and the review of additional hazard and risk information, the NRC concluded that a seismic risk evaluation was not merited for Salem regardless of satisfying the IPEEE acceptance criteria in the SPID. Additionally, in accordance with the October 27, 2015, letter either a HF confirmation or a IPEEE relay chatter review are merited. Finally, a SFP evaluation is merited for Salem

because the IPEEE program did not include the SFP and the GMRS exceeds the SSE from approximately 6 to 40 Hz.

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 from 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 the Salem site stating that the SSE for Salem is based on a postulated intensity VII earthquake occurring approximately 15 miles (24 km) from the site, near Wilmington, Delaware. Based on this earthquake, the Housner response spectrum shape was anchored at a PGA of 0.20 g (20 percent of the acceleration due to earth's gravity). In Section 3.2 of its SHSR, the licensee specified that the SSE control point is defined at the foundation level at a depth of 71 ft. (21 m) below grade.

The NRC staff reviewed the licensee's description of its SSE in the SHSR for the Salem site. With regard to the Salem site SSE, based on its review of the SHSR and Updated Final Safety Analysis Report (UFSAR) (Salem, 2012), the NRC staff confirmed that the licensee's SSE is defined in terms of a PGA and a Housner design response spectrum anchored at 0.2 g, as described by the licensee. Finally, based on its review of the SHSR and the UFSAR (Salem, 2012), the NRC staff confirmed that the licensee's control point elevation for Salem site SSE is defined at a depth of 71 ft. (21 m) below grade and is consistent with the guidance provided in the SPID.

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). The licensee used a minimum magnitude (**M**) of 5.0, as specified in the 50.54(f) letter. The licensee further stated that it included the CEUS-SSC background sources out to a distance of 400 miles (640 km) around the site and included the Charleston, Charlevoix, and Wabash Valley repeated large magnitude earthquake (RLME) sources, which lie within 621 mi (1,000 km) of the site. The RLME sources are those source areas or faults for which more than one large magnitude ($\mathbf{M} \geq 6.5$) 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. Consistent with the SPID, the licensee did not provide its base rock seismic hazard curves since a site response analysis is necessary to determine the control point seismic hazard curves. The licensee provided its control point seismic hazard curves in Section 2.3.7 of its SHSR. The staff's review of the licensee's control point seismic hazard curves is provided in Section 3.3 of this staff assessment.

As part of its confirmatory analysis of the licensee's GMRS, the NRC staff performed PSHA calculations for base or reference rock conditions at the Salem site. As input, the NRC 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 NRC staff included all CEUS-SSC background seismic sources within a 310 mi (500 km) radius of the Salem site. In addition, the NRC staff included RLME sources which lie within 621 mi (1,000 km) of the site. For each of the CEUS-SSC sources used in the PSHA, the NRC staff used the mid- continent version of the updated EPRI GMM (EPRI, 2013). The NRC 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.

Based on its review of the SHSR, the NRC staff concludes that the licensee 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 base 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 the older 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 provided detailed site profile descriptions in Sections 2.3.1 and 2.3.2 of its SHSR based on information provided in the PSEG Early Site Permit Application (ESPA) (PSEG, 2013) and the guidance in Appendix B of the SPID. According to the licensee, the Salem site is located in the eastern U.S. on the Delaware River within the Coastal Plain physiographic province. The Coastal Plain is underlain by a thick wedge of unconsolidated sediment ranging from Cretaceous to recent in age and the bedrock is estimated to be at a depth of about 1,800 ft. (548 m).

In Table 2-1 of its SHSR, the licensee provided a brief description of the subsurface materials in terms of the geologic units and layer thicknesses. In Table 2-1 of its SHSR, the licensee provided the shear-wave velocities determined from the results detailed in the PSEG ESPA (PSEG, 2013). The PSEG ESPA site is the location of potential future construction at the Salem site. The PSEG ESPA site investigations included four compression (P) and shear (S) wave P- S suspension logging surveys ranging to a depth of approximately 300 to 630 ft. (91 to 192 m), two crosshole velocity testing boreholes extending to a depth of approximately 200 ft. (61 m), one down-hole seismic velocity measurement to a depth of approximately 200 ft. (61 m), and one deep production well extending to the top of basement (at approximately 1,800 ft. (548 m)) located beneath the Salem site.

To capture the uncertainty in the shear wave velocity beneath the site, the licensee developed three base case shear-wave velocity profiles for the Salem site. The licensee used a natural log standard deviation of 0.20 to calculate the lower and upper base case shear-wave velocity profiles to a depth of approximately 444 ft. (135 m) and a natural log standard deviation of 0.35 to calculate the lower and upper base case shear-wave velocity profiles from 444 ft. (135 m) depth to bedrock at 1,800 ft. (548 m). Table 2-2 and Figure 2-1 of the SHSR provide the licensee's shear-wave velocity profile for each of the three base cases. Figure 3.3-1 of this assessment shows the licensee's three shear-wave velocity base case profiles.
In Section 2.3.2.2 of its SHSR, the licensee stated that no site-specific dynamic material properties were determined in the initial siting of Salem site. Therefore, the licensee followed the SPID guidance for soil sites and selected two alternative characterizations of nonlinear dynamic material behavior. In one characterization, the licensee used the EPRI soil shear modulus reduction and hysteretic damping curves over the upper 444 ft. (135 m) and assumed linear behavior with no damping below 444 ft. (135 m). In the second characterization, the licensee used the Peninsular Range shear modulus reduction and hysteretic damping curves over the upper 444 ft. (135 m) and linear behavior with no damping below 444 ft. (135 m). The licensee assigned equal weights to the two characterizations.

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 the Salem site, the licensee provided estimates of kappa in Table 2-3 of its SHSR, which the licensee calculated using the empirical relation of Campbell (2009), as described in the SPID Appendix B-5, for shallow soil sites having a depth to bedrock of less than 3,000 ft. (1,000 m). The licensee also added an additional kappa of 0.006 sec to account for the damping in the

underlying base rock material. The licensee's total profile kappa value for the best estimate, upper, and lower base case velocity profiles are all equal to 0.037 sec.

To account for randomness in material properties across the plant site, the licensee states in Section 2.3.3 of its SHSR, that it randomized its base case shear-wave velocity profiles in accordance with Appendix B of the SPID. In addition, as stated in Section 2.3.2.1 of its SHSR, the licensee randomized the depth to bedrock by ±505 ft. (±153 m), which corresponds to 30 percent of the total profile thickness. The licensee states 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 stated 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 of its SHSR, 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 of this assessment), 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 NRC staff performed site response calculations for the Salem site. The NRC staff reviewed the licensee's site response analysis and performed confirmatory calculations to independently test the licensee's calculation following the guidance in Appendix B of the SPID.

Because the site is well characterized and the velocities are reported in the PSEG ESPA (PSEG, 2013), the NRC staff used the same three base case shear-wave velocity profiles developed by the licensee for the Salem site. To capture the uncertainty in the depth to base rock, the NRC staff used a value of ±90 ft. [±27 m], which is less than the ±505 ft. (±153 m) depth to base rock randomization used by the licensee. Figure 3.3-1 of this assessment illustrates the velocity profiles the NRC staff used in its confirmatory analysis.

The NRC staff also used the same approach as the licensee to characterize the potential for nonlinear response to the input bedrock motions by selecting two alternative characterizations of nonlinear dynamic material behavior. In one characterization, the NRC staff used the EPRI soil shear modulus reduction and hysteretic damping curves while for the second

characterization, the NRC staff used the Peninsular Range shear modulus reduction and hysteretic damping curves. The NRC staff assigned equal weights to the two characterizations. To determine kappa for its velocity profiles, the NRC staff used the empirical relation of Campbell (2009), as described in the SPID Appendix B-5, for shallow soil sites having a depth to bedrock of less than 3,000 ft. (1,000 m) and also added an additional kappa of 0.006 sec to account for the damping in the underlying base rock material. As such, the NRC staff determined the same total profile kappa value as the licensee (0.037 sec) for its three base case profiles.

Figure 3.3-2 of this assessment shows a comparison of the NRC staff's and licensee's median site amplification factors and uncertainties (±1 standard deviation) for 2 of the 11 input loading levels. The NRC staff conducted sensitivity tests to evaluate the licensee's characterization of the site and its use of (1) multiple base case velocity profiles, (2) kappa values, and (3) depth to bedrock randomization value. Of these three factors, the NRC staff used a smaller depth to bedrock randomization value (5 percent), compared to the larger value used by the licensee (30 percent). However, as seen in Figure 3.3-2 of this assessment, both the NRC staff and licensee's site amplification factors are similar, such that the difference in the depth to bedrock randomization value does not produce large difference in site amplification factors at the Salem site. Therefore, based on these sensitivity analyses, the NRC staff concludes that the licensee's evaluation for Salem site adequately captures the site amplification occurring as a result of bedrock ground motions travelling upward through the soil/rock column to the control point elevation.

Figure 3.3-3 of this assessment provides the licensee's and NRC staff's control point seismic hazard curves for the Salem site. As shown in Figure 3.3-3, the slight differences in the licensee's and NRC staff's site response analyses do not have a large impact on the control point seismic hazard curves or the resulting GMRS, as discussed below. Appendix B of the SPID provides guidance for performing site response analyses, including capturing the uncertainty for sites with less subsurface data; however, the guidance is neither prescriptive nor comprehensive. As such, various approaches in performing site response analyses, including the modeling of uncertainty, are acceptable for the response to the 50.54(f) letter.

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 confirm 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 Salem site.

3.4 Ground Motion Response Spectra

In Section 2.4 of its SHSR, the licensee states 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.

As shown in Figure 3.4-1, the licensee's GMRS shape is generally similar to that calculated by the NRC staff at frequencies less than 10 Hz. However, NRC staff's confirmatory GMRS is somewhat higher than the licensees at frequencies above 10 Hz. As described above in Section 3.3, the NRC staff concludes that these minor differences over the higher frequency range are primarily due to the differences in the site response analyses performed by the licensee and 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 Salem 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 Salem 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. The NRC staff concluded that the licensee demonstrated that the IHS could be used for comparison with the GMRS for the screening decision. Based upon the preceding analysis, the NRC staff concludes that the licensee provided an acceptable response to Requested Information Items (1) – (3), (5) - (7), and the comparison portion of 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".

In reaching this determination, the NRC staff confirms the licensee's conclusion that the licensee's GMRS for the Salem site is bounded by the IHS or SSE over the frequency range of 1 to 100 Hz. As stated in the October 27, 2015, letter, a seismic risk evaluation (i.e., Item 8) is not requested. Because the IPEEE program did not include an evaluation of the SFP and the GMRS exceeds the SSE, the SFP evaluation (Item 9) is merited. Additionally, in the frequency range above 10 Hz, either a HF confirmation (Item 4) or relay chatter review is merited. The HF confirmation portion of Item (4) is not merited if the IPEEE relay chatter review is successfully completed because the IHS bounds the GMRS in the frequency range above 10 Hz.

The NRC review and acceptance of PSEG's IPEEE relay chatter review or HF confirmation (Item (4)) and SFP evaluation (Item (9)) will complete the Seismic Hazard Evaluation for Salem identified in Enclosure 1 of the 50.54(f) letter.

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

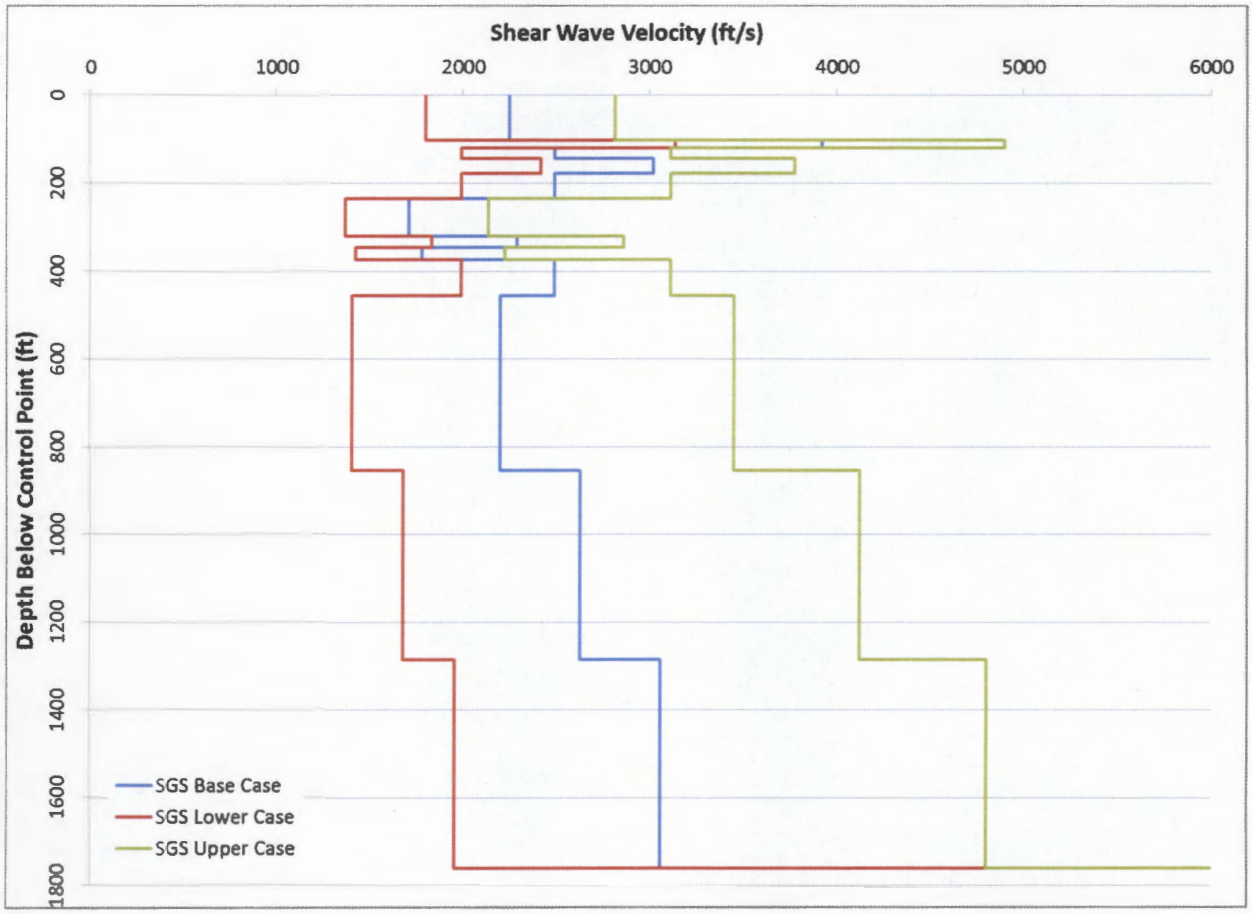


Figure 3.3-2 Plot Comparing the Staff's and the License's Median Amplification Functions and Uncertainties for two input loading levels for the Salem site

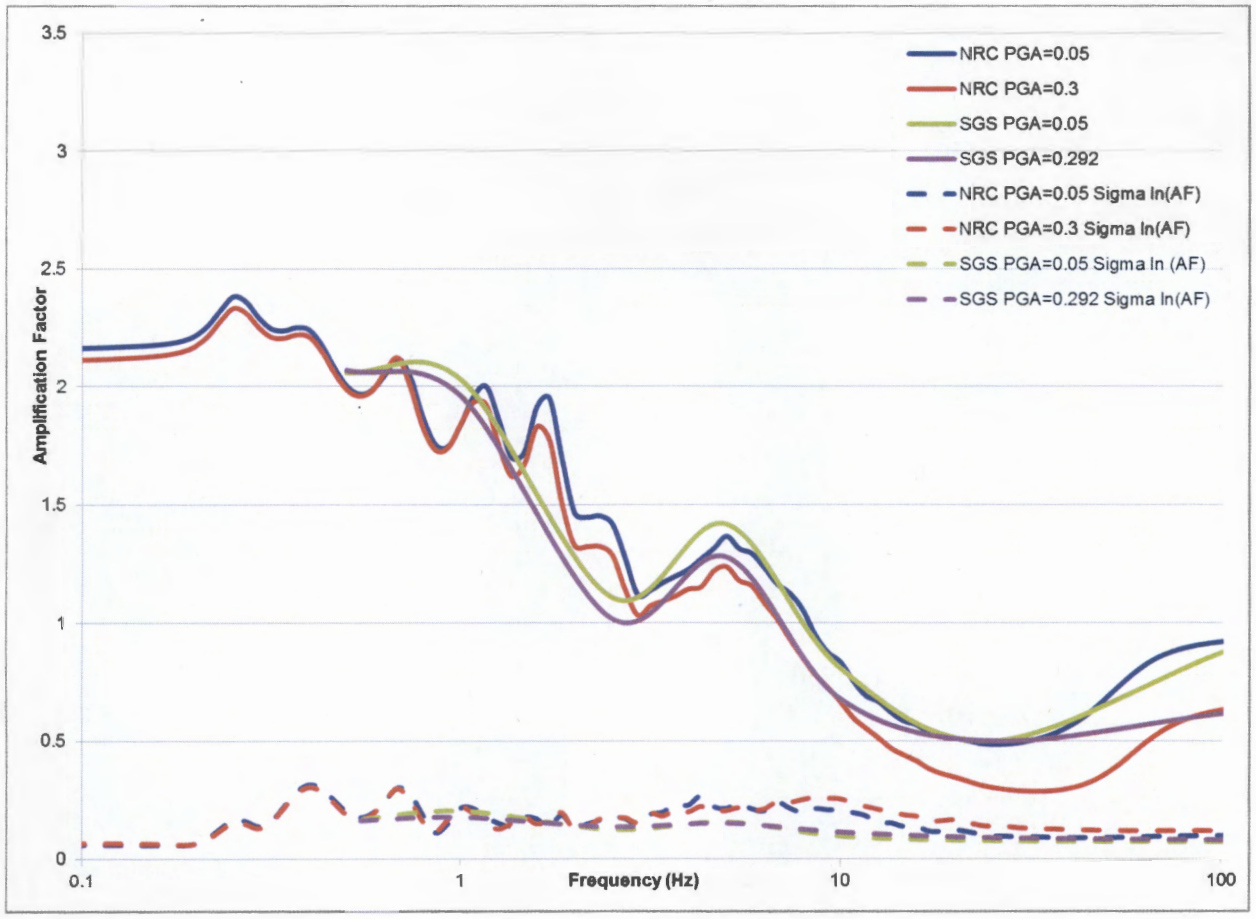


Figure 3.3-3 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Salem site

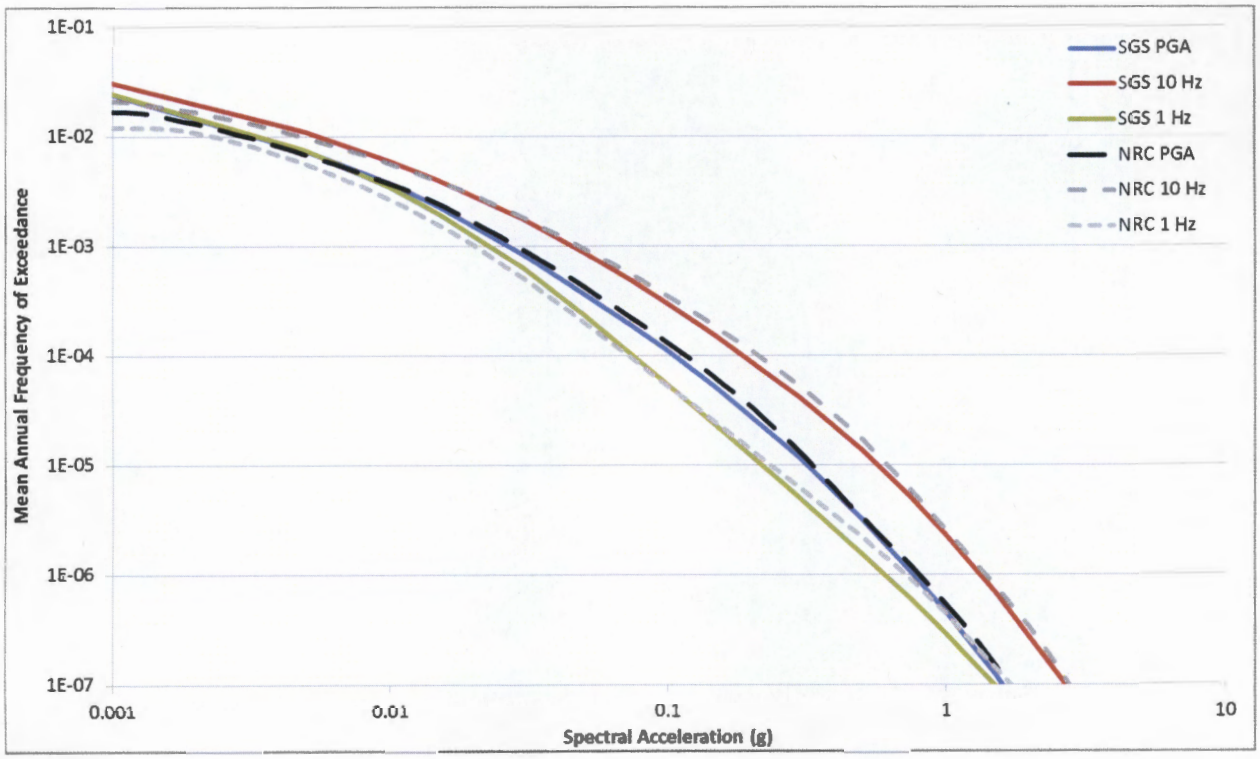
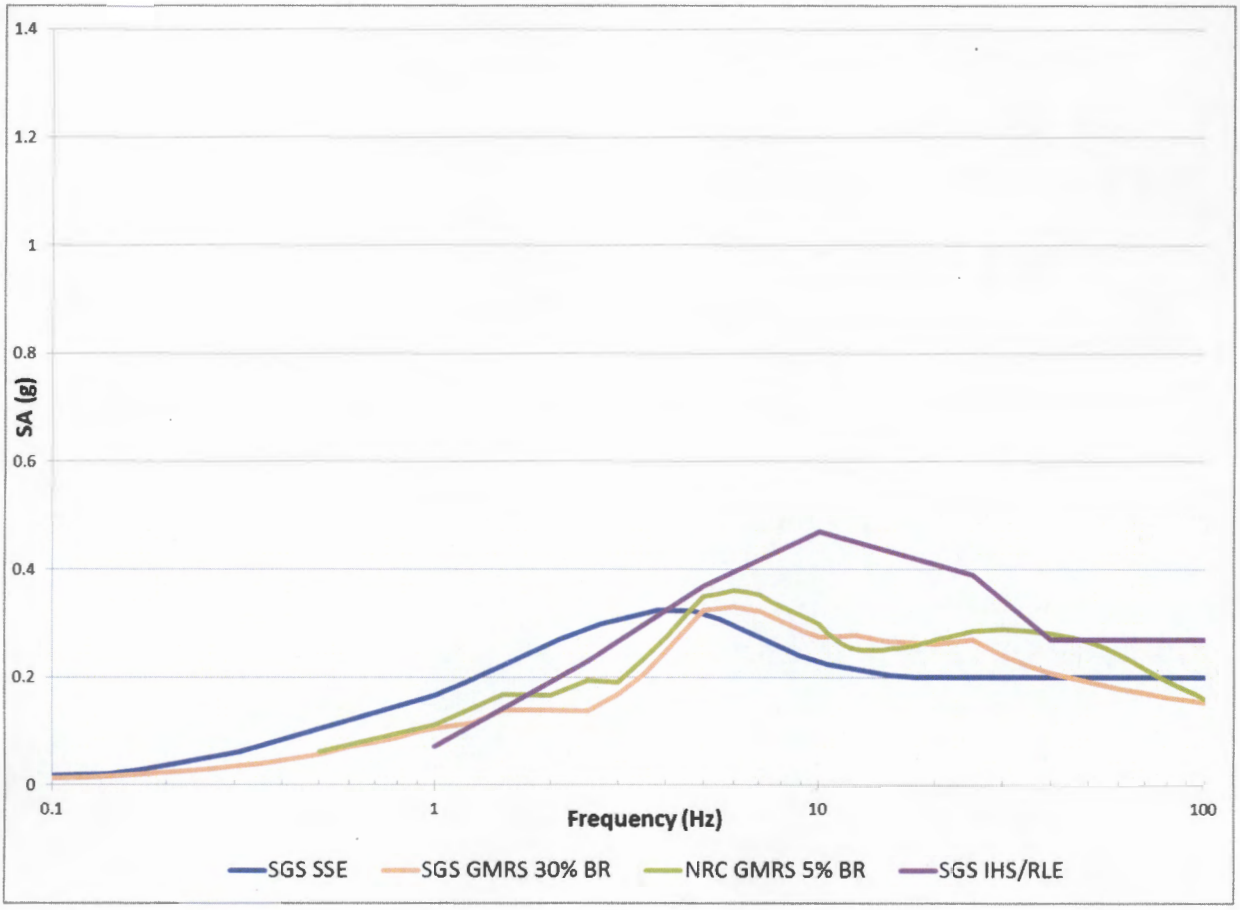


Figure 3.4-1 Comparison of the Staff's GMRS, Licensee's GMRS, Salem site SSE, and the IHS for the Salem site.



Contingent upon the NRC staff's review and acceptance of PSEG's HF confirmation (Item 4) or the full-scope IPEEE relay chatter review and spent fuel pool evaluation (Item (9)) for Salem, 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,

/RA/

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

Docket Nos. 50-272 and 50-311

Enclosure:
Staff Assessment of Seismic
Hazard Evaluation and Screening Report

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