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

October 19, 2015

Mr. Bryan C. Hanson
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President and Chief Nuclear Officer
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SUBJECT: CLINTON POWER STATION, UNIT NO.1 - 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 NO. MF3783)

Dear Mr. Hanson:

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, Exelon Generation Company, LLC (Exelon, the licensee) responded to this request for Clinton Power Station, Unit No. 1 (Clinton).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for Clinton and, as documented in the enclosed staff assessment, determined that the licensee provided sufficient information in response to Enclosure 1, Items (1) – (3), (5) - (9) 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 Exelon's high frequency evaluation (i.e., Item (4)) for Clinton, 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 No. 50-461

Enclosure:
Staff Assessment of Seismic
Hazard Evaluation and Screening Report

cc w/encl: Distribution via Listserv

STAFF ASSESSMENT BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO SEISMIC HAZARD AND SCREENING REPORT

CLINTON POWER STATION, UNIT NO.1

DOCKET NO. 50-461

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 (ESEP) 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 GMM for use by CEUS plants in developing a plant-specific GMRS

By letter dated April 9, 2013 (Pietrangelo, 2013), industry agreed to follow the SPID to develop the SHSR for existing nuclear power plants. By letter dated September 12, 2013 (Kaegi, 2013), Exelon Generation Company, LLC(Exelon, the licensee) submitted at least partial site response information for Clinton Power Station, Unit No. 1 (Clinton). By letter dated March 31, 2014 (Kaegi, 2014), the licensee submitted its SHSR.

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 31, 2014 (Kaegi, 2014), the licensee provided its SHSR for the Clinton site. The licensee's SHSR indicates that the site GMRS is bounded by the site SSE in the frequency range of 1 to 10 Hertz (Hz). As such, Clinton screens out to perform a seismic risk evaluation. However, the GMRS exceeds the SSE at frequencies above 10 Hz. The licensee indicated that it will perform the high frequency confirmation per the SPID Section 3.4.

On May 9, 2014 (NRC, 2014a), the staff issued a letter providing the outcome of its 30-day, preliminary, screening and prioritization evaluation. In the letter, the staff characterized the Clinton site as conditionally screened-in, because additional information was needed to support a screening and prioritization decision. On October 3, 2014 (NRC, 2014b), the staff issued a letter providing the outcome of its final seismic screening and prioritization results. The licensee's GMRS, as well as the NRC staff's confirmatory GMRS is bounded by the SSE for Clinton over the frequency range of 1 to 10 Hz. Therefore, a seismic risk evaluation and SFP evaluation are not merited. However, the licensee's GMRS and staff's confirmatory GMRS exceeds the SSE for frequencies above 10 Hz. Therefore, a high frequency confirmation is merited for Clinton.

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 33 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 3.0 of its SHSR, the licensee described its seismic design bases for the Clinton site and stated that the SSE is defined in terms of a PGA and a design response spectrum. The licensee stated that the SSE for Clinton is based on a postulated Intensity VIII earthquake near the site resulting in a maximum horizontal ground surface acceleration at the site of 0.25g (25 percent of the acceleration due to earth's gravity). In Section 3.1 of its SHSR, the licensee described stated that the SSE shape is a Regulatory Guide 1.60 (NRC, 1973) shape with a PGA of 0.26 g. In Section 3.2 of its SHSR, the licensee defined the SSE control point at the free field ground surface elevation in the vicinity of the main power block structures at elevation 736 ft. (224 m).

The NRC staff reviewed the licensee's description of its SSE in the SHSR for the Clinton site. With regard to the Clinton site SSE, based on its review of the SHSR and Updated Final Safety Analysis Report (UFSAR; Clinton, 2014), the NRC staff confirmed that the licensee's SSE is defined in terms of a PGA and a design response spectrum anchored at 0.26 g, as described by the licensee. Finally, based on its review of the SHSR and the UFSAR (Clinton, 2014), the NRC staff confirmed that the licensee's control point elevation for Clinton site SSE is defined at elevation 736 ft. (224 m) at the bottom of the reactor building foundation 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 Commerce, Eastern Rift Margin – North, Eastern Rift Margin – South, Marianna, Meers, New Madrid Fault System, 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 (**M** ≥ 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 in SHSR Section 2.2.2 since a site response analysis is necessary to determine the control point seismic hazard curves. The licensee provides its control point seismic hazard curves in Section 2.3.7 of its SHSR. The NRC 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 its own PSHA calculations for base rock site conditions the Clinton 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 Clinton 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 review of the SHSR, the NRC staff concludes that the licensee followed guidance provided in the SPID for selecting 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 the licensee 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 provided detailed site profile descriptions in Sections 2.3.1 and 2.3.2 of its SHSR based on information provided in the UFSAR (CPS, 2014) and the guidance in Appendix B of the SPID. The Clinton site is located in the Illinois Basin within the Central Stable Region of the North American Continent and is underlain by 240 ft. (73 m) of soils overlying limestone and shales before encountering hard reference rock at a depth of approximately 6,000 ft. (1,830 m).

Concerning the subsurface layers at the Clinton site, the licensee stated that surficial deposits consist of glacial drift and loess about 5 to 10 ft. (1.5 to 3 m) thick under which lie 20 to 55 ft. (6.1 to 17 m) glacial till of the Wedron Formation. Beneath the Wedron, in some places, is a thin lens of the Robein Silt atop a 10 to 20 ft. (3 to 6.1 m) thick layer of weathered glacial till from the Glasford Formation. The unweathered portions of the Glasford Formation extend to a total thickness of between 90 and 140 ft. (27 and 43 m). Between the Glasford Formation and the sound rock is a complex assemblage of glacial materials varying in thickness from 10 to 105 ft. (3 to 32 m). The licensee noted that the bedrock surface between Elevation 360 and 510 ft. (110 and 155 m) is an erosional surface below which are various formations, as described in the UFSAR.

The licensee developed three base case shear-wave velocity profiles for the Clinton site. Using the shear-wave velocities determined from refraction, uphole and downhole surveys, as well as nearby measurements for recent Early Site Permit (ESP) investigations, the licensee calculated the mean base-case profile. The licensee calculated the lower and upper base case shear-wave velocity profiles using a scale factor of 1.57 reflecting a natural log standard deviation of 0.35. Table 2.3.2-1 and Figure 2.3.2-1 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 2.3.2.1 of its SHSR, the licensee stated that no site-specific dynamic material properties were available for the Clinton site soil and firm rocks. Therefore, the licensee followed the SPID guidance and assumed the response of the rock material to dynamic loading could be modeled as either linear or non-linear. In one characterization, the licensee used the EPRI soil and rock curves (model M1) to represent the upper range of nonlinearity. The licensee assumed that the Peninsular Range (PR) curves for soil combined with a linear analyses (model M2) with a low strain damping of about 3 percent for the rock is an equally plausible alternative response for the upper 500 ft. (152.4 m) of the three base cases.

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 Clinton site, the licensee provided estimates of kappa in Table 2.3.2-2 of its SHSR. As described in Appendix B-5.1.3.1 of the SPID, for sites with at least 3,000 ft. (1,000 m) of soil or firm rock, the corresponding kappa estimates for the base, lower and upper profiles are 0.025s, 0.040s, and 0.020s, respectively. With the additional 0.006s kappa for the hard reference rock, the total kappa for the base, lower and upper profiles are 0.031s, 0.040s, and 0.026s, respectively. The licensee noted that 0.040s is the maximum allowable kappa. To account for uncertainty, the licensee used multiple sets of modulus reduction and hysteretic damping curves for the soils. The licensee also weighted the kappa values, as shown in SHSR Table 2.3.2-2.

To account for randomness in material properties across the plant site, the licensee stated in Section 2.3.3 of its SHSR that it randomized its base case shear-wave velocity profiles following the guidance in 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 ±1,800 ft. (549 m), which corresponds to 30-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 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 described 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 the eleven input loading levels for the base case profile and EPRI soil and firm 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 Clinton site. The NRC staff independently developed a shear-wave velocity profile, damping values, and modeled the potential nonlinear behavior of the site using measurements and geologic information provided in the Clinton UFSAR (Clinton, 2014), the Site Safety Analysis Report (SSAR) for the Clinton ESP site (Exelon, 2006), and Appendix B of the SPID. For its site response calculations, the NRC staff employed the RVT approach and developed input ground motions in accordance with Appendix B of the SPID. Following guidance provided in the SPID for sites with less subsurface information, the NRC staff independently determined best-estimate and upper and lower base case shear-wave velocity profiles. The NRC staff based its best-estimate velocity profile on information provided in the SSAR for the Clinton ESP site. Data collected as part of the Clinton ESP licensing is consistent with data collected when siting the currently operating plant. However, the newer data extends to greater depth and was collected using more modern methods.

The NRC staff modeled the upper 290 ft. (89 m) as layered glacial and lake deposits with shear-wave velocities of 900 to 2,100 fps (274 – 640 m/s). The upper 18 ft. (5.5 m) of rock was modeled as highly weathered with a best-estimate velocity of 3,420 fps (1,042 m/s) to account for the unconformity (gap in geologic ages) between the top of rock and the soil layers above. Below this, to a depth of 1,900 ft. (579 m), the NRC staff modeled the subsurface as rock with a generally increasing velocity as a function of depth. The NRC staff assumed a best-estimate velocity of 4,000 fps (1,219 m/s) for the uppermost rock layers. Between depths of 1900 ft. (m) and a depth of 5,900 ft. (1,798 m), where base rock is assumed to be located, the NRC staff used a constant best-estimate velocity of 8,200 fps (2,499 m/s) and assumed a natural log standard deviation of 0.15 in the soil and weathered rock layers and 0.25 in the rock layers to calculate upper and lower base case profiles. Figure 3.3-1 of this assessment shows a comparison of the three velocity profiles developed by the licensee with those developed by the NRC staff. The profiles developed by the licensee are similar in shape to those developed by the NRC staff. However, the licensee's show greater variability, particularly in the soil portion of the profiles due to the licensee's use of a higher natural log standard deviation. The NRC staff randomized the depth to reference rock by ±10 percent to allow for additional uncertainty.

Similar to the approach used by the licensee, the NRC staff assumed both linear and non-linear behavior for the materials beneath the Clinton site in response to a range of input motions. The NRC staff developed two damping profiles that incorporate different degrees of non-linearity. Similar to the licensee, the NRC staff used EPRI soil and rock curves as one approach to modeling the nonlinear behavior of the site. For the alternative approach, the staff used the Peninsular curves to model the soil and assumed that the rock would behave linearly with constant damping value of 3 percent. The NRC staff's profiles assumed that all layers below the weathered bedrock would behave linearly, and low strain damping was accounted for through the use of kappa in these layers.

To determine kappa for its three profiles, the NRC staff used the low strain damping values, shear wave velocities and layer thicknesses for each geologic layer to arrive at values of 0.023, 0.029, and 0.018 sec, for the best-estimate, lower and upper base cases respectively. These values include the 0.006 sec contribution from the reference rock. To model the uncertainty in kappa, the NRC staff used a natural log standard deviation of 0.15 to calculate lower and upper values of kappa for each profile. This approach results in nine kappa values for the staff's site response analysis, which range from 0.015 sec to 0.035 sec.

Figure 3.3-2 of this assessment shows a comparison of the staff's and the licensee's median site amplification functions and uncertainties (±1 standard deviation) for two of the eleven input loading levels. Peaks in amplification functions occur at approximately 1.5 and 4 Hz in both the staff's and the licensee's curves. Differences in site amplification curves developed by the NRC staff and the licensee are due to differences in site velocity profiles and the licensee's use of damping over the upper 500 ft. (152 m) of the profile, rather than the 308 ft. (94 m) used by the NRC staff.

The licensee's approach to modeling the subsurface soil and rock properties and their uncertainties results in lower site amplification factors than those produced by the NRC staff, particularly at high frequencies. As shown in Figure 3.3-3 of this assessment, these differences in site response have a moderate impact on control point seismic hazard curves and the resulting GMRS, 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 entirely prescriptive nor comprehensive. As such, various approaches in performing site response analyses, including the modeling of uncertainty, are acceptable for the 50.54(f) response.

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 Clinton site.

3.4 Ground Motion Response Spectrum

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 across all frequencies. However, NRC staff's confirmatory GMRS envelopes the licensee's. As described above in Section 3.3, the NRC staff concludes that these differences 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 Clinton 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 Clinton 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) – (3), (5) - (9), 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.

In reaching this determination, the NRC staff confirms the licensee's conclusion that the licensee's GMRS for the Clinton site is bounded by the SSE in the 1 to 10 Hz range, but exceeds the SSE in a portion of the frequency range above 10 Hz. As such, a seismic risk evaluation and SFP evaluation (i.e., Requested Information Items (8) and (9)) are not merited, however a HF confirmation (i.e., Requested Information Item (4)) is merited. The NRC review and acceptance of Exelon's HF confirmation will complete the Seismic Hazard Evaluation identified in Enclosure 1 of the 50.54(f) letter.

REFERENCES

Note: ADAMS Accession Nos. refers to documents available through NRC's Agencywide Documents Access and Management System (ADAMS). Publicly-available ADAMS documents may be accessed through http://www.nrc.gov/reading-rm/adams.html.

U.S. Nuclear Regulatory Commission Documents and Publications

NRC (U.S. Nuclear Regulatory Commission), 1973, Design Response Spectra for Seismic Design of Nuclear Power Plants, Regulatory Guide (RG) 1.60, October 1973, Rev. 2. July 2014.

NRC (U.S. Nuclear Regulatory Commission), 2007, A Performance-based Approach to Define the Site-Specific Earthquake Ground Motion, Regulatory Guide (RG) 1.208, March 2007.

NRC (U.S. Nuclear Regulatory Commission), 2011a, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," Commission Paper SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

NRC (U.S. Nuclear Regulatory Commission), 2011b, "Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," Enclosure to SECY-11-0093, July 12, 2011, ADAMS Accession No. ML11186A950.

NRC (U.S. Nuclear Regulatory Commission), 2011c, "Recommended Actions to be Taken without Delay from the Near-Term Task Force Report," Commission Paper SECY-11-0124, September 9, 2011, ADAMS Accession No. ML11245A158.

NRC (U.S. Nuclear Regulatory Commission), 2011d, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," Commission Paper SECY-11-0137, October 3, 2011, ADAMS Accession No. ML11272A111.

NRC (U.S. Nuclear Regulatory Commission), 2012a, letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation and Michael R. Johnson, Director, Office of New Reactors, to All Power Reactor Licensees and Holders of Construction Permits in Active or Deferred Status, March 12, 2012, ADAMS Accession No. ML12053A340.

NRC (U.S. Nuclear Regulatory Commission), 2012b, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities", NUREG-2115, ADAMS stores the NUREG as multiple ADAMS documents, which are accessed through the web page http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr2115/.

NRC (U.S. Nuclear Regulatory Commission), 2013a. Letter From Eric J. Leeds, to Joseph Pollock, Executive Director NEI, Acceptance Letter for NEI Submittal of Augmented Approach, Ground Motion Model Update Project, and 10 CFR 50.54(f) Schedule Modifications Related to the NTTF Recommendation 2.1, Seismic Reevaluations, May 7, 2013, ADAMS Accession No. ML13106A331.

NRC (U.S. Nuclear Regulatory Commission), 2013b, letter from David L. Skeen, Director, Japan Lessons-Learned Directorate, to Joseph E. Pollock, Executive Director, Nuclear Energy

Institute, Endorsement of Electric Power Research Institute Draft Report 1025287, "Seismic Evaluation Guidance," February 15, 2013, ADAMS Accession No. ML12319A074.

NRC (U.S. Nuclear Regulatory Commission) 2013c. Letter from D. L. Skeen (NRC) to K. A. Keithline (NEI), Approval of Electric Power Research Institute Ground Motion Model Review Project Final Report for Use by Central and Eastern United States Nuclear Power Plants, August 28, 2013 ADAMS Accession No. ML13233A102.

NRC (U.S. Nuclear Regulatory Commission) 2014a. Letter from Eric J. Leeds, Director, Office of Nuclear Reactor Regulation to All Power Reactor Licensees and holders of Construction Permits in Active or Deferred Status, Seismic Screening and Prioritization Results Regarding Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Reevaluations for Recommendations 2.1 of the Near-Term Task Force Review of Insights, May 9, 2014, ADAMS Accession No. ML14111A147.

NRC (U.S. Nuclear Regulatory Commission) 2014b. Letter from D. H. Dorman (NRC) to Select Operating Power Reactor Licensees, Screening and Prioritization Results Regarding Seismic Hazard Reevaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, October 3, 2014, ADAMS Accession No. ML14258A043.

Other References

Clinton Power Station (Clinton, 2014), Updated Final Safety Analysis Report (UFSAR), Revision 16. January 2014.

Exelon Generation Company, LLC (Exelon, 2006). Early Site Permit Application for the Clinton ESP Site Safety Analysis Report, Revision 4, ADAMS Accession No. ML061100260.

Electric Power Research Institute (EPRI), 2004. EPRI Report 1009684, "CEUS Ground Motion Project Final Report." Palo Alto, CA, 2004.

Electric Power Research Institute (EPRI), 2006. EPRI Report 1014381, "Truncation of the Lognormal Distribution and Value of the Standard Deviation for Ground Motion Models in the Central and Eastern United States." Palo Alto, CA, 2006.

Electric Power Research Institute (EPRI), 2012. EPRI Report 1025287 "Seismic Evaluation Guidance, Screening, Prioritization and Implementation Details [SPID] for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" November 27, 2012, ADAMS Accession No. ML12333A170.

Electric Power Research Institute (EPRI), 2013. EPRI Ground Motion Model Review Final Report, June 3, 2013, ADAMS Accession No. ML13155A553.

Kaegi, 2013, Letter from G. Kaegi, Director – Licensing and Regulatory Affairs, Exelon Generation Company to U.S. Nuclear Regulatory Commission, "Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the

Fukushima Dai-ichi Accident - Base Case Velocity Profiles With Supporting Subsurface Materials and Properties," September 12, 2013, ADAMS Accession No. ML13256A070.

Kaegi, 2014, Letter from G. Kaegi, Director – Licensing and Regulatory Affairs, Exelon Generation Company to U.S. Nuclear Regulatory Commission, "Seismic Hazard and Screening Report (CEUS Sites) Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident - Clinton Power Station," March 31, 2014, ADAMS Accession No. ML14091A011.

Keithline, 2012, Letter from Kimberly Keithline, Senior Project Manager, NEI, to David L. Skeen, Director, Japan Lessons Learned Project Directorate, NRC, Final Draft of Industry Seismic Evaluation Guidance (EPRI 1025287), November 27, 2012, ADAMS Accession No. ML12333A168.

Keithline, 2013, Letter from K. Keithline, Senior Project Manager, NEI, to U.S. Nuclear Regulatory Commission, "Relay Chatter Reviews for Seismic Hazard Screening," October 3, 2013, ADAMS Accession No. ML13281A308.

Pietrangelo, 2013. Letter from A. R. Pietrangelo (NEI) to D. L. Skeen (NRC), Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations, April 9, 2013, ADAMS Accession No. ML13101A379.

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

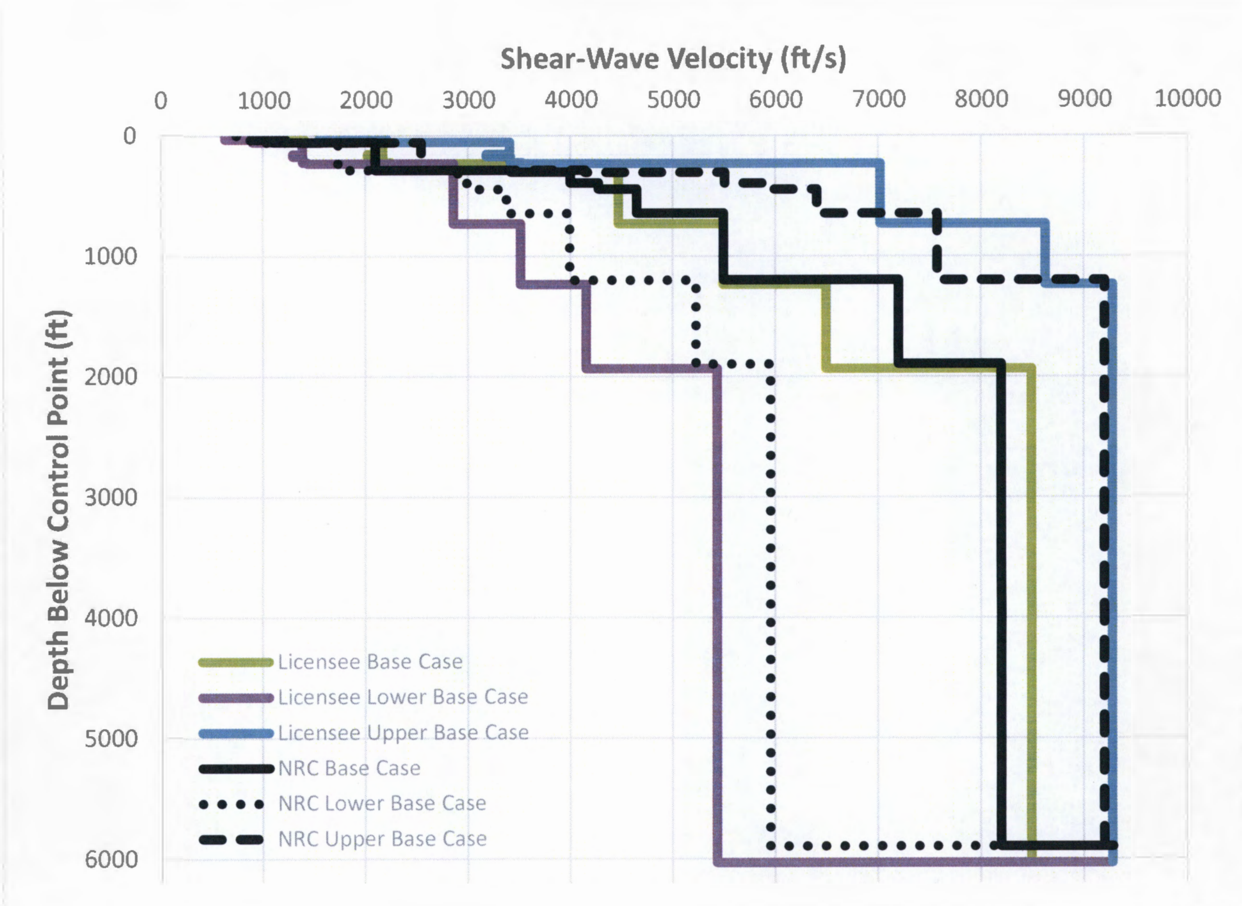


Figure 3.3- 2 Plot Comparing the Staff's and the License's Median Amplification Functions and Uncertainties for two input loading levels for the Clinton Site

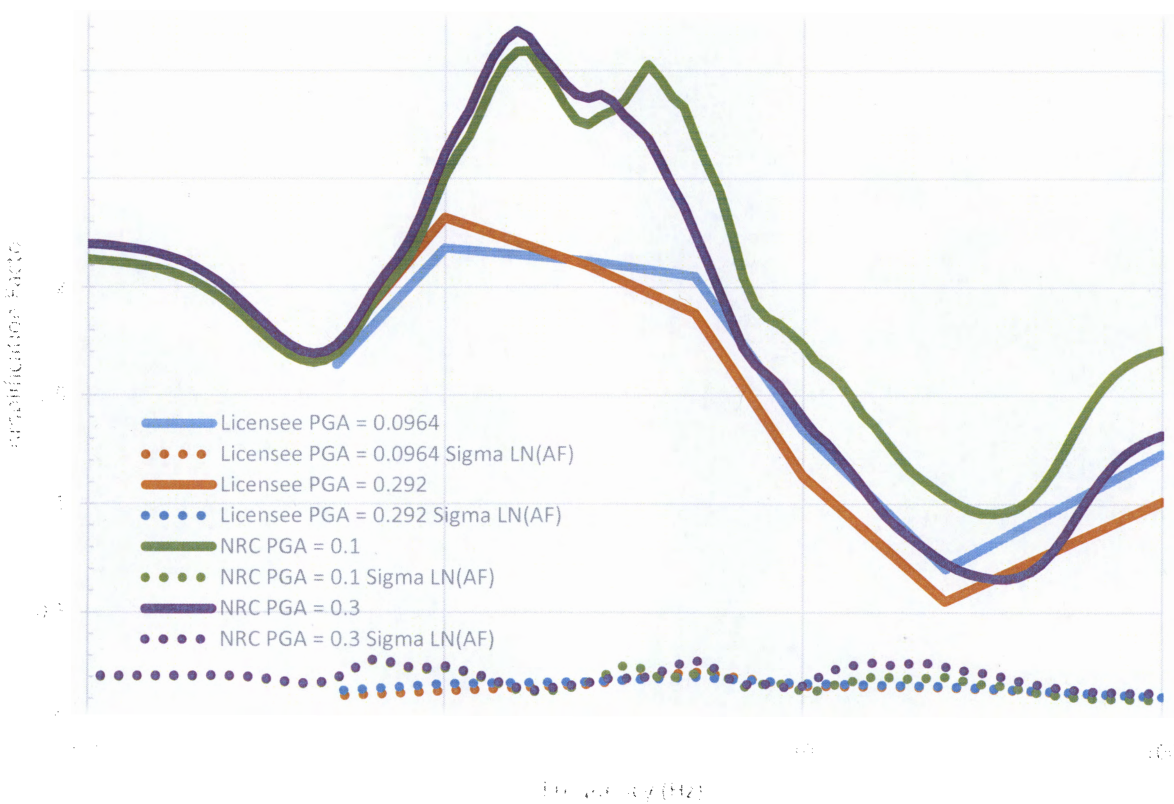


Figure 3.3-3 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Clinton Site

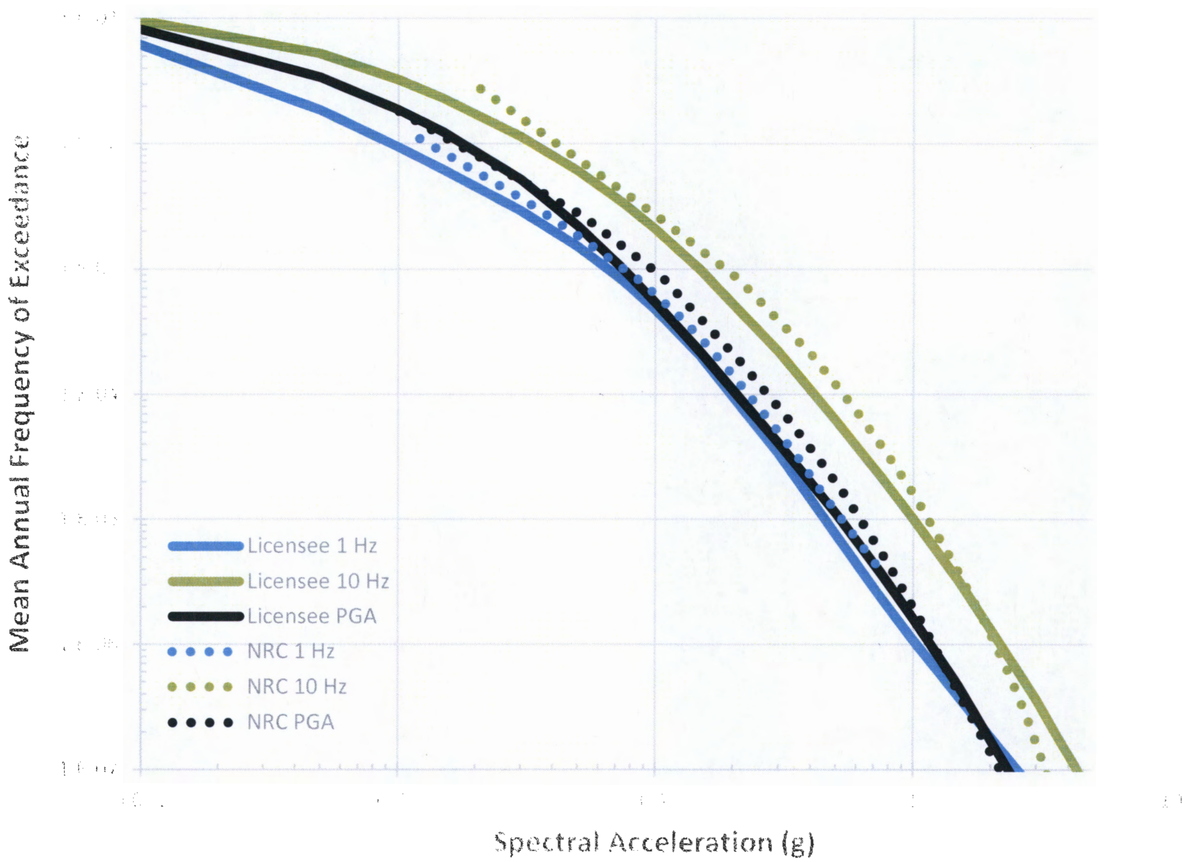
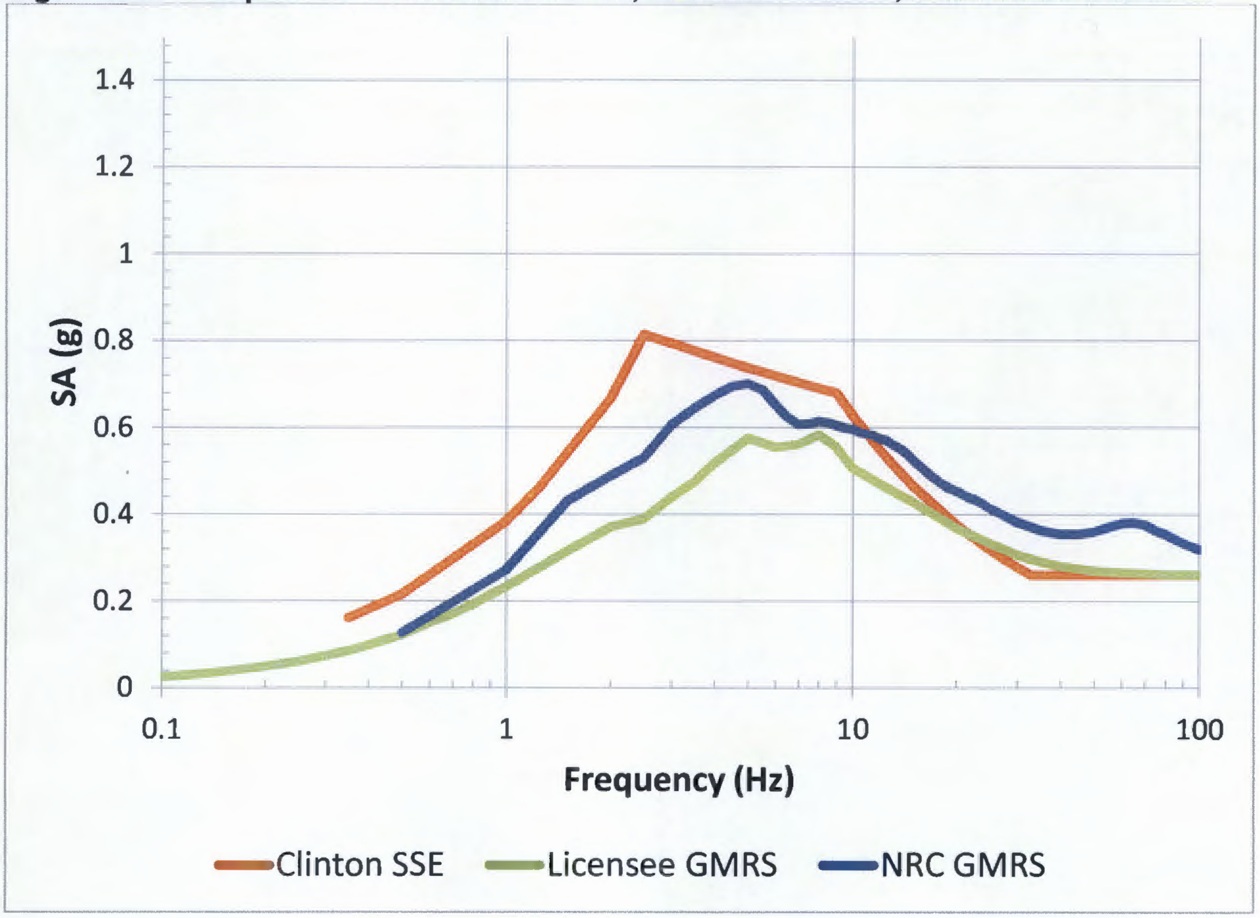


Figure 3.4-1 Comparison of the Staff's GMRS, Licensee's GMRS, and Clinton Site SSE.



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
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Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No. 50-461

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