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

October 5, 2015

Mr. Eric A. Larson
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Beaver Valley Power Station
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SUBJECT: BEAVER VALLEY POWER 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 (TAC NOS. MF3726 AND MF3727)

Dear Mr. Larson:

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, FirstEnergy Nuclear Operating Company (FENOC, the licensee), responded to this request for the Beaver Valley Power Station (BVPS), Units. 1 and 2.

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for BVPS and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to Enclosure 1, Items (1) – (3), (5), (7) 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".

Contingent upon the NRC staff's review and acceptance of the licensee's seismic risk evaluation including the high frequency confirmation and the spent fuel pool evaluation (i.e., Items (4), (8), and (9)) for BVPS, 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. 50-334 and 50-412

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

BEAVER VALLEY POWER STATION, UNITS 1 AND 2

DOCKET NOS. 50-334 AND 50-412

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 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) Selected risk evaluation approach (if 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 NRC 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 ground motion model 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 (Belcher, 2013), FirstEnergy Nuclear Operating Company, LLC (the licensee, FENOC) submitted partial site response information for Beaver Valley Power Station, Units 1 and 2 (Beaver Valley). By letter dated March 31, 2014 (Sena, 2014), the licensee submitted its SHSR. On October 31, 2014, the NRC staff requested additional information to facilitate its review of the Beaver Valley SHSR. By letter dated June 29, 2015 (Larson, 2015), the licensee provided requested supplemental information.

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) GMMs. 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 requests 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 (Sena, 2014), the licensee provided its SHSR for Beaver Valley. The licensee's SHSR indicates that the site GMRS exceeds the SSE for Beaver Valley site within the frequency range of 1 to 10 Hertz (Hz). Therefore, the licensee will perform a risk evaluation, as well as a SFP evaluation. Further, the licensee indicated that it will perform a high frequency (HF) confirmation since the GMRS also exceeds the SSE above 10 Hz.

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

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 Beaver Valley. The SSE for Beaver Valley is anchored at a PGA of 0.125 g and has a Newmark response spectrum shape. The licensee stated that the PGA anchor point is based on a design-basis earthquake with a Modified Mercalli Intensity of V to VI and also takes into account local site amplification.

In Section 3.2 of its SHSR, the licensee specified that the SSE control point is located at the base of the reactor building foundation, which is at elevation 680.9 ft (207.5 m) for both Beaver Valley, Units 1 and 2.

The NRC staff reviewed the licensee's description of its SSE for Beaver Valley in the SHSR. With regard to the SSE for Beaver Valley, based on its review of the SHSR and the updated final safety reports (UFSARs) for Units 1 and 2 (FENOC, 2011 and 2012), the NRC staff confirmed that the licensee's SSE (for both Units 1 and 2) is a 5 percent damped response spectrum anchored at 0.125 g. Finally, based on review of the SHSR and UFSARs for Units 1 and 2 (FENOC, 2011 and 2012), the NRC staff confirmed that the licensee's control point elevation for Beaver Valley SSE 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 Fault northern segment (ERM-N), Eastern Rift Margin Fault southern segment (ERM-S), Marianna, New Madrid Fault System (NMFS), Charleston, Charlevoix, and Wabash Valley repeated large magnitude earthquake (RLME) sources, which lie within 620 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 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 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 PSHA calculations for base rock site conditions at the Beaver Valley 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 Beaver Valley 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 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 licensees 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 ground motion models 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 Beaver Valley Power Station, Units 1 and 2 UFSARs (FENOC, 2011 and 2012), on the regional geologic profile (summarized in SHSR Table 2-2), and the guidance in Appendix B of the SPID. According to the licensee, the upland portion of the site where the main power block structures are located consists of approximately 110 ft (33.5 m) of Pleistocene till resting on about 745 ft (227 m) of firm-to-hard Paleozoic sedimentary rock with Devonian basement at a depth of about 4,435 ft (1,230 m). Additionally, the licensee described the firm-to-hard sedimentary rock units at the site as including Carboniferous and Upper Devonian; shale and sandstone overlying Ordovician limestones, shales, and sandstones.

In Table 2-2 of its SHSR, the licensee provided a brief description of the subsurface materials in terms of the geologic units and layer thicknesses. In Table 2-3 of its SHSR, the licensee provided the shear-wave velocities determined from subsurface investigation reported in the UFSARs (FENOC, 2011 and 2012). These geophysical surveys indicated that the best-estimate shear-wave velocity in the upper 110 ft (33.5 m) is about 1,100 ft/sec (335 m/sec). The licensee stated that the top elevation of its site response is at an elevation of 680.9 ft (207.5 m), which is within the Pleistocene Upper and Lower Terrace and is located beneath the structural fill and natural and densified soil.

To capture the uncertainty in the shear wave velocities beneath the plant, the licensee developed three base-case shear-wave velocities for the Beaver Valley site. The licensee used a scale factor of 1.15 relative to the preferred base case model to calculate the lower and upper base case shear-wave velocity profiles. The licensee utilized sonic log information obtained from nearby oil and gas exploration wells in the vicinity of the Beaver Valley site to constrain the middle or best base case profile and provide insights on the variability in shear-wave velocity with depth. Figure 3.3-1 of this assessment shows the licensee's three shear-wave velocity base case profiles.

The licensee stated that very limited site-specific dynamic material property information was determined in the initial siting of Beaver Valley. As such, the licensee followed the SPID guidance and identified alternative representations of the dynamic material properties for the soil and underlying rock layers. To model the potential nonlinear behavior of the soil, the licensee used the EPRI soil curves. For the underlying upper 100 ft (30.4 m) of sedimentary rock, the licensee used the EPRI rock curves to model the nonlinear behavior and a constant low strain damping value of about 3 percent to model the linear behavior. For the stiffer rock layers over the depth range of 100 to 500 ft (30.4 to 152.4 m), the licensee used shear modulus and damping curves developed for un-weathered shale dynamic properties located at the Y-12 site at Oak Ridge, Tennessee (Stokoe et al., 2013) to model the potential non-linear dynamic behavior. To model the linear behavior of the stiffer rock layers below a depth of 500 ft (152.4 m), the licensee used a minimal low strain damping value less than 1 percent.

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 Beaver Valley site, which is underlain by about 4,381 ft (1336 m) of sedimentary rock, the licensee used the SPID guidance to estimate total site kappa values of 0.0213 sec, 0.0237 sec, and 0.0193 sec for the middle, lower and upper base cases, respectively. These total kappa values include the contribution of 0.006 sec from the underlying basement rock. To augment the representation of uncertainty for kappa, the licensee added a 50 percent variation to the kappa estimates for the upper and lower base case profiles. This increased the range of kappa values from 0.0152 sec for the upper base case profile to 0.0320 sec for the lower base case profile.

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 the base case shear-wave velocity profiles in accordance with Appendix B of the SPID. The licensee used a natural log standard deviation of 0.25 over the top 50 ft (15.2 m) and a natural log standard deviation of 0.15 over the remaining soil column depth. As specified in the SPID, the licensee modeled the correlation of V_s between layers using the footprint correlation model. In addition, the licensee constrained the profiles to not exceed a V_s of 9,200 ft/s (2,804 m/s).

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, 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 two of the eleven input loading levels for the base case profile and EPRI soil and 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 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 (discussed in 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 analyses for the Beaver Valley site. The NRC staff independently developed shear-wave velocity profiles, low-strain damping values, and modeled the potential for non-linear behavior in the near-surface geologic materials.

To capture the uncertainty in the subsurface shear wave velocity, the NRC staff developed three base case velocity profiles. For the middle or best estimate velocity profile, the NRC staff based the upper portion of its velocity profile on the information contained in the UFSARs for Units 1 and 2 (FENOC, 2011 and 2012). The UFSARs contain direct shear-wave velocity measurements within the Upper Terrace deposits, as well as within the upper most portion of the underlying Allegheny Group shales. To estimate the shear wave velocities for the deeper rock layers, the NRC staff used sonic data from the Pennsylvania Department of Conservation and Natural Resources and the Ohio Division of Natural Resources and regional references (Berg, et al., 1980). Observations of lithologic units in the region show that the rock are generally flat-lying and well correlated over large distances (Miles and Whitfield, 2001). To develop the lower and upper base case velocity profiles, the NRC staff used a natural log standard deviation of 0.25. In addition, to account for uncertainty in the depth to reference or basement rock, the NRC staff randomized the total thickness of each profile by +/-20 percent. The NRC staff velocity profiles are compared to the licensee's in Figure 3.3-1 of this staff assessment. As shown in the figure, the NRC staff and licensee profiles are generally similar over all depth ranges.

Consistent with Appendix B of the SPID, the NRC staff assumed both linear and non-linear behavior for the materials beneath the Beaver Valley site over a broad range of input motions. For each velocity profile, the NRC staff assumed two potential types of behavior; one that represented the potential for non-linear response and one that represented a more linear response. For the Upper Terrace deposits, the NRC staff applied both the EPRI depth- dependent soil curves and the Peninsular Range curves. The NRC staff notes that the licensee utilized only the EPRI soil curves for these materials (i.e., did not allow for more linear behavior of the soils). For the upper 100 ft (30.4 m) of the underlying shale deposits, the NRC staff used the EPRI rock damping and modulus degradation curves to represent the potential non-linear response of the rock and a constant damping value of about 3 percent to represent the linear behavior case. For the 100 to 400 ft (30.4 to 125.6 m) depth interval of the Pennsylvanian-age shale/sandstone units, staff used the depth-dependent EPRI rock curves for the potential nonlinear response and a constant damping value of 1.25 percent for the linear response.

To account for the impact of the site kappa, the NRC staff used the same approach as the licensee. Applying the SPID recommended formula for rock sites with at least 3,000 ft (1000 m) of firm sedimentary rock, the NRC staff first calculated kappa values using the licensee's V_{S100} values (average shear wave velocity over the upper 100 ft of the profile) for each of the three base case velocity profiles. The NRC staff's preliminary verification indicated that the licensee incorrectly calculated kappa for the three profiles since the SPID recommended formula already includes the basement or reference rock contribution. By letter dated June 29, 2015 (Larson, 2015), the licensee provided modified kappa estimates for the Beaver Valley site consistent with the NRC staff's confirmatory calculations. The licensee's modified kappa values for the three profiles are 0.0167 sec, 0.0191 sec, and 0.0146 sec, respectively for the middle, lower and upper profiles. As described above, the licensee augmented the lower and upper kappa values by 50 percent to reflect the uncertainty in this parameter.

In addition, to confirming the licensee's kappa values, the NRC staff also calculated kappa values for its three base case velocity profiles. The NRC staff's kappa values for the middle base-case, lower base-case, and upper base-case are 0.0161, 0.0196, and 0.0136 sec, respectively. To augment the uncertainty in these kappa estimates, the NRC staff applied a natural log standard deviation of 0.25 to calculate a range of kappa for each base-case profile. This approach results in nine kappa values, which were used for the NRC staff's site response analyses. Figure 3.3-2 of this assessment shows a comparison of the licensee's and NRC staff's kappa values. As shown in this figure, the range in kappa assumed by the licensee is greater (especially at larger values) than that applied by the NRC staff.

Figure 3.3-3 of this assessment shows a comparison of the amplification functions (median and natural log standard deviation) derived by the NRC staff and by the licensee for two different loading levels. Both the NRC staff and licensee amplification functions peak near 5 Hz. The median amplification functions are generally similar but the peak (absolute value) in the amplification function derived by the licensee is slightly greater than those developed by the NRC staff. As shown in Figure 3.3-4 of this assessment, the NRC staff notes these differences in the site response analysis do not have a large impact on the control point seismic hazard curves between 1 and 10 Hz.

The licensee's and NRC staff's site response analyses produced similar site amplification functions. However, there are some differences in the two approaches with respect to characterizing the uncertainty in kappa, as well as assumptions with respect to modeling the dynamic behavior of the upper soil layers. 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 and assumptions implicit in performing site response analyses when following the SPID, 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 Beaver Valley 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 initial GMRS determined by the licensee, the licensee's updated GMRS (licensee SPRA GMRS), and the confirmatory GMRS determined by the NRC staff. As shown in Figure 3.4-1, the licensee's updated GMRS is very similar to the NRC staff's confirmatory GMRS for frequencies below 15 Hz. However, the NRC staff's confirmatory GMRS is somewhat higher than the licensee's at frequencies above 15 Hz. The NRC staff concludes these differences arise due to differences between the licensee's and NRC staff's site response analyses, as described above in Section 3.3. The NRC staff concludes that the small differences between the two GMRS are acceptable for this application because the spectral shapes are very similar and the differences are confined to frequencies above 15 Hz for the Beaver Valley site.

Based on the assessment of the licensee's SHSR and the additional information provided in the June 29, 2015, letter (Larson, 2015), 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 Beaver Valley 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 Beaver Valley, Units 1 and 2. Based on its review, the NRC staff concludes that the licensee conducted the seismic 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), (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".

In reaching this determination, the NRC staff confirmed the licensee's conclusion that the licensee's GMRS exceeds the SSE for Beaver Valley, Units 1 and 2. As such, the licensee will perform a seismic risk evaluation, SFP evaluation and HF confirmation. The licensee indicated that the HF confirmation could be performed as part of its seismic risk evaluation. The NRC review and acceptance of FENOC's plant seismic risk evaluation, including the HF confirmation, and the SFP evaluation (i.e., Items (4), (8), and (9)) for Beaver Valley, Units 1 and 2, will complete the Seismic Hazard Evaluation identified in Enclosure 1 of the 50.54(f) letter.

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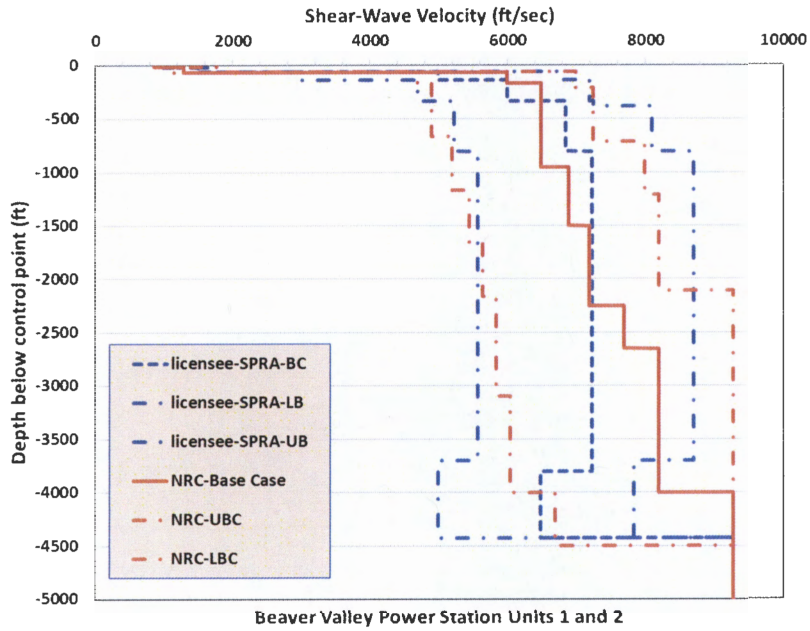
Figure 3.3-1: Plot of Staff's and Licensee's Base Case Shear-Wave Velocity Profiles for the Beaver Valley site



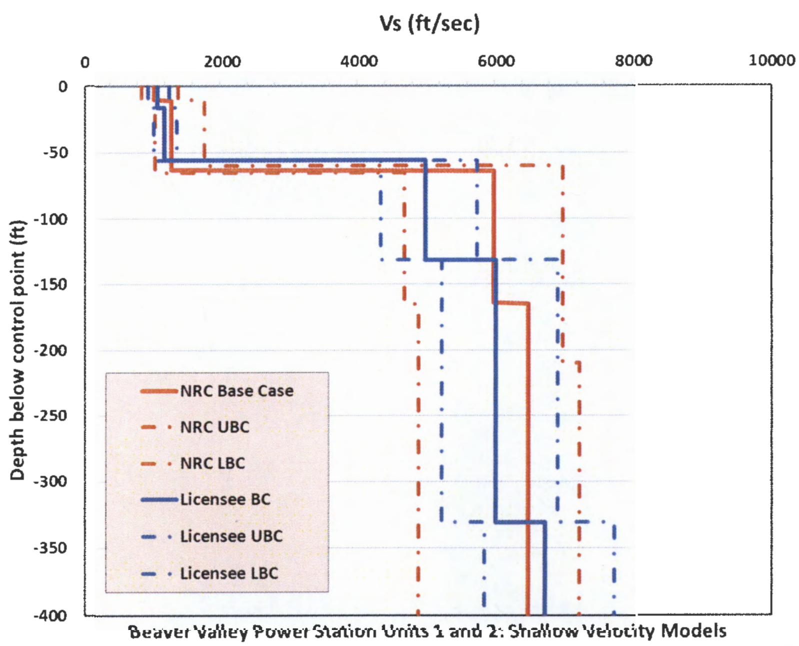


Figure 3.3-2 Plot Comparing the Staff's and the Licensee's estimates of kappa for the Beaver Valley site

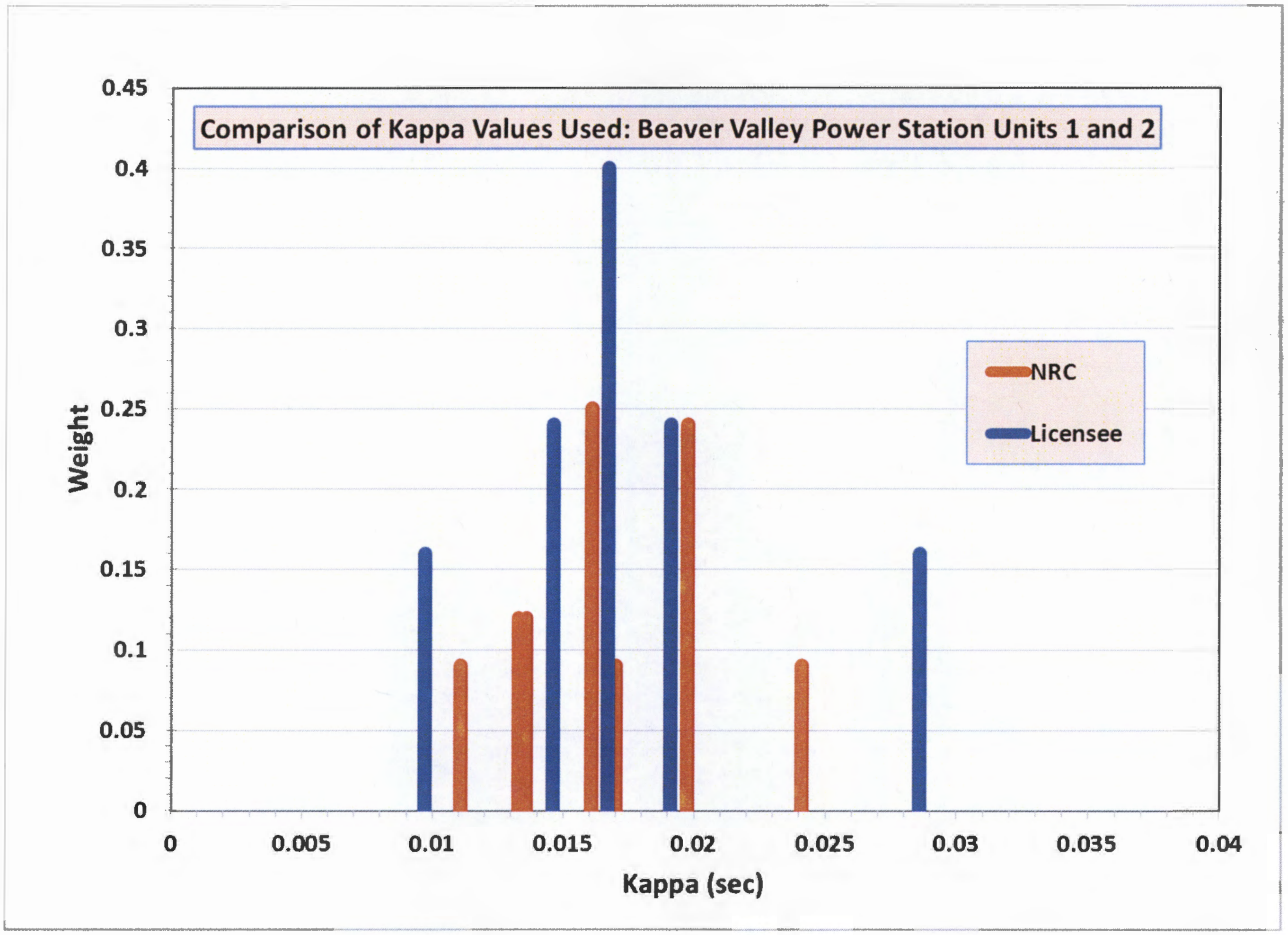


Figure 3.3-3 Plot Comparing the NRC Staff's and the Licensee's Median Amplification Functions and Uncertainties for two input loading levels for the Beaver Valley site

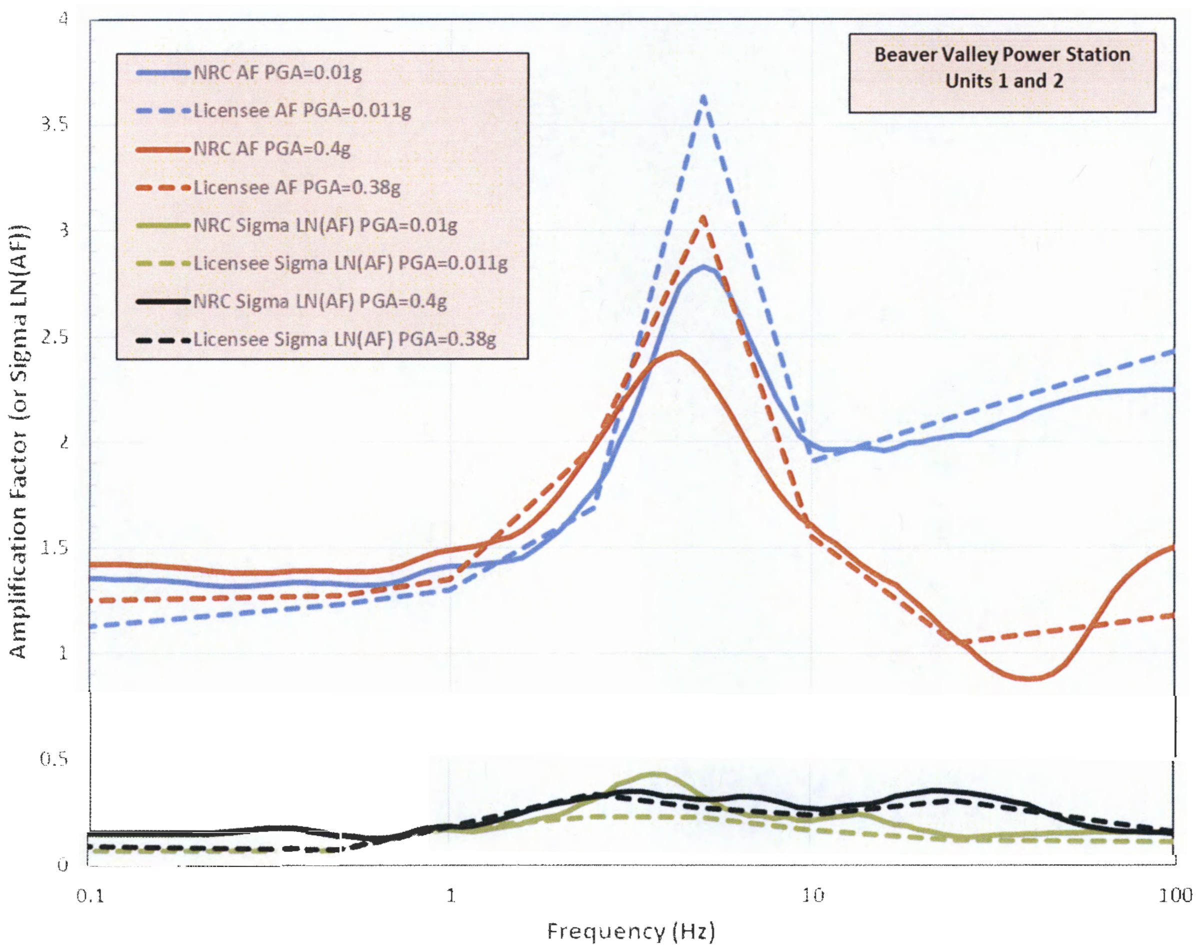


Figure 3.3-4 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Beaver Valley site

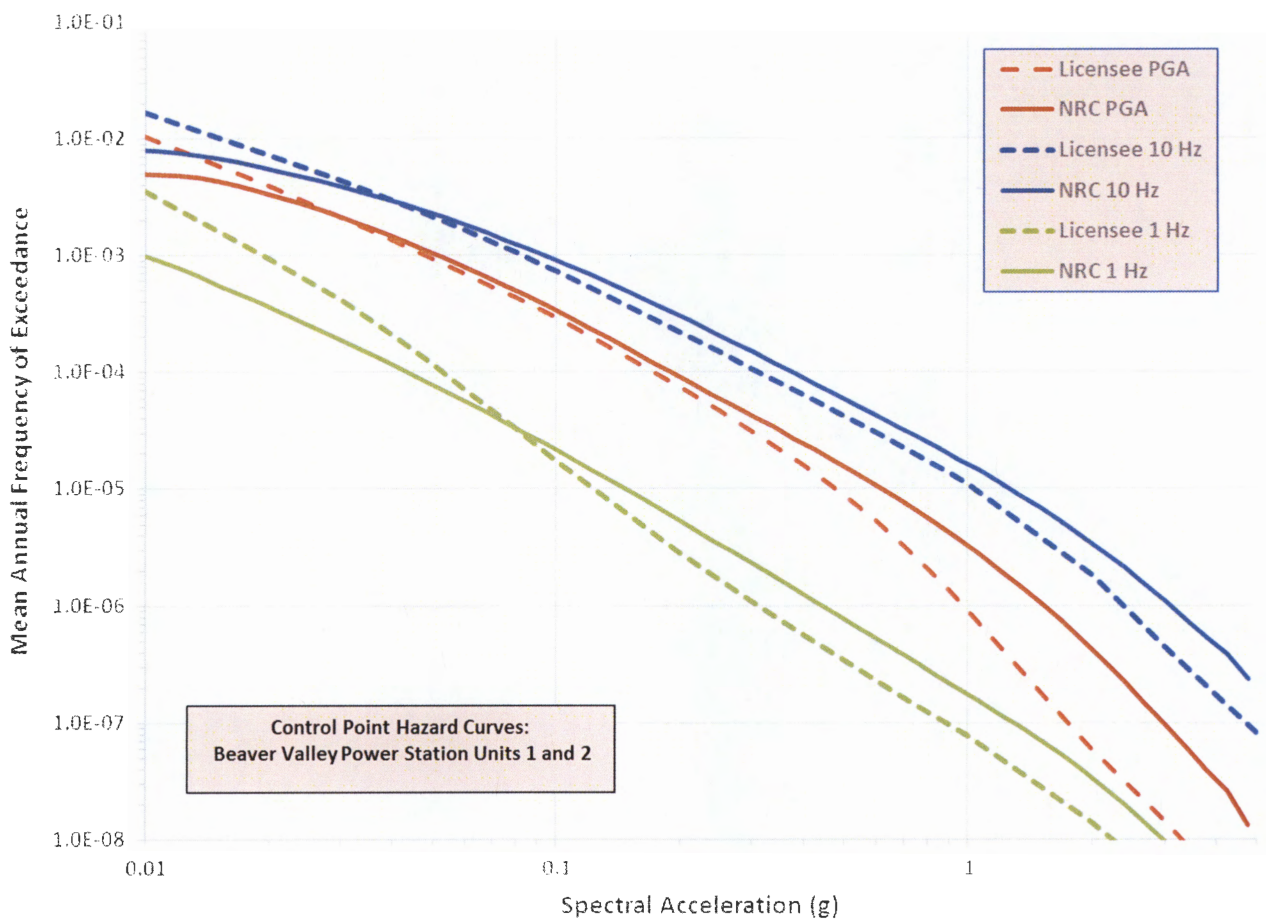
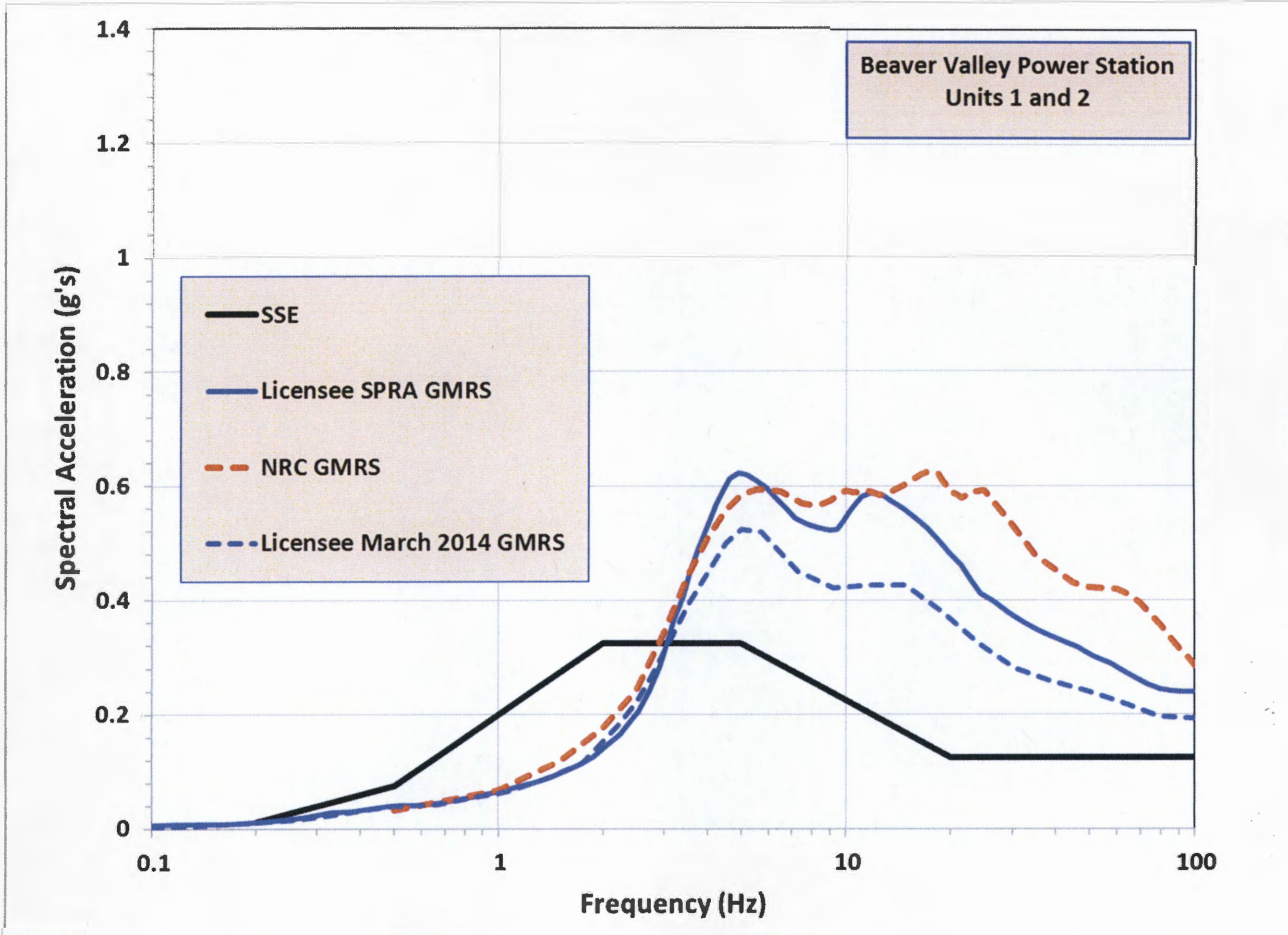


Figure 3.4-1 Comparison of the Staff's GMRS, Licensee's GMRS, and the SSE for the Beaver Valley site



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. 50-334 and 50-412

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