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

October 19, 2015

Mr. Richard Michael Glover, Site Vice President
H.B. Robinson Steam Electric Plant
Duke Energy
3581 West Entrance Road, RNPA01
Hartsville, SC 29550

SUBJECT: H.B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 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 NO. MF3724)

Dear Mr. Glover:

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.

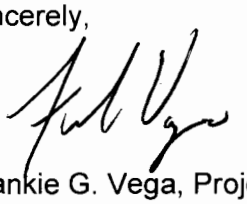
By letter dated March 31, 2014, and revised on July 17, 2015, Duke Energy Progress, Inc. (the licensee), responded to this request for H.B Robinson Steam Electric Plant, Unit No. 2 (Robinson).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for Robinson 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, high frequency confirmation and spent fuel pool evaluation (i.e., Items (4), (8), and (9)) for Robinson, 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
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Office of Nuclear Reactor Regulation

Docket No. 50-261

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

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2

DOCKET NO. 50-261

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,

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

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

(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 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 committed to following the SPID to develop the SHSR for existing nuclear power plants. By letter dated September 11, 2013 (Gideon, 2013), Duke Energy Progress, Inc. (Duke, the licensee) submitted partial site response information for H. B. Robinson Steam Electric Plant (Robinson). By letter dated March 31, 2014 (Gideon, 2014), the licensee submitted its SHSR. By letter dated April 28, 2015 (Gatlin, 2015), the licensee submitted its Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 study on the topics of reservoir induced seismicity (RIS) and the Charleston earthquake locations. By letter dated July 17, 2015 (Glover, 2015b), the licensee supplemented its revised SHSR (RSHSR) with additional information. By letter dated August 29, 2015 (Glover, 2015c), the licensee provided additional 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) ground motion models. The SPID provides further guidance regarding the appropriate use of GMMs for the CEUS. Specifically, Section 2.3 of the SPID recommends the use of the updated GMM (EPRI, 2013) and, as such, licensees used the NRC-endorsed updated EPRI GMM instead of the older EPRI (2004, 2006) GMM to develop PSHA base rock hazard curves. Finally, Attachment 1 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 (Gideon, 2014), the licensee provided its SHSR for Robinson. By letter dated July 17, 2015 (Glover, 2015b), the licensee provided a revision to its Seismic Hazard Evaluation (Revision to SHSR or RSHSR), which includes a revised GMRS using new geotechnical data and shear-wave velocity testing for the Robinson site. The licensee's RSHSR indicates that the site GMRS exceeds the SSE for Robinson over the frequency range of 1 to 10 Hertz (Hz). As such, Robinson screens-in to perform a seismic risk evaluation and SFP evaluation. Additionally, the GMRS also exceeded the SSE at frequencies above 10 Hz. The licensee indicated that it would address the high frequency (HF) exceedance as part of its plant risk evaluation.

On May 9, 2014 (NRC, 2014a), the NRC staff issued a letter providing the outcome of its 30-day screening and prioritization evaluation. As indicated in the letter, the staff characterized Robinson as screened-in for conducting a seismic hazard evaluation. The staff also confirmed that SFP and HF evaluations 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 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 3.1 of its RSHSR, the licensee described its seismic design bases for Robinson. The licensee stated that the SSE is based on the 1959 Modified Mercalli Intensity V-VI McBee, SC earthquake located approximately 15 miles [24 km] from the site. Based on this earthquake it was assumed that a magnitude 4.5 earthquake located less than 10 miles [16.1 km] from the site represented a conservative estimate of the site hazard.
The licensee stated that the SSE for Robinson is based on a Housner response spectral shape. Based on this earthquake, the SSE is anchored at a PGA of 0.2 g (20 percent of the

acceleration due to earth's gravity). The licensee specified that the SSE control point is located at the top of ground surface at a mean sea level elevation of 226 ft. (68.9 m) approximately 85 ft. (26 m) below plant grade elevation.

The NRC staff reviewed the licensee's description of its SSE and the control point in the RSHSR. To confirm the SSE, the NRC staff reviewed the Robinson Updated Final Safety Analysis Report (UFSAR, Duke Energy Progress, 2012 and 2014). Based on its review, the staff confirmed both the SSE spectrum and control point elevation are consistent with information in the UFSAR and guidance provided in the SPID.

3.2 Probabilistic Seismic Hazard Analysis

In Section 2.2 of the RSHSR, the licensee states that, in accordance with the 50.54(f) letter and the SPID, it performed a PSHA using the CEUS-SSC model and the updated EPRI GMM for the CEUS (EPRI, 2013). For its PSHA, the licensee used a minimum moment magnitude (**M**) of 5.0 as specified in the 50.54(f) letter. The licensee further states that it included the CEUS-SSC background sources out to a distance of 400 miles [640 km] and included the Charlevoix, Charleston, New Madrid Fault System, and Wabash Valley repeated large magnitude earthquake (RLME) sources, which lie within 620 miles [1,000 km] of the site. 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. Other RLME sources in the Reelfoot Rift (i.e. the Commerce fault zone, the Eastern Rift Margin- South, the Eastern Rift Margin-North, and the Reelfoot-Marianna) were found to contribute in aggregate less than 1 percent to the total hazard and were not included in the PSHA as a result. The licensee used the updated EPRI GMM (EPRI, 2013) for each of the CEUS-SSC sources.

Rather than implementing the CEUS-SSC model as published for its PSHA, the licensee stated in the SHSR that it performed a site-specific review of the CEUS-SSC seismic catalog with regard to two issues: (1) identification of additional RIS earthquakes in the southeastern U.S. and (2) locations of earthquakes in South Carolina near the time of the 1886 Charleston, SC earthquake sequence. The purpose of the licensee's review was to determine if the magnitude recurrence parameters for the southeastern U.S., as determined in the CEUS-SSC model, needed to be adjusted. In addition to these two issues, the licensee also corrected the maximum magnitudes for several of the CEUS-SSC sources, which were incorrect in the original model. These corrections are on the order of one tenth of a magnitude so they have little to no effect on the hazard results.

Concerning the first issue, the licensee noted that in developing the CEUS-SSC catalog earthquakes identified as RIS were removed from the final earthquake catalog. Taking into consideration the proximity of each earthquake to a reservoir, timing of the earthquake versus the filling of the reservoir, magnitude of the earthquake, and proximity to a nuclear power plant, the licensee further evaluated the CEUS-SSC seismic catalog to determine if there were additional RIS earthquakes. As a result of its review, the licensee removed an additional 30 earthquakes from the CEUS-SSC catalog that it considered to be RIS.

Concerning the second issue, the licensee noted that in developing the CEUS-SSC catalog earthquakes identified as aftershocks of the large Charleston, South Carolina 1886 main shock

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

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

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

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

On the issue of relocating earthquakes potentially associated with the Charleston earthquake sequence, the NRC staff reviewed the SSHAC Level 2 study and the technical comments made by the reviewers. The location of historical seismicity is made difficult by the lack of instrumental data, requiring that scientists rely on historical reports of felt motions, most often recorded in contemporaneous newspaper accounts. The NRC staff notes that significant effort

went into locating events near Charleston during the CEUS-SSC study using the most up to date methods and available reports at the time of the study. The licensee's technical judgment is based on additional reviews of historical newspaper accounts and evidence that some earthquake times may have been misinterpreted in the original catalog. The NRC staff agrees that additional review of earthquake locations, times, and magnitudes is warranted when new information is made available (i.e. additional historical data becomes available), but notes that locating historical seismicity remains a subject of intense debate within the broader technical community.

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

As part of its confirmatory analysis of the licensee's GMRS, the NRC staff performed its own PSHA calculations for base rock conditions at the Robinson 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 H.B. Robinson site. In addition, the NRC staff included all of the RLME sources falling within a 620 mi [1,000 km] radius of the site. For each of the CEUS-SSC sources used in the PSHA, the 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.

As part of its RAI response, the licensee provided control point hazard curves in order to show the impact of its refinements to the CEUS-SSC seismicity catalog. Figure 3.2-1 of this assessment shows the licensee's control point hazard curves developed using the as published CEUS-SSC and control point hazard curves developed using the modified CEUS-SSC. As shown in Figure 3.2-1 of this assessment, the impact of the licensee's changes to the hazard inputs have a very minor impact on the hazard for the Robinson site.

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

3.3 Site Response Evaluation

After completing PSHA calculations for reference rock conditions, Attachment 1 to Enclosure 1 of the 50.54(f) letter requests that the licensee provide a GMRS developed from the site-specific seismic hazard curves at the control point elevation. In addition, the 50.54(f) letter specifies that the subsurface site response model, for both soil and rock sites, should extend to sufficient depth to reach the generic or reference rock conditions as defined in the ground motion models 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 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 would 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 these layers, and the degree to which the shear modulus and damping change with increasing input bedrock amplitude. To develop site-specific hazard curves at the control point, the licensee performed a site response analysis.

3.3.1 Site Base Case Profiles

The original site exploration for Robinson is documented in a report by Dames and Moore (1966). Due to limited geotechnical data at the H.B. Robinson site, the licensee recently performed soil investigations and borings after the initial submittal in March 2014 (AMEC, 2015a and 2015b). In its RSHSR, the licensee indicated that it redid its site response analysis for H.B. Robinson based on its recently performed site investigations, which included drilling a borehole to determine the geologic profile for the site as well as the depth to the top of basement or reference rock and the stratigraphy of the overlying materials.

The geology of the site, based on the recent site investigations, is divided into three layers. Piedmont rock, consisting of hard-green metavolcanics consistent with the Persimmon Fork formation, is encountered at a depth of approximately 400 ft. [122 m]. The shear wave velocity of this material is in excess of 9,285 fps [2,830 m/s] and is considered base rock for the purposes of site response. Overlying the base rock material is weathered bedrock consisting of hard clay and weak claystones extends upward to a depth of approximately 378 ft. [115 m]. Overlying this are soils consisting of alternating layers of sand, hard clay, and sand with variable silt and clay zones that extend to the surface.

In addition to investigating the site geology from the surface to base rock, the licensee conducted geophysical surveys to determine the shear-wave velocities in the subsurface. These surveys consisted of suspension logging of the borehole and geophysical profiling in the

area around the reactor building (AMEC, 2015b). The licensee developed three base case profiles for the site based on these investigations and labeled them Profile A, Profile B, and Profile C. Table 2.3.2-1 and Figure 2.3.2-1 of the RSHSR and Figure 3.3-1 of this assessment illustrate these profiles. Profile A is based on the suspension logging of the borehole, Profile B is based on three geophysical profiles obtained at locations south of the Category I structures, and Profile C is based on five geophysical profiles obtained north of the Category I structures. The licensee weighted the profiles 0.17, 0.33, and 0.5 respectively.

In Section 2.3.2.2 of its RSHSR, the licensee assumed that the soils could be modeled with varying degrees of nonlinearity. To model the upper limit of nonlinear behavior, the licensee used site specific shear modulus degradation and damping curves. To model the lower limit of nonlinear behavior or a more linear response, the licensee used the Peninsular Range curves. The licensee stated that these alternatives are consistent with treating the soils as sand or clay respectively and gave each case equal weight in the analysis. For the weathered rock layer located below the soils, the licensee used the EPRI rock shear modulus degradation and damping curves as one alternative and assumed a linear site with small strain damping set equal to the low strain damping value in the corresponding EPRI rock curve in the other alternative.

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 Robinson, a site with approximately 400 ft. of soil and weathered bedrock, the licensee used the low strain damping values from the damping curves to calculate the kappa values for the three base case profiles. The licensee then calculate the weighted average kappa value for the site using the relative weights of the damping and velocity profiles to determine a site kappa of 0.0112 sec, which the licensee stated was similar to the 0.0136 sec estimated by applying the Campbell (2009) formula for soils.

To account for aleatory variability in material properties across the plant site in its site response calculations, the licensee stated that it randomized its base case profiles in accordance with Appendix B of the SPID using a lognormal standard deviation value of 0.25 for the top 50 ft. (15 m) of the profile, and a value of 0.15 for greater depths. The licensee also randomized layer thicknesses over a range of approximately ±5 percent based on the observed variation in layer boundaries in the individual profiles used to construct site Profiles B and C.

3.3.2 Site Response Method and Results

In Section 2.3.4 of its SHSR, the licensee states that rather than using the guidance in Appendix B of the SPID to develop input ground motions for the site response analysis, it implemented the Conditional Mean Spectrum (CMS) method (Baker and Cornell, 2006). In Section 2.3.5 of the SHSR, the licensee indicated that it used the time history approach rather than using the random vibration theory (RVT) approach to perform its site response calculations. As described below in Section 3.4.3, the NRC staff used the approaches recommended in the SPID to perform its confirmatory site response analysis for H.B. Robinson. A comparison of the licensee's and NRC staff's site response amplification functions and associated uncertainties show very similar results. Finally, Section 2.3.6 of the SHSR shows the resulting amplification

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

3.3.3 Staff Confirmatory Analysis

To confirm the licensee's site response analysis, the NRC staff performed its own site response calculations for the H.B. Robinson 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 Robinson UFSAR (Duke Energy Progress, 2012 and 2014), the recently collected geologic and geotechnical information (AMEC, 2015a; AMEC, 2015b; AMEC 2015c), and Appendix B of the SPID.

Because the recently collected geophysical data represents the most up to date information about the Robinson site, the NRC staff adopted profiles A-C as its base case profiles (Figure 3.3-1 of this assessment). The NRC staff weighed each profile equally, assuming that the differences in the profiles are representative of the epistemic uncertainty across the site. This approach differs from the licensee's approach, which gave greater weight to Profiles, B and C.

Similar to the approach used by the licensee, the NRC staff considered the effect of nonlinear behavior on site response calculations. In contrast to the licensee's approach, the NRC staff used only the EPRI cohesionless soils shear modulus degradation and damping curves since it considered these curves to adequately characterize the potential nonlinear response of the soils. The licensee treated the weathered rock located below the soil as linear with a constant damping value of one-percent.

The NRC staff also considered the effect of kappa on site response. The NRC staff used the low strain damping values, shear wave velocities, and thicknesses for each layer to determine a site kappa value of 0.011 sec. This value includes the contribution of 0.006 sec from hard rock and is consistent with the licensee's estimate of kappa.

Figure 3.3-2 of this staff assessment shows a comparison of the NRC staff's and licensee's median site amplification functions and uncertainties (±1 standard deviation) for two input loading levels. The amplification functions and uncertainties calculated by the NRC staff and the licensee are similar. At high frequencies for the higher loading level, the licensee's site amplification is slightly higher than the NRC staff's, with uncertainties demonstrating opposite behavior. As shown in Figure 3.3-3 of this assessment, differences in the licensee's and NRC staff's site response analyses and PSHAs have only a moderate impact on the control point seismic hazard curves and the resulting GMRS, as discussed below. Differences in control point seismic hazard curves are greatest at low mean annual frequencies of exceedance (MAFE). These differences (up to 14 percent) are significantly lower at the 10^{-4} and 10^{-5} MAFE levels, which are used to calculate the GMRS. The NRC staff attributes these differences in

control point seismic hazard curves primarily to differences in the implementation of the CEUS-SSC model by the licensee.

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 Robinson site.

3.4 Ground Motion Response Spectra

In Section 2.4 of its RSHSR, the licensee stated that it used the control point hazard curves, described in RSHSR 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 analysis, as described in Sections 3.2 and 3.3 of this staff assessment. 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 with minor differences between 1.5 to 4.0 Hz.

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

In reaching this determination, the NRC staff confirmed the licensee's conclusion that the licensee's GMRS for the Robinson site exceeds the SSE over the frequency range of approximately 0.5 to 100 Hz. As such, a seismic risk evaluation, SFP evaluation, and a HF confirmation are merited. The licensee indicated that it could perform the HF confirmation as

part of its seismic risk evaluation. The NRC review and acceptance of seismic risk evaluation with the HF confirmation and SFP evaluation (i.e., Items (4), (8), and (9)) for Robinson will complete the Seismic Hazard Evaluation identified in Enclosure 1 of the 50.54(f).

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Figure 3.2-1 Plot Comparing the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the H. B. Robinson Site. RAI Response Curves are Licensee Curves Developed Using the Currently Endorsed CEUS-SSC (NUREG-2115) for the H. B. Robinson Site

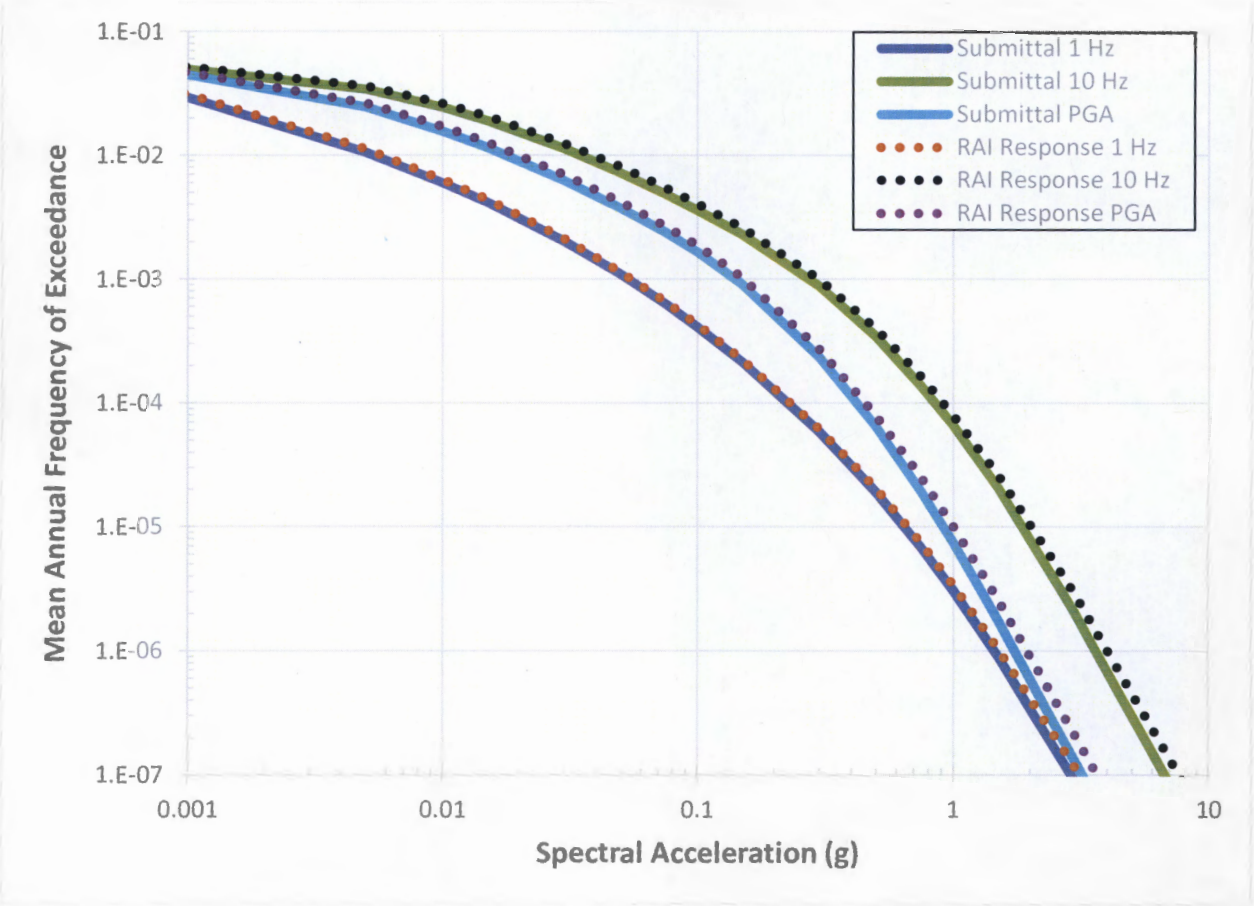


Figure 3.3-1 Plot of Staff's and Licensee's Base Case Shear-Wave Velocity Profiles for the Robinson Site.

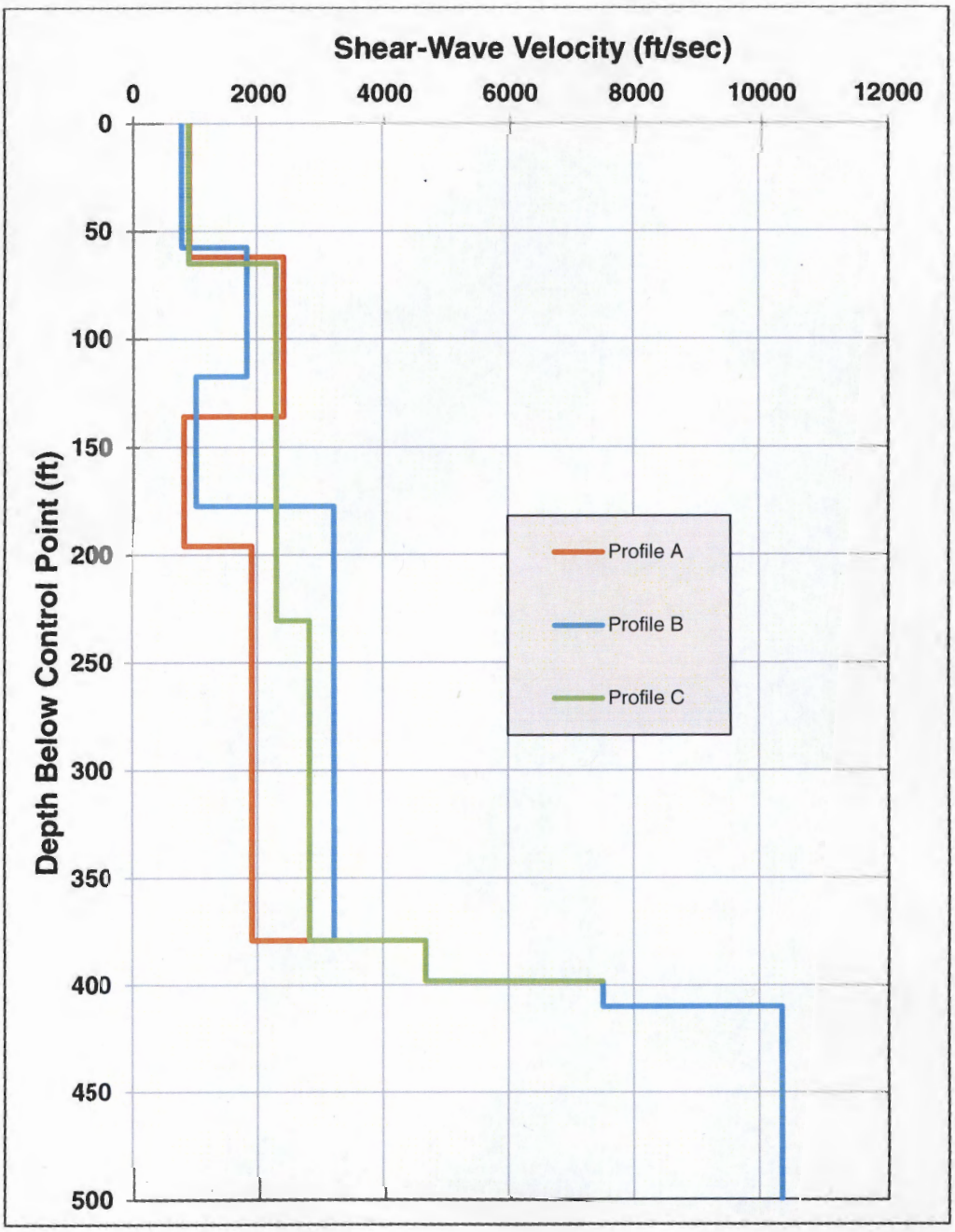


Figure 3.3- 2 Plot Comparing the Staff's and the Licensee's Median Amplification Functions and Uncertainties for the Robinson site.

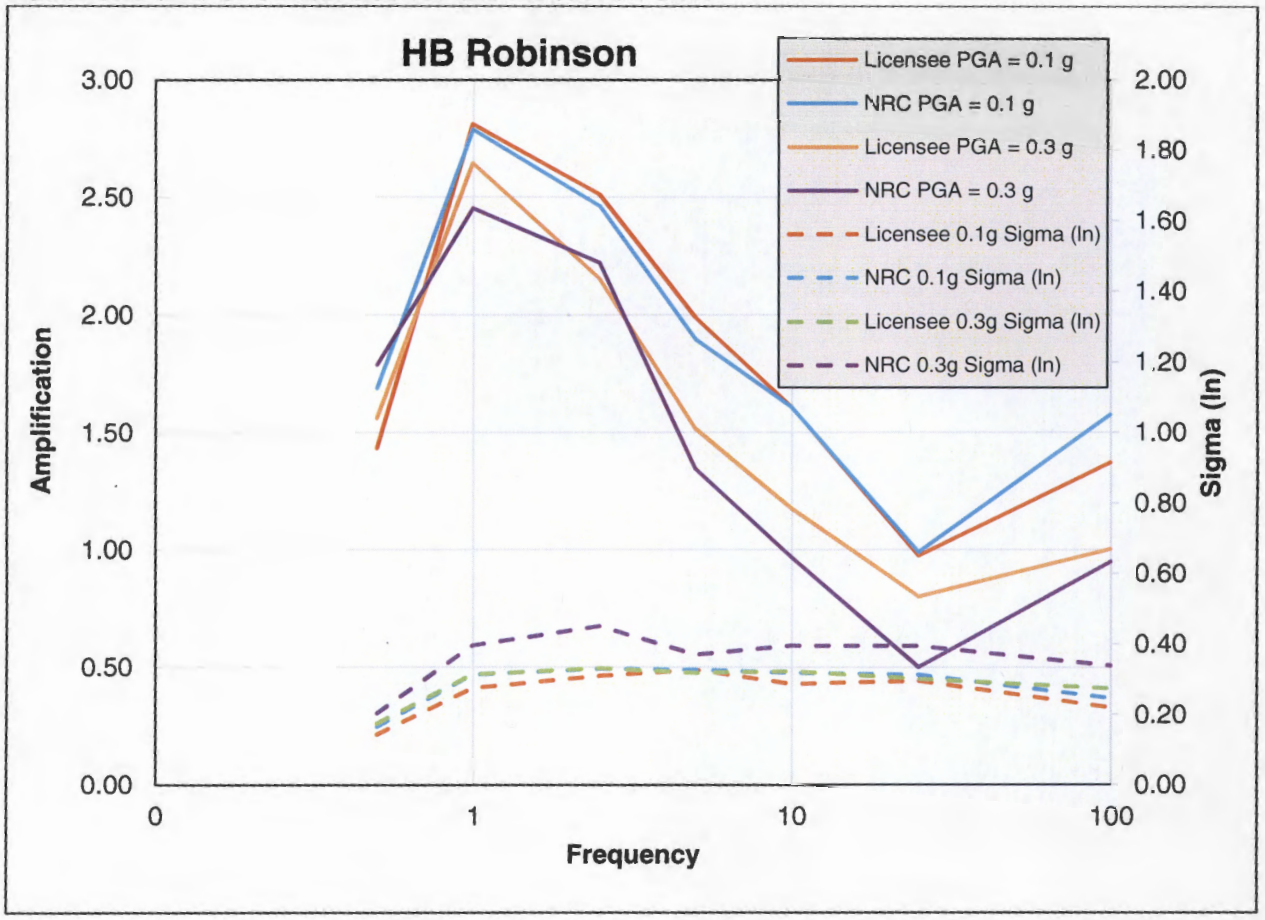


Figure 3.3-3 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Robinson site.

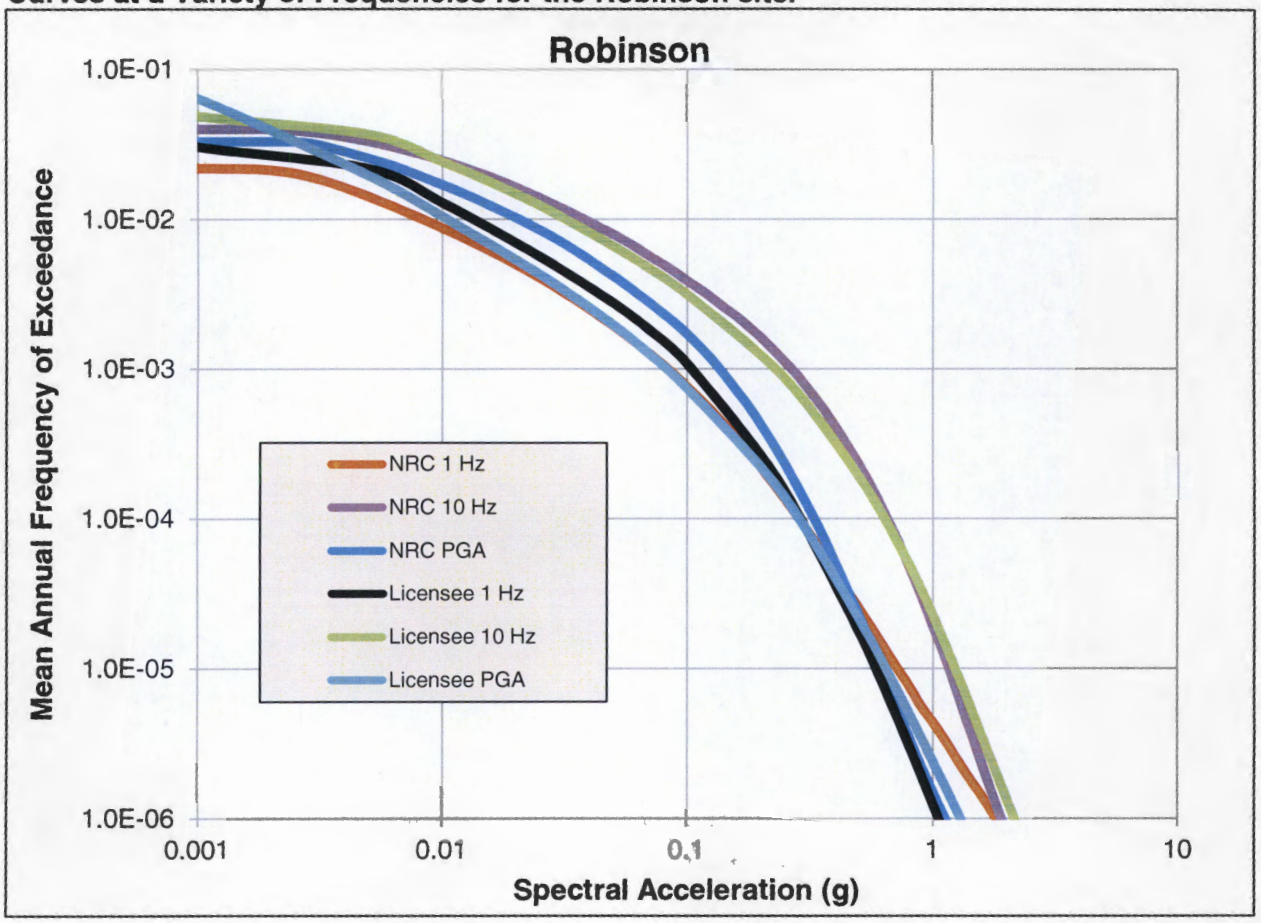
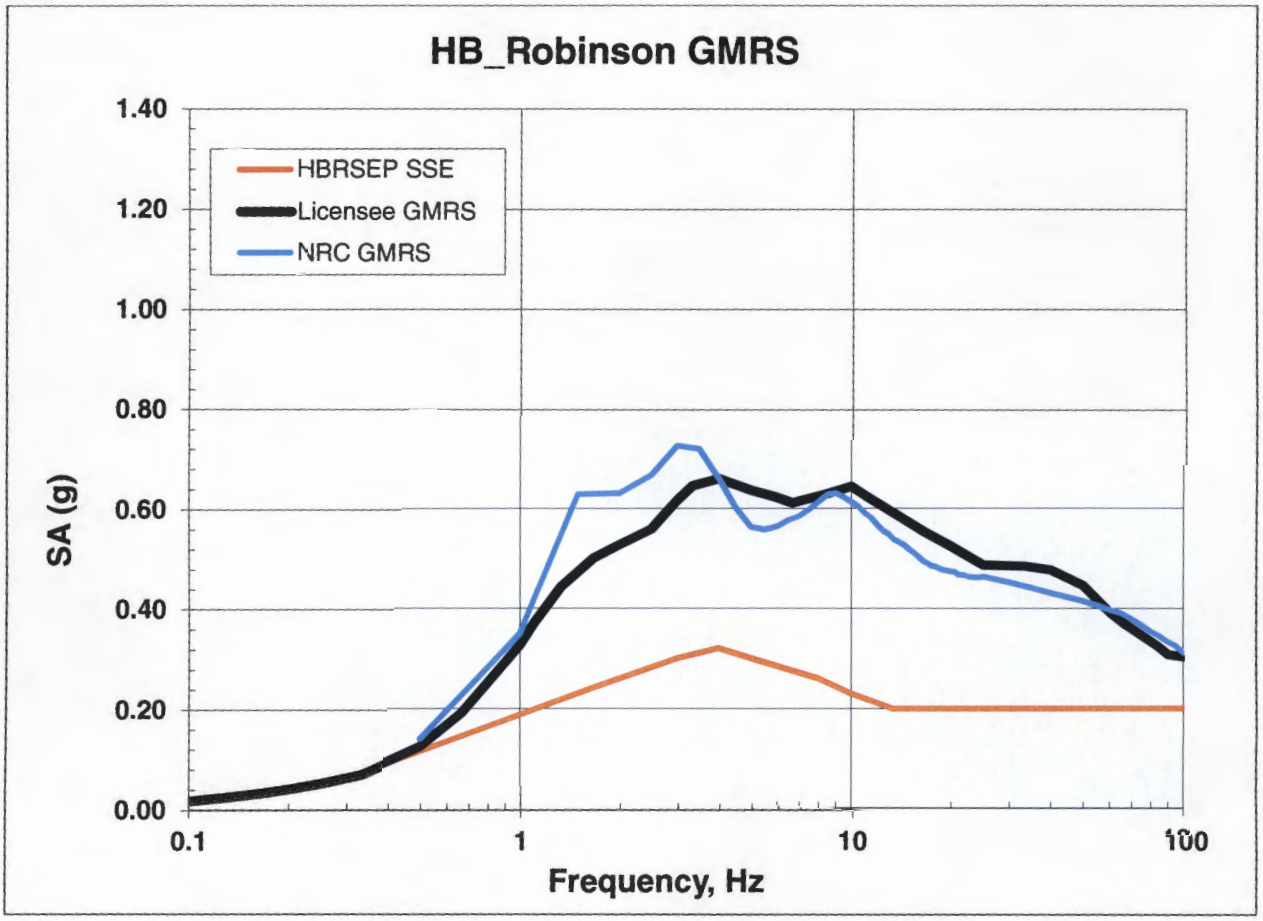


Figure 3.4-1 Comparison of the Staff's GMRS with Licensee's GMRS and the SSE for the Robinson site



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 No. 50-261

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