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

April 21, 2015

Mr. Lawrence J. Weber
Senior Vice President and Chief
Nuclear Officer
Indiana Michigan Power Company
Nuclear Generation Group
One Cook Place
Bridgman, MI 49106

SUBJECT: DONALD C. COOK NUCLEAR PLANT, 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. MF3873 AND MF3874)

Dear Mr. Weber:

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 27, 2014, Indiana Michigan Power Company (the licensee) responded to this request for Donald C. Cook Nuclear Plant, Units 1 and 2 (D.C. Cook).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazard for D.C. Cook 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 screening review portion of Item (4) of the 50.54(f) letter. Further, the staff concludes that the licensee's reevaluated seismic hazard, once adjusted to account for the sand layer (Gebbie, 2014), 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 licensee's expedited seismic evaluation process, and seismic risk evaluation including the high frequency and spent fuel pool evaluations (i.e., Items (4), (6), (8), and (9)) for D.C. Cook, 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 Vega, Project Manager
Hazards Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos. 50-315 and 50-316

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

DONALD C. COOK NUCLEAR PLANT, UNITS. 1 AND 2

DOCKET NOS. 50-315 AND 50-316

1.0 INTRODUCTION

By letter dated March 12, 2012 (NRC, 2012a), the U.S. Nuclear Regulatory Commission (NRC) 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 and taking regulatory action as a result of 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 (SRMs) 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 for screening purposes. 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 (RG) 1.208, "A Performance-based Approach to Define the Site-Specific Earthquake Ground Motion", 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 referred to as 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 (ac) 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 operating nuclear power plants. By letter dated September 12, 2013 (Gebbie, 2013), Indiana Michigan Power Company (the licensee) submitted partial site response information for Donald C. Cook Nuclear Plant, Units 1 and 2 (D.C. Cook). By letter dated March 27, 2014 (Lies, 2014), the licensee submitted its SHSR. By letter dated November 21, 2014 (Gebbie, 2014), the licensee supplemented its SHSR.

2.0 REGULATORY EVALUATION

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." 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. Generally plants with construction permits issued prior to May 21, 1971, were approved for construction based on draft GDC published by the Atomic Energy Commission (AEC).

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. According to Updated Final Safety Analysis Report (UFSAR) Chapter 1, D.C. Cook, Units 1 and 2 used draft AEC GDC when developing its seismic design basis. As described in Section 1.4 of the UFSAR, an evaluation was performed that determined the original seismic siting investigations for D.C. Cook were performed in accordance with Appendix A to 10 CFR Part 100 and meet GDC 2. 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.

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 staff issued request 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 hazard.

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 probabilistic seismic hazard analysis (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

The licensee's SHSR indicated that the plant GMRS exceeded the SSE. As such, the licensee concluded that both a plant seismic risk evaluation and a SFP evaluation are merited. Additionally, due to exceedances at frequencies above 10 Hertz (Hz), the licensee indicated that a high-frequency confirmation would be performed.

Based on the results of a July 9, 2014, public meeting (NRC, 2014a), the licensee submitted a letter dated November 21, 2014 (Gebbie, 2014) to correct an omission in the SHSR, described in Section 3.3.1 of this staff assessment, when performing the seismic risk evaluation.

On May 9, 2014 (NRC, 2014b), the staff issued a letter providing the outcome of its 30-day screening and prioritization evaluation. As indicated in the letter, in the 1 to 10 Hz region, the staff confirmed the licensee's screening results. The GMRS exceeds the SSE in the frequency range of 1 to 10 Hz. Therefore, D.C. Cook screened in for conducting a plant seismic risk evaluation. A SFP evaluation is merited also. Additionally, the staff confirmed the licensee's conclusion that a high-frequency confirmation for D.C. Cook is merited because the GMRS exceeds the SSE above 10 Hz.

3.0 TECHNICAL EVALUATION

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

3.1 Plant Seismic Design Basis

Enclosure 1 of the 50.54(f) letter requests the licensee provide the SSE ground motion values, as well as the specification of the control point elevation(s) for comparison to the GMRS. For operating reactors licensed before 1997, the SSE is the plant licensing basis ground motion 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 the SHSR, the licensee described its seismic design basis. The licensee stated that the design-basis for D.C. Cook was determined by considering the largest historical earthquake felt at the site. The maximum earthquake considered was a magnitude 5 occurring within the upper 6.2 mi (10 km) of crust near the site. Based on these considerations, the licensee anchored the SSE at 0.2 g (20 percent of the acceleration of earth's gravity). The SSE spectrum is a smoothed version of the 1940 El Centro, California, earthquake scaled to the PGA acceleration of 0.2 g. The licensee stated that the control point is located at elevation 587.4 ft (179 m). In the absence of a control point definition in the UFSAR (Indiana Michigan Power, 2010), the licensee relied on internal documents for structural models, along with guidance in the SPID, to identify the control point elevation.

The staff reviewed the licensee's description of the SSE for D.C. Cook and confirms that the SSE, as described in the SHSR, is consistent with information provided in the UFSAR. Additionally, the staff confirms that the licensee's SSE control point elevation is consistent with information provided in the D.C. Cook UFSAR and 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 50.54(f) letter and the SPID, it performed a PSHA using the CEUS-SSC model and the updated EPRI GMM for the CEUS. The licensee used a minimum magnitude cutoff of (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 mi (640 km) around the site and included the Commerce, Eastern Rift Margin – North, Eastern Rift Margin – South, Marianna, New Madrid Fault System, and Wabash Valley repeated large magnitude earthquake (RLME) sources, which lie within 620 mi (1,000 km) of the site. RLMEs are those source areas or faults for which more than one large magnitude (M ≥ 6.5) earthquake has occurred in the historical or paleoearthquake (geologic evidence for prehistoric seismicity) record. The licensee used the mid-continent version of the updated EPRI GMM for each of the CEUS-SSC sources. Consistent with the SPID, the licensee did not provide its base rock seismic hazard curves since a site response analysis is necessary to determine the control point seismic hazard curves. The licensee provided its control point seismic hazard curves in Section 2.3.7 of its SHSR. The staff's review of the licensee's control point seismic hazard curves is provided in Section 3.3 of this staff assessment.

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

GMM (EPRI, 2013). Consistent with the guidance provided in the SPID, and the licensee's approach, the staff included all of the CEUS-SSC background seismic sources within a 310 mi (500 km) radius of the D.C. Cook site. In addition, the staff included the Commerce, Eastern Rift Margin – North, Eastern Rift Margin – South, Marianna, New Madrid Fault System, and Wabash Valley RLME sources, which lie within 620 mi (1,000 km) of the site. For each of the CEUS-SSC sources used in the confirmatory PSHA, the staff used the mid-continent version of the updated EPRI GMM. The staff used the resulting base rock seismic hazard curves together with a confirmatory site response analysis, described in the next section, to develop control point seismic hazard curves and a GMRS for comparison with the licensee's results.

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

3.3 Site Response Evaluation

After completing PSHA calculations for reference rock site conditions, Attachment 1 to Enclosure 1 of the 50.54(f) letter requests that 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 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 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 the SHSR based on information provided in the D.C. Cook UFSAR. The licensee stated that the site is underlain by approximately 171 ft (52 m) of soils over approximately 3,200 ft (975 m) of sedimentary rocks consisting of shales, limestones, sandstones, and dolomites. The soils are characterized by 34 ft (10 m) of dense beach sands over 137 ft (42 m) of lacustrine silts and clays.

Geophysical investigations for the D.C. Cook site included seismic refraction profiles and up-hole compressional-wave seismic velocity measurements. In order to convert the measured compressional-wave velocities to shear-wave velocities, the licensee used an assumed Poisson ratio (a measure of compressional- to shear-wave velocities). The licensee used the shear-wave velocity estimates, along with guidance provided in the SPID, to develop two sets of three best-estimate profiles. For the first set of best-estimate profiles, the licensee assumed that reference rock, defined by a shear-wave velocity greater than 9,285 ft/s (2,830 m/s), occurs at the top of the sedimentary rock section. The licensee based the second set of best-estimate profiles on the assumption that the entire sedimentary section could be modeled with a shear-wave velocity of 5,000 ft/s (1,524 m/s) and reference rock occurs at the top of the Precambrian crystalline rock. For both sets of best-estimate profiles, the licensee developed upper and lower base case profiles using a natural log standard deviation of 0.35 following the guidance in the SPID. The licensee's approach to developing base case shear-wave velocity profiles produced six profiles, rather than the three specified in the SPID. The licensee justified this approach by stating that the lack of geophysical data from the sedimentary rocks beneath the site meant that additional epistemic uncertainty in the depth to reference rock was necessary.

For all six base case profiles, the licensee inadvertently omitted the thin layer of beach sands in its velocity profiles. This omission resulted in total profile thicknesses of 127 ft (39 m) and 3,387 ft (1,032 m) instead of 161 ft (49 m) and 3,421 ft (1,043 m) for the shallow and deep base cases respectively. In its letter dated November 21, 2014 (Gebbie, 2014), the licensee committed to including the 34 ft (10 m) layer of beach sands in future risk evaluation activities.
To model the potential non-linear behavior of the soil and rock layers, the licensee used two sets of shear modulus and damping curves for each set of profiles. For the three profiles in which reference rock conditions occur directly beneath the soil layers, the licensee considered two alternatives for non-linear dynamic material properties. The licensee used the EPRI (1993) model for cohesionless soils for one model and the Peninsular Range dynamic material curves for the other model. The licensee weighted these alternative material behaviors equally, assigning 50 percent to each case.

For the three profiles with reference rock conditions at greater depth, the licensee used the same dynamic material properties for the uppermost soil portion of the profile. For the upper 373 ft (114 m) of rock below the soil layers, the licensee modeled the rock behavior as either linear or non-linear. To model the potential non-linear dynamic material properties, the licensee used the EPRI (1993) rock dynamic material curves. To model the linear behavior of the rock, the licensee used the low strain damping values (approximately 3 percent) from the EPRI rock curves for each of the rock layers. The licensee weighted these alternative material behaviors equally, assigning 50 percent to each case.

The licensee also considered the impact of kappa, or small strain damping, on site response. Kappa is measured in units of seconds (sec), and is the damping contributed by both intrinsic hysteretic damping as well as scattering due to wave propagation in heterogeneous material. The licensee calculated kappa for each profile independently, resulting in six kappa estimates. For the set of profiles with reference rock located at the top of the sedimentary rocks, the licensee used the low strain damping values from the Peninsular Range soil damping curves (approximately 1 percent) over the 127 ft (39 m) of the soil profile to calculate the soil contribution to kappa. For the set of profiles with reference rock located at the base of the sedimentary rock section, the licensee used the low strain damping values from the EPRI cohesionless soil damping curves over the upper 127 ft (39 m) to calculate the kappa contribution from the soil. The licensee used the low strain damping values (approximately 3 percent) from the EPRI rock curves over the upper 373 ft (114 m) of rock and a damping value of 1.25 percent over the remainder of the profile. In addition to considering the kappa contribution from the soil and sedimentary rocks underlying the site, the licensee added an additional 0.006 sec to account for damping in the reference rock material. Kappa values for the profiles with reference rock located at the top of the sedimentary sections are 0.008, 0.007, and 0.009 sec, respectively, for the best-estimate, upper and lower base case profiles. For the profiles with reference rock located at the base of the sedimentary section, kappa values are 0.024, 0.016, and 0.034 sec for the best-estimate, upper and lower base case profiles, respectively.

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, consistent with the SPID. For the profiles with reference rock at a depth of 3,387 ft (1,032 m), the licensee stated that it also randomized the depth to reference rock ±1,016 ft (310 m), which corresponds to 35 percent of the total thickness. The licensee stated that this randomization did not represent actual uncertainty in the depth to reference rock, but was used to broaden the spectral peaks. For the base case profiles with reference rock located at the top of rock, the licensee did not randomize the depth to reference rock.

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 associate uncertainties for two of the eleven input loading levels for the each base case profile. The shallow base case profile is shown with EPRI cohesionless soil damping and the deep base case profile is shown with EPRI cohesionless soil and generic 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 Section 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 reference rock hazard curves, determined from the initial PSHA (Section 3.2 of this assessment), and the amplification function and their associated uncertainties, determined from the site response analysis.

3.3.3 Staff Confirmatory Analysis

To confirm the licensee's site response analysis, the staff performed site response calculations for the D.C. Cook site. The 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 D.C. Cook UFSAR, the nearby Palisades Nuclear Power Plant UFSAR (Entergy, 2011), and Appendix B of the SPID. For its site response calculations, the staff employed the RVT approach and developed input ground motions in accordance with Appendix B of the SPID.

In following the guidance provided in the SPID for sites with less subsurface information, the staff independently determined best-estimate and upper and lower base case shear-wave velocity profiles. The staff based its best-estimate velocity profile on information provided in the D.C. Cook UFSAR and guidance provided in the SPID. The staff modeled the upper 137 ft (42 m) of the profile as beach sand and lake deposits, and the sedimentary rocks underlying the surface soils assuming that the uppermost portions had a best-estimate shear-wave velocity of 6,000 ft/s (1,829 m/s) with a velocity gradient of 0.6 ft/s/ft. The staff used a natural log standard deviation of 0.35 to calculate upper and lower base case velocity profiles in the soil layers and a natural log standard deviation of 0.25 to calculate upper and lower base case velocity profiles in the rock layers. Figure 3.3-1 of this assessment shows a comparison of the six velocity profiles developed by the licensee with the three developed by the staff. The profiles developed by the licensee are more heavily weighted towards higher velocities because three profiles have shallower depths to reference rock. In contrast, all of the staff's profiles have reference rock at greater depth. The velocity profiles developed by the staff are somewhat higher than the second set of profiles developed by the licensee with reference rock at the base of the sedimentary rock section. The staff randomized the depth to reference rock by ±10 percent to allow for additional uncertainty.

Similar to the approach used by the licensee, the staff assumed both linear and non-linear behavior for the materials beneath D.C. Cook in response to the range of input motions. The staff developed two damping profiles that incorporate different degrees of non-linearity using assumptions consistent with those of the licensee.

To determine kappa for its three profiles, the staff used the low strain damping values, shear wave velocities, and layer thicknesses for each geologic layer to arrive at values of 0.020, 0.026 sec, and 0.007 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 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 0.006 to 0.031 sec.

Figure 3.3-2 of this assessment shows a comparison of the staff's and licensee's median site amplification function and uncertainties (±1 standard deviation) for two of the eleven input loading levels. Peaks in amplification functions occur between 3 Hz and 9 Hz in both staff and licensee curves. Differences in the amplification functions developed by the staff and licensee are due to the licensee's use of six profiles, as described above, with three of the six profiles having reference rock directly beneath the soil layers.

The licensee's approach to modeling the subsurface rock properties and their uncertainty results in lower site amplification factors than those produced by the staff, particularly at high frequencies. As shown in Figure 3.3-3 of this assessment, these differences in site response analysis have a relatively minor impact on the 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 this application.

In summary, the staff concludes that the licensee's site response was conducted using present-day guidance and methodology, including the NRC-endorsed SPID. The 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 D.C. Cook site.

3.4 Ground Motion Response Spectra

In Section 2.4 of the 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 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, respectively. Figure 3.4-1 of this assessment shows a comparison of the GMRS determined by the licensee to that determined by the staff.

As shown in Figure 3.4-1 below, the licensee's GMRS shape is generally similar to that calculated by the staff with minor differences in the location and shape of spectral peaks in GMRS. These differences in GMRS are small and are the result of differences in the site response analyses performed by the licensee and staff discussed in Section 3.3 above. The staff concludes that these differences are acceptable for this application because the licensee followed the guidance provided in the SPID with respect to both the PSHA and site response analysis for the D.C. Cook site. The exception to this is the absence of the sand layer in the licensee's site response analysis, which the licensee has committed to including for future risk evaluation activities (Gebbie, 2014). Given that the sand layer was accounted for in the staff's site response confirmatory analysis and the results obtained were consistent to those obtained by the licensee, the staff does not expect any major changes between the hazard curves submitted for this application and the recalculated hazard curves expected to be used for future risk evaluations.

The 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 staff performed both a PSHA and site response confirmatory analysis and achieved results consistent with the licensee's horizontal GMRS. As such, the staff concludes that the GMRS determined by the licensee adequately characterizes the reevaluated hazard for the D.C. Cook site. Therefore, the GMRS with the sand layer accounted for, 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 D.C. Cook site. Based on its review, the staff concludes that the licensee conducted the seismic 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 on the preceding analysis, the NRC staff concludes that the license provided an acceptable response to Requested Information Items (1) – (3), (5) and (7) and screening review portion of Item (4), identified in Enclosure 1 of the 50.54(f) letter. Further, the licensee's reevaluated seismic hazard, once adjusted to account for the sand layer (Gebbie, 2014), is suitable for other activities associated with NTTF Recommendation 2.1, "Seismic".

In reaching this determination, the staff confirmed the licensee's conclusion that the licensee's GMRS exceeds the SSE for the D.C. Cook site in the frequency range of 3.5 to 100 Hz. As such, a plant seismic risk evaluation, SFP evaluation, and high-frequency confirmation are merited for D.C. Cook, Units 1 and 2. The licensee indicated that the high frequency confirmation can be addressed in the risk evaluation. NRC review and acceptance of the licensee's ESEP interim evaluation and seismic risk evaluation with the high frequency and spent fuel pool evaluations (i.e., Items (4), (6), (8), and (9)) for D.C. Cook 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 the Staff's and Licensee's Base Case Shear-Wave Velocity Profiles. Shallow and Deep Refer to a Depth to Reference rock of 127 ft (39 m) and 3,387 ft (337 m) Respectively for the DC Cook site

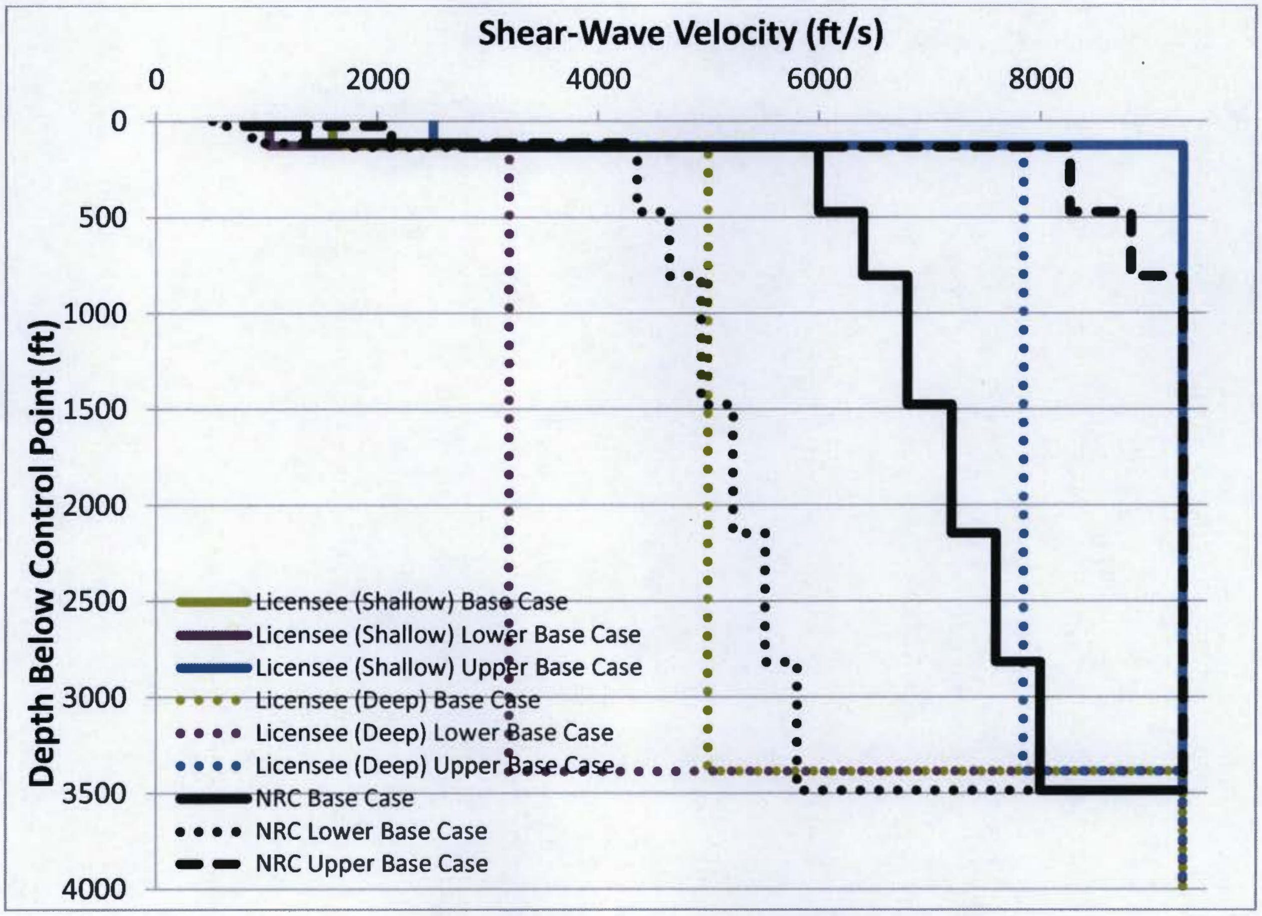


Figure 3.3-1 Plot Comparing the Staff's and the License's Median Amplification Functions and Uncertainties.

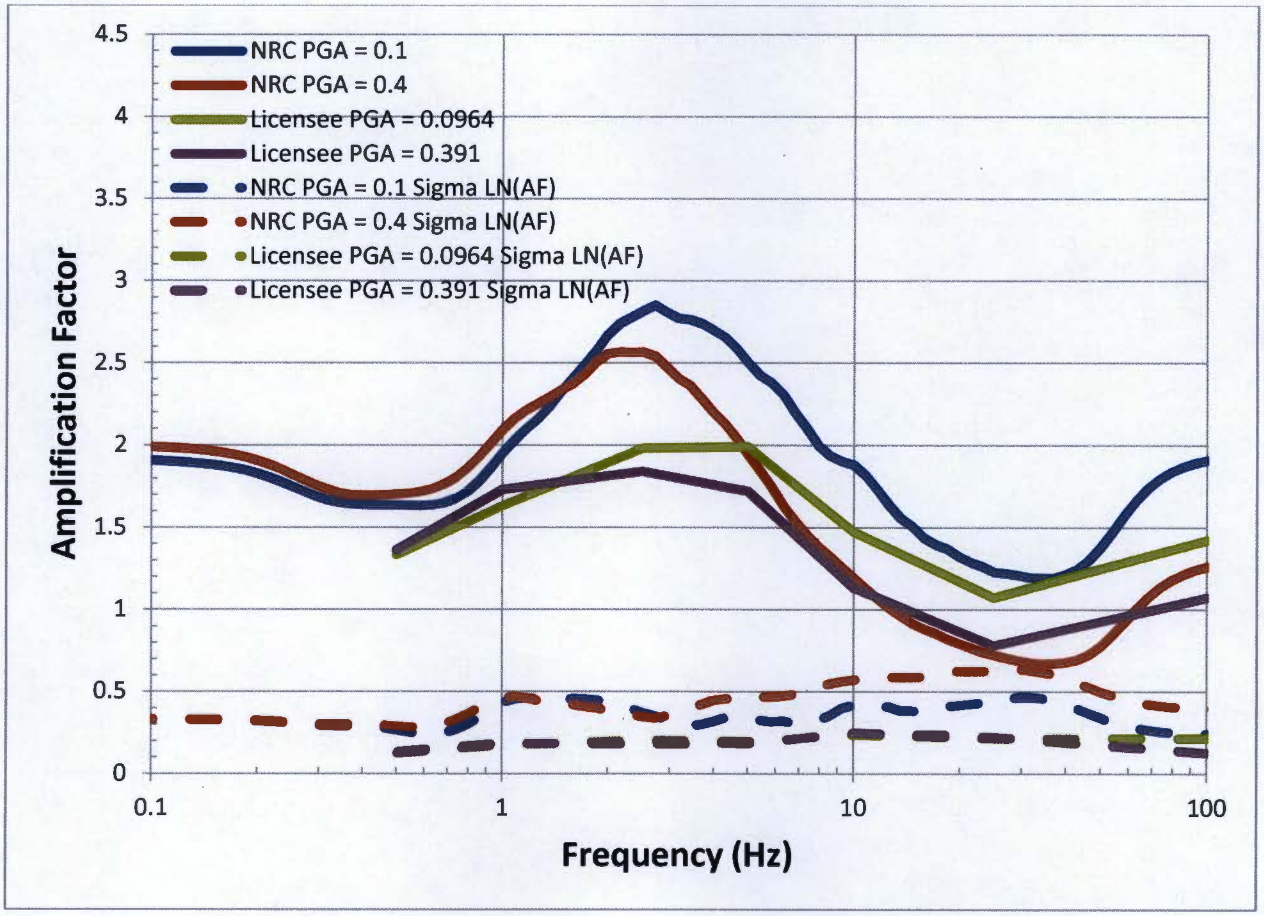


Figure 3.3-2 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the DC Cook site

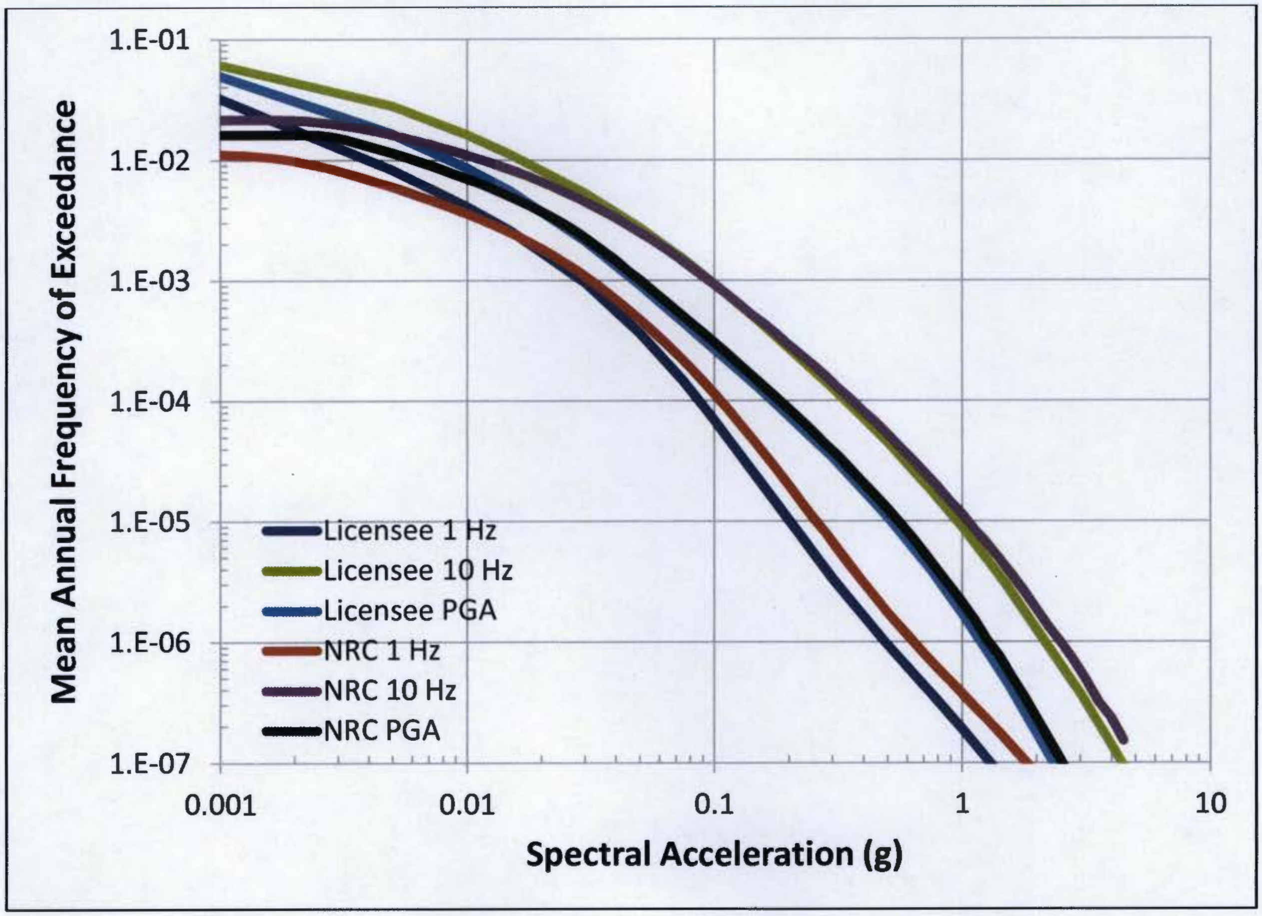
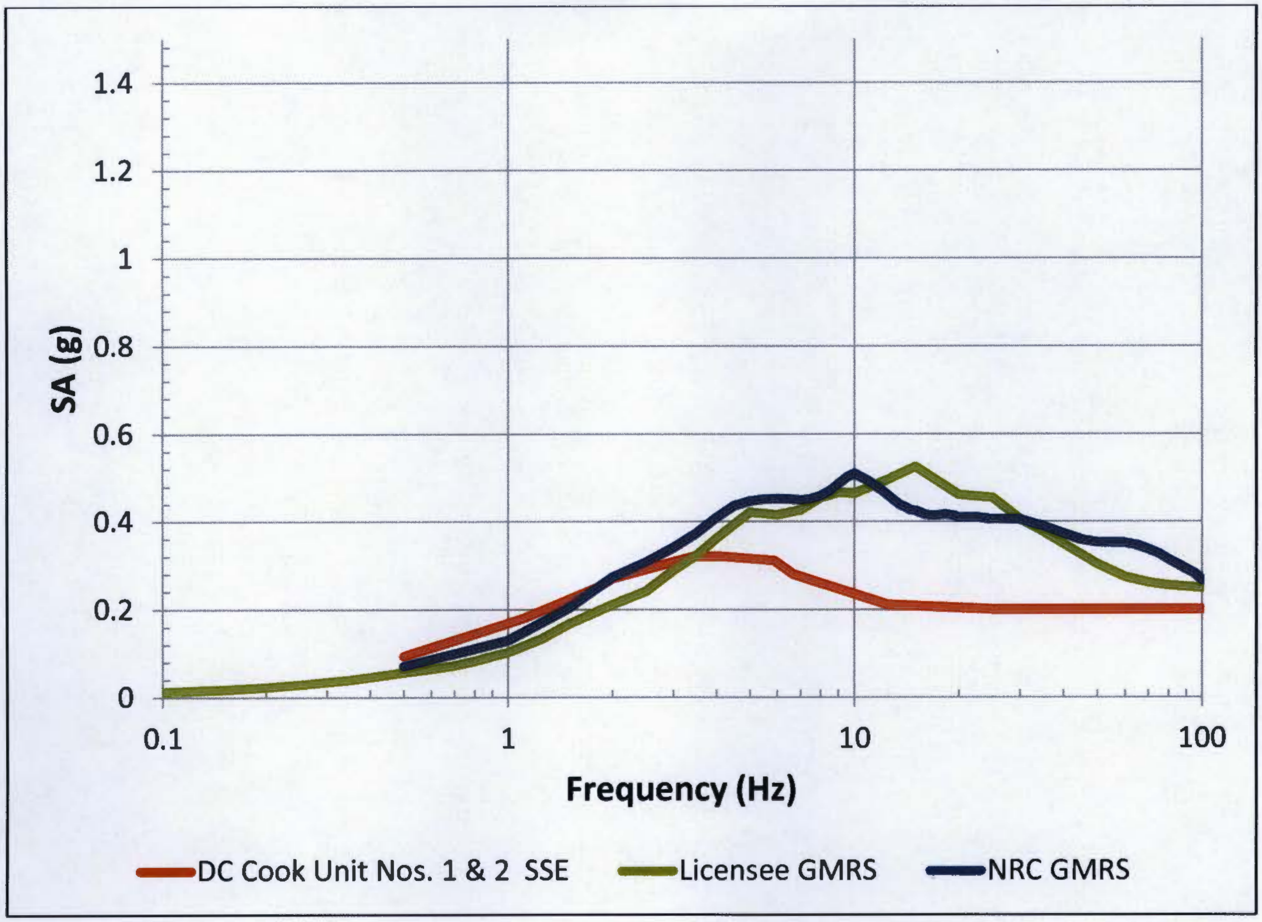


Figure 3.4-1 Comparison of the Staff's GMRS with Licensee's GMRS and the DC Cook Unit Nos. 1 and 2 SSE



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

Sincerely,

/RA/

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

Docket Nos. 50-315 and 50-316

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