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

April 30, 2015

Vice President, Operations
Entergy Nuclear Operations, Inc.
Palisades Nuclear Plant
27780 Blue Star Memorial Highway
Covert, MI 49043-9530

SUBJECT: PALISADES NUCLEAR PLANT- STAFF ASSESSMENT OF INFORMATION PROVIDED PURSUANT TO TITLE 10 OF THE *CODE OF FEDERAL REGULATIONS* PART 50, SECTION 50.54(f), SEISMIC HAZARD REEVALUATIONS RELATING TO RECOMMENDATION 2.1 OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT (TAC NO. MF3786)

Dear Sir or Madam:

By letter dated 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, Entergy Nuclear Operations, Inc. (Entergy) responded to this request for Palisades Nuclear Plant (Palisades).

The NRC staff has reviewed the information provided related to the reevaluated seismic hazards for Palisades and, as documented in the enclosed staff assessment, determined that you provided sufficient information in response to Requested Information Items (1) – (3), (5), (7), and a partial response to Item (4), identified in Enclosure 1 of the 50.54(f) letter. Further, the staff concludes that Entergy's reevaluated seismic hazard for Palisades is suitable for other activities associated with the NRC Near-Term Task Force Recommendation 2.1, "Seismic."

Contingent upon the NRC's review and acceptance of Entergy'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 Palisades, the sesimc hazard evaluation identified in Enclosure 1 of the 50.54(f) letter will be complete.

If you have any questions, please contact me at (301) 415-6197 or via e-mail at Tekia.Govan@nrc.gov.

Sincerely,

Tekia V. Govan

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

Docket No. 50-255

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

PALISADES NUCLEAR PLANT

DOCKET NO. 50-255

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 (If the GMRS is completely bounded by the SSE, an interim action plan or risk evaluation is not necessary. However if the GMRS exceeds the SSE only at higher frequencies, information related to the functionality of high-frequency sensitive SSCs is requested),

(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 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 GMMfor use by CEUS plants in developing a plant-specific GMRS.

By letter dated April 9, 2013 (Pietrangelo, 2013), industry agreed to follow the SPID to develop the SHSR for existing nuclear power plants. By letter dated September 11, 2013 (Vitale, 2013), Entergy Nuclear Operations, Inc. (the licensee, Entergy) submitted at least partial site response information for Palisades Nuclear Plant (Palisades). By letter dated March 31, 2014 (Vitale, 2014), the licensee submitted 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.

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).

The Palisades design bases was developed in accordance with accepted industry practices that existed at the time when their construction permit was issued in 1967. The licensee at that time performed an evaluation of their design bases against the draft proposed "General Design Criteria for Nuclear Power Plant Construction Permits" issued by the Atomic Energy Commission in July 1967. The design bases was later evaluated against the final "General Design Criteria for Nuclear Power Plants," published as 10 CFR 50, Appendix A in July 1971. It was determined that the the design bases for Palisades meets the intent of GDC 2 and is consistent with 10 CFR Part 100.

Section 50.54(f) of 10 CFR states that a licensee shall at any time before expiration of its license, upon request of the Commission, submit written statements, signed under oath or affirmation, to enable the Commission to determine whether or not the license should be modified, suspended, or revoked. On March 12, 2012, the NRC staff issued requests for licensees to reevaluate the seismic hazards at their sites using present-day NRC requirements and guidance, and identify actions planned to address plant-specific vulnerabilities associated with the updated seismic hazards.

Attachment 1 to Enclosure 1 of the 50.54(f) letter described an acceptable approach for performing the seismic hazard reevaluation for plants located in the CEUS. Licensees are expected to use the CEUS Seismic Source Characterization (CEUS-SSC) model in NUREG-2115 (NRC, 2012b) along with the appropriate EPRI (2004, 2006) GMM. The SPID provided further guidance regarding the appropriate use of GMMs for the CEUS. Specifically, Section 2.3 of the SPID recommended the use of the updated GMM (EPRI, 2013) and, as such, licensees used the NRC-endorsed updated EPRI GMM instead of the older EPRI (2004, 2006) GMM to develop PSHA base rock hazard curves. Finally, Attachment 1 requested that licensees conduct an evaluation of the local site response in order to develop site-specific hazard curves and GMRS for comparison with the plant SSE.

2.1 Screening Evaluation Results

By letter dated March 31, 2014 (Vitale, 2014), the licensee provided the SHSR for Palisades. The licensee's SHSR indicated that the plant GMRS exceeded the SSE. The licensee stated that a seismic risk evaluation will be performed. Also, a SFP evaluation will be performed. Additionally, due to exceedances at frequencies above 10 Hertz (Hz), the licensee indicated that a high-frequency confirmation will be performed.

On May 9, 2014 (NRC, 2014), the staff issued a letter providing the outcome of its 30-day screening and prioritization evaluation. As indicated in the letter, the staff confirmed the licensee's screening results. The GMRS exceeds the SSE in the frequency range of 1 to 10 Hz. Therefore, Palisades screened in for conducting a plant seismic risk evaluation. A SFP evaluation is also merited. Additionally, the staff confirmed the licensee's conclusion that a high-frequency confirmation for Palisades 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 requested 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 3.1 of the SHSR, the licensee described its seismic design-basis for Palisades. The licensee stated that the design-basis of Palisades was determined by considering the maximum earthquake potential for the region surrounding the site. The response spectrum for Palisades is anchored at 0.2 g (20 percent the acceleration of earth's gravity) with a spectral shape referred to as the Housner spectrum, which represents the average of several observed earthquake spectra that have been normalized to the same PGA and enveloped to produce a smooth spectrum. The licensee specified that the control point is located at the plant grade elevation which corresponds to 589 ft (180 m) above mean sea level at the reactor building.

Based on the review of the licensee's submittal and the updated final safety analysis report (UFSAR), the staff confirms that the licensee's SSE control point elevation determination is consistent with information provided in the Palisades UFSAR, as well as guidance in the SPID.

3.2 Probabilistic Seismic Hazard Analysis

In Section 2.2 of the 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 cutoff of **M**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 Palisades. 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 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 the 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 Palisades 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 CEUS-SSC background seismic sources within a 310 mi (500 km) radius of the Palisades site. In addition, the staff included the Commerce, Eastern Rift Margin-North, Eastern Rift Margin-South, New Madrid Fault System, and Wabash Valley RLME sources, which lie within 620 km (1,000 mi) of the Palisades site. For each of the CEUS-SSC sources used in the PSHA, the staff used the mid-continent version of the updated EPRI GMM.

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 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 GMMs used in the PSHA. To develop site-specific hazard curves at the control point elevation, Attachment 1 requests that licensees perform a site response analysis.

Detailed site response analyses were not typically performed for many of the older operating plants; therefore, Appendix B of the SPID provides detailed guidance on the development of site-specific amplification factors (including the treatment of uncertainty) for sites that do not have detailed, measured soil and rock parameters to extensive depths.

The purpose of the site response analysis is to determine the site amplification that 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

In its SHSR, the licensee indicated that it performed a site response analysis for Palisades. According to the licensee, the current site grade exists at approximately elevation 589 ft (180 m) and rests on dense to very dense dune sand which extends approximately 25 ft (m) deep. Below this is approximately 23 ft (7 m) of grey, fine-grained silty sand and 22 ft (7 m) of grey, stiff clay overlying 78 ft (24 m) of glacial till. Below these surficial deposits is the Mississippian Age (359 – 318 Ma) Coldwater Shale. According to the licensee, Precambrian crystalline rock lies at an approximate depth of 3,238 ft (987 m).

The licensee provided site profile descriptions in Sections 2.3.1 and 2.3.2 of its SHSR based on information in the Palisades UFSAR (Entergy, 2012). The licensee stated that the site is underlain by approximately 25 ft (8 m) of very dense dune sand overlying 23 ft (7 m) of silty sand, 22 ft (7 m) of gray, stiff clay and 78 ft (24 m) of glacial till. Bedrock at the site, which underlies these surficial soils, is the Mississippian Age (359 – 318 Ma) Coldwater Shale. According to the licensee, Precambrian crystalline rock lies at an approximate depth of 3,238 ft (987 m) below the surface.

Due to the limited geophysical data that was collected at the site during initial construction, the licensee used compressional-wave measurements and an assumed Poisson ratio (a measure of compressional- to shear-wave velocity ratio) to estimate the shear-wave velocities of the site. The licensee used the shear-wave velocity estimates, along with guidance provided in the SPID, to develop two best-estimate profiles. For the first best-estimate profile, the licensee assumed that reference rock, defined by a shear-wave velocity of 9,285 ft/s (2,830 m/s), occurs at a depth of 148 ft (45 m) below the control point, at the top of the sedimentary rock section. The licensee based the second best-estimate profile on the assumption that the entire sedimentary section could be modeled with a shear wave velocity of 5,000 ft/s (1,424 m/s) with reference rock occurring at the top of the Precambrian crystalline rock. For both best-estimate profiles, the licensee developed upper and lower base case profiles using a natural log standard deviation of 0.35, following guidance in the SPID. This approach to developing base case profiles results in six profiles, rather than the three recommended 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.

Because the seismic velocities of the site are different from the generic reference rock velocity used in the PSHA, a site-specific model of shear modulus degradation and damping is required. However, the licensee stated that no site-specific dynamic material properties were determined during the initial investigations of the Palisades site. Therefore, the licensee selected two alternative characterizations of dynamic material behavior following guidance provided in the SPID for each best-estimate profile and associated upper and lower base case models.

For the best-estimate shear wave velocity model in which reference rock conditions occur at the top of the sedimentary rock section, the licensee considered two alternatives for non-linear dynamic material properties. The licensee used the EPRI model for cohesionless soils for one model and the Peninsular Range dynamic material curves for the other model. The licensee weighted these alternatives equally, assigning 50 percent to each case. For the best-estimate profile with reference rock conditions at greater depth, the licensee used the same dynamic material properties for the soil portion of the site. For the upper 352 ft (107 m) of rock, the licensee assumed that the rock material could be modeled as either behaving linearly or non-linearly. To model the potential non-linear dynamic material properties, the licensee used the EPRI rock dynamic material curves. To model the linear behavior over the upper 352 ft (107 m) of 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 alternatives 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 rock section, the licensee used the low strain damping values from the EPRI soil damping curves (approximately 3 percent) over the 148 ft (45 m) of the soil profile. The licensee also added an additional kappa of 0.006 sec to account for the damping in the underlying reference rock material. For the best-estimate profile in which reference rock conditions 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 148 ft (45 m) to calculate the kappa contribution from the soil. The licensee used the low strain damping values from the EPRI rock curves (approximately 3 percent) over the upper 352 ft (107 m) of rock material and assumed 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 section were 0.009, 0.008, and 0.010 for the best-estimate, upper and lower base case profiles respectively. For the profiles with reference rock located at the base of the sedimentary section, kappa values were 0.013, 0.019, and 0.038 sec for the best-estimate, upper, and lower base cases, 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 in accordance with Appendix B of the SPID. For the profiles with reference rock at a depth of 3,238 ft (987 m), the licensee stated that it also randomized the depth to reference rock ±971 ft (296 m), which corresponds to 30 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 peak. 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 both EPRI cohesionless soil damping Peninsular Range damping 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 Palisades 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 Palisades UFSAR (Entergy, 2011), the nearby Donald C. Cook Nuclear Plant UFSAR (Indiana Michigan Power, 2010), 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.

Following guidance provided in the SPID for sites with little at-site information, the staff independently determined a best-estimate and upper and lower base case profiles using guidance provided in the SPID and information provided in the Palisades UFSAR, the Donald C. Cook UFSAR, and literature sources. The staff modeled the upper 45 ft (14 m) of the profile as very dense dune sands and silty sands with a best-estimate shear-wave velocity of 1,360 ft/s (415 m/s). Below the sand layers, the staff modeled 90 ft (27 m) of glacial till with a best-estimate shear-wave velocity of 2,728 ft/s (831 m/s) overlying the sedimentary rocks, which have a best-estimate shear-wave velocity of 5,620 ft/s (1,713 m/s). Due to the lack of detailed stratigraphy and geophysical data, the staff assumed a shear-wave velocity gradient of 0.7 ft/s/ft for the sedimentary rock section and based its best-estimate shear-wave velocities on the General Atomic Site Parameter Study (Leeds, 1974). The staff used a natural log standard deviation of 0.35 to calculate upper and lower base-case profiles in the soil layers and a natural log standard deviation of 0.25 to calculate upper and lower base-case profiles in the rock layers. Staff used information provided in Fisher, et al. (1988) to determine a best-estimate depth to reference rock of 4,295 ft (1,309 m). Figure 3.3-1 of this staff 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 of the six profiles have shallow depths to reference rock. With the exception of the sand layers, the velocity profiles developed by the staff are higher than those developed by the licensee for reference rock located at the base of the sedimentary section. The staff randomized the depth to reference rock by ±15 percent to account for additional uncertainty.

Similar to the approach used by the licensee, the staff assumed both linear and non-linear behavior for the materials beneath the Palisades site in response to the range of input ground motions. The staff developed two damping profiles that incorporate different degrees of non-linearity. The staff used the same damping curves as the licensee when developing the soil profile. However, for the rock layers, the staff assumed that the rock would behave linearly under all loading levels and assumed a constant damping value of 1.25 percent. The staff weighted each of these alternatives equally in the site response analysis.

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 a value of 0.022, 0.028, and 0.012 sec, for the best-estimate, lower, and upper base case velocity profiles, respectively. These values include the 0.006 sec contribution from the reference rock. To model the uncertainty in the kappa values determined in the staff's analysis, the staff used a natural log standard deviation of 0.15 to calculate lower and upper values of kappa for each profile. This approach resulted in nine kappa values for use in the site response analysis, which range from 0.01 to 0.034 sec. Based on staff's confirmatory calculations of the licensee's inputs, kappa values for the profile with reference rock located at the base of the sedimentary section should be 0.026, 0.019, and 0.038 for the best-estimate, upper, and lower base case profile respectively rather than the reported 0.013, 0.019, and 0.038 sec. Staff's confirmatory analysis found that the licensee used the correct values and the reported value of 0.013 sec for this for the best-estimate profile was a typographical error.

Figure 3.3-2 of this assessment shows a comparison on the staff's and the licensee's median site amplification functions and associated uncertainties (±1 standard deviation) for two of the eleven input loading levels. Peaks in amplification functions occur between approximately 1 and 5 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 higher amplification factors at low and high frequencies compared to those developed by the staff. As shown in Figure 3.3-3 of this assessment, these differences in site response analysis have a moderate impact on the control point seismic hazard curves and the resulting GMRS as discussed below. Specifically, hazard curves developed by the licensee are higher than those developed by the staff at 1.0 Hz, but consistent at other frequencies. These differences are the result of differences in site response analysis. 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, alternative 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 to confirm that the licensee's amplification factors and control point hazard curves adequately characterize the site response, including the uncertainty associated with the subsurface material properties, for the Palisades 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) an 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 of this assessment, the licensee's GMRS shape is generally similar to that calculated by the staff. At frequencies where the amplitude of the GMRS determined by the licensee is different from that determined by the staff, the licensee's generally exceeds that of the staff. These differences in GMRS are the result of differences in the site response analyses performed by the licensee and staff, as 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 Palisades site.

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 Palisades site. Therefore, this GMRS is suitable for use in subsequent evaluations and confirmations, as needed, for the licensee's response to the 50.54(f) letter, dated March 12, 2012.

4.0 CONCLUSION

The NRC staff reviewed the information provided by the licensee for the reevaluated seismic hazard for the Palisades 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 licensee provided an acceptable response to Requested Information Items (1) – (3), (5), and (7) and a partial response 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 staff confirmed the licensee's conclusion that the licensee's GMRS exceeds the SSE for the Palisades site in the frequency range of 1 to 10 Hz. As such, a seismic risk evaluation is merited for Palisades. A SFP evaluation is also merited. The staff also confirms the licensee's conclusion that because the GMRS exceeds the SSEs above 10 Hz, Palisades will perform a high-frequency confirmation (i.e., Item (4) of the Seismic Hazard Evaluation), which the licensee indicated would be performed as part of its seismic risk evaluation. NRC review and acceptance of the Entergy's plant seismic risk evaluation which includes the high frequency confirmation, an ESEP interim evaluation and a SFP evaluation (i.e., Items (4), (6), (8), and (9)) for Palisades will complete 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. Shallow and Deep Refer to Reference rock Depths of 148 ft (45 m) and 3,238 ft (987 m), Respectively, for the Palisades Site

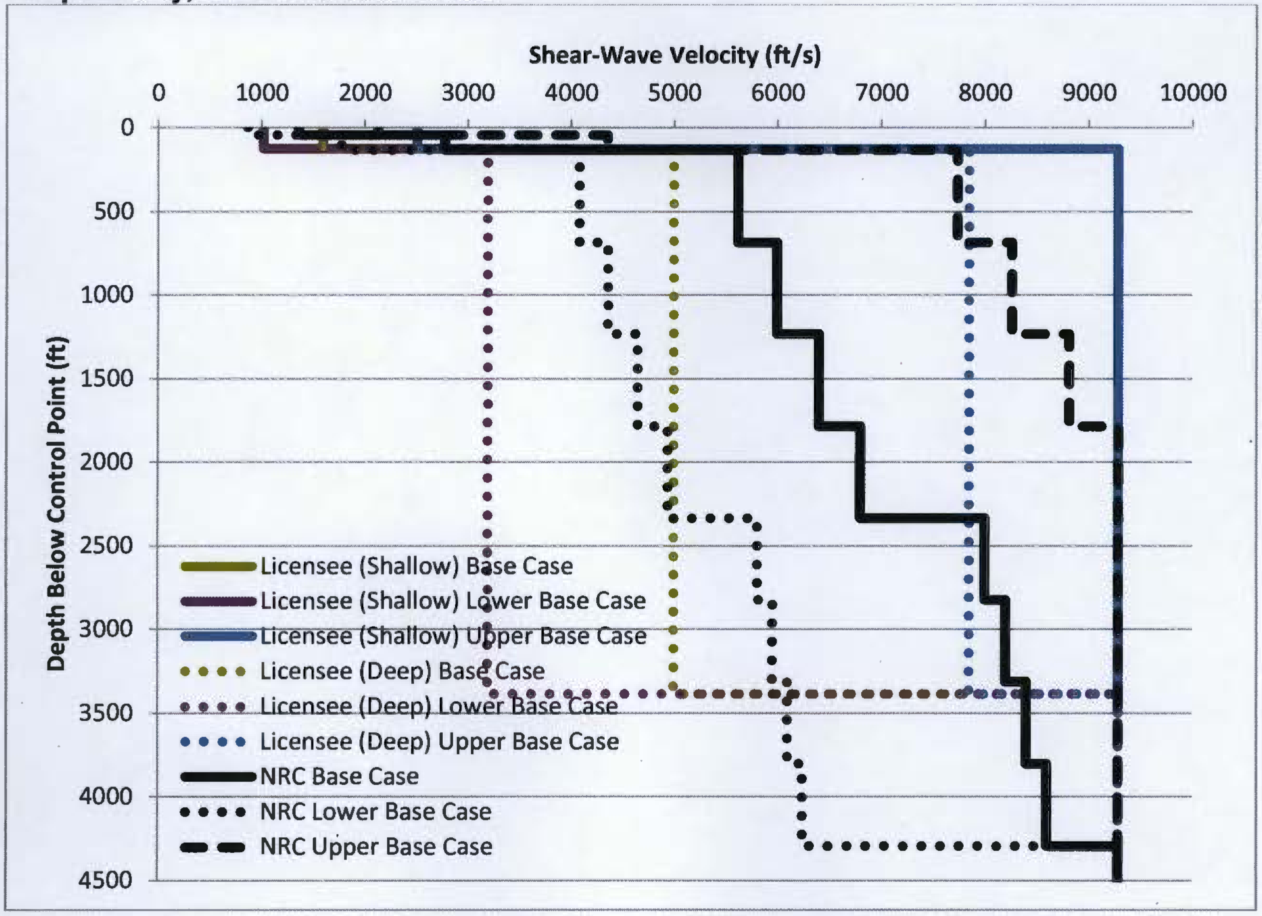


Figure 3.3- 1 Plot Comparing the Staff's and the Licensee's Median Amplification Functions and Uncertainties for the Palisades site.

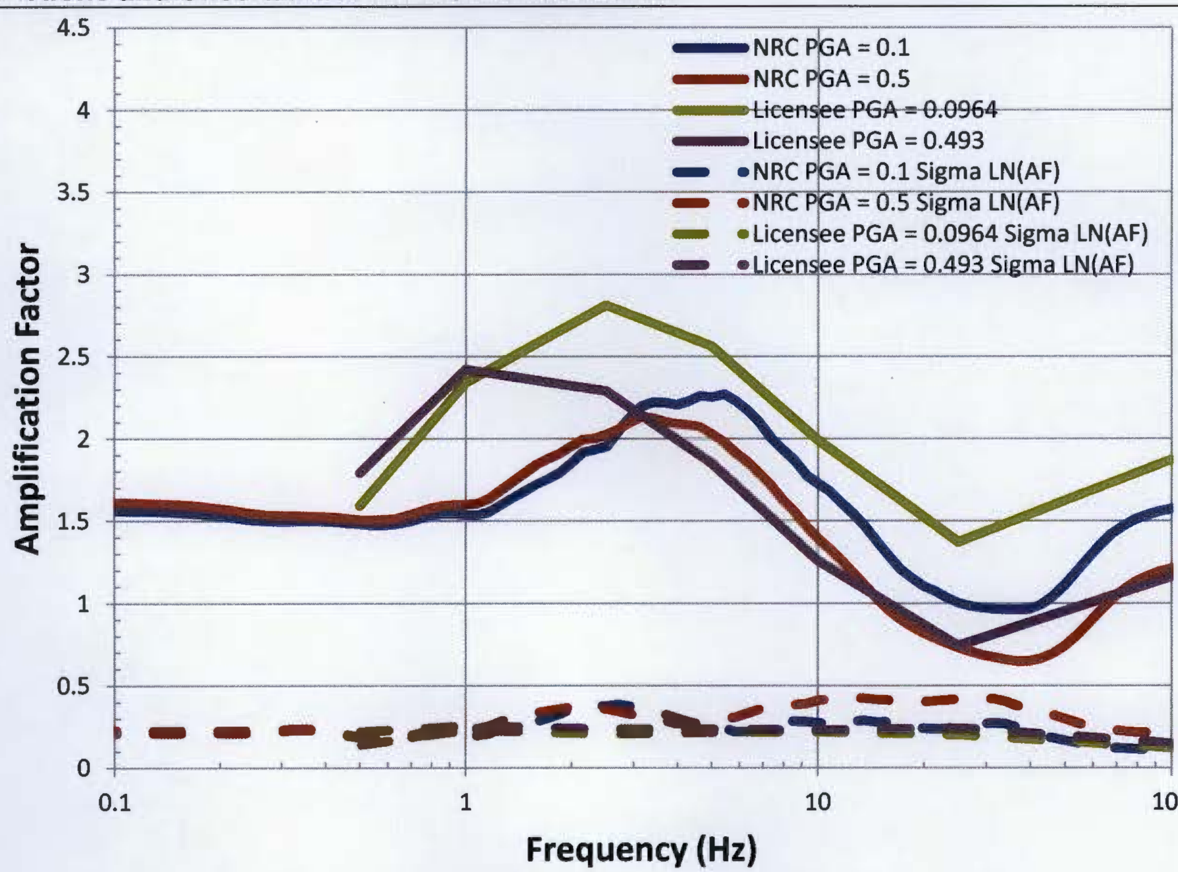


Figure 3.3-2 Plot Comparing the Staff's and the Licensee's Mean Control Point Hazard Curves at a Variety of Frequencies for the Palisades site

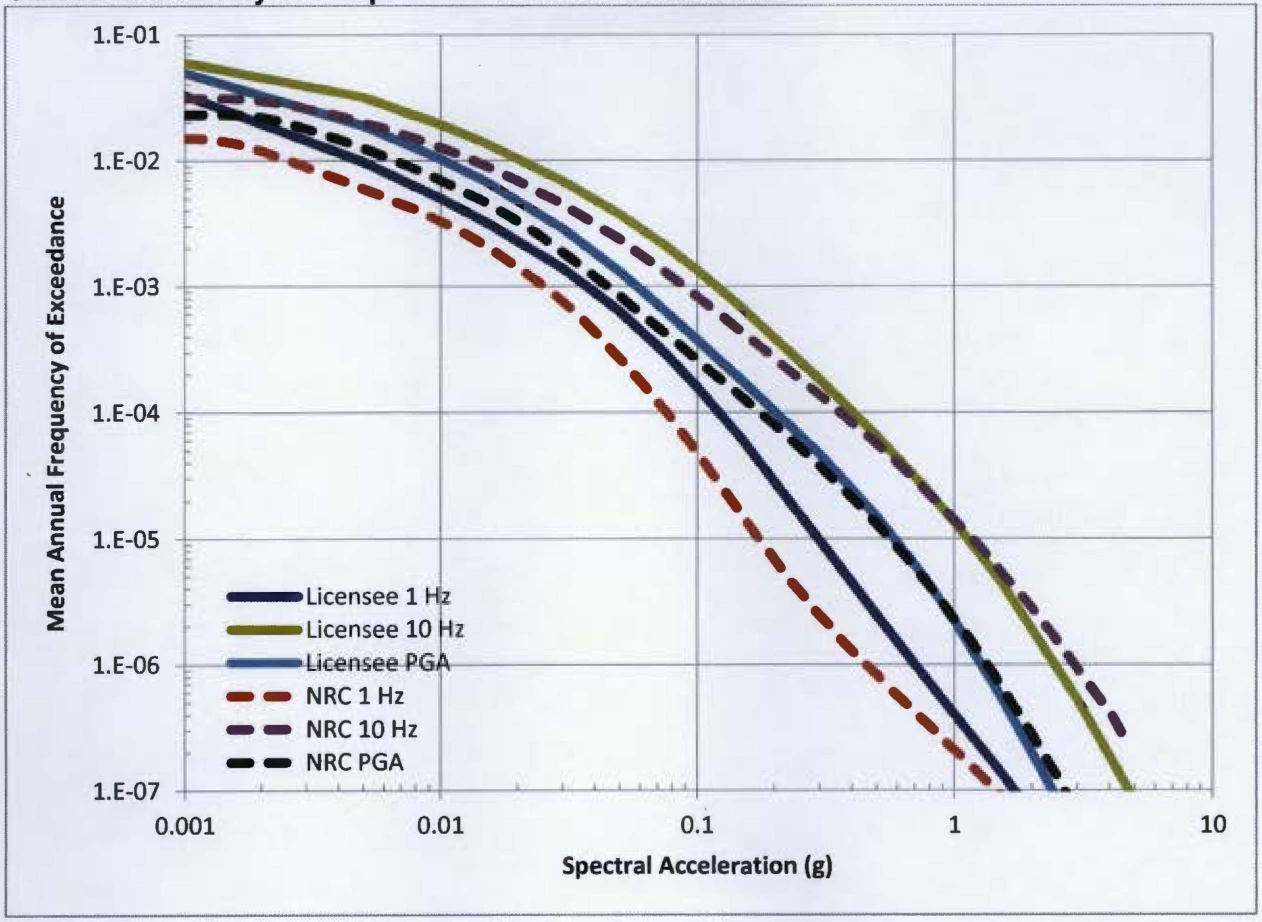
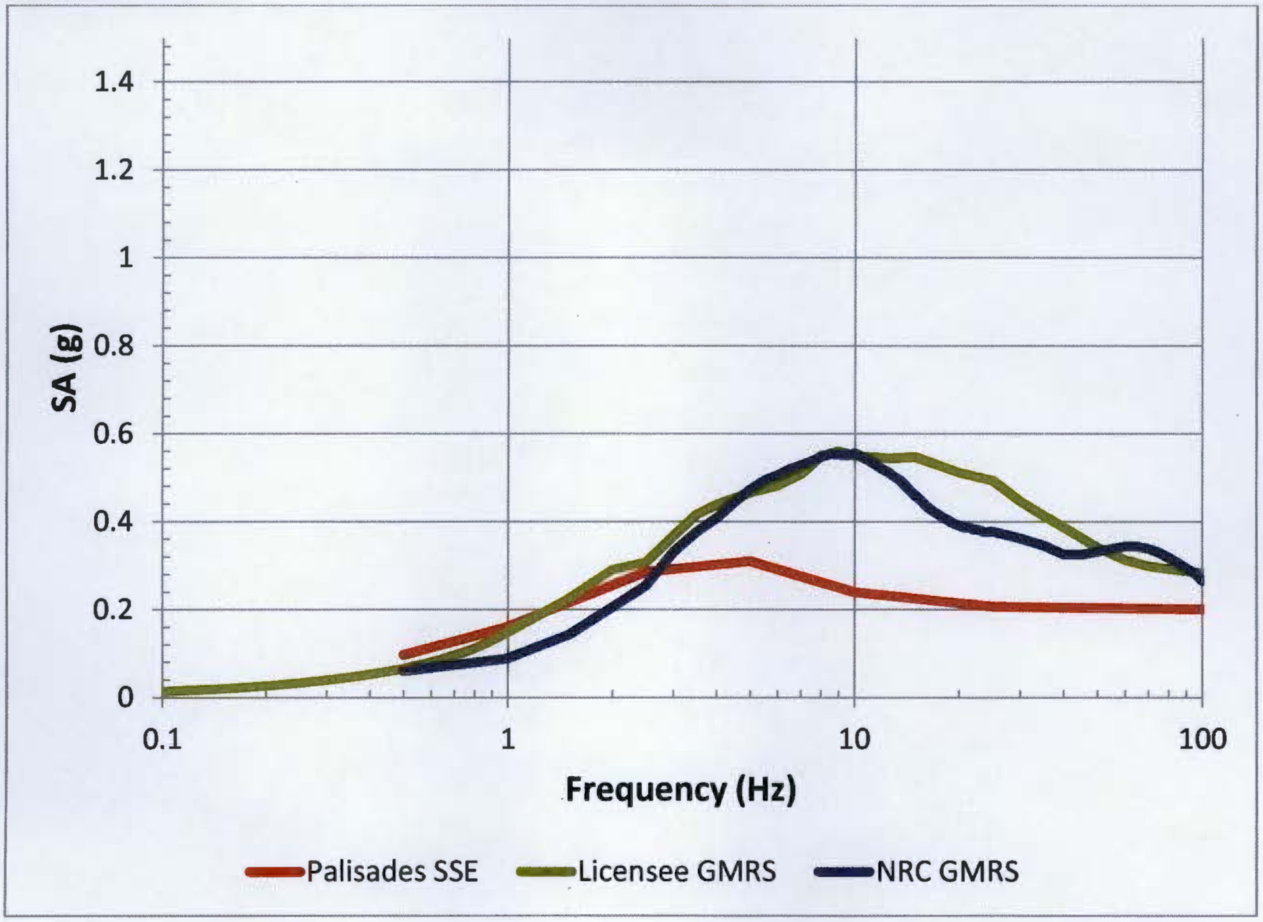


Figure 3.4-1 Comparison of the Staff's GMRS with Licensee's GMRS and the SSE for the Palisades site



If you have any questions, please contact me at (301) 415-6197 or via e-mail at Tekia.Govan@nrc.gov.

Sincerely,

/RA/

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

Docket No. 50-255

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