Entergy

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PNP 2014-033

March 31, 2014

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
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SUBJECT: Palisades Nuclear Plant Seismic Hazard and Screening Report (CEUS Sites), Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident

Palisades Nuclear Plant
Docket No. 50-255
License No. DPR-20

REFERENCES:

1. NRC letter, *Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, dated March 12, 2012 (ADAMS Accession Number ML12056A046)
2. NEI letter, *Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations*, dated April 9, 2013 (ADAMS Accession Number ML13101A379)
3. NRC letter, *Electric Power Research Institute Final Draft Report XXXXXX, "Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," as an Acceptable Alternative to the March 12, 2012, Information Request for Seismic Reevaluations*, dated May 7, 2013 (ADAMS Accession Number ML13106A331)
4. EPRI Report 1025287, *Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*, dated February 2013 (ADAMS Accession Number ML12333A170)
5. NRC letter, *Endorsement of EPRI Final Draft Report 1025287, "Seismic Evaluation Guidance,"* dated February 15, 2013 (ADAMS Accession Number ML12319A074)
6. Entergy Nuclear Operations, Inc. letter, PNP 2013-069, *Palisades Nuclear Plant Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima*

Dai-ichi Accident – 1.5 Year Response for CEUS Sites, dated September 11, 2013 (ADAMS Accession Number ML13255A052)

Dear Sir or Madam:

On March 12, 2012, the Nuclear Regulatory Commission (NRC) issued Reference 1 to all power reactor licensees and holders of construction permits in active or deferred status. Enclosure 1 of Reference 1 requested each addressee located in the Central and Eastern United States (CEUS) to submit a seismic hazard evaluation within 1.5 years from the date of Reference 1.

In Reference 2, the Nuclear Energy Institute (NEI) requested NRC agreement to delay submittal of the final CEUS seismic hazard evaluation so that an update to the Electric Power Research Institute (EPRI) ground motion attenuation model could be completed and used to develop that information. NEI proposed that descriptions of subsurface materials and properties and base case velocity profiles be submitted to the NRC by September 12, 2013, with the remaining seismic hazard information submitted by March 31, 2014. NRC agreed with that proposed path forward in Reference 3.

Entergy Nuclear Operations, Inc. submitted the descriptions of subsurface materials and properties, and base case velocity profiles, for Palisades Nuclear Plant in Reference 6.

Reference 4 contains industry guidance and detailed information to be included in the seismic hazard evaluation submittal. NRC endorsed this industry guidance in Reference 5.

The attached Seismic Hazard and Screening Report for Palisades Nuclear Plant provides the information described in Section 4 of Reference 4 in accordance with the schedule identified in Reference 2.

This letter contains no new commitments and no revised commitments.

I declare under penalty of perjury that the foregoing is true and correct; executed on March 31, 2014.

Sincerely,

ajv/jse

Attachment: Seismic Hazard and Screening Report for Palisades Nuclear Plant

cc: Office Director, NRR, USNRC
Administrator, Region III, USNRC
Project Manager, Palisades, USNRC
Resident Inspector, Palisades, USNRC

ATTACHMENT

Seismic Hazard and Screening Report for

Palisades Nuclear Plant

40 pages follow

Seismic Hazard and Screening Report for Palisades Nuclear Plant

Table of Contents

1.0 Introduction

Following the accident at the Fukushima Daiichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) established a Near-Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations and to determine if the agency should make additional improvements to its regulatory system. The NTTF developed a set of recommendations intended to clarify and strengthen the regulatory framework for protection against natural phenomena. Subsequently, the NRC issued a 50.54(f) letter (U.S. NRC, 2012) that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. In Enclosure 1 of the 50.54(f) letter (U.S. NRC, 2012), the NRC requests that licensees and holders of construction permits under 10 CFR Part 50 reevaluate the seismic hazards at their sites against present-day NRC requirements. Depending on the comparison between the reevaluated seismic hazard and the current design basis, the result is either no further risk evaluation or the performance of a seismic risk assessment. Risk assessment approaches acceptable to the staff include a seismic probabilistic risk assessment (SPRA), or a seismic margin assessment (SMA). Based upon the risk assessment results, the NRC staff will determine whether additional regulatory actions are necessary.

This report provides the information requested in items (1) through (7) of the "Requested Information" section and Attachment 1 of the 50.54(f) letter (U.S. NRC, 2012) pertaining to NTTF Recommendation 2.1 for the Palisades Nuclear Plant (PNP), located in Van Buren County, Michigan. In providing this information, Entergy followed the guidance provided in the *Seismic Evaluation Guidance: Screening, Prioritization, and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic* (EPRI, 2013a). The Augmented Approach, *Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic* (EPRI, 2013c), has been developed as the process for evaluating critical plant equipment as an interim action to demonstrate additional plant safety margin prior to performing the complete plant seismic risk evaluations.

The original geologic and seismic siting investigations for the Palisades Nuclear Plant were performed in accordance with accepted industry practices that existed at the time when the Construction Permit was issued in 1967. These methods pre-date the issuance of 10 CFR Part 100, Appendix A. The Maximum Hypothetical Earthquake (Safe Shutdown Earthquake (SSE)) Ground Response Spectra were developed and used for the design of Safety Related Structures, Systems, and Components (i.e., Seismic Category 1). Appendix I to the original Final Safety Analysis Report (FSAR) contained a comparison to 70 General Design Criteria (GDC) for Nuclear Power Plant Construction Permits issued by the Atomic Energy Commission (AEC) on July 10, 1967. These criteria had been released after the initiation of the plant's design. In the Request for a Full Term Operating License, submitted to the NRC on January 22, 1974, Consumers Power Company (the Licensee at the time) provided an update to compare the PNP design with the GDC's as they appeared in 10 CFR Part 50 Appendix A on July 7,

1971. It was this updated discussion, including the identified exceptions, which formed the original plant Licensing Basis for future compliance with the GDC's.

In response to the 50.54(f) letter (U.S. NRC, 2012) and following the guidance provided in the SPID (EPRI, 2013a), a seismic hazard reevaluation was performed. For screening purposes, a Ground Motion Response Spectrum (GMRS) was developed. Based on the results of the screening evaluation, Palisades Nuclear Plant screens-in for a risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency Confirmation.

2.0 Seismic Hazard Reevaluation

The Palisades Nuclear Plant is located approximately four-and-one-half miles south of the southern city limits of South Haven, Michigan, on the Eastern shore of Lake Michigan, and is in the Eastern Lake Section of the Central Lowland Physiographic Province. The land surface is mantled by glacial drift that ranges from a few feet to several hundred feet in thickness. In the immediate vicinity of the Plant, sand dunes are the prevailing surface feature. Underlying the dunes are glacial deposits of various types. Coldwater shale of Mississippian age lies beneath the dunes and glacial deposits at the site. This bedrock consists of compact blue, gray or occasionally red clay shale. A geophysical study near the site indicated the top of the bedrock to be about 150 feet below the beach fronting Lake Michigan at an approximate elevation of 430 feet to 470 feet Mean Sea Level. (Entergy, 2012a)

The Palisades Nuclear Plant is located in Zone VIII on the seismic regionalization map of the United States (Richter, 1959). The maximum probable seismic intensity was consequently rated at VIII on the Modified Mercalli Intensity Scale of 1931 (MMI). However, a detailed evaluation of historic epicenters, the regional geology and a study of actual foundation conditions at the site indicated that a Zone VIII assignment was too conservative for PNP. Only one epicenter had been reported within 50 miles of the site since 1804. Correlations made in the course of the original site investigations suggested a concentration of the major epicenters (Maximum Intensity VIII (MMI)) about 200 miles southeast from the site focused on the ancient regional structures termed the Cincinnati and Findlay Arches. These structural features are considered the foci of the historic earthquakes experienced along the arch lineation. The occurrence of a major earthquake (Intensity IX (MMI)) along the western end of the St Lawrence rift would result in the assignment of Intensity VIII (MMI) to areas of thick deposits of soft unconsolidated foundation materials. However, foundation conditions such as those reported below at the PNP site warranted a reduction in probable maximum intensity to between VI and VII (MMI). This intensity corresponded to a surface acceleration value of 0.05g. The horizontal ground design spectrum for PNP was generated by averaging several acceleration spectra from actual earthquake records, normalized to the same maximum ground acceleration. The average response spectrum thus obtained covers a variety of foundation conditions ranging from rock to deep alluvium. This spectrum is commonly referred to as the "Housner" spectrum. The recommended surface acceleration value of 0.05g was later doubled to a more conservative value of 0.1g, which became the Design Earthquake (i.e., the Operating Basis Earthquake (OBE)) and 0.2g was used as the SSE. (Entergy, 2012a)

2.1 Regional and Local Geology

Investigations of the geological conditions at the PNP Plant site were conducted in 1965 and 1966. The general geologic profile was disclosed by numerous borings in the areas of interest. The sand dunes, which were excavated from the Plant site, rose steeply from elevation 582 ft Mean Sea Level (MSL) at the shore of Lake Michigan to about elevation 780 ft MSL at the site of the containment vessel. The dune sand extends down to a base elevation between 560 ft to 565 ft MSL. The dune sand is uniform in grain size and is generally loose above elevation 590 ft MSL and dense to very dense below this level. Beneath the dune sand is a stratum of gray sandy silt or silty sand extending to between elevation 518 ft MSL and elevation 530 ft MSL, which becomes finer with increasing depth with gray clay at the lower edge of the stratum. Below this is dense glacial till down to bedrock which was encountered at elevation 440 ft MSL. (Entergy, 2012a)

A geophysical investigation performed in 1966 revealed that the site and vicinity (below the upper dune material) is underlain by materials of three distinct compressional (P wave) seismic velocities. The uppermost zone (average P wave velocity of 5,400 ft per second) extends from about elevation 590 ft MSL down to elevation 545 ft MSL. This material is interpreted as the compact glacial lake deposits. The intermediate zone is generally found below elevation 545 ft MSL and extends downward to an average elevation of 430 ft MSL. This zone has an average P wave velocity of 6,700 ft per second and is probably composed of stiff lake clays and compact glacial till. Below about elevation 430 ft MSL in the vicinity of the Plant, the material has a P wave velocity of 10,000 ft per second. This material is interpreted as the bedrock sequence of Mississippian Coldwater shale. (Entergy, 2012a)

2.2 Probabilistic Seismic Hazard Analysis

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter (U.S. NRC, 2012) and following the guidance in the SPID (EPRI, 2013a), a probabilistic seismic hazard analysis (PSHA) was completed using the recently developed Central and Eastern United States Seismic Source Characterization (CEUS-SSC) for Nuclear Facilities (CEUS-SSC, 2012) together with the updated Electric Power Research Institute (EPRI) Ground-Motion Model (GMM) for the Central and Eastern United States (CEUS) (EPRI, 2013b). For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter (U.S. NRC, 2012). (EPRI, 2014)

For the PSHA, the CEUS-SSC background seismic sources out to a distance of 400 miles (640 km) around PNP were included. This distance exceeds the 200 mile (320 km) recommendation contained in Reg. Guide 1.208 (U.S. NRC, 2007) and was chosen for completeness. Background sources included in this site analysis are the following (EPRI, 2014):

1. Illinois Basin Extended Basement (IBEB)
2. Mesozoic and younger extended prior – narrow (MESE-N)

3. Mesozoic and younger extended prior – wide (MESE-W)
4. Midcontinent-Craton alternative A (MIDC_A)
5. Midcontinent-Craton alternative B (MIDC_B)
6. Midcontinent-Craton alternative C (MIDC_C)
7. Midcontinent-Craton alternative D (MIDC_D)
8. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
9. Non-Mesozoic and younger extended prior – wide (NMESE-W)
10. Paleozoic Extended Crust narrow (PEZ_N)
11. Paleozoic Extended Crust wide (PEZ_W)
12. Reelfoot Rift (RR)
13. Reelfoot Rift including the Rough Creek Graben (RR-RCG)
14. St. Lawrence Rift, including the Ottawa and Saguenay grabens (SLR)
15. Study region (STUDY_R)

For sources of large magnitude earthquakes designated Repeated Large Magnitude Earthquake (RLME) sources in NUREG-2115 (CEUS-SSC, 2012) modeled for the CEUS-SSC, the following sources lie within 1,000 km of the site and were included in the analysis (EPRI, 2014):

1. Commerce
2. Eastern Rift Margin Fault northern segment (ERM-N)
3. Eastern Rift Margin Fault southern segment (ERM-S)
4. Marianna
5. New Madrid Fault System (NMFS)
6. Wabash Valley

For each of the above background and RLME sources, the mid-continent version of the updated CEUS EPRI GMM was used. (EPRI, 2014)

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID (EPRI, 2013a), base rock seismic hazard curves are not provided as the site amplification approach referred to as Method 3 has been used. Seismic hazard curves are shown below in Section 2.3.7 at the SSE control point elevation. (EPRI, 2014)

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the 50.54(f) Request for Information (U.S. NRC, 2012) and in the SPID (EPRI, 2013a) for nuclear power plant sites that are not founded on hard-rock (defined as 2.83 km/sec), a site response analysis was performed for PNP. (EPRI, 2014)

2.3.1 Description of Subsurface Material

The information used to create the site geologic profile at PNP is shown in Table 2.3.1-1. Table 2.3.1-1 shows unit descriptions and estimated shear-wave velocities and densities. This profile was developed using information documented in Entergy (2012a). The SSE Control Point was taken to be at the top of "Brown Dune Sand, very compact", and the profile was modeled up to this location (Entergy, 2012a). (EPRI, 2014)

The site consists of about 148 ft (45 m) of dune sand, clay, and glacial till overlying black massive shale. Due to uncertainty in the depth to reference rock conditions (shear-wave velocity of at least 9,285 ft/s, 2,830 m/s), six base-case shear-wave velocity profiles were developed to model amplification at the site. Profiles 1, 2, and 3 assume that hard basement rock occurs at a depth of 148 ft (45 m), and Profiles 4, 5, and 6 assume that hard rock is at a depth of 3238 ft (987 m). (EPRI, 2014)

The following description of the site geology is taken directly from Entergy (2012a):

> "The Palisades Plant site is located in the Eastern Lake Section of the Central Lowland Physiographic Province. The land surface is mantled by glacial drift that ranges from a few feet to several hundred feet in thickness. In the immediate vicinity of the Plant, sand dunes are the prevailing surface feature. [..] Underlying the dunes are glacial deposits of varying types which were deposited on bedrock consisting of Paleozoic Mississippian shale."
>
> "The dunes fronting Lake Michigan rise steeply from the shoreline (approximate elevation 582 feet MSL) to elevations ranging from elevation 820 feet MSL to elevation 780 feet MSL (near the site) and maintain an average width of about 5,000 feet for approximately two miles north to five miles south of the site. [..] Glacial lake deposits and ground moraine associated with the Covert Ridge terminal moraine are found within the basin."
>
> "The Coldwater shale of Mississippian age lies beneath the dunes and glacial deposits at the site. These sediments represent the last phase of marine deposition in the Paleozoic Michigan Basin. During subsequent Mesozoic and Cenozoic eras, the entire Great Lakes region apparently remained above sea level."
>
> "The bedrock, Coldwater shale, consists of compact blue, gray or occasionally red clay shale. Drill Hole 21, located in the immediate vicinity of the containment building, established bedrock at elevation 440 feet MSL. A geophysical study near the site indicated top bedrock to be about 150 feet below the beach fronting Lake Michigan at an approximate elevation of 430 feet to 470 feet MSL."

Table 2.3.1-1. Summary of Geotechnical Profile Data for PNP (Entergy, 2012a).

Depth Range (feet) [a]	Soil/Rock Description	Density (pcf) [e]	Shear Wave Velocity (fps) [f]	Compressional Wave Velocity (fps)[h]	Poisson's Ratio[g]
	Deepest Structure Foundation Elevation – 564 ft (Portion of Auxiliary Bldg)	---	---	---	---
[b]	Ground Surface Elevation (589 ft MSL)	---	---	---	---
0-100 [c]	Brown Dune Sand	115	---	---	---
100-125 [d]	Brown Dune Sand, very compact	130	750	---	0.30 to 0.48
125-148	Grey Fine-Grained Sand with trace of Silt	127	900	5400	0.48
148-170	Grey Stiff Clay	135	1000	5400	0.48
170-248	Gray Very Stiff Gravelly Sandy Clay (Glacial Till)	140	1600	6700	0.48
248+	Black Massive Shale (top 10 ft weathered)	170	9500	10000	---

NOTES: Embedment depth for Containment (Reactor) Building is approximately 14-21 ft below plant grade at 589 ft. Water table varies between elevation 580 ft to 585 ft.

[a] Boring Log for hole nearest Containment Building (#21 - See FSAR (Entergy, 2012a) Figure 2.12 for variation in layer depth, use in conjunction with FSAR (Entergy, 2012a) Figures 2.10, 2.11 and 2.13).
[b] Control Point was defined as being at the ground surface, in the free field (Elevation 575 ft to 600 ft).
[c] Dune sand from depth 0 ft to 100 ft was removed prior to plant construction.
[d] Plant Grade for the area of the Containment Building is at depth 100 ft, at elevation 589 ft.
[e] Estimated Densities (GEI Consultants,1994).
[f] Estimated Shear Wave Velocities (Best Estimate Values; GEI Consultants,1994).
[g] Estimated Poisson Ratios. Best Estimate Values- 0.30 for dune sand above the water table (GEI Consultants,1994).
[h] See FSAR (Entergy, 2012a) Figure 2.15.

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

Table 2.3.1-1 (Entergy, 2012a) shows the recommended shear-wave velocities and unit weights along with depth ranges and corresponding stratigraphy. The SSE Control Point was taken to be at the top of "Brown Dune Sand, very compact". (EPRI, 2014)

Shear-wave velocities listed on Table 2.3.1-1 were based on compressional-wave velocity measurements and estimated Poisson ratio (Entergy, 2012a). To develop the mean base-case profile, the listed shear-wave velocities and unit weights, which extend to a depth below the SSE of 148 ft (45 m), were used. To accommodate uncertainty in depth to hard rock conditions

two depths were considered: 148 ft (45 m) (P1) (Table 2.3.2-1), and 3,238 ft (987 m) (P4) (approximate depth to Precambrian basement rock from the nearest site (DC Cook)). For profile P4 the shear-wave velocity in the Paleozoic sedimentary rock (black massive shale) was assumed to be 5,000 ft/s (1,524 m/s) based on velocities in similar materials. The profiles were randomized ±971 ft (±296 m). The depth randomization reflects ±30% of the depth and was included to provide a realistic broadening of the fundamental resonance at deep sites rather than reflect actual random variations to basement shear-wave velocities across a footprint. (EPRI, 2014)

Lower- and upper-range profiles, P2 and P3 respectively for shallow depths to Precambrian basement and P5 and P6 respectively for deep depths to hard reference rock were developed using a scale factor of 1.57 as the shear-wave velocities were inferred from compressional-wave velocities and an estimated Poisson ratio. The scale factor of 1.57 reflect $\sigma_{\mu ln}$ of about 0.35 based on the SPID (EPRI, 2013a) 10^{th} and 90^{th} fractiles which implies a 1.28 scale factor on σ_{μ}. (EPRI, 2014)

The six base-case profiles are listed in Table 2.3.2-1, and shown in Figure 2.3.2-1. (EPRI, 2014)

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 6 profiles, at PNP (EPRI, 2014)

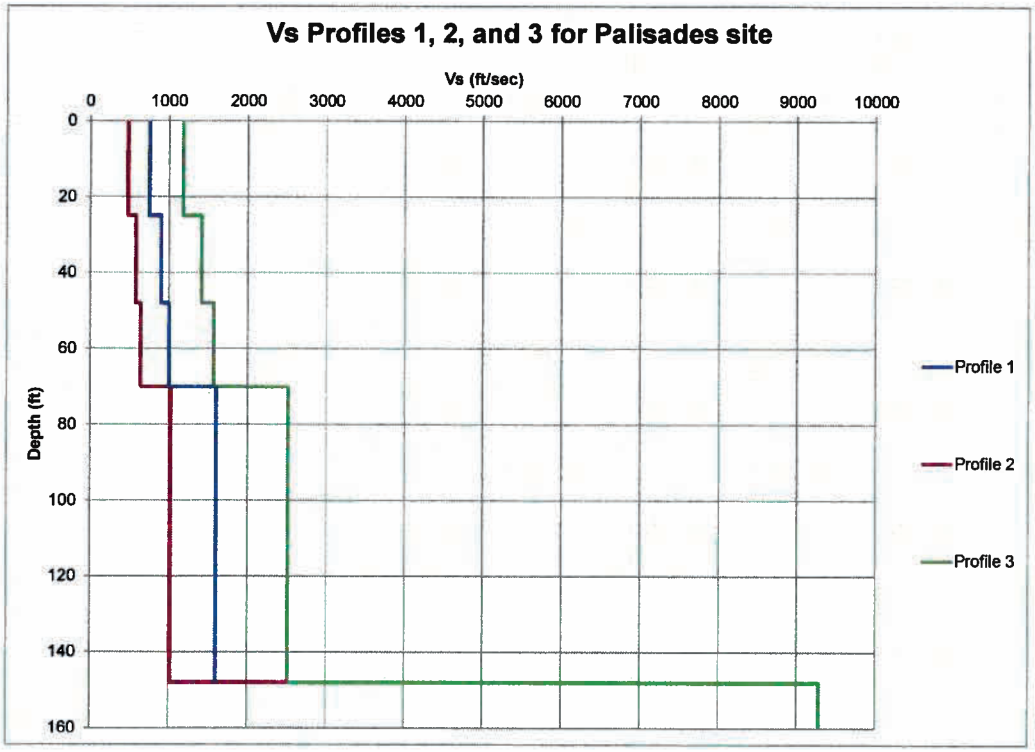
Profile 1			Profile 2			Profile 3		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
	0	750		0	480		0	1177
5.0	5.0	750	5.0	5.0	480	5.0	5.0	1177
5.0	10.0	750	5.0	10.0	480	5.0	10.0	1177
5.0	15.0	750	5.0	15.0	480	5.0	15.0	1177
5.0	20.0	750	5.0	20.0	480	5.0	20.0	1177
5.0	25.0	750	5.0	25.0	480	5.0	25.0	1177
3.0	28.0	900	3.0	28.0	576	3.0	28.0	1413
5.0	33.0	900	5.0	33.0	576	5.0	33.0	1413
5.0	38.0	900	5.0	38.0	576	5.0	38.0	1413
5.0	43.0	900	5.0	43.0	576	5.0	43.0	1413
5.0	48.0	900	5.0	48.0	576	5.0	48.0	1413
2.0	50.0	1000	2.0	50.0	640	2.0	50.0	1570
5.0	55.0	1000	5.0	55.0	640	5.0	55.0	1570
5.0	60.0	1000	5.0	60.0	640	5.0	60.0	1570
5.0	65.0	1000	5.0	65.0	640	5.0	65.0	1570
5.0	70.0	1000	5.0	70.0	640	5.0	70.0	1570
5.0	75.0	1600	5.0	75.0	1024	5.0	75.0	2512
5.0	80.0	1600	5.0	80.0	1024	5.0	80.0	2512
5.0	85.0	1600	5.0	85.0	1024	5.0	85.0	2512
5.0	90.0	1600	5.0	90.0	1024	5.0	90.0	2512
5.0	95.0	1600	5.0	95.0	1024	5.0	95.0	2512
5.0	100.0	1600	5.0	100.0	1024	5.0	100.0	2512
5.0	105.0	1600	5.0	105.0	1024	5.0	105.0	2512
5.0	110.0	1600	5.0	110.0	1024	5.0	110.0	2512
5.0	115.0	1600	5.0	115.0	1024	5.0	115.0	2512
5.0	120.0	1600	5.0	120.0	1024	5.0	120.0	2512
5.0	125.0	1600	5.0	125.0	1024	5.0	125.0	2512
5.0	130.0	1600	5.0	130.0	1024	5.0	130.0	2512
5.0	135.0	1600	5.0	135.0	1024	5.0	135.0	2512
5.0	140.0	1600	5.0	140.0	1024	5.0	140.0	2512
5.0	145.0	1600	5.0	145.0	1024	5.0	145.0	2512
3.0	148.0	1600	3.0	148.0	1024	3.0	148.0	2512
6371.4	6519.4	9285	6371.4	6519.4	9285	6371.4	6519.4	9285

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 6 profiles, at PNP (continued) (EPRI, 2014)

Profile 4			Profile 5			Profile 6		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
	0	750		0	480		0	1177
5.0	5.0	750	5.0	5.0	480	5.0	5.0	1177
5.0	10.0	750	5.0	10.0	480	5.0	10.0	1177
5.0	15.0	750	5.0	15.0	480	5.0	15.0	1177
5.0	20.0	750	5.0	20.0	480	5.0	20.0	1177
5.0	25.0	750	5.0	25.0	480	5.0	25.0	1177
3.0	28.0	900	3.0	28.0	576	3.0	28.0	1413
5.0	33.0	900	5.0	33.0	576	5.0	33.0	1413
5.0	38.0	900	5.0	38.0	576	5.0	38.0	1413
5.0	43.0	900	5.0	43.0	576	5.0	43.0	1413
5.0	48.0	900	5.0	48.0	576	5.0	48.0	1413
2.0	50.0	1000	2.0	50.0	640	2.0	50.0	1570
5.0	55.0	1000	5.0	55.0	640	5.0	55.0	1570
5.0	60.0	1000	5.0	60.0	640	5.0	60.0	1570
5.0	65.0	1000	5.0	65.0	640	5.0	65.0	1570
5.0	70.0	1000	5.0	70.0	640	5.0	70.0	1570
5.0	75.0	1600	5.0	75.0	1024	5.0	75.0	2512
5.0	80.0	1600	5.0	80.0	1024	5.0	80.0	2512
5.0	85.0	1600	5.0	85.0	1024	5.0	85.0	2512
5.0	90.0	1600	5.0	90.0	1024	5.0	90.0	2512
5.0	95.0	1600	5.0	95.0	1024	5.0	95.0	2512
5.0	100.0	1600	5.0	100.0	1024	5.0	100.0	2512
5.0	105.0	1600	5.0	105.0	1024	5.0	105.0	2512
5.0	110.0	1600	5.0	110.0	1024	5.0	110.0	2512
5.0	115.0	1600	5.0	115.0	1024	5.0	115.0	2512
5.0	120.0	1600	5.0	120.0	1024	5.0	120.0	2512
5.0	125.0	1600	5.0	125.0	1024	5.0	125.0	2512
5.0	130.0	1600	5.0	130.0	1024	5.0	130.0	2512
5.0	135.0	1600	5.0	135.0	1024	5.0	135.0	2512
5.0	140.0	1600	5.0	140.0	1024	5.0	140.0	2512
5.0	145.0	1600	5.0	145.0	1024	5.0	145.0	2512
3.0	148.0	1600	3.0	148.0	1024	3.0	148.0	2512
20.4	168.4	5000	20.4	168.4	3200	20.4	168.4	7850
20.4	188.8	5000	20.4	188.8	3200	20.4	188.8	7850
20.4	209.2	5000	20.4	209.2	3200	20.4	209.2	7850
20.4	229.6	5000	20.4	229.6	3200	20.4	229.6	7850
20.4	250.0	5000	20.4	250.0	3200	20.4	250.0	7850
22.6	272.6	5000	22.6	272.6	3200	22.6	272.6	7850
22.6	295.2	5000	22.6	295.2	3200	22.6	295.2	7850

Table 2.3.2-1. Layer thicknesses, depths, and shear-wave velocities (Vs) for 6 profiles, at PNP (continued) (EPRI, 2014)

Profile 4			Profile 5			Profile 6		
thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)	thickness (ft)	depth (ft)	Vs (ft/s)
22.6	317.8	5000	22.6	317.8	3200	22.6	317.8	7850
22.6	340.5	5000	22.6	340.5	3200	22.6	340.5	7850
22.6	363.1	5000	22.6	363.1	3200	22.6	363.1	7850
22.6	385.7	5000	22.6	385.7	3200	22.6	385.7	7850
22.6	408.3	5000	22.6	408.3	3200	22.6	408.3	7850
22.6	430.9	5000	22.6	430.9	3200	22.6	430.9	7850
22.6	453.5	5000	22.6	453.5	3200	22.6	453.5	7850
22.6	476.1	5000	22.6	476.1	3200	22.6	476.1	7850
23.9	500.0	5000	23.9	500.0	3200	23.9	500.0	7850
152.1	652.1	5000	152.1	652.1	3200	152.1	652.1	7850
152.1	804.2	5000	152.1	804.2	3200	152.1	804.2	7850
164.0	968.2	5000	164.0	968.2	3200	164.0	968.2	7850
164.0	1132.3	5000	164.0	1132.3	3200	164.0	1132.3	7850
164.0	1296.3	5000	164.0	1296.3	3200	164.0	1296.3	7850
164.0	1460.3	5000	164.0	1460.3	3200	164.0	1460.3	7850
164.0	1624.4	5000	164.0	1624.4	3200	164.0	1624.4	7850
164.0	1788.4	5000	164.0	1788.4	3200	164.0	1788.4	7850
164.0	1952.5	5000	164.0	1952.5	3200	164.0	1952.5	7850
164.0	2116.5	5000	164.0	2116.5	3200	164.0	2116.5	7850
164.0	2280.6	5000	164.0	2280.6	3200	164.0	2280.6	7850
164.0	2444.6	5000	164.0	2444.6	3200	164.0	2444.6	7850
164.0	2608.6	5000	164.0	2608.6	3200	164.0	2608.6	7850
164.0	2772.7	5000	164.0	2772.7	3200	164.0	2772.7	7850
164.0	2936.7	5000	164.0	2936.7	3200	164.0	2936.7	7850
301.8	3238.6	5000	301.8	3238.6	3200	301.8	3238.6	7850
3280.8	6519.4	9285	3280.8	6519.4	9285	3280.8	6519.4	9285



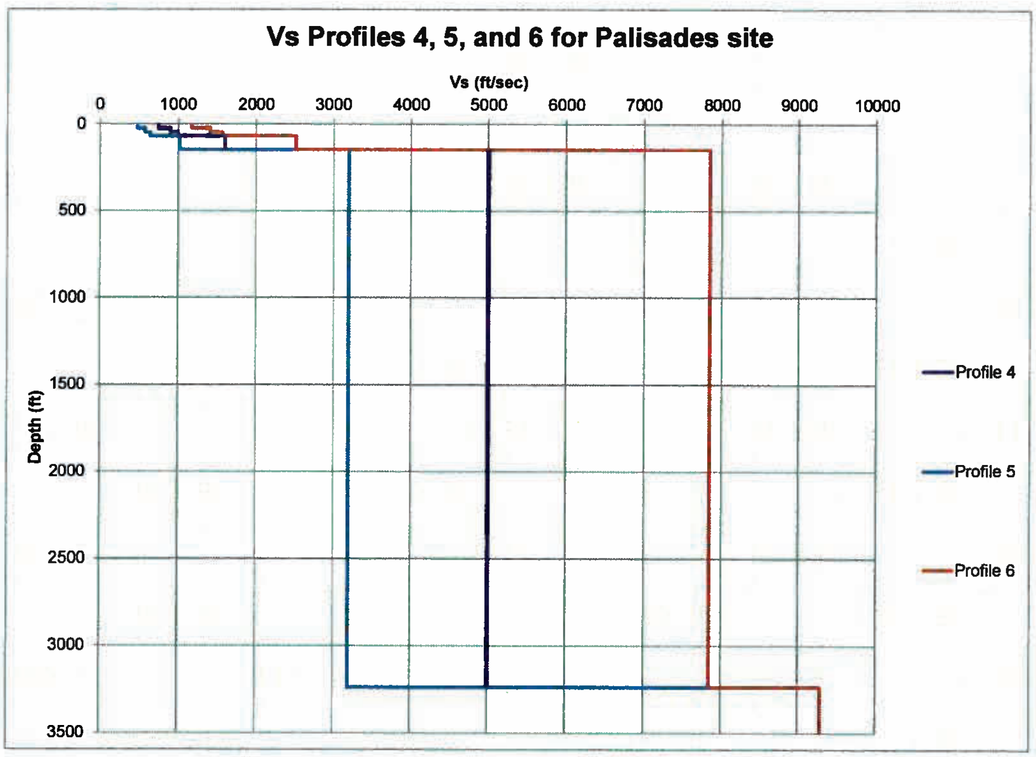


Figure 2.3.2-1. Shear-wave velocity profiles for the PNP site (EPRI, 2014)

2.3.2.1 Shear Modulus and Damping Curves

No site-specific nonlinear dynamic material properties were available for PNP for the soils or firm rock. The firm soil material over the upper 148 ft (45 m) was assumed to have behavior that could be modeled with either EPRI cohesionless soil or Peninsular Range G/G_{max} and hysteretic damping curves (EPRI, 2013a). To reflect epistemic uncertainty in non-linear dynamic material properties, the deeper firm rock material at the site was assumed to have behavior that could be modeled as either linear or non-linear. Consistent with the SPID (EPRI, 2013a), the EPRI soil and rock curves (model M1) were considered to be appropriate to represent the upper range nonlinearity likely in the materials at the site and Peninsular Range (PR) curves for soils combined with linear analyses (model M2) for firm rock was assumed to represent an equally plausible less nonlinear alternative response across loading level. For the linear firm rock analyses, the low strain damping from the EPRI rock curves were used as the constant damping values in the upper 500 ft (150 m) in the profile. (EPRI, 2014)

2.3.2.2 Kappa

Because two base case profiles (median and upper range and the lower range) have been defined for the Palisades site, two sets of kappa values are required for the site response analyses. Base-case kappa estimates were determined using Section B-5.1.3.1 of the SPID (EPRI, 2013a) for a firm CEUS rock site. Kappa for a firm rock site with at least 3,000 ft (1 km) of sedimentary rock may be estimated from the average S-wave velocity over the upper 100 ft (V_{s100}) of the subsurface profile while for a site with less than 3,000 ft (1 km) of firm rock, kappa may be estimated with a Q_s of 40 below 500 ft combined with the low strain damping from the EPRI rock curves and an additional kappa of 0.006 s for the underlying hard rock. For the PNP site, with about 3,000 ft (1 km) of firm rock, a Q_s of 40 below 500 ft combined with the low-strain damping from the EPRI rock curves and an additional kappa of 0.006 s for the underlying hard-rock was considered appropriate for the deep profiles (P4, P5 and P6). (EPRI, 2014)

For the shallow PNP profiles (P1, P2 and P3) with about 148 ft (45m) of soils over hard reference rock, the kappa value of 0.006 s for hard rock (EPRI, 2013a) dominates profile damping. The 148 ft (45 m) of soils, based on the low-strain damping from the EPRI soil G/G_{max} and hysteretic damping curves, reflects a contribution of only about 0.003 s, with the addition of the hard basement rock value of 0.006 s resulting in a total kappa for Profile P1 of 0.009 s (SPID (EPRI, 2013a)) (Table 2.3.2-2). As a result, the dominate source of epistemic uncertainty in low strain kappa was assumed to be incorporated in the reference rock hazard. Additionally, at higher loading levels of significance to design, epistemic uncertainty in profile damping (kappa) is accommodated in the EPRI and PR G/G_{max} and hysteretic damping curves for these profiles. (EPRI, 2014)

For the deeper profiles (P4, P5 and P6), with about 3,000 ft (914 m) to hard rock site conditions, the estimates of kappa were based on the low-strain damping in the hysteretic damping curves over the top 500 ft (152 m) plus the assumption of a constant hysteretic damping of 1.25 (Q_S of 40) for the remaining firm rock profile in addition to a kappa value of 0.006 s for hard-rock,

conditioned with an upper bound of 0.04 s (EPRI, 2013a). For base-case profiles P4, P5, and P6 the kappa contributions from the profiles was 0.007 s, 0.032 s, and 0.013 s respectively. The total kappa values, after adding the hard reference rock value of 0.006 s, were 0.013 s, 0.038 s, and 0.019 s respectively (Table 2.3.2-2). The range in kappa from 0.007 s to 0.038 s was considered to reflect a sufficient characterization of epistemic uncertainty in damping for the profile (Table 2.3.2-2). (EPRI, 2014)

Table 2.3.2-2. Kappa Values and Weights Used for Site Response Analyses. (EPRI, 2014)

Velocity Profile	Kappa(s)
P1	0.009
P2	0.010
P3	0.008
P4	0.013
P5	0.038
P6	0.019
	Weights
P1	0.20
P2	0.15
P3	0.15
P4	0.20
P5	0.15
P6	0.15
G/G_{max} and Hysteretic Damping Curves	Weights
M1	0.5
M2	0.5

2.3.3 Randomization of Base Case Profiles

To account for the aleatory variability in dynamic material properties that is expected to occur across a site at the scale of a typical nuclear facility, variability in the assumed shear-wave velocity profiles has been incorporated in the site response calculations. For the PNP site, random shear wave velocity profiles were developed from the base case profiles shown in Figure 2.3.2-1. Consistent with the discussion in Appendix B of the SPID (EPRI, 2013a), the velocity randomization procedure made use of random field models which describe the statistical correlation between layering and shear wave velocity. The default randomization parameters developed in the *Description and Validation of the Stochastic Ground Motion Model* (Toro, 1997) for United States Geological Survey (USGS) "A" site conditions were used for this site. Thirty random velocity profiles were generated for each base case profile. These random velocity profiles were generated using a natural log standard deviation of 0.25 over the upper 50 ft and 0.15 below that depth. As specified in the SPID (EPRI, 2013a), correlation of shear wave velocity between layers was modeled using the USGS A correlation model. In the correlation model, a limit of ±2 standard deviations about the median value in each layer was assumed for

the limits on random velocity fluctuations. All random velocities were limited to be less than or equal to 9830 ft/s. (EPRI, 2014)

2.3.4 Input Spectra

Consistent with the guidance in Appendix B of the SPID (EPRI, 2013a), input Fourier amplitude spectra were defined for a single representative earthquake magnitude (**M** 6.5) using two different assumptions regarding the shape of the seismic source spectrum (single-corner and double-corner). A range of 11 different input amplitudes (median peak ground accelerations (PGA) ranging from 0.01 to 1.5g) were used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the PNP site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID (EPRI, 2013a) as appropriate for typical CEUS sites. (EPRI, 2014)

2.3.5 Methodology

To perform the site response analyses for the PNP site, a random vibration theory (RVT) approach was employed. This process utilizes a simple, efficient approach for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID (EPRI, 2013a). The guidance contained in Appendix B of the SPID (EPRI, 2013a) on incorporating epistemic uncertainty in shear-wave velocities, kappa, non-linear dynamic properties and source spectra for plants with limited at-site information was followed for the PNP site. (EPRI, 2014)

2.3.6 Amplification Functions

The results of the site response analysis consist of amplification factors (5% damped pseudo absolute response spectra) which describe the amplification (or de-amplification) of hard reference rock motion as a function of frequency and input reference rock amplitude. The amplification factors are represented in terms of a median amplification value and an associated standard deviation (sigma) for each oscillator frequency and input rock amplitude. Consistent with the SPID (EPRI, 2013a) a minimum median amplification value of 0.5 was employed in the present analysis. Figure 2.3.6-1 illustrates the median and ±1 standard deviation in the predicted amplification factors developed for the eleven loading levels parameterized by the median reference (hard-rock) peak acceleration (0.01g to 1.50g) for profile P1 and EPRI soil and rock G/G_{max} and hysteretic damping curves. The variability in the amplification factors results from variability in shear-wave velocity, depth to hard-rock, and modulus reduction and hysteretic damping curves. To illustrate the effects of nonlinearity in the soils at the PNP site, Figure 2.3.6-2 shows the corresponding amplification factors developed with Peninsular Range G/G_{max} and hysteretic damping curves for soil (model M2). Figures 2.3.6-1 and Figure 2.3.6-2 respectively show only a relatively minor difference for the 0.3g loading level and below. Above about the 0.3g loading level, the differences increase mainly in frequencies above about 1 Hz. Tabulated values of the amplification factors are provided in Appendix A, For Information Only. (EPRI, 2014)

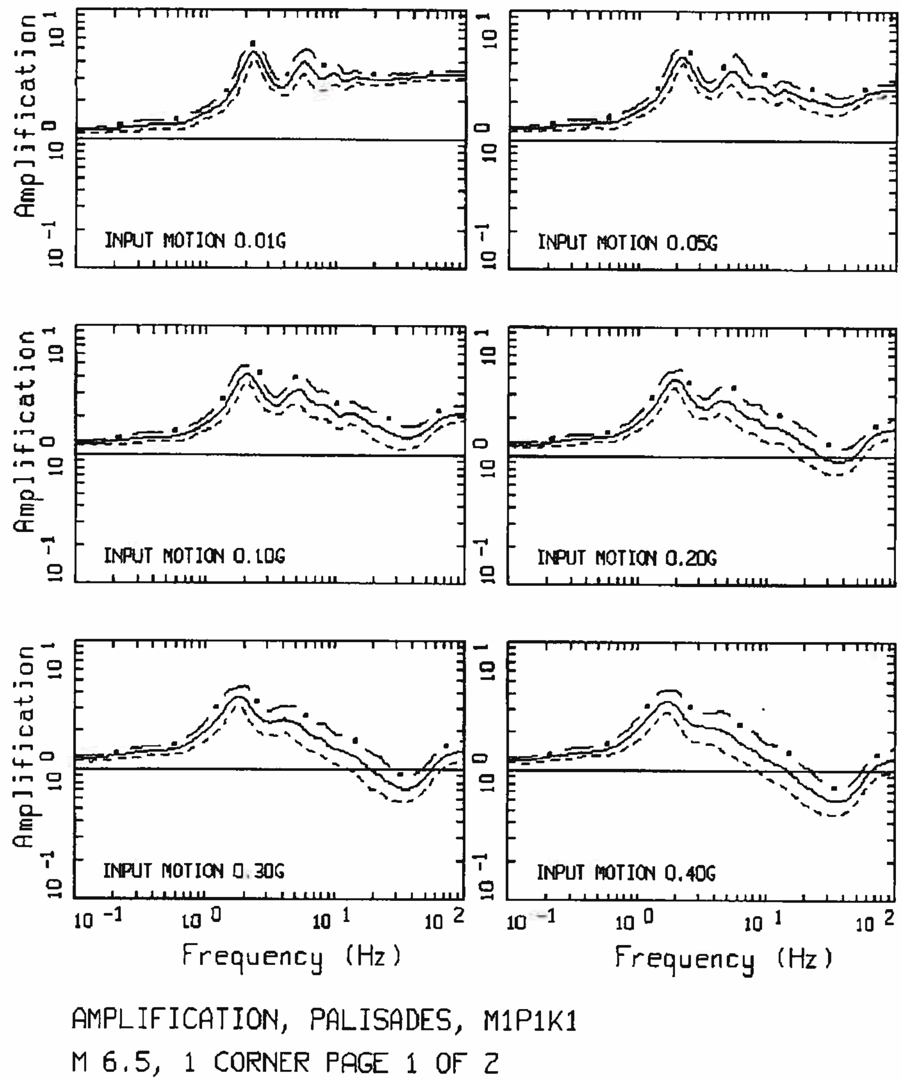
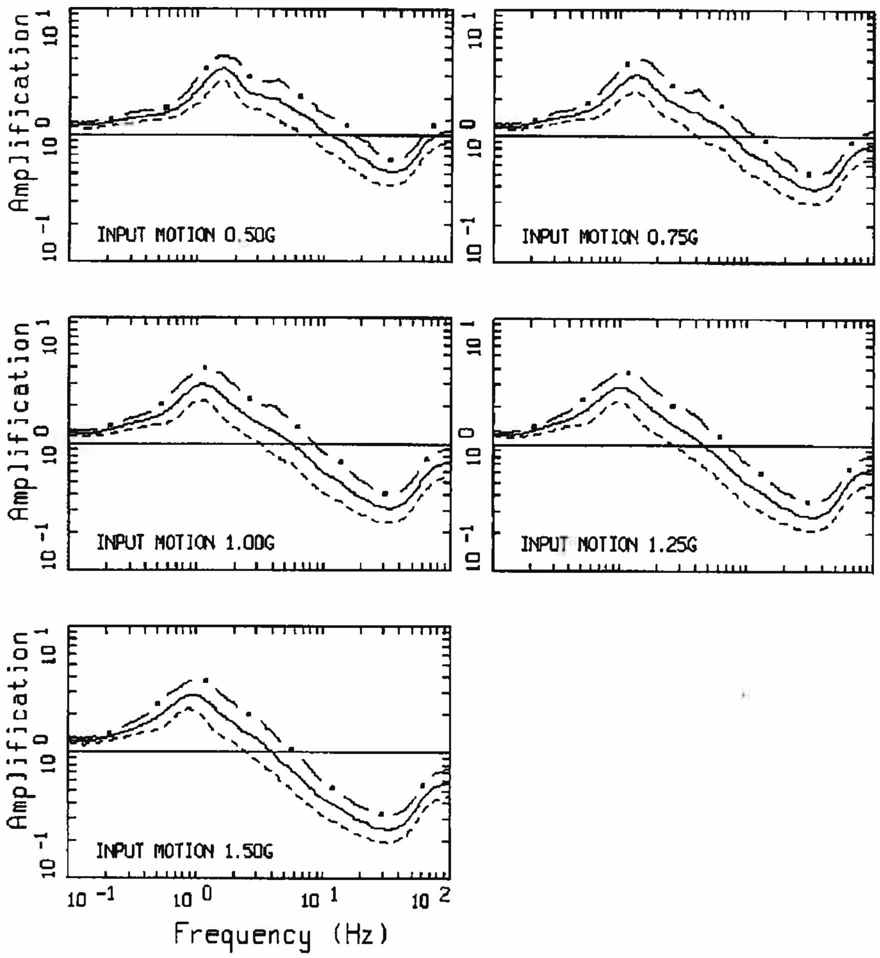


Figure 2.3.6-1. Example suite of amplification factors (5% damping pseudo-absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI soil and rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at eleven loading levels of hard-rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (EPRI, 2013a). (EPRI, 2014)



AMPLIFICATION, PALISADES, M1P1K1
M 6.5, 1 CORNER PAGE 2 OF 2

Figure 2.3.6-1.(cont.)

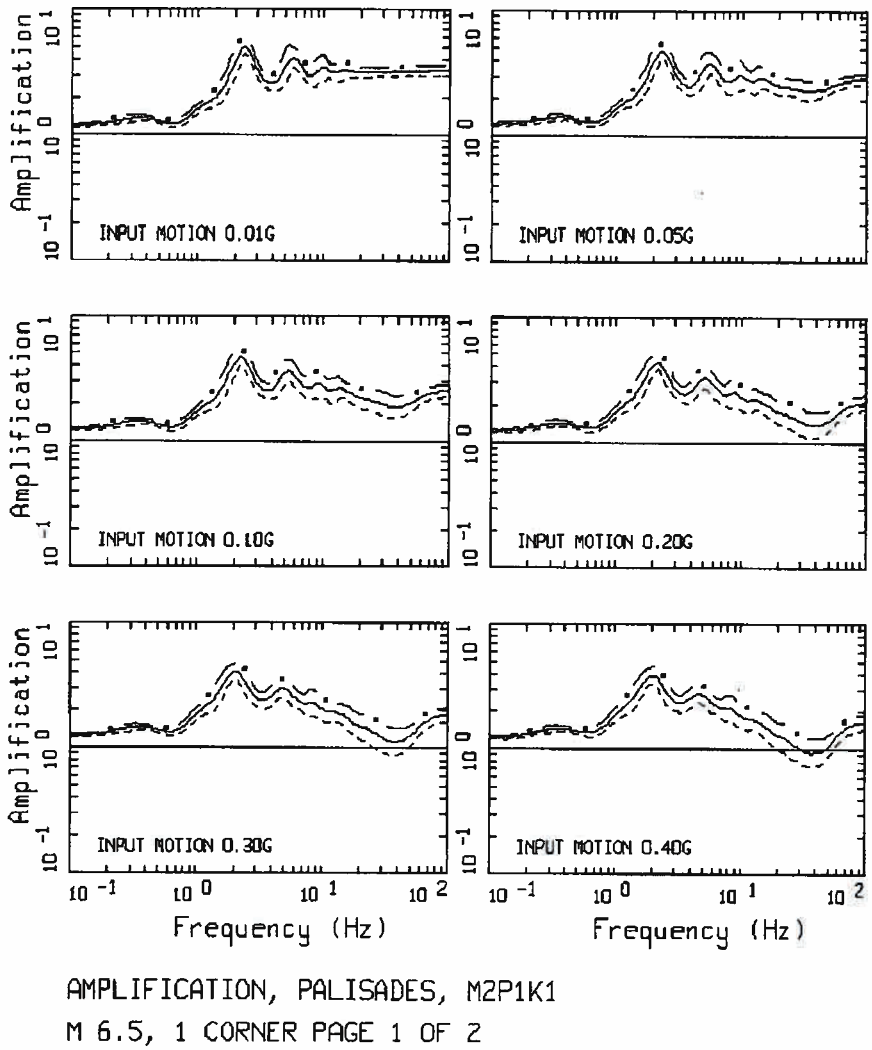
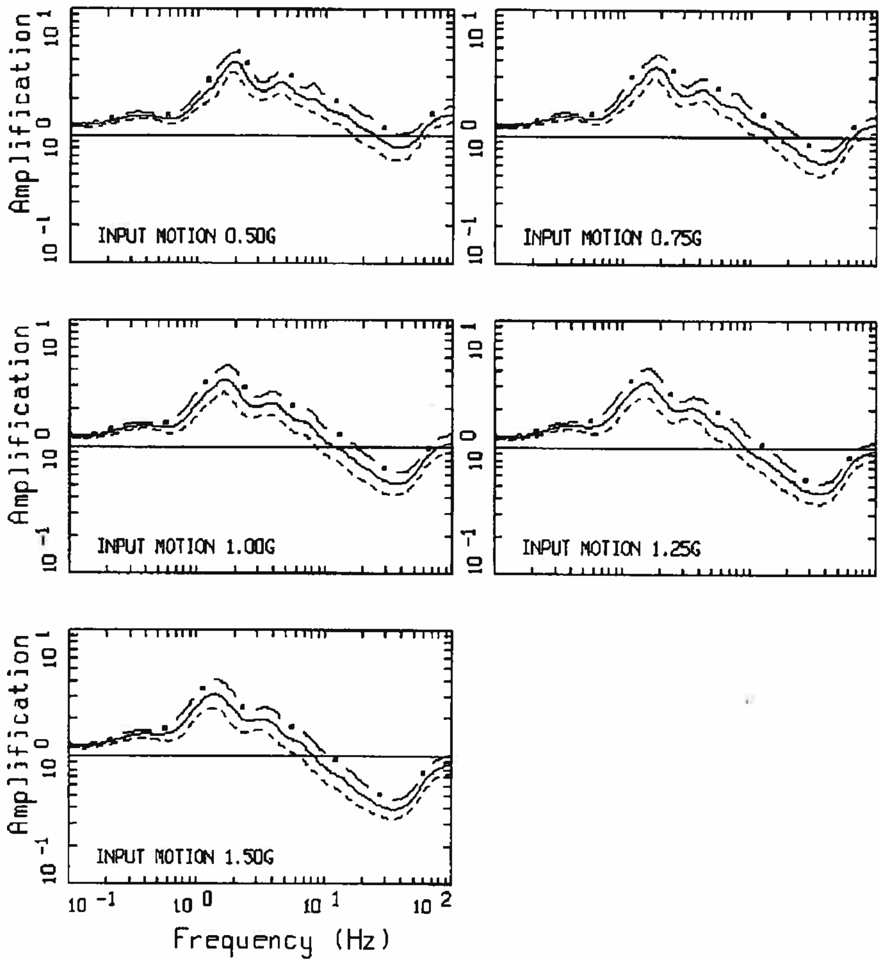


Figure 2.3.6-2. Example suite of amplification factors (5% damping pseudo-absolute acceleration spectra) developed for the mean base-case profile (P1), Peninsular Range modulus reduction and hysteretic damping curves for soil and linear site response for rock (model M2), and base-case kappa (K1) at eleven loading levels of hard-rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (EPRI, 2013a). (EPRI, 2014)



AMPLIFICATION, PALISADES, M2P1K1
M 6.5, 1 CORNER PAGE 2 OF 2

Figure 2.3.6-2.(cont.)

2.3.7 Control Point Seismic Hazard Curves

The procedure to develop probabilistic site-specific control point hazard curves used in the present analysis follows the methodology described in Section B-6.0 of the SPID (EPRI, 2013a). This procedure (referred to as Method 3) computes a site-specific control point hazard curve for a broad range of spectral accelerations given the site-specific bedrock hazard curve and site-specific estimates of soil or soft-rock response and associated uncertainties. This process is repeated for each of the seven spectral frequencies for which ground motion equations are available. The dynamic response of the materials below the control point was represented by the frequency- and amplitude-dependent amplification functions (median values and standard deviations) developed and described in the previous section. The resulting control point mean hazard curves for PNP are shown in Figure 2.3.7-1 for the seven spectral frequencies for which ground motion equations are defined. Tabulated values of mean and fractile seismic hazard curves and site response amplification functions are provided in Appendix A. (EPRI, 2014)

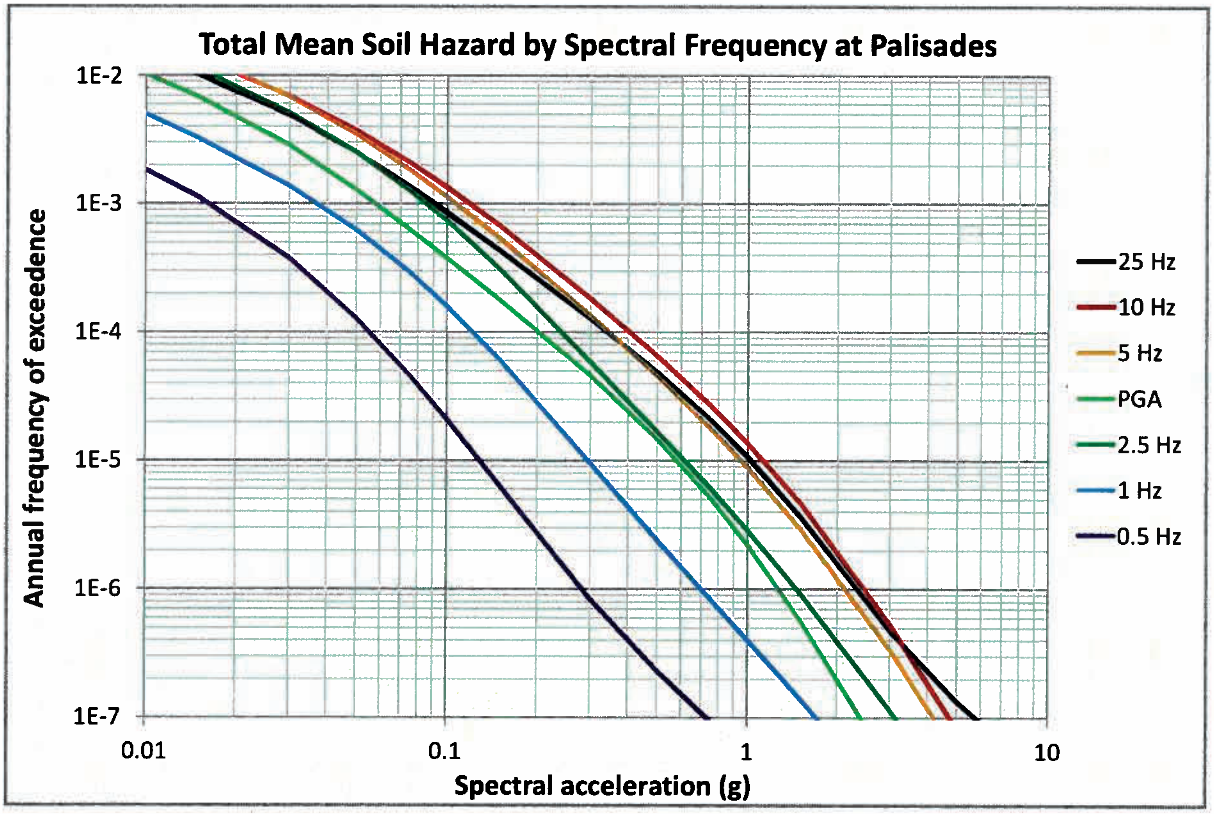


Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1.0, 2.5, 5.0, 10, 25 and PGA (100 Hz) at PNP. (EPRI, 2014)

2.4 Control Point Response Spectrum

The control point hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the GMRS. The UHRS were obtained through linear interpolation in log-log space to estimate the spectral acceleration at each spectral frequency for

the 10^{-4} and 10^{-5} per year hazard levels. Table 2.4-1 shows the UHRS and GMRS accelerations for a range of frequencies. (EPRI, 2014)

Table 2.4-1. UHRS and GMRS for PNP. (EPRI, 2014)

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	2.02E-01	5.82E-01	2.83E-01
90	2.03E-01	5.91E-01	2.87E-01
80	2.05E-01	6.03E-01	2.92E-01
70	2.09E-01	6.20E-01	2.99E-01
60	2.18E-01	6.50E-01	3.13E-01
50	2.38E-01	7.08E-01	3.41E-01
40	2.71E-01	8.02E-01	3.87E-01
35	2.88E-01	8.55E-01	4.13E-01
30	3.11E-01	9.24E-01	4.46E-01
25	3.41E-01	1.03E+00	4.93E-01
20	3.52E-01	1.06E+00	5.11E-01
15	3.92E-01	1.12E+00	5.46E-01
12.5	3.78E-01	1.13E+00	5.43E-01
10	4.03E-01	1.12E+00	5.49E-01
9	4.10E-01	1.14E+00	5.59E-01
8	3.85E-01	1.13E+00	5.49E-01
7	3.51E-01	1.06E+00	5.08E-01
6	3.51E-01	9.87E-01	4.82E-01
5	3.46E-01	9.52E-01	4.66E-01
4	3.22E-01	8.96E-01	4.38E-01
3.5	3.12E-01	8.47E-01	4.16E-01
3	2.75E-01	7.47E-01	3.67E-01
2.5	2.41E-01	6.17E-01	3.07E-01
2	2.28E-01	5.82E-01	2.90E-01
1.5	1.86E-01	4.47E-01	2.25E-01
1.25	1.63E-01	3.73E-01	1.90E-01
1	1.22E-01	2.96E-01	1.49E-01
0.9	1.04E-01	2.61E-01	1.30E-01
0.8	8.77E-02	2.24E-01	1.11E-01
0.7	7.50E-02	1.90E-01	9.47E-02
0.6	6.47E-02	1.59E-01	7.97E-02
0.5	5.52E-02	1.29E-01	6.51E-02
0.4	4.42E-02	1.03E-01	5.21E-02
0.35	3.87E-02	9.00E-02	4.56E-02
0.3	3.31E-02	7.71E-02	3.91E-02
0.25	2.76E-02	6.43E-02	3.26E-02
0.2	2.21E-02	5.14E-02	2.60E-02
0.15	1.66E-02	3.86E-02	1.95E-02
0.125	1.38E-02	3.21E-02	1.63E-02
0.1	1.10E-02	2.57E-02	1.30E-02

The 10^{-4} and 10^{-5} UHRS are used to compute the GMRS at the control point and are shown in Figure 2.4-1. (EPRI, 2014)

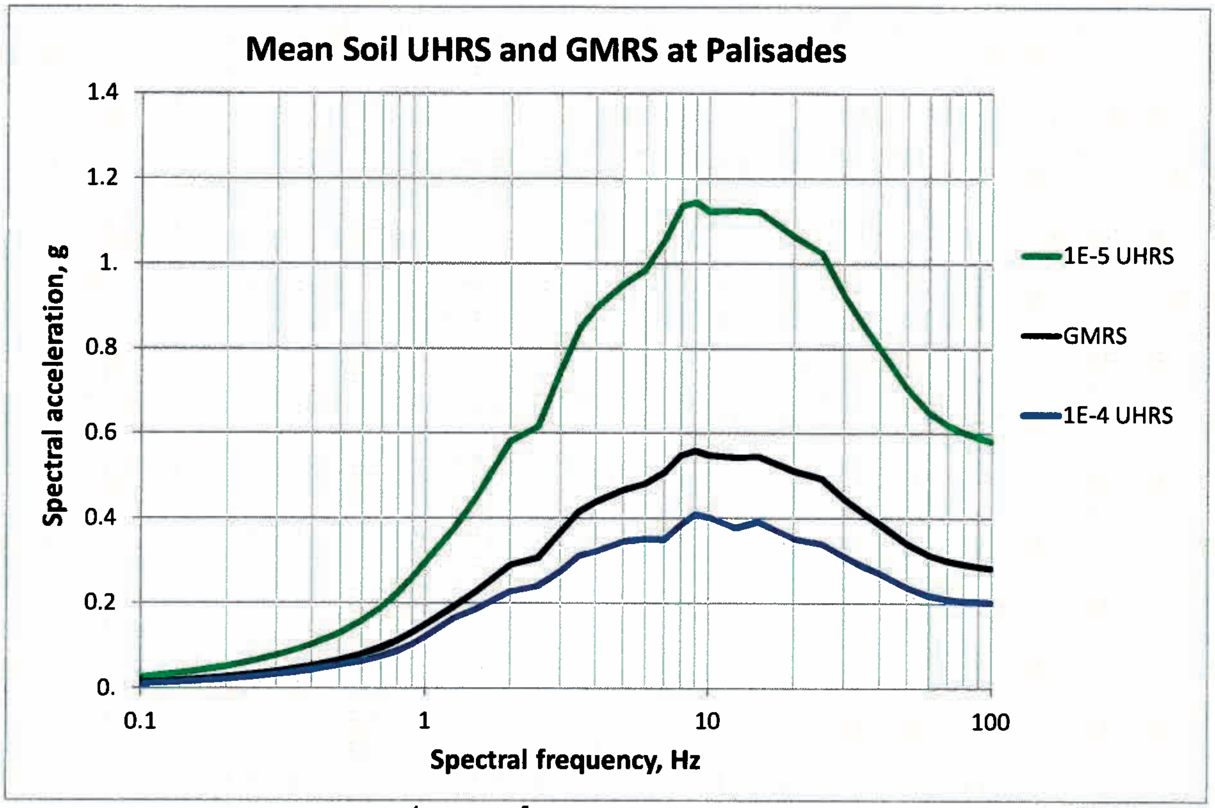


Figure 2.4-1. UHRS for 10^{-4} and 10^{-5} and GMRS at control point for PNP (5%-damped response spectra). (EPRI, 2014)

3.0 Plant Design Basis and Beyond Design Basis Evaluation Ground Motion

The seismic design basis for PNP is discussed in the Updated Final Safety Analysis Report (Entergy, 2012a). An evaluation for Beyond Design Basis (BDB) ground motions was performed for the resolution of Generic Letter 88-20, Supplement 4, for the Individual Plant Examination of External Events (IPEEE) (U.S. NRC, 1991).

3.1 Safe Shutdown Earthquake Description of Spectral Shape

The SSE was developed through an evaluation of the maximum earthquake potential for the region surrounding the site. Considering the historic seismicity of the site region, PNP is located in Zone VIII on the Richter seismic regionalization map (Richter, 1959) with a maximum probable seismic intensity of VIII (MMI). A detailed evaluation of historic epicenters, the regional geology, and a study of actual foundation conditions at the site indicated that a Zone VIII assignment was too conservative for PNP. It was determined, based on the foundation conditions at the PNP site, that a reduction in probable maximum intensity to between VI and VII

(MMI) was warranted. However, because of the uncertainties involved in associating regional activity with specific geologic structures, a conservative value of 0.2g PGA was used as the SSE. (Entergy, 2012a)

The SSE is defined in terms of a PGA and a design response spectrum. The horizontal ground design spectrum was generated by averaging several acceleration spectra from actual earthquake records, normalized to the same maximum ground acceleration. The average response spectrum thus obtained covers a variety of foundation conditions ranging from rock to deep alluvium. This spectrum is commonly referred to as the "Housner" spectrum. Table 3.1-1 shows the spectral acceleration (SA) values as a function of frequency for the 5% damped horizontal SSE. (Entergy, 2012a)

Table 3.1-1. SSE for PNP (Entergy, 2012a).

Freq. (Hz)	100	25	10	5	2.5	1	0.5
SA (g)	0.2	0.206	0.24	0.310	0.285	0.16	0.096

3.2 Control Point Elevation

The SSE control point elevation is defined at the ground surface, in the free field (Entergy, 2012a).

3.3 IPEEE Description and Capacity Response Spectrum

A Level 1 Probabilistic Risk Assessment (PRA) with a Containment Performance Analysis was performed during the scope of the IPEEE assessment, however this assessment was not reviewed in detail as PNP will not be screening-out based on the revised GMRS. (Entergy, 1996)

4.0 Screening Evaluation

In accordance with SPID (EPRI, 2013a) Section 3, a screening evaluation was performed as described below.

4.1 Risk Evaluation Screening (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the SSE. Therefore, the Palisades Nuclear Plant screens-in for a risk evaluation.

4.2 High Frequency Screening (> 10 Hz)

In the frequency range greater than 10 Hz, the GMRS exceeds the SSE. The high frequency exceedances can be addressed in the risk evaluation discussed in 4.1 above.

4.3 Spent Fuel Pool Evaluation Screening (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the SSE. Therefore, the Palisades Nuclear Plant screens-in for a Spent Fuel Pool evaluation.

5.0 Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in EPRI 3002000704 (EPRI, 2013c) will be performed as proposed in a letter to the NRC (ML13101A379) dated April 9, 2013 (NEI, 2013) and agreed to by the NRC (ML13106A331) in a letter dated May 7, 2013 (U.S. NRC, 2013).

Consistent with NRC letter (ML14030A046) dated February 20, 2014 (U.S. NRC, 2014), the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of PNP. Therefore, the results do not call into question the operability or functionality of SSCs and are not reportable pursuant to 10 CFR 50.72, "Immediate notification requirements for operating nuclear power reactors," and 10 CFR 50.73, "Licensee event report system".

The NRC letter also requests that licensees provide an interim evaluation or actions to demonstrate that the plant can cope with the reevaluated hazard while the expedited approach and risk evaluations are conducted. In response to that request, NEI letter dated March 12, 2014 (NEI, 2014), provides seismic core damage risk estimates using the updated seismic hazards for the operating nuclear plants in the Central and Eastern United States. These risk estimates continue to support the following conclusions of the NRC GI-199 Safety/Risk Assessment (U.S. NRC, 2010):

> Overall seismic core damage risk estimates are consistent with the Commission's Safety Goal Policy Statement because they are within the subsidiary objective of 10^{-4}/year for core damage frequency. The GI-199 Safety/Risk Assessment, based in part on information from the U.S. Nuclear Regulatory Commission's (NRC's) Individual Plant Examination of External Events (IPEEE) program, indicates that no concern exists regarding adequate protection and that the current seismic design of operating reactors provides a safety margin to withstand potential earthquakes exceeding the original design basis.

PNP is included in the March 12, 2014 risk estimates. Using the methodology described in the NEI letter, all plants were shown to be below 10^{-4}/year; thus, the above conclusions apply (NEI, 2014).

In accordance with the Near-Term Task Force Recommendation 2.3, PNP performed seismic walkdowns using the guidance in EPRI Report 1025286 (EPRI, 2012). The seismic walkdowns were completed and captured in Fukushima Seismic Walkdown Report PNP-RPT-12-00141 (Entergy, 2012b). The goal of the walkdowns was to verify current plant configuration with the existing licensing basis, to verify the current maintenance plans, and to identify any

vulnerabilities. The walkdown also verified that any vulnerabilities identified in the IPEEE (Entergy, 1996) are adequately addressed. The results of the walkdown, including any identified corrective actions, confirm that PNP can adequately respond to a seismic event.

6.0 Conclusions

In accordance with the 50.54(f) request for information (U.S. NRC, 2012), a seismic hazard and screening evaluation was performed for PNP. A GMRS was developed solely for purpose of screening for additional evaluations in accordance with the SPID (EPRI, 2013a). Based on the results of the screening evaluation, the Palisades Nuclear Plant screens-in for a risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency Confirmation.

7.0 References

10 CFR Part 50. Title 10, Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington DC.

10 CFR Part 50.72. Title 10, Code of Federal Regulations, Part 50.72, "Immediate Notification Requirements for Operating Nuclear Power Reactors," U.S. Nuclear Regulatory Commission, Washington DC.

10 CFR Part 50.73. Title 10, Code of Federal Regulations, Part 50.73, "Licensee Event Report System," U.S. Nuclear Regulatory Commission, Washington DC.

10 CFR Part 100. Title 10, Code of Federal Regulations, Part 100, "Reactor Site Criteria," U.S. Nuclear Regulatory Commission, Washington DC.

CEUS-SSC (2012). "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," U.S. Nuclear Regulatory Commission Report, NUREG-2115; EPRI Report 1021097, 6 Volumes; DOE Report# DOE/NE-0140.

Entergy (1996). Consumers Power Co. letter to NRC, "Submittal of Revised IPEEE Report Based on Reanalysis of Internal Fires," May 31, 1996.

Entergy (2012a). Entergy Nuclear Operations, Inc. letter, PNP 2012-067, "Palisades Nuclear Power Plant Final Safety Analysis Report Update – Revision 30," Docket 50-255, October 18, 2012.

Entergy (2012b). Entergy Nuclear Operations, Inc. letter, PNP 2012-102, "Seismic Walkdown Report – Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," dated November 27, 2012. (ADMAS Accession Number ML12334A093)

EPRI (2012). EPRI 1025286, "Seismic Walkdown Guidance for Resolution of Fukushima Near-Term Task Force Recommendation 2.3: Seismic," June 2012.

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Appendix A

Tabulated Data

Table A-1a. Mean and Fractile Seismic Hazard Curves for 100 Hz (PGA) at PNP (EPRI, 2014)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.92E-02	3.37E-02	4.31E-02	6.00E-02	7.55E-02	8.47E-02
0.001	4.96E-02	2.32E-02	3.42E-02	4.90E-02	6.54E-02	7.66E-02
0.005	1.89E-02	6.64E-03	1.11E-02	1.77E-02	2.68E-02	3.52E-02
0.01	1.03E-02	3.19E-03	5.42E-03	9.24E-03	1.46E-02	2.13E-02
0.015	6.83E-03	1.92E-03	3.23E-03	5.91E-03	9.93E-03	1.51E-02
0.03	2.87E-03	6.73E-04	1.10E-03	2.22E-03	4.31E-03	7.66E-03
0.05	1.29E-03	2.49E-04	4.13E-04	8.98E-04	1.92E-03	3.84E-03
0.075	6.34E-04	9.79E-05	1.74E-04	4.07E-04	9.65E-04	1.95E-03
0.1	3.77E-04	5.12E-05	9.37E-05	2.29E-04	5.83E-04	1.18E-03
0.15	1.78E-04	1.90E-05	3.84E-05	1.04E-04	2.80E-04	5.75E-04
0.3	4.61E-05	2.76E-06	6.64E-06	2.57E-05	7.45E-05	1.57E-04
0.5	1.48E-05	4.50E-07	1.44E-06	7.77E-06	2.49E-05	5.20E-05
0.75	5.18E-06	9.24E-08	3.90E-07	2.35E-06	9.11E-06	1.90E-05
1.	2.21E-06	2.76E-08	1.40E-07	8.72E-07	3.95E-06	8.47E-06
1.5	5.75E-07	4.31E-09	2.53E-08	1.82E-07	1.04E-06	2.39E-06
3.	4.37E-08	1.53E-10	6.17E-10	8.47E-09	6.83E-08	1.92E-07
5.	5.91E-09	9.51E-11	1.21E-10	6.64E-10	7.13E-09	2.57E-08
7.5	1.09E-09	9.11E-11	1.21E-10	1.51E-10	1.04E-09	4.63E-09
10.	3.01E-10	8.12E-11	9.11E-11	1.21E-10	2.92E-10	1.32E-09

Table A-1b. Mean and Fractile Seismic Hazard Curves for 25 Hz at PNP (EPRI, 2014)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.14E-02	3.84E-02	4.50E-02	6.17E-02	7.77E-02	8.60E-02
0.001	5.34E-02	2.92E-02	3.79E-02	5.35E-02	6.93E-02	7.89E-02
0.005	2.40E-02	9.93E-03	1.46E-02	2.25E-02	3.33E-02	4.31E-02
0.01	1.43E-02	5.12E-03	7.89E-03	1.31E-02	2.01E-02	2.84E-02
0.015	1.01E-02	3.33E-03	5.20E-03	8.98E-03	1.44E-02	2.10E-02
0.03	4.92E-03	1.27E-03	2.04E-03	4.07E-03	7.55E-03	1.16E-02
0.05	2.51E-03	4.43E-04	7.66E-04	1.90E-03	4.01E-03	6.73E-03
0.075	1.36E-03	1.57E-04	3.05E-04	9.65E-04	2.19E-03	3.95E-03
0.1	8.52E-04	7.77E-05	1.60E-04	5.66E-04	1.40E-03	2.60E-03
0.15	4.30E-04	3.28E-05	6.83E-05	2.68E-04	7.23E-04	1.34E-03
0.3	1.27E-04	9.65E-06	2.10E-05	7.45E-05	2.13E-04	4.25E-04
0.5	4.86E-05	4.07E-06	9.11E-06	2.76E-05	8.23E-05	1.62E-04
0.75	2.09E-05	1.74E-06	4.25E-06	1.13E-05	3.63E-05	7.13E-05
1.	1.07E-05	8.35E-07	2.13E-06	5.66E-06	1.90E-05	3.68E-05
1.5	3.67E-06	2.04E-07	5.83E-07	2.01E-06	6.64E-06	1.27E-05
3.	4.74E-07	5.75E-09	3.05E-08	2.39E-07	9.24E-07	1.74E-06
5.	1.34E-07	2.88E-10	2.19E-09	2.32E-08	2.80E-07	6.45E-07
7.5	5.82E-08	1.21E-10	2.35E-10	3.01E-09	1.21E-07	3.14E-07
10.	3.27E-08	9.11E-11	1.21E-10	7.66E-10	6.73E-08	1.82E-07

Table A-1c. Mean and Fractile Seismic Hazard Curves for 10 Hz at PNP (EPRI, 2014)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.49E-02	4.37E-02	4.83E-02	6.45E-02	8.12E-02	8.85E-02
0.001	5.98E-02	3.84E-02	4.43E-02	6.00E-02	7.55E-02	8.35E-02
0.005	3.17E-02	1.53E-02	2.04E-02	3.05E-02	4.31E-02	5.20E-02
0.01	1.93E-02	8.23E-03	1.15E-02	1.82E-02	2.72E-02	3.42E-02
0.015	1.37E-02	5.35E-03	7.66E-03	1.27E-02	1.95E-02	2.57E-02
0.03	6.89E-03	2.19E-03	3.33E-03	6.09E-03	1.04E-02	1.42E-02
0.05	3.72E-03	1.01E-03	1.55E-03	3.09E-03	5.83E-03	8.47E-03
0.075	2.10E-03	4.90E-04	7.77E-04	1.67E-03	3.37E-03	5.20E-03
0.1	1.34E-03	2.80E-04	4.63E-04	1.02E-03	2.16E-03	3.47E-03
0.15	6.70E-04	1.16E-04	2.07E-04	4.83E-04	1.08E-03	1.82E-03
0.3	1.82E-04	2.16E-05	4.31E-05	1.21E-04	3.05E-04	5.42E-04
0.5	6.45E-05	5.12E-06	1.13E-05	4.07E-05	1.13E-04	2.04E-04
0.75	2.67E-05	1.46E-06	3.57E-06	1.60E-05	4.83E-05	8.85E-05
1.	1.36E-05	5.91E-07	1.57E-06	7.55E-06	2.49E-05	4.70E-05
1.5	4.68E-06	1.57E-07	4.98E-07	2.19E-06	8.72E-06	1.74E-05
3.	5.27E-07	1.21E-08	4.13E-08	1.82E-07	9.93E-07	2.22E-06
5.	8.23E-08	7.03E-10	2.88E-09	2.72E-08	1.49E-07	3.47E-07
7.5	1.88E-08	1.27E-10	2.96E-10	4.90E-09	3.23E-08	8.35E-08
10.	7.10E-09	1.05E-10	1.27E-10	1.31E-09	1.15E-08	3.42E-08

Table A-1d. Mean and Fractile Seismic Hazard Curves for 5.0 Hz at PNP (EPRI, 2014)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.56E-02	4.43E-02	4.83E-02	6.54E-02	8.12E-02	8.98E-02
0.001	6.13E-02	4.01E-02	4.56E-02	6.09E-02	7.66E-02	8.60E-02
0.005	3.42E-02	1.64E-02	2.19E-02	3.28E-02	4.70E-02	5.66E-02
0.01	2.07E-02	8.85E-03	1.23E-02	1.95E-02	2.92E-02	3.63E-02
0.015	1.44E-02	5.66E-03	8.23E-03	1.34E-02	2.07E-02	2.60E-02
0.03	6.83E-03	2.29E-03	3.52E-03	6.26E-03	1.01E-02	1.32E-02
0.05	3.47E-03	1.02E-03	1.60E-03	3.05E-03	5.35E-03	7.45E-03
0.075	1.85E-03	4.98E-04	7.77E-04	1.53E-03	2.88E-03	4.31E-03
0.1	1.13E-03	2.88E-04	4.50E-04	8.98E-04	1.77E-03	2.80E-03
0.15	5.36E-04	1.23E-04	1.95E-04	4.07E-04	8.35E-04	1.38E-03
0.3	1.35E-04	2.35E-05	4.25E-05	9.79E-05	2.19E-04	3.63E-04
0.5	4.57E-05	5.83E-06	1.21E-05	3.19E-05	7.66E-05	1.31E-04
0.75	1.81E-05	1.57E-06	3.57E-06	1.18E-05	3.14E-05	5.50E-05
1.	8.85E-06	5.20E-07	1.31E-06	5.42E-06	1.62E-05	2.84E-05
1.5	2.95E-06	7.77E-08	2.39E-07	1.55E-06	5.50E-06	1.05E-05
3.	3.37E-07	1.40E-09	8.60E-09	1.07E-07	6.36E-07	1.46E-06
5.	5.43E-08	1.38E-10	6.64E-10	9.65E-09	9.37E-08	2.57E-07
7.5	1.14E-08	1.21E-10	1.51E-10	1.29E-09	1.64E-08	5.50E-08
10.	3.59E-09	9.11E-11	1.21E-10	3.33E-10	4.37E-09	1.69E-08

Table A-1e. Mean and Fractile Seismic Hazard Curves for 2.5 Hz at PNP (EPRI, 2014)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.42E-02	4.31E-02	4.77E-02	6.45E-02	8.00E-02	8.85E-02
0.001	5.82E-02	3.52E-02	4.25E-02	5.75E-02	7.45E-02	8.35E-02
0.005	2.91E-02	1.13E-02	1.62E-02	2.72E-02	4.25E-02	5.35E-02
0.01	1.67E-02	5.58E-03	8.35E-03	1.51E-02	2.53E-02	3.37E-02
0.015	1.13E-02	3.33E-03	5.27E-03	1.01E-02	1.74E-02	2.35E-02
0.03	5.13E-03	1.10E-03	1.92E-03	4.43E-03	8.35E-03	1.15E-02
0.05	2.52E-03	4.07E-04	7.45E-04	2.01E-03	4.37E-03	6.45E-03
0.075	1.28E-03	1.69E-04	3.19E-04	9.37E-04	2.25E-03	3.63E-03
0.1	7.41E-04	8.98E-05	1.69E-04	5.05E-04	1.29E-03	2.22E-03
0.15	3.10E-04	3.47E-05	6.64E-05	2.01E-04	5.35E-04	9.51E-04
0.3	5.92E-05	6.36E-06	1.32E-05	3.79E-05	1.01E-04	1.82E-04
0.5	1.69E-05	1.60E-06	3.68E-06	1.10E-05	2.88E-05	5.27E-05
0.75	6.13E-06	4.56E-07	1.18E-06	3.84E-06	1.07E-05	1.95E-05
1.	2.88E-06	1.67E-07	4.77E-07	1.69E-06	5.05E-06	9.65E-06
1.5	9.33E-07	3.47E-08	1.08E-07	4.63E-07	1.64E-06	3.37E-06
3.	1.15E-07	1.38E-09	4.50E-09	3.19E-08	1.92E-07	4.98E-07
5.	2.19E-08	1.67E-10	3.33E-10	3.01E-09	3.14E-08	1.05E-07
7.5	5.44E-09	9.65E-11	1.21E-10	4.43E-10	6.26E-09	2.60E-08
10.	1.91E-09	9.11E-11	1.21E-10	1.60E-10	1.82E-09	9.11E-09

Table A-1f. Mean and Fractile Seismic Hazard Curves for 1.0 Hz at PNP (EPRI, 2014)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	4.57E-02	2.01E-02	2.84E-02	4.43E-02	6.26E-02	7.45E-02
0.001	3.30E-02	1.20E-02	1.77E-02	3.09E-02	4.83E-02	6.00E-02
0.005	9.76E-03	2.46E-03	4.13E-03	8.60E-03	1.53E-02	2.10E-02
0.01	5.00E-03	8.72E-04	1.74E-03	4.37E-03	8.23E-03	1.13E-02
0.015	3.25E-03	4.13E-04	9.11E-04	2.72E-03	5.58E-03	8.00E-03
0.03	1.39E-03	8.98E-05	2.19E-04	9.11E-04	2.64E-03	4.19E-03
0.05	6.29E-04	2.39E-05	6.36E-05	3.14E-04	1.20E-03	2.32E-03
0.075	2.95E-04	7.66E-06	2.16E-05	1.20E-04	5.27E-04	1.20E-03
0.1	1.59E-04	3.33E-06	9.93E-06	5.83E-05	2.72E-04	6.64E-04
0.15	6.07E-05	1.04E-06	3.19E-06	2.01E-05	9.65E-05	2.53E-04
0.3	9.65E-06	1.32E-07	4.77E-07	3.05E-06	1.53E-05	3.84E-05
0.5	2.43E-06	2.64E-08	1.20E-07	7.77E-07	3.79E-06	1.01E-05
0.75	8.41E-07	7.23E-09	3.47E-08	2.60E-07	1.34E-06	3.63E-06
1.	4.03E-07	2.64E-09	1.40E-08	1.16E-07	6.45E-07	1.72E-06
1.5	1.42E-07	6.45E-10	3.57E-09	3.42E-08	2.13E-07	6.26E-07
3.	2.18E-08	1.31E-10	3.19E-10	3.01E-09	2.68E-08	9.93E-08
5.	4.85E-09	1.21E-10	1.23E-10	4.77E-10	4.70E-09	2.13E-08
7.5	1.33E-09	9.11E-11	1.21E-10	1.60E-10	1.08E-09	5.42E-09
10.	5.00E-10	8.72E-11	9.79E-11	1.21E-10	3.84E-10	1.87E-09

Table A-1g. Mean and Fractile Seismic Hazard Curves for 0.5 Hz at PNP (EPRI, 2014)

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	2.19E-02	1.01E-02	1.40E-02	2.10E-02	2.96E-02	3.68E-02
0.001	1.31E-02	5.58E-03	8.00E-03	1.23E-02	1.79E-02	2.32E-02
0.005	3.52E-03	8.00E-04	1.46E-03	3.14E-03	5.58E-03	7.55E-03
0.01	1.82E-03	2.10E-04	4.63E-04	1.42E-03	3.23E-03	4.77E-03
0.015	1.13E-03	8.12E-05	1.98E-04	7.34E-04	2.13E-03	3.47E-03
0.03	3.77E-04	1.23E-05	3.47E-05	1.64E-04	7.13E-04	1.44E-03
0.05	1.28E-04	2.64E-06	7.66E-06	4.13E-05	2.16E-04	5.50E-04
0.075	4.64E-05	7.03E-07	2.10E-06	1.21E-05	6.93E-05	2.07E-04
0.1	2.09E-05	2.53E-07	8.12E-07	4.83E-06	2.88E-05	9.24E-05
0.15	6.35E-06	5.35E-08	2.04E-07	1.31E-06	8.00E-06	2.80E-05
0.3	8.42E-07	2.64E-09	1.53E-08	1.44E-07	1.05E-06	3.84E-06
0.5	2.34E-07	3.01E-10	1.82E-09	2.84E-08	2.68E-07	1.08E-06
0.75	9.45E-08	1.25E-10	3.63E-10	7.89E-09	9.37E-08	4.37E-07
1.	5.04E-08	1.21E-10	1.64E-10	3.01E-09	4.37E-08	2.25E-07
1.5	2.02E-08	1.04E-10	1.21E-10	7.77E-10	1.42E-08	8.47E-08
3.	3.58E-09	9.11E-11	1.21E-10	1.36E-10	1.64E-09	1.27E-08
5.	8.27E-10	8.12E-11	9.11E-11	1.21E-10	3.33E-10	2.42E-09
7.5	2.27E-10	8.12E-11	9.11E-11	1.21E-10	1.44E-10	6.09E-10
10.	8.39E-11	8.12E-11	9.11E-11	1.21E-10	1.21E-10	2.53E-10

Table A-2. Amplification Functions for PNP (EPRI, 2014)

PGA	Median AF	Sigma ln(AF)	25 Hz	Median AF	Sigma ln(AF)	10 Hz	Median AF	Sigma ln(AF)	5 Hz	Median AF	Sigma ln(AF)
1.00E-02	2.80E+00	1.01E-01	1.30E-02	2.48E+00	1.11E-01	1.90E-02	2.67E+00	1.90E-01	2.09E-02	2.88E+00	2.38E-01
4.95E-02	2.17E+00	1.13E-01	1.02E-01	1.63E+00	1.80E-01	9.99E-02	2.22E+00	2.17E-01	8.24E-02	2.70E+00	2.20E-01
9.64E-02	1.87E+00	1.21E-01	2.13E-01	1.37E+00	2.01E-01	1.85E-01	1.99E+00	2.19E-01	1.44E-01	2.56E+00	2.16E-01
1.94E-01	1.56E+00	1.28E-01	4.43E-01	1.09E+00	2.16E-01	3.56E-01	1.70E+00	2.20E-01	2.65E-01	2.31E+00	2.13E-01
2.92E-01	1.39E+00	1.35E-01	6.76E-01	9.36E-01	2.27E-01	5.23E-01	1.51E+00	2.25E-01	3.84E-01	2.13E+00	2.20E-01
3.91E-01	1.26E+00	1.43E-01	9.09E-01	8.25E-01	2.36E-01	6.90E-01	1.37E+00	2.28E-01	5.02E-01	1.97E+00	2.31E-01
4.93E-01	1.16E+00	1.48E-01	1.15E+00	7.39E-01	2.42E-01	8.61E-01	1.26E+00	2.29E-01	6.22E-01	1.85E+00	2.36E-01
7.41E-01	9.91E-01	1.59E-01	1.73E+00	5.94E-01	2.57E-01	1.27E+00	1.06E+00	2.40E-01	9.13E-01	1.61E+00	2.46E-01
1.01E+00	8.71E-01	1.68E-01	2.36E+00	5.00E-01	2.73E-01	1.72E+00	9.13E-01	2.52E-01	1.22E+00	1.44E+00	2.51E-01
1.28E+00	7.85E-01	1.76E-01	3.01E+00	5.00E-01	2.82E-01	2.17E+00	8.05E-01	2.65E-01	1.54E+00	1.31E+00	2.52E-01
1.55E+00	7.24E-01	1.83E-01	3.63E+00	5.00E-01	2.87E-01	2.61E+00	7.25E-01	2.80E-01	1.85E+00	1.21E+00	2.48E-01
2.5 Hz	**Median AF**	**Sigma ln(AF)**	**1 Hz**	**Median AF**	**Sigma ln(AF)**	**0.5 Hz**	**Median AF**	**Sigma ln(AF)**			
2.18E-02	3.04E+00	1.69E-01	1.27E-02	2.11E+00	2.07E-01	8.25E-03	1.52E+00	1.26E-01			
7.05E-02	2.92E+00	1.95E-01	3.43E-02	2.25E+00	2.28E-01	1.96E-02	1.57E+00	1.29E-01			
1.18E-01	2.81E+00	2.04E-01	5.51E-02	2.34E+00	2.31E-01	3.02E-02	1.59E+00	1.37E-01			
2.12E-01	2.64E+00	2.13E-01	9.63E-02	2.43E+00	2.08E-01	5.11E-02	1.65E+00	1.65E-01			
3.04E-01	2.51E+00	2.21E-01	1.36E-01	2.44E+00	2.19E-01	7.10E-02	1.70E+00	1.91E-01			
3.94E-01	2.39E+00	2.30E-01	1.75E-01	2.43E+00	2.41E-01	9.06E-02	1.76E+00	2.10E-01			
4.86E-01	2.29E+00	2.36E-01	2.14E-01	2.42E+00	2.55E-01	1.10E-01	1.79E+00	2.19E-01			
7.09E-01	2.10E+00	2.40E-01	3.10E-01	2.41E+00	2.62E-01	1.58E-01	1.85E+00	2.29E-01			
9.47E-01	1.95E+00	2.48E-01	4.12E-01	2.41E+00	2.58E-01	2.09E-01	1.90E+00	2.40E-01			
1.19E+00	1.84E+00	2.58E-01	5.18E-01	2.41E+00	2.56E-01	2.62E-01	1.94E+00	2.43E-01			
1.43E+00	1.80E+00	2.67E-01	6.19E-01	2.42E+00	2.55E-01	3.12E-01	1.97E+00	2.40E-01			

Tables A-3a and A-3b are tabular versions of the typical amplification factors provided in Figures 2.3.6-1 and 2.3.6-2. Values are provided for two input motion levels at approximately 10^{-4} and 10^{-5} mean annual frequency of exceedance. These factors are unverified and are provided for information only. The figures should be considered the governing information.

Table A-3a. Median AFs and sigmas for Model 1, Profile 1, for 2 PGA levels
(For Information Only)

M1P1K1	Rock PGA=0.0964			M1P1K1	PGA=0.493		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.204	2.115	0.131	100.0	0.541	1.099	0.205
87.1	0.205	2.085	0.132	87.1	0.542	1.067	0.206
75.9	0.207	2.032	0.135	75.9	0.543	1.013	0.207
66.1	0.211	1.930	0.140	66.1	0.546	0.916	0.209
57.5	0.218	1.756	0.150	57.5	0.549	0.770	0.212
50.1	0.229	1.568	0.166	50.1	0.555	0.640	0.218
43.7	0.245	1.426	0.182	43.7	0.565	0.551	0.227
38.0	0.261	1.367	0.201	38.0	0.578	0.518	0.237
33.1	0.278	1.358	0.216	33.1	0.595	0.510	0.248
28.8	0.301	1.444	0.245	28.8	0.616	0.535	0.267
25.1	0.325	1.529	0.259	25.1	0.648	0.564	0.287
21.9	0.339	1.648	0.267	21.9	0.688	0.637	0.316
19.1	0.353	1.711	0.229	19.1	0.719	0.682	0.327
16.6	0.379	1.885	0.209	16.6	0.773	0.772	0.341
14.5	0.400	2.059	0.194	14.5	0.829	0.874	0.339
12.6	0.405	2.122	0.209	12.6	0.866	0.947	0.329
11.0	0.375	1.992	0.218	11.0	0.898	1.015	0.330
9.5	0.406	2.235	0.259	9.5	0.927	1.104	0.312
8.3	0.406	2.401	0.240	8.3	0.967	1.258	0.323
7.2	0.387	2.421	0.237	7.2	0.993	1.387	0.315
6.3	0.404	2.670	0.291	6.3	1.002	1.499	0.333
5.5	0.452	3.106	0.296	5.5	1.039	1.637	0.350
4.8	0.442	3.086	0.238	4.8	1.105	1.788	0.377
4.2	0.386	2.760	0.185	4.2	1.148	1.926	0.353
3.6	0.332	2.427	0.172	3.6	1.139	1.972	0.305
3.2	0.324	2.503	0.157	3.2	1.124	2.074	0.274
2.8	0.361	2.922	0.241	2.8	1.093	2.133	0.289
2.4	0.426	3.720	0.231	2.4	1.089	2.314	0.305
2.1	0.439	4.192	0.122	2.1	1.171	2.744	0.324
1.8	0.353	3.758	0.214	1.8	1.210	3.184	0.260
1.6	0.241	2.947	0.248	1.6	1.109	3.378	0.221
1.4	0.165	2.332	0.189	1.4	0.895	3.178	0.238
1.2	0.126	2.009	0.160	1.2	0.685	2.774	0.258
1.0	0.103	1.817	0.135	1.0	0.527	2.378	0.250
0.91	0.086	1.661	0.106	0.91	0.410	2.044	0.202
0.79	0.073	1.535	0.112	0.79	0.324	1.795	0.163
0.69	0.061	1.447	0.118	0.69	0.260	1.628	0.140
0.60	0.052	1.395	0.104	0.60	0.211	1.525	0.116
0.52	0.044	1.372	0.083	0.52	0.172	1.468	0.095
0.46	0.037	1.364	0.072	0.46	0.140	1.436	0.084
0.10	0.001	1.226	0.030	0.10	0.005	1.229	0.041

Table A-3b. Median AFs and sigmas for Model 2, Profile 1, for 2 PGA levels
(For Information Only)

M2P1K1	PGA=0.0964			M2P1K1	PGA=0.493		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.243	2.519	0.107	100.0	0.736	1.493	0.143
87.1	0.245	2.493	0.109	87.1	0.739	1.455	0.145
75.9	0.250	2.448	0.111	75.9	0.745	1.389	0.148
66.1	0.257	2.359	0.117	66.1	0.755	1.269	0.154
57.5	0.273	2.203	0.128	57.5	0.775	1.087	0.166
50.1	0.299	2.046	0.153	50.1	0.808	0.932	0.187
43.7	0.330	1.920	0.181	43.7	0.859	0.838	0.222
38.0	0.359	1.880	0.190	38.0	0.908	0.814	0.238
33.1	0.393	1.916	0.216	33.1	0.969	0.831	0.250
28.8	0.420	2.016	0.212	28.8	1.037	0.899	0.260
25.1	0.443	2.084	0.183	25.1	1.119	0.974	0.268
21.9	0.447	2.172	0.188	21.9	1.172	1.084	0.266
19.1	0.462	2.240	0.174	19.1	1.213	1.151	0.258
16.6	0.485	2.413	0.168	16.6	1.286	1.283	0.252
14.5	0.504	2.595	0.154	14.5	1.366	1.441	0.230
12.6	0.494	2.582	0.213	12.6	1.393	1.523	0.199
11.0	0.479	2.542	0.197	11.0	1.397	1.578	0.212
9.5	0.512	2.818	0.258	9.5	1.458	1.737	0.221
8.3	0.458	2.709	0.239	8.3	1.497	1.948	0.261
7.2	0.422	2.641	0.194	7.2	1.408	1.968	0.218
6.3	0.469	3.101	0.210	6.3	1.390	2.080	0.184
5.5	0.517	3.555	0.196	5.5	1.480	2.332	0.216
4.8	0.472	3.293	0.247	4.8	1.603	2.595	0.182
4.2	0.382	2.734	0.223	4.2	1.547	2.594	0.189
3.6	0.340	2.484	0.148	3.6	1.362	2.358	0.178
3.2	0.350	2.699	0.147	3.2	1.225	2.261	0.167
2.8	0.423	3.426	0.195	2.8	1.266	2.473	0.212
2.4	0.508	4.433	0.155	2.4	1.439	3.056	0.254
2.1	0.456	4.358	0.182	2.1	1.581	3.705	0.213
1.8	0.325	3.462	0.249	1.8	1.411	3.712	0.170
1.6	0.215	2.631	0.234	1.6	1.035	3.152	0.212
1.4	0.153	2.167	0.176	1.4	0.729	2.590	0.232
1.2	0.123	1.964	0.130	1.2	0.557	2.256	0.193
1.0	0.102	1.792	0.100	1.0	0.441	1.988	0.148
0.91	0.082	1.581	0.093	0.91	0.343	1.711	0.122
0.79	0.067	1.407	0.085	0.79	0.270	1.495	0.103
0.69	0.056	1.319	0.082	0.69	0.221	1.382	0.092
0.60	0.049	1.306	0.074	0.60	0.187	1.354	0.081
0.52	0.043	1.339	0.057	0.52	0.161	1.375	0.063
0.46	0.037	1.386	0.041	0.46	0.138	1.413	0.046
0.10	0.001	1.251	0.028	0.10	0.005	1.242	0.025