Xcel Energy®

Prairie Island Nuclear Generating Plant
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MAR 2 7 2014

L-PI-14-028
10 CFR 50.54(f)

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Prairie Island Nuclear Generating Plant Units 1 and 2
Docket Nos. 50-282 and 50-306
Renewed Operating License Nos. DPR-42 and DPR-60

<u>PINGP Seismic Hazard and Screening Report (CEUS Sites), Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident</u>

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 No. ML12056A046.
2. NRC Letter, "Endorsement of Electric Power Research Institute Final Draft Report 1025287, 'Seismic Evaluation Guidance,'" dated February 15, 2013, ADAMS Accession No. ML12319A074.
3. Electric Power Research Institute (EPRI) Report Number 1025287, "Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," dated November 2012, ADAMS Accession No. ML12333A170.
4. Nuclear Energy Institute (NEI) letter to NRC, "Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations," dated April 9, 2013, ADAMS Accession No. ML13101A379.
5. 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 No. ML13106A331.

6. NSPM Letter to NRC, "PINGP's 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," dated April 29, 2013, ADAMS Accession No. ML13120A058.
7. NSPM Letter to NRC, "NSPM's 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 12, 2013, ADAMS Accession No. ML13256A069.

On March 12, 2012, the Nuclear Regulatory Commission (NRC) Staff issued Reference 1 to all power reactor licensees and holders of construction permits in active or deferred status. Enclosure 1 of Reference 1 contains specific Requested Actions, Requested Information, and Required Responses associated with Near-Term Task Force (NTTF) Recommendation 2.1, Seismic Evaluations. Enclosure 1 of Reference 1 requested each addressee in the Central and Eastern United States (CEUS) to submit a written response consistent with the requested seismic hazard evaluation information (items 1 through 7) by September 12, 2013. On February 15, 2013, the NRC issued Reference 2, endorsing the Reference 3 industry guidance for responding to Reference 1. Section 4 of Reference 3 identifies the detailed information to be included in the seismic hazard evaluation submittals.

On April 9, 2013, NEI submitted Reference 4 to the NRC, requesting NRC agreement to delay submittal of some of the CEUS seismic hazard evaluation information so that an update to the EPRI (2004, 2006) 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 (items 3a and 3b in Section 4 of Reference 3) be submitted to NRC by September 12, 2013, with the remaining seismic hazard and screening information submitted to NRC by March 31, 2014. In Reference 5, the NRC agreed with the proposed path forward.

Northern States Power Company, a Minnesota corporation (NSPM), d/b/a Xcel Energy, submitted the description of subsurface materials and properties, and base case velocity profiles (items 3a and 3b in Section 4 of Reference 3) for the Prairie Island Nuclear Generating Plant (PINGP) in Reference 7.

The enclosure to this letter provides the Seismic Hazard Evaluation and Screening Report for PINGP in accordance with the schedule identified in Reference 4. This letter completes the commitment made by NSPM in the Reference 6 letter to submit the remaining information described in Section 4 of Reference 3.

If there are any questions or if additional information is needed, please contact Ms. Jennie Wike, Licensing Engineer, at 612-330-5788.

Summary of Commitments

This letter proposes no new commitments and no revisions to existing commitments.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on

MAR 27 2014

Kevin Davison
Site Vice President, Prairie Island Nuclear Generating Plant
Northern States Power Company - Minnesota

Enclosure

cc: Administrator, Region III, USNRC
Director of Nuclear Reactor Regulation (NRR), USNRC
Project Manager, Prairie Island Nuclear Generating Plant, USNRC
Resident Inspector, Prairie Island Nuclear Generating Plant, USNRC

ENCLOSURE

Prairie Island Nuclear Generating Plant Units 1 and 2

Seismic Hazard Evaluation and Screening Report

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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 NRC Commission 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 that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. The 50.54(f) letter 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 pertaining to NTTF Recommendation 2.1 for the Prairie Island Nuclear Generating Plant, located in Goodhue County, Minnesota. In providing this information, Northern States Power Company, a Minnesota corporation (NSPM), d/b/a Xcel Energy, followed the guidance provided in the Electric Power Research Institute (EPRI) guidance document titled "Seismic Evaluation Guidance: Screening, Prioritization, and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" (Reference 7.3). The EPRI guidance document titled "Augmented Approach, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" (Reference 7.11), 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 Prairie Island Nuclear Generating Plant (PINGP) were performed as described in Updated Safety Analysis Report (USAR) Section 2.5 and 2.6 (Reference 7.2) and USAR Section 1.2 (Reference 7.13). PINGP was designed and constructed to comply with Northern States Power's, the predecessor to NSPM, understanding of the intent of the AEC (Atomic Energy Commission) General Design Criteria for Nuclear Power Plant Construction Permits, as proposed on July 10, 1967. Since the construction of the plant was significantly completed prior to the issuance of the February 20, 1971, 10 CFR 50, Appendix A General Design Criteria, the plant was not reanalyzed and the Final Safety Analysis Report (FSAR) was not revised to reflect these later criteria. However, the AEC Safety Evaluation Report acknowledged that the AEC staff assessed the plant, as described in the FSAR, against the Appendix A design criteria and "are satisfied that the plant design generally conforms to the intent of these criteria." Original plant (all plant structures except D5/D6 Diesel Generator Building) building seismic criteria are described in terms of the Operational Basis Earthquake (OBE) and Design Basis Earthquake (DBE). For the D5/D6 Diesel Generator Building, the seismic criteria are described in terms of the OBE and Safe Shutdown Earthquake (SSE). The DBE is synonymous with SSE. The DBE is based upon a maximum horizontal ground acceleration of 0.12 g and the response spectra are given on Plate 4.6 in USAR Appendix E (Reference 7.14, Section 12.2.1.3.5).

In response to the 50.54(f) letter and following the guidance provided in the SPID (Reference 7.3), 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, no further evaluations will be performed.

2.0 Seismic Hazard Reevaluation

PINGP is located within the city limits of Red Wing, Minnesota on the west bank of the Mississippi River (Reference 7.2, Section 2.2.1). PINGP is a low island terrace associated with the Mississippi River flood plain. It is separated from other parts of the lowland by the Vermillion River on the west, and by the Mississippi River on the east. The uppermost bedrock unit at the site is sandstone and is believed to be part of the Franconia formation. Its thickness at this location is unknown, but would be much less than 180 feet, the total measured thickness of the Franconia formation in complete sections. Underneath the Franconia formation are several hundred feet of lower Cambrian and Precambrian sandstone with minor shale horizons.

The plant is located in a region of very low seismic activity. There is no evidence of ancient inactive faulting within six miles of the site. Inactive faults are located approximately 6 and 13 miles from the site. No activity has occurred along either of these faults in recent geological times (Reference 7.2, Section 2.5.1). Based on the seismic history and the regional tectonics, it is anticipated that the site will not experience any significant earthquake motion during the economic life of the nuclear facility. Historically, there is no basis for expecting ground motion of more than a few percent of gravity. However, for conservatism, the plant is designed to respond elastically to earthquake ground motion as high as 6 percent gravity, with no loss of function. Provisions have also been made for safe shutdown of the reactor if ground motions reach as high as 12 percent of gravity in the overburden soils at the site (Reference 7.2, Section 2.6.1).

Further detail on the seismic design basis for PINGP is provided in the PINGP Updated Safety Analysis Report (USAR) Sections 2.2, 2.5 and 2.6 (Reference 7.2).

2.1 Regional and Local Geology

Precambrian granite, gneiss, schist, and volcanics comprise the oldest bedrock in the Minnesota-Wisconsin region. The basement rock is overlain by as much as 800 ft of Paleozoic sandstone, shale and dolomite. Younger formations originally present in the region have been removed by erosion, and an irregular topography has been developed on the exposed bedrock surface. Except for local areas in southeastern Minnesota and parts of Wisconsin, bedrock is concealed under 100 to 300 feet of Pleistocene glacial drift. In contrast, the extreme southeastern tip of Minnesota, including the site vicinity, is covered by only a thin veneer of drift. It is therefore considered a part of the "driftless" area commonly referred to by glacial geologists. In this driftless area of Minnesota and central and southwestern Wisconsin, the unconsolidated materials consist primarily of loess, recent alluvium, and residual soil (Reference 7.2, Section 2.5.2).

The site sub-surface soil consists of permeable sandy alluvium. The sandy alluvium ranges from 158 to 185 feet. Several hundred feet of sound sandstone underlie the alluvial soils (Reference 7.2, Section 2.5.1).

The Mississippi River flood plain near the plant area is confined within a valley about three miles wide. Rocky bluffs and heavily forested slopes rise abruptly from both sides of the valley to a height of about 300 feet. The uplands immediately surrounding the valley reach elevations ranging from approximately 1000 to 1200 feet. They are deeply trenched by numerous streams emptying into the Mississippi River (Reference 7.2, Section 2.5.3).

2.2 Probabilistic Seismic Hazard Analysis

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter and following the guidance in the SPID (Reference 7.3), 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 (Reference 7.4) together with the updated EPRI Ground-Motion Model (GMM) for the CEUS (Reference 7.5). For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter.

For the PSHA, the CEUS-SSC background seismic sources out to a distance of 400 miles (640 km) around PINGP were included. This distance exceeds the 200 mile (320 km) recommendation contained in Reference 7.19 and was chosen for completeness. Background sources included in this site analysis are the following:

1. Illinois Basin Extended Basement (IBEB)
2. Mesozoic and younger extended prior – wide (MESE-W)
3. Midcontinent-Craton alternative A (MIDC_A)
4. Midcontinent-Craton alternative B (MIDC_B)
5. Midcontinent-Craton alternative C (MIDC_C)
6. Midcontinent-Craton alternative D (MIDC_D)
7. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
8. Non-Mesozoic and younger extended prior – wide (NMESE-W)
9. Study region (STUDY_R)

For sources of large magnitude earthquakes, designated as Repeated Large Magnitude Earthquake (RLME) sources in Reference 7.4, the following sources lie within 1,000 km of the site and were included in the analysis:

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

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

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID (Reference 7.3), 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.

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the March 12, 2012, 10 CFR 50.54(f) Request for Information and in the SPID (Reference 7.3) 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 PINGP.

2.3.1 Description of Subsurface Material

PINGP is located near Red Wing, Minnesota on an island terrace associated with the Mississippi River flood plain. The basic information used to create the site geologic profile at the PINGP is shown in Table 1 of Reference 7.7. This profile was developed using information documented in Reference 7.7 and consists of about 180 ft (55 m) of soils overlying about 3,900 ft (1,189 m) of firm sedimentary rock. As indicated in Reference 7.7, the SSE Control Point is defined at the surface, and the profile was modeled up to the surface.

The following description of the site properties is taken directly from Reference 7.7:

> "Prairie Island is a low island terrace associated with the Mississippi River flood plain. It is separated from other parts of the lowland by the Vermillion River on the west, and by the Mississippi River on the east. Ground surface elevations range from approximately 675 to 706 feet. Most of Prairie Island is under cultivation. Other lowland areas near the site are forested or covered by swamp vegetation.
>
> "The Mississippi River flood plain in this area is confined within a valley about three miles wide. Rocky bluffs and heavily forested slopes rise abruptly from both sides of the valley to a height of about 300 feet. The uplands immediately surrounding the valley reach elevations ranging from approximately 1000 to 1200 feet. They are deeply trenched by numerous streams emptying into the Mississippi River.
>
> "The overburden materials at the site are permeable sandy alluvial soils which were deposited as glacial outwash and as recent river sedimentation. Preliminary borings indicated that the overburden soils at the site vary from 158 to 185 feet thick. The uppermost bedrock unit at the site is sandstone and is believed to be part of the Franconia formation. Its thickness at this location is unknown, but would be much less than 180 feet, the total measured thickness of the Franconia formation in complete sections. Underneath the Franconia formation are several hundred feet of lower Cambrian and Precambrian sandstone with minor shale horizons.

"The final design called for dewatering the foundation area to elevation 642 ft, excavation of the area to elevation 645 ft, and re-compacting the area using the excavated material as fill. The fill was placed in three inch layers and compacted to 100% maximum density as determined by the American Association of State Highway Officials Test Designation T 180 - 57. This corresponds to at least 85% relative density - the figure above which soils of this type will not liquefy. The fill was replaced and compacted to the appropriate elevations upon which the foundation slabs were placed."

Table 2.3.1-1, below, shows the geotechnical properties for the PINGP.

TABLE 2.3.1-1
Summary of Geotechnical Profile Data for the PINGP (Reference 7.7)

Depth Range (feet)	Soil/Rock Description	Density (pcf)	Shear Wave Velocity (fps)	Compressional Wave Velocity (fps)[c]	Poisson's Ratio[c]
0	SSE control point (at surface)	---	---	---	---
0-50[a]	Compacted Site Fill composed of fine to Medium sand with gravel and occasional cobbles.	125[b]	2,150[b]	4,750[b]	0.37[b]
50-180	Pleistocene Glacial (outwash of dense to very dense sand with gravel)	130	2,860	6,300	0.37
180-4100	Cambrian and Precambrian sandstone with minor shale horizons	150-155	5,020	9,200	0.28
4100+	Precambrian granite basement rock	170[d]	11200[d]	18,000[d]	0.18[d]

NOTES: The bottom of the base mat of the combined Reactor, Turbine, and Auxiliary Buildings varies from 5 ft to 30 ft below the surface elevation of the site.

[a] If thicknesses vary across site, indicate range in thickness.
[b] Conservatively used from the 20-50 ft. soil column previous to excavation and compaction. Actual values would be improved but are not reported in the USAR.
[c] Compressional-wave velocity and Poisson's ratio should be reported if those were the measurements taken at the site, and ranges in measurements should be reported. If shear-wave velocity measurements were taken, with ranges reported, the compressional-wave velocities and Poisson's ratio are not needed.
[d] Assumed values as stated in USAR Appendix E, Plate 4.1.

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

Table 2.3.1-1 (Reference 7.7) shows the recommended shear-wave velocities and unit weights along with depth ranges and corresponding stratigraphy. As indicated in Reference 7.7, the SSE Control Point is located at the surface at the top of compacted fill with a thickness of 50 ft (15 m) with an estimated shear-wave velocity of 2,150 ft/s (655 m/s). Mean base-case shear-wave velocities and unit weights were taken from Table 2.3.1-1 to Precambrian basement at a depth of about 4,100 ft (1,250 m). The velocities are based on compressional-wave refraction surveys and assumed Poisson ratios.

To accommodate epistemic uncertainty in shear-wave velocities two scale factors were used: 1.25 for the compacted fill and Pleistocene glacial outwash, reflecting measured compressional-wave velocities and Poisson ration, and 1.57 for the Cambrian and Precambrian sandstone formation, reflecting assumed shear-wave velocities. Profiles extended to a depth below the SSE of 4,100 ft (1,250 m), randomized ± 1,230 ft (± 375 m). The base-case profiles (P1, P2, and P3) are shown in Figure 2.3.2-1 and listed in Table 2.3.2-1. 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. The scale factors of 1.25 and 1.57 reflect a σ_{ln} of about 0.20 and 0.35, based on the SPID (Reference 7.3) 10th and 90th fractiles which implies a 1.28 scale factor on σ_{μ}.

TABLE 2.3.2-1

Geologic Profile and Estimated Layer Thicknesses for PINGP

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	2150		0	1720		0	2687
5.0	5.0	2150	5.0	5.0	1720	5.0	5.0	2687
5.0	10.0	2150	5.0	10.0	1720	5.0	10.0	2687
5.0	15.0	2150	5.0	15.0	1720	5.0	15.0	2687
5.0	20.0	2150	5.0	20.0	1720	5.0	20.0	2687
5.0	25.0	2150	5.0	25.0	1720	5.0	25.0	2687
5.0	30.0	2150	5.0	30.0	1720	5.0	30.0	2687
5.0	35.0	2150	5.0	35.0	1720	5.0	35.0	2687
5.0	40.0	2150	5.0	40.0	1720	5.0	40.0	2687
5.0	45.0	2150	5.0	45.0	1720	5.0	45.0	2687
5.0	50.0	2150	5.0	50.0	1720	5.0	50.0	2687
5.0	55.0	2860	5.0	55.0	2288	5.0	55.0	3575
5.0	60.0	2860	5.0	60.0	2288	5.0	60.0	3575
5.0	65.0	2860	5.0	65.0	2288	5.0	65.0	3575
5.0	70.0	2860	5.0	70.0	2288	5.0	70.0	3575
5.0	75.0	2860	5.0	75.0	2288	5.0	75.0	3575
5.0	80.0	2860	5.0	80.0	2288	5.0	80.0	3575
5.0	85.0	2860	5.0	85.0	2288	5.0	85.0	3575

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)
5.0	90.0	2860	5.0	90.0	2288	5.0	90.0	3575
5.0	95.0	2860	5.0	95.0	2288	5.0	95.0	3575
5.0	100.0	2860	5.0	100.0	2288	5.0	100.0	3575
5.0	105.0	2860	5.0	105.0	2288	5.0	105.0	3575
5.0	110.0	2860	5.0	110.0	2288	5.0	110.0	3575
5.0	115.0	2860	5.0	115.0	2288	5.0	115.0	3575
5.0	120.0	2860	5.0	120.0	2288	5.0	120.0	3575
5.0	125.0	2860	5.0	125.0	2288	5.0	125.0	3575
5.0	130.0	2860	5.0	130.0	2288	5.0	130.0	3575
5.0	135.0	2860	5.0	135.0	2288	5.0	135.0	3575
5.0	140.0	2860	5.0	140.0	2288	5.0	140.0	3575
5.0	145.0	2860	5.0	145.0	2288	5.0	145.0	3575
5.0	150.0	2860	5.0	150.0	2288	5.0	150.0	3575
5.0	155.0	2860	5.0	155.0	2288	5.0	155.0	3575
5.0	160.0	2860	5.0	160.0	2288	5.0	160.0	3575
5.0	165.0	2860	5.0	165.0	2288	5.0	165.0	3575
5.0	170.0	2860	5.0	170.0	2288	5.0	170.0	3575
5.0	175.0	2860	5.0	175.0	2288	5.0	175.0	3575
5.0	180.0	2860	5.0	180.0	2288	5.0	180.0	3575
10.0	190.0	5020	10.0	190.0	3197	10.0	190.0	7881
10.0	200.0	5020	10.0	200.0	3197	10.0	200.0	7881
10.0	210.0	5020	10.0	210.0	3197	10.0	210.0	7881
10.0	220.0	5020	10.0	220.0	3197	10.0	220.0	7881
10.0	230.0	5020	10.0	230.0	3197	10.0	230.0	7881
10.0	240.0	5020	10.0	240.0	3197	10.0	240.0	7881
10.0	250.0	5020	10.0	250.0	3197	10.0	250.0	7881
10.0	260.0	5020	10.0	260.0	3197	10.0	260.0	7881
10.0	270.0	5020	10.0	270.0	3197	10.0	270.0	7881
10.0	280.0	5020	10.0	280.0	3197	10.0	280.0	7881
10.0	290.0	5020	10.0	290.0	3197	10.0	290.0	7881
10.0	300.0	5020	10.0	300.0	3197	10.0	300.0	7881
10.0	310.0	5020	10.0	310.0	3197	10.0	310.0	7881
10.0	320.0	5020	10.0	320.0	3197	10.0	320.0	7881
10.0	330.0	5020	10.0	330.0	3197	10.0	330.0	7881
10.0	340.0	5020	10.0	340.0	3197	10.0	340.0	7881
10.0	350.0	5020	10.0	350.0	3197	10.0	350.0	7881
10.0	360.0	5020	10.0	360.0	3197	10.0	360.0	7881
10.0	370.0	5020	10.0	370.0	3197	10.0	370.0	7881
10.0	380.0	5020	10.0	380.0	3197	10.0	380.0	7881
10.0	390.0	5020	10.0	390.0	3197	10.0	390.0	7881
10.0	400.0	5020	10.0	400.0	3197	10.0	400.0	7881

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)
10.0	410.0	5020	10.0	410.0	3197	10.0	410.0	7881
10.0	420.0	5020	10.0	420.0	3197	10.0	420.0	7881
10.0	430.0	5020	10.0	430.0	3197	10.0	430.0	7881
10.0	440.0	5020	10.0	440.0	3197	10.0	440.0	7881
10.0	450.0	5020	10.0	450.0	3197	10.0	450.0	7881
10.0	460.0	5020	10.0	460.0	3197	10.0	460.0	7881
10.0	470.0	5020	10.0	470.0	3197	10.0	470.0	7881
10.0	480.0	5020	10.0	480.0	3197	10.0	480.0	7881
10.0	490.0	5020	10.0	490.0	3197	10.0	490.0	7881
10.0	500.0	5020	10.0	500.0	3197	10.0	500.0	7881
154.9	654.9	5020	154.9	654.9	3197	154.9	654.9	7881
164.0	819.0	5020	164.0	819.0	3197	164.0	819.0	7881
164.0	983.0	5020	164.0	983.0	3197	164.0	983.0	7881
164.0	1147.0	5020	164.0	1147.0	3197	164.0	1147.0	7881
164.0	1311.1	5020	164.0	1311.1	3197	164.0	1311.1	7881
164.0	1475.1	5020	164.0	1475.1	3197	164.0	1475.1	7881
164.0	1639.2	5020	164.0	1639.2	3197	164.0	1639.2	7881
164.0	1803.2	5020	164.0	1803.2	3197	164.0	1803.2	7881
164.0	1967.2	5020	164.0	1967.2	3197	164.0	1967.2	7881
164.0	2131.3	5020	164.0	2131.3	3197	164.0	2131.3	7881
164.0	2295.3	5020	164.0	2295.3	3197	164.0	2295.3	7881
164.0	2459.4	5020	164.0	2459.4	3197	164.0	2459.4	7881
164.0	2623.4	5020	164.0	2623.4	3197	164.0	2623.4	7881
164.0	2787.5	5020	164.0	2787.5	3197	164.0	2787.5	7881
164.0	2951.5	5020	164.0	2951.5	3197	164.0	2951.5	7881
164.0	3115.5	5020	164.0	3115.5	3197	164.0	3115.5	7881
164.0	3279.6	5020	164.0	3279.6	3197	164.0	3279.6	7881
164.0	3443.6	5020	164.0	3443.6	3197	164.0	3443.6	7881
164.0	3607.7	5020	164.0	3607.7	3197	164.0	3607.7	7881
164.0	3771.7	5020	164.0	3771.7	3197	164.0	3771.7	7881
164.0	3935.7	5020	164.0	3935.7	3197	164.0	3935.7	7881
164.0	4099.8	5020	164.0	4099.8	3197	164.0	4099.8	7881
3280.8	7380.6	9285	3280.8	7380.6	9285	3280.8	7380.6	9285

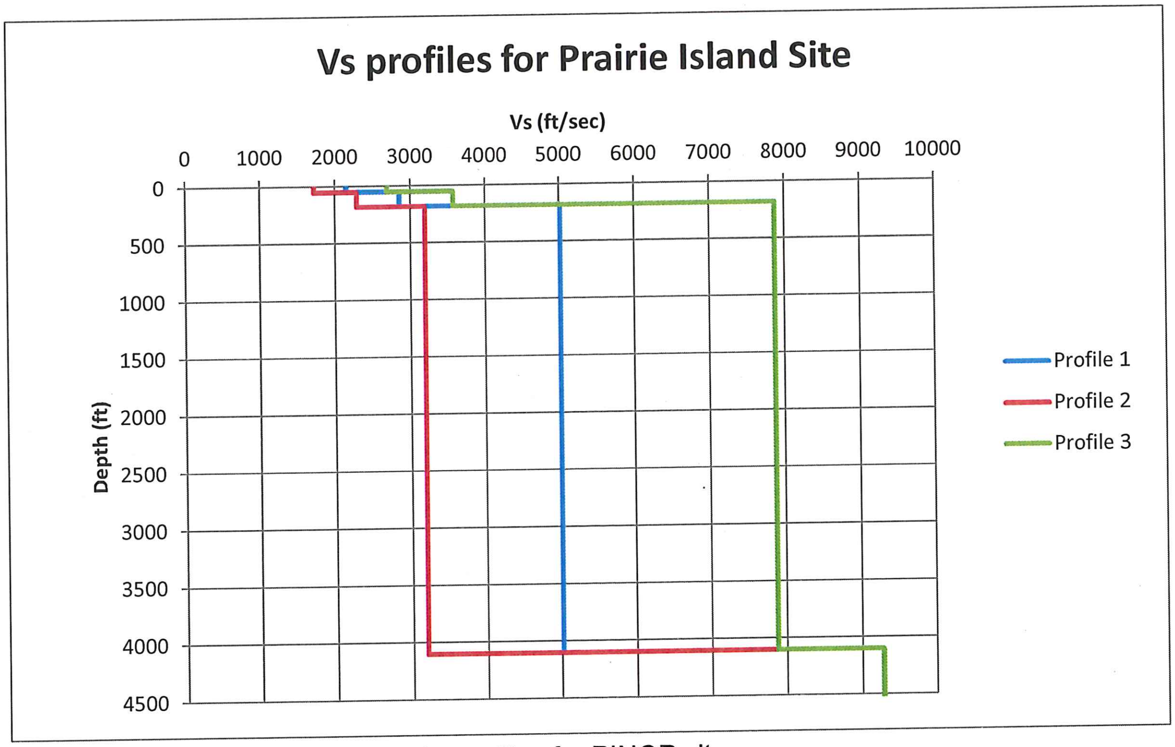

Figure 2.3.2-1. Shear-wave velocity profiles for PINGP site.

2.3.2.1 Shear Modulus and Damping Curves

No site-specific nonlinear dynamic material properties for the soils were available for the PINGP. The fill and firm soil material (glacial outwash) over the upper 180 ft (55 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 (Reference 7.3). The rock material between 180 ft (55 m) and 500 ft (152 m) was assumed to have behavior that could be modeled as either non-linear (model M1) or linear (model M2). To represent this potential for either case in the top 320 ft (97.5 m) of firm rock at the PINGP site, two sets of shear modulus reduction and hysteretic damping curves were used. Consistent with the SPID (Reference 7.3), the EPRI soil and rock curves (model M1) were considered to be appropriate to represent the upper range nonlinearity likely in the materials at this site and Peninsular Range (soil) and linear analyses (firm rock) (model M2) was assumed to represent an equally plausible alternative soil and rock response across loading level. For the linear analyses of the firm rock material, the low strain damping from the EPRI rock curves were used as the constant damping values in the upper 500 ft.

2.3.2.2 Kappa

For the PINGP profile of about 4,100 ft (1,250 m) of fill, soils and firm rock over hard reference rock, 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 (QS 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 (Reference 7.3). For base-case

profiles P1, P2, and P3, the kappa contributions from the profiles were 0.024 s, 0.036 s, and 0.015 s, respectively. The total kappa values, after adding the hard reference rock value of 0.006 s, were 0.030 s, 0.040 s (upper bound), and 0.021 s, respectively (see Table 2.3.2-2). About the mean base-case (P1) the epistemic uncertainty in kappa is only approximately 3%, similar to that of corresponding firm rock velocities. While the epistemic uncertainty in kappa should be larger than that of velocity, additional epistemic uncertainty in profile damping (kappa) is accommodated at design loading levels through two sets of modulus reduction and hysteretic damping curves for the soils.

TABLE 2.3.2-2

Kappa Values and Weights Used for Site Response Analyses

Velocity Profile	Kappa (s)
P1	0.030
P2	0.040
P3	0.021
Velocity Profile	Weights
P1	0.4
P2	0.3
P3	0.3
G/G_{max} and Hysteretic Damping Curves	
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 PINGP 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 (Reference 7.3), 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 Reference 7.15 for the 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 (Reference 7.3), correlation of shear wave velocity between layers was modeled using the footprint 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.

2.3.4 Input Spectra

Consistent with the guidance in Appendix B of the SPID (Reference 7.3), 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 1.5 g) were used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the PINGP site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID (Reference 7.3), as appropriate for typical CEUS sites.

2.3.5 Methodology

To perform the site response analyses for the PINGP 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 (Reference 7.3). The guidance contained in Appendix B of the SPID (Reference 7.3) 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 PINGP site.

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 (Reference 7.3) 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 at the PINGP soil site, Figure 2.3.6-2 shows the corresponding amplification factors developed with Peninsular Range G/G_{max} (soil) and linear (firm rock) and hysteretic damping curves for soil (model M2). Figures 2.3.6-1 and 2.3.6-2 show only a relatively minor difference for the 0.5g loading level and below. Above the 0.5g loading level, the differences increase mainly in frequencies above 10 Hz to 20 Hz. Tabulated values of the amplification factors are provided in Appendix A.

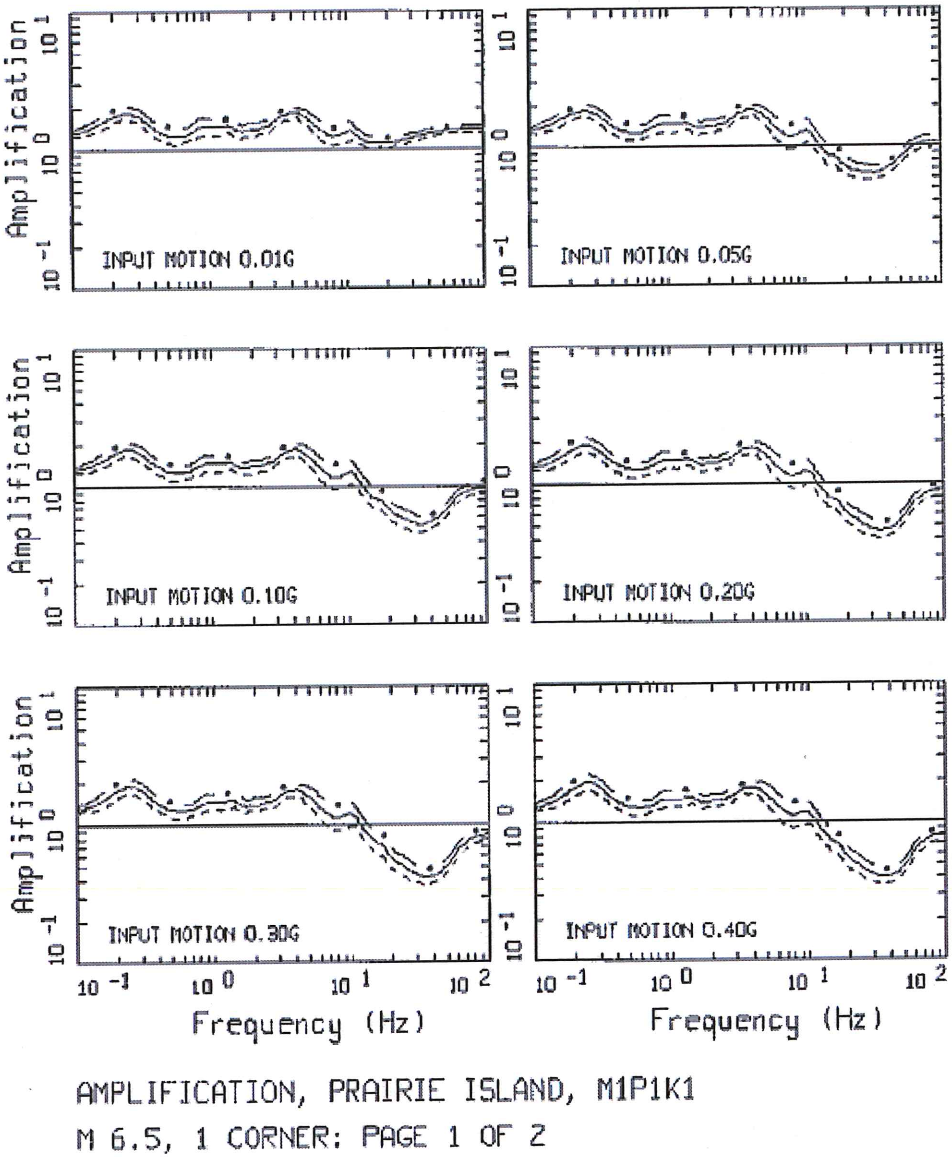

Figure 2.3.6-1: Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI soil and rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa at eleven loading levels of hard rock median peak acceleration values from 0.01 g to 1.50 g. M 6.5 and single-corner source model (Reference 7.3).

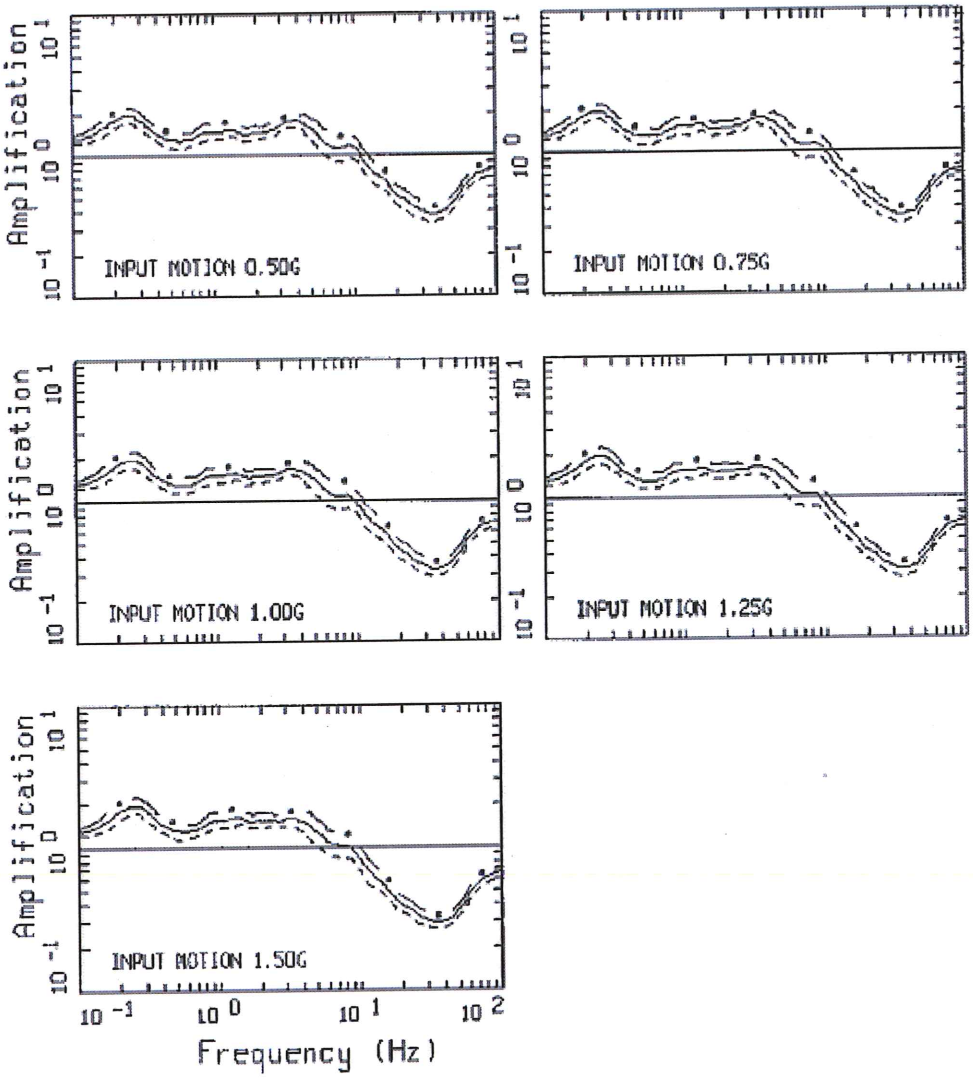

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Figure 2.3.6-1 (cont.)

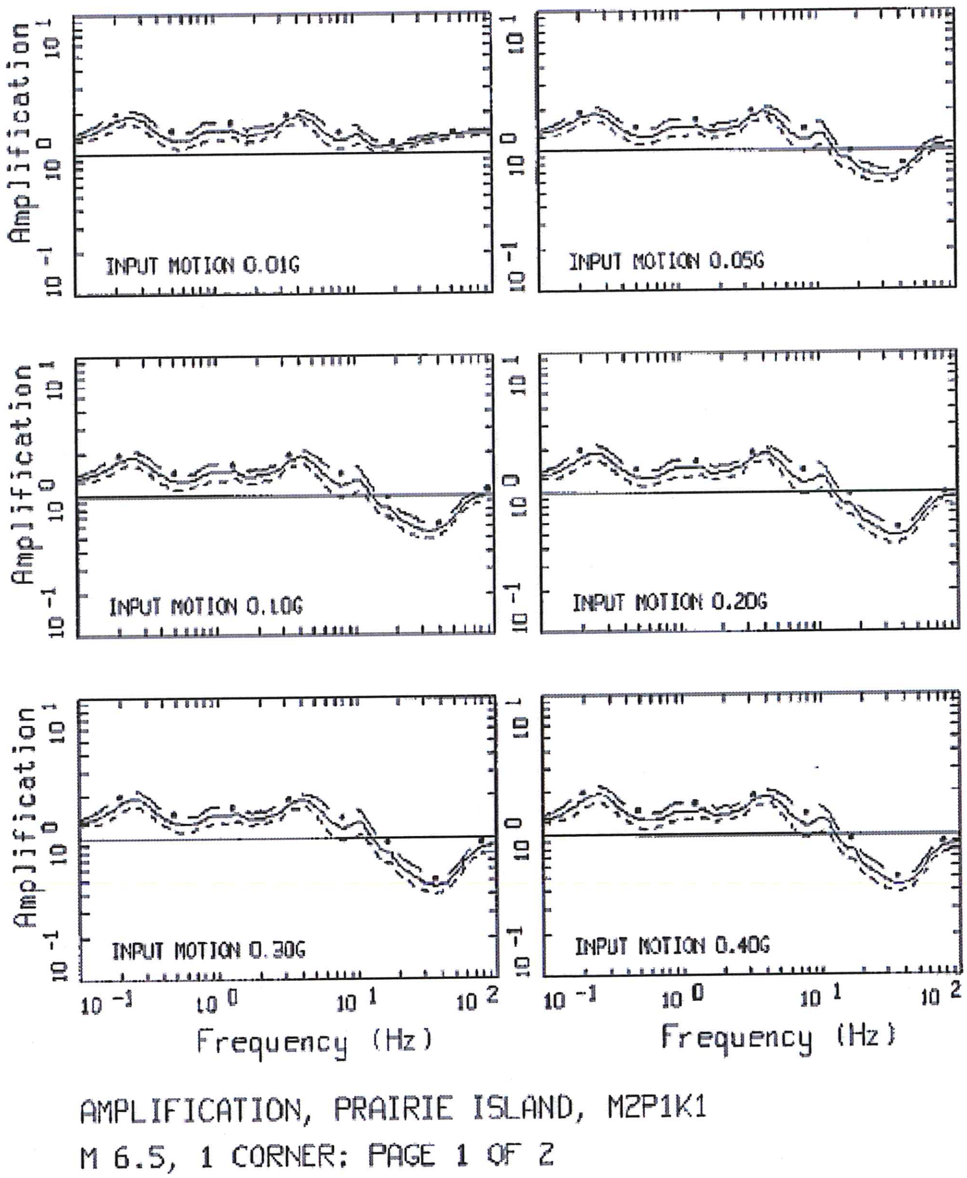

Figure 2.3.6-2. Example suite of amplification factors (5% damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), Peninsular Range modulus reduction and hysteretic damping curves for soil and linear site response for rock (model M2), and base-case kappa at eleven loading levels of hard rock median peak acceleration values from 0.01 g to 1.50 g. M 6.5 and single-corner source model (Reference 7.3).

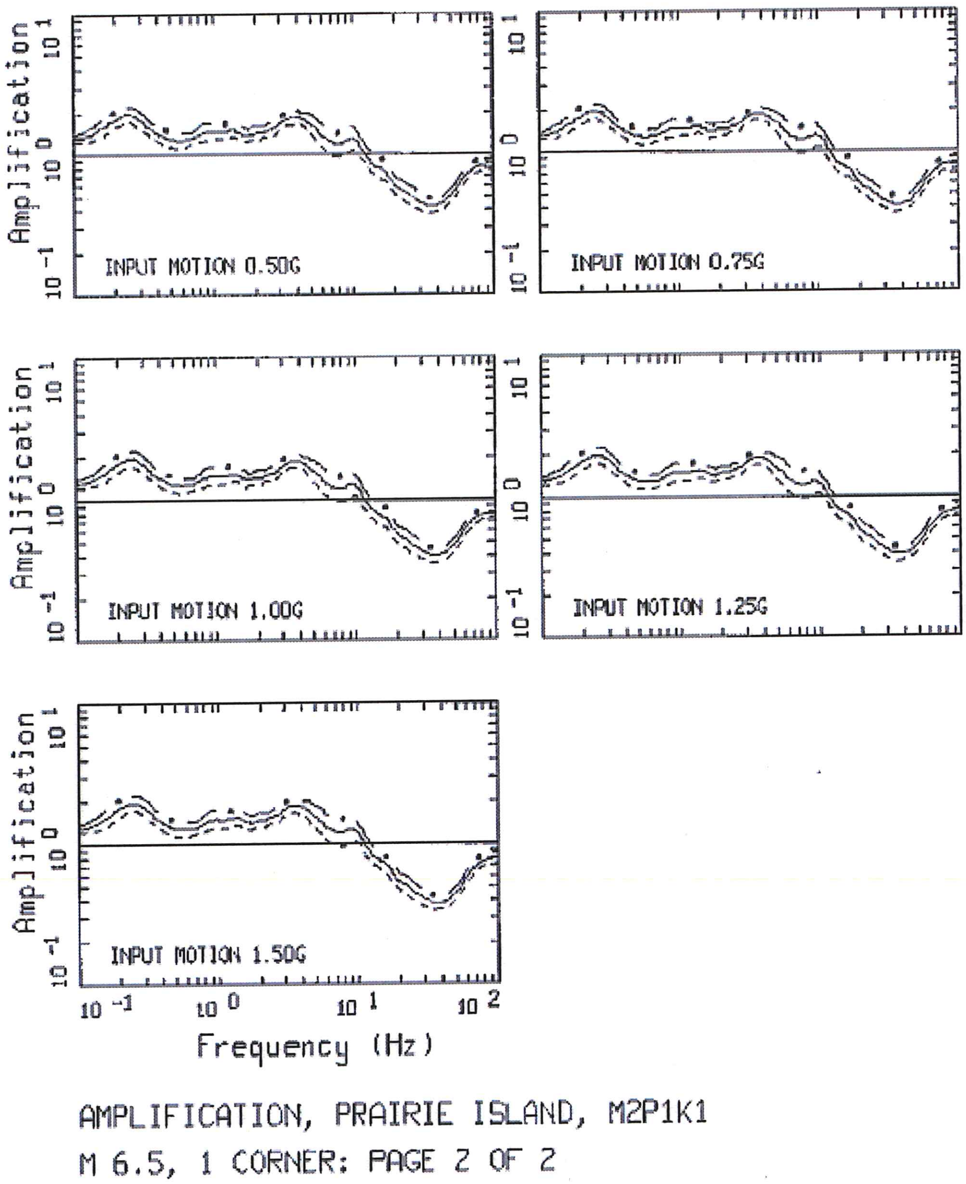

Figure 2.3.6-2 (cont.)

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 (Reference 7.3). 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 PINGP 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.

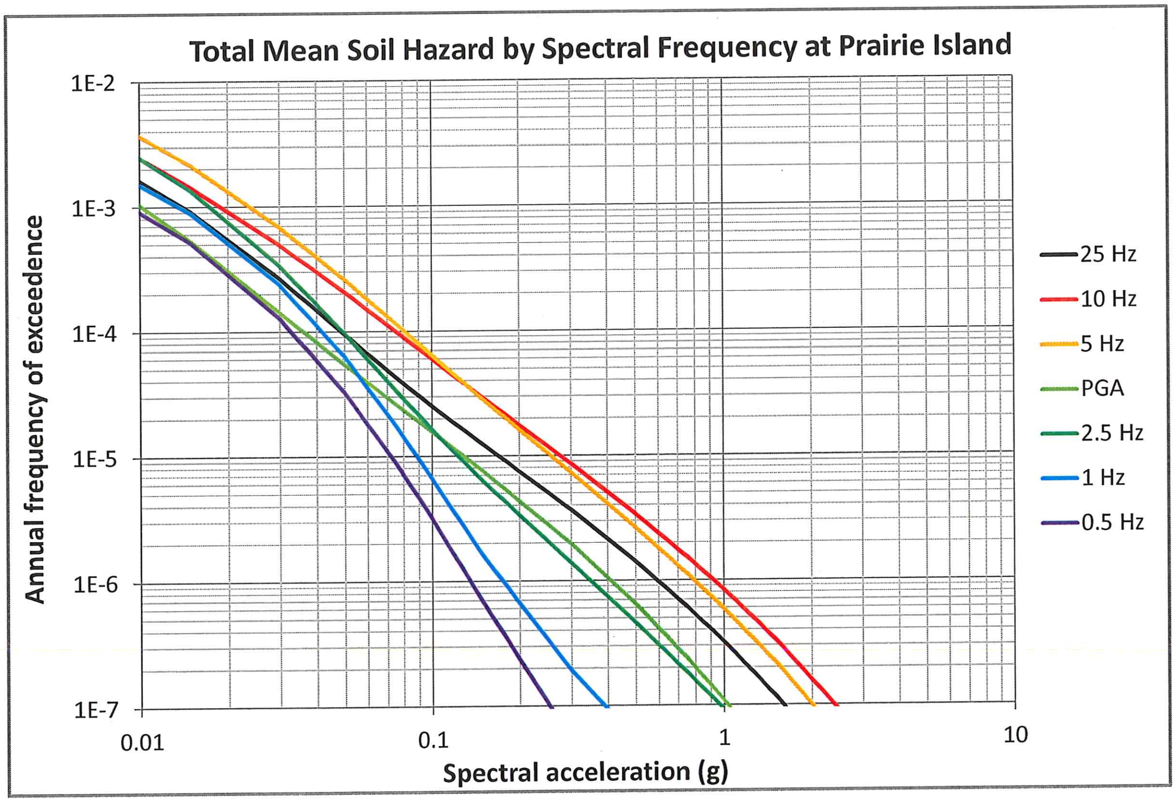

Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz at PINGP.

2.4 Control Point Response Spectra

The control point hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the ground motion response spectrum (GMRS). The UHRS were obtained through linear interpolation in log-log space to estimate the spectral acceleration at each spectral frequency for the 1E-4 and 1E-5 per year hazard levels. Table 2.4-1 shows the UHRS and GMRS accelerations for a range of spectral frequencies. The 1E-4 and 1E-5 UHRS are used to compute the GMRS at the control point and are shown in Figure 2.4-1.

TABLE 2.4-1

UHRS and GMRS for PINGP

Freq. (Hz)	10^{-4} UHRS (g)	10^{-5} UHRS (g)	GMRS (g)
100	3.63E-02	1.29E-01	6.01E-02
90	3.65E-02	1.29E-01	6.02E-02
80	3.67E-02	1.29E-01	6.03E-02
70	3.71E-02	1.30E-01	6.05E-02
60	3.76E-02	1.31E-01	6.11E-02
50	3.85E-02	1.34E-01	6.25E-02
40	4.06E-02	1.41E-01	6.59E-02
35	4.24E-02	1.47E-01	6.89E-02
30	4.50E-02	1.57E-01	7.33E-02
25	4.88E-02	1.70E-01	7.94E-02
20	5.48E-02	1.95E-01	9.08E-02
15	6.27E-02	2.26E-01	1.05E-01
12.5	7.43E-02	2.70E-01	1.25E-01
10	7.55E-02	2.77E-01	1.28E-01
9	7.17E-02	2.57E-01	1.20E-01
8	7.00E-02	2.44E-01	1.14E-01
7	7.03E-02	2.39E-01	1.12E-01
6	7.54E-02	2.48E-01	1.17E-01
5	8.07E-02	2.56E-01	1.22E-01
4	8.03E-02	2.36E-01	1.14E-01
3.5	7.22E-02	2.03E-01	9.90E-02
3	6.15E-02	1.64E-01	8.08E-02
2.5	4.94E-02	1.24E-01	6.18E-02
2	4.81E-02	1.16E-01	5.82E-02
1.5	4.51E-02	1.03E-01	5.24E-02
1.25	4.37E-02	9.64E-02	4.94E-02
1	4.20E-02	8.90E-02	4.59E-02
0.9	4.18E-02	8.91E-02	4.59E-02
0.8	3.97E-02	8.51E-02	4.38E-02
0.7	3.75E-02	8.11E-02	4.17E-02
0.6	3.61E-02	7.86E-02	4.03E-02
0.5	3.30E-02	7.25E-02	3.72E-02
0.4	2.64E-02	5.80E-02	2.97E-02
0.35	2.31E-02	5.07E-02	2.60E-02
0.3	1.98E-02	4.35E-02	2.23E-02
0.25	1.65E-02	3.62E-02	1.86E-02
0.2	1.32E-02	2.90E-02	1.49E-02
0.15	9.90E-03	2.17E-02	1.11E-02
0.125	8.25E-03	1.81E-02	9.29E-03
0.1	6.60E-03	1.45E-02	7.43E-03

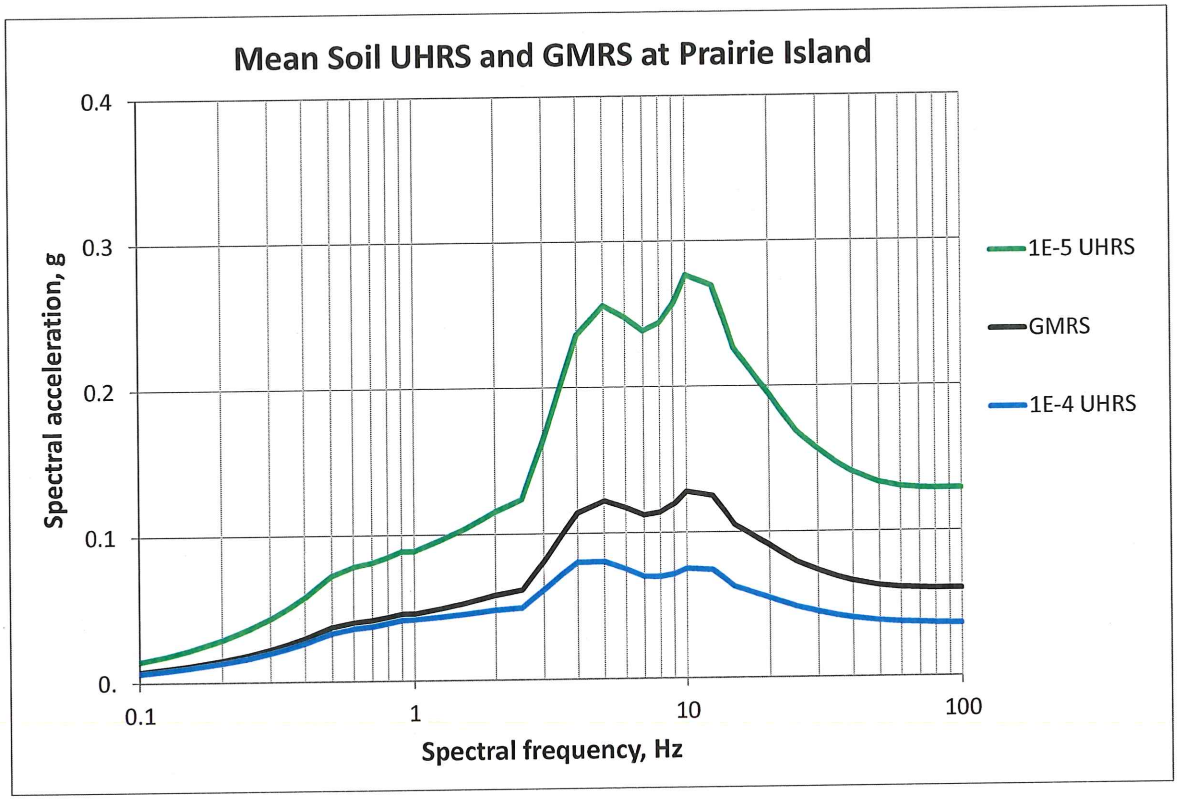

Figure 2.4-1. Plots of 1E-4 and 1E-5 UHRS and GMRS at control point for PINGP (5%-damped response spectra).

3.0 Safe Shutdown Earthquake Ground Motion

The design basis for PINGP is identified in the Updated Safely Evaluation Report (USAR).

3.1 SSE Description of Spectral Shape

All Class I structures and equipment were analyzed to assure that a safe shutdown can be made during ground accelerations of 0.06 g (operating basis earthquake) and 0.12 g (design basis or maximum earthquake) (Reference 7.14, Section 12.2.1.4).

The OBE is based upon a maximum horizontal ground acceleration of 0.06 g and the response spectra are given in USAR, Appendix E, Plate 4.5. The Design Basis Earthquake is based upon a maximum horizontal ground acceleration of 0.12 g and the response spectra are given on USAR, Appendix E, Plate 4.6. However, the response spectra for the D5/D6 Diesel Generator

Building design are based upon Regulatory Guide 1.60, Revision 1, spectra for maximum ground acceleration (zero period acceleration) of 0.06 g OBE and 0.12 g SSE (Reference 7.14, Section 12.2).

Only 0.5% and 1% damping values were used for original site design (Reference 7.9). The 5% damping values were developed by analysis (Reference 7.10) from the original site spectra. The 5% damped horizontal SSE is shown in Table 3.1-1.

Refer to PINGP USAR Section 2 (Reference 7.2), USAR Section 12 (Reference 7.14), and USAR Appendix E (Reference 7.6) for additional description on the SSE.

TABLE 3.1-1

SSE for PINGP (Reference 7.7)

Freq. (Hz)	SA (g)
33	0.12
9	0.14
5	0.18
2.5	0.17
1	0.10
0.5	0.06

3.2 Control Point Elevation

PINGP USAR does not explicitly define the SSE control point. The SSE control point elevation is defined at the surface per Table 1 of Reference 7.7, and is based on the site geologic profile at the PINGP.

The profile was modeled up to the surface, in accordance with Reference 7.7. For dynamic properties of soft rock layers, modulus and damping curves were represented with 2 models. The first model used rock curves, the second model assumed linear behavior. These dynamic property models were weighted equally. For dynamic properties of fill and compacted sand layers, modulus and damping curves were also represented with 2 models. These dynamic property models were weighted equally. To model the profile, rock modulus and damping curves were paired with soil modulus and damping curves, and linear rock modulus and damping curves were paired with soil modulus and damping curves.

4.0 Screening Evaluation

In accordance with SPID Section 3 (Reference 7.3), a screening evaluation was performed as described below.

The horizontal GMRS determined from the hazard reevaluation is used to characterize the amplitude of the new seismic hazard at PINGP. The PINGP screening evaluation is based upon a comparison of the site-specific GMRS with 5% damped horizontal SSE.

4.1 Risk Evaluation Screening (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the SSE exceeds the GMRS (Reference 7.1). Therefore, a risk evaluation will not be performed for PINGP.

4.2 High Frequency Screening (> 10 Hz)

Above 10 Hz, the SSE exceeds the GMRS (Reference 7.1). Therefore, a high frequency confirmation will not be performed for PINGP.

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

In the 1 to 10 Hz part of the response spectrum, the SSE exceeds the GMRS (Reference 7.1). Therefore, a spent fuel pool evaluation will not be performed for PINGP.

5.0 Interim Actions

Based on the screening evaluation, the expedited seismic evaluation described in Reference 7.11 will not be performed. PINGP screens out from this activity since the GMRS is less than the SSE between 1 and 10 Hz.

Consistent with NRC letter dated February 20, 2014 (Reference 7.21), the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of PINGP. 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 (Reference 7.21) 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 (Reference 7.12) 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 Generic Issue (GI)-199 Safety/Risk Assessment (Reference 7.22):

- 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.

The comparisons documented in the March 12, 2014, letter (Reference 7.12) show that there has not been an overall increase in seismic risk for the fleet of U.S. nuclear plants. In addition, all sixty-one of the CEUS sites have seismic core damage risk estimates below the 10^{-4}/year threshold considered in the NRC 2010 Safety / Risk Assessment (Reference 7.22). PINGP is included in the March 12, 2014, risk estimates. Thus, it can be concluded that the current seismic design of PINGP continues to provide a safety margin to withstand potential earthquakes exceeding the seismic design basis, as was concluded in the NRC 2010 Safety / Risk Assessment (Reference 7.22).

6.0 Conclusions

In accordance with the 50.54(f) request for information, a seismic hazard and screening evaluation was performed for PINGP. A GMRS was developed solely for purpose of screening for additional evaluations in accordance with the SPID.

Based on the results of the screening evaluation, no further evaluations will be performed.

7.0 References

7.1 Prairie Island Seismic Hazard and Screening Report, prepared by EPRI / LCI, Project Number 1041, dated December 18, 2013.

7.2 PINGP USAR, Section 02, *Site and Environs*, Revision 32.

7.3 EPRI Report Number 1025287, "Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic," dated November 2012, ADAMS Accession No. ML12333A170.

7.4 Technical Report, NUREG-2115, "Central and Eastern United States Seismic Source Characterization for Nuclear Facilities," EPRI, Palo Alto, CA, U.S. DOE, and U.S. NRC, dated 2012.

7.5 EPRI Report Number 3002000717, "EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project," dated June 2013.

7.6 PINGP USAR, Appendix E, *Report of Environmental Studies, Geology, Hydrology and Seismology, Proposed Nuclear Power Plant Prairie Island Site Near Red Wing, Minnesota*, Revision 32.

7.7 NSPM Engineering Change (EC) 22628, "Site Geological Profile for 10 CFR 50.54f Seismic Reevaluation."

7.8 Nuclear Energy Institute (NEI) letter to NRC, "Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations," dated April 9, 2013, ADAMS Accession No. ML13101A379.

7.9 John A. Blume and Associates, Engineers, Calculation No. JAB-PS-04, *Earthquake Analysis: Reactor-Auxiliary-Turbine Building Response Acceleration Spectra*, Revision 0.

7.10 Stevenson and Associates, Calculation No. 00Q4159-C-001, *PINGP Floor Response Spectra*, Revision 0.

7.11 EPRI Report Number 3002000704, "Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1 - Seismic," dated May 2013, ADAMS Accession No. ML13107B387.

7.12 NEI Letter to NRC, "Seismic Risk Evaluations for Plants in the Central and Eastern United States," dated March 12, 2014.

7.13 PINGP USAR Section 01, *Introduction and Summary Description*, Revision 32.

7.14 PINGP USAR Section 12, *Plant Structures and Shielding*, Revision 32.

7.15 Silva, W.J., Abrahamson, N., Toro, G., and Costantino, C. (1997). "Description and validation of the stochastic ground motion model", Report Submitted to Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York 11973, Contract No. 770573.

7.16 USNRC NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities," dated June 1991, ADAMS Accession No. ML063550238.

7.17 USNRC NUREG-1488, "Revised Livermore Seismic Hazard Estimates for Sixty-Nine Nuclear Power Plant Sites East of the Rocky Mountains," Final Report dated April 1994, ADAMS Accession No. ML052640591.

7.18 USNRC NUREG-1742, "Perspectives Gained From the Individual Plant Examination of External Events (IPEEE) Program," dated September 2001, ADAMS Accession No. ML021270070.

7.19 USNRC Regulatory Guide 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," Revision 0.

7.20 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 No. ML13106A331.

7.21 NRC Letter, "Supplemental Information Related to Request for Information Pursuant to Title 10 of the *Code of Federal Regulations* 50.54(f) Regarding Seismic Hazard Reevaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," dated February 20, 2014, ADAMS Accession No. ML14030A046.

7.22 NRC Generic Issue (GI) 199 Report, "Implications of Updated Probabilistic Seismic Hazard Estimates In Central And Eastern United States On Existing Plants, Safety/Risk Assessment," dated August 2010, ADAMS Accession No. ML100270639.

Appendix A

Mean and Fractile Seismic Hazard Curves

TABLE A-1a. Mean and Fractile Seismic Hazard Curves for PGA at PINGP

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.65E-02	6.73E-03	1.18E-02	1.64E-02	2.16E-02	2.49E-02
0.001	1.18E-02	3.42E-03	7.66E-03	1.16E-02	1.62E-02	1.95E-02
0.005	2.74E-03	4.98E-04	1.05E-03	2.22E-03	4.43E-03	6.93E-03
0.01	1.04E-03	1.40E-04	2.96E-04	7.34E-04	1.64E-03	3.33E-03
0.015	5.29E-04	5.66E-05	1.25E-04	3.47E-04	8.47E-04	1.79E-03
0.03	1.43E-04	9.93E-06	2.13E-05	8.12E-05	2.42E-04	4.70E-04
0.05	5.48E-05	2.32E-06	5.58E-06	2.72E-05	9.24E-05	1.92E-04
0.075	2.64E-05	7.34E-07	2.16E-06	1.23E-05	4.43E-05	9.79E-05
0.1	1.58E-05	3.33E-07	1.18E-06	7.34E-06	2.64E-05	5.91E-05
0.15	7.62E-06	1.15E-07	5.35E-07	3.52E-06	1.31E-05	2.84E-05
0.3	1.99E-06	1.95E-08	1.29E-07	8.72E-07	3.52E-06	7.34E-06
0.5	6.49E-07	4.25E-09	3.52E-08	2.60E-07	1.18E-06	2.46E-06
0.75	2.39E-07	1.02E-09	1.02E-08	8.60E-08	4.31E-07	9.51E-07
1.	1.10E-07	3.57E-10	3.73E-09	3.47E-08	1.95E-07	4.56E-07
1.5	3.32E-08	1.08E-10	7.66E-10	8.35E-09	5.58E-08	1.44E-07
3.	3.16E-09	7.13E-11	8.72E-11	4.70E-10	4.31E-09	1.44E-08
5.	4.21E-10	7.13E-11	7.77E-11	9.37E-11	4.90E-10	1.92E-09
7.5	6.97E-11	7.13E-11	7.13E-11	8.12E-11	1.20E-10	3.57E-10
10.	1.74E-11	7.13E-11	7.13E-11	8.12E-11	8.12E-11	1.36E-10

TABLE A-1b. Mean and Fractile Seismic Hazard Curves for 25 Hz at PINGP

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.74E-02	8.72E-03	1.29E-02	1.74E-02	2.22E-02	2.57E-02
0.001	1.30E-02	4.98E-03	8.98E-03	1.29E-02	1.74E-02	2.07E-02
0.005	3.69E-03	8.35E-04	1.60E-03	3.14E-03	5.66E-03	8.85E-03
0.01	1.62E-03	2.64E-04	5.27E-04	1.20E-03	2.53E-03	4.83E-03
0.015	9.09E-04	1.20E-04	2.42E-04	6.26E-04	1.42E-03	2.88E-03
0.03	2.67E-04	2.32E-05	4.90E-05	1.67E-04	4.50E-04	8.35E-04
0.05	9.53E-05	5.75E-06	1.29E-05	5.50E-05	1.69E-04	3.09E-04
0.075	4.30E-05	1.82E-06	4.63E-06	2.32E-05	7.77E-05	1.46E-04
0.1	2.53E-05	8.47E-07	2.46E-06	1.34E-05	4.56E-05	8.72E-05
0.15	1.24E-05	3.05E-07	1.13E-06	6.54E-06	2.29E-05	4.25E-05
0.3	3.70E-06	5.91E-08	3.28E-07	2.01E-06	6.93E-06	1.23E-05
0.5	1.42E-06	1.87E-08	1.20E-07	7.66E-07	2.76E-06	4.77E-06
0.75	6.16E-07	6.26E-09	4.77E-08	3.19E-07	1.21E-06	2.13E-06
1	3.24E-07	2.80E-09	2.35E-08	1.62E-07	6.45E-07	1.15E-06
1.5	1.19E-07	8.12E-10	7.77E-09	5.58E-08	2.35E-07	4.31E-07
3	1.62E-08	1.23E-10	8.00E-10	6.36E-09	3.05E-08	6.45E-08
5	2.86E-09	7.34E-11	1.55E-10	9.37E-10	4.90E-09	1.25E-08
7.5	6.10E-10	7.13E-11	8.12E-11	2.13E-10	1.01E-09	2.88E-09
10	1.86E-10	7.13E-11	8.12E-11	1.02E-10	3.28E-10	9.65E-10

TABLE A-1c. Mean and Fractile Seismic Hazard Curves for 10 Hz at PINGP

AMPS (g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.99E-02	1.29E-02	1.51E-02	1.98E-02	2.46E-02	2.80E-02
0.001	1.63E-02	9.51E-03	1.18E-02	1.60E-02	2.07E-02	2.39E-02
0.005	5.46E-03	1.74E-03	2.88E-03	5.12E-03	8.00E-03	1.05E-02
0.01	2.49E-03	5.66E-04	1.04E-03	2.10E-03	3.84E-03	5.83E-03
0.015	1.44E-03	2.68E-04	5.12E-04	1.13E-03	2.25E-03	3.73E-03
0.03	4.97E-04	6.54E-05	1.32E-04	3.52E-04	8.00E-04	1.40E-03
0.05	2.08E-04	2.13E-05	4.31E-05	1.38E-04	3.52E-04	6.17E-04
0.075	1.01E-04	8.23E-06	1.72E-05	6.45E-05	1.79E-04	3.09E-04
0.1	6.04E-05	4.07E-06	8.85E-06	3.73E-05	1.10E-04	1.90E-04
0.15	2.94E-05	1.46E-06	3.57E-06	1.72E-05	5.50E-05	9.79E-05
0.3	8.68E-06	2.46E-07	8.12E-07	4.56E-06	1.64E-05	3.05E-05
0.5	3.42E-06	6.26E-08	2.80E-07	1.72E-06	6.54E-06	1.23E-05
0.75	1.55E-06	2.01E-08	1.11E-07	7.34E-07	2.96E-06	5.66E-06
1.	8.49E-07	8.60E-09	5.58E-08	3.79E-07	1.64E-06	3.19E-06
1.5	3.39E-07	2.42E-09	1.79E-08	1.34E-07	6.54E-07	1.34E-06
3.	5.56E-08	2.22E-10	1.77E-09	1.64E-08	1.04E-07	2.46E-07
5.	1.17E-08	8.12E-11	2.57E-10	2.57E-09	2.01E-08	5.50E-08
7.5	2.91E-09	7.13E-11	9.24E-11	5.12E-10	4.56E-09	1.40E-08
10.	9.92E-10	7.13E-11	8.12E-11	1.84E-10	1.44E-09	4.83E-09

TABLE A-1d. Mean and Fractile Seismic Hazard Curves for 5 Hz at PINGP

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	2.11E-02	1.40E-02	1.62E-02	2.10E-02	2.57E-02	2.92E-02
0.001	1.85E-02	1.13E-02	1.36E-02	1.82E-02	2.32E-02	2.68E-02
0.005	7.68E-03	2.68E-03	4.25E-03	7.34E-03	1.11E-02	1.38E-02
0.01	3.71E-03	8.98E-04	1.64E-03	3.33E-03	5.83E-03	7.77E-03
0.015	2.14E-03	4.25E-04	8.12E-04	1.79E-03	3.47E-03	5.05E-03
0.03	6.88E-04	9.51E-05	1.98E-04	5.05E-04	1.11E-03	1.90E-03
0.05	2.63E-04	2.80E-05	6.09E-05	1.79E-04	4.37E-04	7.55E-04
0.075	1.16E-04	1.01E-05	2.22E-05	7.55E-05	2.01E-04	3.47E-04
0.1	6.46E-05	4.77E-06	1.08E-05	4.07E-05	1.16E-04	2.01E-04
0.15	2.85E-05	1.60E-06	3.84E-06	1.69E-05	5.27E-05	9.37E-05
0.3	7.35E-06	2.42E-07	7.34E-07	3.90E-06	1.40E-05	2.57E-05
0.5	2.67E-06	5.50E-08	2.22E-07	1.32E-06	5.12E-06	9.65E-06
0.75	1.14E-06	1.53E-08	8.12E-08	5.27E-07	2.19E-06	4.25E-06
1.	5.97E-07	6.36E-09	3.84E-08	2.64E-07	1.16E-06	2.29E-06
1.5	2.24E-07	1.62E-09	1.18E-08	9.11E-08	4.31E-07	8.85E-07
3.	3.30E-08	1.64E-10	1.11E-09	1.01E-08	5.91E-08	1.44E-07
5.	6.48E-09	8.12E-11	1.84E-10	1.49E-09	1.05E-08	2.96E-08
7.5	1.55E-09	7.13E-11	8.35E-11	3.05E-10	2.25E-09	7.13E-09
10.	5.19E-10	7.13E-11	8.12E-11	1.25E-10	6.93E-10	2.39E-09

TABLE A-1e. Mean and Fractile Seismic Hazard Curves for 2.5 Hz at PINGP

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.97E-02	1.27E-02	1.49E-02	1.95E-02	2.46E-02	2.80E-02
0.001	1.60E-02	8.98E-03	1.13E-02	1.55E-02	2.07E-02	2.42E-02
0.005	5.45E-03	1.82E-03	2.88E-03	5.12E-03	8.00E-03	1.02E-02
0.01	2.49E-03	5.66E-04	1.01E-03	2.16E-03	4.01E-03	5.58E-03
0.015	1.35E-03	2.35E-04	4.43E-04	1.05E-03	2.25E-03	3.47E-03
0.03	3.39E-04	3.95E-05	8.35E-05	2.25E-04	5.42E-04	1.04E-03
0.05	9.72E-05	8.72E-06	2.04E-05	6.17E-05	1.55E-04	3.14E-04
0.075	3.41E-05	2.49E-06	6.09E-06	2.10E-05	5.91E-05	1.10E-04
0.1	1.66E-05	1.02E-06	2.53E-06	1.01E-05	3.01E-05	5.35E-05
0.15	6.35E-06	2.92E-07	7.77E-07	3.63E-06	1.18E-05	2.13E-05
0.3	1.40E-06	3.33E-08	1.16E-07	6.83E-07	2.64E-06	5.12E-06
0.5	4.62E-07	6.00E-09	2.92E-08	1.98E-07	8.72E-07	1.77E-06
0.75	1.85E-07	1.49E-09	9.24E-09	7.03E-08	3.42E-07	7.34E-07
1.	9.34E-08	5.58E-10	3.84E-09	3.19E-08	1.69E-07	3.90E-07
1.5	3.37E-08	1.67E-10	1.05E-09	9.79E-09	5.83E-08	1.49E-07
3.	4.80E-09	8.12E-11	1.29E-10	9.51E-10	7.23E-09	2.22E-08
5.	9.19E-10	7.13E-11	8.12E-11	1.74E-10	1.21E-09	4.31E-09
7.5	2.12E-10	7.13E-11	7.77E-11	8.35E-11	2.88E-10	1.01E-09
10.	6.87E-11	7.13E-11	7.13E-11	8.12E-11	1.25E-10	3.57E-10

TABLE A-1f. Mean and Fractile Seismic Hazard Curves for 1 Hz at PINGP

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.37E-02	6.36E-03	8.85E-03	1.32E-02	1.84E-02	2.19E-02
0.001	9.30E-03	3.68E-03	5.58E-03	8.98E-03	1.31E-02	1.60E-02
0.005	2.90E-03	5.05E-04	1.05E-03	2.57E-03	4.77E-03	6.45E-03
0.01	1.51E-03	1.25E-04	3.09E-04	1.11E-03	2.76E-03	4.19E-03
0.015	8.88E-04	4.70E-05	1.29E-04	5.42E-04	1.69E-03	2.84E-03
0.03	2.41E-04	6.64E-06	2.07E-05	9.93E-05	4.37E-04	9.65E-04
0.05	6.36E-05	1.31E-06	4.31E-06	2.16E-05	1.02E-04	2.72E-04
0.075	1.79E-05	3.28E-07	1.10E-06	5.75E-06	2.60E-05	7.66E-05
0.1	6.71E-06	1.16E-07	4.01E-07	2.19E-06	9.65E-06	2.88E-05
0.15	1.63E-06	2.64E-08	9.37E-08	5.42E-07	2.46E-06	7.03E-06
0.3	1.94E-07	1.69E-09	7.55E-09	5.58E-08	3.14E-07	8.35E-07
0.5	5.39E-08	2.32E-10	1.11E-09	1.13E-08	7.77E-08	2.39E-07
0.75	2.02E-08	8.98E-11	2.72E-10	3.14E-09	2.68E-08	9.11E-08
1.	9.86E-09	8.12E-11	1.29E-10	1.21E-09	1.20E-08	4.50E-08
1.5	3.38E-09	7.13E-11	8.12E-11	3.28E-10	3.57E-09	1.51E-08
3.	4.41E-10	7.13E-11	7.89E-11	8.12E-11	3.73E-10	1.79E-09
5.	8.00E-11	7.13E-11	7.13E-11	8.12E-11	1.04E-10	3.28E-10
7.5	1.79E-11	7.13E-11	7.13E-11	8.12E-11	8.12E-11	1.15E-10
10.	5.72E-12	7.13E-11	7.13E-11	8.12E-11	8.12E-11	8.12E-11

TABLE A-1g. Mean and Fractile Seismic Hazard Curves for 0.5 Hz at PINGP

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	7.47E-03	3.23E-03	4.63E-03	7.23E-03	1.02E-02	1.27E-02
0.001	4.91E-03	1.67E-03	2.68E-03	4.63E-03	7.13E-03	8.98E-03
0.005	1.79E-03	1.32E-04	3.57E-04	1.40E-03	3.28E-03	4.77E-03
0.01	9.11E-04	2.39E-05	8.23E-05	5.12E-04	1.82E-03	3.05E-03
0.015	5.14E-04	7.45E-06	2.92E-05	2.16E-04	1.07E-03	1.95E-03
0.03	1.29E-04	7.77E-07	3.57E-06	3.19E-05	2.25E-04	5.83E-04
0.05	3.28E-05	1.29E-07	6.26E-07	5.83E-06	4.70E-05	1.53E-04
0.075	8.97E-06	2.84E-08	1.40E-07	1.32E-06	1.10E-05	4.01E-05
0.1	3.23E-06	9.24E-09	4.56E-08	4.56E-07	3.73E-06	1.40E-05
0.15	6.91E-07	1.74E-09	8.98E-09	9.65E-08	7.45E-07	3.19E-06
0.3	5.36E-08	1.23E-10	5.42E-10	6.45E-09	6.00E-08	2.57E-07
0.5	1.21E-08	8.12E-11	1.08E-10	9.11E-10	1.10E-08	5.12E-08
0.75	4.29E-09	7.13E-11	8.12E-11	2.32E-10	2.92E-09	1.69E-08
1.	2.07E-09	7.13E-11	8.12E-11	1.16E-10	1.13E-09	7.55E-09
1.5	7.10E-10	7.13E-11	7.23E-11	8.12E-11	3.19E-10	2.25E-09
3.	9.47E-11	7.13E-11	7.13E-11	8.12E-11	8.23E-11	2.72E-10
5.	1.77E-11	7.13E-11	7.13E-11	8.12E-11	8.12E-11	9.24E-11
7.5	4.06E-12	7.13E-11	7.13E-11	8.12E-11	8.12E-11	8.12E-11
10.	1.32E-12	7.13E-11	7.13E-11	8.12E-11	8.12E-11	8.12E-11

TABLE A-2

Amplification Functions for PINGP

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	1.36E+00	8.25E-02	1.30E-02	1.10E+00	9.00E-02	1.90E-02	1.22E+00	1.80E-01	2.09E-02	1.71E+00	1.13E-01
4.95E-02	1.07E+00	1.06E-01	1.02E-01	6.49E-01	1.43E-01	9.99E-02	1.15E+00	2.17E-01	8.24E-02	1.69E+00	1.20E-01
9.64E-02	9.63E-01	1.13E-01	2.13E-01	5.72E-01	1.60E-01	1.85E-01	1.13E+00	2.24E-01	1.44E-01	1.67E+00	1.23E-01
1.94E-01	8.84E-01	1.18E-01	4.43E-01	5.22E-01	1.72E-01	3.56E-01	1.12E+00	2.29E-01	2.65E-01	1.64E+00	1.29E-01
2.92E-01	8.45E-01	1.20E-01	6.76E-01	5.00E-01	1.77E-01	5.23E-01	1.10E+00	2.33E-01	3.84E-01	1.62E+00	1.35E-01
3.91E-01	8.20E-01	1.21E-01	9.09E-01	5.00E-01	1.79E-01	6.90E-01	1.09E+00	2.36E-01	5.02E-01	1.61E+00	1.41E-01
4.93E-01	8.01E-01	1.21E-01	1.15E+00	5.00E-01	1.81E-01	8.61E-01	1.08E+00	2.38E-01	6.22E-01	1.59E+00	1.46E-01
7.41E-01	7.67E-01	1.21E-01	1.73E+00	5.00E-01	1.82E-01	1.27E+00	1.06E+00	2.43E-01	9.13E-01	1.55E+00	1.58E-01
1.01E+00	7.42E-01	1.21E-01	2.36E+00	5.00E-01	1.76E-01	1.72E+00	1.03E+00	2.44E-01	1.22E+00	1.52E+00	1.70E-01
1.28E+00	7.20E-01	1.20E-01	3.01E+00	5.00E-01	1.72E-01	2.17E+00	9.90E-01	2.40E-01	1.54E+00	1.48E+00	1.78E-01
1.55E+00	7.02E-01	1.19E-01	3.63E+00	5.00E-01	1.68E-01	2.61E+00	9.57E-01	2.36E-01	1.85E+00	1.45E+00	1.86E-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	1.41E+00	1.20E-01	1.27E-02	1.41E+00	1.42E-01	8.25E-03	1.35E+00	1.51E-01			
7.05E-02	1.41E+00	1.20E-01	3.43E-02	1.41E+00	1.39E-01	1.96E-02	1.35E+00	1.45E-01			
1.18E-01	1.41E+00	1.21E-01	5.51E-02	1.41E+00	1.38E-01	3.02E-02	1.35E+00	1.43E-01			
2.12E-01	1.42E+00	1.24E-01	9.63E-02	1.42E+00	1.38E-01	5.11E-02	1.36E+00	1.42E-01			
3.04E-01	1.42E+00	1.26E-01	1.36E-01	1.42E+00	1.38E-01	7.10E-02	1.36E+00	1.41E-01			
3.94E-01	1.43E+00	1.28E-01	1.75E-01	1.43E+00	1.38E-01	9.06E-02	1.36E+00	1.40E-01			
4.86E-01	1.44E+00	1.29E-01	2.14E-01	1.43E+00	1.38E-01	1.10E-01	1.36E+00	1.40E-01			
7.09E-01	1.45E+00	1.30E-01	3.10E-01	1.44E+00	1.38E-01	1.58E-01	1.37E+00	1.40E-01			
9.47E-01	1.46E+00	1.32E-01	4.12E-01	1.45E+00	1.38E-01	2.09E-01	1.37E+00	1.40E-01			
1.19E+00	1.47E+00	1.34E-01	5.18E-01	1.46E+00	1.39E-01	2.62E-01	1.37E+00	1.41E-01			
1.43E+00	1.47E+00	1.35E-01	6.19E-01	1.46E+00	1.39E-01	3.12E-01	1.38E+00	1.41E-01			

Appendix A (Continued)
Median Amplification Factors and Uncertainties

Tables and figures showing median amplification factors and uncertainties.

These tables and figures concentrate on the frequency range of 0.5 Hz to 25 Hz, with values up to 100 Hz included, and a single value at 0.1 Hz included for completeness.

TABLE A2-b1. Median AFs and Sigmas for Model 1, Profile 1, for 2 PGA levels.

M1P1K1	Rock PGA=0.0495			M1P1K1	PGA=0.194		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.054	1.094	0.089	100.0	0.174	0.899	0.102
87.1	0.054	1.080	0.090	87.1	0.175	0.878	0.102
75.9	0.054	1.058	0.090	75.9	0.175	0.843	0.103
66.1	0.055	1.014	0.091	66.1	0.176	0.777	0.104
57.5	0.055	0.934	0.092	57.5	0.178	0.670	0.106
50.1	0.056	0.831	0.095	50.1	0.180	0.566	0.111
43.7	0.057	0.734	0.099	43.7	0.185	0.490	0.115
38.0	0.058	0.674	0.107	38.0	0.191	0.462	0.127
33.1	0.060	0.639	0.113	33.1	0.200	0.456	0.136
28.8	0.063	0.646	0.125	28.8	0.211	0.481	0.147
25.1	0.067	0.660	0.136	25.1	0.228	0.514	0.161
21.9	0.069	0.689	0.131	21.9	0.236	0.559	0.156
19.1	0.079	0.764	0.149	19.1	0.266	0.639	0.168
16.6	0.087	0.849	0.172	16.6	0.302	0.752	0.187
14.5	0.089	0.886	0.158	14.5	0.306	0.797	0.177
12.6	0.106	1.052	0.160	12.6	0.352	0.944	0.173
11.0	0.126	1.255	0.172	11.0	0.421	1.158	0.163
9.5	0.122	1.243	0.208	9.5	0.422	1.212	0.216
8.3	0.110	1.180	0.194	8.3	0.370	1.153	0.207
7.2	0.108	1.209	0.188	7.2	0.350	1.164	0.200
6.3	0.114	1.343	0.184	6.3	0.363	1.283	0.200
5.5	0.128	1.548	0.156	5.5	0.400	1.481	0.176
4.8	0.143	1.730	0.125	4.8	0.439	1.660	0.142
4.2	0.150	1.845	0.088	4.2	0.458	1.786	0.090
3.6	0.143	1.788	0.108	3.6	0.440	1.764	0.108
3.2	0.128	1.668	0.088	3.2	0.392	1.670	0.091
2.8	0.110	1.499	0.118	2.8	0.337	1.509	0.116
2.4	0.098	1.429	0.103	2.4	0.297	1.444	0.102
2.1	0.087	1.382	0.109	2.1	0.261	1.396	0.108
1.8	0.077	1.353	0.099	1.8	0.229	1.368	0.099
1.6	0.069	1.385	0.125	1.6	0.203	1.396	0.121
1.4	0.064	1.486	0.115	1.4	0.187	1.494	0.111
1.2	0.056	1.460	0.134	1.2	0.162	1.468	0.134
1.0	0.051	1.456	0.134	1.0	0.145	1.462	0.133

M1P1K1	Rock PGA=0.0495			M1P1K1	PGA=0.194		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
0.91	0.047	1.459	0.143	0.91	0.132	1.464	0.139
0.79	0.041	1.382	0.138	0.79	0.114	1.387	0.134
0.69	0.035	1.288	0.105	0.69	0.094	1.295	0.104
0.60	0.030	1.260	0.128	0.60	0.080	1.267	0.126
0.52	0.026	1.268	0.137	0.52	0.069	1.274	0.135
0.46	0.023	1.316	0.135	0.46	0.060	1.320	0.132
0.10	0.001	1.336	0.055	0.10	0.003	1.336	0.055

TABLE A2-b2. Median AFs and sigmas for Model 2, Profile 1, for 2 PGA levels.

M2P1K1	PGA=0.0495			M2P1K1	PGA=0.194		
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
100.0	0.055	1.110	0.084	100.0	0.182	0.937	0.095
87.1	0.055	1.097	0.085	87.1	0.182	0.916	0.096
75.9	0.055	1.074	0.085	75.9	0.183	0.879	0.096
66.1	0.056	1.030	0.086	66.1	0.184	0.811	0.097
57.5	0.056	0.949	0.087	57.5	0.186	0.700	0.100
50.1	0.057	0.845	0.090	50.1	0.189	0.594	0.104
43.7	0.058	0.748	0.093	43.7	0.195	0.517	0.109
38.0	0.059	0.687	0.101	38.0	0.203	0.489	0.120
33.1	0.061	0.653	0.106	33.1	0.213	0.486	0.129
28.8	0.064	0.661	0.119	28.8	0.227	0.516	0.145
25.1	0.069	0.677	0.130	25.1	0.246	0.555	0.157
21.9	0.071	0.706	0.121	21.9	0.253	0.600	0.143
19.1	0.081	0.790	0.142	19.1	0.292	0.699	0.158
16.6	0.089	0.873	0.166	16.6	0.325	0.810	0.180
14.5	0.091	0.905	0.144	14.5	0.325	0.847	0.159
12.6	0.109	1.083	0.148	12.6	0.382	1.023	0.157
11.0	0.130	1.292	0.170	11.0	0.456	1.253	0.163
9.5	0.124	1.262	0.207	9.5	0.437	1.257	0.214
8.3	0.111	1.192	0.188	8.3	0.379	1.181	0.199
7.2	0.109	1.225	0.182	7.2	0.362	1.203	0.192
6.3	0.116	1.364	0.178	6.3	0.377	1.334	0.188
5.5	0.130	1.574	0.150	5.5	0.416	1.541	0.161
4.8	0.145	1.761	0.123	4.8	0.456	1.727	0.130
4.2	0.152	1.877	0.090	4.2	0.475	1.855	0.089
3.6	0.145	1.809	0.111	3.6	0.452	1.811	0.111
3.2	0.128	1.679	0.089	3.2	0.398	1.694	0.090
2.8	0.111	1.504	0.117	2.8	0.339	1.519	0.115
2.4	0.098	1.432	0.101	2.4	0.297	1.445	0.100
2.1	0.087	1.382	0.106	2.1	0.261	1.392	0.106
1.8	0.077	1.354	0.098	1.8	0.228	1.362	0.098
1.6	0.069	1.386	0.127	1.6	0.202	1.392	0.126

M2P1K1		PGA=0.0495		M2P1K1		PGA=0.194	
Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)	Freq. (Hz)	Soil_SA	med. AF	sigma ln(AF)
1.4	0.064	1.487	0.116	1.4	0.186	1.490	0.114
1.2	0.056	1.460	0.132	1.2	0.161	1.463	0.130
1.0	0.051	1.456	0.134	1.0	0.145	1.458	0.133
0.91	0.047	1.460	0.144	0.91	0.132	1.461	0.141
0.79	0.041	1.382	0.139	0.79	0.113	1.385	0.135
0.69	0.035	1.289	0.105	0.69	0.094	1.294	0.103
0.60	0.030	1.261	0.128	0.60	0.080	1.266	0.125
0.52	0.026	1.269	0.137	0.52	0.069	1.274	0.134
0.46	0.023	1.316	0.134	0.46	0.060	1.320	0.131
0.10	0.001	1.337	0.055	0.10	0.003	1.336	0.055

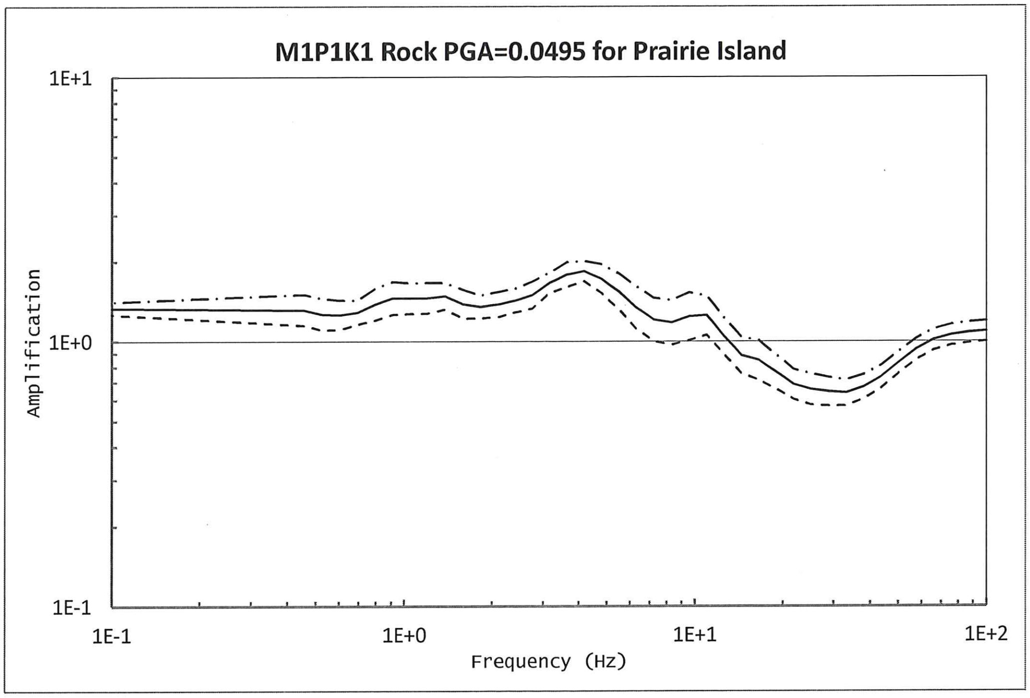

Figure 1. Amplification factors (median and median ± sigma) plotted from Table A2-b1 for PGA 0.0495g.

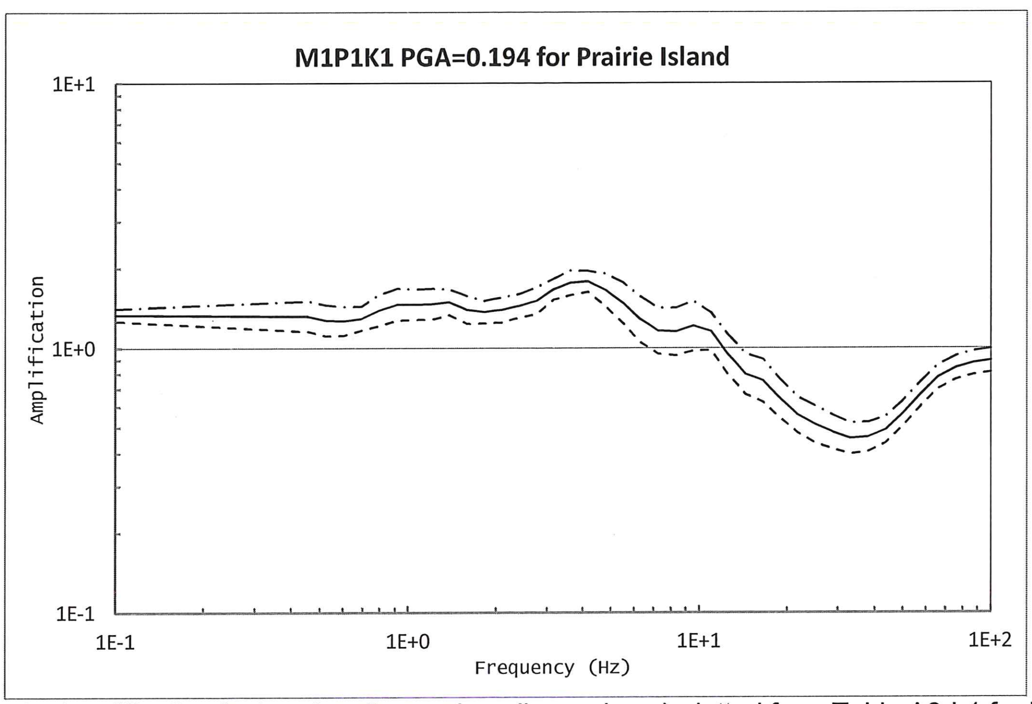

Figure 2. Amplification factors (median and median ± sigma) plotted from Table A2-b1 for PGA 0.194g.

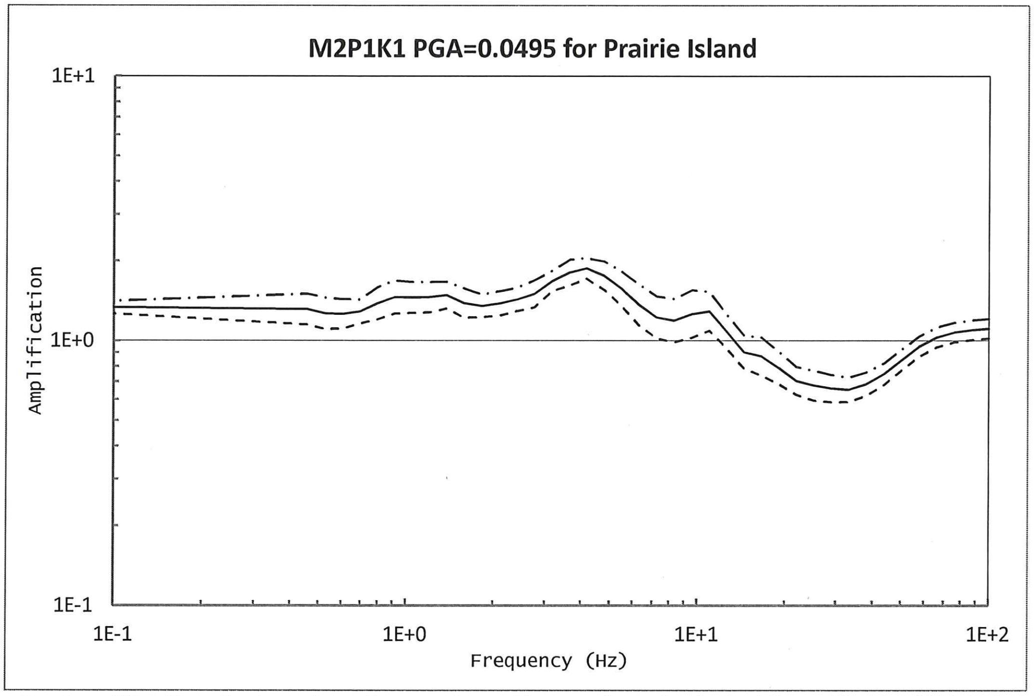

Figure 3. Amplification factors (median and median ± sigma) plotted from Table A2-b2 for PGA 0.0495g.

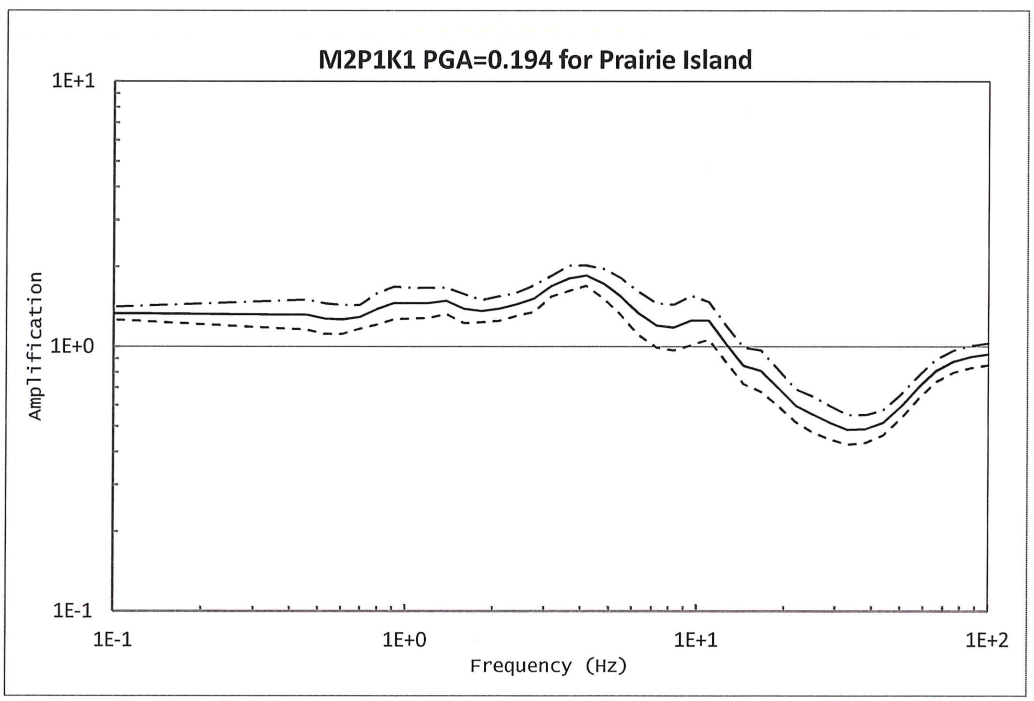

Figure 4. Amplification factors (median and median ± sigma) plotted from Table A2-b2 for PGA 0.194g.