Nuclear Operating Company
South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

March 31, 2014
NOC-AE-14003114
10 CFR 54(f)
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File: G25

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

South Texas Project
Units 1 and 2
Docket Nos. STN 50-498, STN 50-499
Seismic Hazard and Screening Report (CEUS Sites),
Response 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

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
2. NEI Letter, Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations, dated April 9, 2013, ADAMS Accession No. 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 No. 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, ADAMS Accession No. ML12333A170
5. NRC Letter, Endorsement of EPRI Final Draft Report 1025287, "Seismic Evaluation Guidance," dated February 15, 2013, ADAMS Accession No. ML12319A074

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 and Screening Report within 1.5 years from the date of Reference 1.

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In Reference 2, the Nuclear Energy Institute (NEI) requested NRC agreement to delay submittal of the final CEUS Seismic Hazard Evaluation and Screening Reports 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 and screening information submitted by March 31, 2014. NRC agreed with that proposed path forward in Reference 3.

Reference 4 contains industry guidance and detailed information to be included in the Seismic Hazard Evaluation and Screening Report submittals. NRC endorsed this industry guidance in Reference 5.

The attached Seismic Hazard and Screening Report for the South Texas Project Electric Generating Station, Units 1 and 2 (STPEGS) provides the information described in Section 4 of Reference 4 in accordance with the schedule identified in Reference 2.

This letter contains no new regulatory commitments.

Should you have any questions regarding this letter, please contact Rafael Gonzales, STP Licensing Engineer 361-972-4779 or me at 361-972-7566.

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

Executed on March 31, 2014
Date

G. T. Powell

G. T. Powell
Site Vice President

RJG

Attachment: Seismic Hazard and Screening Report for the South Texas Project Electric Generating Station, Units 1 and 2 (STPEGS)

cc:
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Seismic Hazard and Screening Report for the South Texas Project Electric Generating Station, Units 1 and 2 (STPEGS)

Revision 001

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 South Texas Project Electric Generating Station, Units 1 and 2 ("STPEGS") nuclear power plants (NPP), located in Matagorda County, Texas. In providing this information, South Texas Project Nuclear Operating Company (STPNOC), licensee for STPEGS, 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 1025287, 2013). The Augmented Approach, Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (EPRI 3002000704, 2013), 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 STPEGS were performed in accordance with Appendix A to 10 CFR Part 100 and meet General Design Criterion 2 in Appendix A to 10 CFR Part 50. The Safe Shutdown Earthquake Ground Motion (SSE) was developed in accordance with Appendix A to 10 CFR Part 100 and used for the design of seismic Category I systems, structures and components.

In response to the 50.54(f) letter and following the guidance provided in the SPID (EPRI 1025287, 2013), a seismic hazard reevaluation was performed for STPEGS.

Since the reevaluation shows that the updated GMRS does not exceed the SSE, based on the results of the screening evaluation, no further evaluations will be performed.

2.0 Seismic Hazard Reevaluation

The STPEGS site is located in south-central Matagorda County, Texas, west of the Colorado River, approximately 8 miles north-northwest of the town of Matagorda, and about 89 miles southwest of Houston. The station is located at the north end of the 7,000-Acre Main Cooling Reservoir (MCR), which is the primary cooling source for Units 1 and 2.

STPEGS is in the Gulf Coastal Plain of Texas. The Coastal Plain sediments are underlain by Cretaceous bedrock, followed by the Mesozoic basement rock which occurs at a top depth of approximately 34,500 ft. Stratigraphy at the site is essentially horizontal. As discussed in Section 2.5.1 of the UFSAR, there is no evidence of regional warping which could significantly impact the site, nor deformational zones such as joints, shear zones, fractures, faults or folds. The reactor containment buildings are founded on dense to very dense fine sand at 60 ft below plant grade. Plant grade is at El. 28 ft (NGVD 29).

Earthquake activity in historic time within 200 miles of the plant site has been low. Sources of major earthquakes in the central and eastern United States (CEUS) are distant, and have not had an appreciable effect at the site. The original investigation of historical seismic activity in the region indicated that a design intensity of VI (Modified Mercalli Scale) is adequately conservative for the site. STPEGS determined that Intensity VI corresponds to a peak ground acceleration of 0.07 g, which was increased to 0.10 g for the SSE (i.e., the minimum Peak Ground Acceleration (PGA) value established in Appendix A of 10 CFR 100).

2.1 Regional and Local Geology

STPEGS is located in south-central Matagorda County, Texas in the Gulf Coastal Plain of Texas. The uppermost soils consist of Beaumont Formation (Pleistocene) sediments extending to a minimum depth of approximately 750 ft, underlain by soil and soft rock deposits of Pleistocene, Pliocene, and Miocene ages. These lower deposits extend to a depth of approximately 4,400 ft., at which point they transition to the Oakville Sandstone Formation sediments, with a base depth at approximately 6,200 ft. These sediments are, in turn, underlain by Cretaceous bedrock, followed by the Mesozoic basement rock which occurs at a top depth of approximately 34,500 ft. The basement rock beneath the site is presently believed to be continental crustal material from the Grenville Orogeny.

The principal plant structures are founded on the upper soils of the Beaumont Formation. This formation consists of alternating layers of mostly dense to very dense sands and very stiff to hard clays. Layer thicknesses range from less than 10 ft to over 70 ft. One boring at Units 1 & 2 was extended to a depth of about 2,620 ft, and encountered alternating layers of clays and sands, transitioning to soft sedimentary claystones and siltstones at depths greater than approximately 1,100 ft.

2.2 Probabilistic Seismic Hazard Analysis

In response to the 50.54(f) letter and following the guidance provided in the SPID (EPRI 1025287, 2013), a seismic hazard reevaluation was performed for STPEGS. Because STPEGS is one of the most recently constructed nuclear power plants (NPPs), the subsurface information and analyses available in the UFSAR were developed using relatively recent techniques, compared with many older plants, and provide a good basis for the seismic reevaluation.

Similar to several other operating units, because of planned construction of the two new nuclear units (STP 3 & 4) adjacent to STP 1 & 2, there is an extensive amount of very recently developed, well-documented site subsurface information, collected and developed with current technologies, together with seismic analyses which have been completed using current state-of-practice methodologies (such as those referred to the SPID, Section B1.0, and NUREG/CR-6728) which can be combined with the UFSAR information to provide very detailed complete geotechnical information for completion of the seismic hazard reevaluation for STPEGS.

These two sets of information have been combined and developed using methodologies consistent with the applicable requirements of the NRC 50.54(f) letter, the EPRI SPID Report and NUREG/CR-6728 to provide a thorough and accurate seismic reevaluation which provides all of the information which has been requested by the NRC for the seismic reevaluation and also maintains a consistent seismic licensing basis for all of the plants on the STP site.

The use of current information and current state-of-practice methodologies available due to the licensing of new plants on the site is endorsed by the SPID in several locations, such as Appendix B, Section B2.0 which indicates "for sites with recent COL and ESP submittals, the co-located operating plants would be expected to utilize any applicable information developed in the ESP and COL site characterizations to the maximum extent possible."

To provide a consistent seismic licensing basis for the site, STPNOC utilized NUREG/CR-6728 Method 2A for the analysis. This methodology is endorsed as an acceptable methodology by the NRC 10 CFR 50.54(f) RFI Letter, Attachment 1 to Seismic Enclosure 1 (which endorses the use of either NUREG/CR-6728 Method 2 or 3) and also the SPID, Section 2.5.3.

EPRI provided hard rock seismic hazard information, developed in accordance with the SPID, for STPNOC to use as the basis for the analysis. STPNOC then utilized this hard rock seismic hazard information and both the new and existing subsurface information to develop updated soil profiles and updated amplification factors.

For screening purposes, an updated Ground Motion Response Spectrum (GMRS) was then developed. Following the development of the new GMRS, the seismic reevaluation was completed in accordance with the SPID and the results documented in this report, which provides all of the information required by the template, developed by the industry and endorsed by the NRC.

Since the reevaluation summarized in this report determined that the updated GMRS does not exceed the SSE, based on the results of this screening evaluation, no further evaluations will be performed.

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter and following the guidance in the SPID (EPRI 1025287, 2013), 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 and NUREG-2115, 2012) together with the updated EPRI Ground-Motion Model (GMM) for the CEUS (EPRI 3002000717, 2013). For the PSHA, a minimum moment magnitude cutoff of 5.0 was used, as specified in the 50.54(f) letter.

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

1. Extended Continental Crust—Gulf Coast (ECC_GC)
2. Gulf Highly Extended Crust (GHEX)
3. Mesozoic and younger extended prior – narrow (MESE-N)
4. Mesozoic and younger extended prior – wide (MESE-W)
5. Midcontinent-Craton alternative A (MIDC_A)
6. Midcontinent-Craton alternative B (MIDC_B)
7. Midcontinent-Craton alternative C (MIDC_C)
8. Midcontinent-Craton alternative D (MIDC_D)
9. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
10. Non-Mesozoic and younger extended prior – wide (NMESE-W)
11. Oklahoma Aulacogen (OKA)
12. Study region (STUDY_R)

For sources of large magnitude earthquakes, designated Repeated Large Magnitude Earthquake (RLME) sources in CEUS-SSC (2012), 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. Marianna
5. Meers
6. New Madrid Fault System (NMFS)

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

2.2.2 Base Rock Seismic Hazard Curves

Base rock hazard curves, provided by EPRI in their Project Report 1041, "South Texas Seismic Hazard and Screening Report, Rev. 1" (EPRI 1041, 2013), are available for STPEGS, as provided in Figure 2.2.2-1, in accordance with the requirement in Section 2.5.3 of the SPID for plants using Method 2A.

The procedure to develop probabilistic seismic hazard curves for hard rock follows standard techniques documented in the technical literature (e.g., McGuire, 2004). Separate seismic hazard calculations are conducted for the 7 spectral frequencies for which ground motion equations are available (100 Hz=peak ground acceleration or PGA, 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz). As discussed in Section 2.2.1, ground motion equations from the updated EPRI Ground-Motion Model (GMM) for Gulf Coast Region from the CEUS (CEUS-SSC, 2012) were used for the calculation of rock hazard. All spectra accelerations presented herein correspond to 5% of critical damping. Figure 2.2.2-1 shows the mean hard-rock seismic hazard curves for the 7 spectral frequencies. The digital values for the mean and fractile hazard curves are provided in Table 2.2.2-1a through Table 2.2.2-1g.

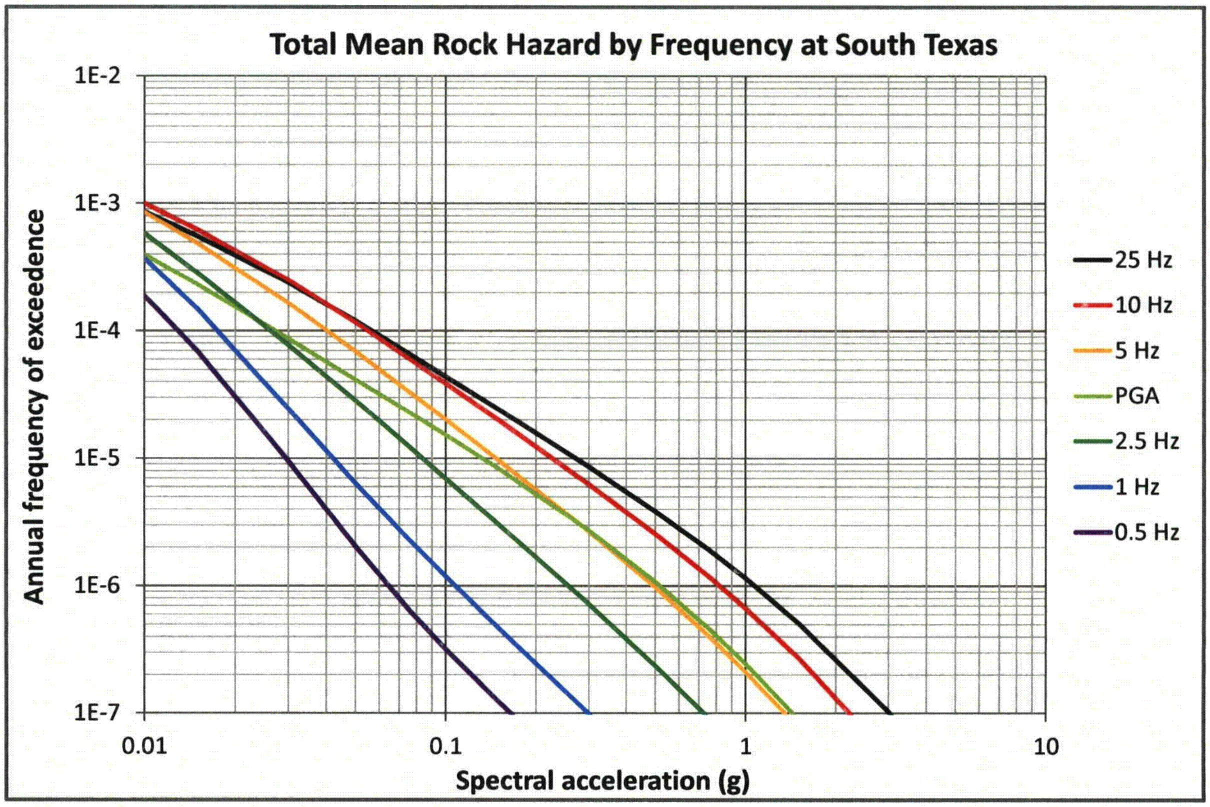

Figure 2.2.2-1. Control point mean hazard curves for oscillator frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz at STPEGS.

Table 2.2.2-1a. Mean and Fractile Seismic Hazard Curves for PGA at STPEGS

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.50E-03	3.14E-03	5.05E-03	8.00E-03	1.20E-02	1.55E-02
0.001	5.15E-03	1.64E-03	2.84E-03	4.63E-03	7.55E-03	1.01E-02
0.005	9.36E-04	3.05E-04	4.70E-04	8.00E-04	1.31E-03	2.19E-03
0.01	3.95E-04	1.16E-04	1.79E-04	3.19E-04	5.35E-04	1.05E-03
0.015	2.30E-04	6.00E-05	9.51E-05	1.77E-04	3.23E-04	6.83E-04
0.03	8.67E-05	1.51E-05	2.76E-05	5.75E-05	1.29E-04	3.01E-04
0.05	4.16E-05	4.63E-06	1.08E-05	2.57E-05	6.45E-05	1.49E-04
0.075	2.31E-05	1.82E-06	5.35E-06	1.42E-05	3.63E-05	8.12E-05
0.1	1.52E-05	9.37E-07	3.33E-06	9.24E-06	2.42E-05	5.20E-05
0.15	8.28E-06	3.73E-07	1.74E-06	5.20E-06	1.32E-05	2.76E-05
0.3	2.71E-06	5.75E-08	5.75E-07	1.79E-06	4.43E-06	8.72E-06
0.5	1.07E-06	1.36E-08	2.19E-07	7.23E-07	1.74E-06	3.42E-06
0.75	4.69E-07	3.79E-09	8.35E-08	3.05E-07	7.77E-07	1.51E-06
1.	2.45E-07	1.55E-09	3.84E-08	1.55E-07	4.01E-07	8.12E-07
1.5	8.87E-08	4.25E-10	1.08E-08	5.20E-08	1.44E-07	3.19E-07
3.	1.13E-08	1.23E-10	8.00E-10	5.12E-09	1.72E-08	4.83E-08
5.	1.80E-09	1.21E-10	1.55E-10	6.83E-10	2.60E-09	9.11E-09
7.5	3.39E-10	9.79E-11	1.21E-10	1.79E-10	5.42E-10	1.92E-09
10.	9.16E-11	9.11E-11	1.01E-10	1.21E-10	2.13E-10	6.17E-10

Table 2.2.2-1b. Mean and Fractile Seismic Hazard Curves for 25 Hz at STPEGS

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.06E-02	4.98E-03	6.83E-03	9.93E-03	1.44E-02	1.84E-02
0.001	7.05E-03	2.80E-03	4.25E-03	6.54E-03	9.93E-03	1.29E-02
0.005	1.74E-03	6.45E-04	9.65E-04	1.51E-03	2.39E-03	3.73E-03
0.01	8.58E-04	3.14E-04	4.56E-04	7.45E-04	1.16E-03	1.92E-03
0.015	5.53E-04	1.90E-04	2.80E-04	4.77E-04	7.55E-04	1.27E-03
0.03	2.39E-04	7.23E-05	1.10E-04	1.98E-04	3.33E-04	6.17E-04
0.05	1.19E-04	2.96E-05	4.90E-05	9.51E-05	1.72E-04	3.33E-04
0.075	6.67E-05	1.31E-05	2.39E-05	5.05E-05	9.93E-05	1.92E-04
0.1	4.38E-05	6.93E-06	1.42E-05	3.19E-05	6.64E-05	1.29E-04
0.15	2.41E-05	2.76E-06	6.93E-06	1.74E-05	3.79E-05	7.03E-05
0.3	8.58E-06	5.35E-07	2.25E-06	6.45E-06	1.38E-05	2.42E-05
0.5	3.85E-06	1.40E-07	1.01E-06	3.01E-06	6.17E-06	1.07E-05
0.75	1.94E-06	4.50E-08	5.12E-07	1.55E-06	3.14E-06	5.12E-06
1.	1.15E-06	1.98E-08	2.92E-07	9.24E-07	1.87E-06	3.05E-06
1.5	5.13E-07	5.75E-09	1.23E-07	4.07E-07	8.60E-07	1.42E-06
3.	1.03E-07	6.26E-10	1.87E-08	7.66E-08	1.74E-07	3.14E-07
5.	2.50E-08	1.82E-10	3.33E-09	1.62E-08	4.19E-08	8.72E-08

7.5	6.94E-09	1.21E-10	7.23E-10	3.79E-09	1.16E-08	2.68E-08
10.	2.55E-09	1.21E-10	2.72E-10	1.29E-09	4.31E-09	1.08E-08

Table 2.2.2-1c. Mean and Fractile Seismic Hazard Curves for 10 Hz at STPEGS

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.22E-02	6.45E-03	8.23E-03	1.15E-02	1.64E-02	2.10E-02
0.001	8.39E-03	3.95E-03	5.27E-03	7.77E-03	1.15E-02	1.49E-02
0.005	2.09E-03	8.72E-04	1.23E-03	1.87E-03	2.88E-03	4.19E-03
0.01	9.95E-04	4.01E-04	5.66E-04	8.98E-04	1.38E-03	1.98E-03
0.015	6.20E-04	2.35E-04	3.37E-04	5.58E-04	8.72E-04	1.27E-03
0.03	2.49E-04	8.23E-05	1.25E-04	2.16E-04	3.52E-04	5.58E-04
0.05	1.17E-04	3.28E-05	5.27E-05	9.93E-05	1.72E-04	2.84E-04
0.075	6.16E-05	1.40E-05	2.46E-05	4.98E-05	9.24E-05	1.57E-04
0.1	3.86E-05	7.23E-06	1.38E-05	3.01E-05	5.91E-05	1.02E-04
0.15	1.99E-05	2.72E-06	6.26E-06	1.51E-05	3.14E-05	5.35E-05
0.3	6.26E-06	4.37E-07	1.67E-06	4.70E-06	1.01E-05	1.72E-05
0.5	2.56E-06	9.79E-08	6.45E-07	1.95E-06	4.13E-06	7.03E-06
0.75	1.19E-06	2.80E-08	2.92E-07	9.24E-07	1.95E-06	3.28E-06
1.	6.65E-07	1.10E-08	1.53E-07	5.12E-07	1.10E-06	1.87E-06
1.5	2.72E-07	2.72E-09	5.75E-08	2.04E-07	4.56E-07	8.00E-07
3.	4.60E-08	3.28E-10	7.13E-09	3.09E-08	7.77E-08	1.51E-07
5.	9.76E-09	1.29E-10	1.11E-09	5.66E-09	1.64E-08	3.63E-08
7.5	2.42E-09	1.21E-10	2.68E-10	1.25E-09	4.13E-09	9.93E-09
10.	8.15E-10	1.13E-10	1.42E-10	4.31E-10	1.40E-09	3.63E-09

Table 2.2.2-1d. Mean and Fractile Seismic Hazard Curves for 5 Hz at STPEGS

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.32E-02	6.93E-03	8.72E-03	1.23E-02	1.77E-02	2.25E-02
0.001	9.18E-03	4.25E-03	5.75E-03	8.60E-03	1.25E-02	1.64E-02
0.005	2.05E-03	7.89E-04	1.16E-03	1.84E-03	2.92E-03	4.07E-03
0.01	8.56E-04	3.28E-04	4.70E-04	7.66E-04	1.23E-03	1.69E-03
0.015	4.85E-04	1.82E-04	2.60E-04	4.37E-04	7.03E-04	9.51E-04
0.03	1.65E-04	5.50E-05	8.35E-05	1.46E-04	2.39E-04	3.52E-04
0.05	6.94E-05	1.92E-05	3.14E-05	6.00E-05	1.02E-04	1.57E-04
0.075	3.38E-05	7.55E-06	1.34E-05	2.84E-05	5.20E-05	8.12E-05
0.1	2.02E-05	3.63E-06	7.23E-06	1.62E-05	3.14E-05	5.05E-05
0.15	9.67E-06	1.23E-06	3.05E-06	7.55E-06	1.55E-05	2.53E-05
0.3	2.67E-06	1.67E-07	7.13E-07	2.07E-06	4.37E-06	7.13E-06
0.5	9.74E-07	3.19E-08	2.39E-07	7.55E-07	1.62E-06	2.68E-06
0.75	4.09E-07	7.77E-09	9.11E-08	3.05E-07	6.93E-07	1.18E-06
1.	2.11E-07	2.84E-09	4.31E-08	1.53E-07	3.63E-07	6.26E-07
1.5	7.68E-08	6.83E-10	1.27E-08	5.12E-08	1.34E-07	2.42E-07
3.	1.06E-08	1.38E-10	1.11E-09	5.58E-09	1.82E-08	3.84E-08
5.	1.92E-09	1.21E-10	2.04E-10	8.47E-10	3.23E-09	8.12E-09
7.5	4.20E-10	1.01E-10	1.21E-10	2.19E-10	7.45E-10	1.95E-09
10.	1.30E-10	9.11E-11	1.04E-10	1.32E-10	2.84E-10	6.93E-10

Table 2.2.2-1e. Mean and Fractile Seismic Hazard Curves for 2.5 Hz at STPEGS

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	1.29E-02	6.83E-03	8.60E-03	1.21E-02	1.72E-02	2.22E-02
0.001	9.05E-03	4.25E-03	5.66E-03	8.47E-03	1.23E-02	1.60E-02
0.005	1.76E-03	6.00E-04	8.85E-04	1.53E-03	2.57E-03	3.79E-03
0.01	5.79E-04	1.92E-04	2.92E-04	4.90E-04	8.47E-04	1.29E-03
0.015	2.82E-04	9.37E-05	1.40E-04	2.42E-04	4.19E-04	6.17E-04
0.03	7.73E-05	2.29E-05	3.63E-05	6.64E-05	1.15E-04	1.77E-04
0.05	2.83E-05	6.83E-06	1.16E-05	2.35E-05	4.31E-05	6.83E-05
0.075	1.25E-05	2.32E-06	4.50E-06	9.93E-06	1.98E-05	3.14E-05
0.1	6.95E-06	1.04E-06	2.22E-06	5.42E-06	1.13E-05	1.84E-05
0.15	3.03E-06	3.09E-07	8.23E-07	2.25E-06	5.05E-06	8.47E-06
0.3	7.17E-07	3.09E-08	1.46E-07	4.98E-07	1.23E-06	2.16E-06
0.5	2.36E-07	4.83E-09	3.68E-08	1.49E-07	4.19E-07	7.66E-07
0.75	9.20E-08	1.13E-09	1.10E-08	5.20E-08	1.62E-07	3.14E-07
1.	4.52E-08	4.25E-10	4.25E-09	2.29E-08	8.12E-08	1.62E-07
1.5	1.54E-08	1.60E-10	1.05E-09	6.54E-09	2.72E-08	6.00E-08
3.	1.86E-09	1.21E-10	1.44E-10	5.91E-10	3.09E-09	8.35E-09
5.	3.03E-10	9.37E-11	1.13E-10	1.51E-10	5.20E-10	1.51E-09
7.5	6.00E-11	9.11E-11	1.01E-10	1.21E-10	1.72E-10	3.84E-10
10.	1.73E-11	9.11E-11	1.01E-10	1.21E-10	1.23E-10	1.82E-10

Table 2.2.2-1f. Mean and Fractile Seismic Hazard Curves for 1 Hz at STPEGS

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.94E-03	3.95E-03	5.50E-03	8.47E-03	1.23E-02	1.55E-02
0.001	5.90E-03	2.10E-03	3.28E-03	5.58E-03	8.47E-03	1.08E-02
0.005	1.27E-03	1.95E-04	3.68E-04	9.24E-04	2.22E-03	3.47E-03
0.01	3.69E-04	4.70E-05	8.98E-05	2.25E-04	6.09E-04	1.20E-03
0.015	1.47E-04	1.82E-05	3.47E-05	8.85E-05	2.29E-04	4.98E-04
0.03	2.44E-05	2.92E-06	5.83E-06	1.51E-05	3.79E-05	8.47E-05
0.05	6.38E-06	6.73E-07	1.44E-06	3.90E-06	1.11E-05	2.04E-05
0.075	2.33E-06	1.92E-07	4.50E-07	1.36E-06	4.07E-06	7.45E-06
0.1	1.18E-06	7.66E-08	1.98E-07	6.54E-07	2.01E-06	4.01E-06
0.15	4.67E-07	1.98E-08	6.26E-08	2.32E-07	7.66E-07	1.72E-06
0.3	9.84E-08	1.51E-09	7.55E-09	3.95E-08	1.57E-07	4.07E-07
0.5	3.01E-08	2.60E-10	1.40E-09	9.37E-09	4.70E-08	1.32E-07
0.75	1.10E-08	1.25E-10	3.73E-10	2.64E-09	1.62E-08	5.05E-08
1.	5.19E-09	1.21E-10	1.82E-10	1.05E-09	7.23E-09	2.42E-08
1.5	1.65E-09	1.01E-10	1.21E-10	2.92E-10	2.01E-09	7.89E-09
3.	1.79E-10	9.11E-11	1.01E-10	1.21E-10	2.46E-10	9.24E-10
5.	2.74E-11	9.11E-11	1.01E-10	1.21E-10	1.21E-10	2.16E-10
7.5	5.26E-12	9.11E-11	1.01E-10	1.21E-10	1.21E-10	1.23E-10
10.	1.48E-12	9.11E-11	1.01E-10	1.21E-10	1.21E-10	1.21E-10

Table 2.2.2-1g. Mean and Fractile Seismic Hazard Curves for 0.5 Hz at STPEGS

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.29E-03	1.98E-03	2.96E-03	5.05E-03	7.55E-03	9.51E-03
0.001	3.51E-03	8.47E-04	1.49E-03	3.23E-03	5.50E-03	7.34E-03
0.005	7.01E-04	4.56E-05	1.02E-04	3.79E-04	1.36E-03	2.32E-03
0.01	1.87E-04	8.35E-06	2.04E-05	7.45E-05	3.14E-04	7.45E-04
0.015	6.92E-05	2.80E-06	6.73E-06	2.60E-05	1.07E-04	2.88E-04
0.03	9.48E-06	3.42E-07	8.47E-07	3.52E-06	1.40E-05	3.90E-05
0.05	2.05E-06	6.83E-08	1.87E-07	7.23E-07	3.57E-06	8.23E-06
0.075	6.63E-07	1.82E-08	5.42E-08	2.19E-07	1.15E-06	2.76E-06
0.1	3.20E-07	6.36E-09	2.13E-08	9.79E-08	5.12E-07	1.44E-06
0.15	1.23E-07	1.36E-09	5.83E-09	3.28E-08	1.77E-07	6.00E-07
0.3	2.57E-08	1.62E-10	5.83E-10	4.56E-09	3.05E-08	1.34E-07
0.5	7.83E-09	1.21E-10	1.62E-10	9.65E-10	7.89E-09	4.13E-08
0.75	2.89E-09	1.01E-10	1.21E-10	2.96E-10	2.32E-09	1.51E-08
1.	1.36E-09	9.37E-11	1.18E-10	1.62E-10	9.65E-10	6.73E-09
1.5	4.41E-10	9.11E-11	1.01E-10	1.21E-10	2.92E-10	2.07E-09
3.	5.00E-11	9.11E-11	1.01E-10	1.21E-10	1.21E-10	2.84E-10
5.	7.95E-12	9.11E-11	1.01E-10	1.21E-10	1.21E-10	1.23E-10
7.5	1.58E-12	9.11E-11	1.01E-10	1.21E-10	1.21E-10	1.21E-10
10.	4.56E-13	9.11E-11	1.01E-10	1.21E-10	1.21E-10	1.21E-10

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the 3/12/2012 50.54(f) Request for Information and in the SPID (EPRI 1025287, 2013) for nuclear power plant sites that are not sited on hard rock (defined as 2.83 km/sec), a site response analysis was performed for STPEGS.

2.3.1 Description of Subsurface Material

Sampling and testing of the site soils was performed in the top approximately 600 ft. Clays in the upper 600 ft comprise about 60 percent of the materials, and the sands about 40 percent. There are 12 distinct clay interbeds which range from stiff to hard, and are predominantly high plasticity materials. There are 11 distinct sand interbeds which range from medium dense to very dense, and are predominantly silty sand materials. There is one silt interbed. The Beaumont formation encountered in the top 600 ft extends to about 750 ft depth and is underlain by similar deposits of Pleistocene, Pliocene and Miocene age to about 1,100 ft depth. The soils then grade into soft claystone and siltstone to about 4,400 ft depth. The Oakville Sandstone extends from about 4,400 to 6,000 ft depth and is underlain by Cretaceous rock to about 34,500 ft depth. Mezozoic basement rock extends below about 34,500 ft depth.
Table 2.3.1-1 provides a brief description of the subsurface material in terms of the geologic units and layer thicknesses. This table includes best estimate values of shear wave velocity (V_S), compressive wave velocity (V_P), unit weight and Poisson's ratio. Note that the stratigraphy

in Table 2.3.1-1 for the upper 341 ft (the limit of detailed exploration for Units 1 & 2) is the average stratigraphy for Units 1 & 2.

The Unit 1 & 2 stratigraphy is very similar to the Units 3 & 4 stratigraphy, with layer thicknesses exhibiting variation that would be expected to typically occur for measurements taken over a large site in this area of the US. From 341 to 603 ft depth, the stratigraphy is the average Units 3 & 4 stratigraphy, since there is no detailed stratigraphy available for Units 1 & 2 below 341 ft depth. As described in Section 2.3.2, two base case profiles are used for the upper 341 ft, since there was some difference in the measured V_S values for Units 1 & 2 and Units 3 & 4. The Values given in Table 2.3.1-1 are the Base Case 2 values (Units 3 & 4) since they have a higher weighting than the Base Case 1 values.

Table 2.3.1-1 Geologic profile and estimated layer thicknesses for STPEGS

Depth Range (ft)	Stratum	Soil/Rock Description	Density (pcf)	Vs[a] (ft/sec)	Vp[b] (ft/sec)	PR[c]
0		SSE control point (at surface)	---	---	---	---
0-22	A	Medium Stiff to Very Stiff Clay	125	575	1905	0.45
22 – 36.5	B	Loose to Dense Sandy Silt	125	725	3695	0.48
36.5 – 44	C	Dense to Very Dense Silty Sand	125	785	5605	0.49
44 – 59.5	D	Very Stiff to Hard Silty Clay	126	925	4715	0.48
59.5 – 81.5	E	Dense to Very Dense Slightly Silty Fine Sand	126	1080	5505	0.48
81.5 – 119.5	F	Very Stiff to Hard Silty Clay	129	945	4820	0.48
119.5 – 132	H	Very Dense Silty Sand	128	1075	5480	0.48
132 – 172	J clay	Hard Silty Clay	126	1180	5705	0.48
172 – 212	J sand	Very Dense Silty Sand	126	1040	5255	0.48
212 – 222	K clay	Stiff to Hard Sandy Clay	130	1170	5965	0.48
222 – 232	K sand	Dense to Very Dense Silty Sand	130	1370	5760	0.47
232 – 281	L	Very Stiff to Hard Silty Clay	128	975	4970	0.48
281 – 291	M	Dense to Very Dense Silty Sand	125	1165	4895	0.47
291 – 331	N clay1	Very Stiff to Hard Silty Clay	127	1230	5170	0.47
331 – 352	N sand1	Dense to Very Dense Silty Sand	125	1645	6045	0.46
352 – 360	N clay2	Very Stiff to Hard Silty Clay	123	1535	5640	0.46
360 – 393	N sand2	Dense to Very Dense Silty Sand	128	1665	5520	0.45
393 – 401	N clay3	Very Stiff to Hard Silty Clay	123	1850	6135	0.45
401 – 420	N sand3	Dense to Very Dense Silty Sand	128	1570	5770	0.46
420 – 450	N clay4	Very Stiff to Hard Silty Clay	123	1205	5065	0.47
450 – 458	N sand4	Dense to Very Dense Silty Sand	128	1355	5695	0.47
458 – 512	N clay5	Very Stiff to Hard Silty Clay	123	1220	6220	0.48
512 – 530	N sand5	Dense to Very Dense Silty Sand	128	1845	6120	0.45
530 – 603	N clay6	Very Stiff to Hard Silty Clay	123	1345	5655	0.47
603 – 750	-	Beaumont Formation (Pleistocene)	128	1645	6045	0.46
750 – 1100	-	Pleistocene, Pliocene & Miocene Deposits	129	1785	6170	0.45
1100 – 4400	-	Soft Claystone & Siltstone	130-140	2005-4230	6560-9045	0.45-0.34
4400 – 6200	-	Oakville Sandstone	140	4045-5285	8190-9890	0.34-0.30
6200 – 34,500	-	Cretaceous Rock	140	3470-6440[d]	6495-12,050	0.30
34,500+	-	Mesozoic Basement Rock	165	9200+	15,900+	0.25

Notes for Table 2.3.1-1

(a) V_S from Base Case 2, measured by P-S Suspension Logging to 603 ft depth, computed from V_P below 603 ft depth. Values tabulated are best estimate values; upper and lower bound values are presented in Section 2.3.2.

(b) V_P from Base Case 2, measured by P-S Suspension Logging to 603 ft depth, obtained from well logs below 603 ft depth.

(c) Poisson's ratio computed from V_S and V_P to 603 ft depth, extrapolated below 603 ft depth.

(d) Measurements only computed to approximately 20,000 ft depth.

(e) Various modulus and damping curves are used for the soils; these are described in Section 2.3.2.1.

2.3.2 Development of Base Case Profiles and Nonlinear Material Properties

V_S and V_P measurements were obtained for Units 1 & 2 and Units 3 & 4. V_P measurements were obtained to a depth of approximately 20,000 ft in oil-field borings.

Units 1 & 2 Shear and Compression Wave Velocity

Seismic cross-hole measurements were used to determine V_S and V_P. Measurements were taken in two receiver boreholes, 15 ft apart. In the initial series of tests, readings were taken to 280 and 298 ft depth in Unit 1 and Unit 2 locations, respectively. A final series of tests was run to 315 ft depth at a location between Units 1 and 2. Tests were made at 5-ft depth intervals. Four to 10 readings were taken at each depth interval, and individual readings were generally within 6 percent of the average reading. STP UFSAR indicates that V_S values between 305 and 341 ft were derived based on the soil stratigraphy and extrapolation of the V_S data in the upper 305 ft.

Units 3 & 4 Shear and Compression Wave Velocity

Suspension P-S logging was performed in 11 boreholes, 6 at the proposed Unit 3 location and 5 at the proposed Unit 4 location. P-S measurements were taken to about 200 ft depth in 8 of the borings and to about 470 ft in one boring. In one boring in the Unit 3 area and one boring in the Unit 4 area P-S measurements were taken to about 600 ft depth. Readings were taken at either 0.5-meter (1.6-ft) or 1-meter (3.2-ft) intervals.

Oil Well Log Data

The oil wells are located about 11, 13 and 19 miles from the STP site. Readings extend from a depth of approximately 600 ft to depths of about 16,000 ft in two of the wells, and 20,000 ft in the third well. V_P was measured at 0.5-ft intervals in each well. For analysis, the readings were averaged over 200-ft intervals in each well. These averaged V_P measurements were converted to V_S using typical values of Poisson's ratio.

Design Shear and Compression Wave Velocity Profiles

Comparison of the V_S values in the upper 341 ft showed that the Units 1 & 2 values were typically somewhat higher than those measured in the top 341 ft for Units 3 & 4. The technique used to measure V_S for Units 1&2 (seismic cross-hole) is well established and is still commonly used today (ASTM D4428). We examined the Unit 1&2 V_S results in detail and could find no reason to doubt their credibility. Since these results were part of the input to the Units 1&2 seismic analysis, we did not want to dismiss them. In addition, the Suspension P-S logging used for proposed Units 3&4 is the accepted state-of-the-art technique and has been used for all of the COL investigations. As a result, two base cases are developed.

Base Case 1 uses the average V_S values from Units 1 & 2 to 341 ft depth. Base Case 2 uses the V_S values from Units 3 & 4 to 341 ft depth, but uses the stratigraphy from Units 1 & 2. Below 341 ft depth, both base cases use the Units 3 & 4 V_S values to 603 ft depth, and the sonic log values from 603 to 20,000 ft depth. The values for Base Cases 1 and 2 to 341 ft depth are given in Tables 2.3.2-1 and 2.3.2-2, respectively. The values below 341 ft depth are the same for both base cases and are given in Table 2.3.2-3.

The best estimate and upper and lower bound V_S values are provided along with the best estimate V_P values in Tables 2.3.2-1, 2.3.2-2 and 2.3.2-3. The upper and lower bound V_S values to 341 ft depth in Table 2.3.2-1 are taken directly from STP UFSAR. Coefficients of variation range from about 0.21 to 0.25. The upper and lower bound V_S values from 341 to 530 ft depth in Table 2.3.2-1 and from zero to 530 ft depth in Table 2.3.2-2 have a logarithmic standard deviation of 0.20; from 530 to 603 ft depth the logarithmic standard deviation is 0.19. Below 603 ft, the upper and lower bound V_S values are based on the standard deviation of all of the data within the 200 ft depth interval.

For analysis using the V_S and V_P data in Tables 2.3.2-1 and 2.3.2-2, weighting of 40% should be given to Base Case 1 (Table 2.3.2-1) and weighting of 60% should be given to Base Case 2 (Table 2.3.2-2).

The Base Case 1 and 2 V_S values to 341 ft depth are plotted on Figure 2.3.2-1. The V_S values below 341 ft (same for both base cases) are plotted on Figure 2.3.2-2.

The depth to hard rock for both base cases is defined as the depth where the V_S reaches a value of 9300 ft/sec (2830 m/s). As noted above, this depth is approximately 34,500 ft. Consistent with the guidance in the SPID (EPRI 1025287, 2013), the depth to hard rock can be

modeled at a shallower depth provided reasonable site amplification values can be obtained for spectral frequencies of 0.5 Hz and higher. Soil column analysis for Units 3 & 4 showed that the column could be truncated at less than 10,000 ft (3050 m) depth with no change in the site response at frequencies above 0.5 Hz at the STPEGS site. Because the depth to hard rock is very large (34,500 ft) at this site, no epistemic uncertainty in this parameter was incorporated in the analyses.

Table 2.3.2-1 Geologic profile and estimated layer thicknesses for top 341 ft, Base Case 1, STPEGS

Soil Stratum	Below Grade (El 28 ft)		Shear Wave Velocity, V_S (ft/sec)		
	Thickness (ft)	Top Depth (ft)	Best Estimate	Lower Bound	Upper Bound
A	6.0	0	610	460	760
	5.0	6.0	610	460	760
	5.0	11.0	625	475	775
	6.0	16.0	790	600	980
B	7.5	22.0	900	685	1115
	7.0	29.5	910	700	1120
C	7.5	36.5	910	700	1120
D	6.0	44.0	840	645	1035
	9.5	50.0	1150	880	1420
E	11.0	59.5	1150	880	1420
	11.0	70.5	1160	890	1430
F	9.5	81.5	1280	990	1570
	9.0	91.0	1280	990	1570
	9.0	100.0	1220	930	1510
	10.5	109.0	1460	1130	1790
H	12.5	119.5	1560	1210	1910
J	40.0	132.0	1229	950	1508
	40.0	172.0	1173	900	1446
K	20.0	212.0	1541	1190	1892
L	49.0	232.0	1271	990	1552
M	10.0	281.0	1520	1190	1850
N clay1	40.0	291.0	1324	1040	1608
N sand1	10.0	331.0	1585	1268	1902

Table 2.3.2-2 Geologic profile and estimated layer thicknesses for top 341 ft, Base Case 2, STPEGS

Soil Stratum	Below Grade (El 28 ft)		Shear Wave Velocity, V_S (ft/sec)		
	Thickness (ft)	Top Depth (ft)	Best Estimate	Lower Bound	Upper Bound
A	6.0	0	575	460	690
	5.0	6.0			
	5.0	11.0			
	6.0	16.0			
B	7.5	22.0	725	580	870
	7.0	29.5			
C	7.5	36.5	785	628	942
D	6.0	44.0	925	740	1110
	9.5	50.0			
E	11.0	59.5	1080	864	1296
	11.0	70.5			
F	9.5	81.5	945	756	1134
	9.0	91.0			
	9.0	100.0			
	10.5	109.0			
H	12.5	119.5	1075	860	1290
J	40.0	132.0	1180	945	1415
	40.0	172.0	1040	835	1250
K	8.0	212.0	1170	936	1404
	12.0	220.0	1370	1096	1644
L	49.0	232.0	975	780	1170
M	10.0	281.0	1165	932	1398
N clay1	40.0	291.0	1230	984	1476
N sand1	10.0	331.0	1645	1316	1974

Table 2.3.2-3 Geologic profile and estimated layer thicknesses below 341 ft, Base Cases 1 & 2, STPEGS

Soil Stratum	Below Grade (El 28 ft)		Shear Wave Velocity, V_S (ft/sec)		
	Thickness (ft)	Top Depth (ft)	Best Estimate	Lower Bound	Upper Bound
N sand1	11.0	341	1645	1316	1974
N clay2	8.0	352	1535	1228	1842
N sand2	33.0	360	1665	1332	1998
N clay3	8.0	393	1850	1480	2220
N sand3	19.0	401	1570	1256	1884
N clay4	30.0	420	1205	964	1446
N sand4	8.0	450	1355	1084	1626
N clay5	54.0	458	1220	976	1464
N sand5	18.0	512	1845	1476	2214
N clay6	73.0	530	1345	1089	1601
-	91.0	603	1625	1427	1824
-	200	694	1677	1524	1830
-	200	894	1862	1703	2022
-	200	1094	2006	1794	2218
-	200	1294	2147	1913	2381
-	200	1494	2311	1993	2629
-	200	1694	2336	1986	2686
-	200	1894	2510	2175	2844
-	200	2094	2700	2351	3048
-	200	2294	2965	2666	3263
-	200	2494	2980	2577	3383
-	200	2694	3234	2841	3628
-	200	2894	2901	2484	3319
-	200	3094	3305	2823	3788
-	200	3294	3663	3130	4197
-	200	3494	3887	3198	4577
-	200	3694	4231	3599	4863
-	200	3894	3932	3133	4730
-	200	4094	3860	3137	4583
-	200	4294	4046	3380	4712
-	200	4494	4166	3647	4684
-	200	4694	4126	3664	4588
-	200	4894	4393	4045	4742
-	200	5094	4607	4237	4976
-	200	5294	4773	4216	5330
-	200	5494	5008	4229	5787

Soil Stratum	Below Grade (El 28 ft)		Shear Wave Velocity, V_S (ft/sec)		
	Thickness (ft)	Top Depth (ft)	Best Estimate	Lower Bound	Upper Bound
-	200	5694	4889	4323	5454
-	200	5894	4976	4526	5426
-	200	6094	5287	4740	5833
-	200	6294	5045	4520	5570
-	200	6494	4607	3776	5438
-	200	6694	3928	3160	4697
-	200	6894	3741	3257	4225
-	200	7094	3644	3352	3937
-	200	7294	3610	3477	3744
-	200	7494	3575	3447	3703
-	200	7694	3472	3318	3626
-	200	7894	3511	3354	3668
-	200	8094	3576	3475	3677
-	200	8294	3619	3433	3805
-	200	8494	3703	3499	3906
-	200	8694	3690	3502	3878
-	200	8894	3840	3592	4088
-	200	9094	3827	3560	4094
-	200	9294	3849	3531	4167
-	200	9494	3897	3585	4208
-	200	9694	3966	3666	4266
-	200	9894	3924	3691	4158
-	200	10094	3880	3697	4063
-	200	10294	3943	3714	4172
-	200	10494	4047	3804	4291
-	200	10694	4080	3826	4334
-	200	10894	4117	3856	4377
-	200	11094	4163	3913	4412
-	200	11294	4299	4065	4532
-	200	11494	4291	4015	4566
-	200	11694	4260	4001	4518
-	200	11894	4328	4072	4583
-	200	12094	4473	4157	4789
-	200	12294	4568	4280	4857
-	200	12494	4621	4356	4886
-	200	12694	4619	4335	4903
-	200	12894	4610	4453	4767
-	200	13094	4674	4479	4869

Soil Stratum	Below Grade (El 28 ft)		Shear Wave Velocity, V_S (ft/sec)		
	Thickness (ft)	Top Depth (ft)	Best Estimate	Lower Bound	Upper Bound
-	200	13294	4873	4584	5162
-	200	13494	4679	4487	4870
-	200	13694	4749	4498	4999
-	200	13894	4879	4571	5188
-	200	14094	4942	4423	5461
-	200	14294	5054	4622	5487
-	200	14494	5000	4672	5328
-	200	14694	5361	4896	5825
-	200	14894	5195	4767	5623
-	200	15094	5219	4869	5570
-	200	15294	5083	4596	5570
-	200	15494	4910	4565	5255
-	200	15694	4864	4406	5322
-	200	15894	5084	4742	5426
-	200	16094	5369	5070	5668
-	200	16294	5490	5136	5845
-	200	16494	5527	5157	5897
-	200	16694	5405	5159	5651
-	200	16894	5424	5118	5730
-	200	17094	5405	5152	5659
-	200	17294	5268	5109	5427
-	200	17494	5321	5074	5567
-	200	17694	5565	5327	5803
-	200	17894	5664	5398	5929
-	200	18094	6442	5911	6974
-	200	18294	6376	5941	6810
-	200	18494	5767	5593	5941
-	200	18694	5720	5594	5847
-	200	18894	5447	5223	5671
-	200	19094	5635	5462	5808
-	200	19294	5817	5288	6345
-	200	19494	5320	5006	5634
-	200	19694	4898	4688	5107
-	200	19894	4803	4724	4881

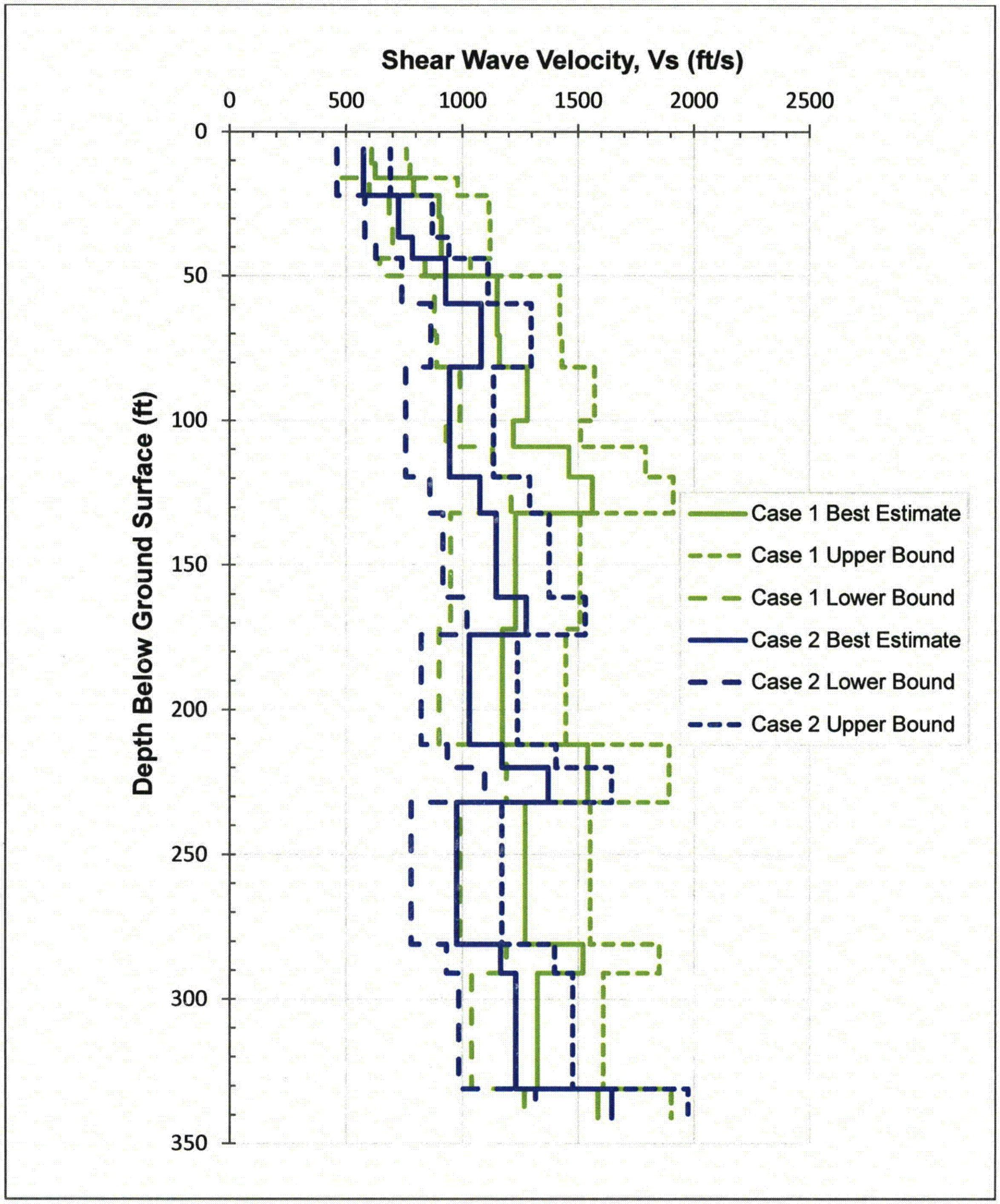

Figure 2.3.2-1. Shear wave velocity profiles, Base Cases 1 & 2, used in site response calculations for STPEGS above 341 ft depth

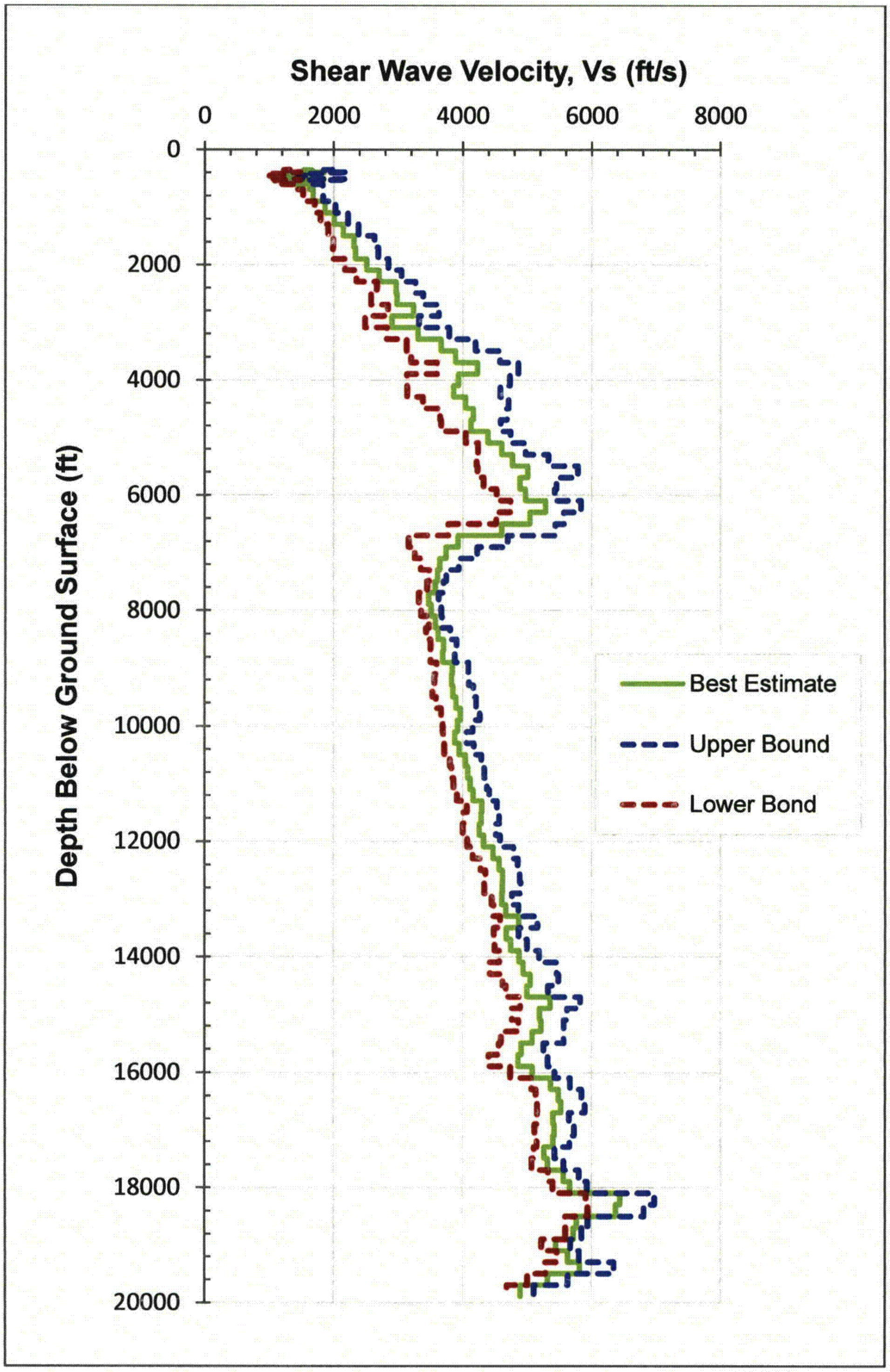

Figure 2.3.2-2. Shear wave velocity profiles, Base Cases 1 & 2, used in site response calculations for STPEGS below 341 ft depth

2.3.2.1 Shear Modulus and Damping Curves

Shear Modulus

The shear modulus reduction (G/G_{MAX}) versus cyclic shear strain curves from Units 1 & 2 (STP UFSAR) were digitized and compared against the curves from Units 3 & 4 (STP FSAR) for each stratum. The curves for Units 1 & 2 were generated based on laboratory cyclic triaxial test results while the curves for Units 3 & 4 were generated based on laboratory resonant column torsional shear (RCTS) tests. The comparison indicated that values from Units 1 & 2 decrease much more rapidly with increasing strain (more strain dependent). Considering the improved technology used in RCTS tests, the corresponding test results from Units 3 & 4 are expected to more accurately reflect the actual soil characteristics. They are adopted here for both base case profiles down to 603 ft depth.

Based on the comparison between the RCTS test results and published curves, the following shear modulus reduction curves for sand, clay and silt are adopted. The EPRI curves are from EPRI 102293 (1993) and the Vucetic & Dobry curves are from Vucetic & Dobry (1991).

- For sands located at depths greater than or equal to 100 ft, use the EPRI curve for depths of 500 to 1000 ft
- For sands located at depths less than 100 ft, use the EPRI curve for depths of 250 to 500 ft
- For clays with PI greater than or equal to 30, use the Vucetic & Dobry curve for PI = 100
- For silt, use the EPRI curve for PI = 50.

Based on the soil type and the corresponding plasticity index, the recommended modulus reduction curves are provided in Table 2.3.2-4 for each stratum. The G/G_{MAX} values with increasing cyclic shear strain are given in Table 2.3.2-5 for each material. Note that the RCTS tests gave very consistent G/G_{MAX} results for each material tested. This is reflected in the small variation given in Table 2.3.2-5. The curves are plotted in Figure 2.3.2-3 without showing the variation (for clarity).

Linear properties (implying $G/G_{MAX} = 1$ in the strain range of the response analysis) are used for soils below 603 ft depth.

Damping Ratio

Like the shear modulus reduction curves, the damping ratio (D) versus cyclic shear strain curves from Units 1 & 2 were generated based on laboratory cyclic triaxial test results while the curves for Units 3 & 4 were generated based on laboratory RCTS tests. Comparison between the two sets of curves indicated that values from Units 1 & 2 increase much more rapidly with increasing strain and constantly stay higher. As with the shear modulus reduction curves, the corresponding test results from Units 3 & 4 are expected to more accurately reflect the actual soil characteristics, because of the improved testing technology. They are adopted here for both base case profiles down to 603 ft depth.

Based on the comparison between the RCTS test results and published curves, the following damping ratio curves for sand, clay and silt are adopted. The EPRI curves are from EPRI 102293 (1993) and the Vucetic & Dobry curves are from Vucetic & Dobry (1991).

- For all sands, use EPRI curve for depths of 500 to 1000 ft
- For clays with PI greater than or equal to 30, use the Vucetic & Dobry curve for PI = 200.
- For low PI clay and silt samples, use the Vucetic & Dobry (1991) curve for PI = 200 up to strains of 0.005% and use the EPRI interpolated PI = 60 curve for strains above 0.05%.

Based on the soil type and the corresponding plasticity index, the recommended damping ratio curves are provided in Table 2.3.2-4 for each stratum. The values of D with increasing cyclic shear strain are given in Table 2.3.2-6 for each material. Note that the RCTS tests gave consistent results of D for each material tested. This is reflected in the relatively small variation (about 10 percent) given in Table 2.3.2-6. The curves are plotted in Figure 2.3.2-4 without showing the variation (for clarity).

Linear behavior is used for soils below a depth of 603 ft. and kappa estimates are used to account for the strain-independent damping ratios, see Section 2.3.2.2

Table 2.3.2-4 Modulus reduction and damping curves assigned for each stratum for STPEGS

Stratum	PI (%)	G/G_{max}	Damping
A-fill	N/A	None Given	None Given
A	40	CLAY (V&D PI = 100)	CLAY (V&D, PI=200)
B	20	SILT (EPRI PI = 50)	Low PI CLAY and SILT (Hybrid)
C	N/A	SAND at < 100 ft depth (EPRI 250 ft - 500 ft)	SAND (EPRI 500 ft - 1000 ft)
D	40	CLAY (V&D PI = 100)	CLAY (V&D, PI=200)
E	N/A	SAND at < 100 ft depth (EPRI 250 ft - 500 ft)	SAND (EPRI 500 ft - 1000 ft)
F	40	CLAY (V&D PI = 100)	CLAY (V&D, PI=200)
H	N/A	SAND at ≥ 100 ft depth (EPRI 500 ft - 1000 ft)	SAND (EPRI 500 ft - 1000 ft)
J Clay	35	CLAY (V&D PI = 100)	CLAY (V&D, PI=200)
J Sand	N/A	SAND at ≥ 100 ft depth (EPRI 500 ft - 1000 ft)	SAND (EPRI 500 ft - 1000 ft)
K Clay	35	CLAY (V&D PI = 100)	CLAY (V&D, PI=200)
K Sand	N/A	SAND at ≥ 100 ft depth (EPRI 500 ft - 1000 ft)	SAND (EPRI 500 ft - 1000 ft)
L	50	CLAY (V&D PI = 100)	CLAY (V&D, PI=200)
M	N/A	SAND at ≥ 100 ft depth (EPRI 500 ft - 1000 ft)	SAND (EPRI 500 ft - 1000 ft)
N Clay	45	CLAY (V&D PI = 100)	CLAY (V&D, PI=200)
N Sand	N/A	SAND at ≥ 100 ft depth (EPRI 500 ft - 1000 ft)	SAND (EPRI 500 ft - 1000 ft)

Table 2.3.2-5 Modulus reduction curves for profiles for Base Cases 1 & 2 for STPEGS

Strain (%)	Sand at ≥ 100 ft depth (EPRI 500 ft-1000 ft)	Sand at < 100 ft depth (EPRI 250 ft - 500 ft)	Clay (V&D PI =100)	Silt (EPRI PI = 50)	
	G/G_{max}				
1.0	0.20 ± 0.05	0.15 ± 0.05	0.36 ± 0.05	0.14 ± 0.05	
0.316	0.40 ± 0.05	0.33 ± 0.05	0.62 ± 0.04	0.32 ± 0.05	
0.1	0.65 ± 0.04	0.57 ± 0.04	0.82 ± 0.03	0.58 ± 0.04	
0.0316	0.86 ± 0.03	0.80 ± 0.03	0.93 ± 0.02	0.81 ± 0.03	
0.01	0.95 ± 0.02	0.94 ± 0.02	0.98 ± 0.01	0.95 ± 0.02	
0.00316	1.00	0.99 ± 0.01	1.00	1.00	
0.001	1.00	1.00	1.00	1.00	
0.000316	1.00	1.00	1.00	1.00	
0.0001	1.00	1.00	1.00	1.00	

Table 2.3.2-6 Damping curves for profiles for Base Cases 1 & 2 for STPEGS

Strain (%)	Sand (EPRI 500 ft-1000 ft)	Clay (V&D, PI = 200)	Low PI Clay and Silt (Hybrid)
	Damping Ratio (%)		
1.0	16.66 ± 1.7	8.08 ± 0.8	15.72 ± 1.6
0.316	10.70 ± 1.1	4.86 ± 0.5	10.96 ± 1.1
0.1	5.64 ± 0.6	3.09 ± 0.3	6.61 ± 0.7
0.0316	2.67 ± 0.3	2.22 ± 0.2	3.54 ± 0.4
0.01	1.30 ± 0.1	1.65 ± 0.2	2.03 ± 0.2
0.00316	0.83 ± 0.08	1.33 ± 0.1	1.33 ± 0.1
0.001	0.67 ± 0.07	1.09 ± 0.1	1.09 ± 0.1
0.000316	0.60 ± 0.06	1.09 ± 0.1	1.09 ± 0.1
0.0001	0.60 ± 0.06	1.09 ± 0.1	1.09 ± 0.1

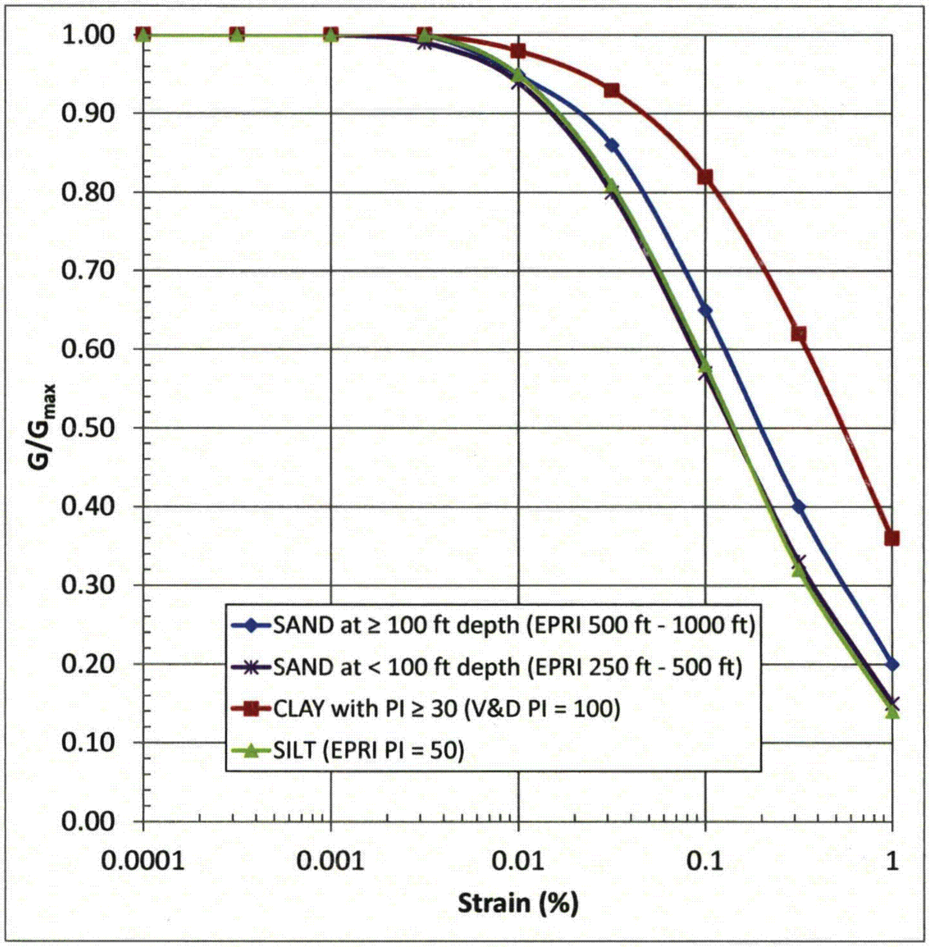

Figure 2.3.2-3. Shear modulus reduction curves for STPEGS

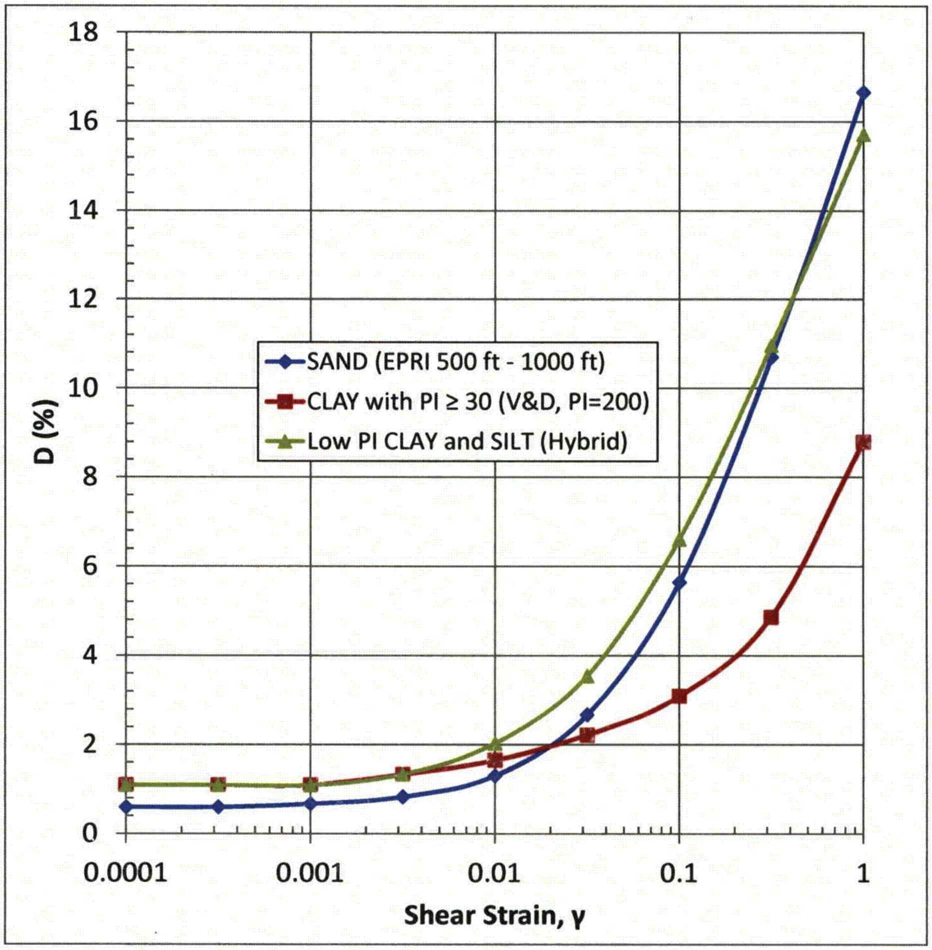

Figure 2.3.2-4. Damping ratio curves for STPEGS

2.3.2.2 Kappa

In site response analysis, the material above the depth of 603 ft is modeled as nonlinear with strain-dependent shear modulus reduction and material damping curves as discussed above in Section 2.3.2.1. Below the depth of 603 ft, the material is considered to be linear for all analyses with damping ratio calibrated to provide the prescribed kappa for the soil column at the surface of the site.

Based on the guidance in the Section B-5.1.3.1 of the SPID (EPRI 1025287, 2013), the STPEGS site is considered a deep soil site. Thus, a median value of kappa of 0.04 sec is considered for the soil column. As specified in Section B-5.1.3.2 of the SPID (EPRI 1025287, 2013), a natural log standard deviation of 0.4 was used to estimate the upper and lower range values of kappa. Table 2.3.2-7 summarizes the soil column kappa values used for site response analysis, where BC1 and BC2 refer to the two alternative V_S profiles, presented in Section 2.3.2. The range of kappa values in the table encompasses the values listed in the SPID (EPRI 1025287, 2013) for deep soil sites (e.g., 0.060, 0.054, and 0.052 sec).

Table 2.3.2-7. Soil Column Kappa Values Used for Site Response Analyses

Velocity Profile	Lower (sec)	Median (sec)	Upper (sec)
BC1	0.024	0.040	0.067
BC2	0.024	0.040	0.067

Because two base case V_S profiles were considered, a total of six alternative soil columns (2 base cases for V_S x 3 for kappa) are used for randomization and site response analysis. These soil columns, as well as their associated weights for the purpose of site response analysis, are summarized in Table 2.3.2-8.

Table 2.3.2-8. Alternative Base Case Soil Columns and Associated Weights

Base Soil Column Name	Shear Wave Velocity		Kappa		Soil Column Weight (wVs x wk)
	Profile	Weight (wVs)	Profile	Weight (wk)	
BC1-kL	Base Case 1 (BC1)	0.4	Lower range (kL)	0.3	0.12
BC1-kM			Median (kM)	0.4	0.16
BC1-kU			Upper range(kU)	0.3	0.12
BC2-kL	Base Case 2 (BC2)	0.6	Lower range (kL)	0.3	0.18
BC2-kM			Median (kM)	0.4	0.24
BC2-kU			Upper range (kU)	0.3	0.18
				Total	1.0

2.3.3 Randomization of Base Case Profiles

To account for the aleatory variability in material properties and soil profile data that is expected to occur across a site at the scale of a typical nuclear facility, variability in the assumed V_S profiles has been incorporated in the site response calculations. For the STPEGS site, random V_S profiles were developed from the base case profiles, presented in Section 2.3.2. The simulation procedure generates a set of site-specific simulated soil profiles which include uncertainty associated with the dynamic property and soil profile configuration, and correlations between different parameters.

Note that epistemic uncertainty at the STPEGS site is limited given the level of geotechnical investigation conducted at the site, refer to Section 2.3.2. Six profiles (2 base cases for V_S x 3 for kappa) are adopted, as described in Section 2.3.2.2 (see Table 2.3.2-8), and a set of sixty random profiles was generated for each. The random V_S profiles, presented in Figure 2.3.3-1 and Figure 2.3.3-2 for two of the six soil columns, were generated using a natural log standard deviation ranging from 0.19 to 0.25 over the upper 603 ft, and ranging from 0.1 to 0.2 below that depth (see Section 2.3.2 and Tables 2.3.2-1, 2.3.2-2 and 2.3.2-3). Note that some values of the measured natural log standard deviation below 603 ft depth were less than 0.1; these were set at 0.1 for the analysis. As specified in the SPID (EPRI 1025287, 2013), correlation of V_S between layers was modeled using the USGS C correlation model. In profile simulation, a limit of +/- 2 standard deviations about the median value in each layer was assumed for the limits on random velocity fluctuations, as well as on strain-dependent shear modulus reduction and damping ratios. All random velocities were limited to be less than or equal to 9,200 ft/sec.

Bedrock at the STPEGS site is found at a very large depth (about 34,500 ft deep). For the purpose of soil profile simulation and seismic site response analysis, the soil column is truncated at a best estimate depth of 8094 ft. The truncation depth is determined such that the soil column frequency at that depth is less than 0.1 Hz, where bedrock with a V_S of 9200 ft/sec is placed. Since the soil hazard and GMRS calculation only needs to consider frequencies higher than about 0.5 Hz (EPRI 1025287, 2013), appropriately truncated soil profiles can be used to produce accurate results for the site response in the range of frequencies of interest. A 10% uniform variation on the best estimate (BE) total depth of the soil column is applied. The thicknesses of individual soil/rock formations were also simulated, where the maximum and minimum thicknesses for each soil/rock formation were estimated by a 20% increase and decrease from the BE value, respectively.

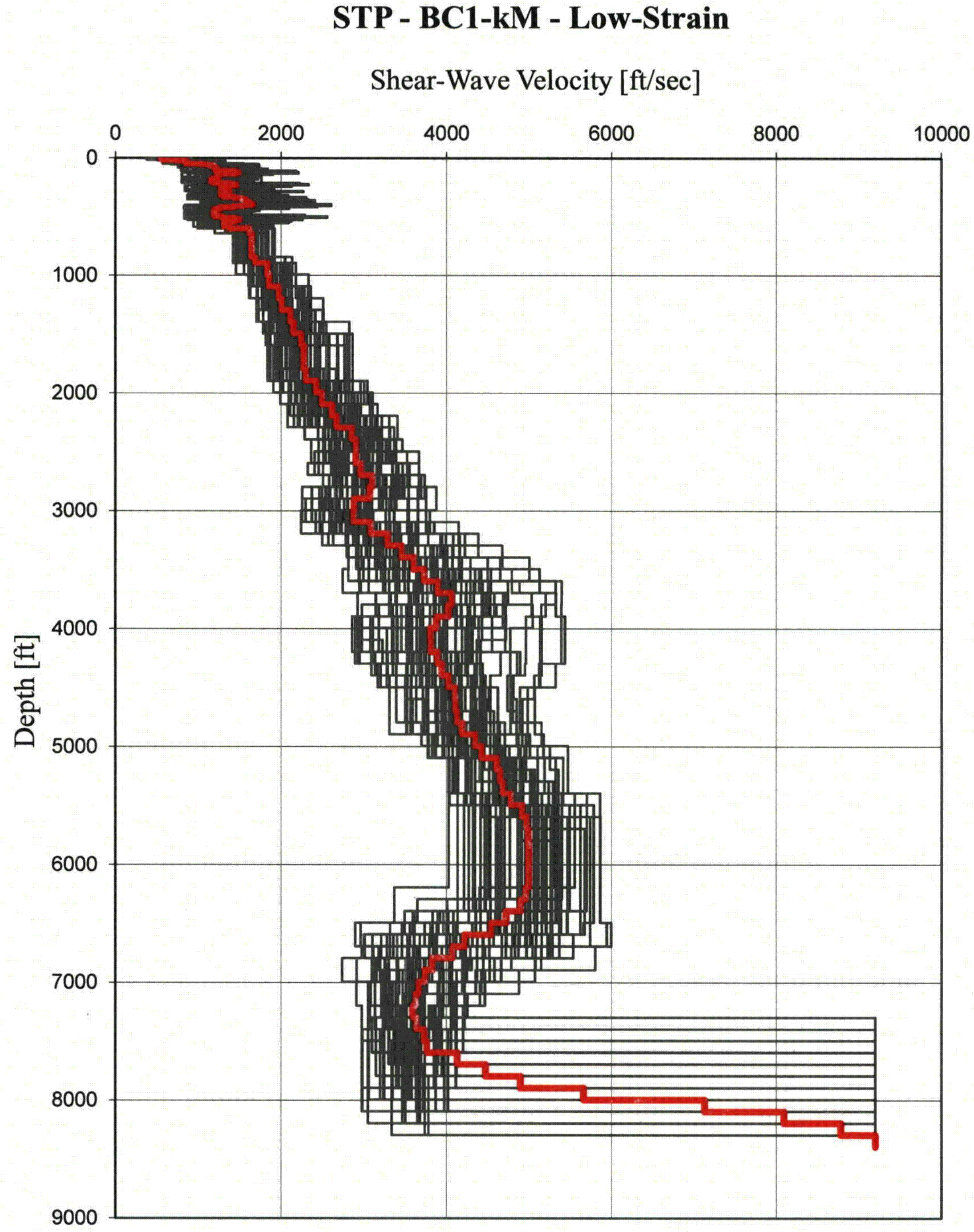

Figure 2.3.3-1. Simulated shear wave velocity profiles for the BC1-kM base soil column (Individual profiles plotted in gray, and median profile plotted in red)

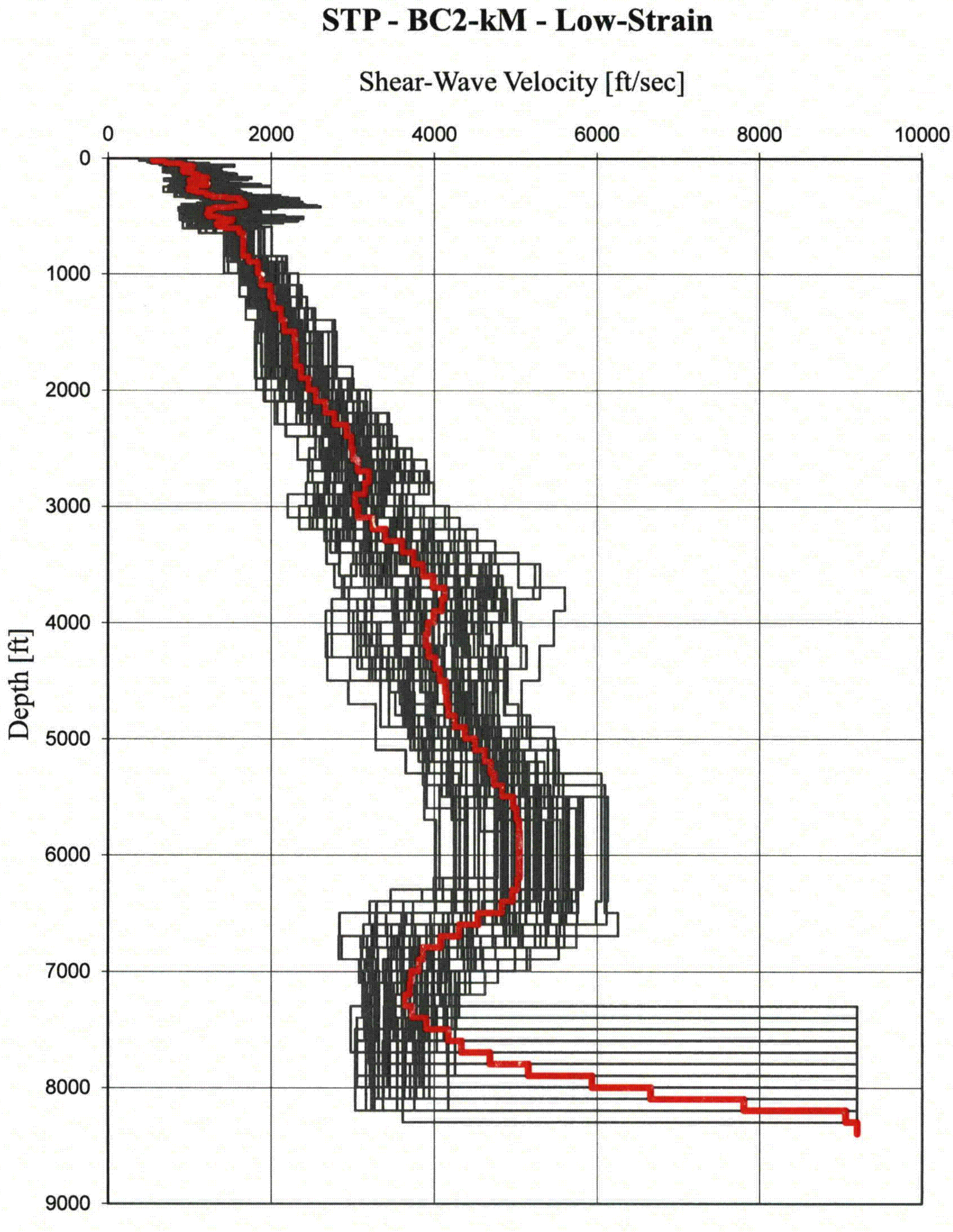

Figure 2.3.3-2. Simulated shear wave velocity profiles for the BC2-kM base soil column (Individual profiles plotted in gray, and median profile plotted in red)

2.3.4 Input Spectra

For the calculation of the control point motions, Method 2A (McGuire et al., 2001) was used, which is endorsed as an acceptable methodology by both the NRC 10 CFR 50.54(f) RFI Letter, Attachment 1 to Seismic Enclosure 1 (which endorses the use of either NUREG/CR-6728 Method 2 or 3) and also the SPID, Section 2.5.3. Consistent with Method 2A, the input spectra used for the site response analysis are based on the base rock hazard results for both high frequency (HF) and low frequency (LF) cases. Given the hazard curves presented in Section 2.2.2, the deaggregation results for annual frequency of exceedance (AFE) levels of 10^{-4}, 10^{-5}, and 10^{-6} from a previous probabilistic seismic hazard analysis for the STP Units 3&4 (STPNOC, 2012) were adopted to be acceptable in the Method 2A approach for STP Units 1&2.

This assumption is acceptable based on the expectation that the mean magnitude and mean distance values would not change between the PSHA studies in a way to significantly change the resulting HF and LF spectra. The adopted controlling mean magnitude and distances are listed in Table 2.3.4-1. The 10^{-4} AFE level values were assumed to be equal to the 10^{-3} AFE level values. Similarly, the AFE level values less than 10^{-6} were assumed to be equal to the 10^{-6} AFE level values. These deaggregation magnitude and distance values were also adopted for the fractile cases.

Table 2.3.4-1 Mean magnitude and distance values for the high frequency (HF) and low frequency (LF) cases. For the LF cases the values are computed based on the contribution from sources greater than 100 km following the guidance provided in NRC (2007).

	High Frequency (HF)		Low Frequency (LF)	
AFE	Mean Magnitude	Mean Distance (km)	Mean Magnitude	Mean Distance (km)
10^{-3}	6.7	230	7.6	880
10^{-4}	6.7	230	7.6	880
10^{-5}	6.1	46	7.7	890
10^{-6}	5.6	10	7.8	890
10^{-7}	5.6	10	7.8	890

Separate input spectra were developed for HF and LF cases. For the HF cases the spectral shape is anchored to the uniform hazard response spectra (UHRS) values at PGA (100 Hz), 25 Hz, 10 Hz, and 5 Hz in order to reflect accurately the UHRS values. In between these frequencies, the spectrum is logarithmically smoothed using shapes anchored to the next higher and next lower frequencies. This technique provides a reasonable spectral shape at these intermediate frequencies. Below 5 Hz, the spectral amplitudes were scaled using the HF spectral shape given the appropriate magnitude and distance values anchored to the 5 Hz spectral amplitude.

For the LF cases a similar procedure was used except that the LF spectral shape was anchored to the UHRS values at all seven ground motion frequencies (PGA(100 Hz), 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz). Anchoring the LF spectral shape to all frequencies was adopted to prevent the high frequency ground motions values associated with the LF case to exceed the high frequency ground motion values associated with the HF case. With this constraint, the HF and LF input spectra were constrained to be equal at the PGA (100 Hz), 25 Hz, 10 Hz, and 5 Hz

spectral frequencies and were similar for frequencies between these reference spectra frequencies based on the interpolated spectral shapes given the appropriate magnitude and distance values.

As an example the HF, LF and Broadband input spectra are plotted in Figure 2.3.4-1 for the mean hazard curve case for 10^{-4} AFE level. The Broadband spectrum is the envelope of the HF and LF spectra and is not used in the site amplification analysis. The UHS ground motion values for the seven reference frequencies are shown in the figure as the red open circles. Similar results for the 10^{-5} AFE level are plotted in Figure 2.3.4-2. The digital values for the HF and LF spectra for the mean hazard curve case are provided in Table 2.3.4-2 at a suite of 38 spectral frequencies. These resulting HF and LF spectra for the suite of AFE level (i.e., 10^{-3} to 10^{-8}) for the mean and five fractile levels are used as the input spectra for the site response analysis.

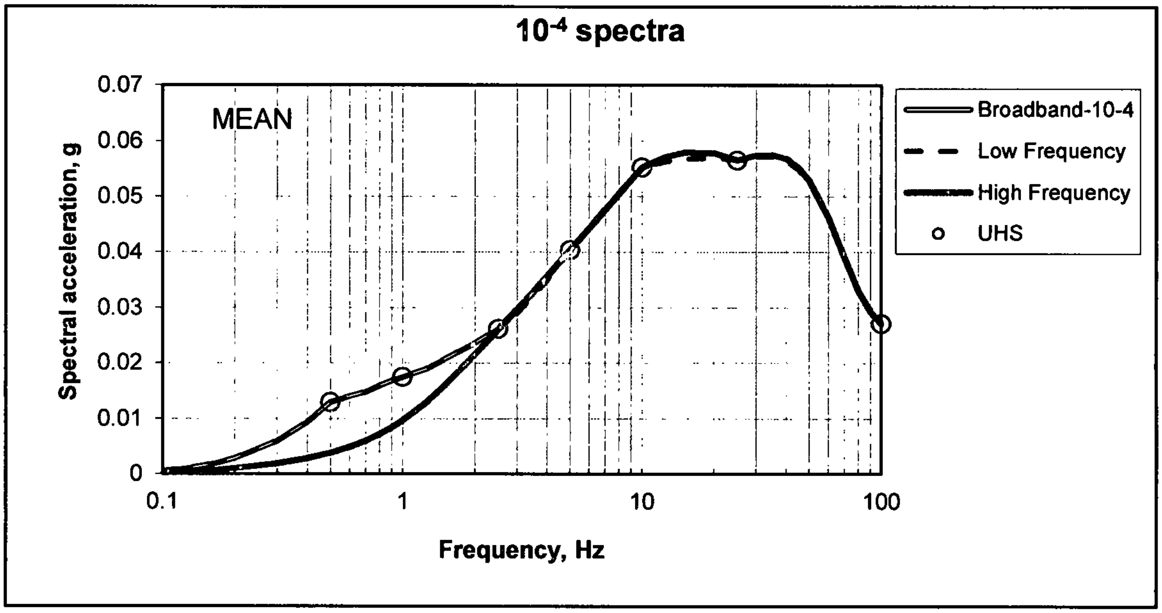

Figure 2.3.4-1 Mean, LF, HF, and Broadband 10^{-4} spectra for STP Units 1 & 2.

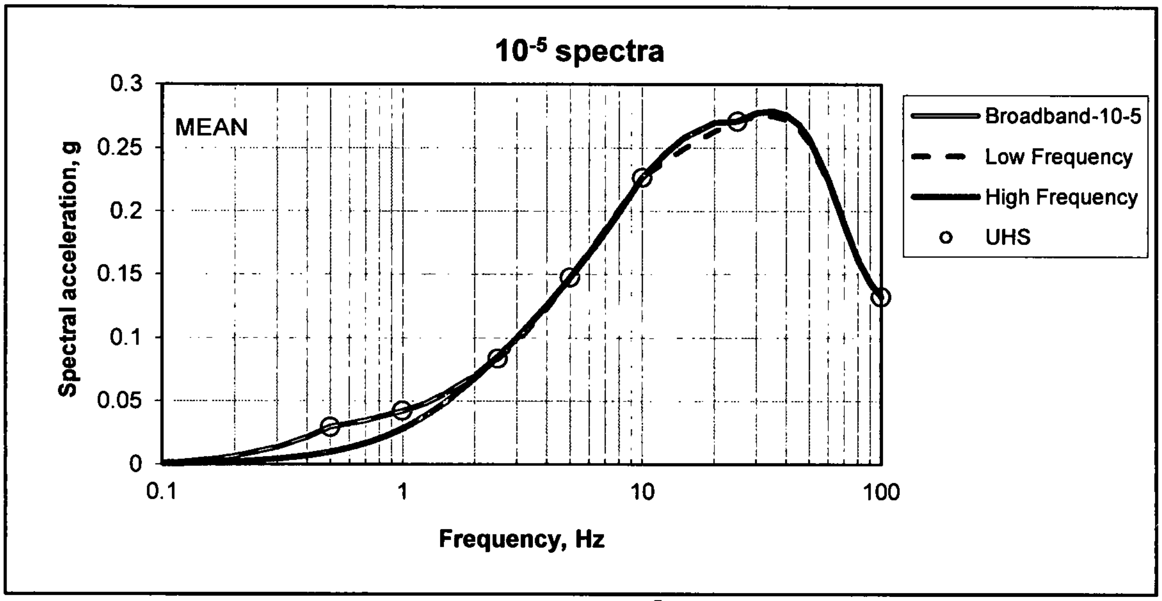

Figure 2.3.4-2 Mean, LF, HF, and Broadband 10^{-5} spectra for STP Units 1 & 2.

Table 2.3.4-2 Input HF and LF spectra for the 10^{-4} and 10^{-5} AFE level associated with the mean hazard curves at a suite of 38 spectral frequencies.

Frequency (Hz)	HF 10-4 (g)	LF 10-4 (g)	HF 10-5 (g)	LF 10-5 (g)
100	2.711E-02	2.711E-02	1.322E-01	1.322E-01
90	2.928E-02	2.926E-02	1.428E-01	1.425E-01
80	3.311E-02	3.305E-02	1.615E-01	1.608E-01
70	3.896E-02	3.884E-02	1.899E-01	1.887E-01
60	4.620E-02	4.600E-02	2.251E-01	2.230E-01
50	5.281E-02	5.251E-02	2.571E-01	2.540E-01
45	5.519E-02	5.485E-02	2.684E-01	2.649E-01
40	5.675E-02	5.638E-02	2.757E-01	2.719E-01
35	5.749E-02	5.713E-02	2.787E-01	2.750E-01
30	5.741E-02	5.715E-02	2.773E-01	2.746E-01
25	5.648E-02	5.648E-02	2.707E-01	2.707E-01
20	5.780E-02	5.694E-02	2.696E-01	2.628E-01
15	5.793E-02	5.677E-02	2.581E-01	2.495E-01
12.5	5.709E-02	5.625E-02	2.457E-01	2.397E-01
10	5.522E-02	5.522E-02	2.266E-01	2.266E-01
9	5.303E-02	5.304E-02	2.138E-01	2.144E-01
8	5.051E-02	5.056E-02	1.996E-01	2.008E-01
7	4.761E-02	4.770E-02	1.838E-01	1.854E-01
6	4.425E-02	4.434E-02	1.665E-01	1.678E-01
5	4.031E-02	4.031E-02	1.473E-01	1.473E-01
4	3.563E-02	3.498E-02	1.255E-01	1.232E-01
3	2.975E-02	2.910E-02	1.003E-01	9.690E-02
2.5	2.605E-02	2.614E-02	8.543E-02	8.367E-02
2	2.154E-02	2.358E-02	6.828E-02	7.001E-02
1.5	1.599E-02	2.069E-02	4.866E-02	5.575E-02
1.25	1.287E-02	1.881E-02	3.832E-02	4.806E-02
1	9.686E-03	1.740E-02	2.813E-02	4.214E-02
0.9	8.434E-03	1.672E-02	2.421E-02	3.993E-02
0.8	7.212E-03	1.584E-02	2.041E-02	3.732E-02
0.7	6.031E-03	1.472E-02	1.677E-02	3.428E-02
0.6	4.899E-03	1.394E-02	1.332E-02	3.210E-02
0.5	3.821E-03	1.291E-02	1.007E-02	2.945E-02
0.4	2.803E-03	9.363E-03	7.085E-03	2.142E-02
0.3	1.854E-03	5.934E-03	4.403E-03	1.364E-02
0.2	9.953E-04	2.795E-03	2.129E-03	6.457E-03
0.167	7.402E-04	1.898E-03	1.500E-03	4.391E-03
0.125	4.457E-04	9.387E-04	8.185E-04	2.171E-03
0.1	2.922E-04	5.044E-04	4.917E-04	1.162E-03

2.3.5 Methodology

This section defines the random vibration theory (RVT) methodology which was used to perform the site response analyses for the STPEGS site. This process utilizes a simple, efficient approach for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID (EPRI 1025287, 2013).

Using the input spectra developed for STPEGS, as defined in Section 2.3.4, as well as the significant amount of initial and newly developed information which is now available for the STPEGS site, , the 5% damped acceleration response spectra at the ground surface (SSE control point) are computed, and the amplification functions are calculated as the ratio of the surface response spectra to the hard rock spectra, both at 5% spectral damping. Arithmetic mean (mean) and natural log-mean (median) amplification functions and associated natural log-standard deviations are calculated for each of the six sets of 60 profiles. The analysis is carried out at 301 frequency points ranging from 0.1 to 100 Hz and equally spaced in logarithmic space.

The total (weighted average) arithmetic mean and log-mean amplification as a function of frequency, at each hard rock motion level, are calculated as:

$$\mu_T = \sum_i w_i \mu_i$$

In this equation, μ_T is the total arithmetic mean (or log-mean) amplification at each spectral frequency, μ_i is the arithmetic mean (or log-mean) amplification function for soil column *i* at the same spectral frequency, and w_i is the weight assigned to soil column *i*. In the case of the STPEGS site, six soil columns are used and their associated weights are provided in Table 2.3.2-4. Similarly, the total natural log-standard deviation σ_T of the amplification as a function of spectral frequency, is calculated by the equation below, where σ_i is the natural log-standard deviation of soil column *i*.

$$\sigma_T = \sqrt{\sum_i w_i \left[(\mu_i - \mu_T)^2 + \sigma_i^2\right]}$$

The site amplification function is inherently probabilistic in nature and the SPID Report (Section B2.1) provides definitions of aleatory variability and epistemic uncertainties (Appendix A, Section B2.1) and requires that they be addressed in the Seismic Reevaluation. However, it also acknowledges that, for a site like STPEGS, with extensive seismic data and analyses, "For well-characterized sites, with abundant high-quality data, this uncertainty would be reduced, possibly eliminating the need to vary some of the site parameters such as the site profile."

Development of the GMRS and hazard curves involves establishment of frequency-dependent spectral amplification factors that define how the input rock motion corresponding to a defined return period is amplified because of the site response, and convolution of the rock hazard with site amplification function (since magnitude of site amplification depends on the input rock amplitude, which itself has a range of values).

Even for a "well characterized" site, such as STP 1&2, with an exhaustive recent subsurface investigation that supplements the existing UFSAR seismic information, there will be random variability of soil properties within each soil layer, for parameters such as V_S, non-linear dynamic material properties, the overall thickness of soil/soft rock above firm rock, and inherent near surface site damping (kappa value, which represents damping of soil layers below the depth of subsurface investigation). In addition, the soil layer thickness itself will randomly vary. Additional random variability could occur with the kappa value. As explained below, although the depth to bedrock may vary, it is not expected to impact results for frequencies greater than or equal to 0.5 Hz.

Aleatory variability is addressed through the randomization process. The potential V_S variability for each soil layer and potential variability for each soil layer thickness is captured by considering random perturbations to the "base case" soil column mode. Sixty randomizations are used to address the aleatory variability (60 being a large enough number to help provide stable statistical mean and standard deviation values for the amp function for each profile). Perturbations relative to the kappa value are considered to address its aleatory variability.

For STP 1&2, the soil amplification function is essentially insensitive to the as-modeled soil column height for the frequency range of interest (i.e., 1 Hz to 100 Hz). The epistemic uncertainty primarily impacts the base case soil column model and is accounted for by employing alternative base case models. Based on the SPID recommendations, in addition to the base case model, upper and lower-range alternative base case models are developed. Soil properties for upper-range and lower-range models are assigned using a "profile epistemic uncertainty factor".

For well characterized sites such as STP, due to the availability of good subsurface data from Units 3 and 4, the epistemic uncertainty is relatively small. The SPID states that "For well-characterized sites, with abundant high-quality data, this uncertainty would be reduced, possibly eliminating the need to vary some of the site parameters such as the site profile" (the term "site profile" is used here to refer to the base case soil model).

The V_S measurement data for Units 1 and 2 considered two alternative base cases to account for the modeling ("epistemic") uncertainty of Vs. For both base cases, the local soil layering under Units 1 and 2 is based on the lithology reported in the UFSAR for Units 1 and 2. The soil dynamic properties for depths below 341-ft are based on the new data used for Units 3 and 4 since no such data are available for Units 1 and 2. Also, for both base cases, the strain-dependent properties for each layer (e.g., soil damping and modulus) were wholly based on the data from Units 3 and 4 since the recent RCTS-based test data are considered highly reliable compared to the older testing methods. So, the only difference between the two base cases is that one base case considers the V_S values entirely based on Units 3 and 4 data, whereas the other base case considers the reported V_S values for Units 1 and 2 (down to the reported depth). Kappa estimates are used to calculate strain-independent damping rations for layers below 603 ft. depth, and three alternative values (lower range, median and upper range are adopted. This results in a total of 6 alternative soil columns (2 base cases for Vs C3 for kappa).

The approach for STP Units 1 and 2 thus employs an appropriate basis for developing the alternative base case profiles and the associated weighting factors, and will result in more accurate estimation of the GMRS and hazard curves. A higher weighting was assigned to the base case model that is based on velocity measurements from Units 3 and 4, since the data were developed by more recent techniques. Each base case is then randomized to address aleatory variability concerning soil properties and layer thickness. The final GMRS results are obtained using a weighted average approach to the corresponding results for the individual alternative base cases.

Thus, for STP 1&2, the epistemic uncertainty has been fully considered by: (a) proper selection of the base case models and (b) judicious assignment of the "profile epistemic uncertainty factors".

2.3.6 Amplification Functions

The results of site response analysis consist of amplification functions which describe the amplification (or de-amplification) of hard rock motion as a function of frequency and input reference rock amplitude. The amplification factors are represented in terms of a mean (and median) amplification value and an associated standard deviation (sigma) as a function of spectral frequency for the hard rock spectra presented in Section 2.3.4 (mean High Frequency (HF) and Low Frequency (LF) at various annual frequencies of exceedance (AFE), from 1E-3 to 1E-7, as well at different fractile levels).

As an example, Figure 2.3.6-1a illustrates the mean amplification functions developed for the BC1-kM soil column (see Table 2.3.2-8 for a definition of alternative base soil columns). The variability in the amplification factors results from variability in V_S, depth to hard rock, and modulus reduction and hysteretic damping curves, and is represented by the natural log-standard deviations illustrated in Figure 2.3.6-1b. Figure 2.3.6-2a and Figure 2.3.6-2b show similar results for the BC2-kM soil column. Similarly, amplification functions are developed for all six alternative base soil columns.

The total (weighted average) mean amplification functions and corresponding standard deviations are presented in Figure 2.3.6-3a and Figure 2.3.6-3b, respectively. Note that while the illustrated amplification functions are computed using the mean bedrock input motions, amplification functions are also developed for 5^{th}, 16^{th}, 50^{th}, 84^{th}, and 95^{th} percentile rock motions at the 1E-3 through 1E-7 AFE.

Tabulated values of the amplification factors for the presented figures, at the 1E-4 and 1E-5 AFE, are provided in Tables 2.3.6-1, 2.3.6-2 and 2.3.6-3. Additionally, the weighted average amplification and total standard deviation is reported at the seven frequencies, for which the GMM is defined, in Table A-2 in the Appendix for the 1E-3 through 1E-7 AFE.

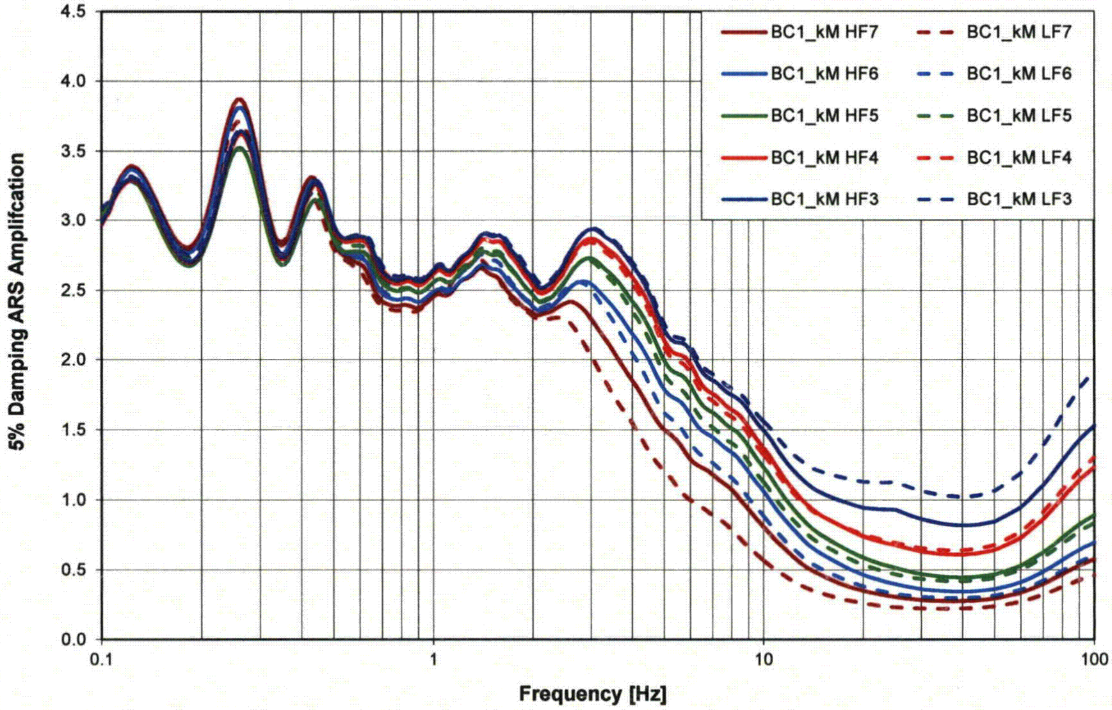

Figure 2.3.6-1a. Example suite of mean site amplification functions for the BC1-kM soil column for the 1E-3 through 1E-7 AFE input motions.

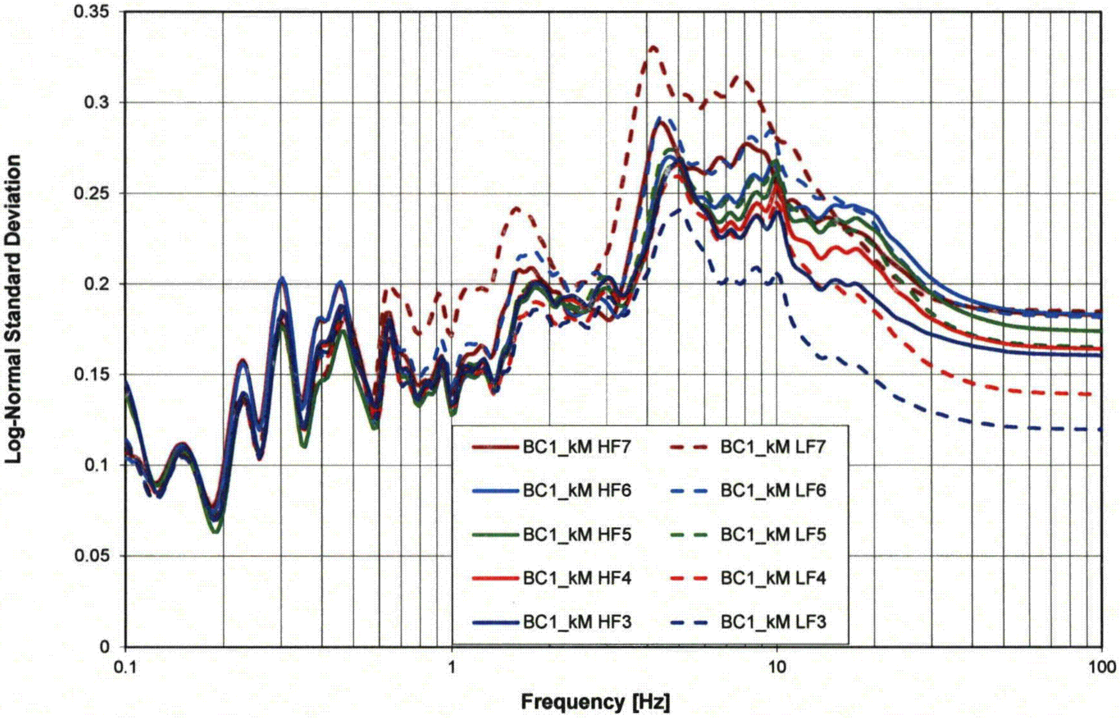

Figure 2.3.6-1b. Example suite of natural logarithmic standard deviations of the amplification functions for the BC1-kM soil column.

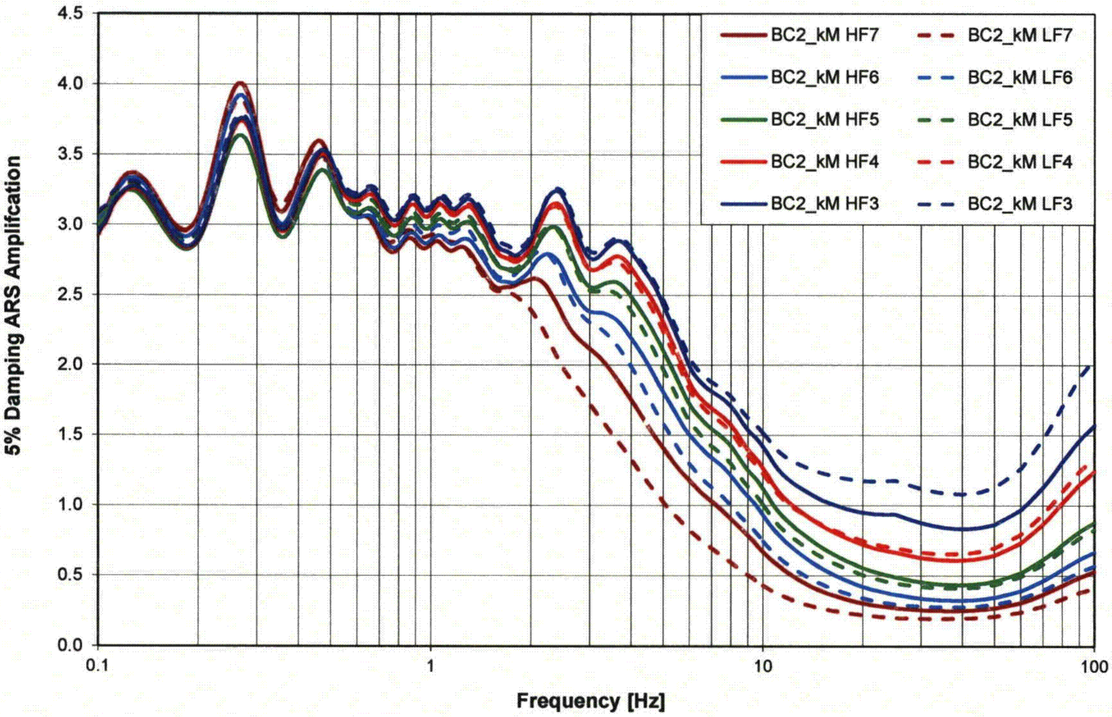

Figure 2.3.6-2a. Example suite of mean site amplification functions for the BC2-kM soil column for the 1E-3 through 1E-7 AFE input motions.

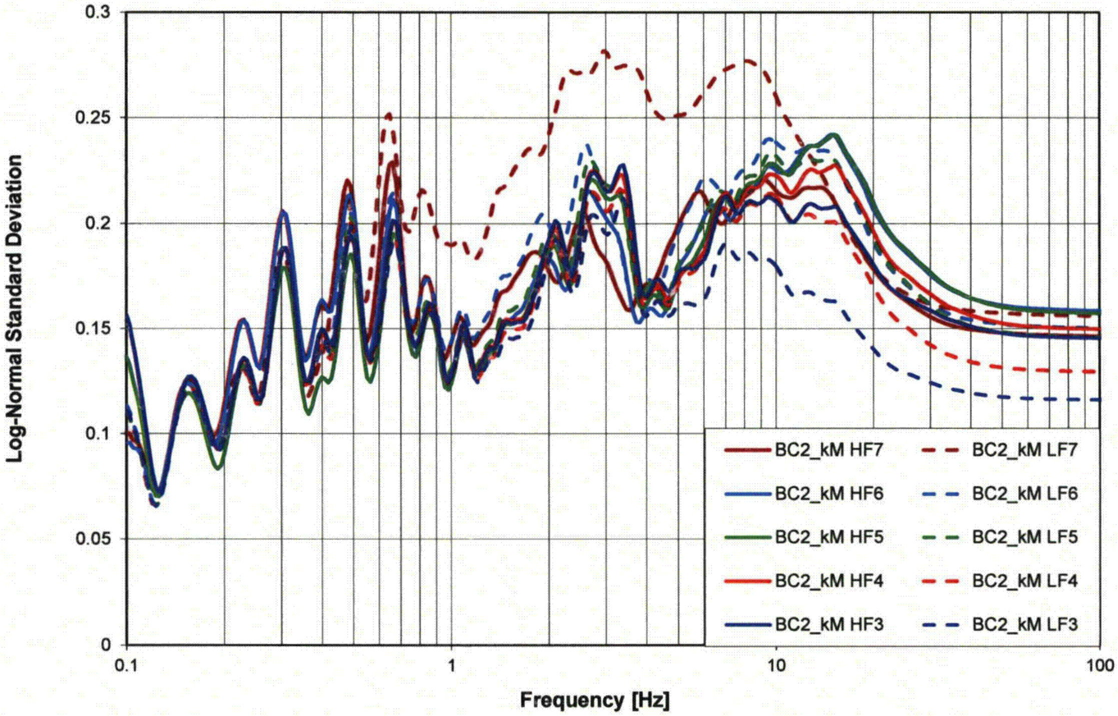

Figure 2.3.6-2b. Example suite of natural logarithmic standard deviations of the amplification functions for the BC2-kM soil column.

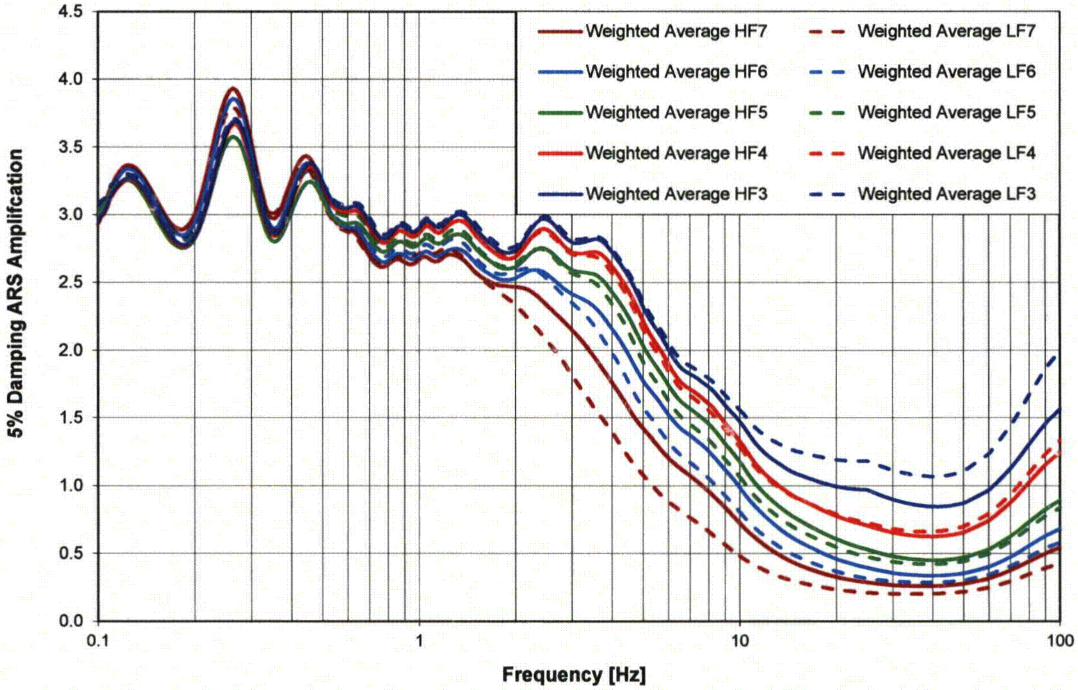

Figure 2.3.6-3a. Total (weighted average) mean site amplification functions for the STPEGS site for the 1E-3 through 1E-7 AFE input motions.

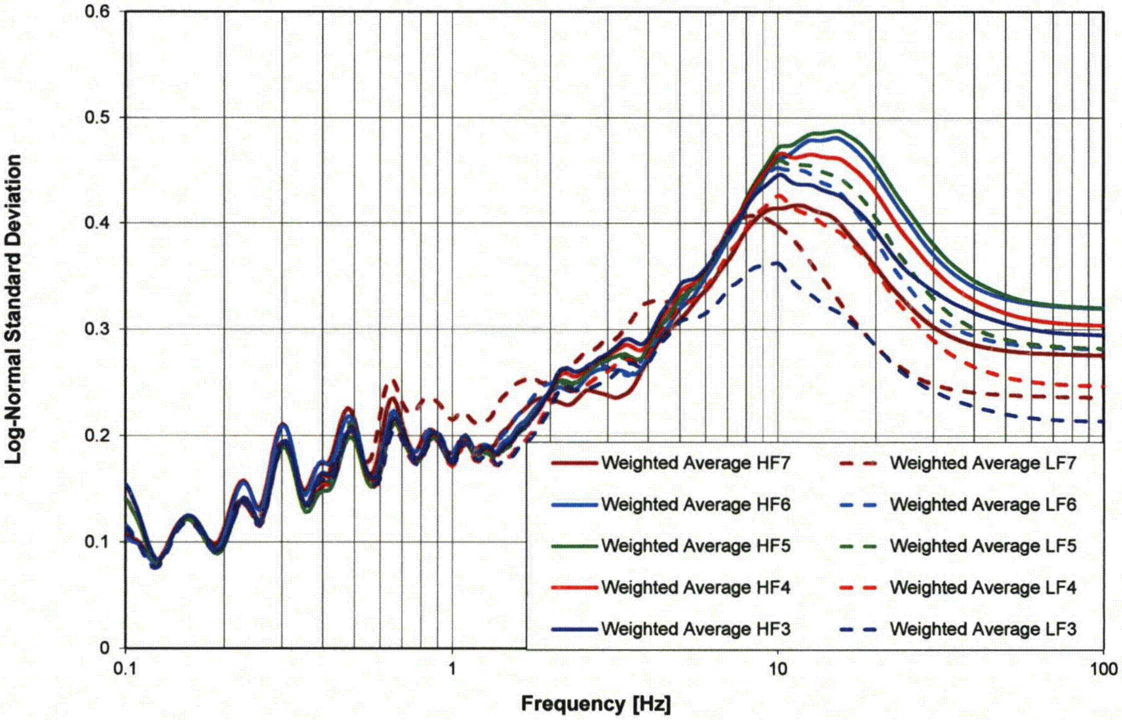

Figure 2.3.6-3b. Total (weighted average) natural logarithmic standard deviations of the amplification functions for the STPEGS site.

Table 2.3.6-1. Arithmetic mean and log-standard deviation of the 5% damped amplification function (AF) for the BC1-kM soil column and the HF4, LF4, HF5, and LF5 motions

Frequency	HF 1E-4		LF 1E-4		HF 1E-5		LF 1E-5	
[Hz]	Mean AF	Ln (AF)	Mean AF	Ln (AF)	Mean AF	Ln (AF)	Mean AF	Ln (AF)
0.1	2.97E+00	1.46E-01	3.08E+00	1.12E-01	3.01E+00	1.38E-01	3.06E+00	1.11E-01
0.125	3.29E+00	8.45E-02	3.31E+00	8.18E-02	3.28E+00	8.89E-02	3.30E+00	8.19E-02
0.167	2.77E+00	9.58E-02	2.81E+00	9.12E-02	2.74E+00	8.99E-02	2.80E+00	9.16E-02
0.2	2.77E+00	8.18E-02	2.83E+00	8.43E-02	2.75E+00	7.68E-02	2.82E+00	8.52E-02
0.3	3.24E+00	1.83E-01	3.25E+00	1.81E-01	3.13E+00	1.76E-01	3.23E+00	1.82E-01
0.4	3.04E+00	1.66E-01	3.05E+00	1.60E-01	2.97E+00	1.47E-01	3.05E+00	1.61E-01
0.5	2.94E+00	1.62E-01	2.92E+00	1.69E-01	2.86E+00	1.54E-01	2.89E+00	1.70E-01
0.6	2.85E+00	1.38E-01	2.86E+00	1.29E-01	2.77E+00	1.29E-01	2.82E+00	1.31E-01
0.7	2.61E+00	1.53E-01	2.65E+00	1.45E-01	2.55E+00	1.49E-01	2.59E+00	1.51E-01
0.8	2.55E+00	1.39E-01	2.57E+00	1.37E-01	2.50E+00	1.34E-01	2.51E+00	1.40E-01
0.9	2.54E+00	1.48E-01	2.55E+00	1.45E-01	2.49E+00	1.44E-01	2.49E+00	1.51E-01
1	2.62E+00	1.33E-01	2.62E+00	1.32E-01	2.56E+00	1.28E-01	2.56E+00	1.35E-01
1.25	2.72E+00	1.57E-01	2.72E+00	1.52E-01	2.66E+00	1.52E-01	2.68E+00	1.56E-01
1.5	2.84E+00	1.65E-01	2.84E+00	1.55E-01	2.75E+00	1.64E-01	2.78E+00	1.68E-01
2	2.53E+00	1.94E-01	2.54E+00	1.83E-01	2.46E+00	1.91E-01	2.46E+00	1.94E-01
2.5	2.65E+00	1.89E-01	2.64E+00	1.79E-01	2.57E+00	1.85E-01	2.57E+00	1.88E-01
3	2.87E+00	2.03E-01	2.84E+00	1.97E-01	2.73E+00	1.98E-01	2.71E+00	2.04E-01
4	2.59E+00	2.21E-01	2.54E+00	2.18E-01	2.42E+00	2.20E-01	2.35E+00	2.33E-01
5	2.14E+00	2.66E-01	2.09E+00	2.60E-01	1.99E+00	2.66E-01	1.90E+00	2.72E-01
6	1.97E+00	2.41E-01	1.91E+00	2.37E-01	1.81E+00	2.43E-01	1.70E+00	2.51E-01
7	1.76E+00	2.32E-01	1.71E+00	2.26E-01	1.62E+00	2.38E-01	1.52E+00	2.46E-01
8	1.64E+00	2.33E-01	1.59E+00	2.28E-01	1.51E+00	2.40E-01	1.40E+00	2.50E-01
9	1.52E+00	2.42E-01	1.47E+00	2.35E-01	1.38E+00	2.48E-01	1.27E+00	2.56E-01
10	1.37E+00	2.54E-01	1.32E+00	2.45E-01	1.23E+00	2.62E-01	1.12E+00	2.68E-01
12.5	1.05E+00	2.22E-01	1.03E+00	2.07E-01	9.15E-01	2.34E-01	8.36E-01	2.37E-01
15	8.85E-01	2.20E-01	8.81E-01	1.99E-01	7.45E-01	2.35E-01	6.81E-01	2.32E-01
20	7.39E-01	2.10E-01	7.52E-01	1.85E-01	5.86E-01	2.29E-01	5.37E-01	2.21E-01
25	6.80E-01	1.93E-01	6.96E-01	1.66E-01	5.15E-01	2.10E-01	4.68E-01	1.99E-01
30	6.32E-01	1.81E-01	6.57E-01	1.55E-01	4.70E-01	1.95E-01	4.35E-01	1.84E-01
35	6.12E-01	1.75E-01	6.42E-01	1.49E-01	4.50E-01	1.87E-01	4.22E-01	1.76E-01
40	6.10E-01	1.71E-01	6.42E-01	1.45E-01	4.46E-01	1.82E-01	4.20E-01	1.72E-01
45	6.21E-01	1.69E-01	6.56E-01	1.43E-01	4.52E-01	1.80E-01	4.28E-01	1.70E-01
50	6.44E-01	1.67E-01	6.81E-01	1.42E-01	4.68E-01	1.77E-01	4.43E-01	1.68E-01
60	7.31E-01	1.65E-01	7.74E-01	1.40E-01	5.31E-01	1.76E-01	5.02E-01	1.67E-01
70	8.63E-01	1.65E-01	9.13E-01	1.40E-01	6.26E-01	1.75E-01	5.91E-01	1.66E-01
80	1.01E+00	1.64E-01	1.07E+00	1.40E-01	7.33E-01	1.74E-01	6.91E-01	1.65E-01
90	1.14E+00	1.64E-01	1.21E+00	1.39E-01	8.27E-01	1.74E-01	7.77E-01	1.65E-01
100	1.23E+00	1.64E-01	1.30E+00	1.39E-01	8.93E-01	1.74E-01	8.39E-01	1.65E-01

Table 2.3.6-2. Arithmetic mean and log-standard deviation of the 5% damped amplification function (AF) for the BC2-kM soil column and the HF4, LF4, HF5, and LF5 motions

Frequency	HF 1E-4		LF 1E-4		HF 1E-5		LF 1E-5	
[Hz]	Mean AF	Ln (AF)	Mean AF	Ln (AF)	Mean AF	Ln (AF)	Mean AF	Ln (AF)
0.1	2.93E+00	1.57E-01	3.08E+00	1.11E-01	2.99E+00	1.37E-01	3.07E+00	1.10E-01
0.125	3.26E+00	7.33E-02	3.31E+00	6.70E-02	3.25E+00	7.06E-02	3.29E+00	6.72E-02
0.167	2.91E+00	1.21E-01	2.97E+00	1.16E-01	2.88E+00	1.11E-01	2.95E+00	1.16E-01
0.2	2.90E+00	9.83E-02	2.97E+00	9.91E-02	2.89E+00	9.11E-02	2.96E+00	1.00E-01
0.3	3.49E+00	1.86E-01	3.52E+00	1.86E-01	3.38E+00	1.78E-01	3.51E+00	1.87E-01
0.4	3.17E+00	1.48E-01	3.19E+00	1.42E-01	3.10E+00	1.27E-01	3.19E+00	1.41E-01
0.5	3.43E+00	1.91E-01	3.42E+00	1.98E-01	3.32E+00	1.81E-01	3.39E+00	2.00E-01
0.6	3.17E+00	1.55E-01	3.19E+00	1.50E-01	3.08E+00	1.47E-01	3.14E+00	1.55E-01
0.7	3.14E+00	1.84E-01	3.17E+00	1.77E-01	3.05E+00	1.77E-01	3.11E+00	1.81E-01
0.8	3.01E+00	1.46E-01	3.04E+00	1.47E-01	2.94E+00	1.42E-01	2.98E+00	1.52E-01
0.9	3.14E+00	1.53E-01	3.15E+00	1.51E-01	3.04E+00	1.48E-01	3.07E+00	1.54E-01
1	3.08E+00	1.27E-01	3.10E+00	1.27E-01	2.99E+00	1.24E-01	3.03E+00	1.31E-01
1.25	3.12E+00	1.36E-01	3.14E+00	1.31E-01	3.01E+00	1.33E-01	3.06E+00	1.38E-01
1.5	2.91E+00	1.54E-01	2.93E+00	1.49E-01	2.80E+00	1.52E-01	2.82E+00	1.58E-01
2	2.85E+00	1.91E-01	2.87E+00	1.87E-01	2.77E+00	1.87E-01	2.81E+00	1.95E-01
2.5	3.11E+00	1.96E-01	3.08E+00	1.90E-01	2.92E+00	1.97E-01	2.89E+00	2.11E-01
3	2.69E+00	2.16E-01	2.68E+00	2.06E-01	2.56E+00	2.12E-01	2.53E+00	2.18E-01
4	2.69E+00	1.65E-01	2.64E+00	1.63E-01	2.49E+00	1.62E-01	2.39E+00	1.69E-01
5	2.31E+00	1.74E-01	2.24E+00	1.71E-01	2.10E+00	1.73E-01	1.97E+00	1.80E-01
6	1.88E+00	1.86E-01	1.83E+00	1.83E-01	1.72E+00	1.92E-01	1.60E+00	2.01E-01
7	1.69E+00	2.14E-01	1.64E+00	2.07E-01	1.55E+00	2.12E-01	1.42E+00	2.13E-01
8	1.57E+00	2.13E-01	1.52E+00	2.07E-01	1.42E+00	2.16E-01	1.30E+00	2.20E-01
9	1.40E+00	2.18E-01	1.36E+00	2.09E-01	1.25E+00	2.22E-01	1.14E+00	2.26E-01
10	1.27E+00	2.23E-01	1.23E+00	2.13E-01	1.12E+00	2.28E-01	1.00E+00	2.32E-01
12.5	9.86E-01	2.24E-01	9.77E-01	2.04E-01	8.41E-01	2.36E-01	7.58E-01	2.30E-01
15	8.58E-01	2.27E-01	8.65E-01	2.01E-01	7.04E-01	2.42E-01	6.36E-01	2.30E-01
20	7.23E-01	1.96E-01	7.49E-01	1.70E-01	5.57E-01	2.10E-01	5.08E-01	1.93E-01
25	6.69E-01	1.76E-01	6.99E-01	1.51E-01	4.93E-01	1.88E-01	4.49E-01	1.73E-01
30	6.29E-01	1.66E-01	6.68E-01	1.42E-01	4.56E-01	1.77E-01	4.24E-01	1.61E-01
35	6.12E-01	1.60E-01	6.56E-01	1.37E-01	4.39E-01	1.69E-01	4.13E-01	1.55E-01
40	6.11E-01	1.56E-01	6.58E-01	1.34E-01	4.37E-01	1.64E-01	4.13E-01	1.51E-01
45	6.23E-01	1.54E-01	6.73E-01	1.33E-01	4.44E-01	1.62E-01	4.21E-01	1.50E-01
50	6.47E-01	1.53E-01	7.00E-01	1.32E-01	4.61E-01	1.60E-01	4.37E-01	1.48E-01
60	7.36E-01	1.51E-01	7.96E-01	1.31E-01	5.23E-01	1.59E-01	4.96E-01	1.47E-01
70	8.69E-01	1.51E-01	9.40E-01	1.30E-01	6.17E-01	1.58E-01	5.84E-01	1.47E-01
80	1.02E+00	1.50E-01	1.10E+00	1.30E-01	7.23E-01	1.58E-01	6.83E-01	1.46E-01
90	1.15E+00	1.50E-01	1.24E+00	1.30E-01	8.15E-01	1.57E-01	7.69E-01	1.46E-01
100	1.24E+00	1.50E-01	1.34E+00	1.30E-01	8.81E-01	1.57E-01	8.30E-01	1.46E-01

Table 2.3.6-3. Total (weighted Average) arithmetic mean and log-standard deviation of the 5% damped amplification function (AF) for the HF4, LF4, HF5, and LF5 motions

Frequency	HF 1E-4		LF 1E-4		HF 1E-5		LF 1E-5	
[Hz]	Mean AF	Ln (AF)	Mean AF	Ln (AF)	Mean AF	Ln (AF)	Mean AF	Ln (AF)
0.1	2.93E+00	1.54E-01	3.07E+00	1.13E-01	2.99E+00	1.40E-01	3.06E+00	1.12E-01
0.125	3.26E+00	8.36E-02	3.30E+00	7.67E-02	3.26E+00	8.24E-02	3.28E+00	7.73E-02
0.167	2.84E+00	1.17E-01	2.89E+00	1.12E-01	2.82E+00	1.13E-01	2.88E+00	1.13E-01
0.2	2.83E+00	9.86E-02	2.90E+00	9.85E-02	2.83E+00	9.67E-02	2.89E+00	9.99E-02
0.3	3.37E+00	1.93E-01	3.39E+00	1.91E-01	3.27E+00	1.88E-01	3.38E+00	1.92E-01
0.4	3.10E+00	1.63E-01	3.12E+00	1.56E-01	3.03E+00	1.48E-01	3.11E+00	1.57E-01
0.5	3.21E+00	2.02E-01	3.20E+00	2.07E-01	3.11E+00	1.96E-01	3.17E+00	2.09E-01
0.6	3.02E+00	1.69E-01	3.04E+00	1.60E-01	2.93E+00	1.65E-01	2.99E+00	1.65E-01
0.7	2.91E+00	2.06E-01	2.94E+00	1.96E-01	2.83E+00	2.02E-01	2.88E+00	2.00E-01
0.8	2.81E+00	1.81E-01	2.83E+00	1.77E-01	2.74E+00	1.79E-01	2.77E+00	1.81E-01
0.9	2.87E+00	2.00E-01	2.89E+00	1.95E-01	2.79E+00	1.97E-01	2.82E+00	1.98E-01
1	2.87E+00	1.76E-01	2.88E+00	1.71E-01	2.79E+00	1.74E-01	2.82E+00	1.75E-01
1.25	2.93E+00	1.87E-01	2.94E+00	1.79E-01	2.84E+00	1.86E-01	2.88E+00	1.83E-01
1.5	2.85E+00	1.93E-01	2.86E+00	1.81E-01	2.75E+00	1.94E-01	2.77E+00	1.91E-01
2	2.69E+00	2.42E-01	2.71E+00	2.30E-01	2.62E+00	2.42E-01	2.64E+00	2.41E-01
2.5	2.89E+00	2.59E-01	2.87E+00	2.45E-01	2.74E+00	2.55E-01	2.73E+00	2.55E-01
3	2.72E+00	2.76E-01	2.71E+00	2.61E-01	2.59E+00	2.72E-01	2.57E+00	2.71E-01
4	2.62E+00	2.87E-01	2.57E+00	2.77E-01	2.43E+00	2.82E-01	2.34E+00	2.83E-01
5	2.21E+00	3.36E-01	2.15E+00	3.21E-01	2.03E+00	3.29E-01	1.91E+00	3.28E-01
6	1.90E+00	3.57E-01	1.85E+00	3.40E-01	1.74E+00	3.56E-01	1.62E+00	3.55E-01
7	1.71E+00	3.93E-01	1.66E+00	3.71E-01	1.57E+00	3.92E-01	1.45E+00	3.88E-01
8	1.60E+00	4.22E-01	1.55E+00	3.95E-01	1.46E+00	4.23E-01	1.34E+00	4.19E-01
9	1.46E+00	4.46E-01	1.41E+00	4.14E-01	1.31E+00	4.50E-01	1.19E+00	4.43E-01
10	1.33E+00	4.65E-01	1.29E+00	4.26E-01	1.18E+00	4.72E-01	1.07E+00	4.60E-01
12.5	1.05E+00	4.65E-01	1.03E+00	4.08E-01	8.99E-01	4.84E-01	8.14E-01	4.55E-01
15	9.13E-01	4.62E-01	9.10E-01	3.94E-01	7.56E-01	4.88E-01	6.84E-01	4.45E-01
20	7.75E-01	4.29E-01	7.87E-01	3.55E-01	6.06E-01	4.58E-01	5.48E-01	4.05E-01
25	7.08E-01	3.86E-01	7.25E-01	3.16E-01	5.30E-01	4.13E-01	4.77E-01	3.61E-01
30	6.55E-01	3.58E-01	6.83E-01	2.90E-01	4.81E-01	3.81E-01	4.41E-01	3.30E-01
35	6.31E-01	3.39E-01	6.64E-01	2.75E-01	4.59E-01	3.60E-01	4.26E-01	3.11E-01
40	6.25E-01	3.28E-01	6.62E-01	2.65E-01	4.52E-01	3.47E-01	4.23E-01	3.01E-01
45	6.35E-01	3.21E-01	6.74E-01	2.60E-01	4.57E-01	3.38E-01	4.29E-01	2.95E-01
50	6.57E-01	3.15E-01	7.00E-01	2.56E-01	4.72E-01	3.33E-01	4.44E-01	2.91E-01
60	7.43E-01	3.09E-01	7.93E-01	2.51E-01	5.33E-01	3.26E-01	5.02E-01	2.86E-01
70	8.75E-01	3.07E-01	9.35E-01	2.49E-01	6.27E-01	3.23E-01	5.91E-01	2.84E-01
80	1.03E+00	3.05E-01	1.10E+00	2.48E-01	7.34E-01	3.22E-01	6.90E-01	2.83E-01
90	1.16E+00	3.04E-01	1.23E+00	2.48E-01	8.28E-01	3.21E-01	7.77E-01	2.83E-01
100	1.25E+00	3.04E-01	1.33E+00	2.47E-01	8.94E-01	3.20E-01	8.38E-01	2.82E-01

2.3.7 Control Point Seismic Hazard Curves

The SSE control point for STPEGS is defined as the site ground surface. The dynamic response of the materials below the control point was represented by the frequency and amplitude-dependent amplification functions (mean values and standard deviations) developed and described in the previous section. The procedure to develop probabilistic site-specific control point hazard curves used in the present analysis follows Method 2A (McGuire et al., 2001) which is endorsed as an acceptable methodology by both the NRC 10 CFR 50.54(f) RFI Letter, Attachment 1 to Seismic Enclosure 1 (which endorses the use of either NUREG/CR-6728 Method 2 or 3) and also the SPID, Section 2.5.3.

This method computes a site-specific control point hazard curve for a broad range of spectral accelerations (corresponding to the input bedrock motions at a range of AFE) given the site-specific bedrock hazard curve and associated uncertainties and site-specific estimates of soil or soft-rock response.

As an example, the mean 5 Hz hazard curve point at 1E-3 AFE is the product of the total (weighted average) arithmetic mean amplification function of the 1E-3 motion multiplied by the mean 1E-3 bedrock motion (envelope of LF and HF mean 1E-3 bedrock motions). Similarly the 16^{th} percentile 5 Hz hazard curve at 1E-3 AFE is the product of the total (weighted average) arithmetic mean amplification function of the 1E-3 motion multiplied by the 16^{th} percentile 1E-3 bedrock motion (envelope of LF and HF 16^{th} percentile 1E-3 bedrock motions).

The resulting control point mean hazard curves for the STPEGS site are shown in Figure 2.3.7-1 for the seven oscillator frequencies for which the GMM is defined. Tabulated values of the site response amplification functions and control point hazard curves are provided in Tables A-1a through A1-g in Appendix A.

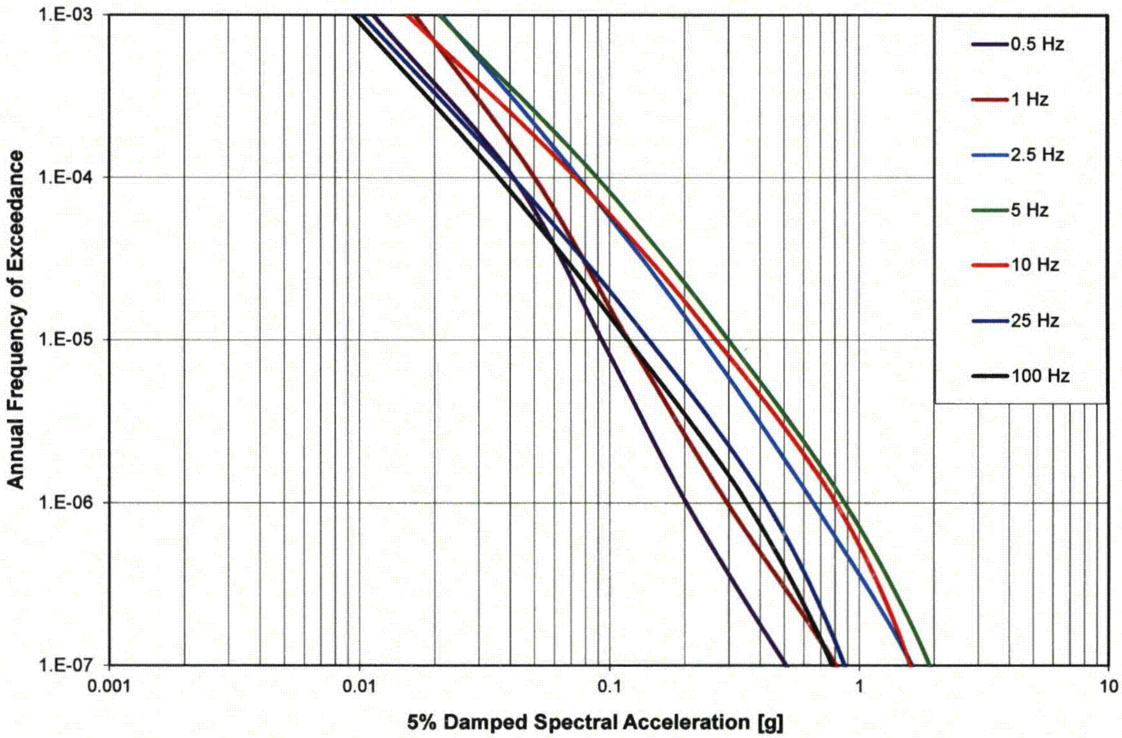

Figure 2.3.7-1. Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz (PGA) at the STPEGS site.

2.4 Control Point Response Spectra

The control point hazard curves described above have been used to develop UHRS and the ground motion response spectrum (GMRS).

The 1E-4 and 1E-5 UHRS, along with a design factor (DF) are used to compute the GMRS at the control point using the criteria in Regulatory Guide 1.208. Figure 2.4-1 shows the control point UHRS and GMRS. Table 2.4-1 shows the UHRS and GMRS spectral accelerations. Note that the UHRS are computed at 301 frequency points ranging from 0.1 to 100 Hz and equally spaced in logarithmic space. These values were interpolated at the 38 frequency points presented in Table 2.4-1.

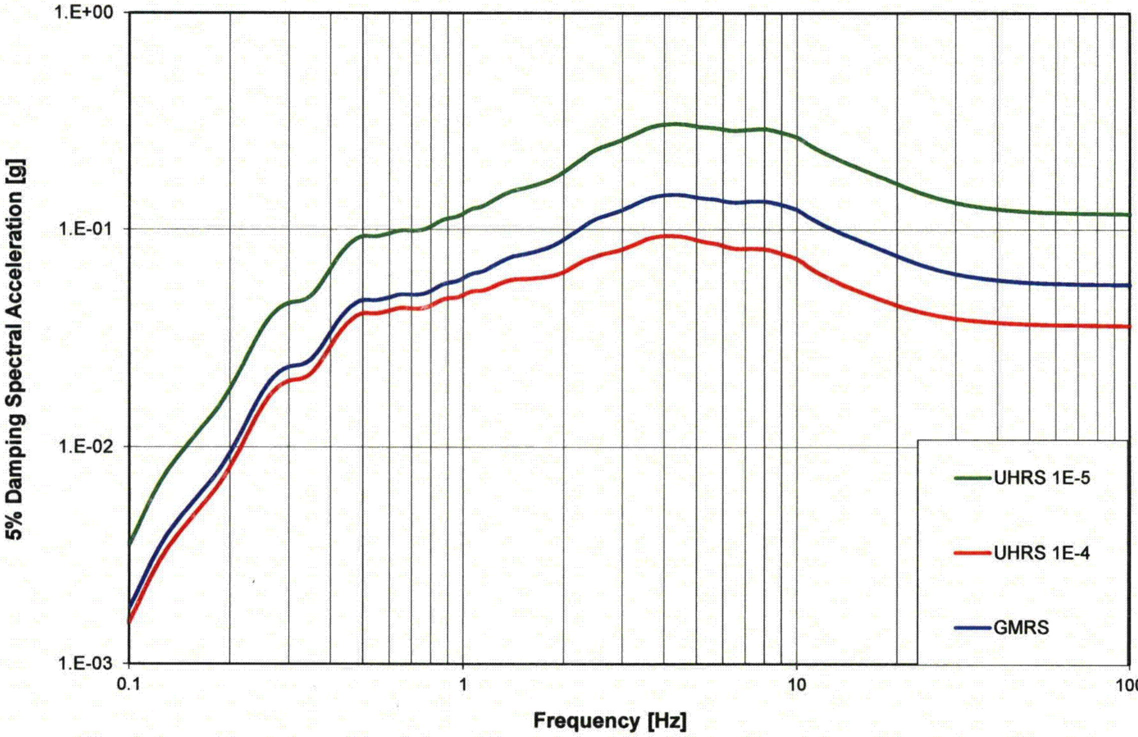

Figure 2.4-1. UHRS for 1E-4 and 1E-5 and GMRS at control point for STPEGS.

Table 2.4-1. UHRS for 1E-4 and 1E-5 and GMRS at control point for STPEGS.

Frequency [Hz]	UHRS 1E-4 [g]	UHRS 1E-5 [g]	GMRS [g]
0.1	1.55E-03	3.55E-03	1.81E-03
0.125	3.09E-03	7.12E-03	3.61E-03
0.167	5.49E-03	1.26E-02	6.42E-03
0.2	8.10E-03	1.87E-02	9.47E-03
0.3	2.01E-02	4.60E-02	2.34E-02
0.4	2.92E-02	6.66E-02	3.39E-02
0.5	4.12E-02	9.32E-02	4.75E-02
0.6	4.24E-02	9.60E-02	4.89E-02
0.7	4.34E-02	9.87E-02	5.02E-02
0.8	4.48E-02	1.03E-01	5.25E-02
0.9	4.82E-02	1.12E-01	5.70E-02
1	5.01E-02	1.19E-01	5.99E-02
1.25	5.54E-02	1.39E-01	6.92E-02
1.5	5.92E-02	1.55E-01	7.66E-02
2	6.39E-02	1.85E-01	8.98E-02
2.5	7.53E-02	2.34E-01	1.12E-01
3	8.10E-02	2.60E-01	1.23E-01
4	9.32E-02	3.05E-01	1.44E-01
5	8.92E-02	2.99E-01	1.41E-01
6	8.40E-02	2.90E-01	1.36E-01
7	8.15E-02	2.88E-01	1.34E-01
8	8.10E-02	2.90E-01	1.35E-01
9	7.73E-02	2.80E-01	1.30E-01
10	7.33E-02	2.67E-01	1.24E-01
12.5	5.97E-02	2.21E-01	1.02E-01
15	5.28E-02	1.95E-01	9.01E-02
20	4.48E-02	1.63E-01	7.57E-02
25	4.10E-02	1.44E-01	6.70E-02
30	3.90E-02	1.33E-01	6.26E-02
35	3.79E-02	1.28E-01	6.01E-02
40	3.73E-02	1.24E-01	5.87E-02
45	3.70E-02	1.23E-01	5.78E-02
50	3.67E-02	1.21E-01	5.73E-02
60	3.64E-02	1.20E-01	5.66E-02
70	3.63E-02	1.19E-01	5.63E-02
80	3.62E-02	1.19E-01	5.62E-02
90	3.62E-02	1.18E-01	5.60E-02
100	3.61E-02	1.18E-01	5.60E-02

3.0 Plant Design Basis [and Beyond Design Basis Evaluation Ground Motion]

The design basis for STPEGS is identified in the STPEGS Updated Final Safely Evaluation Report (UFSAR), and other pertinent documents.

3.1 SSE Description of Spectral Shape

The SSE was developed in accordance with 10 CFR Part 100, Appendix A through an evaluation of the maximum earthquake potential for the region surrounding the site. The maximum earthquake is about an intensity VI (modified Mercalli Scale), produced by either an intensity VII (modified Mercalli Scale) earthquake 70 miles away in basement rocks in the Ouachita Seismotectonic Province or by an intensity VI (modified Mercalli Scale) adjacent to the STPEGS site produced by an earthquake in the pre-Cretaceous basement rocks at least 34,000 ft below the surface.

The SSE is defined in terms of a PGA and a design response spectrum. Considering a site intensity of VI (modified Mercalli Scale), a PGA of 0.07 g was estimated. Because this acceleration value is below the minimum established in Appendix A of 10 CFR 100, the selected SSE acceleration is 0.10 g in accordance with the 10 CFR Part 100, Appendix A criteria. The spectral shape is defined by NRC Regulatory Guide 1.60 (NRC, 1973). The 5% damped horizontal SSE spectrum is shown in Table 3.1-1.

Table 3.1-1. SSE for STPEGS

Freq (Hz)	SSE (g)
0.1	0.00754
0.25	0.0471
2.5	0.313
9.00	0.261
33.00	0.100
100.00	0.100

3.2 Control Point Elevation

The SSE control point elevation is defined at the ground surface.

3.3 IPEEE Description and Capacity Response Spectrum

The IPEEE is not required for screening, since the SSE envelopes the GMRS throughout the required spectra.

4.0 Screening Evaluation

In accordance with SPID 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 SSE exceeds the GMRS. Therefore, a risk evaluation will not be performed.

4.2 High Frequency Screening (> 10 Hz)

Above 10 Hz, the SSE exceeds the GMRS. Therefore, the high frequency confirmation will not be performed.

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. Therefore, a spent fuel pool evaluation will not be performed.

5.0 Interim Actions

Since the screening evaluation results summarized in Section 4.0, confirm that the SSE exceeds the updated GMRS across the total spectrum required, based on the methodology in the SPID, STPEGS screens out and no further evaluations are required.

Consistent with NRC letter dated February 20, 2014, [ML14030A046] the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of STPEGS. Therefore, the results do not call into question the operability or functionality of SSCs and are not reportable pursuant to10 CFR 50.72, "Immediate notification requirements for operating nuclear power reactors," and10 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, 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:

> 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.

STPEGS 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.

6.0 Conclusions

In accordance with the 50.54(f) request for information, a seismic hazard and screening evaluation was performed for STPEGS. 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

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2. Electric Power Research Institute (EPRI), "Guidelines for Determining Design Basis Ground Motions", Vols. 1-5, Report No. TR-102293, Palo Alto, CA, 1993.

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7. McGuire, R.K., W. J. Silva, and C. J. Costantino (2001). "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines", NUREG/CR-6728, (Nonproprietary), U.S. Nuclear Regulatory Commission, Washington, D.C., 2001.

8. McGuire, R.K. (2004). Seismic Hazard and Risk Analysis, Earthquake Engineering Research Institute, Monograph MNO-10.

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10. STP UFSAR, South Texas Project Electric Generating Station (STPEGS) Updated Final Safety Analysis Report (UFSAR), Rev. 015, for Units 1 & 2 Project.

11. U.S. NRC (2007). "A performance-based approach to define the site-specific earthquake ground motion," U.S. Nuclear Regulatory Commission Reg. Guide 1.208.

12. Vucetic, M. and R. Dobry (1991). "Effect of Soil Plasticity on Cyclic Response," Journal of Geotechnical Engineering, ASCE, Vol. 117, No. 1.

Appendix A

Table A-1a. PGA Seismic Hazard Curves at *STPEGS (Mean and Fractiles).*

Mean		5th		16th		50th		84th		95th	
PGA (g)	AFE	PGA (g)	AFE	PGA (g)	AFE	PGA (g)	AFE	PGA (g)	AFE	PGA (g)	AFE
0.0094	1E-03	0.0038	1E-03	0.0053	1E-03	0.0082	1E-03	0.0126	1E-03	0.0169	1E-03
0.0361	1E-04	0.0181	1E-04	0.0230	1E-04	0.0321	1E-04	0.0443	1E-04	0.0584	1E-04
0.1182	1E-05	0.0536	1E-05	0.0693	1E-05	0.1037	1E-05	0.1508	1E-05	0.1937	1E-05
0.3538	1E-06	0.1238	1E-06	0.1958	1E-06	0.3174	1E-06	0.4336	1E-06	0.5308	1E-06
0.7794	1E-07	0.2534	1E-07	0.4841	1E-07	0.7051	1E-07	0.8994	1E-07	1.0443	1E-07

Table A-1b. 0.5 Hz Seismic Hazard Curves at *STPEGS (Mean and Fractiles).*

Mean		5th		16th		50th		84th		95th	
PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE
0.0113	1E-03	0.0028	1E-03	0.0041	1E-03	0.0078	1E-03	0.0186	1E-03	0.0268	1E-03
0.0412	1E-04	0.0105	1E-04	0.0162	1E-04	0.0282	1E-04	0.0490	1E-04	0.0689	1E-04
0.0932	1E-05	0.0297	1E-05	0.0414	1E-05	0.0663	1E-05	0.1075	1E-05	0.1476	1E-05
0.2027	1E-06	0.0672	1E-06	0.0898	1E-06	0.1414	1E-06	0.2465	1E-06	0.3688	1E-06
0.5090	1E-07	0.1407	1E-07	0.1921	1E-07	0.3093	1E-07	0.5826	1E-07	1.0417	1E-07

Table A-1c. 1 Hz Seismic Hazard Curves at *STPEGS (Mean and Fractiles).*

Mean		5th		16th		50th		84th		95th	
PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE
0.0167	1E-03	0.0048	1E-03	0.0070	1E-03	0.0135	1E-03	0.0224	1E-03	0.0317	1E-03
0.0501	1E-04	0.0199	1E-04	0.0272	1E-04	0.0408	1E-04	0.0593	1E-04	0.0803	1E-04
0.1187	1E-05	0.0535	1E-05	0.0690	1E-05	0.0988	1E-05	0.1460	1E-05	0.1857	1E-05
0.2956	1E-06	0.1224	1E-06	0.1580	1E-06	0.2333	1E-06	0.3675	1E-06	0.5298	1E-06
0.8078	1E-07	0.2554	1E-07	0.3483	1E-07	0.5697	1E-07	0.9903	1E-07	1.4355	1E-07

Table A-1d. 2.5 Hz Seismic Hazard Curves at *STPEGS (Mean and Fractiles)*.

Mean		5th		16th		50th		84th		95th	
PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE
0.0212	1E-03	0.0098	1E-03	0.0134	1E-03	0.0194	1E-03	0.0268	1E-03	0.0340	1E-03
0.0753	1E-04	0.0423	1E-04	0.0519	1E-04	0.0698	1E-04	0.0938	1E-04	0.1211	1E-04
0.2342	1E-05	0.1207	1E-05	0.1497	1E-05	0.2068	1E-05	0.3002	1E-05	0.3873	1E-05
0.6534	1E-06	0.2777	1E-06	0.3709	1E-06	0.5784	1E-06	0.8208	1E-06	1.0339	1E-06
1.6280	1E-07	0.5510	1E-07	0.9309	1E-07	1.4389	1E-07	1.9362	1E-07	2.3116	1E-07

Table A-1e. 5 Hz Seismic Hazard Curves at *STPEGS (Mean and Fractiles)*.

Mean		5th		16th		50th		84th		95th	
PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE
0.0208	1E-03	0.0094	1E-03	0.0132	1E-03	0.0191	1E-03	0.0271	1E-03	0.0336	1E-03
0.0892	1E-04	0.0483	1E-04	0.0607	1E-04	0.0830	1E-04	0.1106	1E-04	0.1414	1E-04
0.2990	1E-05	0.1438	1E-05	0.1829	1E-05	0.2659	1E-05	0.3771	1E-05	0.4772	1E-05
0.8744	1E-06	0.3299	1E-06	0.4954	1E-06	0.7835	1E-06	1.0699	1E-06	1.3070	1E-06
1.9135	1E-07	0.6624	1E-07	1.1939	1E-07	1.7279	1E-07	2.1995	1E-07	2.5189	1E-07

Table A-1f. 10 Hz Seismic Hazard Curves at *STPEGS (Mean and Fractiles)*.

Mean		5th		16th		50th		84th		95th	
PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE
0.0155	1E-03	0.0067	1E-03	0.0093	1E-03	0.0140	1E-03	0.0205	1E-03	0.0274	1E-03
0.0733	1E-04	0.0372	1E-04	0.0474	1E-04	0.0668	1E-04	0.0924	1E-04	0.1260	1E-04
0.2666	1E-05	0.1145	1E-05	0.1506	1E-05	0.2308	1E-05	0.3415	1E-05	0.4406	1E-05
0.8066	1E-06	0.2702	1E-06	0.4453	1E-06	0.7282	1E-06	0.9724	1E-06	1.1694	1E-06
1.6003	1E-07	0.5463	1E-07	1.0706	1E-07	1.4858	1E-07	1.7856	1E-07	1.9985	1E-07

Table A-1g. 25 Hz Seismic Hazard Curves at *STPEGS (Mean and Fractiles)*.

Mean		5th		16th		50th		84th		95th	
PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE	PSA (g)	AFE
0.0102	1E-03	0.0041	1E-03	0.0058	1E-03	0.0089	1E-03	0.0136	1E-03	0.0185	1E-03
0.0410	1E-04	0.0206	1E-04	0.0262	1E-04	0.0365	1E-04	0.0505	1E-04	0.0680	1E-04
0.1435	1E-05	0.0628	1E-05	0.0820	1E-05	0.1250	1E-05	0.1826	1E-05	0.2342	1E-05
0.4249	1E-06	0.1469	1E-06	0.2407	1E-06	0.3856	1E-06	0.5130	1E-06	0.6156	1E-06
0.8727	1E-07	0.2971	1E-07	0.5688	1E-07	0.7999	1E-07	0.9897	1E-07	1.1318	1E-07

Table A-2. Mean and logarithmic standard deviation of amplification factors for STPEGS

Motion	0.5 Hz			1.0 Hz			2.5 Hz			5.0 Hz		
	Input [g]	AF	Ln(AF)	Input [g]	AF	Ln(AF)	Input [g]	AF	Ln(AF)	Input [g]	AF	Ln(AF)
HF 1E-3	0.0008	3.242	0.203	0.0021	2.905	0.177	0.0057	2.964	0.262	0.0088	2.316	0.343
LF 1E-3	0.0035	3.236	0.206	0.0057	2.912	0.174	0.0071	2.985	0.244	0.0088	2.356	0.308
HF 1E-4	0.0038	3.214	0.202	0.0097	2.867	0.176	0.0260	2.889	0.259	0.0403	2.214	0.336
LF 1E-4	0.0129	3.202	0.207	0.0174	2.879	0.171	0.0261	2.871	0.245	0.0403	2.155	0.321
HF 1E-5	0.0101	3.113	0.196	0.0281	2.790	0.174	0.0854	2.743	0.255	0.1472	2.031	0.329
LF 1E-5	0.0294	3.171	0.209	0.0421	2.818	0.175	0.0837	2.728	0.255	0.1472	1.913	0.328
HF 1E-6	0.0231	3.161	0.213	0.0721	2.701	0.175	0.2553	2.560	0.251	0.4933	1.773	0.320
LF 1E-6	0.0646	3.138	0.210	0.1075	2.749	0.184	0.2556	2.526	0.261	0.4933	1.572	0.325
HF 1E-7	0.0632	3.171	0.217	0.1971	2.670	0.184	0.6982	2.332	0.240	1.3490	1.418	0.310
LF 1E-7	0.1642	3.101	0.211	0.2979	2.712	0.215	0.7233	2.072	0.276	1.3491	1.077	0.333
Motion	**10.0 Hz**			**25.0 Hz**			**100.0 Hz (PGA)**					
	Input [g]	**AF**	**Ln(AF)**	**Input [g]**	**AF**	**Ln(AF)**	**Input [g]**	**AF**	**Ln(AF)**			
HF 1E-3	0.0100	1.471	0.446	0.0086	0.970	0.355	0.0047	1.566	0.295			
LF 1E-3	0.0100	1.558	0.363	0.0086	1.182	0.256	0.0047	2.001	0.214			
HF 1E-4	0.0552	1.327	0.465	0.0565	0.708	0.386	0.0271	1.250	0.304			
LF 1E-4	0.0552	1.285	0.426	0.0565	0.725	0.316	0.0271	1.333	0.247			
HF 1E-5	0.2266	1.177	0.472	0.2708	0.530	0.413	0.1322	0.894	0.320			
LF 1E-5	0.2266	1.066	0.460	0.2706	0.477	0.361	0.1322	0.838	0.282			
HF 1E-6	0.8174	0.987	0.461	1.0729	0.396	0.402	0.5169	0.685	0.320			
LF 1E-6	0.8174	0.804	0.453	1.0721	0.318	0.342	0.5169	0.584	0.282			
HF 1E-7	2.2161	0.722	0.414	3.0321	0.288	0.324	1.4299	0.545	0.276			
LF 1E-7	2.2161	0.481	0.397	3.0297	0.212	0.261	1.4299	0.427	0.236			

Appendix A Note:
Although tabular versions of the typical amplification factors included in Section 2.3.6 were provided in Appendix A in the NEI Template, for STPEGS, these tabular values are provided in Tables 2.3.6.1, 2.3.6.2 and 2.3.6.3, which are provided in the body of this Report, following the amplification factor curves, Figures 2.3.6-1 a and b, Figures 2.3.6-2 a and b and Figures 2.3.6-3 a and b.