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ONS-2014-046

March 31, 2014

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

10 CFR 50.54(f)

Duke Energy Carolina, LLC (Duke Energy)
Oconee Nuclear Station, Units 1, 2 and 3
Docket Numbers 50-269, 50-270, 50-287
Renewed License Numbers DPR-38, DPR-47, and DPR-55

Subject: Seismic Hazard and Screening Report (CEUS Sites), Response to NRC 10 CFR 50.54(f) 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

References:

1. NRC Letter, *Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, dated March 12, 2012, ADAMS Accession No. ML12053A340
2. 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
3. NRC Letter, *Endorsement of EPRI Final Draft Report 1025287, "Seismic Evaluation Guidance,"* dated February 15, 2013, ADAMS Accession No. ML12319A074
4. NEI Letter, *Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations*, dated April 9, 2013, ADAMS Accession No. ML13101A379
5. NRC Letter, *Electric Power Research Institute Final Draft Report XXXXXX, "Seismic Evaluation Guidance: Augmented Approach for the Resolution of Near-Term Task Force Recommendation 2.1: Seismic," as an Acceptable Alternative to the March 12, 2012, Information Request for Seismic Reevaluations*, dated May 7, 2013, ADAMS Accession No. ML13106A331
6. NEI Letter, *Seismic Risk Evaluations for Plants in the Central and Eastern United States,* dated March 12, 2014 ADAMS Accession No. ML14083A584

Ladies and Gentlemen,

On March 12, 2012, the Nuclear Regulatory Commission (NRC) issued Reference 1 to all power reactor licensees. Enclosure 1 of this reference requested each licensee located in the Central and Eastern United States (CEUS) to submit a Seismic Hazard Evaluation and Screening Report within 1.5 years.

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The Nuclear Energy Institute (NEI) submitted Reference 4 requesting the submittal of the CEUS Seismic Hazard Evaluation and Screening Report be delayed so that Electric Power Research Institute (EPRI) could update its ground motion attenuation model for use in developing the report. Reference 4 proposed that a partial report that included base case velocity profiles and descriptions of subsurface materials and properties would be submitted by September 12, 2013, with the remaining seismic hazard and screening information submitted by March 31, 2014. The NRC accepted the schedule modification by Reference 5.

Attachment 1 to this letter provides the Seismic Hazard and Screening Report for Oconee Nuclear Station Units 1, 2, and 3 as described in the NRC endorsed guidance (Section 4 of the SPID, Reference 2).

By letter dated March 12, 2014 (Reference 6), NEI provided the NRC with seismic core damage risk estimates based on updated seismic hazard information as it applies to operating reactors in the CEUS, which includes Oconee Nuclear Station. These risk assessments continue to support the conclusions of NRC Generic Issue-199, "Safety/Risk Assessment" and indicate that current seismic design of operating reactors provide adequate protection and safety margin to withstand potential earthquakes that exceed the original design basis.

There are no regulatory commitments associated with this letter.

Should you have any questions regarding this submittal, please contact David Haile with Oconee Regulatory Affairs, at (864) 873-4742.

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

Sincerely,

Scott L. Batson
Vice President
Oconee Nuclear Station

Attachment:

1. Oconee Nuclear Station, Seismic Hazard and Screening Report

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Mr. Eddy Crowe
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Oconee Nuclear Station

Attachment 1: Oconee Nuclear Station Seismic Hazard and Screening Report

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SEISMIC HAZARD AND SCREENING REPORT

IN RESPONSE TO THE 50.54(f) INFORMATION REQUEST REGARDING FUKUSHIMA NEAR-TERM TASK FORCE RECOMMENDATION 2.1: SEISMIC

for

OCONEE NUCLEAR STATION

DUKE ENERGY CAROLINAS

Prepared by:	Shana Gibbs (signed)	Date:	3/13/14
Reviewed by:	Natalie Doulgerakis (signed)	Date:	03/13/2014
Approved by:	Benjamin Kosbab (signed)	Date:	3/13/14

PROJECT REPORT REVISION STATUS

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0		Initial issue.

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All	0		

APPENDIX REVISION STATUS

APPENDIX NO.	PAGE NO.	REVISION NO.	APPENDIX NO.	PAGE NO.	REVISION NO.
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1 Introduction

Following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the Nuclear Regulatory Commission (NRC) established a Near-Term Task Force (NTTF) to conduct a systematic review of NRC processes and regulations and to determine if the agency should make additional improvements to its regulatory system. The NTTF developed a set of recommendations intended to clarify and strengthen the regulatory framework for protection against natural phenomena. Subsequently, the NRC issued a 50.54(f) letter (Reference 1) that requests information to assure that these recommendations are addressed by all U.S. nuclear power plants. The 50.54(f) letter (Reference 1) requests that licensees and holders of construction permits under 10 CFR Part 50 (Reference 2) 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 in Attachment 1 of the 50.54(f) letter (Reference 1) pertaining to NTTF Recommendation 2.1: Seismic for the Oconee Nuclear Station (Oconee), located in Oconee County, South Carolina. In providing this information, Duke Energy Carolinas (Duke) 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* (Reference 3). The Augmented Approach, *Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic* (Reference 4), 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 Oconee meet General Design Criterion 2 in Appendix A to 10 CFR Part 50 (Reference 2). The Safe Shutdown Earthquake Ground Motion (SSE) was developed in accordance with General Design Criterion 2 in Appendix A to 10 CFR Part 50 (Reference 2) and used for the design of seismic Category I structures, systems, and components (SSCs). (Reference 10, Scetion 3.1)

In response to the 50.54(f) letter (Reference 1) and following the guidance provided in the SPID (Reference 3), a seismic hazard reevaluation was performed. For screening purposes, a Ground Motion Response Spectrum (GMRS) was developed. The GMRS development and supporting seismic hazard analysis (Sections 2.2, 2.3, and 2.4 of this report) for Oconee was performed by the Electric Power Research Institute (EPRI) (Reference 8). Based on the results of the screening evaluation, Oconee screens in for a risk evaluation and a spent fuel pool integrity evaluation.

2

Seismic Hazard Reevaluation

Oconee is located in eastern Oconee County, South Carolina, approximately 8 miles northeast of Seneca, South Carolina (Reference 10, Section 2.1). The Oconee site is located within the Inner Piedmont Belt, at this locality the westernmost component of the Piedmont Physiographic Province. The region is comprised of three large northeast-southwest trending tectonic zones: the coastal plain, the crystalline-metamorphic zone and the overthrust zone. The great system of thrust faults in the overthrust zone and most of the known faulting within the crystalline-metamorphic zone apparently occurred during the last period of metamorphism (260 million years ago). From the late Triassic time until the present, the coastal plain has accumulated a sedimentary cover over its crystalline-metamorphic bedrock. These sediments overlap the bedrock and thicken toward the southeast, effectively masking any ancient faulting in the basement. The foundation rock is biotite and hornblende gneiss. The Oconee structures are founded on normal Piedmont granite gneisses. (Reference 10, Section 2.5)

The southeastern Piedmont rocks are highly stable seismologically, and the Oconee site should be one of the nation's most inactive areas with respect to earthquake activity. Although larger earthquakes occur within other fault zones, the highest ground accelerations at the site would be experienced from an earthquake along the Brevard fault zone. The assumption of a shock of less than Richter Magnitude five (Modified Mercalli Intensity VI) occurring along the Brevard fault zone at its closest location to the site (11 miles) would give ground motions on the order of five percent of gravity at the site. The Maximum Hypothetical Earthquake (MHE) peak ground acceleration (PGA) is 0.10g for Class 1 structures founded on bedrock and 0.15g for structures founded on overburden. (Reference 10, Section 2.5)

2.1 Regional and Local Geology

The Oconee site is located within the Inner Piedmont Belt, at this locality the westernmost component of the Piedmont Physiographic Province. The topography of the area is undulating to rolling; the surface elevations ranging from about 700 ft. to 900 ft. The regional structure is typical of the southern Piedmont and Blue Ridge. The region was subjected to compression in the northwest-southeast direction which produced a complex assortment of more or less parallel folds whose axes lie in a northeast-southwest direction. The regional geology of the Oconee site can be accepted as typical of the southeastern Piedmont - narrow belts of metamorphic rocks trending northeast, with the foliation dipping generally to the southeast. The rocks in the belts consist of metamorphosed sediments and volcanics that have been folded, faulted, and intruded with igneous rocks. (Reference 10, Section 2.5)

Oconee is located in eastern Oconee County, South Carolina, approximately 8 miles northeast of Seneca, South Carolina. Lake Keowee occupies the area immediately north and west of the Oconee site and the Hartwell Reservoir is south of the site (Reference 10, Section 2.1). The local geology of the Oconee site is typical of the southeastern Inner Piedmont Belt. The foundation rock is biotite and hornblende gneiss, striking generally

northeast, with the foliation dipping southeast. The rock is overlain by residual soils, which vary from silty clays at the surface, where the rock decomposition has completed its cycle, to partially weathered rock, and finally to sound rock. The structures are founded on normal Piedmont granite gneisses. The rock underlying the site, below surface weathering, is hard and structurally sound and contains no defects which would influence the design of heavy structures. While the well known Brevard Fault passes 11 miles northwest of the site, there is no indication of a major fault in the immediate vicinity of the site. Furthermore, the major faults of the region are ancient and dormant, except for minor adjustments at considerable depth. Therefore, there is no indication of any structural hazard to foundations. (Reference 10, Section 2.5)

2.2 PROBABILISTIC SEISMIC HAZARD ANALYSIS

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter (Reference 1) and following the guidance in the SPID (Reference 3), a probabilistic seismic hazard analysis (PSHA) was completed using the recently developed Central and Eastern United States Seismic Source Characterization (CEUS-SSC) for Nuclear Facilities (Reference 5) together with the updated EPRI Ground-Motion Model (GMM) for the CEUS (Reference 6). A site-specific review of the CEUS-SSC earthquake catalog was also performed as described below, and these results are incorporated into the PSHA for the Oconee site. For the PSHA, a lower-bound moment magnitude of 5.0 was used, as specified in the 50.54(f) letter (Reference 1).

Site-Specific CEUS-SSC Catalog Review

A site-specific review (Reference 22) of the CEUS-SSC catalog published in the CEUS-SSC (Reference 5) was performed with regard to two issues: (1) identification of additional reservoir induced seismicity (RIS) earthquakes in the southeastern U.S. and (2): locations of earthquakes in South Carolina near the time of the 1886 Charleston, SC earthquake sequence.

In developing the CEUS-SSC catalog, earthquakes identified as RIS were removed from the final earthquake listing. The source for this identification in the southeastern U.S. was the set of available Southeastern U.S. Seismic Network (SEUSSN) Bulletins. The master list contained 120 earthquakes. Sixteen of these were large enough to be in the CEUS-SSC catalog. These earthquakes occurred primarily near Monticello Reservoir and Lake Keowee. These earthquakes were removed from the final (Version 7) CEUS-SSC catalog published in NUREG-2115 (Reference 5).

Additional reviews were performed of available published information to identify potential additional RIS earthquakes that are in the CEUS-SSC catalog. The basis for each of the potential RIS records was reviewed, taking into consideration the magnitude of the earthquake and depth, proximity to a reservoir, timing of the earthquake versus the filling of the reservoir, and proximity to a nuclear plant.

Thirty additional reservoir induced (RI) or potentially RI earthquakes were identified in the CEUS-SSC catalog. Of these, thirteen were large enough (expected moment magnitude, E[**M**] ≥ 2.9) to potentially affect recurrence calculations. Some of these were identified as dependent events of other earthquakes in the catalog. After review, it was

determined that all thirty RI or potentially RI earthquakes should be removed from the catalog. Table 2.2.1-1 lists the specific earthquake database records reviewed.

Seven additional earthquakes in the CEUS-SSC catalog from the time period 1799 to 1888 in South Carolina were also identified as being potentially mislocated, as identified in Table 2.2.1-2. The majority of these earthquakes have locations and times that come from the United States Geological Survey (USGS) earthquake catalog used for seismic hazard mapping. The primary source of the USGS catalog is the NCEER-91 catalog. The events in question have alternative locations in the SUSN catalog that place them at the location of the 1886 Charleston, SC main shock. A review was performed of the identification of these earthquakes and assignment of these locations in the development of the CEUS-SSC catalog in light of additional information in the paper by W.H. Bakun and M.G. Hopper (2004, "Magnitudes and Locations of the 1811-1812 New Madrid, Missouri, and the 1886 Charleston, South Carolina, Earthquakes," Bulletin of the Seismological Society of America, 94, 64-75) and recent information provided by Donald Stevenson and Dr. Pradeep Talwani.

The review identified another potential duplicate record. Bakun and Hopper (2004) also studied the Charleston aftershock on 1886/11/5 17:20 and found a location near Charleston, but slightly inland from other locations. Talwani and Sharma (1999) also concluded that this earthquake occurred at a slightly different location than other Charleston aftershocks. This earthquake appears in the CEUS-SSC catalog as TMP02071. There is also an event TMP02072 that is listed in the USGS catalog with time 12:25 with a location to the northwest of Charleston. Both events were identified as Charleston aftershocks in the declustering, but the timing suggests that they may be duplicates. The recommendation was to remove TMP02072 and use the magnitude and location given in Bakun and Hopper for TMP02071.

An additional review was performed of earthquake locations provided by Seeber and Armbruster (1987). These locations and size assessments were incorporated into the NCEER-91 catalog and then into the USGS catalog used as the primary source for the CEUS-SSC catalog. The original Seeber and Armbruster (1987) listing was also incorporated into the CEUS-SSC catalog, along with their listed values of felt area. During the review, the classification of nine additional earthquakes at locations in the vicinity of Charleston significant to hazard ($E[\mathbf{M}]\geq 2.9$) were changed from dependent to independent. Previously, these earthquakes had been classified as dependent earthquakes in clusters associated with the earthquakes identified above. The information for each of these earthquakes was reviewed, including additional information provided by Stevenson and Talwani.

Table 2.2.1-3 summarizes the assessment of the larger events in the CEUS-SSC catalog located at sufficient distance from Charleston to not be identified as aftershocks of the 1886/09/01 main shock.

Table 2.2.1-1 Summary of RIS Earthquake Review

TMPID	Yr	Mo	Dy	Hr	Mn	Sec	Lat	Lon	Depth (km)	E[**M**]	Comment / Disposition
TMP07012	1969	12	13	10	19	29.7	35.04	-82.85	6	3.46	Retain as non RIS
TMP07159	1971	7	13	11	42	26	34.8	-83	n/a	3.63	Possible RIS
TMP07565	1974	8	2	8	52	11.1	33.91	-82.53	4	3.91	Retain as non RIS
TMP08078	1975	11	25	15	17	34.8	34.93	-82.9	10(1)	3.21	RIS
TMP08787	1977	9	7	14	41	32.7	34.982	-82.927	n/a	2.77	RIS
TMP08971	1978	1	25	8	29	39	34.301	-81.234	5(2)	2.6	RIS
TMP09354	1978	8	27	10	23	8	34.313	-81.337	2	2.93	RIS
TMP08998	1978	2	10	20	23	38.7	34.343	-81.348	1	2.77	Possible RIS
TMP08999	1978	2	11	0	19	0.7	34.343	-81.35	3	2.77	Possible RIS
TMP09000	1978	2	11	5	19	0.2	34.346	-81.349	1	2.93	Possible RIS
TMP09006	1978	2	14	12	45	7.2	34.342	-81.346	2	2.77	Possible RIS
TMP09007	1978	2	14	13	9	59.5	34.351	-81.343	2	2.85	Possible RIS
TMP09013	1978	2	15	21	14	34.2	34.349	-81.346	0	2.77	Possible RIS
TMP09014	1978	2	16	2	14	33.4	34.332	-81.362	2	2.85	Possible RIS
TMP09023	1978	2	22	7	13	25.1	34.327	-81.35	1	2.85	Possible RIS
TMP09024	1978	2	22	12	13	24.3	34.339	-81.35	1	3.00	Possible RIS
TMP09025	1978	2	22	13	4	59.2	34.356	-81.352	0	2.77	Possible RIS
TMP09027	1978	2	24	7	34	10.5	34.334	-81.348	1	2.93	Possible RIS
TMP09029	1978	2	25	4	2	42.7	34.345	-81.351	1	2.77	Possible RIS
TMP09031	1978	2	26	6	52	35.4	34.315	-81.297	1	2.85	Possible RIS
TMP09032	1978	2	26	11	52	33	34.391	-81.361	1	3.00	Possible RIS
TMP09033	1978	2	26	18	17	48.8	34.321	-81.348	0	3.08	Possible RIS
TMP09343	1978	8	24	10	23	7.6	34.311	-81.341	2	2.85	Possible RIS
TMP09355	1978	8	27	10	23	8	34.313	-81.337	7	2.77	Possible RIS
TMP09460	1978	10	27	16	27	18.1	34.302	-81.326	2	3.08	RIS
TMP09518	1978	11	24	11	54	40.9	34.296	-81.347	1	2.85	Possible RIS
TMP10034	1979	8	26	1	31	45	34.916	-82.956	1	3.64	RIS
TMP39374	1979	10	8	8	54	19.4	34.31	-81.33	2	2.85	RIS
TMP10104	1979	10	8	23	20	11	34.306	-81.344	1	3.16	RIS
TMP10109	1979	10	14	8	24	57.6	34.306	-81.338	2	3.08	RIS
TMP10506	1980	7	29	1	10	22.7	34.351	-81.364	1	3.31	Possible RIS
TMP16282	1988	1	27	22	5	42.9	34.189	-82.75	6.1	2.32	RIS

(1) Depth 17 km in RANDJ.
(2) Depth 1 km in Stover & Coffman.

Table 2.2.1-2 Potential Charleston SC Area Aftershocks from CEUS-SSC Catalog

TMPID	Yr	Mo	Dy	Hr	Mn	Sec	Lat	Lon	E[**M**]	Source of Catalog Location
TMP00331	1799	4	11	8	20	0	33.95	-80.18	4.68	USGSnd_000145 Revised by Jeff Munsey of TVA based on Bakun and Hopper Method
TMP01089	1860	1	19	23	0	0	33.68	-80.57	4.21	USGSnd_000427
TMP01731	1886	9	1	6	0	0	33.91	-82.02	4.54	SeebArm87_000014
TMP01739	1886	9	1	9	45	0	34.3	-82.86	4.17	USGSnd_000771
TMP02019	1886	10	22	5	0	0	34.71	-81.66	4.13	USGSnd_000805
TMP02025	1886	10	22	14	45	0	33.87	-81.01	4.5	USGSnd_000807
TMP02360	1888	1	12	9	55	0	34.18	-80.17	4.33	USGSnd_000860

Table 2.2.1-3 Summary of Events Affected by the Charleston Aftershock Review

TMPID	Yr	Mo	Dy	Hr	Mn	Sec	Lat	Lon	Comment / Disposition
TMP00331	1799	4	11	8	20	0	33.95	-80.18	Retain as is.
TMP01089	1860	1	19	23	0	0	33.68	-80.57	Move to Charleston and base E[**M**] on I0.
TMP01731	1886	9	1	6	0	0	33.91	-82.02	Event removed from catalog as a duplicate of TMP01732. Location and magnitude of TMP01732 do not require modification.
TMP01739	1886	9	1	14(1)	45	0	34.04	-82.9	Event removed from catalog as a duplicate of TMP01738. Location and magnitude of TMP01738 do not require modification.
TMP01942	1886	9	28	3	0	0	34.7	-81.62	Consider as a false event.
TMP02002	1886	10	12	11	0	0	34.14	-81.33	Not use reported felt area, event becomes < E[**M**] 2.9.
TMP02019	1886	10	22	5	0	0	34.71	-81.66	Event removed from catalog as a duplicate of TMP02023.
TMP02023	1886	10	22	10	20		32.9	-80	Magnitude taken from Bakun and Hopper (2004).
TMP02024	1886	10	22	10(1)	25		33.69	-81	Event removed from catalog as a duplicate of TMP02023.
TMP02025	1886	10	22	14	45	0	33.87	-81.01	Location moved to Charleston, magnitude taken from Bakun and Hopper (2004).
TMP02068	1886	11	5	5	0	0	33.38	-82.49	Not use reported felt area, event becomes < E[**M**] 2.9.
TMP02071	1886	11	5	17	20	0	32.9	-80	Magnitude taken from Bakun and Hopper (2004).
TMP02072	1886	11	5	12	25		33.4	-80.42	Event removed from catalog as a duplicate of TMP02071.
TMP02134	1886	12	8	10	25	0	34.039	-80.886	Revise I0 from 4.5 to 4.
TMP02136	1886	12	11	21	0	0	34.18	-82.06	Retain as is.
TMP02173	1887	1	12	11	0	0	34.35	-82.42	Retain as less than E[**M**] 2.9, remove felt area.
TMP02210	1887	3	4	10	0	0	33.74	-81.5	Not use reported felt area, event becomes < E[**M**] 2.9.
TMP02360	1888	1	12	9	55	0	34.18	-80.17	Event removed from catalog as a duplicate of TMP39326.
TMP02393	1888	4	5	0	0	0	34.21	-81.534	Retain, reduce to I0 4, E[**M**] less than 2.9.
TMP02423	1888	8	15	23	30	0	34.37	-81.08	Retain as is.

(1) Change in hour.

Probabilistic Seismic Hazard Analysis

For the PSHA, the CEUS-SSC background seismic sources out to a distance of 400 miles (640 km) around Oconee were included. This distance exceeds the 200 mile (320 km) recommendation contained in NRC Reg. Guide 1.208 (Reference 7) and was chosen for completeness. Background sources included in this site analysis are the following:

1. Atlantic Highly Extended Crust (AHEX)
2. Extended Continental Crust—Atlantic Margin (ECC_AM)
3. Extended Continental Crust—Gulf Coast (ECC_GC)
4. Illinois Basin Extended Basement (IBEB)
5. Mesozoic and younger extended prior – narrow (MESE-N)
6. Mesozoic and younger extended prior – wide (MESE-W)
7. Midcontinent-Craton alternative A (MIDC_A)
8. Midcontinent-Craton alternative B (MIDC_B)
9. Midcontinent-Craton alternative C (MIDC_C)
10. Midcontinent-Craton alternative D (MIDC_D)
11. Non-Mesozoic and younger extended prior – narrow (NMESE-N)
12. Non-Mesozoic and younger extended prior – wide (NMESE-W)
13. Paleozoic Extended Crust narrow (PEZ_N)
14. Paleozoic Extended Crust wide (PEZ_W)
15. Reelfoot Rift (RR)
16. Reelfoot Rift including the Rough Creek Graben (RR-RCG)
17. Study region (STUDY_R)

For sources of large magnitude earthquakes, designated as Repeated Large Magnitude Earthquake (RLME) sources in CEUS-SSC (Reference 5), the following sources lie within 621 miles (1,000 km) of the site and were included in the analysis:

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

For each of the above background and RLME sources, the mid-continent version of the updated CEUS EPRI GMM (Reference 6) was used.

2.2.2 Base Rock Seismic Hazard Curves

Consistent with the SPID (Reference 3), base rock seismic hazard curves are not provided as the site amplification approach referred to as Method 3 from NUREG/CR-6728 (Reference 16) has been used. Seismic hazard curves are shown below in Section 2.3.7 at the SSE control point elevation (discussed below in Section 3.2).

2.3 Site Response Evaluation

Following the guidance contained in Seismic Enclosure 1 of the 50.54(f) letter (Reference 1) and in the SPID (Reference 3) for nuclear power plant sites that are not

founded on hard rock (considered as having a shear-wave velocity of at least 9285 fps (2.83 km/sec), or 9200 fps as approximated in the SPID (Reference 3)), a site response analysis was performed for Oconee.

2.3.1 Description of Subsurface Material

Oconee is located in the Piedmont Physiographic Province of South Carolina. The general site conditions consist of residual soils overlying partially weathered rock grading into hard metamorphic igneous rocks (Reference 9). As depth into partially weathered rock increases, the degree of weathering decreases as continuous rock is encountered.

Oconee consists of three units (1, 2, and 3) with the three reactor buildings supported on continuous rock. Tables 2.3.1-1, 2.3.1-2, and 2.3.1-3 show the geotechnical properties for Units 1, 2, and 3 respectively.

Table 2.3.1-1 Summary of geotechnical profile data for Oconee Unit 1 (Reference 9)

Boring No. (Surface El.)	Layer	Depth Interval		Unit Weight		Shear-wave Velocity
		From (ft.)	To (ft.)	Moist (pcf)	Saturated (pcf)	V_s (fps)
MSB1B (796.95)	Reinforced Concrete Replaced as Soil Fill	0.0	4.5	113.5	-	242
	Soil Fill, Soft Micaceous Sandy Silt to Clayey Silt (MH)	4.5	9.5	113.5	-	262
		9.5	16.5	113.5	-	350
	Waste Concrete Replaced as Soil Fill	16.5	17.7	113.5	-	395
		17.7	20.0	-	115	403
	Soil Fill, Micaceous Silty Sand (SM)	20.0	26.5	-	115	418
	Disturbed Rock-Granite Gneiss	26.5	28.7	-	170	2085
	Rock- Granite Gneiss	28.7	55	-	170	8265
		55	110	-	170	8265
		110+	-	-	170	9200

(1) The control point elevation is taken to be 43 ft. below the Yard Grade Elevation.

Table 2.3.1-2 Summary of geotechnical profile data for Oconee Unit 2 (Reference 9)

Boring No. (Surface El.)	Layer	Depth Interval		Unit Weight		Shear-wave Velocity
		From (ft.)	To (ft.)	Moist (pcf)	Saturated (pcf)	V_s (fps)
MSB2A (795.89)	Granular Fill- poorly graded gravel (GP) fine to coarse, subangular	0.0	5.0	126	-	387
		5.0	8.5	126	-	496
		8.5	15.0	126	-	569
		15.0	20.0	126	-	629
		20.0	25.0	126	-	670
		25.0	27.8	126	-	697
	Disturbed Rock-Granite Gneiss	27.8	29.5	-	160.0	1606
		29.5 (1)	34.6	-	160 (170) (1)	1606 (8265) (1)
	Rock- Granite Gneiss	34.6	55	-	170	8265
		55	110	-	170	8265
		110+	-	-	170	9200

(1) Boring MSB2A of the MSIV Project encountered disturbed rock from 27.8 ft. to 34.6 ft. Boring MSB2A is located approximately 23.5 ft. south-southwest of the southern edge of the reactor building. At its south edge, the bottom of the reactor building's mat foundation is 43 ft. below Yard Grade Elevation. No fill concrete below this reactor building is indicated in the Updated Final Safety Analysis Report (UFSAR) (Reference 10). It is reasonable to assume the rock beneath the reactor building mat is not disturbed.

(2) The control point elevation is taken to be 43 ft. below the Yard Grade Elevation.

Table 2.3.1-3 Summary of geotechnical profile data for Oconee Unit 3 (Reference 9)

Boring No. (Surface El.)	Layer	Depth Interval		Unit Weight		Shear-wave Velocity
		From (ft.)	To (ft.)	Moist (pcf)	Saturated (pcf)	V_s (fps)
MSB3A (796.23)	Granular Fill (GP)	0.0	5.0	126	-	387
		5.0	8.0	126	-	491
	Soil Fill, Silty Sand (SM) with gravel	8.0	13.5	117.5	-	483
		13.5	18.5	117.5	-	538
		18.5	23.5	117.5	-	586
		23.5	28.5	126.5	-	713
	Residual Soil (SM)	28.5	29.5	-	145	1234
	Partially Weathered Rock [1]	29.5	31.0	-	145, (170)[1]	1583 (8277)[1]
		31.0	33.7	-	145, (170)[1]	2727 (8277)[1]
	Rock-Granite Gneiss	33.7	79	-	170	8277
		79	110	-	170	8277
		110+	-	-	170	9200

(1) Boring MSB3A of the MSIV project encountered partially weathered rock from 29.5 ft. to 33.7 ft. Boring MSB3A is located approximately 28 ft. south-southeast of the southern edge of the reactor building. At its south edge, the bottom of the reactor building's mat foundation is 43 ft. below Yard Grade Elevation. No fill concrete below the reactor building is indicated in the UFSAR (Reference 10). It is thus reasonable to assume that rock exists at the bottom of the reactor building mat.

(2) The control point elevation is taken to be 43 ft. below the Yard Grade Elevation.

The following description of the general geology at the site is taken directly from the AMEC Data for Site Amplifications (Reference 9):

> "The bedrock at the site consists mostly of granite gneiss, the dominant rock type, and biotite and hornblende gneiss. Also present are relatively thin bands of mica schist. A few quartz, quartz-biotite pegmatite and quartz veins may also be present.
>
> "The rock has weathered in-place and is covered by residual soils and partially weathered rock. The weathering profile shows clayey surface soils grading with depth below the preconstruction surface into micaceous silty sand or micaceous sandy silt. The soils are of low to medium plasticity and are SM and ML classifications in the Unified Soils Classification System. With increasing depth, the profile has a transition zone between soil and rock, consisting of alternating seams of soft decomposed rock and hard partially decomposed rock. The degree of weathering becomes less as the relatively sound rock is approached. The delineation of relative sound rock is not specifically described in the UFSAR; it is based primarily on degree of weathering (decomposition) visually observed in the rock core samples."

2.3.2 *Development of Base Case Profiles and Nonlinear Material Properties*

Tables 2.3.1-1, 2.3.1-2, and 2.3.1-3 show the recommended shear-wave velocities and unit weights for Units 1, 2, and 3 respectively. All three units reflect yard grade at the surface at a nominal elevation of 796 ft. with the "Deepest Structure Foundation Elevation" (SSE control point) taken at the bottom of the mat foundation for the reactor buildings at a depth of 43 ft. (13 m).

Based on Tables 2.3.1-1, 2.3.1-2, and 2.3.1-3 and the adopted location of the SSE control point at a depth of 43 ft. (13 m), the profile consists of 67 ft. (20 m) of firm rock overlying hard metamorphic basement rock.

Shear-wave velocities for the materials below a depth of 43 ft. (13 m) to a depth of 110 ft. (33.5 m) were based on P-S log measurements (Reference 9). Depth to hard rock (e.g. shear-wave velocity of 9,285 fps or above) not sampled in the P-S log measurements, was estimated to occur at a depth of 110 ft. (33.5 m) based on extrapolations at sites with very similar geology, McGuire and Catawba nuclear power plants.

Based on the specified shear-wave velocities reflecting a mixture of predominately measured values as well as assumed values regarding depth to hard reference rock, and considering the recommended shear-wave velocities follow the expected trend of increasing with depth, analogous to other sites having similar geology, a scale factor of 1.25 was adopted to reflect upper and lower range base-cases. The scale factor of 1.25 reflects a $\sigma_{\mu ln}$ of about 0.2 based on the SPID (Reference 3) 10^{th} and 90^{th} fractiles which implies a 1.28 scale factor on σ_{μ}.

Using shear-wave velocities specified in Table 2.3.1-1 through Table 2.3.1-3, three base-case profiles were developed using the scale factor of 1.25. The specified shear-wave velocities were taken as the mean or best estimate base-case profile (P1) with lower and upper range base-case profiles P2 and P3 respectively. With a best-estimate shear-wave velocity of a constant 8,265 fps (2519 m/s), the upper range profile (P3) exceeds the defined hard reference rock shear-wave velocity of 9,285 fps (2,830 m/s). As such profile P3 was considered hard rock and amplification factors not required. The remaining two base-case profiles P1 and P2, have a mean depth below the SSE control point of 67 ft. (20.4 m) to hard reference rock, randomized ± 13 ft. (± 4.1 m). The base-case profiles (P1, P2, and P3) are shown in Figure 2.3.2-1 and listed in Table 2.3.2-2. (Note: Table 2.3.2-1 is not used.) The depth randomization reflects ± 20% of the depth and was included to provide a realistic broadening of the fundamental resonance rather than reflect actual random variations to basement shear-wave velocities across a footprint.

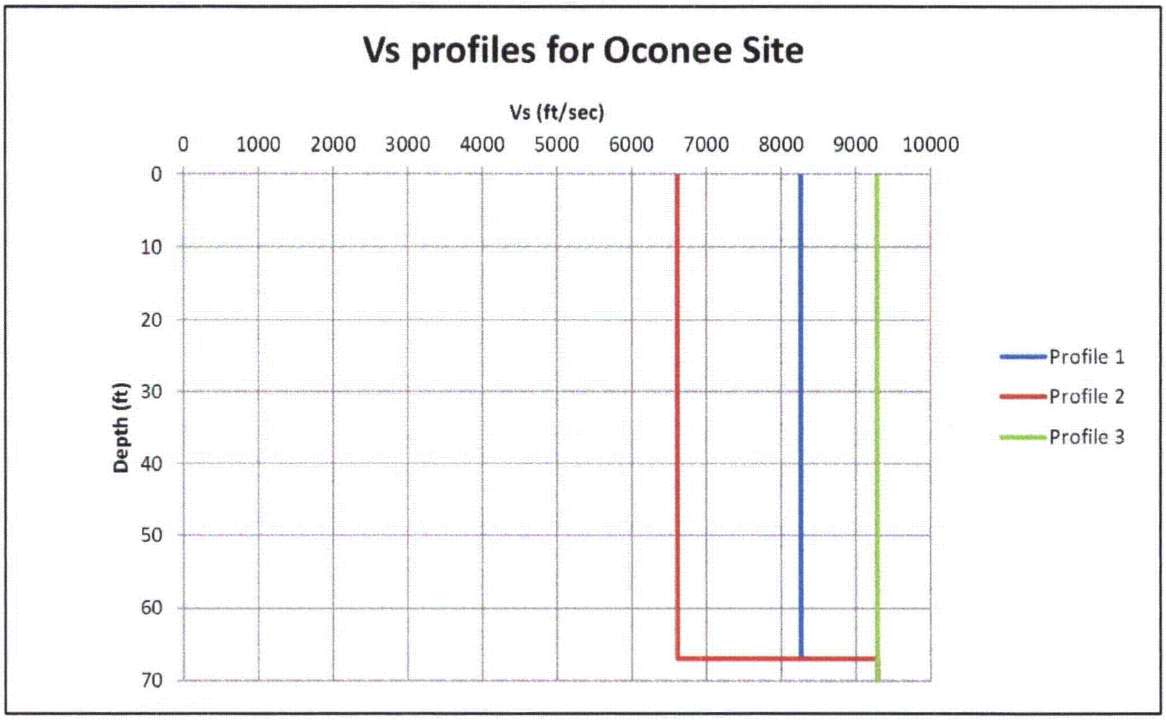


Figure 2.3.2-1 Shear-wave velocity profiles for the Oconee site

Table 2.3.2-2 Layer thicknesses, depths, and shear-wave velocities (V_s) for three profiles, the Oconee site

Profile 1			Profile 2			Profile 3		
Thickness (ft)	Depth (ft)	V_s (fps)	Thickness (ft)	Depth (ft)	V_s (fps)	Thickness (ft)	Depth (ft)	V_s (fps)
	0	8265		0	6612		0	9285
10.0	10.0	8265	10.0	10.0	6612	3280.8	3280.8	9285
10.0	20.0	8265	10.0	20.0	6612			
10.0	30.0	8265	10.0	30.0	6612			
10.0	40.0	8265	10.0	40.0	6612			
10.0	50.0	8265	10.0	50.0	6612			
8.5	58.5	8265	8.5	58.5	6612			
8.5	67.0	8265	8.5	67.0	6612			
3280.8	3347.8	9285	3280.8	3347.8	9285			

2.3.2.1 Shear Modulus and Damping Curves

No site-specific nonlinear dynamic material properties were determined for the firm rock materials in the initial siting of Oconee. The rock material over the upper 67 ft. (20.4 m) was assumed to have behavior that could be modeled as either linear or nonlinear. To represent this potential for either case in the upper 67 ft. (20.4 m) of firm rock at the Oconee site, two sets of shear modulus reduction and hysteretic damping curves were used. Consistent with the SPID (Reference 3), the EPRI rock curves (model M1) were considered to be appropriate to represent the upper range nonlinearity likely in the materials at this site and linear analyses (model M2) was assumed to represent an equally plausible alternative rock response across loading level. For the linear analyses, the low strain damping from the EPRI rock curves was used as the constant damping values in the upper 67 ft. (20.4 m).

2.3.2.2 Kappa

For the Oconee site profile of about 67 ft. (20.4 m) of firm rock over hard reference rock, the kappa value of 0.006s for hard rock (Reference 3) dominates profile damping. The 67 ft. (20.4 m) of firm rock, based on the low strain damping from the EPRI rock G/G_{max} and hysteretic damping curves, reflects a contribution of only about 0.0007s (Table 2.3.2-3). As a result, the dominant epistemic uncertainty in low strain kappa was assumed to be incorporated in the reference rock hazard.

Table 2.3.2-3 Kappa values and weights used for site response analyses

Velocity Profile	Kappa (s)	Weights
P1	0.0065	0.4
P2	0.0067	0.3
P3	0.0060	0.3
G/G_{max} and Hysteretic Damping Curves		
M1		0.5
M2		0.5

2.3.3 Randomization of Base Case Profiles

To account for the aleatory variability in dynamic material properties that is expected to occur across a site at the scale of a typical nuclear facility, variability in the assumed shear-wave velocity profiles has been incorporated in the site response calculations. For the Oconee site, random shear-wave velocity profiles were developed from the base case profiles shown in Figure 2.3.2-1. Consistent with the discussion in Appendix B of the SPID (Reference 3), the velocity randomization procedure made use of random field models which describe the statistical correlation between layering and shear wave velocity. The default randomization parameters developed in Reference 25 for USGS "A" site conditions were used for this site. Thirty random velocity profiles were generated for each base case profile. These random velocity profiles were generated using a natural log standard deviation of 0.25 over the upper 50 ft. and a natural log standard deviation of 0.15 below that depth. As specified in the SPID (Reference 3), correlation of shear-wave velocity between layers was modeled using the footprint correlation model. In the correlation model, a limit of +/- 2 standard deviations about the median value in each layer was assumed for the limits on random velocity fluctuations.

2.3.4 *Input Spectra*

Consistent with the guidance in Appendix B of the SPID (Reference 3), input Fourier amplitude spectra were defined for a single representative earthquake magnitude (**M** 6.5) using two different assumptions regarding the shape of the seismic source spectrum (single-corner and double-corner). A range of 11 different input amplitudes (median PGA ranging from 0.01g to 1.5g) was used in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the Oconee site were the same as those identified in Tables B-4, B-5, B-6 and B-7 of the SPID (Reference 3) as appropriate for typical CEUS sites.

2.3.5 *Methodology*

To perform the site response analyses for the Oconee site, a random vibration theory (RVT) approach was employed. This process utilizes a simple, efficient approach for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID (Reference 3). The guidance contained in Appendix B of the SPID (Reference 3) on incorporating epistemic uncertainty in shear-wave velocities, kappa, nonlinear dynamic properties and source spectra for plants with limited at-site information was followed for the Oconee site.

2.3.6 *Amplification Functions*

The results of the site response analysis consist of amplification factors (5% of critical damping pseudo absolute response spectra) which describe the amplification (or de-amplification) of hard reference rock motion as a function of frequency and input reference rock amplitude. The amplification factors are represented in terms of a median amplification value and an associated standard deviation (sigma) for each oscillator frequency and input rock amplitude. Consistent with the SPID (Reference 3) a minimum median amplification value of 0.5 was employed in the present analysis. Figure 2.3.6-1 illustrates the median and +/- 1 standard deviation in the predicted amplification factors developed for the eleven loading levels parameterized by the median reference (hard rock) peak acceleration (0.01g to 1.50g) for profile P1 and EPRI rock G/G_{max} and hysteretic damping curves (model M1). The variability in the amplification factors results from variability in shear-wave velocity, depth to hard rock, and modulus reduction and hysteretic damping curves. To illustrate the effects of nonlinearity at the Oconee firm rock site, Figure 2.3.6-2 shows the corresponding amplification factors developed with linear site response analyses (model M2). Between the linear and nonlinear (equivalent-linear) analyses, Figure 2.3.6-1 and Figure 2.3.6-2 show only a minor difference across structural frequency as well as loading level. Tabulated values of the amplification factors are provided in Appendix A.

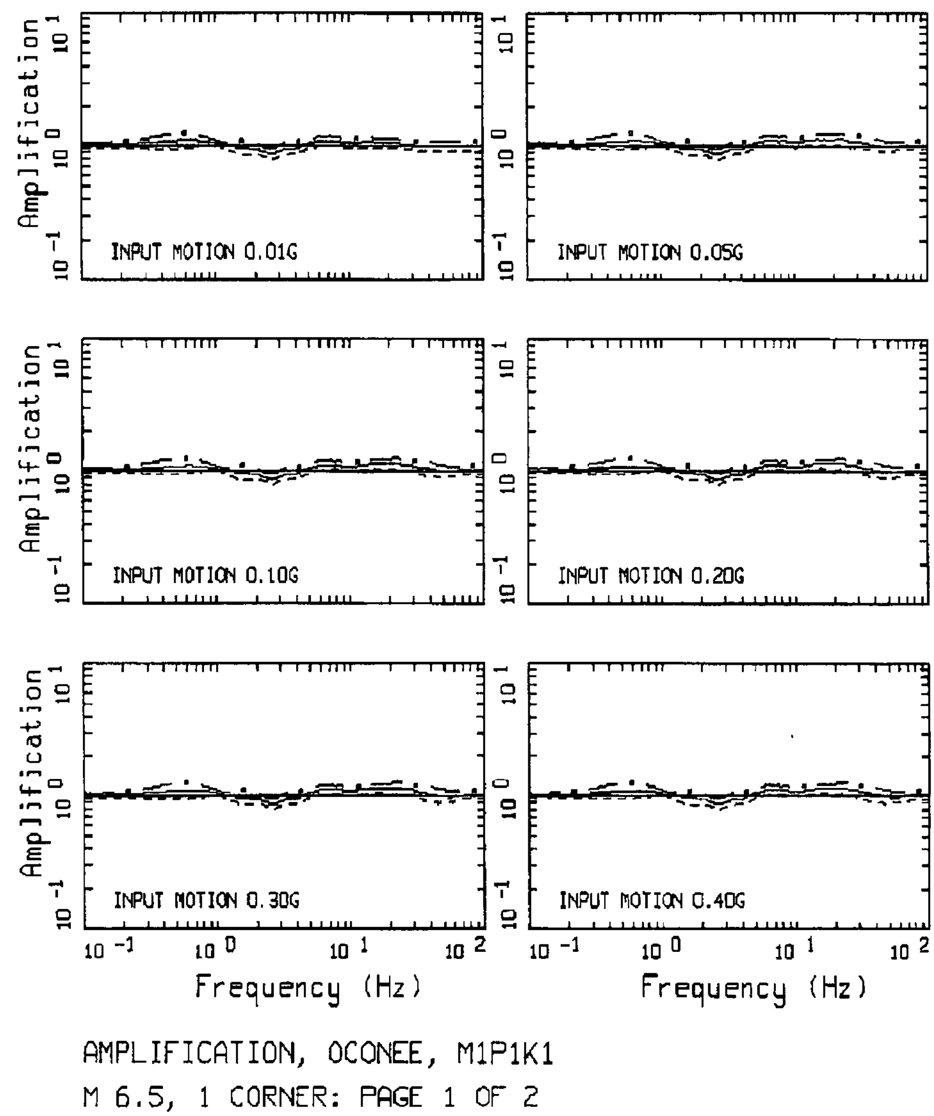
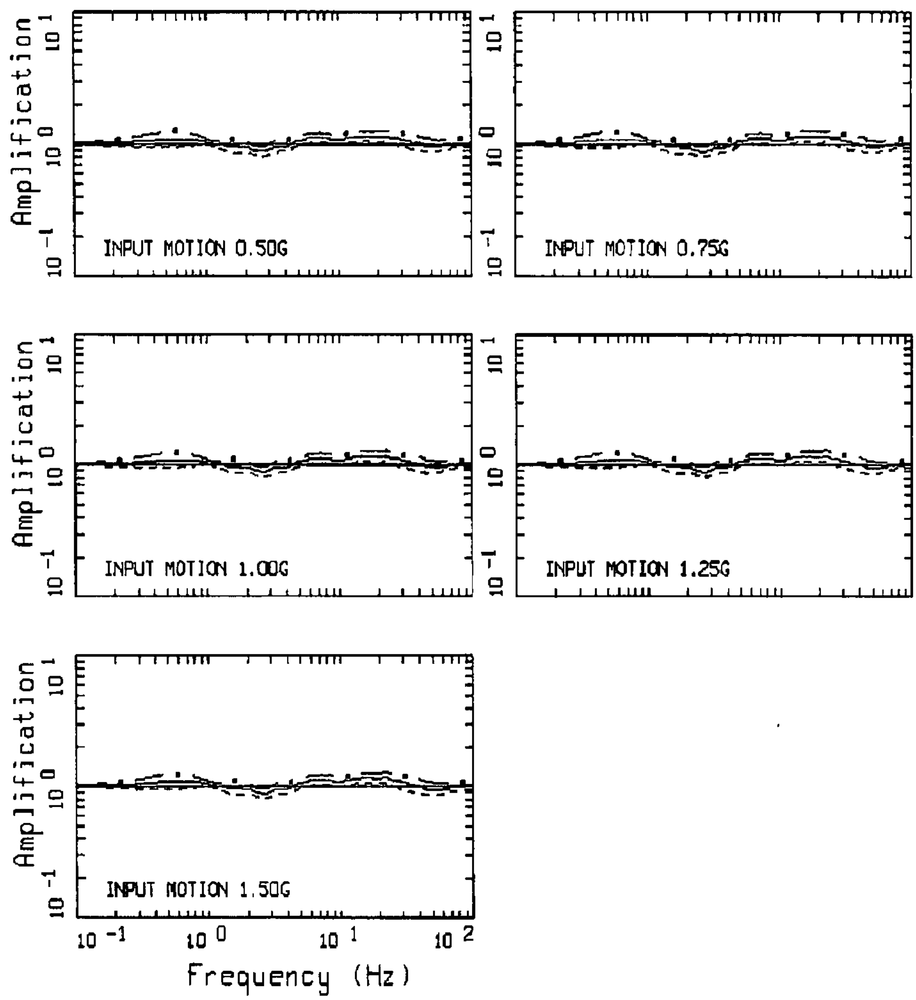


Figure 2.3.6-1 Example suite of amplification factors (5% of critical damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), EPRI rock modulus reduction and hysteretic damping curves (model M1), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (Reference 3)



AMPLIFICATION, OCONEE, M1P1K1
M 6.5, 1 CORNER: PAGE 2 OF 2

Figure 2.3.6-1 continued

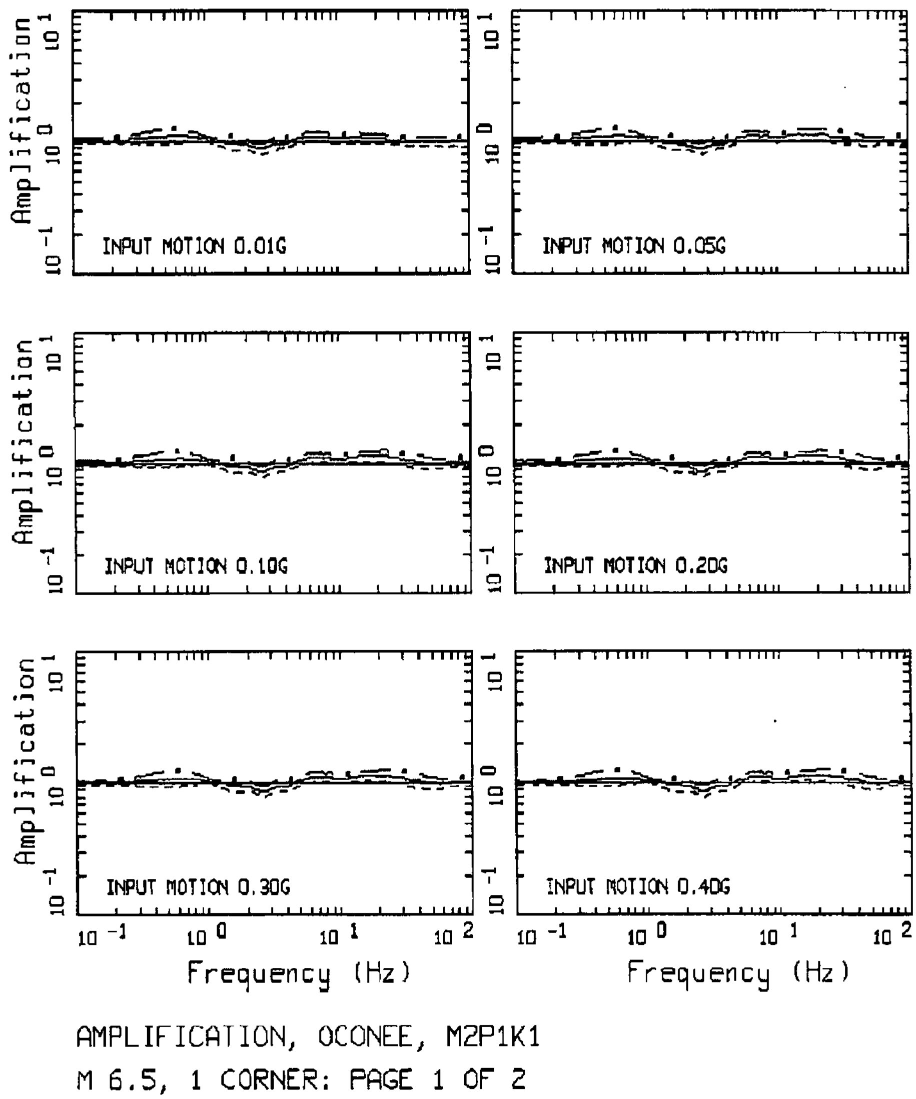
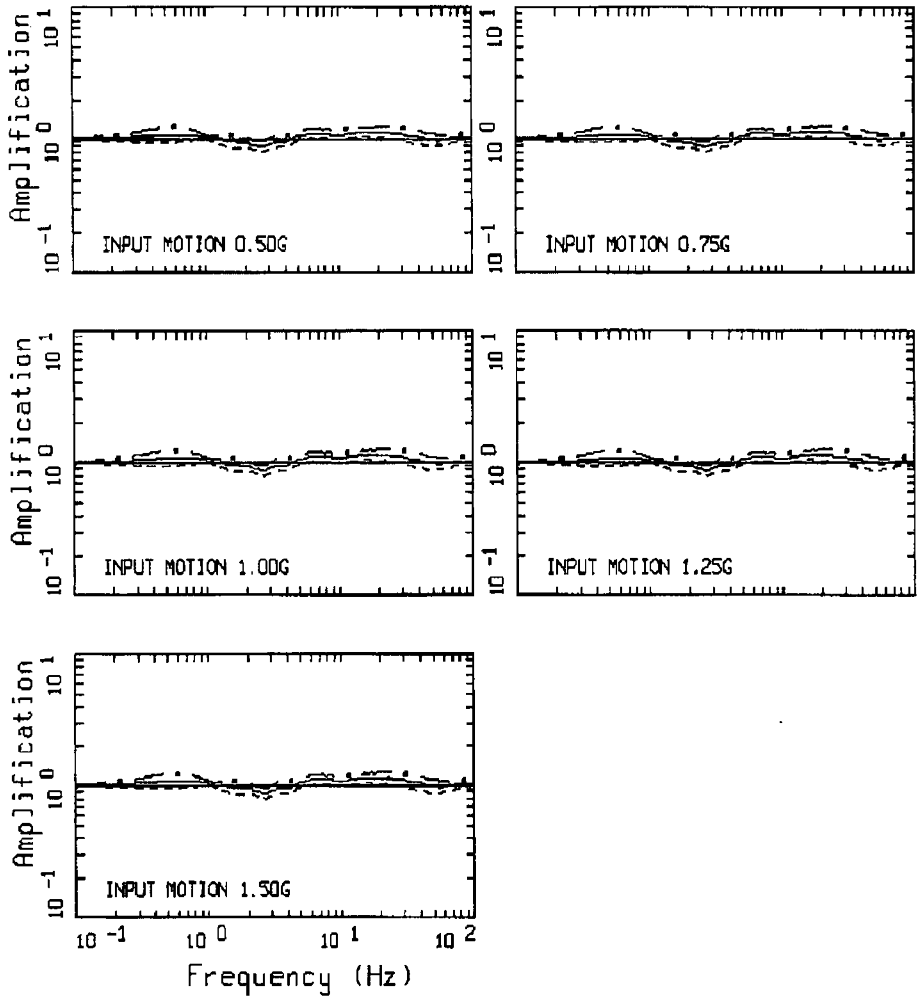


Figure 2.3.6-2 Example suite of amplification factors (5% of critical damping pseudo absolute acceleration spectra) developed for the mean base-case profile (P1), linear site response (model M2), and base-case kappa (K1) at eleven loading levels of hard rock median peak acceleration values from 0.01g to 1.50g. **M** 6.5 and single-corner source model (Reference 3)



AMPLIFICATION, OCONEE, M2P1K1
M 6.5, 1 CORNER: PAGE 2 OF 2

Figure 2.3.6-2 continued

2.3.7 *Control Point Seismic Hazard Curves*

The procedure to develop probabilistic site-specific control point hazard curves used in the present analysis follows the methodology described in Section B-6.0 of the SPID (Reference 3). This procedure (referred to as Method 3 from NUREG/CR-6728 (Reference 16)) computes a site-specific control point hazard curve for a broad range of spectral accelerations given the site-specific bedrock hazard curve and site-specific estimates of soil or soft-rock response and associated uncertainties. This process is repeated for each of the seven spectral frequencies for which ground motion equations are available. The dynamic response of the materials below the control point was represented by the frequency- and amplitude-dependent amplification functions (median values and standard deviations) developed and described in the previous section. The resulting control point mean hazard curves for Oconee are shown in Figure 2.3.7-1 for the seven spectral frequencies for which ground motion equations are defined. Tabulated values of mean and fractile seismic hazard curves and site response amplification functions are provided in Appendix A.

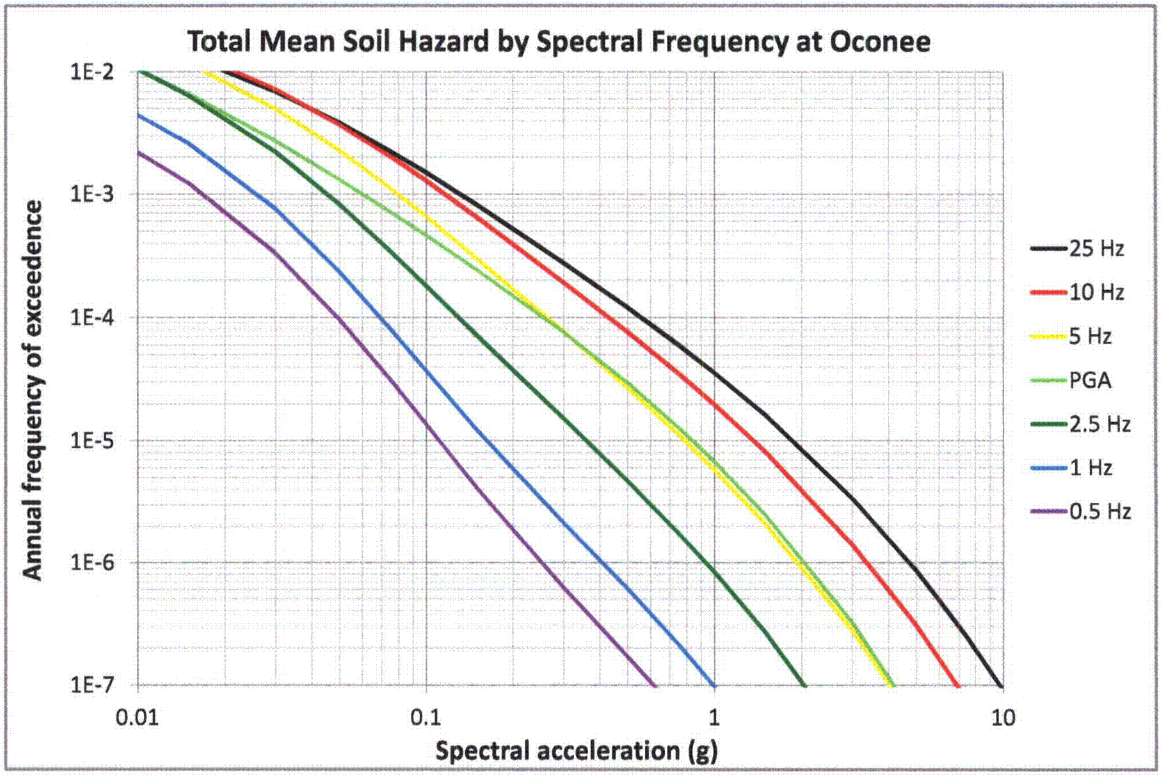


Figure 2.3.7-1 Control point mean hazard curves for spectral frequencies of 0.5, 1, 2.5, 5, 10, 25 and 100 Hz (PGA) at Oconee (5% of critical damping)

2.4 CONTROL POINT RESPONSE SPECTRA

The control point mean hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the GMRS. The UHRS were obtained through linear interpolation in log-log space to estimate the spectral acceleration at each spectral frequency for the 1E-4 and 1E-5 per year hazard levels. 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 NRC Reg. Guide 1.208 (Reference 7). Figure 2.4-1 shows the control point UHRS and GMRS. Table 2.4-1 shows the UHRS and GMRS spectral accelerations for each of the seven frequencies.

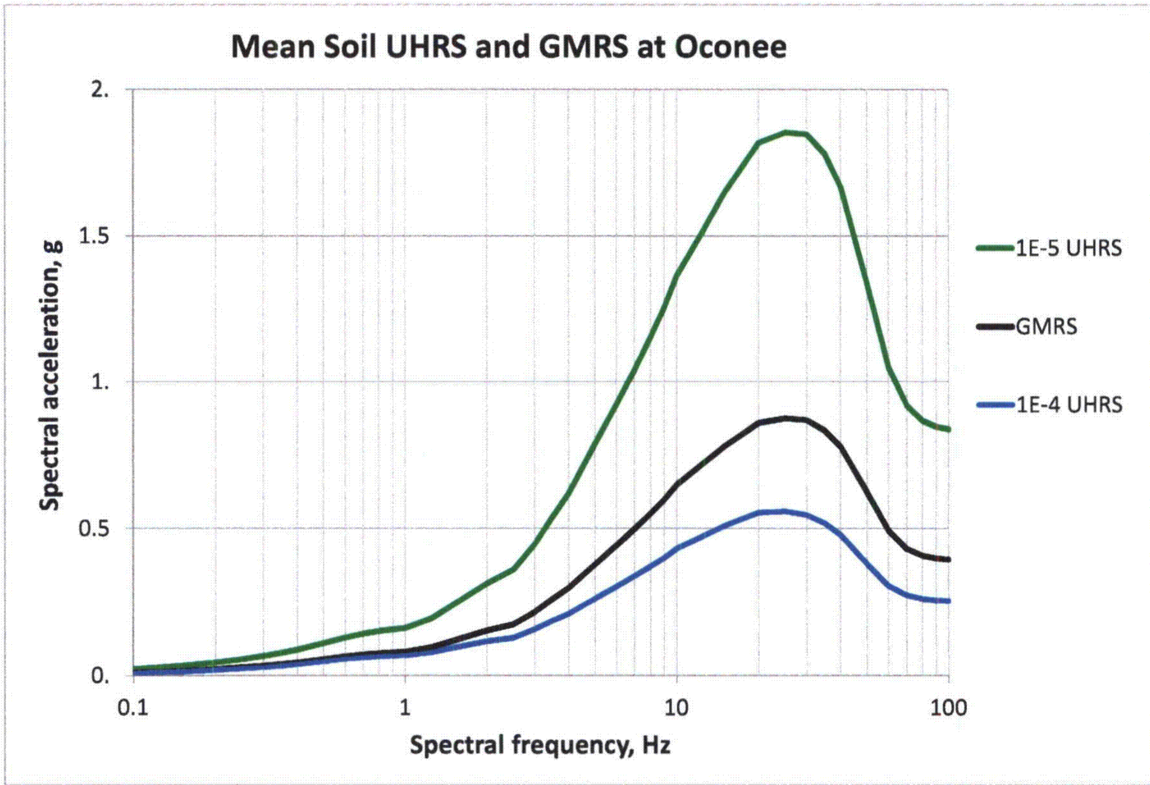


Figure 2.4-1 Plots of 1E-4 and 1E-5 uniform hazard spectra and GMRS at control point for Oconee (5% of critical damping response spectra)

Table 2.4-1 UHRS and GMRS at control point for Oconee (5% of critical damping response spectra)

Freq (Hz)	1E-4 UHRS (g)	1E-5 UHRS (g)	GMRS (g)
100	2.55E-01	8.37E-01	3.96E-01
90	2.56E-01	8.46E-01	4.00E-01
80	2.61E-01	8.66E-01	4.09E-01
70	2.73E-01	9.18E-01	4.32E-01
60	3.05E-01	1.05E+00	4.92E-01
50	3.81E-01	1.34E+00	6.24E-01
40	4.78E-01	1.67E+00	7.79E-01
35	5.17E-01	1.78E+00	8.34E-01
30	5.46E-01	1.85E+00	8.68E-01
25	5.58E-01	1.85E+00	8.74E-01
20	5.54E-01	1.82E+00	8.60E-01
15	5.10E-01	1.65E+00	7.81E-01
12.5	4.75E-01	1.52E+00	7.22E-01
10	4.32E-01	1.36E+00	6.50E-01
9	4.01E-01	1.26E+00	6.00E-01
8	3.71E-01	1.15E+00	5.51E-01
7	3.39E-01	1.04E+00	4.99E-01
6	3.03E-01	9.22E-01	4.43E-01
5	2.62E-01	7.88E-01	3.79E-01
4	2.11E-01	6.19E-01	2.99E-01
3.5	1.88E-01	5.41E-01	2.63E-01
3	1.58E-01	4.48E-01	2.18E-01
2.5	1.29E-01	3.59E-01	1.76E-01
2	1.17E-01	3.13E-01	1.54E-01
1.5	9.48E-02	2.40E-01	1.20E-01
1.25	7.96E-02	1.95E-01	9.79E-02
1	6.91E-02	1.62E-01	8.21E-02
0.9	6.73E-02	1.57E-01	7.96E-02
0.8	6.53E-02	1.51E-01	7.68E-02
0.7	6.22E-02	1.43E-01	7.27E-02
0.6	5.71E-02	1.30E-01	6.61E-02
0.5	4.93E-02	1.11E-01	5.66E-02
0.4	3.94E-02	8.87E-02	4.53E-02
0.35	3.45E-02	7.76E-02	3.96E-02
0.3	2.96E-02	6.65E-02	3.39E-02
0.25	2.46E-02	5.55E-02	2.83E-02
0.2	1.97E-02	4.44E-02	2.26E-02
0.15	1.48E-02	3.33E-02	1.70E-02
0.125	1.23E-02	2.77E-02	1.41E-02
0.1	9.85E-03	2.22E-02	1.13E-02

3 Plant Design Basis Ground Motion

The maximum earthquake potential at the Oconee site is based upon the previously recorded earthquake activity and the known geology of the area. Previous maximum-sized shocks from three significant fault zones of varying distances from the site are considered: an intensity VI event 11 miles from the site, an intensity VIII event 75 miles from the site, and an intensity VII to VIII event 30 miles from the site. Since the magnitudes of these shocks are fairly small, the distance from the epicenter becomes extremely important as ground accelerations would diminish rapidly with the distance from the epicenter. Therefore, the highest ground acceleration at the site would be experienced from an earthquake along the Brevard fault zone, with the previous maximum-sized shock considered to be an intensity VI. The intensity VI event occurring 11 miles from the site would give ground motions on the order of five percent of gravity at the Oconee site. (Reference 10, Section 2.5) The Design Basis Earthquake horizontal PGA at the Oconee site is 0.05g, and the MHE horizontal PGA is 0.10g and 0.15g for Class 1 structures founded on bedrock and overburden respectively. The SSE is equivalent to the MHE (Reference 10, Section 3.2). The structures are founded on normal Piedmont granite gneisses rock (Reference 10, Section 2.5). Therefore, for seismic hazard screening purposes in response to NTTF 2.1, the horizontal PGA of 0.10g associated with bedrock-founded structures is the appropriate anchor point for the Oconee SSE.

3.1 SSE Description of Spectral Shape

The Oconee SSE is defined in terms of a PGA and a design response spectrum shape. Considering an intensity VI shock occurring along the Brevard fault zone, the MHE PGA is 0.10g for Class 1 structures founded on bedrock, designating the SSE PGA anchor point. The Oconee design response spectrum is based on the Recommended Response Spectrum for the 0.10g earthquake provided in the Oconee UFSAR, Figure 2-53 (Reference 10, Section 2.5). The associated spectral shape is based upon a Housner-type spectrum (Reference 11). For the purposes of NTTF 2.1: Seismic screening, the spectral acceleration values for the Oconee horizontal SSE (5% of critical damping) are shown as a function of frequency in Table 3.1-1 and plotted in Figure 3.1-1.

Table 3.1-1 Horizontal SSE for Oconee (5% of critical damping response spectrum)

Frequency (Hz)	Spectral Acceleration (g)
0.2	0.020
0.27	0.028
0.37	0.038
0.47	0.045
0.57	0.052
0.69	0.060
0.79	0.067
0.89	0.074
0.99	0.081
1.29	0.102
1.49	0.115
2	0.140
2.5	0.148
2.98	0.146
3.48	0.141
4	0.137
4.9	0.131
6	0.125
7	0.121
8	0.118
9	0.115
10	0.112
12	0.108
15	0.102
16.7	0.100
100/PGA	0.100

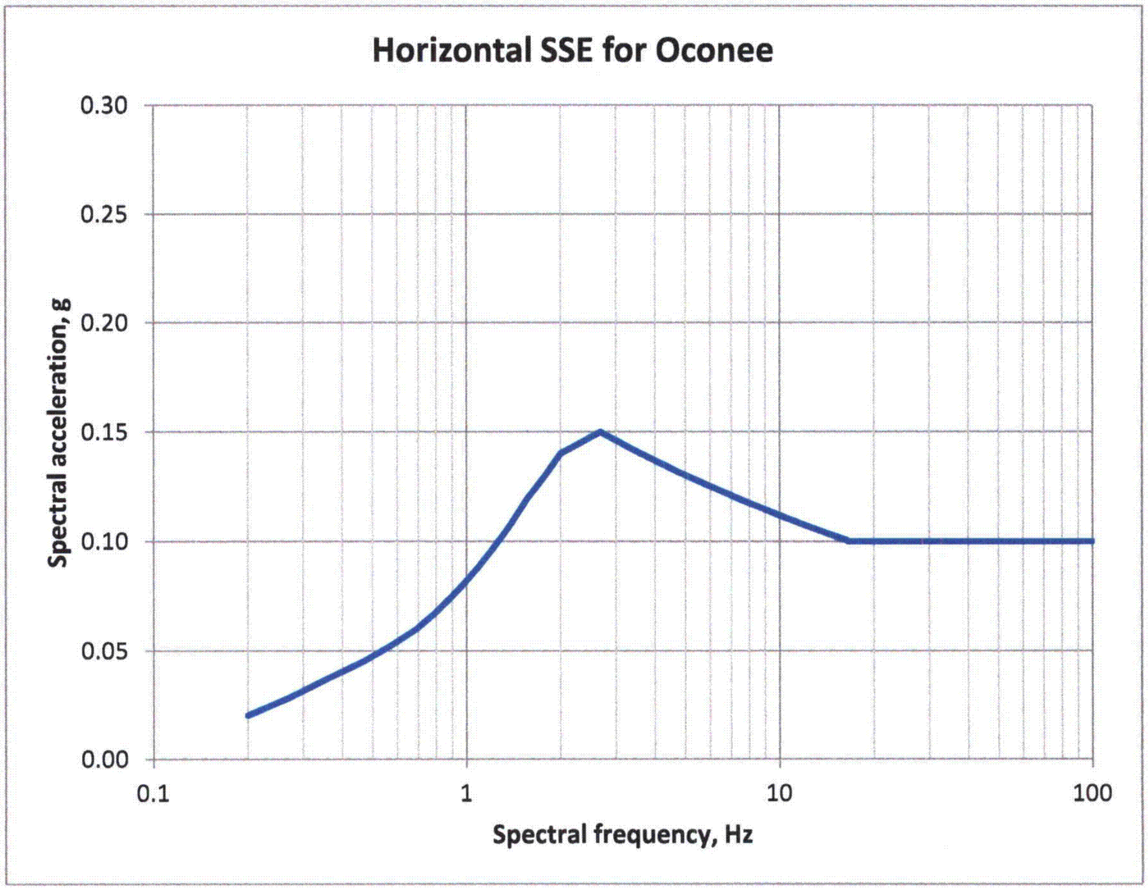


Figure 3.1-1 Horizontal SSE for Oconee (5% of critical damping response spectrum)

3.2 CONTROL POINT ELEVATION

The Oconee UFSAR (Reference 10) does not clearly define an SSE control point. The structures are founded on normal Piedmont granite gneisses. The rock is overlain by residual soils, which vary from silty clays at the surface, where the rock decomposition has completed its cycle, to partially weathered rock, and finally to sound rock. While highly variable, the normal range of depth before sound rock is reached is 30 to 50 ft. (Reference 10, Section 2.5). The yard grade is 796 ft. mean sea level (MSL) (Reference 10, Section 2.4). As the major Class 1 structures, the Reactor Building and Auxiliary Buildings, are founded on a common rock foundation (Reference 10, Section 3.7), the SSE control point elevation is based upon the top of rock. Therefore, the SSE control point elevation is taken to be at the bottom of the mat foundation for the Reactor Buildings at El. 753 ft. MSL, consistent with the approach described in the SPID, Section 2.4.2 (Reference 3).

4 Screening Evaluation

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

4.1 Risk Evaluation Screening (1 to 10 Hz)

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

4.2 High Frequency Screening (> 10 Hz)

Above 10 Hz, the GMRS exceeds the SSE for Oconee. The high frequency exceedances can be addressed in the risk evaluation discussed in Section 4.1 above.

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

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the SSE for Oconee. Therefore, Oconee screens in for a spent fuel pool integrity evaluation.

5 Interim Actions and Assessments

As described in Section 4, the GMRS developed in response to the NTTF 2.1: Seismic portion of the 10 CFR 50.54(f) Request for Information dated March 12, 2012 (Reference 1) exceeds the design basis SSE. The NRC 50.54(f) letter (Reference 1) requests: "interim evaluation and actions taken or planned to address the higher seismic hazard relative to the design basis, as appropriate, prior to completion of the risk evaluation." These evaluations and actions are discussed below.

Consistent with NRC letter dated February 20, 2014 (Reference 17), the seismic hazard reevaluations presented herein are distinct from the current design and licensing bases of Oconee. Therefore, the results do not call into question the operability or functionality of SSCs and are not reportable pursuant to 10 CFR 50.72, "Immediate notification requirements for operating nuclear power reactors" (Reference 2, Section 50.72) and 10 CFR 50.73, "Licensee event report system" (Reference 2, Section 50.73).

5.1 Expedited Seismic Evaluation Program

An expedited seismic evaluation process (ESEP) is being performed at Oconee in accordance with the methodology in EPRI 3002000704 (Reference 4) as proposed in a letter to the NRC dated April 9, 2013 (Reference 12) and agreed to by the NRC in a letter dated May 7, 2013 (Reference 13). Duke plans to submit a report on the ESEP to the NRC in December 2014 (Reference 20), in accordance with the schedule in the Nuclear Energy Institute (NEI) April 9, 2013 letter to the NRC (Reference 12).

5.2 Seismic Risk Estimates

The NRC letter (Reference 17) also requests that licensees provide an interim evaluation or actions to address the higher seismic hazard relative to the design basis while the expedited approach and risk evaluations are conducted. In response to that request, the NEI letter dated March 12, 2014 (Reference 15) provides seismic core damage risk estimates using the updated seismic hazards for the operating nuclear plants in the CEUS. These risk estimates continue to support the following conclusions of the NRC GI-199 Safety/Risk Assessment (Reference 14):

> "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."

Oconee is included in the March 12, 2014 risk estimates (Reference 15). Using the methodology described in the NEI letter (Reference 15), the seismic core damage risk

estimates for all plants were shown to be below 1E-4/year; thus, the above conclusions apply.

5.3 Individual Plant Examination of External Events

An evaluation of beyond-design-basis ground motions was performed for Oconee as part of the IPEEE program. The SPRA methodology was utilized to perform the IPEEE seismic evaluation for Oconee (Reference 19). The results of the SPRA determined the SCDF for Oconee to be less than the Commission's Safety Goal subsidiary objective of 1E-4/year (References 21 and 14). The Oconee IPEEE seismic evaluation concluded that there are no unduly significant vulnerabilities with regard to severe accident risk, including seismic, and confirmed that the plant poses no undue risk to the public health and safety (Reference 21). Additionally, improvements were made to the plant based on the Oconee IPEEE seismic evaluation, as confirmed in the NTTF 2.3 seismic walkdown report (Reference 23), to enhance the Oconee seismic margin.

5.4 Walkdowns to Address NRC Fukushima NTTF Recommendation 2.3

Walkdowns have been performed for Oconee in accordance with the EPRI seismic walkdown guidance, with a few remaining inaccessible items for Unit 3 scheduled to be completed in the third quarter of 2014. Potentially adverse seismic conditions (PASC) found were entered into the corrective action program (CAP) for resolution. None of the PASC items challenged operability of the plant. There were no vulnerabilities identified under IPEEE, however, previously identified IPEEE enhancements were reviewed and found to be complete. Duke confirmed through the walkdowns that the existing monitoring and maintenance procedures keep the plant consistent with the licensing basis. (References 23 and 24)

6 Conclusions

In accordance with the 50.54(f) letter (Reference 1), a seismic hazard and screening evaluation was performed for Oconee. A GMRS was developed solely for the purpose of screening for additional evaluations in accordance with the SPID (Reference 3).

Based on the results of the screening evaluation, Oconee screens in for a risk evaluation and a spent fuel pool integrity evaluation.

7 References

1. NRC (E. Leeds and M. Johnson) Letter to All Power Reactor Licensees et al., *Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident,* dated March 12, 2012, ADAMS Accession No. ML12053A340.

2. Title 10 Code of Federal Regulations Part 50.

3. EPRI 1025287, *Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*, Palo Alto, CA, February 2013.

4. EPRI 3002000704, *Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*, Palo Alto, CA, May 2013.

5. EPRI 1021097 (NUREG-2115), *Central and Eastern United States Seismic Source Characterization for Nuclear Facilities*, Palo Alto, CA, January 2012.

6. EPRI 3002000717, *EPRI (2004, 2006) Ground-Motion Model (GMM) Review Project*, Palo Alto, CA, June 2013.

7. NRC Regulatory Guide 1.208, *A performance-based approach to define the site-specific earthquake ground motion*, 2007.

8. EPRI RSM-030614-073, *Oconee Seismic Hazard and Screening Report (Revision 1)*, dated March 6, 2014.

9. AMEC Project No. 6234-12-0031, *Data for Site Amplifications – Oconee Phase 2, EPRI Seismic Attenuation and GMRS Project, Oconee Nuclear Station,* July 26, 2012.

10. Duke Energy Company, *Oconee Nuclear Station, Updated Final Safety Analysis Report,* Revision 22.

11. NUREG/CR-1429, *Seismic Review Table*, May 1980.

12. NEI (A. R. Pietrangelo) Letter to the NRC, *Proposed Path Forward for NTTF Recommendation 2.1: Seismic Reevaluations,* dated April 9, 2013, ADAMS Accession No. ML13101A379.

13. NRC (E. Leeds) Letter to NEI (J. Pollock), *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.

14. NRC Memorandum (from P. Hiland to B. Sheron), "Safety/Risk Assessment Results for Generic Issue 199, Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants," dated September 2, 2010, ADAMS Accession No. ML100270582.

15. NEI (A. R. Pietrangelo) Letter to the NRC, *Seismic Risk Evaluations for Plants in the Central and Eastern United States,* dated March 12, 2014.

16. NUREG/CR-6728, *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk- Consistent Ground Motion Spectra Guidelines*, October 2001.

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

18. EPRI 1025286, *Seismic Walkdown Guidance for Resolution of Fukushima Near-Term Task Force Recommendation 2.3: Seismic*, Palo Alto, CA, June 2012.

19. Duke Power Company, *Oconee Nuclear Station IPEEE Submittal Report,* dated December 21, 1995.

20. Duke Energy (B. Waldrep) Letter to the NRC, *Duke Energy Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident*, dated April 26, 2013, ADAMS Accession No. ML13121A061.

21. NRC (D. LaBarge) Letter to Duke Energy Corporation (W. McCollum, Jr.), *Oconee Nuclear Station, Units 1, 2 and 3 Re: Review of Individual Plant Examination of External Events (TAC Nos. MA83649, M83650, and M83651)*, dated March 15, 2000.

22. EPRI RSM-0030514-071, *Review of EPRI 1021097 Earthquake Catalog for RIS Earthquakes in the Southeastern U.S. and Earthquakes in South Carolina Near the Time of the 1886 Charleston Earthquake Sequence*, dated March 5, 2014.

23. Duke Energy Carolinas (T. Gillespie Jr.) Letter to the NRC, *Oconee Nuclear Station (ONS), Units 1, 2 and 3, Seismic Walkdown Information Requested by 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,* dated November 27, 2012, ADAMS Accession No. ML12347A252.

24. Duke Energy Carolinas (S. Batson) Letter to the NRC, *Oconee Nuclear Station (ONS), Units 1, 2 and 3, ONS Unit 1, Update to the ONS Seismic Walkdown Information Submitted November 27, 2012*, dated July 1, 2013, ADAMS Accession No. ML13192A155.

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

A

Additional Tables

Table A-1a Mean and fractile seismic hazard curves for PGA at Oconee, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	6.88E-02	3.63E-02	5.50E-02	6.93E-02	8.47E-02	9.37E-02
0.001	4.95E-02	2.72E-02	3.90E-02	4.83E-02	6.17E-02	7.13E-02
0.005	1.88E-02	9.11E-03	1.29E-02	1.82E-02	2.39E-02	3.23E-02
0.01	1.03E-02	4.31E-03	6.09E-03	9.65E-03	1.34E-02	2.13E-02
0.015	6.64E-03	2.53E-03	3.47E-03	5.83E-03	8.85E-03	1.62E-02
0.03	2.71E-03	8.23E-04	1.13E-03	1.98E-03	3.79E-03	8.85E-03
0.05	1.31E-03	3.37E-04	4.70E-04	8.47E-04	1.84E-03	4.90E-03
0.075	7.14E-04	1.69E-04	2.39E-04	4.37E-04	1.01E-03	2.84E-03
0.1	4.60E-04	1.07E-04	1.51E-04	2.84E-04	6.54E-04	1.82E-03
0.15	2.43E-04	5.58E-05	8.12E-05	1.55E-04	3.47E-04	9.11E-04
0.3	7.59E-05	1.64E-05	2.68E-05	5.20E-05	1.10E-04	2.46E-04
0.5	2.95E-05	5.66E-06	9.79E-06	2.10E-05	4.43E-05	8.85E-05
0.75	1.28E-05	2.07E-06	3.79E-06	9.11E-06	1.98E-05	3.79E-05
1.	6.71E-06	9.11E-07	1.74E-06	4.63E-06	1.05E-05	2.07E-05
1.5	2.45E-06	2.35E-07	4.98E-07	1.60E-06	3.95E-06	8.12E-06
3.	3.19E-07	1.31E-08	3.42E-08	1.64E-07	5.05E-07	1.29E-06
5.	5.18E-08	9.93E-10	2.92E-09	1.95E-08	7.45E-08	2.46E-07
7.5	9.82E-09	1.98E-10	4.01E-10	2.80E-09	1.27E-08	5.27E-08
10.	2.65E-09	1.36E-10	1.69E-10	6.73E-10	3.28E-09	1.53E-08

Table A-1b Mean and fractile seismic hazard curves for 25 Hz at Oconee, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	7.92E-02	4.56E-02	6.83E-02	8.00E-02	9.24E-02	9.93E-02
0.001	6.08E-02	3.57E-02	5.05E-02	6.00E-02	7.34E-02	8.60E-02
0.005	2.71E-02	1.55E-02	2.01E-02	2.64E-02	3.33E-02	4.43E-02
0.01	1.79E-02	9.11E-03	1.21E-02	1.72E-02	2.25E-02	3.05E-02
0.015	1.33E-02	6.17E-03	8.47E-03	1.27E-02	1.72E-02	2.42E-02
0.03	6.96E-03	2.84E-03	3.95E-03	6.26E-03	9.24E-03	1.51E-02
0.05	3.85E-03	1.44E-03	1.95E-03	3.23E-03	5.20E-03	9.65E-03
0.075	2.25E-03	7.77E-04	1.05E-03	1.79E-03	3.09E-03	6.26E-03
0.1	1.50E-03	4.83E-04	6.64E-04	1.15E-03	2.10E-03	4.37E-03
0.15	8.19E-04	2.46E-04	3.42E-04	6.09E-04	1.16E-03	2.46E-03
0.3	2.78E-04	8.00E-05	1.16E-04	2.13E-04	4.01E-04	7.77E-04
0.5	1.21E-04	3.47E-05	5.27E-05	9.51E-05	1.79E-04	3.05E-04
0.75	6.01E-05	1.69E-05	2.64E-05	4.83E-05	9.11E-05	1.44E-04
1.	3.56E-05	9.51E-06	1.53E-05	2.92E-05	5.50E-05	8.47E-05
1.5	1.61E-05	3.79E-06	6.45E-06	1.31E-05	2.57E-05	3.90E-05
3.	3.37E-06	5.50E-07	1.05E-06	2.57E-06	5.58E-06	8.85E-06
5.	8.51E-07	9.37E-08	2.01E-07	5.91E-07	1.44E-06	2.57E-06
7.5	2.43E-07	1.77E-08	4.31E-08	1.49E-07	4.19E-07	8.23E-07
10.	9.06E-08	4.77E-09	1.25E-08	4.98E-08	1.55E-07	3.33E-07

Table A-1c Mean and fractile seismic hazard curves for 10 Hz at Oconee, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.90E-02	6.45E-02	7.77E-02	8.98E-02	9.93E-02	9.93E-02
0.001	7.16E-02	4.83E-02	6.09E-02	7.13E-02	8.35E-02	9.24E-02
0.005	3.15E-02	1.95E-02	2.42E-02	3.09E-02	3.84E-02	4.56E-02
0.01	2.01E-02	1.13E-02	1.42E-02	1.98E-02	2.53E-02	3.09E-02
0.015	1.46E-02	7.55E-03	9.79E-03	1.42E-02	1.87E-02	2.39E-02
0.03	7.22E-03	3.23E-03	4.37E-03	6.73E-03	9.65E-03	1.36E-02
0.05	3.73E-03	1.51E-03	2.04E-03	3.28E-03	5.12E-03	8.12E-03
0.075	2.04E-03	7.45E-04	1.04E-03	1.72E-03	2.84E-03	4.90E-03
0.1	1.29E-03	4.37E-04	6.17E-04	1.05E-03	1.82E-03	3.28E-03
0.15	6.50E-04	2.04E-04	2.92E-04	5.20E-04	9.37E-04	1.72E-03
0.3	1.93E-04	5.50E-05	8.23E-05	1.55E-04	2.88E-04	4.90E-04
0.5	7.66E-05	2.07E-05	3.28E-05	6.26E-05	1.18E-04	1.87E-04
0.75	3.54E-05	8.85E-06	1.44E-05	2.88E-05	5.50E-05	8.47E-05
1.	1.97E-05	4.50E-06	7.66E-06	1.60E-05	3.14E-05	4.83E-05
1.5	8.12E-06	1.57E-06	2.84E-06	6.36E-06	1.32E-05	2.07E-05
3.	1.40E-06	1.77E-07	3.63E-07	9.93E-07	2.35E-06	4.13E-06
5.	3.02E-07	2.39E-08	5.50E-08	1.87E-07	5.20E-07	1.01E-06
7.5	7.53E-08	3.79E-09	9.93E-09	3.95E-08	1.29E-07	2.84E-07
10.	2.54E-08	9.79E-10	2.60E-09	1.18E-08	4.31E-08	1.02E-07

Table A-1d Mean and fractile seismic hazard curves for 5 Hz at Oconee, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	9.02E-02	6.64E-02	7.77E-02	8.98E-02	9.93E-02	9.93E-02
0.001	7.33E-02	4.83E-02	5.91E-02	7.34E-02	8.85E-02	9.65E-02
0.005	3.00E-02	1.74E-02	2.22E-02	2.96E-02	3.79E-02	4.25E-02
0.01	1.74E-02	9.24E-03	1.23E-02	1.72E-02	2.25E-02	2.64E-02
0.015	1.18E-02	5.83E-03	7.89E-03	1.15E-02	1.55E-02	1.87E-02
0.03	4.99E-03	2.16E-03	2.96E-03	4.63E-03	6.83E-03	9.24E-03
0.05	2.27E-03	8.72E-04	1.23E-03	2.01E-03	3.19E-03	4.77E-03
0.075	1.12E-03	3.90E-04	5.66E-04	9.51E-04	1.57E-03	2.57E-03
0.1	6.54E-04	2.16E-04	3.14E-04	5.50E-04	9.37E-04	1.55E-03
0.15	3.00E-04	9.37E-05	1.38E-04	2.49E-04	4.43E-04	7.23E-04
0.3	7.67E-05	2.16E-05	3.33E-05	6.36E-05	1.18E-04	1.82E-04
0.5	2.71E-05	6.73E-06	1.11E-05	2.19E-05	4.25E-05	6.45E-05
0.75	1.12E-05	2.35E-06	4.19E-06	8.85E-06	1.79E-05	2.84E-05
1.	5.75E-06	1.05E-06	1.92E-06	4.43E-06	9.37E-06	1.51E-05
1.5	2.07E-06	2.88E-07	5.66E-07	1.49E-06	3.47E-06	5.91E-06
3.	2.76E-07	1.95E-08	4.70E-08	1.64E-07	4.77E-07	9.37E-07
5.	4.86E-08	1.84E-09	5.12E-09	2.25E-08	8.12E-08	1.87E-07
7.5	1.03E-08	3.14E-10	7.55E-10	3.73E-09	1.64E-08	4.31E-08
10.	3.09E-09	1.60E-10	2.49E-10	9.79E-10	4.63E-09	1.36E-08

Table A-1e Mean and fractile seismic hazard curves for 2.5 Hz at Oconee, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	8.25E-02	5.91E-02	6.83E-02	8.23E-02	9.79E-02	9.93E-02
0.001	6.29E-02	4.01E-02	4.83E-02	6.17E-02	7.89E-02	8.72E-02
0.005	2.08E-02	1.15E-02	1.46E-02	2.01E-02	2.68E-02	3.19E-02
0.01	1.04E-02	5.20E-03	6.93E-03	1.01E-02	1.40E-02	1.69E-02
0.015	6.40E-03	2.88E-03	3.95E-03	6.00E-03	8.85E-03	1.13E-02
0.03	2.20E-03	7.77E-04	1.13E-03	1.95E-03	3.23E-03	4.63E-03
0.05	8.22E-04	2.46E-04	3.73E-04	6.83E-04	1.25E-03	1.95E-03
0.075	3.43E-04	9.24E-05	1.46E-04	2.72E-04	5.35E-04	8.47E-04
0.1	1.79E-04	4.50E-05	7.34E-05	1.40E-04	2.88E-04	4.50E-04
0.15	7.15E-05	1.64E-05	2.72E-05	5.42E-05	1.16E-04	1.82E-04
0.3	1.51E-05	2.57E-06	4.77E-06	1.10E-05	2.49E-05	4.19E-05
0.5	4.69E-06	5.42E-07	1.16E-06	3.14E-06	8.00E-06	1.42E-05
0.75	1.75E-06	1.38E-07	3.28E-07	1.07E-06	3.05E-06	5.75E-06
1.	8.27E-07	4.63E-08	1.21E-07	4.56E-07	1.46E-06	2.88E-06
1.5	2.65E-07	8.47E-09	2.60E-08	1.23E-07	4.70E-07	1.01E-06
3.	2.86E-08	3.90E-10	1.23E-09	8.47E-09	4.63E-08	1.25E-07
5.	4.22E-09	1.53E-10	1.95E-10	8.72E-10	5.91E-09	1.95E-08
7.5	7.75E-10	1.01E-10	1.49E-10	2.04E-10	9.93E-10	3.63E-09
10.	2.11E-10	9.11E-11	1.02E-10	1.53E-10	3.14E-10	1.04E-09

Table A-1f Mean and fractile seismic hazard curves for 1 Hz at Oconee, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	5.55E-02	2.88E-02	4.07E-02	5.58E-02	7.03E-02	8.00E-02
0.001	3.61E-02	1.74E-02	2.53E-02	3.63E-02	4.63E-02	5.58E-02
0.005	9.29E-03	3.95E-03	5.75E-03	8.85E-03	1.27E-02	1.60E-02
0.01	4.43E-03	1.38E-03	2.22E-03	4.01E-03	6.64E-03	8.85E-03
0.015	2.58E-03	6.26E-04	1.08E-03	2.19E-03	4.07E-03	5.83E-03
0.03	7.58E-04	1.21E-04	2.25E-04	5.50E-04	1.25E-03	2.13E-03
0.05	2.34E-04	2.96E-05	5.66E-05	1.51E-04	3.79E-04	7.34E-04
0.075	8.06E-05	8.98E-06	1.77E-05	4.77E-05	1.36E-04	2.64E-04
0.1	3.67E-05	3.68E-06	7.66E-06	2.04E-05	6.45E-05	1.20E-04
0.15	1.22E-05	1.04E-06	2.25E-06	6.36E-06	2.16E-05	4.13E-05
0.3	2.12E-06	9.65E-08	2.53E-07	9.51E-07	3.57E-06	8.23E-06
0.5	6.05E-07	1.32E-08	4.25E-08	2.16E-07	9.93E-07	2.53E-06
0.75	2.13E-07	2.25E-09	8.85E-09	5.83E-08	3.33E-07	9.51E-07
1.	9.70E-08	6.54E-10	2.68E-09	2.10E-08	1.42E-07	4.50E-07
1.5	2.96E-08	1.92E-10	4.90E-10	4.31E-09	3.79E-08	1.38E-07
3.	2.99E-09	1.05E-10	1.53E-10	2.88E-10	2.64E-09	1.31E-08
5.	4.35E-10	9.11E-11	1.01E-10	1.53E-10	3.57E-10	1.64E-09
7.5	8.04E-11	9.11E-11	1.01E-10	1.53E-10	1.55E-10	3.42E-10
10.	2.22E-11	9.11E-11	1.01E-10	1.53E-10	1.53E-10	1.69E-10

Table A-1g Mean and fractile seismic hazard curves for 0.5 Hz at Oconee, 5% of critical damping

AMPS(g)	MEAN	0.05	0.16	0.50	0.84	0.95
0.0005	2.97E-02	1.57E-02	2.25E-02	2.88E-02	3.73E-02	4.43E-02
0.001	1.79E-02	9.11E-03	1.27E-02	1.69E-02	2.32E-02	2.96E-02
0.005	4.70E-03	1.34E-03	2.25E-03	4.31E-03	7.13E-03	9.37E-03
0.01	2.19E-03	3.37E-04	6.93E-04	1.77E-03	3.73E-03	5.42E-03
0.015	1.23E-03	1.27E-04	2.84E-04	8.47E-04	2.19E-03	3.52E-03
0.03	3.32E-04	1.90E-05	4.56E-05	1.72E-04	5.83E-04	1.21E-03
0.05	9.64E-05	4.01E-06	9.65E-06	4.01E-05	1.62E-04	3.84E-04
0.075	3.15E-05	1.07E-06	2.64E-06	1.10E-05	5.27E-05	1.29E-04
0.1	1.36E-05	3.95E-07	1.05E-06	4.31E-06	2.32E-05	5.58E-05
0.15	4.12E-06	8.98E-08	2.68E-07	1.11E-06	6.83E-06	1.77E-05
0.3	6.18E-07	5.05E-09	2.01E-08	1.21E-07	8.12E-07	3.14E-06
0.5	1.70E-07	5.20E-10	2.46E-09	2.10E-08	1.82E-07	8.85E-07
0.75	6.03E-08	1.74E-10	4.83E-10	4.56E-09	5.27E-08	3.05E-07
1.	2.81E-08	1.53E-10	2.13E-10	1.46E-09	2.01E-08	1.34E-07
1.5	8.95E-09	1.11E-10	1.53E-10	3.33E-10	4.63E-09	3.84E-08
3.	1.01E-09	9.11E-11	1.01E-10	1.53E-10	3.57E-10	3.09E-09
5.	1.64E-10	9.11E-11	1.01E-10	1.53E-10	1.53E-10	4.43E-10
7.5	3.33E-11	9.11E-11	9.37E-11	1.53E-10	1.53E-10	1.72E-10
10.	9.84E-12	9.11E-11	9.11E-11	1.53E-10	1.53E-10	1.53E-10

Table A- 2 Amplification functions for Oconee, 5% of critical damping

PGA	Median AF	Sigma ln(AF)	25 Hz	Median AF	Sigma ln(AF)	10 Hz	Median AF	Sigma ln(AF)	5 Hz	Median AF	Sigma ln(AF)
1.00E-02	1.02E+00	6.68E-02	1.30E-02	1.06E+00	6.81E-02	1.90E-02	1.06E+00	7.12E-02	2.09E-02	1.04E+00	8.27E-02
4.95E-02	1.04E+00	5.92E-02	1.02E-01	1.10E+00	9.96E-02	9.99E-02	1.08E+00	7.08E-02	8.24E-02	1.05E+00	8.18E-02
9.64E-02	1.05E+00	6.00E-02	2.13E-01	1.11E+00	1.03E-01	1.85E-01	1.08E+00	7.06E-02	1.44E-01	1.05E+00	8.14E-02
1.94E-01	1.05E+00	6.10E-02	4.43E-01	1.11E+00	1.04E-01	3.56E-01	1.08E+00	7.06E-02	2.65E-01	1.05E+00	8.11E-02
2.92E-01	1.05E+00	6.16E-02	6.76E-01	1.11E+00	1.04E-01	5.23E-01	1.08E+00	7.07E-02	3.84E-01	1.05E+00	8.10E-02
3.91E-01	1.04E+00	6.19E-02	9.09E-01	1.11E+00	1.04E-01	6.90E-01	1.08E+00	7.09E-02	5.02E-01	1.05E+00	8.09E-02
4.93E-01	1.04E+00	6.21E-02	1.15E+00	1.10E+00	1.04E-01	8.61E-01	1.08E+00	7.12E-02	6.22E-01	1.05E+00	8.09E-02
7.41E-01	1.04E+00	6.24E-02	1.73E+00	1.10E+00	1.03E-01	1.27E+00	1.08E+00	7.19E-02	9.13E-01	1.05E+00	8.09E-02
1.01E+00	1.04E+00	6.26E-02	2.36E+00	1.10E+00	1.03E-01	1.72E+00	1.08E+00	7.26E-02	1.22E+00	1.05E+00	8.10E-02
1.28E+00	1.04E+00	6.26E-02	3.01E+00	1.10E+00	1.03E-01	2.17E+00	1.09E+00	7.36E-02	1.54E+00	1.05E+00	8.12E-02
1.55E+00	1.04E+00	6.26E-02	3.63E+00	1.10E+00	1.03E-01	2.61E+00	1.09E+00	7.49E-02	1.85E+00	1.06E+00	8.14E-02

2.5 Hz	Median AF	Sigma ln(AF)	1 Hz	Median AF	Sigma ln(AF)	0.5 Hz	Median AF	Sigma ln(AF)
2.18E-02	9.31E-01	8.88E-02	1.27E-02	1.02E+00	4.33E-02	8.25E-03	1.08E+00	1.44E-01
7.05E-02	9.32E-01	8.81E-02	3.43E-02	1.02E+00	4.29E-02	1.96E-02	1.08E+00	1.41E-01
1.18E-01	9.33E-01	8.77E-02	5.51E-02	1.02E+00	4.28E-02	3.02E-02	1.08E+00	1.40E-01
2.12E-01	9.34E-01	8.74E-02	9.63E-02	1.02E+00	4.28E-02	5.11E-02	1.08E+00	1.40E-01
3.04E-01	9.34E-01	8.73E-02	1.36E-01	1.02E+00	4.27E-02	7.10E-02	1.08E+00	1.40E-01
3.94E-01	9.34E-01	8.72E-02	1.75E-01	1.02E+00	4.27E-02	9.06E-02	1.08E+00	1.39E-01
4.86E-01	9.35E-01	8.71E-02	2.14E-01	1.02E+00	4.27E-02	1.10E-01	1.08E+00	1.39E-01
7.09E-01	9.35E-01	8.71E-02	3.10E-01	1.02E+00	4.27E-02	1.58E-01	1.08E+00	1.39E-01
9.47E-01	9.35E-01	8.71E-02	4.12E-01	1.02E+00	4.27E-02	2.09E-01	1.08E+00	1.39E-01
1.19E+00	9.35E-01	8.71E-02	5.18E-01	1.02E+00	4.27E-02	2.62E-01	1.08E+00	1.39E-01
1.43E+00	9.36E-01	8.71E-02	6.19E-01	1.02E+00	4.27E-02	3.12E-01	1.08E+00	1.39E-01

Tables A2-b1 and A2-b2 are tabular versions of the typical amplification factors provided in Figures 2.3.6-1 and 2.3.6-2. Values are provided for two input motion levels at approximately 1E-4 and 1E-5 mean annual frequency of exceedance. These tables concentrate on the frequency range of 0.5 Hz to 25 Hz, with values up to 100 Hz included, and a single value at 0.1 Hz included for completeness. These factors are unverified and are provided for information only. The figures should be considered the governing information.

Table A2-b1. Median AFs and sigmas for Model 1, Profile 1, for 2 PGA levels

M1P1K1	Rock PGA=0.292			M1P1K1	PGA=1.01		
Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)	Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)
100.0	0.300	1.027	0.070	100.0	1.028	1.022	0.070
87.1	0.308	1.025	0.070	87.1	1.059	1.018	0.071
75.9	0.322	1.020	0.071	75.9	1.114	1.011	0.072
66.1	0.350	1.007	0.074	66.1	1.222	0.991	0.077
57.5	0.405	0.984	0.084	57.5	1.433	0.960	0.089
50.1	0.494	0.993	0.101	50.1	1.764	0.968	0.107
43.7	0.592	1.006	0.112	43.7	2.111	0.980	0.117
38.0	0.668	1.037	0.114	38.0	2.369	1.017	0.118
33.1	0.716	1.057	0.112	33.1	2.530	1.045	0.115
28.8	0.741	1.099	0.107	28.8	2.604	1.094	0.109
25.1	0.744	1.102	0.101	25.1	2.604	1.104	0.104
21.9	0.732	1.145	0.097	21.9	2.544	1.153	0.099
19.1	0.710	1.131	0.092	19.1	2.445	1.142	0.095
16.6	0.681	1.136	0.087	16.6	2.325	1.148	0.091
14.5	0.649	1.138	0.083	14.5	2.193	1.149	0.086
12.6	0.617	1.116	0.081	12.6	2.064	1.125	0.084
11.0	0.584	1.087	0.081	11.0	1.936	1.094	0.083
9.5	0.551	1.079	0.080	9.5	1.813	1.085	0.082
8.3	0.520	1.107	0.083	8.3	1.698	1.112	0.084
7.2	0.487	1.110	0.087	7.2	1.579	1.114	0.087
6.3	0.453	1.102	0.079	6.3	1.458	1.105	0.079
5.5	0.421	1.076	0.080	5.5	1.349	1.079	0.080
4.8	0.397	1.039	0.084	4.8	1.265	1.042	0.084
4.2	0.363	0.981	0.081	4.2	1.149	0.983	0.081
3.6	0.341	0.950	0.082	3.6	1.076	0.952	0.082
3.2	0.316	0.937	0.099	3.2	0.993	0.939	0.099
2.8	0.283	0.885	0.094	2.8	0.885	0.887	0.094
2.4	0.264	0.897	0.081	2.4	0.823	0.898	0.081
2.1	0.251	0.939	0.087	2.1	0.779	0.939	0.087
1.8	0.229	0.960	0.111	1.8	0.708	0.960	0.111
1.6	0.200	0.969	0.121	1.6	0.617	0.970	0.121
1.4	0.175	0.985	0.095	1.4	0.536	0.985	0.095
1.2	0.157	1.005	0.047	1.2	0.478	1.005	0.047
1.0	0.145	1.030	0.041	1.0	0.439	1.030	0.041
0.91	0.135	1.056	0.064	0.91	0.407	1.056	0.064
0.79	0.124	1.078	0.089	0.79	0.372	1.077	0.089
0.69	0.111	1.090	0.112	0.69	0.332	1.089	0.112
0.60	0.097	1.092	0.129	0.60	0.287	1.091	0.129
0.52	0.082	1.086	0.136	0.52	0.241	1.085	0.135
0.46	0.067	1.075	0.130	0.46	0.198	1.075	0.130
0.10	0.003	1.013	0.033	0.10	0.008	1.010	0.027

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

M2P1K1	PGA=0.292			M2P1K1	PGA=1.01		
Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)	Freq (Hz)	Soil SA	Median AF	Sigma ln(AF)
100.0	0.301	1.030	0.073	100.0	1.036	1.030	0.074
87.1	0.309	1.028	0.073	87.1	1.068	1.027	0.075
75.9	0.323	1.023	0.073	75.9	1.127	1.022	0.076
66.1	0.351	1.010	0.076	66.1	1.242	1.006	0.080
57.5	0.407	0.989	0.086	57.5	1.466	0.983	0.092
50.1	0.498	1.000	0.102	50.1	1.819	0.998	0.108
43.7	0.597	1.014	0.112	43.7	2.181	1.013	0.117
38.0	0.673	1.044	0.115	38.0	2.438	1.046	0.118
33.1	0.721	1.063	0.113	33.1	2.581	1.066	0.115
28.8	0.744	1.103	0.108	28.8	2.632	1.106	0.109
25.1	0.746	1.105	0.103	25.1	2.610	1.106	0.104
21.9	0.733	1.147	0.098	21.9	2.535	1.149	0.099
19.1	0.710	1.132	0.093	19.1	2.429	1.135	0.094
16.6	0.681	1.136	0.088	16.6	2.306	1.139	0.088
14.5	0.649	1.138	0.083	14.5	2.176	1.140	0.084
12.6	0.616	1.115	0.081	12.6	2.049	1.117	0.081
11.0	0.583	1.086	0.081	11.0	1.924	1.088	0.081
9.5	0.551	1.078	0.080	9.5	1.804	1.079	0.080
8.3	0.520	1.107	0.083	8.3	1.691	1.108	0.083
7.2	0.487	1.110	0.087	7.2	1.574	1.111	0.086
6.3	0.453	1.101	0.079	6.3	1.454	1.102	0.079
5.5	0.421	1.076	0.079	5.5	1.346	1.077	0.079
4.8	0.397	1.039	0.084	4.8	1.262	1.040	0.084
4.2	0.363	0.981	0.081	4.2	1.148	0.982	0.081
3.6	0.341	0.950	0.082	3.6	1.075	0.951	0.082
3.2	0.316	0.937	0.099	3.2	0.992	0.938	0.098
2.8	0.283	0.885	0.094	2.8	0.885	0.886	0.094
2.4	0.264	0.897	0.081	2.4	0.823	0.898	0.081
2.1	0.251	0.939	0.087	2.1	0.778	0.939	0.086
1.8	0.229	0.960	0.111	1.8	0.708	0.960	0.111
1.6	0.200	0.969	0.121	1.6	0.616	0.970	0.121
1.4	0.175	0.985	0.095	1.4	0.536	0.985	0.095
1.2	0.157	1.005	0.047	1.2	0.478	1.005	0.047
1.0	0.145	1.030	0.041	1.0	0.439	1.030	0.041
0.91	0.135	1.056	0.064	0.91	0.407	1.056	0.064
0.79	0.124	1.078	0.089	0.79	0.372	1.077	0.088
0.69	0.111	1.090	0.112	0.69	0.332	1.089	0.112
0.60	0.097	1.092	0.129	0.60	0.287	1.091	0.129
0.52	0.082	1.086	0.136	0.52	0.241	1.085	0.135
0.46	0.067	1.075	0.130	0.46	0.198	1.075	0.130
0.10	0.003	1.013	0.033	0.10	0.008	1.010	0.027