Enclosure A
L-14-120

NTTF 2.1 Seismic Hazard and Screening Report
for Beaver Valley Power Station Unit 1
Beaver County, Pennsylvania
(85 pages follow)

ABS Consulting

2734294-R-017
Revision 1

PCR
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NTTF 2.1 Seismic Hazard and Screening Report Beaver Valley Power Station Unit 1 Beaver County, Pennsylvania

March 20, 2014

Prepared for:
FirstEnergy Nuclear Operating Company

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REVISION 1 REPORT

NTTF 2.1 SEISMIC HAZARD AND SCREENING REPORT BEAVER VALLEY POWER STATION UNIT 1 BEAVER COUNTY, PENNSYLVANIA

ABSG CONSULTING INC. REPORT NO. 2734294-R-017
REVISION 1
PROJECT NO. R10 12-4735
MARCH 20, 2014

ABSG CONSULTING INC.
PAUL C. RIZZO ASSOCIATES, INC.

APPROVALS

Report Name: NTTF 2.1 Seismic Hazard and Screening Report
Beaver Valley Power Station Unit 1
Beaver County, Pennsylvania

Date: March 20, 2014

Revision No.: 1

Approval by the responsible manager signifies that the document is complete, all required reviews are complete, and the document is released for use.

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LIST OF ACRONYMS

2D	TWO-DIMENTIONAL
AF	AMPLIFICATION FACTOR
AHEX	ATLANTIC HIGHLY EXTENDED CRUST
BE	BEST ESTIMATE
BVPS	BEAVER VALLEY POWER STATION
BVPS-1	BEAVER VALLEY POWER STATION UNIT 1
BVPS-2	BEAVER VALLEY POWER STATION UNIT 2
CDF	CORE DAMAGE FREQUENCY
CEUS	CENTRAL AND EASTERN UNITED STATES
CEUS-SSC	CENTRAL AND EASTERN UNITED STATES SEISMIC SOURCE CHARACTERIZATION
COV	COEFFICIENT OF VARIATION
DBE	DESIGN BASIS EARTHQUAKE
DF	DESIGN FACTOR
ECC_AM	EXTENDED CONTINENTAL CRUST – ATLANTIC MARGIN
EL	ELEVATION
EPRI	ELECTRIC POWER RESEARCH INSTITUTE
ERM-N	EASTERN RIFT MARGIN FAULT NORTHERN SEGMENT
ERM-S	EASTERN RIFT MARGIN FAULT SOUTHERN SEGMENT
FENOC	FIRSTENERGY NUCLEAR OPERATING COMPANY
FSAR	FINAL SAFETY ANALYSIS REPORT
ft	FEET
ft/s	FEET PER SECOND
g	GRAVITY
GMM	GROUND MOTION MODEL
GMRS	GROUND MOTION RESPONSE SPECTRUM
HCLPF	HIGH CONFIDENCE OF LOW PROBABILITY OF FAILURE
HZ	HERTZ

LIST OF ACRONYMS (CONTINUED)

IBEB	ILLINOIS BASIS EXTENDED BASEMENT
IEPRA	INTERNAL EVENTS PROBABILISTIC RISK ASSESSMENT
IHS	IPEEE HCLPF SPECTRUM
IPEEE	INDIVIDUAL PLANT EXAMINATION OF EXTERNAL EVENTS
ISRS	IN-STRUCTURE RESPONSE SPECTRA
km	KILOMETERS
km/s	KILOMETER PER SECOND
LR	LOWER RANGE
M	MAGNITUDE
MAFE	MEAN ANNUAL FREQUENCY EXCEEDANCE
MESE-N	MESOZOIC AND YOUNGER EXTENDED CRUST – NARROW
MESE-W	MESOZOIC AND YOUNGER EXTENDED CRUST – WIDE
MIDC_A	MIDCONTINENT-CRATON ALTERNATIVE A
MIDC_B	MIDCONTINENT-CRATON ALTERNATIVE B
MIDC_C	MIDCONTINENT-CRATON ALTERNATIVE C
MIDC_D	MIDCONTINENT-CRATON ALTERNATIVE D
MMI	MODIFIED MERCALLI INTENSITY
MWt	MEGA WATTS THERMAL
NAP	NORTHERN APPALACHIANS
NEI	NUCLEAR ENERGY INSTITUTE
NMESE-N	NON-MESOZOIC AND YOUNGER EXTENDED CRUST – NARROW
NMESE-W	NON-MESOZOIC AND YOUNGER EXTENDED CRUST – WIDE
NMFS	NEW MADRID FAULT SYSTEM
NPP	NUCLEAR POWER PLANT
NRC	UNITED STATES NUCLEAR REGULATORY COMMISSION
NSSS	NUCLEAR STEAM SUPPLY SYSTEM
NTTF	NEAR-TERM TASK FORCE
NUREG	NUCLEAR REGULATORY COMMISSION TECHNICAL REPORT
NUREG/CR	NUCLEAR REGULATORY COMMISSION CONTRACTOR REPORT

LIST OF ACRONYMS (CONTINUED)

OBE	OPERATING BASIS EARTHQUAKE
PEZ_N	PALEOZOIC EXTENDED CRUST NARROW
PEZ_W	PALEOZOIC EXTENDED CRUST WIDE
PGA	PEAK GROUND ACCELERATION
PRA	PROBABILISTIC RISK ASSESSMENT
PSHA	PROBABILISTIC SEISMIC HAZARD ANALYSIS
RB	REACTOR BUILDING
RG	REGULATORY GUIDE
RLE	REVIEW LEVEL EARTHQUAKE
RLME	REPEAT LARGE MAGNITUDE EARTHQUAKE
RR	REELFOOT RIFT
RR-RCG	REELFOOT RIFT INCLUDING THE ROUGH CREEK GRABEN
RVT	RANDOM VIBRATION THEORY
s	SECONDS
SER	SAFETY EVALUATION REPORT
SEWS	SEISMIC EVALUATION WORKSHEETS
SLR	ST. LAWRENCE RIFT ZONE
SMA	SEISMIC MARGIN ASSESSMENT
SPID	SCREENING, PRIORITIZATION, AND IMPLEMENTATION DETAILS
SPRA	SEISMIC PROBABILISTIC RISK ASSESSMENT
SPT	STANDARD PENETRATION TEST
SQUG	SEISMIC QUALIFICATION UTILITY GROUP
SRSS	SQUARE-ROOT OF THE SUM OF THE SQUARES
SSC	SYSTEM, STRUCTURE, AND COMPONENTS
SSE	SAFE SHUTDOWN EARTHQUAKE
SSEL	SAFE SHUTDOWN EQUIPMENT LIST
SSI	SOIL STRUCTURE INTERACTION
STUDY_R	STUDY REGION
S&W	STONE & WEBSTER ENGINEERING COORPORATION

LIST OF ACRONYMS (CONTINUED)

UHRS	UNIFORM HAZARD RESPONSE SPECTRA
UFSAR	UPDATED SAFETY ANALYSIS REPORT
UR	UPPER RANGE
V_p	PRESSURE WAVE VELOCITY
V_s	SHEAR WAVE VELOCITY

NTTF 2.1 SEISMIC HAZARD AND SCREENING REPORT BEAVER VALLEY POWER STATION UNIT 1 BEAVER COUNTY, PENNSYLVANIA

1.0 INTRODUCTION

Following the accident at the Fukushima Daiichi Nuclear Power Plant (NPP) resulting from the March 11, 2011, Great Tohoku Earthquake and subsequent tsunami, the United States 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 (NRC, 2012a) that requests information to assure that these recommendations are addressed by all United States NPPs. 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 NRC 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 (NRC, 2012a) pertaining to NTTF Recommendation 2.1 for the Beaver Valley Power Station Unit 1 (BVPS-1). The BVPS-1 is located in Shippingport Borough on the south bank of the Ohio River in Beaver County. The Site is approximately one mile from Midland, Pennsylvania, five miles from East Liverpool, Ohio, and approximately 25 miles from Pittsburgh, Pennsylvania. BVPS-1 includes a pressurized water reactor Nuclear Steam Supply System (NSSS) and turbine generator furnished by Westinghouse Electric Corporation. The balance of the unit was designed and constructed by

the Licensee, with the assistance of their agent, Stone & Webster Engineering Corporation (S&W). The nominal NSSS power level for BVPS-1 is set at 2,910 Mega Watts Thermal (MWt). The initial fuel load commenced in February, 1976 and commercial operation was achieved in September, 1976.

In providing the information contained here, FirstEnergy Nuclear Operating Company (FENOC) has 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* (Electric Power Research Institute [EPRI], 2013a). The Augmented Approach, *Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima NTTF Recommendation 2.1: Seismic* (EPRI, 2013b), 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 evaluation, if required.

Reference is made to FENOC's Partial Submittal (FENOC, 2013a) summarizing the Site geologic and geotechnical information. The "Description of Subsurface Materials and Properties," and the "Development of Base-Case Profiles and Nonlinear Material Properties" presented in FENOC, (2013a), are repeated here for completeness.

1.1 Summary of Licensing Basis

The original geologic and seismic siting investigations for BVPS-1 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 (SSCs). The Category I SSCs are identified in Table B.1-1 of Appendix B of the Updated Safety Analysis Report (UFSAR) (FENOC, 2011).

1.2 Summary of Ground Motion Response Spectrum and Screening Results

In response to the 50.54(f) letter and following the guidance provided in the SPID (EPRI 1025287, 2012), a seismic hazard reevaluation was performed. For screening purposes, a horizontal Ground Motion Response Spectrum (GMRS) was developed. Based on the results of

the screening evaluation, BVPS-1 screens in for risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency Confirmation. In the 1 to 10 Hertz (Hz) part of the response spectrum, the GMRS exceeds the horizontal SSE and above 10 Hz the GMRS also exceeds the horizontal SSE.

1.3 ORGANIZATION OF THIS REPORT

The remainder of this Report is organized as follows: ***Section 2*** provides the Seismic Hazard Reevaluation that was performed for the BVPS Site, including the probabilistic seismic hazard analysis (PSHA) for hard rock site conditions, the site response evaluation, seismic hazard at the SSE control point, and the derivation of the horizontal GMRS. The discussion in ***Section 2*** applies to both Units 1 and 2 of the BVPS. ***Section 3*** provides a summary of the BVPS-1 SSE ground motion. ***Section 4*** provides the screening evaluation, including a comparison between the GMRS and SSE, and the screening evaluation outcome. ***Section 5*** describes interim actions completed for BVPS-1, and ***Section 6*** provides conclusions.

2.0 SEISMIC HAZARD REEVALUATION

The BVPS-1 is located in Shippingport Borough on the south bank of the Ohio River in Beaver County, Pennsylvania. The Ohio River Valley is an erosional, flat-bottomed, and steep-walled valley. The bedrock of Pennsylvanian age is a sequence of flat-lying shale and sandstone strata occasionally inter-bedded with coal seams. It is overlain by about 100 feet (ft) thick alluvial granular terraces that formed during the Pleistocene. Plant grade is elevation (EL) 735 ft and the top of bedrock is at approximate EL 625 ft.

The Site area is located in a region with a low rate of seismicity. Historically, no earthquake of epicentral Modified Mercalli Intensity (MMI) V, or greater, has occurred within 80 miles of the Site. The Site has experienced vibratory ground motion as a result of regional and distant earthquakes, most notably the 1811-12 earthquake sequence at New Madrid, Missouri, and the 1886 earthquake at Charleston, South Carolina.

Category I SSCs are designed for a safe shutdown following SSE ground motions associated with horizontal zero-period acceleration of 12.5 percent gravity (0.125g) at the rock surface at foundation level.

2.1 REGIONAL AND LOCAL GEOLOGY

The Beaver Valley Power Station (BVPS) is located in an unglaciated area on sand and gravel deposits along the Ohio River, west of Pittsburgh and a few miles east of the Pennsylvania - Ohio border.

Physiographically, the Site is located in the Appalachian Plateau Province. The bedrock in the area is the Allegheny Formation of Pennsylvanian Age. It consists of approximately two-thirds shale and one-third sandstone with several interbedded coal seams and a thin bed of fossiliferous Vanport limestone.

The stratigraphic materials underlying the bedrock are characterized by various sedimentary sequences of Mississippian, Devonian, Silurian, Ordovician, and Precambrian age, consisting of

shales, interbedded sandstones, siltstones and dolomites, and limestone. These rocks overlie the Precambrian basement at a depth of approximately 11,000 ft.

Structurally, the bedrock is generally flat lying. It has a regional dip of approximately 15 to 20 feet per mile to the south and southeast with low amplitude anticlines and synclines. The regional dip and structure were imposed by orogenic movements that formed the Appalachian Mountains, about 100 miles southeast of the Site, at the close of the Paleozoic Era.

2.2 PROBABILISTIC SEISMIC HAZARD ANALYSIS

2.2.1 Probabilistic Seismic Hazard Analysis Results

In accordance with the 50.54(f) letter (NRC, 2012a) and following the guidance in the SPID (EPRI, 2013a), a PSHA was completed using the recently developed Central and Eastern United States Seismic Source Characterization (CEUS-SSC) for Nuclear Facilities (EPRI/DOE/NRC, 2012). The PSHA uses a minimum moment magnitude cutoff of 5.0 for hazard integration, as specified in the 50.54(f) letter (NRC, 2012a).

The CEUS-SSC model consists of distributed seismicity sources and repeated large magnitude earthquake (RLME) sources. Distributed seismicity sources are characterized following two approaches: the M_{max} approach and the seismotectonic approach.

The BVPS-1 PSHA accounts for the CEUS-SSC distributed seismicity source zones out to at least a distance of 400 miles (640 kilometers [km]) around the BVPS-1. This distance exceeds the 200 mile (320 km) recommendation contained in NRC (2007) and was chosen for completeness. Distributed seismicity source zones included in this Site PSHA are the following:

- Mesozoic and younger extended crust – narrow and wide (MESE-N and MESE-W)
- Non-Mesozoic and younger extended crust – narrow and wide (NMESE-N and NMESE-W)
- Study Region (STUDY_R)
- Atlantic Highly Extended Crust (AHEX)
- Northern Appalachians (NAP)

- St. Lawrence Rift, including the Ottawa and Saguenay grabens (SLR)
- Extended Continental Crust – Atlantic Margin (ECC_AM)
- Illinois Basin Extended Basement (IBEB)
- Midcontinent-Craton (MIDC_A, MIDC_B, MID_C, and MID_D)
- Paleozoic Extended Crust – narrow and wide (PEZ_N and PEZ_W)
- Reelfoot Rift (RR and RR-RCG)

RLME seismic sources within or near 1,000 km from the Site are included in the PSHA as follows:

- Charlevoix
- Charleston
- New Madrid Fault System (NMFS)
- Eastern Rift Margin Fault - northern and southern segments (ERM-N and ERM_S)
- Marianna Zone
- Commerce Fault
- Wabash Valley

For each of the above distributed seismicity and RLME sources, the mid-continent version of the updated EPRI Ground Motion Model (GMM) was used (EPRI, 2013c).

2.2.2 Base Rock Seismic Hazard Curves

While the SPID (EPRI, 2013a) does not require that base rock seismic hazard curves be provided, they are included here as background information. These were developed by FENOC as part of an on-going SPRA effort. ***Figure 2-1 and Table 2-1*** present the mean hard-rock hazard curves at the BVPS-1 Site resulting from the PSHA. The hazard curves show the mean annual frequency of exceedance (MAFE) for spectral acceleration at the seven response spectral frequencies (100 Hz, 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz), for which the updated EPRI GMM (2013c) is defined.

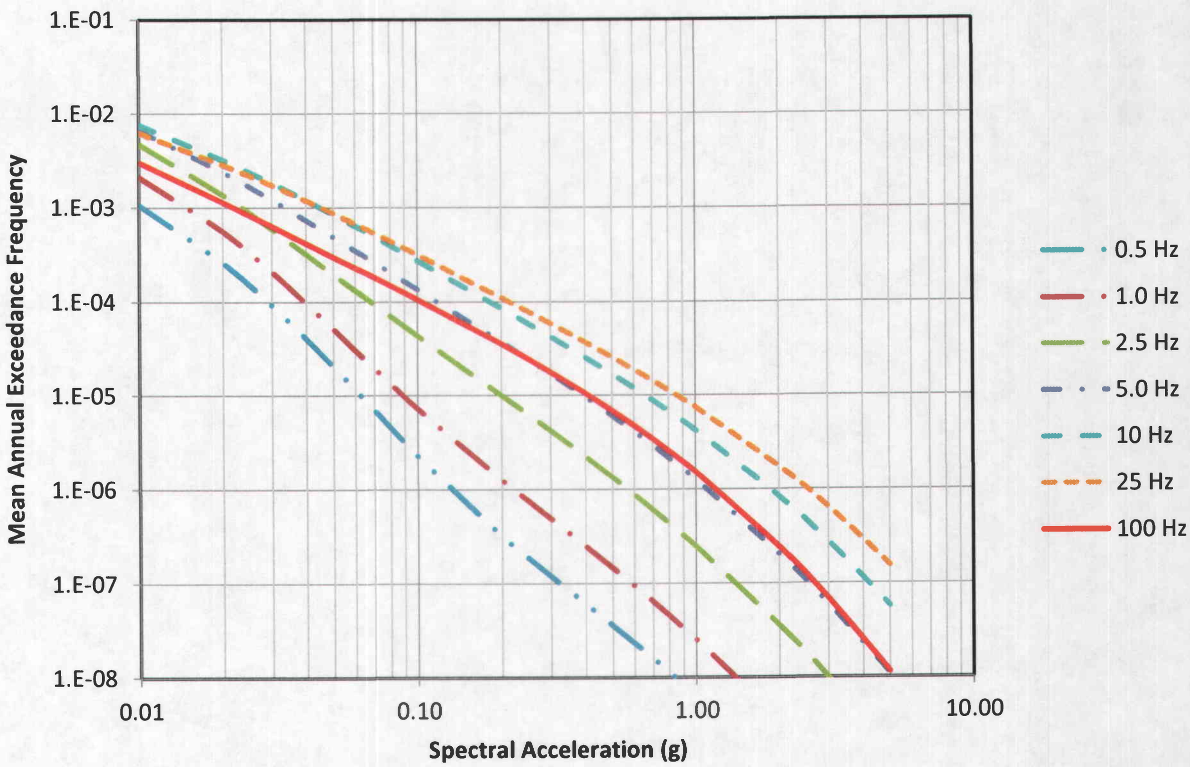


FIGURE 2-1
BVPS-1 MEAN SEISMIC HAZARD AT HARD ROCK

Consistent with the SPID (EPRI, 2013a), Approach 3 of Nuclear Regulatory Commission Contractor Report (NUREG/CR-6728) (McGuire et al., 2001) is used to calculate the seismic hazard curves at the SSE control point elevation (the base of the Reactor Building [RB] foundation). This method uses the median and log standard deviation of the site amplification factors (AF) developed as described in ***Section 2.3***. The control point hazard curves are presented in ***Section 2.4.4***.

TABLE 2-1
MEAN SEISMIC HAZARD AT HARD ROCK
BVPS-1 SITE

GROUND MOTION LEVEL [g]	MEAN ANNUAL FREQUENCY OF EXCEEDANCE FOR SPECTRAL FREQUENCY						
	0.5 Hz	1 Hz	2.5 Hz	5 Hz	10 Hz	25 Hz	100 Hz
0.01	1.05E-03	2.10E-03	4.67E-03	6.62E-03	7.53E-03	6.17E-03	3.01E-03
0.02	2.59E-04	5.58E-04	1.36E-03	2.38E-03	3.20E-03	2.84E-03	1.14E-03
0.03	9.17E-05	2.09E-04	5.91E-04	1.21E-03	1.82E-03	1.73E-03	6.34E-04
0.04	4.02E-05	9.64E-05	3.17E-04	7.28E-04	1.19E-03	1.18E-03	4.16E-04
0.05	2.04E-05	5.14E-05	1.94E-04	4.86E-04	8.41E-04	8.67E-04	2.99E-04
0.06	1.15E-05	3.05E-05	1.31E-04	3.48E-04	6.30E-04	6.69E-04	2.29E-04
0.07	7.01E-06	1.96E-05	9.33E-05	2.62E-04	4.91E-04	5.35E-04	1.82E-04
0.08	4.57E-06	1.34E-05	6.99E-05	2.05E-04	3.94E-04	4.40E-04	1.49E-04
0.09	3.15E-06	9.66E-06	5.43E-05	1.64E-04	3.25E-04	3.70E-04	1.25E-04
0.10	2.27E-06	7.24E-06	4.33E-05	1.35E-04	2.72E-04	3.16E-04	1.06E-04
0.20	3.20E-07	1.27E-06	1.00E-05	3.71E-05	8.46E-05	1.10E-04	3.57E-05
0.25	1.84E-07	7.49E-07	6.23E-06	2.42E-05	5.77E-05	7.81E-05	2.45E-05
0.30	1.19E-07	4.90E-07	4.21E-06	1.70E-05	4.21E-05	5.86E-05	1.78E-05
0.40	6.05E-08	2.50E-07	2.23E-06	9.62E-06	2.53E-05	3.69E-05	1.06E-05
0.50	3.57E-08	1.47E-07	1.34E-06	6.05E-06	1.68E-05	2.55E-05	6.87E-06
0.60	2.30E-08	9.39E-08	8.73E-07	4.09E-06	1.19E-05	1.87E-05	4.75E-06
0.70	1.58E-08	6.38E-08	6.02E-07	2.91E-06	8.78E-06	1.43E-05	3.42E-06
0.80	1.13E-08	4.54E-08	4.33E-07	2.14E-06	6.72E-06	1.12E-05	2.55E-06
0.90	8.36E-09	3.33E-08	3.22E-07	1.62E-06	5.27E-06	9.03E-06	1.95E-06
1.00	6.36E-09	2.52E-08	2.45E-07	1.26E-06	4.21E-06	7.39E-06	1.52E-06
2.00	9.20E-10	3.41E-09	3.54E-08	2.01E-07	8.26E-07	1.72E-06	2.42E-07
3.00	2.61E-10	9.24E-10	9.86E-09	5.93E-08	2.74E-07	6.38E-07	6.85E-08
5.00	4.60E-11	1.53E-10	1.66E-09	1.08E-08	5.67E-08	1.54E-07	1.13E-08

2.3 SITE RESPONSE EVALUATION

Category I structures of the BVPS-1 are founded in the Pleistocene Upper and Lower Terrace unit at elevations varying from 680.9 ft for the RB to 703 ft for the Control Building to about 735 ft for the Diesel Generator Building. The Pleistocene Upper and Lower Terrace unit is characterized by a shear-wave velocity (V_S) of about 1,100 to 1,200 feet per second (ft/s). Following the guidance contained in Seismic Enclosure 1, of the March 12, 2012, 50.54(f)

Request for Information (NRC, 2012a) and in the SPID (EPRI, 2013a) for NPPs that are not sited on hard rock (defined as 2.83 kilometers per second [km/s]), a site response analysis was performed for BVPS-1 Site. The following sections describe the various inputs to the site response analysis. These inputs are summarized in ***Appendix A***.

2.3.1 Description of Subsurface Materials and Properties

The site stratigraphy presented here is based in part on site-specific geotechnical investigations reported in the UFSAR (FENOC, 2011, Section 2.6.2 and Appendix 2E). Thirty-five dry sample borings at the Shippingport Power Station were supplemented by 30 additional borings at the BVPS. These included 10 dry sample borings on the high terrace, and the remaining borings located in the intermediate and low terrace materials. All borings penetrated approximately 20 ft into bedrock. The geologic profile below the reported subsurface investigation depth is based on the analysis of formation tops and bottoms from available deep well logs in the vicinity of the Site (within about 7 miles), obtained from the Pennsylvania Geological Survey. This is supplemented by information from West Virginia and Ohio Geological Surveys, as well as the UFSAR.

The terrace deposits in the Site area are characterized by three levels: high, intermediate, and low. The low terrace is the most recent, where the upper alluvial deposit is composed of brown silty clay approximately 20 to 30 ft thick. The intermediate terrace consists of medium clays extending to about EL 660 ft. The oldest, high terrace is the most abundant deposit at the plant location. The terrace materials in the plant area (high terrace deposits) consist of unconsolidated and stratified sand and gravel outwash derived from the melting of glacial ice at the end of Pleistocene time. The surface sand and gravel layer is underlain by relatively dense and incompressible sand and gravel extending down to bedrock at approximately EL 625 ft. Major structures of the plant are founded in the high terrace sands and gravel either directly or on compacted backfill. Thin deposits of mud, silt, and sand deposited by flood water on the Ohio River and tributary streams overlay the terrace sands and gravel.

The subsurface materials properties summarized here are based on the geotechnical investigations described in the UFSAR. The borings in the intermediate and low terrace materials retrieved undisturbed samples of surface clays and silts for physical testing. However, no samples were obtained in the high terrace materials. The properties for these materials are

based on Standard Penetration Test (SPT) blow counts and in-situ geophysical measurements. Properties of the bedrock material are based on both laboratory tests and in-situ geophysical measurements.

Figure 2-2 presents the stratigraphic soil/rock column underlying the Site, and ***Table 2-2*** presents the stratigraphy, identifying unit boundary elevations and depths as estimated from the subsurface investigations reported in the UFSAR and available well logs in the Site vicinity. Due to the relative proximity of the deep wells to the Site, the unit lithologies and depths encountered in those wells can be reliably assumed to be similar to those below the Site.

Legend	Epoch or Period	Lithology
	Ple-istocene	(1). Pleistocene: upper terrace: unconsolidated sand and gravel with varying amounts of clay and silt. Lower terrace: 30-40' of silt and clay with sand and gravel overlying gravels
	Pennsylvanian	(2). Middle Pennsylvanian Allegheny Group: gray shale with interbedded sandstones, coal seams, underclays and a limestone bed
		(3). Lower Pennsylvanian Pottsville Group: sandstone and conglomerate
	Mississipian	(4). Upper Mississippian Mauch Chunk Formation: red shale with sandstone
		(5). Lower Mississippian Pocono Group: sandstone and conglomerate w/ shale
	U. Devonian	(6). Upper Devonian undivided: interbedded shale, sandstone and siltstone. (Equivalent to the Ohio Shale)
	M. Devonian	(7). Middle Devonian Tully Limestone
		(8). Middle Devonian Mahantango shale
		(9). Middle Devonian Marcellus Shale
		(10). Middle Devonian Onondaga Group (Eqv. to Needmore shale/ Selinsgrove Limestone): limestones and dolomites
	L. Devonian	(11). Lower Devonian Ridgeley (Oriskany) sandstone
		(12). Lower Devonian Helderberg Formation: limestone/shale
	U. Silurian	(13). Upper Silurian Bass Island Group: dolomite and limestone
		(14). Upper Silurian Salina Group/Tonoloway Formation: dolomite and limestone
		(15). Upper Silurian Wells Creek Formation: shale
	L/M. Silurian	(16). Middle Silurian Lockport dolomite
		(17). Middle Silurian Rochester Shale
		(18). Middle Silurian Rose Hill formation: shale with sandstone
		(19). Lower Silurian Tuscarora Formation: sandstone with conglomerate
	U. Ordovcian	(20). Upper Ordovician Queenston Formation: shale, siltstone and sandstone
		(21). Upper Ordovician Reedsville Shale
	L/M. Ordovician	(22). Middle Ordovician Utica Shale
		(23). Middle Ordovician Trenton Group (Black River
		(24). Middle Ordovician Gull River and Glenwood Formations: limestone and dolomite
		(25). Lower Ordovician Beekmantown Group: dolomite
	Cambrian	(26). Upper Cambrian Gatesburg Formation: dolomite and dolomitic sandstone
		(27). Middle Cambrian Rome Formation: dolomite
		(28). Lower Cambrian Mt. Simon Formation: sandstone
	PerC.	(29). Precambrian Granite

FIGURE 2-2
STRATIGRAPHIC COLUMN UNDERLYING THE BVPS-1 SITE

TABLE 2-2
SUBSURFACE STRATIGRAPHY AND UNIT THICKNESSES AT THE BVPS-1 SITE

TOP EL [ft]	BOTTOM EL [ft]	LITHOLOGY	TOP DEPTH [ft]	BOTTOM DEPTH [ft]
735	625	Pleistocene: upper terrace: Unconsolidated sand and gravel with varying amounts of clay and silt. Lower terrace: 30 to 40 ft of silt and clay with sand and gravel overlying gravels	0	110
625	550	Middle Pennsylvanian Allegheny Group: gray shale with interbedded sandstones, coal seams, underclays, and a limestone bed	110	185
550	350	Lower Pennsylvanian Pottsville Group: sandstone and conglomerate	185	385
350	300	Upper Mississippian Mauch Chunk Formation: red shale with sandstone	385	435
300	-120	Lower Mississippian Pocono Group: sandstone and conglomerate with shale	435	855
-120	-3,700	Upper Devonian undivided: interbedded shale, sandstone, and siltstone.	855	4,435
-3,700	-3,820	Middle Devonian Tully Limestone	4,435	4,555
-3,820	-3,900	Middle Devonian Mahantango Shale	4,555	4,635
-3,900	-3,935	Middle Devonian Marcellus Shale	4,635	4,670
-3,935	-4,150	Middle Devonian Onondaga Group Shale/Selinsgrove Limestone	4,670	4,885
-4,150	-4,250	Lower Devonian Ridgeley (Oriskany) Sandstone	4,885	4,985
-4,250	-4,450	Lower Devonian Helderberg Formation: limestone/shale	4,985	5,185

2.3.2 Development of Base Case Profiles and Non-Linear Material Properties

Most major structures of the BVPS-1 are founded in the upper terrace sand and gravel layers. The RB is supported on in-situ soils at EL 680.9 ft. Other structures are supported on compacted backfill placed on the terrace sand and gravel at foundation elevations varying between EL 703 ft for the Control Building to about EL 735 ft for the Diesel Generator Building. Based on the UFSAR (FENOC, 2011) description of the seismic analysis, the control point elevation for GMRS is taken to be the base of the RB foundation level (EL 680.9 ft).

The shear and compression wave velocities of the overburden soils and the shale bedrock are based on the subsurface investigations reported in the UFSAR (FENOC, 2011), particularly Appendix 2G. Appendix 2G summarizes the geophysical investigations consisting of cross-hole, up-hole, and down-hole measurements in five drill holes located in the reactor area. Compression- and shear-wave velocities were measured from direct arrival times. A limited amount of seismic refraction survey investigation was also performed to verify the elevation of bedrock, and to determine velocity layering.

Variabilities in the Vs of the bedrock material and the overburden soil are estimated, respectively, from velocity measurements and lab tests, and the SPT data.

The deep rock stratigraphy, as well as the seismic velocities of these strata, relies on sonic logs recorded in wells in the Site vicinity (within 7 miles). The sonic data were converted to compression-wave velocities (Vp) and (Vs) based on published literature (Pickett, 1963; Rafavich, 1984; Miller, 1990; and Castagna, 1993) reflecting the material type (limestone and dolomite, anhydrites and salts), porosity and density, and to a lesser extent, the lithology. Additionally, based on published literature, Vp/Vs ratios for these types of geologic units were used to define the epistemic uncertainty for V_S.

Varying unit thicknesses, incomplete well logs, and non-standard lithologic descriptions present some challenges to reliably estimating contact locations. However, the lithologic units in the region are generally flat lying and for the most part, laterally consistent. Consequently, the velocity structure in the wells examined is similar and consistent from well to well for similar depths. Due to the proximity of these deep wells to the Site and the general flat lying (low dip) nature of the geologic units, the unit lithologies and thicknesses can be reliably assumed to be similar to those below the Site

Table 2-3 presents the summary geotechnical profile identifying the layer thicknesses, Vs and Vp, and uncertainties in these parameters. From ***Table 2-3***, the SSE control point is at EL 680.9 ft within the Pleistocene Upper and Lower Terrace unit with a best estimate (BE) Vs of 1,100 ft/s.

TABLE 2-3
CHARACTERISTICS OF SUBSURFACE STRATIGRAPHIC UNITS - BVPS-1 SITE

ELEVATION [ft]	LAYER NO.	SOIL/ROCK DESCRIPTION	γ_{total} [D] [pcf]	Vs[A] [ft/s]	μ[E]
Plant Grade (Surface Elevation)					
735		Structural Fill/ Natural and Densified Soil	136	730±183[B]	0.35[B]
720		Structural Fill/ Natural and Densified Soil	136	1015±254[B]	0.35[B]
680.9	1(d)	Pleistocene Upper and Lower Terrace	125	1100±275[B]	0.28[B]
680.9	.	**GMRS Elevation - SSE Control Point at Base of Nuclear Island Foundation**			
665		**Ground Water Elevation**			
665	1(e)	Pleistocene Upper and Lower Terrace	136	1200±300[B]	0.48[B]
625	2	Middle Pennsylvanian Allegheny Shale	160	5000±1000[B]	0.39[B]
550[C]	3	Lower Pennsylvanian Pottsville Sandstone, conglomerate	160	6,026	0.30
350	4	Upper Mississippian Mauch Chunk Shale	155	6,744	0.30
300	5	Lower Mississippian Pocono Sandstone conglomerate	155	6,744	0.30
-120	6	Upper Devonian Interbedded Shale, Sandstone, Siltstone	155	7,112	0.30
-2,994			155	6,416	0.30
-3,700	7	Middle Devonian Tully Limestone	168	9,856	0.30
-3,820	8	Middle Devonian Mahantango Shale	157	9,856	0.30
-3,900	9	Middle Devonian Marcellus Shale	157	9,856	0.30
-3,935	10	Middle Devonian Onondaga Limestone, Dolomite	170	9,856	0.30
-4,150	11	Lower Devonian Ridgeley Sandstone	160	9,856	0.30
-4,250	12	Lower Devonian Helderberg Limestone, Shale	170	9,856	0.30
-4,450	13	Upper Silurian Bass Island Dolomite, Limestone	170	8,352	0.30
-4,540	14	Upper Silurian Salina Dolomite, Limestone	170	8,352	0.30
-5,034			170	9,547	0.30
-5,330	15	Upper Silurian Wells Creek Shale	163	11,534	0.30
-5,550	16	Middle Silurian Lockport Dolomite	170	9,015	0.30
-5,900	17	Middle Silurian Rochester Shale	163	9,015	0.30
-5,980	18	Middle Silurian Rose Hill Shale	163	9,015	0.30
-6,170	19	Lower Silurian Tuscarora Sandstone	163	8,588	0.30
-6,390	20	Upper Ordovician Queenston Shale, Siltstone, Sandstone	163	8,588	0.30
-7,123	21		163	7,835	0.30
-7,455	21(a)	Upper Ordovician Reedsville Shale	163	7835	0.30
-7,698	21(b)		163	6834	0.30
-8,265	22	Middle Ordovician Utica Shale	163	6834	0.30
-8,565	23	Middle Ordovician Trenton Limestone	175	10,520	0.30
-9,305	24	Middle Ordovician Gull River Limestone, Dolomite	175	10,520	0.30
-9,455	25	Lower Ordovician Beekmantown Dolomite	175	10,520	0.30

TABLE 2-3
CHARACTERISTICS OF SUBSURFACE STRATIGRAPHIC UNITS - BVPS-1 SITE (CONTINUED)

ELEVATION [ft]	LAYER NO.	SOIL/ROCK DESCRIPTION	γ_{total}[D] [pcf]	Vs[A] [ft/s]	μ[E]
-9,645	26	Upper Cambrian Gatesburg Dolomite Sandstone	170	10,520	0.30
-9,995	27	Middle Cambrian Rome Dolomite	175	10,520	0.30
-10,695	28	Lower Cambrian Mt. Simon Sandstone	170	10,520	0.30
-10,865	29	Precambrian Granite	175	10,520	0.30

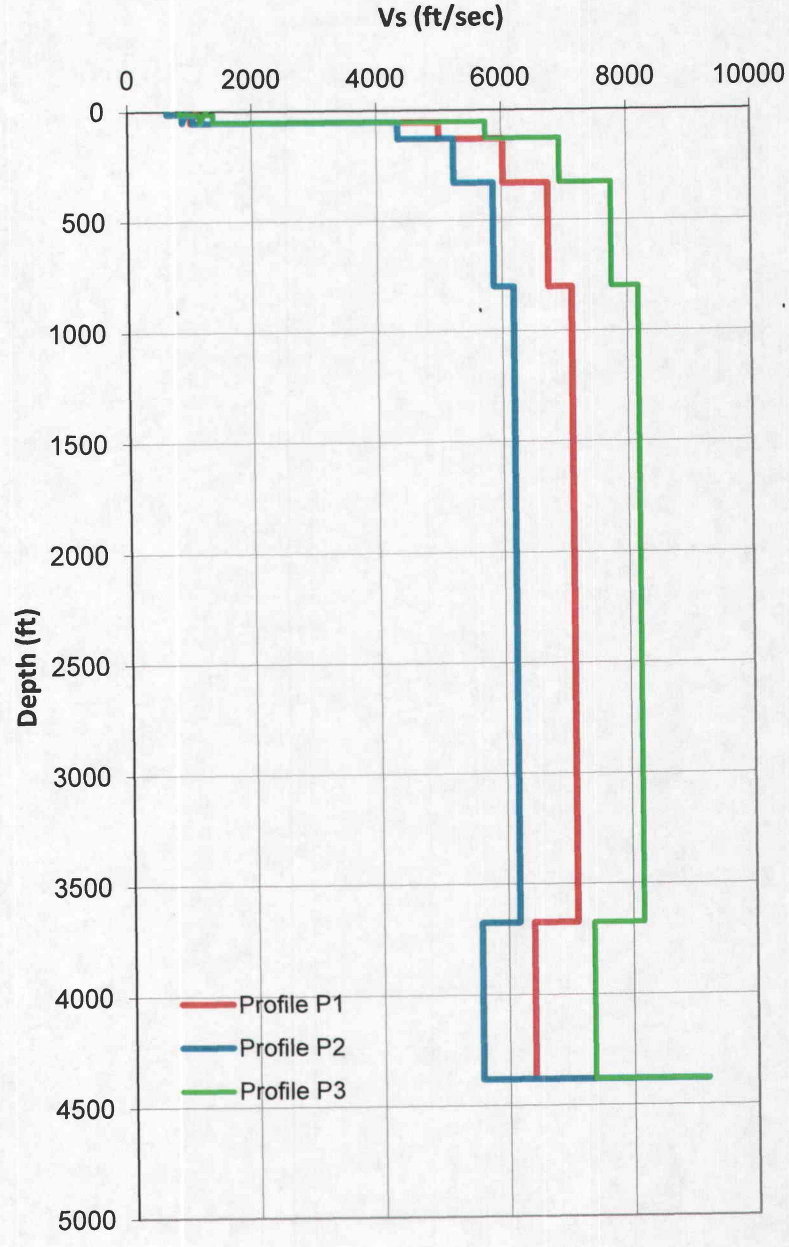
Notes:

A. Variability in Vs of soil is based on SPT-V_s correlations (COV=25 percent). COV is assumed 20 percent as average of soil and rock for the rock at the top and for deeper rock units COV = 11 percent is assumed based on the information from deep wells; B. Appendix 2D, 2G and 2H of BVPS-1 UFSAR; C. From this elevation down, soil parameters are estimates from sonic velocities of deep wells except unit weight. Unit weights are typical values from the literature. Poisson's ratio is calculated by following formula: Poisson's Ratio = $[(Vp/Vs)^2 - 2] / [2(Vp/Vs)^2 - 2]$; D. Unit weight; E. Poisson's ratio.

2.3.2.1 Base-Case Shear-Wave Velocity Profiles

Based on the well characterized nature of the Site, the generally flat lying geologic units, and the geology-specific V_P to V_S conversions, a scale factor of 1.15 is used for developing upper and lower base-cases to reflect epistemic uncertainty in the V_S. The scale factor of 1.15 reflects a realistic range in Poisson's ratio for the type of geologic units found in the Paleozoic rocks underlying the site. The V_s profiles determined using the scale factor represent the epistemic uncertainty in the soil and rock column from the Tully Limestone formation at EL -3,700 ft to the top of the Pleistocene Upper and Lower Terrace unit underlying the base of the RB foundation mat.

Using the BE V_S specified in ***Table 2-3***, three base-case profiles were developed using the scale factor of 1.15. The specified V_S were taken as the mean or BE base-case profile (P1) and the scaled profiles as the lower and upper range (UR) base-cases profiles (P2 and P3), respectively. All three profiles extend to hard rock conditions below the RB foundation at a depth of 4,380.9 ft. The base-case profiles (P1, P2, and P3) are shown on ***Figure 2-3*** and listed in ***Table 2-4***.



*Depth 0 ft corresponds to EL 680.9 ft

FIGURE 2-3
BASE CASE V_S PROFILES, BVPS-1 SITE

TABLE 2-4
BASE CASE V_S PROFILES, BVPS-1 SITE

TOP OF LAYER ELEVATION [ft]	PROFILE P1		PROFILE P2		PROFILE P3	
	V_s [ft/s]	DEPTH [ft]	V_s [ft/s]	DEPTH [ft]	V_s [ft/s]	DEPTH [ft]
680.9	1100	0	957	0	1265	0
665	1100	15.9	957	15.9	1265	15.9
665	1200	15.9	1043	15.9	1380	15.9
625	1200	55.9	1043	55.9	1380	55.9
625	5000	55.9	4348	55.9	5750	55.9
550	5000	130.9	4348	130.9	5750	130.9
550	6026	130.9	5240	130.9	6930	130.9
350	6026	330.9	5240	330.9	6930	330.9
350	6744	330.9	5864	330.9	7756	330.9
300	6744	380.9	5864	380.9	7756	380.9
300	6744	380.9	5864	380.9	7756	380.9
-120	6744	800.9	5864	800.9	7756	800.9
-120	7112	800.9	6184	800.9	8179	800.9
-2994	7112	3674.9	6184	3674.9	8179	3674.9
-2994	6416	3674.9	5579	3674.9	7378	3674.9
-3700	6416	4380.9	5579	4380.9	7378	4380.9
-3700	9200	4380.9	9200	4380.9	9200	4380.9

2.3.2.2 Shear Modulus and Damping Curves

The site response analysis represents non-linear material properties by utilizing shear modulus degradation and material damping as functions of the seismic shear strain. Strain-dependent dynamic parameters for the overburden soils are reported in Appendix 2D, Figure 2D-3 of BVPS-1 UFSAR (FENOC, 2011), and Figure 2.5.4-71 of the Beaver Valley Power Station Unit 2 (BVPS-2) UFSAR (FENOC, 2012). The material damping ratio is limited to a maximum of 15 percent in the calculations following guidance in NRC (2007) (Regulatory Guide [RG] 1.208).

Consistent with the SPID (EPRI 2013a), uncertainty and variability in material dynamic properties are included in the site response analysis. For the rock material over the upper 500 ft, uncertainty is represented by modeling the material as either linear or non-linear in its dynamic behavior. To represent the epistemic uncertainty in shear modulus and damping, two sets of shear modulus reduction, and hysteretic damping curves were used. Consistent with the SPID

(EPRI, 2013a), the EPRI rock curves (model M1) were used to represent the UR nonlinearity likely in the materials at this Site, and linear behavior (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 500 ft. Below a depth of 500 ft, linear material behavior is assumed for both models, with the damping value specified consistent with the kappa estimates for the Site (values discussed in ***Section 2.3.2.3*** and shown in ***Table 2-5***).

2.3.2.3 Kappa

Near-surface site damping is often described in terms of the parameter kappa (EPRI, 2013a). Section B-5.1.3.1 of the SPID (EPRI, 2013a) recommends the following procedure for evaluating kappa:

1. Kappa for a firm rock site with at least 3,000 ft (1 km) of sedimentary rock may be estimated from the time-averaged V_S over the upper 100 ft (V_{s100}) of the subsurface profile.

2. Kappa for a site with less than 3,000 ft (1 km) of firm rock may be estimated with Q_s of 40 below 500 ft combined with the low strain damping from the EPRI rock curves and an additional kappa of 0.006s for the underlying hard rock.

For the BVPS-1 Site, kappa was estimated using the first of the above approaches because the thickness of the sedimentary rock overlying hard rock is 4,380.9 ft. There is sufficient confidence, based on deep well data, that the hard-rock horizon is more than 3,000 ft below the elevation of the RB foundation. Including a kappa of 0.006s for the underlying hard rock, the total site kappa is estimated to be 0.0213s for profile P1, 0.0237s for profile P2, and 0.0193s for Profile P3.

To complete the representation of uncertainty in kappa and, at the same time, reduce computational demands, a 50 percent variation to the base-case kappa estimates was added for profiles P2 and P3. For profile P2, the softest profile, the base-case kappa estimate of 0.0237s was augmented with a 50 percent increase in kappa to a value of 0.0320s, resulting in two sets of analyses for profile P2. Similarly, uncertainty in kappa for profile P3, the stiffest profile, was augmented with a 50 percent reduction in kappa, resulting in analyses with low strain kappa

values of 0.0193s and 0.0152s. The suite of kappa estimates and associated weights is listed in ***Table 2-5***. The base-case kappa estimates were judged to be the more likely (by 50 percent) with weights of 0.6 compared to the augmented values with weights of 0.4.

To maintain consistency in the site response analyses, the low-strain damping values are adjusted consistent with the kappa value associated with each profile.

TABLE 2-5
KAPPA VALUES AND WEIGHTS USED IN SITE RESPONSE ANALYSIS

VELOCITY PROFILE	PROFILE WEIGHT	KAPPA [s]	KAPPA WEIGHT
P1 Base-Case	0.4	0.0213 (Kappa 1)	1.0
P2 Lower Range	0.3	0.0237 (Kappa 1)	0.6
		0.0320 (Kappa 2)	0.4
P3 Upper Range	0.3	0.0193 (Kappa 1)	0.6
		0.0152 (Kappa 2)	0.4

This unsymmetric approach results in an appropriate representation of the epistemic uncertainty in site response. It also significantly reduces computational demands relative to specifying three alternative kappa values for each velocity profile. When uncertainty and variability in other inputs are also considered, it results in 6,600 site response analyses (5 combinations of profiles and kappa values, 2 material behavior models [linear and nonlinear for the upper 500 ft], 2 source models [single and double corner inputs], 11 loading levels, and 30 soil profile realizations). The range of kappa values presented in ***Table 2-5*** is utilized in the site response analysis that is combined with the hard-rock seismic hazard to obtain the control point seismic hazard and the GMRS.

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 V_S profiles and shear-strain-dependent shear modulus reduction, and damping curves are incorporated in the site response calculations.

2.3.3.1 Randomization of Shear-wave Velocity Profiles

For the BVPS-1 Site, aleatory variability in the V_S profile for the Site is represented by 30 randomized profiles developed from each of the base-case profiles shown on ***Figure 2-3***.

These randomized V_S profiles were generated using a natural log standard deviation of 0.25 over the top 50 ft and 0.15 over the remaining soil column depth. As specified in the SPID (EPRI, 2013a), correlation of V_S between layers was modeled using the footprint correlation model. In the correlation model, a limit of +/- 2 standard deviations, and a factor of 1.3 about the median value in each layer was assumed for the limits on random velocity fluctuations. Additionally, profiles were constrained to not exceed a V_S of 9,200 ft/s.

2.3.3.2 Randomization of Modulus Reduction and Hysteretic Damping Curves

For the BVPS-1 Site, aleatory variability in dynamic material property curves is represented using 30 randomizations derived from the base-case for each alternative model. The random generation of G/G_{max} and damping ratio values are limited to upper and lower bounds of the BE ± two standard deviations, consistent with the SPID (EPRI, 2013a). The damping ratio values are limited to 15 percent. Also consistent with the SPID (EPRI, 2013a), a log normal distribution is used with a natural log standard deviation of 0.15 and 0.30 for modulus reduction and hysteretic damping, respectively.

2.3.4 Input Fourier Amplitude Spectra

Consistent with the guidance in Appendix B of the SPID (EPRI, 2013a), input Fourier amplitude spectra were defined for a single representative earthquake magnitude (M 6.5) using two different models for the shape of the seismic source spectrum (single-corner and double-corner). By selecting appropriate distances and depths, a suite of 11 different input amplitudes (median peak ground acceleration (PGA) ranging from 0.01 to 1.5 g) were modeled for use in the site response analyses. The characteristics of the seismic source and upper crustal attenuation properties assumed for the analysis of the BVPS-1 Site were the same as those identified in Tables B-4, B-5, B-6, and B-7 of the SPID (EPRI, 2013a) as appropriate for typical Central and Eastern United States (CEUS) Sites.

2.3.5 Site Response Methodology

The site response analysis reported here implements an equivalent-linear method using the random vibration theory (RVT) approach. This process utilizes a simple, efficient method for computing site-specific amplification functions and is consistent with existing NRC guidance and the SPID (EPRI, 2013a). The guidance contained in Appendix B of the SPID (EPRI, 2013a) on incorporating epistemic uncertainty in V_S, kappa, dynamic material properties, and source spectra was followed for the BVPS-1 Site.

2.3.6 Amplification Factors

The results of the site response analysis consist of factors (5-percent damped pseudo absolute acceleration response spectra), that describe the amplification (or de-amplification) of reference hard-rock response spectra as a function of frequency and input reference hard-rock PGA amplitude. Amplification is determined for the SSE control point elevation at the base of the RB foundation level. Because of the uncertainty and variability incorporated in the site response analysis, a distribution of AF is produced. The AF are represented by a median (i.e., log-mean) amplification value and an associated log standard deviation (sigma-ln) for each oscillator frequency and input rock amplitude. Consistent with the SPID (EPRI, 2013a), median amplification was constrained to not fall below 0.5 to avoid extreme de-amplification that may reflect limitations of the methodology.

Figure 2-4 presents the median and +/- 1 standard deviation in the predicted AF developed for the 11 loading levels parameterized by the reference (hard rock) PGA (0.01 to 1.50g) for profile P1 and EPRI rock G/G_{max}, and hysteretic damping curves (EPRI, 2003a). Further, the AF shown on ***Figure 2-4*** are developed for the hard-rock input motion based on the single-corner frequency source model. The variability in the AF results from variability in V_S and modulus reduction and hysteretic damping curves. ***Figure 2-5*** presents similar information for profile P1 using the linear dynamic material property representation.

Comparison of AF, including the effects of material nonlinearity in the BVPS-1 Site firm rock layers (model M1),with the corresponding AF developed with linear site response analyses (model M2) shows only minor effects of non-linearity for frequencies below about 20 Hz and a

loading level less than about 0.5g. Above about the 0.5g loading level, the differences increase, but only for spectral frequencies in excess of about 20 Hz.

Appendix A provides several tables that summarize the site response uncertainty analysis, including the development of the site response logic tree (Vs models, kappa, and dynamic properties) and a summary of the numerical values of the AF at seven spectral frequencies and 11 input PGA values at hard-rock. Additionally, ***Appendix A*** provides tables of the AF for three loading levels consistent with the information shown on ***Figures 2-4 and 2-5.***

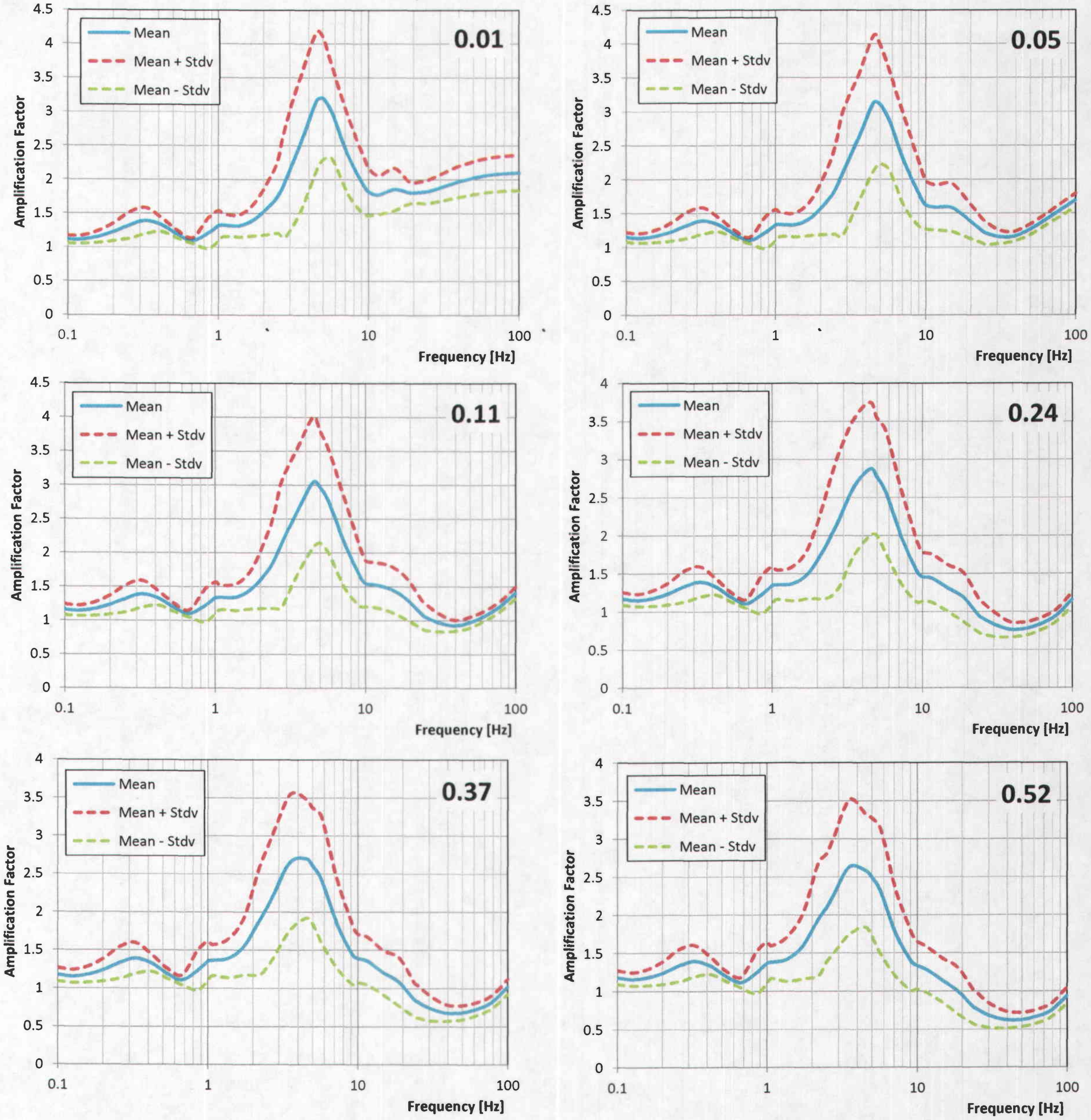


FIGURE 2-4
BVPS-1 SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), EPRI ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:

Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

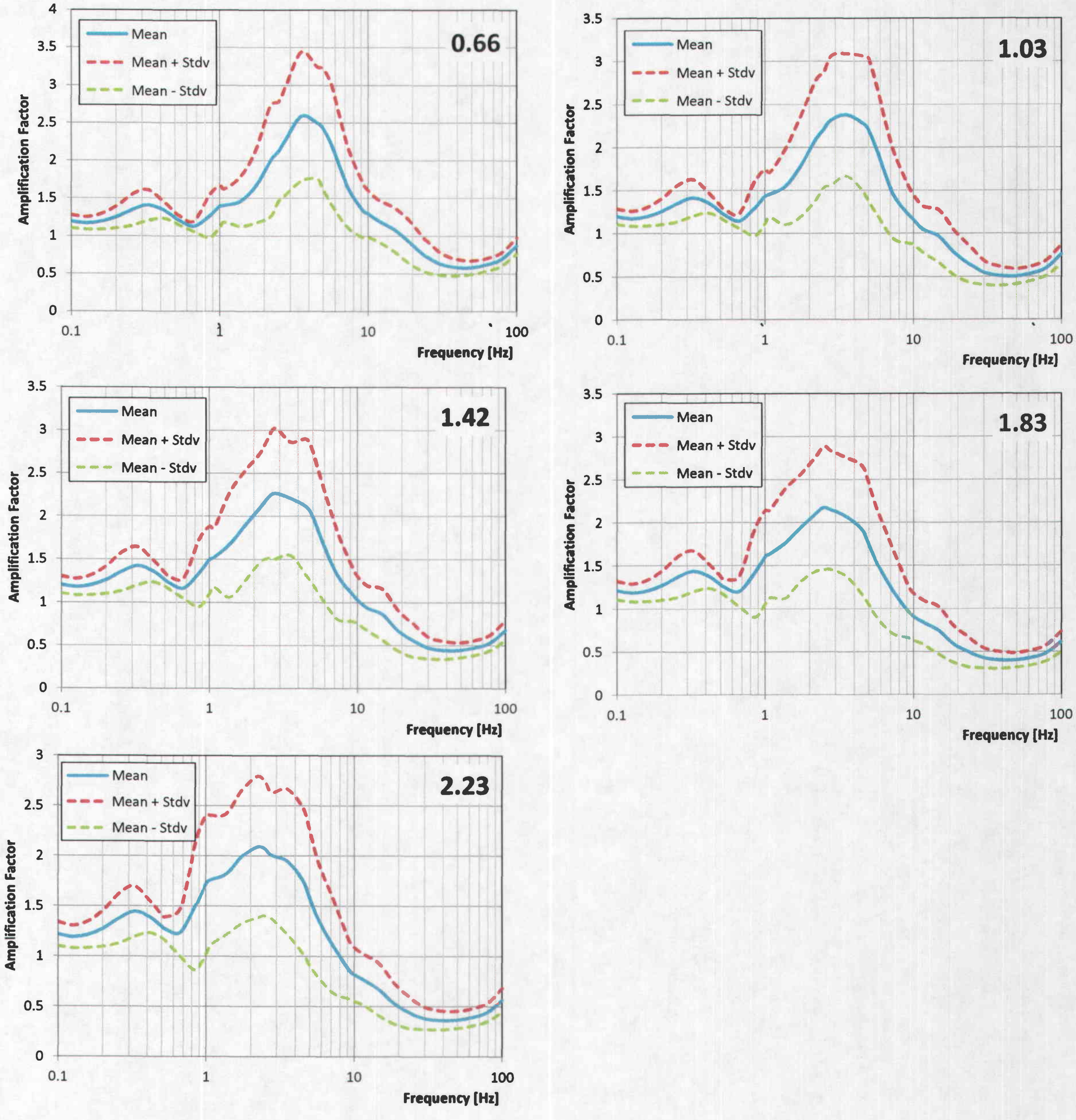


FIGURE 2-4
(CONTINUED)
BVPS-1 SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), EPRI ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:

Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

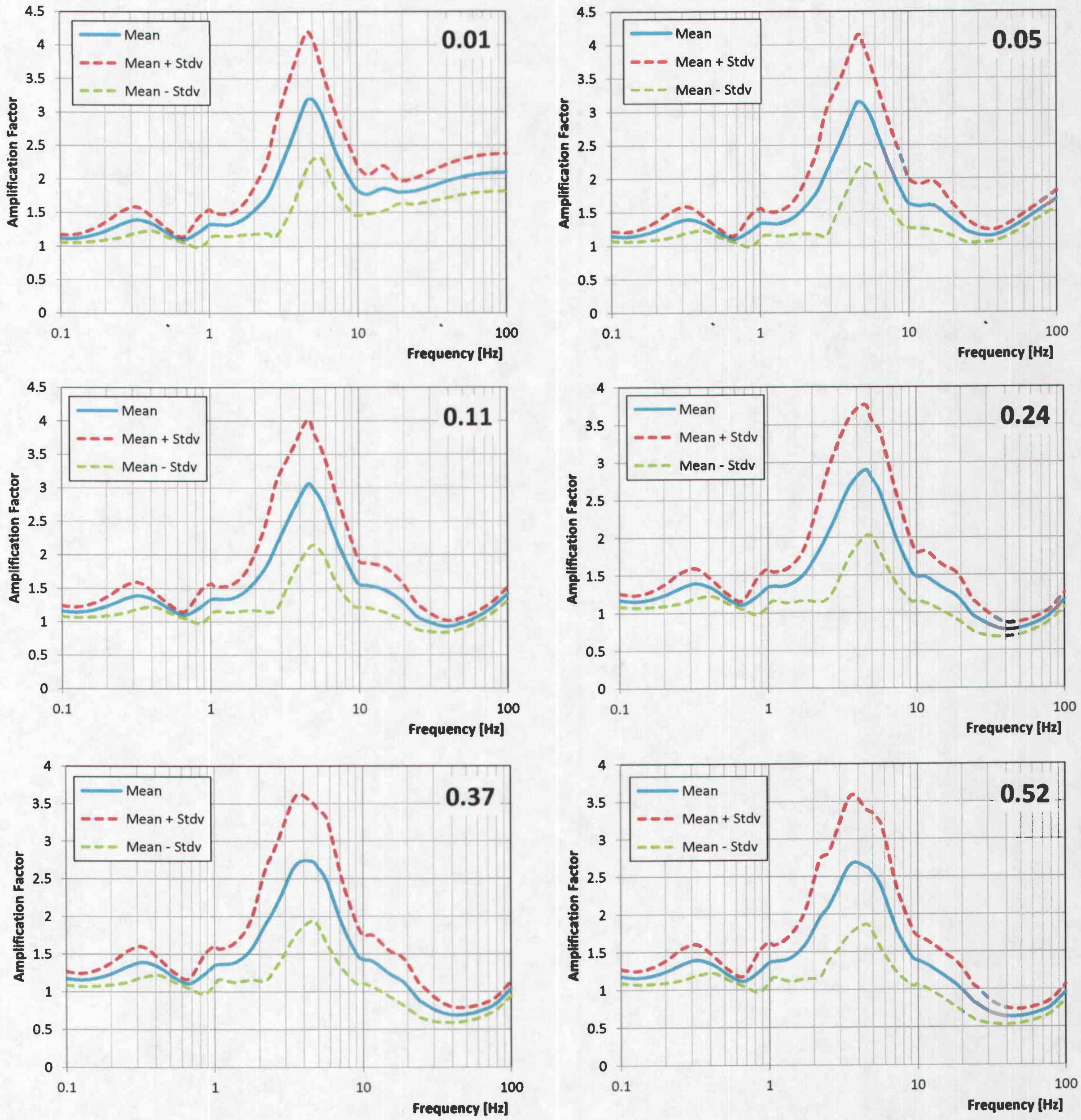


FIGURE 2-5
BVPS-1 SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), LINEAR ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:

Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

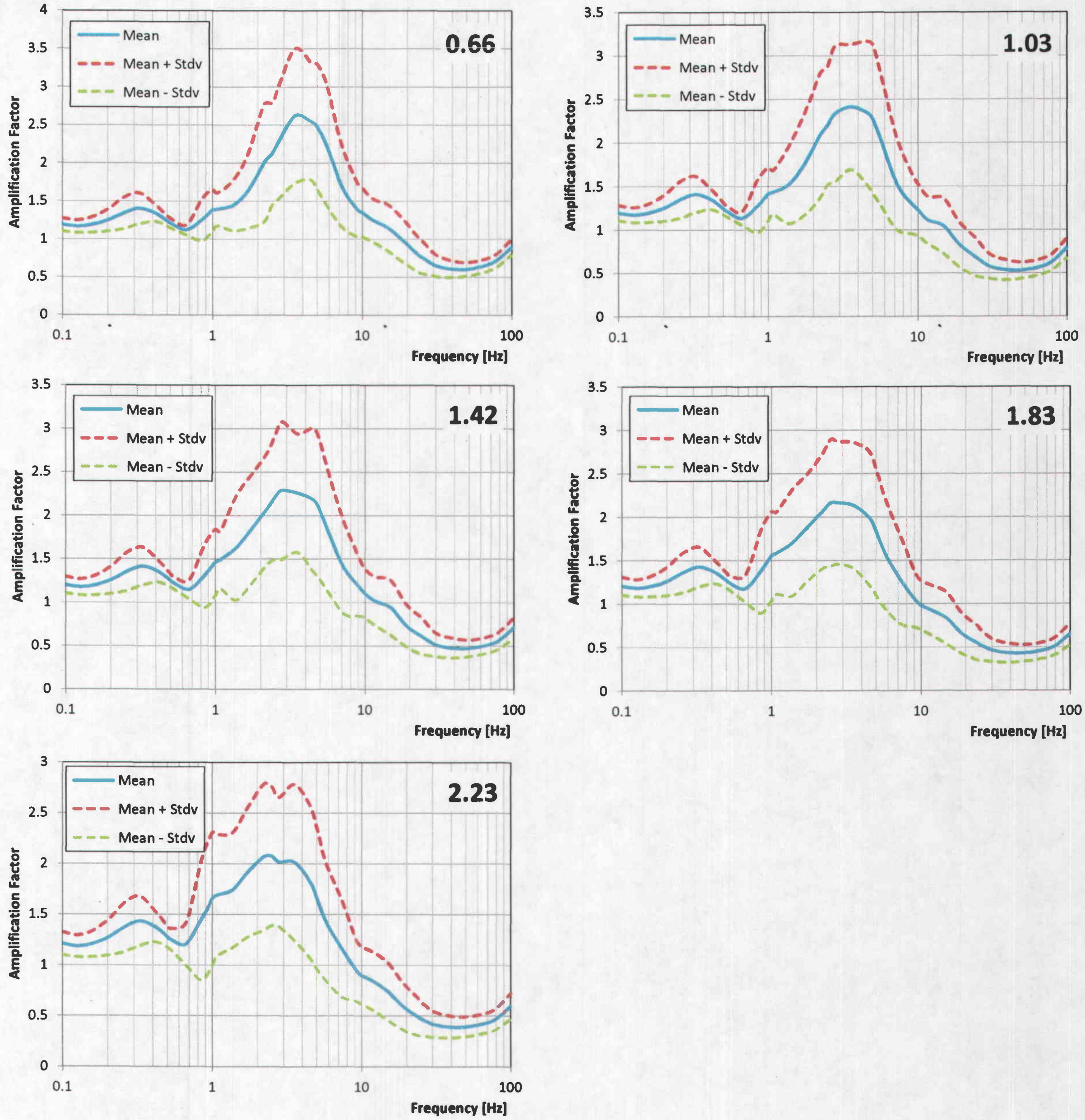


FIGURE 2-5
(CONTINUED)
BVPS-1 SITE AMPLIFICATION FACTORS, BASE-CASE PROFILE (P1), LINEAR ROCK G/GMAX AND DAMPING, KAPPA 1, 1-CORNER SOURCE MODEL

Note:

Quantities in the upper right hand corner represent the hard rock input 100 Hz spectral acceleration in g's.

2.4 CONTROL POINT SEISMIC HAZARD CURVES

As presented in ***Section 3.2*** below, the control point elevation is taken to be the base of the RB foundation level (EL 680.9 ft). The procedure to develop probabilistic site-specific control point hazard curves follows the methodology described in Section B-6.0 of the SPID (EPRI, 2013a). This procedure (referred to as Approach 3) computes a site-specific control point hazard curve for a broad range of spectral accelerations given the site-specific bedrock hazard curve and site-specific estimates of soil or soft-rock response and associated uncertainties. This process is repeated for each of the seven specified spectral frequencies, for which the EPRI (2013c) GMM is defined.

The dynamic response of the rock column below the control point elevation is represented by the frequency and amplitude-dependent amplification functions (median values and ln-standard deviations) developed and described in the previous section. The resulting control point mean hazard curves for the BVPS-1 Site are shown on ***Figure 2-6 and in Table 2-6*** for the seven spectral frequencies, for which the EPRI (2013c) GMM is defined. Tabulated values of the site response amplification functions and the control point hazard curves for various fractiles are provided in ***Appendix C***.

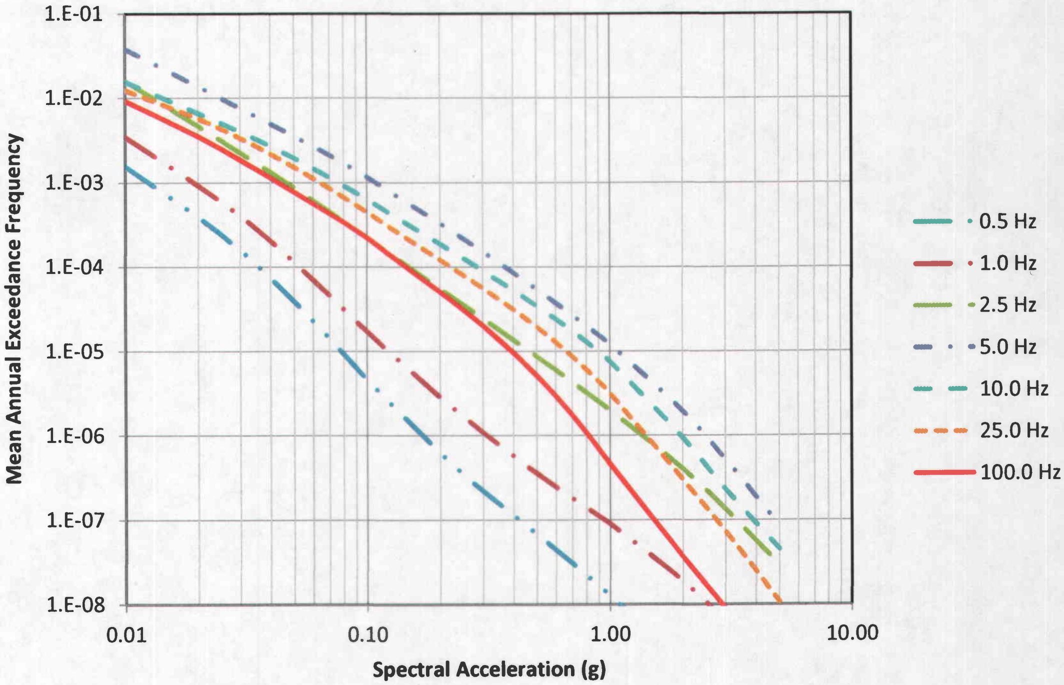


FIGURE 2-6
BVPS-1 MEAN CONTROL POINT SEISMIC HAZARD AT SELECTED SPECTRAL FREQUENCIES

TABLE 2-6
BVPS-1 MEAN CONTROL POINT SEISMIC HAZARD AT SELECTED SPECTRAL FREQUENCIES

GROUND MOTION LEVEL [g]	MEAN ANNUAL FREQUENCY OF EXCEEDANCE FOR SPECTRAL FREQUENCIES						
	0.5 Hz	1.0 Hz	2.5 Hz	5.0 Hz	10 Hz	25 Hz	100 Hz
0.02	3.86E-04	9.16E-04	4.59E-03	1.36E-02	6.54E-03	5.65E-03	3.49E-03
0.03	1.55E-04	3.99E-04	2.22E-03	7.48E-03	3.94E-03	3.30E-03	1.83E-03
0.04	7.32E-05	2.01E-04	1.30E-03	4.89E-03	2.67E-03	2.14E-03	1.13E-03
0.05	3.87E-05	1.13E-04	8.56E-04	3.50E-03	1.92E-03	1.50E-03	7.68E-04
0.06	2.25E-05	6.94E-05	6.02E-04	2.65E-03	1.45E-03	1.10E-03	5.59E-04
0.07	1.40E-05	4.54E-05	4.45E-04	2.08E-03	1.13E-03	8.40E-04	4.26E-04
0.08	9.21E-06	3.13E-05	3.42E-04	1.68E-03	9.11E-04	6.62E-04	3.36E-04
0.09	6.35E-06	2.26E-05	2.70E-04	1.38E-03	7.49E-04	5.34E-04	2.69E-04
0.10	4.56E-06	1.69E-05	2.19E-04	1.15E-03	6.27E-04	4.40E-04	2.19E-04
0.20	6.21E-07	2.83E-06	5.46E-05	3.26E-04	1.86E-04	1.20E-04	5.03E-05
0.25	3.41E-07	1.66E-06	3.49E-05	2.14E-04	1.25E-04	7.89E-05	3.06E-05

TABLE 2-6
BVPS-1 MEAN CONTROL POINT SEISMIC HAZARD AT SELECTED SPECTRAL FREQUENCIES (CONTINUED)

GROUND MOTION LEVEL [g]	MEAN ANNUAL FREQUENCY OF EXCEEDANCE FOR SPECTRAL FREQUENCIES						
	0.5 Hz	1.0 Hz	2.5 Hz	5.0 Hz	10 Hz	25 Hz	100 Hz
0.30	2.18E-07	1.08E-06	2.42E-05	1.50E-04	8.94E-05	5.54E-05	1.99E-05
0.40	1.13E-07	5.69E-07	1.35E-05	8.49E-05	5.24E-05	3.10E-05	9.52E-06
0.50	6.72E-08	3.53E-07	8.58E-06	5.39E-05	3.41E-05	1.92E-05	5.08E-06
0.60	4.37E-08	2.43E-07	5.89E-06	3.69E-05	2.37E-05	1.26E-05	2.90E-06
0.70	3.03E-08	1.79E-07	4.26E-06	2.66E-05	1.72E-05	8.56E-06	1.73E-06
0.80	2.19E-08	1.39E-07	3.21E-06	1.99E-05	1.28E-05	6.00E-06	1.07E-06
0.90	1.64E-08	1.10E-07	2.49E-06	1.53E-05	9.69E-06	4.30E-06	6.89E-07
1.00	1.27E-08	8.95E-08	1.98E-06	1.20E-05	7.48E-06	3.14E-06	4.59E-07
2.00	1.96E-09	1.87E-08	3.98E-07	1.92E-06	9.25E-07	2.97E-07	3.64E-08
3.00	6.07E-10	6.19E-09	1.32E-07	5.15E-07	2.28E-07	7.21E-08	8.88E-09
5.00	1.17E-10	1.35E-09	2.89E-08	8.50E-08	4.47E-08	1.07E-08	1.22E-09

2.5 CONTROL POINT RESPONSE SPECTRUM

The control point hazard curves described above have been used to develop uniform hazard response spectra (UHRS) and the GMRS. To ensure that important site response frequencies are accurately modeled, the control point response spectra are based on smoothed UHRS developed at the hard-rock boundary using the approach described by NRC (2007a) and McGuire et al., (2001). The UHRS was obtained through linear interpolation in log-log space to estimate the spectral acceleration at each oscillator 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 RG 1.208. ***Table 2-7*** presents the control point 1E-4 and 1E-5 UHRS and the GMRS, and ***Figure 2-7*** graphically illustrates the GMRS relative to the UHRS.

TABLE 2-7
BVPS-1 5%-DAMPED UHRS AND GMRS AT THE SSE CONTROL POINT

FREQUENCY [Hz]	CONTROL POINT HORIZONTAL SPECTRAL ACCELERATION [g]		
	1x10^{-4} UHRS	1x10^{-5} UHRS	GMRS
0.10	0.0027	0.0067	0.0033
0.13	0.0039	0.0096	0.0048
0.16	0.0057	0.0141	0.0071
0.20	0.0088	0.0213	0.0107
0.26	0.0136	0.0325	0.0164
0.33	0.0203	0.0473	0.0240
0.42	0.0284	0.0640	0.0326
0.50	0.0357	0.0782	0.0401
0.53	0.0356	0.0786	0.0402
0.67	0.0375	0.0844	0.0431
0.85	0.0468	0.1081	0.0549
1.00	0.0524	0.1217	0.0617
1.08	0.0563	0.1336	0.0674
1.37	0.0688	0.1771	0.0879
1.74	0.0832	0.2373	0.1154
2.21	0.1189	0.3783	0.1801
2.50	0.1476	0.4650	0.2218
2.81	0.1842	0.5725	0.2738
3.56	0.2661	0.8292	0.3964
4.52	0.3501	1.0356	0.5002
5.00	0.3691	1.0801	0.5228
5.74	0.3707	1.0691	0.5190
7.28	0.3180	0.9291	0.4499
9.24	0.2816	0.8816	0.4210
10.00	0.2824	0.8879	0.4237
11.72	0.2869	0.8895	0.4256
14.87	0.2888	0.8880	0.4256
18.87	0.2646	0.7877	0.3800
23.95	0.2255	0.6776	0.3263
25.00	0.2205	0.6580	0.3173
30.39	0.2027	0.5765	0.2807
38.57	0.1904	0.5267	0.2578
48.94	0.1828	0.4871	0.2402
62.10	0.1704	0.4431	0.2196
78.80	0.1526	0.3938	0.1955
100.00	0.1455	0.3929	0.1933

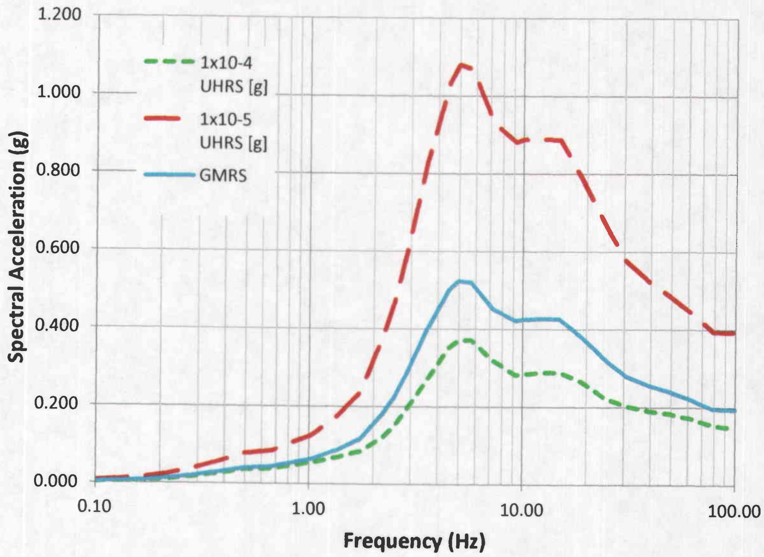


FIGURE 2-7
CONTROL POINT UNIFORM HAZARD RESPONSE SPECTRA AT MEAN ANNUAL FREQUENCIES OF EXCEEDANCE OF 1X10^{-4} AND 1X10^{-5}, AND GROUND MOTION RESPONSE SPECTRUM AT BVPS-1

3.0 PLANT DESIGN BASIS GROUND MOTION

The design basis for BVPS-1 is identified in the UFSAR (FENOC, 2011).

3.1 SSE DESCRIPTION OF SPECTRAL SHAPE

The SSE was developed in accordance with conservative deterministic principles through an evaluation of the maximum earthquake potential for the region surrounding the Site. Based on deterministic hazard analysis, the UFSAR (FENOC, 2011, Section 2.5 and Appendix 2C) reports two design basis earthquakes, the SSE and the Operating Basis Earthquake (OBE). The purpose of the seismicity analysis is to evaluate earthquakes that have been recorded historically and instrumentally in order to determine the OBE and the SSE. The SSE ground motion accounts for the soil conditions at the Site.

The SSE response spectra for the BVPS-1 Site are anchored at PGA of 0.125g horizontal and 0.083g vertical (Section 2.5.3 of UFSAR [FENOC, 2011]). Dynamic AF used for these spectra give a maximum spectral acceleration of 0.44g for two percent damping, with appropriate relative values for other amounts of damping. The spectra are flat from 2 to 5 Hz and reduce to an amplification ratio of unity for frequency exceeding 20 Hz.

The 5-percent-damped horizontal SSE spectral accelerations are presented in ***Table 3-1***. The corresponding vertical spectrum for the SSE is taken to be 2/3 of the horizontal. ***Figure 3-1*** presents the SSE 5%-Damped Response Spectra.

TABLE 3-1
SSE HORIZONTAL GROUND MOTION RESPONSE SPECTRUM FOR BVPS-1

FREQUENCY [Hz]	SPECTRAL ACCELERATION [g]
0.20	0.012
0.50	0.076
2.00	0.325
5.00	0.325
20.00	0.125
100.00	0.125

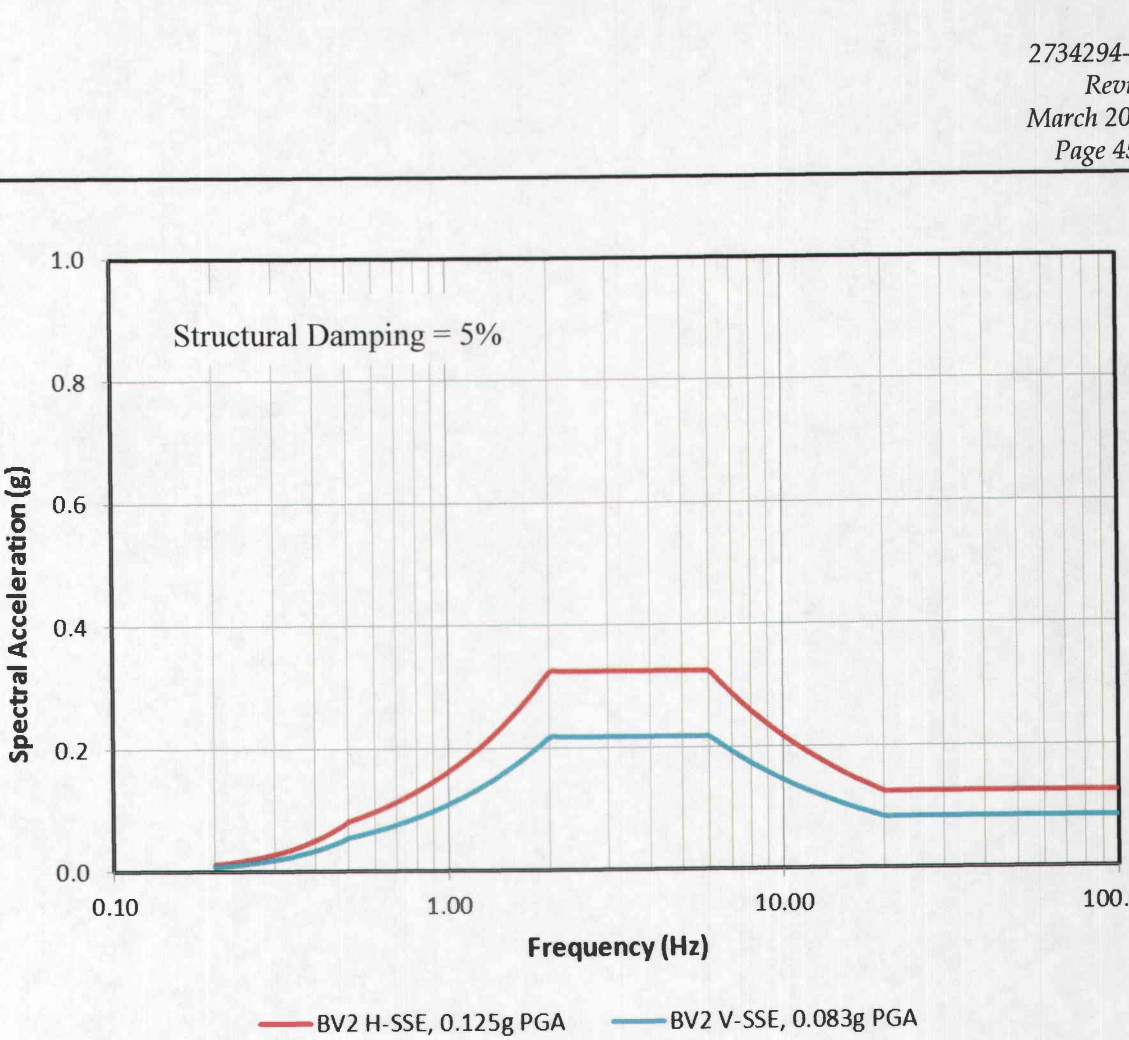


FIGURE 3-1
BVPS-1 SAFE SHUTDOWN EARTHQUAKE 5%-DAMPED RESPONSE SPECTRA

3.2 SSE CONTROL POINT ELEVATION

The horizontal and vertical SSE response spectra shown on ***Figure 3-1*** represent the design basis ground motion input applied at the base of the foundation levels of the BVPS-1 structures. At BVPS-1, the top of bedrock is at EL 625 ft and the foundation elevation of the RB and the Nuclear Island is 680.9 ft. The SSE control point elevation is taken to be the base of the RB foundation, and the SSE response spectra are, therefore, compared to the GMRS at EL 680.9 ft.

4.0 SCREENING EVALUATION

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

The screening process determines if a seismic risk evaluation is needed. The horizontal GMRS determined from the hazard reevaluation is used to characterize the amplitude of the updated evaluation of seismic hazard at the BVPS-1 Site. The screening evaluation is based upon a comparison of the GMRS with the horizontal SSE ground motion spectrum.

4.1 Risk Evaluation Screening (1 to 10 Hz)

In the 1 to 10 Hz part of the response spectrum, the GMRS exceeds the horizontal SSE (at frequencies above about 6 Hz). Therefore, the plant screens in for a risk evaluation.

The GMRS exceedance relative to the SSE spectrum above about 3-4 Hz is characterized as broad banded with spectral accelerations exceeding 0.4g at some frequencies in the 1.0 to 10 Hz frequency range. However, the SSE spectrum envelops the GMRS below 3-4 Hz. Therefore, SSCs and failure modes associated with low frequency are not affected by the GMRS. As discussed in the SPID (EPRI, 2013a), these SSCs and failure modes include flexible distribution systems, sliding and rocking of unanchored components, fuel assemblies inside the reactor vessel, soil liquefaction, and liquid sloshing in atmospheric pressure storage tanks. Accordingly, no new high confidence of low probability of failure (HCLPF) analysis of low frequency SSCs and failure modes is planned.

4.2 High Frequency Screening (> 10 Hz)

In the range of frequencies above 10 Hz, the GMRS exceeds the horizontal SSE. The high frequency exceedances will be addressed in the risk evaluation discussed in ***Section 4.1*** above.

Although safety equipment in BVPS-1 was evaluated in the A-46 program, the SSE ground motions used in this evaluation do not have significant frequency content above 10 Hz. The A-46 program verified the seismic adequacy of mechanical and electrical equipment for the plant

SSE using the seismic criteria defined in the USI A-46 technical resolution (NRC Generic Letter 87-02). The USI A-46 procedures make use of earthquake experience data supplemented by test data to verify the seismic capability of equipment below specified earthquake motion bounds. Additionally, the consideration of high-frequency vulnerability of components in the Individual Plant Examination of External Events (IPEEE) was focused on "bad actor" relays mutually agreed to by the industry and the NRC, with known earthquake or shock sensitivity. These specific model relays, designated as low ruggedness relays, were identified in EPRI Report 7148 (EPRI, 1990). Rather than considering high frequency capacity versus demand screening, "bad actor" relays were considered program outliers and were evaluated using circuit analysis, operator actions, or component replacement.

The response of components to the high frequency ground motion associated with the GMRS will be addressed as part of the on-going SPRA. EPRI Report NP-7498 (EPRI, 1991), as well as more recent studies related to licensing activities for new plants (EPRI, 2007a and 2007b), summarize the basis and conclude that "...high-frequency vibratory motions above about 10 Hz are not damaging to the large majority of NPP structures, components, and equipment. An exception to this is the functional performance of vibration sensitive components, such as relays and other electrical and instrumentation devices whose output signals could be affected by high-frequency excitation."

The SPRA will utilize the information from EPRI's on-going test program to develop estimates of fragility for potential high-frequency sensitive components. The test program is expected to "... use accelerations or spectral levels that are sufficiently high to address the anticipated high-frequency in-structure and in-cabinet responses of various plants."

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 horizontal SSE. Therefore, a spent fuel pool evaluation will be performed following the guidance in Section 7 of the SPID (EPRI, 2013a).

5.0 INTERIM ACTIONS

Based on the screening evaluation, the expedited seismic evaluation described in EPRI (2013b) is being performed as proposed in a letter to NRC dated April 9, 2013, (NEI, 2013), and agreed to by NRC in a letter dated May 7, 2013, (ML13106A331).

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 the BVPS-1. 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 (NEI, 2014), 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 (NRC, 2010a):

> 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 (CDF). The GI-199 Safety/Risk Assessment, based in part on information from the 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.

BVPS-1 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.

Additionally, as requested in Enclosure 1 of the 50.54(f) letter (Item 5), the following paragraphs provide insights from the NTTF Recommendation 2.3 walkdowns, and the IPEEE program accomplished for BVPS-1. These programs further illustrate the plant seismic capacity.

5.1 NTTF 2.3 WALKDOWNS

In response to NTTF Recommendation 2.3, FENOC completed the Seismic 2.3 walkdown for BVPS-1 in September 2012 (FENOC, 2013b). This walkdown identified no major anomalies. However, some potentially adverse seismic conditions were identified during the seismic walkdowns as documented in the 2.3 submittal report. The walkdown report summarizes these conditions. Condition reports were inititiated as appropriate. Justifications for findings, for which a Licensing Evaluation is not required, are provided in the Component's respective SWCs. Items that were not accessible during the initial walkdown were subsequently walked down during the following refueling outage. The walkdown of these additional items identified no potentially adverse findings (FENOC, 2013c).

The 2.3 walkdown for the Beaver Valley Power Station was subsequently audited by NRC staff. The staff concurred with the process, as well as the findings and conclusions.

5.2 IPEEE DESCRIPTION AND CAPACITY RESPONSE SPECTRUM

The IPEEE for BVPS-1 accomplished a SPRA for selected plant SSCs (Duquesne Light Co, 1995) in accordance with Nuclear Regulatory Commission Technical Report (NUREG-1407) (NRC, 1991). The seismic fragilities, developed in support of the SPRA, are based on the 1E-4 return period UHRS developed in the EPRI SOG program (EPRI, 1989a, 1989b). The IPEEE did not identify any seismic vulnerabilities. Several submittals to the NRC addressed A-46 enhancements, as well as IPEEE enhancements. None of these was classified as potential vulnerability.

The IPEEE HCLPF spectrum (IHS) is not used for screening. However, it is provided here for reference and to document the level of the BDB seismic ground motion, for which the plant SSCs have been evaluated. ***Appendix B*** summarizes the elements of the IPEEE, following the IPEEE adequacy requirements in SPID Section 3.3.1 (EPRI, 2013a).

The IPEEE reports a minimum HCLPF value of about 0.1g, associated with failure of the unrestrained station batteries. However, the supporting SPRA estimates a mean seismic-initiated core damage frequency (CDF) of 9.07E-6, and the plant level HCLPF of 0.2g PGA (NRC, 2010b). Accordingly, the 5-percent damped horizontal IHS spectral accelerations provided in ***Table 5-1*** correspond to the 0.20g PGA UHRS. The SSE spectrum and the IHS in the horizontal direction are shown on ***Figure 5-1***.

TABLE 5-1
HORIZONTAL IHS FOR BVPS-1

FREQUENCY [Hz]	SPECTRAL ACCELERATION [g]
1.0	0.015
2.5	0.100
5.0	0.233
10.0	0.295
25.0	0.295
100.0	0.200

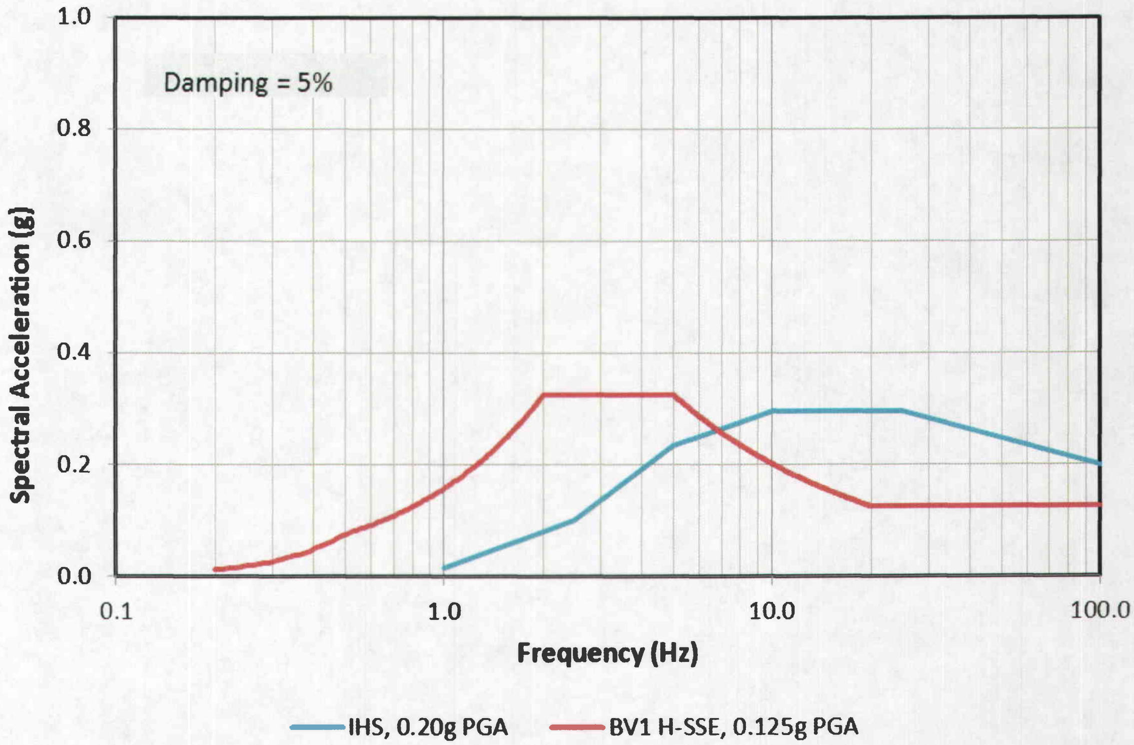


FIGURE 5-1
BVPS-1 SSE AND IPEEE HCLPF SPECTRA

6.0 CONCLUSIONS

In accordance with the 50.54(f) request for information letter (NRC, 2012a) a seismic hazard and screening evaluation was performed for BVPS-1. This reevaluation followed the guidance provided in the SPID (EPRI, 2013a) and developed the control point GMRS for the Site. The screening evaluation compares the horizontal SSE spectrum to the control point GMRS.

Based on the results of the screening evaluation, the plant screens in for risk evaluation, a Spent Fuel Pool evaluation, and a High Frequency Confirmation. The GMRS exceeds the horizontal SSE both in the 1 to 10 Hz part of the response spectrum and above 10 Hz.

Although the BVPS-1 IPEEE is a focused scope SPRA, and is not used for screening, this Report (***Appendix B***) performs the evaluation of the completed IPEEE. It concludes that the IPEEE is of good quality and meets all other prerequisites and the adequacy requirements in accordance with the SPID (EPRI, 2013a). The Report compares the GMRS to the IPEEE spectrum for reference and to illustrate the robustness in the plant design relative to the design basis for new plants.

The SPRA for BVPS-1 is currently on-going and is expected to be completed in accordance with the schedule for CEUS nuclear plants provided in the April 9, 2013, letter from industry to the NRC (NEI, 2013) and agreed to by NRC in a letter dated May 7, 2013, (ML13106A331).

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APPENDIX A

NTTF 2.1 SITE RESPONSE ANALYSIS BVPS-1 SITE

APPENDIX A – NTTF 2.1 SITE RESPONSE ANALYSIS INPUTS AND RESULTS, BEAVER VALLEY POWER STATION SITE

Uncertainty and variability in inputs to the site response analysis are addressed as follows:

1. Epistemic uncertainty in shear wave velocity (V_s) is modeled using three V_s profiles. The derivation of upper range (UR) and lower range (LR) V_s profiles is based on using a factor of 1.15, which is derived from a range of reasonable V_p/V_s ratios based on literature review for the type of Paleozoic rocks that exist at the Site.

2. The randomized site profile realizations use the log standard deviation as the layer by layer coefficient of variation: 0.25 for the upper 50 ft and 0.15 at greater depths . Based on the review of sonic log data from the three FirstEnergy Nuclear Operating Company (FENOC) Sites, an upper and lower V_s limit is defined by a factor of 1.3 relative to the base case Vs for each of the three V_s profiles.

3. The SPID (EPRI 2013a) specifies the use of the Electric Power Research Institute (EPRI) rock degradation curves for rock units such as found at the FENOC Sites. These curves were used for the top 500 feet (ft) of rock. Below 500 ft, damping for the bedrock is derived consistent with kappa estimates.

4. At the BVPS-1 Site strain-dependent properties for the soil overburden are based on UFSAR data for the Pleistocene Upper and Lower Terrace Units (1E).

5. Consistent with the SPID (EPRI 2013a), kappa is estimated for each site profile. For both the lower and UR Vs profiles, uncertainty is represented using a secondary kappa value by applying a factor of 1.5 (multiplied by 1.5 for LR profile and divided by 1.5 for UR profile). For profiles greater than 3,000 ft the SPID (EPRI 2013a) specifies use of an equation between V_s (30m) and kappa; all three profiles at BVPS-1 are greater than 3,000 ft thickness. The total kappa is based on adding the soil kappa, the rock kappa, and the hard rock kappa.

6. For the secondary kappa profiles the rock damping in the top 500 ft is modified by the same factor of 1.5 used to characterize uncertainty in kappa. Below 500 ft rock damping was adjusted to preserve the total kappa for the profile.

7. ***Table A-1*** provided below specifies the site response inputs consistent with these assessments of uncertainty and variability.

8. ***Table A-8*** lists the resulting median AF and the related ln-sigma for seven selected frequencies and 11 values of input hard rock peak ground acceleration (PGA).

9. ***Tables A-9 to A-11*** list the resulting median AF and the related ln-sigma for three loading levels associated with ***Figures 2-6 and 2-7***.

TABLE A-1
SITE RESPONSE INPUT

Input Parameter		Value					
Seismic Source Input		M = 6.5 with distances and depths resulting in at 11 peak ground acceleration values from 0.01 g to 1.5 g at the Site					
		Single-corner Table B-4 SPID	Double-corner Table B-6 SPID	Single-corner Table B-4 SPID	Double-corner Table B-6 SPID	Single-corner Table B-4SPID	Double-corner Table B-6 SPID
Source Model		Additional parameters used in the point source model found below Table B-4					
Profile		Best Estimate (P1)		Lower Ranger (P2)		Upper Range (P3)	
Vs		Table A-2 (P1) W = 0.40 30 Randomized Realizations		Table A-2 (P2) BE divided by 1.15 W = 0.30 30 Randomized Realizations		Table A-2 (P3) BE multiplied by 1.15 W = 0.30 30 Randomized Realizations	
Site Kappa (k1)		Total Thickness 4380.9 ft (k1) = .0213s (see Table A-3) W = 1.0		Total Thickness 4380.9 ft (k1) = .0237s (see Table A-4) W = 0.60		Total Thickness 4380.9 ft (k1) = .0193s (see Table A-6) W = 0.60	
Shear Modulus and Damping[1] With (k1)	Top 500 ft	EPRI Rock	3.2% Linear damping	EPRI Rock	3.2% Linear damping	EPRI Rock	3.2% Linear damping
	501 ft to profile base	0.8% Linear damping	0.8% Linear damping	0.8% Linear damping	0.8% Linear damping	0.8% Linear damping	0.8% Linear damping
	Weight	W = 0.50	W = 0.50	W = 0.50	W = 0.50	W = 0.50	W = 0.50
Site Kappa (k2)		Not Applicable		Total Thickness 4380.9 ft (k2) = .0320s (see Table A-5) W = 0.40		Total Thickness 4380.9 ft (k2) = .0152s (see Table A-7) W = 0.40	
Shear Modulus and Damping[1] With (k2)	Top 500 ft	Not Applicable		EPRI Rock scaled up to get low strain damping of 4.8%	4.8% Linear Damping	EPRI Rock scaled up to get low strain damping of 1.6%	1.6% Linear damping
	501 ft to profile base	Not Applicable		1.25% Linear damping	1.25% Linear damping	0.65% Linear damping	0.65% Linear damping
	Weight	Not Applicable		W = 0.50	W = 0.50	W = 0.50	W = 0.50

Note:

Properties listed are for top 500 feet of rock. Site profiles include 55.9 feet of soil over rock. The FSAR dynamic material properties are used for the soil in the site response analysis.

TABLE A-2
SHEAR WAVE VELOCITY [ft/s] PROFILES

LAYER ELEVATION [ft]	PROFILE P1 [ft/s]	DEPTH [ft]	PROFILE P2 [ft/s]	DEPTH [ft]	PROFILE P3 [ft/s]	DEPTH [ft]
680.9	1100	0	957	0	1265	0
665	1100	15.9	957	15.9	1265	15.9
665	1200	15.9	1043	15.9	1380	15.9
625	1200	55.9	1043	55.9	1380	55.9
625	5000	55.9	4348	55.9	5750	55.9
550	5000	130.9	4348	130.9	5750	130.9
550	6026	130.9	5240	130.9	6930	130.9
350	6026	330.9	5240	330.9	6930	330.9
350	6744	330.9	5864	330.9	7756	330.9
300	6744	380.9	5864	380.9	7756	380.9
300	6744	380.9	5864	380.9	7756	380.9
-120	6744	800.9	5864	800.9	7756	800.9
-120	7112	800.9	6184	800.9	8179	800.9
-2994	7112	3674.9	6184	3674.9	8179	3674.9
-2994	6416	3674.9	5579	3674.9	7378	3674.9
-3700	6416	4380.9	5579	4380.9	7378	4380.9
-3700	9200	4380.9	9200	4380.9	9200	4380.9

TABLE A-3
KAPPA (k1) USED WITH BEST ESTIMATE PROFILE P1

KAPPA (ROCK) BASED ON: LOG (k) = 2.2189 – 1.093 * LOG (Vs_{100}) Vs_{100} FOR BEDROCK = 5222 ft/s; KAPPA (P1) = .0143s KAPPA (SOIL) BASED ON: KAPPA (ms) = .0605 * H (m) = .0605 * 17.038 = .001s TOTAL KAPPA = .001 + .0143 + .006 (HARD ROCK) = .0213s		
V_s [ft/s] P1	THICKNESS [ft]	DEPTH TO TOP [ft]
1100	15.9	
1200	40	15.9
5000	75	55.9
6026	200	130.9
6744	50	330.9
6744	420	380.9
7112	2874	800.9
6416	706	3674.9
9200	-	4380.9

TABLE A-4
KAPPA (k1) USED WITH LOWER RANGE PROFILE P2

KAPPA (ROCK) BASED ON: LOG (k) = 2.2189 – 1.093 * LOG (Vs_{100}) Vs_{100} FOR BEDROCK = 4541 ft/s; KAPPA (P2) = .0167s KAPPA (SOIL) BASED ON: KAPPA (ms) = .0605 * H (m) = .0605 * 17.038 = .001s TOTAL KAPPA = .001 + .0167 + .006 (HARD ROCK) = .0237s		
V_s [ft/s] P2	THICKNESS [ft]	DEPTH TO TOP [ft]
957	15.9	
1043	40	15.9
4348	75	55.9
5240	200	130.9
5864	50	330.9
5864	420	380.9
6184	2874	800.9
5579	706	3674.9
9200	-	4380.9

TABLE A-5
KAPPA (k2) USED WITH LOWER RANGE PROFILE P2

KAPPA (ROCK) BASED ON 1.5 * k(1) = .025s KAPPA (SOIL) BASED ON: KAPPA (ms) = .0605 * H (m) = .0605 * 17.038 = .001s TOTAL KAPPA = .001 + .025 + .006 (HARD ROCK) = .032s		
V_s [ft/s] P2	Thickness [ft]	DEPTH TO TOP [ft]
957	15.9	
1043	40	15.9
4348	75	55.9
5240	200	130.9
5864	50	330.9
5864	420	380.9
6184	2874	800.9
5579	706	3674.9
9200	-	4380.9

TABLE A-6
KAPPA (k1) USED WITH UPPER RANGE PROFILE P3

KAPPA (ROCK) BASED ON: LOG (k) = 2.2189 – 1.093 * LOG (Vs_{100}) Vs_{100} FOR BEDROCK = 6006 ft/s; KAPPA (P3) = .0123s KAPPA (SOIL) BASED ON: KAPPA (ms) = .0605 * H (m) = .0605 * 17.038 = .001s TOTAL KAPPA = .001 + .0123 + .006 (HARD ROCK) = .0193s		
V_s [ft/s] P3	THICKNESS [ft]	DEPTH TO TOP [ft]
1265	15.9	
1380	40	15.9
5750	75	55.9
6930	200	130.9
7756	50	330.9
7756	420	380.9
8179	2874	800.9
7378	706	3674.9
9200	-	4380.9

TABLE A-7
KAPPA (k2) USED WITH UPPER RANGE PROFILE P3

KAPPA (ROCK) BASED ON K(1) / 1.5 = .0082s KAPPA (SOIL) BASED ON: KAPPA (ms) = .0605 * H (m) = .0605 * 17.038 = .001s TOTAL KAPPA = .001 + .0082 + .006 (HARD ROCK) = .0152s		
V_s [ft/s] P3	THICKNESS [ft]	DEPTH TO TOP [ft]
1265	15.9	
1380	40	15.9
5750	75	55.9
6930	200	130.9
7756	50	330.9
7756	420	380.9
8179	2874	800.9
7378	706	3674.9
9200	-	4380.9

TABLE A-8
AMPLIFICATION FUNCTIONS FOR BVPS-1 SITE

100 Hz SA [g]	Median AF	Sigma Ln(AF)	25 Hz SA [g]	Median AF	Sigma Ln(AF)	10 Hz SA [g]	Median AF	Sigma Ln(AF)	5 Hz SA [g]	Median AF	Sigma Ln(AF)
1.02E-02	2.23E+00	1.36E-01	1.31E-02	1.87E+00	1.19E-01	2.07E-02	1.76E+00	2.05E-01	2.35E-02	3.10E+00	2.92E-01
5.45E-02	1.70E+00	1.05E-01	1.07E-01	1.17E+00	2.11E-01	1.13E-01	1.56E+00	2.49E-01	9.41E-02	2.98E+00	3.03E-01
1.15E-01	1.39E+00	1.17E-01	2.26E-01	1.01E+00	2.57E-01	2.10E-01	1.49E+00	2.56E-01	1.64E-01	2.86E+00	3.12E-01
2.52E-01	1.11E+00	1.39E-01	4.73E-01	8.59E-01	3.00E-01	4.04E-01	1.40E+00	2.57E-01	3.02E-01	2.66E+00	3.36E-01
3.97E-01	9.74E-01	1.54E-01	7.19E-01	7.67E-01	3.20E-01	5.93E-01	1.33E+00	2.51E-01	4.35E-01	2.48E+00	3.49E-01
5.48E-01	8.82E-01	1.69E-01	9.70E-01	7.00E-01	3.33E-01	7.83E-01	1.26E+00	2.51E-01	5.68E-01	2.35E+00	3.59E-01
7.03E-01	8.13E-01	1.83E-01	1.22E+00	6.45E-01	3.46E-01	9.75E-01	1.20E+00	2.58E-01	7.02E-01	2.22E+00	3.73E-01
1.10E+00	6.93E-01	2.08E-01	1.86E+00	5.41E-01	3.71E-01	1.45E+00	1.08E+00	2.68E-01	1.03E+00	1.92E+00	4.03E-01
1.51E+00	6.14E-01	2.27E-01	2.53E+00	4.68E-01	3.82E-01	1.95E+00	9.69E-01	2.89E-01	1.38E+00	1.69E+00	4.16E-01
1.95E+00	5.52E-01	2.46E-01	3.23E+00	4.11E-01	3.92E-01	2.47E+00	8.65E-01	3.23E-01	1.74E+00	1.50E+00	4.29E-01
2.37E+00	5.05E-01	2.59E-01	3.89E+00	3.68E-01	3.97E-01	2.97E+00	7.85E-01	3.45E-01	2.09E+00	1.34E+00	4.54E-01
2.5 Hz SA [g]	**Median AF**	**Sigma Ln(AF)**	**1 Hz SA [g]**	**Median AF**	**Sigma Ln(AF)**	**0.5 Hz SA [g]**	**Median AF**	**Sigma Ln(AF)**			
2.16E-02	1.70E+00	4.36E-01	1.46E-02	1.28E+00	1.72E-01	8.44E-03	1.22E+00	6.90E-02			
6.85E-02	1.77E+00	4.66E-01	3.72E-02	1.30E+00	1.76E-01	1.87E-02	1.23E+00	7.19E-02			
1.14E-01	1.84E+00	4.42E-01	5.86E-02	1.31E+00	1.79E-01	2.84E-02	1.24E+00	7.34E-02			
2.03E-01	1.94E+00	4.07E-01	1.01E-01	1.32E+00	1.86E-01	4.77E-02	1.25E+00	7.48E-02			
2.88E-01	2.00E+00	3.77E-01	1.41E-01	1.34E+00	1.93E-01	6.59E-02	1.25E+00	7.58E-02			
3.73E-01	2.05E+00	3.53E-01	1.81E-01	1.35E+00	2.01E-01	8.39E-02	1.25E+00	7.63E-02			
4.59E-01	2.09E+00	3.45E-01	2.21E-01	1.36E+00	2.09E-01	1.02E-01	1.26E+00	7.68E-02			
6.71E-01	2.17E+00	3.38E-01	3.20E-01	1.40E+00	2.39E-01	1.47E-01	1.27E+00	7.91E-02			
8.92E-01	2.17E+00	3.25E-01	4.23E-01	1.44E+00	2.95E-01	1.93E-01	1.28E+00	8.50E-02			
1.12E+00	2.12E+00	3.15E-01	5.31E-01	1.49E+00	3.36E-01	2.42E-01	1.29E+00	9.46E-02			
1.34E+00	2.07E+00	3.14E-01	6.34E-01	1.54E+00	3.74E-01	2.88E-01	1.31E+00	1.06E-01			

TABLE A-9
AMPLIFICATION FUNCTIONS AT SPECIFIC LOADING LEVELS FOR BVPS-1 SITE
100 Hz SPECTRAL ACCELERATION = 0.11g

FREQUENCY [HZ]	PROFILE P1 KAPPA 1 EPRI ROCK NONLINEAR CURVES 1-CORNER GROUND MOTION MODEL		PROFILE P1 KAPPA 1 LINEAR ROCK CURVES 1-CORNER GROUND MOTION MODEL	
	MEDIAN AF	SIGMA LN(AF)	MEDIAN AF	SIGMA LN(AF)
0.1	1.15E+00	6.96E-02	1.15E+00	7.05E-02
0.13	1.14E+00	6.92E-02	1.14E+00	6.98E-02
0.16	1.16E+00	8.66E-02	1.17E+00	8.69E-02
0.2	1.22E+00	1.18E-01	1.22E+00	1.18E-01
0.26	1.31E+00	1.53E-01	1.31E+00	1.53E-01
0.33	1.37E+00	1.44E-01	1.37E+00	1.44E-01
0.42	1.32E+00	8.18E-02	1.32E+00	8.18E-02
0.5	1.22E+00	5.70E-02	1.22E+00	5.69E-02
0.53	1.19E+00	5.36E-02	1.19E+00	5.36E-02
0.67	1.10E+00	4.80E-02	1.10E+00	4.88E-02
0.85	1.19E+00	2.00E-01	1.19E+00	2.02E-01
1	1.30E+00	1.82E-01	1.30E+00	1.82E-01
1.08	1.32E+00	1.38E-01	1.33E+00	1.39E-01
1.37	1.32E+00	1.48E-01	1.33E+00	1.55E-01
1.74	1.43E+00	2.02E-01	1.43E+00	2.06E-01
2.21	1.62E+00	3.24E-01	1.63E+00	3.39E-01
2.5	1.75E+00	4.00E-01	1.75E+00	4.27E-01
2.81	1.92E+00	4.73E-01	1.92E+00	4.85E-01
3.56	2.45E+00	3.71E-01	2.46E+00	3.73E-01
4.52	2.88E+00	3.29E-01	2.89E+00	3.31E-01
5	2.85E+00	2.87E-01	2.86E+00	2.87E-01
5.74	2.64E+00	2.84E-01	2.65E+00	2.83E-01
7.28	2.04E+00	3.16E-01	2.05E+00	3.07E-01
9.24	1.59E+00	2.71E-01	1.60E+00	2.69E-01
10	1.51E+00	2.26E-01	1.51E+00	2.23E-01
11.72	1.49E+00	2.23E-01	1.50E+00	2.23E-01
14.87	1.42E+00	2.36E-01	1.43E+00	2.32E-01
18.87	1.28E+00	2.37E-01	1.29E+00	2.21E-01
23.95	1.07E+00	1.94E-01	1.07E+00	1.82E-01
25	1.04E+00	1.92E-01	1.04E+00	1.79E-01
30.39	9.64E-01	1.44E-01	9.70E-01	1.38E-01
38.57	9.19E-01	9.20E-02	9.23E-01	9.56E-02
48.94	9.65E-01	8.38E-02	9.68E-01	8.84E-02
62.1	1.06E+00	7.05E-02	1.07E+00	7.63E-02
78.8	1.20E+00	6.38E-02	1.21E+00	7.15E-02
100	1.40E+00	6.19E-02	1.41E+00	7.03E-02

TABLE A-10
AMPLIFICATION FUNCTIONS AT SPECIFIC LOADING LEVELS FOR BVPS-1 SITE
100 Hz SPECTRAL ACCELERATION = 0.37g

FREQUENCY [Hz]	PROFILE P1 KAPPA 1 EPRI ROCK NONLINEAR CURVES 1-CORNER GROUND MOTION MODEL		PROFILE P1 KAPPA 1 LINEAR ROCK CURVES 1-CORNER GROUND MOTION MODEL	
	MEDIAN AF	SIGMA LN(AF)	MEDIAN AF	SIGMA LN(AF)
0.1	1.17E+00	7.36E-02	1.17E+00	7.45E-02
0.13	1.15E+00	7.26E-02	1.15E+00	7.31E-02
0.16	1.18E+00	8.93E-02	1.18E+00	8.95E-02
0.2	1.23E+00	1.21E-01	1.23E+00	1.21E-01
0.26	1.32E+00	1.56E-01	1.32E+00	1.56E-01
0.33	1.38E+00	1.46E-01	1.38E+00	1.46E-01
0.42	1.33E+00	8.41E-02	1.33E+00	8.39E-02
0.5	1.23E+00	5.78E-02	1.23E+00	5.77E-02
0.53	1.20E+00	5.40E-02	1.20E+00	5.39E-02
0.67	1.11E+00	5.52E-02	1.11E+00	5.52E-02
0.85	1.20E+00	2.14E-01	1.20E+00	2.14E-01
1	1.33E+00	1.93E-01	1.32E+00	1.93E-01
1.08	1.35E+00	1.49E-01	1.35E+00	1.49E-01
1.37	1.37E+00	1.84E-01	1.36E+00	1.91E-01
1.74	1.50E+00	2.47E-01	1.50E+00	2.57E-01
2.21	1.74E+00	3.92E-01	1.74E+00	4.16E-01
2.5	1.91E+00	3.97E-01	1.91E+00	4.02E-01
2.81	2.09E+00	3.86E-01	2.10E+00	3.91E-01
3.56	2.50E+00	3.49E-01	2.52E+00	3.57E-01
4.52	2.59E+00	2.98E-01	2.62E+00	2.98E-01
5	2.50E+00	2.97E-01	2.53E+00	3.00E-01
5.74	2.29E+00	3.54E-01	2.32E+00	3.50E-01
7.28	1.76E+00	3.27E-01	1.79E+00	3.18E-01
9.24	1.39E+00	2.75E-01	1.43E+00	2.64E-01
10	1.36E+00	2.33E-01	1.39E+00	2.25E-01
11.72	1.32E+00	2.34E-01	1.36E+00	2.49E-01
14.87	1.17E+00	2.44E-01	1.21E+00	2.47E-01
18.87	1.04E+00	2.99E-01	1.08E+00	2.81E-01
23.95	8.27E-01	2.63E-01	8.57E-01	2.48E-01
25	8.05E-01	2.62E-01	8.35E-01	2.52E-01
30.39	7.24E-01	2.25E-01	7.46E-01	2.10E-01
38.57	6.71E-01	1.60E-01	6.90E-01	1.51E-01
48.94	6.76E-01	1.35E-01	6.92E-01	1.30E-01
62.1	7.26E-01	1.17E-01	7.41E-01	1.12E-01
78.8	8.19E-01	1.03E-01	8.35E-01	9.93E-02
100	1.02E+00	9.68E-02	1.04E+00	9.39E-02

TABLE A-11
AMPLIFICATION FUNCTIONS AT SPECIFIC LOADING LEVELS FOR BVPS-1 SITE
100 Hz SPECTRAL ACCELERATION = 1.03g

FREQUENCY [HZ]	PROFILE P1 KAPPA 1 EPRI ROCK NONLINEAR CURVES 1-CORNER GROUND MOTION MODEL		PROFILE P1 KAPPA 1 LINEAR ROCK CURVES 1-CORNER GROUND MOTION MODEL	
	MEDIAN AF	SIGMA LN(AF)	MEDIAN AF	SIGMA LN(AF)
0.1	1.19E+00	7.82E-02	1.19E+00	7.75E-02
0.13	1.17E+00	7.69E-02	1.16E+00	7.62E-02
0.16	1.19E+00	9.37E-02	1.19E+00	9.30E-02
0.2	1.24E+00	1.26E-01	1.24E+00	1.25E-01
0.26	1.33E+00	1.62E-01	1.33E+00	1.61E-01
0.33	1.39E+00	1.52E-01	1.39E+00	1.51E-01
0.42	1.35E+00	8.98E-02	1.34E+00	8.85E-02
0.5	1.25E+00	6.10E-02	1.24E+00	6.00E-02
0.53	1.21E+00	5.67E-02	1.21E+00	5.58E-02
0.67	1.13E+00	7.79E-02	1.13E+00	7.40E-02
0.85	1.24E+00	2.53E-01	1.23E+00	2.49E-01
1	1.39E+00	2.28E-01	1.37E+00	2.26E-01
1.08	1.42E+00	1.85E-01	1.40E+00	1.82E-01
1.37	1.47E+00	2.95E-01	1.45E+00	3.05E-01
1.74	1.67E+00	3.44E-01	1.64E+00	3.49E-01
2.21	1.96E+00	3.50E-01	1.94E+00	3.62E-01
2.5	2.09E+00	3.16E-01	2.08E+00	3.23E-01
2.81	2.18E+00	3.38E-01	2.19E+00	3.50E-01
3.56	2.26E+00	3.10E-01	2.30E+00	3.09E-01
4.52	2.14E+00	3.56E-01	2.20E+00	3.64E-01
5	2.04E+00	3.96E-01	2.10E+00	3.96E-01
5.74	1.80E+00	3.98E-01	1.86E+00	3.89E-01
7.28	1.36E+00	3.75E-01	1.42E+00	3.62E-01
9.24	1.17E+00	2.85E-01	1.24E+00	2.73E-01
10	1.12E+00	2.58E-01	1.19E+00	2.54E-01
11.72	1.00E+00	2.67E-01	1.07E+00	2.55E-01
14.87	9.13E-01	3.29E-01	9.90E-01	3.19E-01
18.87	7.26E-01	3.55E-01	7.89E-01	3.27E-01
23.95	6.00E-01	3.50E-01	6.51E-01	3.42E-01
25	5.85E-01	3.41E-01	6.33E-01	3.32E-01
30.39	5.17E-01	2.66E-01	5.53E-01	2.57E-01
38.57	4.89E-01	2.29E-01	5.18E-01	2.29E-01
48.94	4.89E-01	1.88E-01	5.14E-01	1.88E-01
62.1	5.21E-01	1.69E-01	5.45E-01	1.69E-01
78.8	5.86E-01	1.57E-01	6.11E-01	1.56E-01
100	7.45E-01	1.52E-01	7.76E-01	1.50E-01

APPENDIX B

EVALUATION OF BVPS-1 IPEEE SUBMITTAL

APPENDIX B – EVALUATION OF BVPS-1 IPEEE SUBMITTAL

The Individual Plant Examination of External Events (IPEEE) for the BVPS-1 accomplished a probabilistic risk assessment that included seismic initiating events (Duquesne Light Co, 1995). Although allowed by *Seismic Evaluation Guidance, Screening, Prioritization, and Implementation Details* (SPID) *for the Resolution of the Fukushima Near-Term Task Force Recommendation 2.1: Seismic* (EPRI, 2013a), this IPEEE is not utilized in the Near-Term Task Force (NTTF) 2.1 plant screening. Nevertheless, it is summarized here for information, and because, in combination with the A-46 program, the IPEEE findings indicate that the plant design is seismically robust and exhibits significant margins in excess of the design basis. The IPEEE was performed in accordance with the guidelines in Nuclear Regulatory Commission (NRC) Technical Report (NUREG)-1407 (NRC, 1991). The plant high confidence of low probability of failure (HCLPF) value estimated from the Core Damage Frequency (CDF) is reported to be 0.2g peak ground acceleration (PGA). It is largely controlled by failure scenarios involving the station batteries.

B.1 IPEEE Prerequisites

The SPID (EPRI, 2013a) guidelines require that the following prerequisites be documented prior to the possible use of the IPEEE for screening.

1. Confirm that commitments made under the IPEEE have been met. If not, address and close those commitments.

2. Confirm whether all of the modifications and other changes credited in the IPEEE analysis are in place.

3. Confirm that any identified deficiencies or weaknesses to NUREG-1407 (NRC, 1991) in the plant specific NRC Safety Evaluation Report (SER) are properly justified to ensure that the IPEEE conclusions remain valid.

4. Confirm that major plant modifications since the completion of the IPEEE have not degraded/impacted the conclusions reached in the IPEEE.

As part of the NTTF 2.3 Seismic walkdown effort for BVPS-1, the IPEEE was examined to verify that the corrective actions were implemented and documents closed. Available Seismic Evaluation Worksheets (SEWS) generated during the IPEEE walkdowns were included in the NTTF 2.3 Report (FENOC, 2013b). The NTTF 2.3 walkdowns identified no potential adverse seismic conditions.

The BVPS-1 IPEEE identified no seismic vulnerabilities for the Plant. This was recognized by the NRC in NUREG-1437 Supplement 36 "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 36, Regarding Beaver Valley Power Station Units 1 and 2" (NRC, 2009). Page G20 and 21 states "The NRC staff also notes that the use of the integrated PSA to facilitate identification of SAMAs for external events, the prior implementation of plant modifications for seismic and fire events, and the absence of external event vulnerabilities ensure that the search for external event SAMAs was reasonably comprehensive."

B.2 IPEEE Adequacy Demonstration

Consistent with the guidelines in NUREG -1407 (NRC, 1991), the BVPS-1 IPEEE is based on a seismic PRA (SPRA), which extends the Internal Events Probabilistic Risk Assessment (IEPRA). The SPRA evaluates the risk contribution and significance of seismic initiated events to the total plant risk. The SPRA was selected to accomplish the IPEEE over the seismic margins assessment based on the following considerations:

- The SPRA would be integrated with the IEPRA. The integrated PRA would consistently treat all internal and external initiating events. This model rigorously accounts for all accident sequences resulting from any combination of internal and external events. The resulting risk information provided from this integrated approach was viewed as more useful to management to make decisions about allocating resources to manage the risks of severe accidents.
- With the ability to link the Level 1 and Level 2 event trees as demonstrated in the IPE submittal, the selected PRA approach was found to provide a more rigorous examination of potential containment vulnerabilities and seismic/systems interactions impacting containment effectiveness than was possible using the seismic margins approach.

- With the previous decision to perform an internal events PRA for the IPE, the ability to utilize insights from the completed internal events PRA, and the external events capabilities of the software that was used, there was a higher confidence that the seismic PRA would be completed within the resources budgeted for the IPEEE program in comparison with the seismic margins approach.

The seismic PRA consisted of the following main steps:

- Seismic Hazard Analysis
- Fragility Analysis
- Plant Logic Analysis and development of logic models
- Integration of Level 1 seismic event tress with Level 2 containment event trees
- Risk Quantification
- Uncertainty Quantification

Enhancements to the foregoing steps were made to be responsive to the requirements from NUREG-1407 (NRC, 1991). Seismic events below about 0.1g were found to have an insignificant chance of failing any equipment. Seismic events above 1.33g were of low enough hazards and were ignored. The seismic PRA results showed that 95% of the seismic CDF comes from earthquakes that are at least twice as severe as the peak ground acceleration of the SSE (0.125g). Core damage sequences resulting from earthquakes between roughly one and two times the SSE mainly involved seismic failure of either emergency DC power or emergency AC power.

The following paragraphs briefly summarize the IPEEE in accordance with the requirements of the SPID (EPRI 2013a) guidelines.

B.2.1 Building Seismic Analysis

The design seismic analysis of Category I structures of BVPS-1 is based on the time history modal superposition method using simulated time histories representing the SSE spectra. Lumped mass models of the buildings were utilized in the seismic analysis. These models

represent the building mass at floor elevations and include the floor system, a portion of the walls above, and the walls below the floor system, and major component and equipment loads.

In addition, masses are located at elevations where any other response values are required. The lumped masses are connected by story stiffnesses.

Most major structures of the BVPS-1 are founded on the dense gravel layer underlying the upper terrace deposits. The soil structure interaction (SSI) effects on the seismic response are represented by soil springs representing the stiffness and damping characteristics of the supporting soil medium. The soil springs represent a range of shear moduli values to envelope the variation of peak floor response periods. Additionally, the Containment Building seismic model considers uncracked and partially cracked reinforced concrete sections to account for normal and pressurized conditions.

Modal responses from the dynamic model are combined using the square root of the sum of the squares (SRSS) method to establish Seismic Category I structure seismic loads. This is used even when modes have closely spaced frequencies, since no well-established criterion to combine modes under this condition was available.

In-structure response spectra (ISRS) used as seismic inputs to Category I structural systems, components, and equipment is derived from the lumped mass dynamic models. The dynamic model is also used to determine forces and overturning moments on the building structure. Overturning moments are combined with vertical acceleration forces in order to check structure overturning stability and subgrade reactions.

Seismic response forces and stresses are determined for simultaneous application of horizontal and vertical earthquake ground motions using the response spectrum technique. It is assumed that the response in the vertical direction is uncoupled from the lateral motion. Accordingly, two dynamic models, one for horizontal and one for the vertical, are used to obtain the respective response. The responses obtained from the two-dimensional (2D) planar models are combined using the SRSS method.

B.2.2 IPEEE Seismic Response

ISRS for use in the seismic IPEEE were developed using median based soil properties, structural properties, and the median 1x10-4 uniform hazard spectrum. The best estimate (BE) structural models used for this analysis were based on the mathematical models used in the design seismic analysis.

The design basis SSE floor response spectra for one percent damping are scaled by use of S&A in-house computer program PSD107.1. Scaling of the spectra incorporated the following:

- Change PGA from 0.125g to 0.151g
- Change Equipment Damping Ratio from 1% to 5%
- Change SSE response spectrum shape to the IPEEE Uniform Hazard Spectrum Shape

The scaling assumes that the IPEEE analysis is based on the composite modal damping developed from the soil-structure interaction (SSI) analysis performed in 1979, limited to 7%.

The seismic floor response spectra developed as described above and used for the fragility evaluations are provided in the IPEEE report (Duquesne Light Co, 1995).

B.2.3 Screening of Components

The development of the Safe Shutdown Equipment List (SSEL) and the screening evaluations were performed following the SPRA guidelines and based on the plant systems models. Initial screening prior to the walkdowns was based on HCLPF levels estimated relative to the median spectral shape of NUREG/CR-0098 (Newmark and Hall, 1978) anchored to 0.3g. The subsequent fragility analysis used floor response spectra associated with the Review Level Earthquake (RLE) spectrum. This screening utilized the guidelines in EPRI NP-6041 (EPRI, 1991).

B.2.4 Seismic Capability Walkdowns

The IPEEE walkdowns were performed to support the subsequent fragility analysis, and to screen out components that have a high enough HCLPF value and the site hazard curves. The preparation activities reviewed the seismic design criteria and design specifications for equipment and components for all the items on the seismic equipment list.

In general, the walkdown team evaluated equipment aspect ratios, equipment, and piping anchorages and supports, the potential seismic interactions. The walkdowns assessed potential seismic vulnerabilities, assigned preliminary HCLPF values, and identified potentially seismic-vulnerable component(s) in each group of similar type components based on the preliminary HCLPF values and the importance of the component as determined in the IPE. Preliminary HCLPF values were assigned based on judgment and experience of the seismic review team, and references from both the Seismic Qualification Utility Group (SQUG) and EPRI NP-6041 (EPRI, 1991).

The seismic capacities for other components were conservatively assigned based on the more vulnerable components in each group. Upon completion of the initial sequence quantifications the fragilities of significant contributors were improved using component-specific analysis. A confirmatory walkdown of components verified that representative fragilities of each group are still applicable after detailed study.

B.3 GMRS and IHS Comparison

The IPEEE for BVPS-1 is not used for the plant screening evaluation. However, comparison of the IPEEE HCLPF spectrum (IHS) and the ground motion response spectra (GMRS) at the base of the Reactor Building (RB) foundation level shows that the GMRS exceeds the IHS in the range of frequencies of interest.

APPENDIX C
REACTOR BUILDING MEAN AND FRACTILE SEISMIC HAZARD
BVPS-1 SITE

APPENDIX C - REACTOR BUILDING MEAN AND FRACTILE SEISMIC HAZARD FOR THE SSE CONTROL POINT

TABLE C-1
100 HZ SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT BEAVER VALLEY 1 RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	9.25E-03	5.42E-03	6.85E-03	9.26E-03	1.22E-02	1.41E-02
0.02	3.49E-03	1.56E-03	2.05E-03	3.16E-03	4.91E-03	6.77E-03
0.03	1.83E-03	6.83E-04	9.20E-04	1.55E-03	2.70E-03	4.16E-03
0.04	1.13E-03	3.65E-04	5.02E-04	9.05E-04	1.71E-03	2.88E-03
0.05	7.68E-04	2.19E-04	3.05E-04	5.88E-04	1.19E-03	2.14E-03
0.06	5.59E-04	1.41E-04	2.01E-04	4.11E-04	8.83E-04	1.67E-03
0.07	4.26E-04	9.60E-05	1.40E-04	3.03E-04	6.89E-04	1.33E-03
0.08	3.36E-04	6.88E-05	1.01E-04	2.33E-04	5.54E-04	1.07E-03
0.09	2.69E-04	5.08E-05	7.55E-05	1.83E-04	4.53E-04	8.61E-04
0.10	2.19E-04	3.84E-05	5.79E-05	1.46E-04	3.73E-04	7.04E-04
0.20	5.03E-05	6.75E-06	1.13E-05	3.24E-05	8.97E-05	1.63E-04
0.25	3.06E-05	3.91E-06	6.73E-06	1.98E-05	5.46E-05	9.67E-05
0.30	1.99E-05	2.45E-06	4.30E-06	1.28E-05	3.56E-05	6.12E-05
0.40	9.52E-06	1.08E-06	1.99E-06	6.03E-06	1.73E-05	2.93E-05
0.50	5.08E-06	5.16E-07	9.99E-07	3.18E-06	9.26E-06	1.59E-05
0.60	2.90E-06	2.62E-07	5.27E-07	1.78E-06	5.30E-06	9.24E-06
0.70	1.73E-06	1.40E-07	2.90E-07	1.04E-06	3.19E-06	5.60E-06
0.80	1.07E-06	7.67E-08	1.66E-07	6.18E-07	1.98E-06	3.53E-06
0.90	6.89E-07	4.35E-08	9.73E-08	3.81E-07	1.27E-06	2.32E-06
1.00	4.59E-07	2.54E-08	5.90E-08	2.42E-07	8.47E-07	1.58E-06
2.00	3.64E-08	7.10E-10	2.03E-09	1.34E-08	6.53E-08	1.49E-07
3.00	8.88E-09	8.55E-11	2.84E-10	2.51E-09	1.54E-08	3.89E-08
5.00	1.22E-09	4.83E-12	2.00E-11	2.51E-10	2.04E-09	5.70E-09

TABLE C-2
25 HZ SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT BEAVER VALLEY 1 RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	1.23E-02	7.29E-03	8.73E-03	1.17E-02	1.60E-02	1.93E-02
0.02	5.65E-03	2.88E-03	3.62E-03	5.21E-03	7.71E-03	9.94E-03
0.03	3.30E-03	1.51E-03	1.97E-03	2.98E-03	4.64E-03	6.27E-03
0.04	2.14E-03	8.97E-04	1.19E-03	1.89E-03	3.08E-03	4.33E-03
0.05	1.50E-03	5.81E-04	7.80E-04	1.29E-03	2.19E-03	3.20E-03
0.06	1.10E-03	4.01E-04	5.44E-04	9.28E-04	1.65E-03	2.47E-03
0.07	8.40E-04	2.89E-04	3.96E-04	6.96E-04	1.28E-03	1.96E-03
0.08	6.62E-04	2.16E-04	2.98E-04	5.41E-04	1.03E-03	1.60E-03
0.09	5.34E-04	1.65E-04	2.30E-04	4.31E-04	8.36E-04	1.32E-03
0.10	4.40E-04	1.29E-04	1.82E-04	3.51E-04	6.96E-04	1.11E-03
0.20	1.20E-04	2.52E-05	3.86E-05	8.98E-05	2.07E-04	3.25E-04
0.25	7.89E-05	1.52E-05	2.40E-05	5.82E-05	1.39E-04	2.15E-04
0.30	5.54E-05	1.01E-05	1.64E-05	4.08E-05	9.83E-05	1.51E-04
0.40	3.10E-05	5.31E-06	8.88E-06	2.30E-05	5.52E-05	8.41E-05
0.50	1.92E-05	3.14E-06	5.34E-06	1.42E-05	3.41E-05	5.19E-05
0.60	1.26E-05	1.99E-06	3.42E-06	9.31E-06	2.24E-05	3.42E-05
0.70	8.56E-06	1.31E-06	2.28E-06	6.31E-06	1.54E-05	2.34E-05
0.80	6.00E-06	8.89E-07	1.56E-06	4.39E-06	1.08E-05	1.66E-05
0.90	4.30E-06	6.16E-07	1.10E-06	3.12E-06	7.78E-06	1.20E-05
1.00	3.14E-06	4.35E-07	7.82E-07	2.26E-06	5.71E-06	8.86E-06
2.00	2.97E-07	2.73E-08	5.62E-08	1.91E-07	5.55E-07	9.38E-07
3.00	7.21E-08	4.47E-09	1.03E-08	4.07E-08	1.36E-07	2.47E-07
5.00	1.07E-08	4.58E-10	1.17E-09	5.38E-09	2.01E-08	3.89E-08

TABLE C-3
10 HZ SPECTRAL ACCLERATION MEAN AND FRACTILE SEISMIC HAZARD AT BEAVER VALLEY 1 RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	1.54E-02	9.77E-03	1.16E-02	1.51E-02	1.93E-02	2.25E-02
0.02	6.54E-03	3.61E-03	4.45E-03	6.23E-03	8.67E-03	1.05E-02
0.03	3.94E-03	2.00E-03	2.52E-03	3.69E-03	5.40E-03	6.74E-03
0.04	2.67E-03	1.26E-03	1.63E-03	2.47E-03	3.74E-03	4.77E-03
0.05	1.92E-03	8.55E-04	1.12E-03	1.76E-03	2.74E-03	3.57E-03
0.06	1.45E-03	6.12E-04	8.10E-04	1.31E-03	2.11E-03	2.79E-03
0.07	1.13E-03	4.58E-04	6.11E-04	1.01E-03	1.67E-03	2.25E-03
0.08	9.11E-04	3.53E-04	4.75E-04	8.03E-04	1.36E-03	1.86E-03
0.09	7.49E-04	2.80E-04	3.79E-04	6.52E-04	1.13E-03	1.57E-03
0.10	6.27E-04	2.26E-04	3.08E-04	5.40E-04	9.55E-04	1.35E-03
0.20	1.86E-04	4.89E-05	7.25E-05	1.50E-04	3.09E-04	4.51E-04
0.25	1.25E-04	2.95E-05	4.45E-05	9.77E-05	2.12E-04	3.13E-04
0.30	8.94E-05	1.95E-05	2.99E-05	6.88E-05	1.55E-04	2.30E-04
0.40	5.24E-05	1.01E-05	1.61E-05	3.95E-05	9.25E-05	1.39E-04
0.50	3.41E-05	6.07E-06	9.97E-06	2.55E-05	6.05E-05	9.19E-05
0.60	2.37E-05	3.97E-06	6.66E-06	1.76E-05	4.22E-05	6.44E-05
0.70	1.72E-05	2.74E-06	4.67E-06	1.26E-05	3.07E-05	4.69E-05
0.80	1.28E-05	1.96E-06	3.38E-06	9.30E-06	2.30E-05	3.52E-05
0.90	9.69E-06	1.43E-06	2.51E-06	7.00E-06	1.75E-05	2.70E-05
1.00	7.48E-06	1.06E-06	1.90E-06	5.36E-06	1.36E-05	2.11E-05
2.00	9.25E-07	9.35E-08	1.88E-07	6.05E-07	1.72E-06	2.86E-06
3.00	2.28E-07	1.67E-08	3.68E-08	1.35E-07	4.29E-07	7.60E-07
5.00	4.47E-08	2.03E-09	4.99E-09	2.23E-08	8.62E-08	1.67E-07

TABLE C-4
5 HZ SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT BEAVER VALLEY 1 RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	3.78E-02	2.76E-02	3.05E-02	3.85E-02	4.57E-02	4.94E-02
0.02	1.36E-02	8.53E-03	9.99E-03	1.35E-02	1.73E-02	1.96E-02
0.03	7.48E-03	4.29E-03	5.20E-03	7.28E-03	9.81E-03	1.14E-02
0.04	4.89E-03	2.63E-03	3.27E-03	4.71E-03	6.55E-03	7.74E-03
0.05	3.50E-03	1.80E-03	2.27E-03	3.34E-03	4.78E-03	5.73E-03
0.06	2.65E-03	1.31E-03	1.67E-03	2.51E-03	3.67E-03	4.45E-03
0.07	2.08E-03	9.90E-04	1.28E-03	1.96E-03	2.92E-03	3.58E-03
0.08	1.68E-03	7.71E-04	1.01E-03	1.57E-03	2.38E-03	2.94E-03
0.09	1.38E-03	6.14E-04	8.08E-04	1.28E-03	1.98E-03	2.46E-03
0.10	1.15E-03	4.98E-04	6.60E-04	1.06E-03	1.67E-03	2.09E-03
0.20	3.26E-04	1.12E-04	1.58E-04	2.86E-04	5.07E-04	6.77E-04
0.25	2.14E-04	6.61E-05	9.63E-05	1.83E-04	3.40E-04	4.65E-04
0.30	1.50E-04	4.26E-05	6.33E-05	1.27E-04	2.44E-04	3.39E-04
0.40	8.49E-05	2.10E-05	3.23E-05	6.96E-05	1.42E-04	2.02E-04
0.50	5.39E-05	1.20E-05	1.90E-05	4.32E-05	9.21E-05	1.33E-04
0.60	3.69E-05	7.58E-06	1.22E-05	2.90E-05	6.40E-05	9.36E-05
0.70	2.66E-05	5.11E-06	8.37E-06	2.06E-05	4.66E-05	6.88E-05
0.80	1.99E-05	3.61E-06	6.00E-06	1.52E-05	3.52E-05	5.24E-05
0.90	1.53E-05	2.64E-06	4.44E-06	1.16E-05	2.73E-05	4.08E-05
1.00	1.20E-05	1.99E-06	3.38E-06	9.00E-06	2.16E-05	3.25E-05
2.00	1.92E-06	2.32E-07	4.34E-07	1.32E-06	3.56E-06	5.62E-06
3.00	5.15E-07	4.85E-08	9.75E-08	3.29E-07	9.66E-07	1.60E-06
5.00	8.50E-08	4.87E-09	1.11E-08	4.56E-08	1.61E-07	2.96E-07

TABLE C-5
2.5 HZ SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT BEAVER VALLEY 1 RB FOUNDATION LEVEL

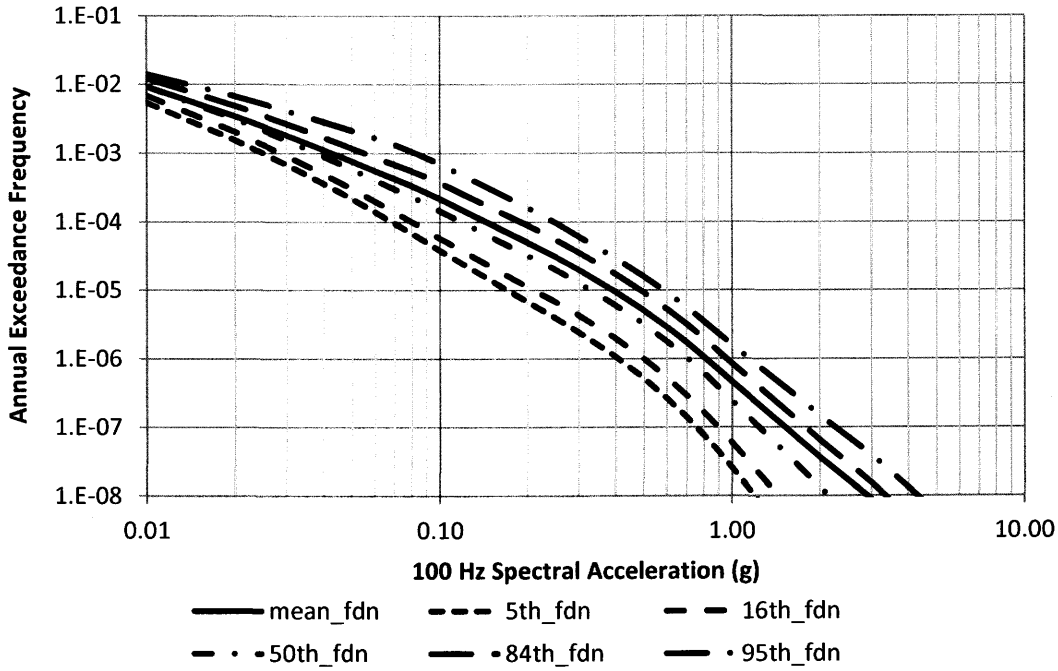
SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	1.58E-02	1.09E-02	1.26E-02	1.59E-02	1.93E-02	2.11E-02
0.02	4.59E-03	2.61E-03	3.18E-03	4.46E-03	6.06E-03	7.08E-03
0.03	2.22E-03	1.13E-03	1.41E-03	2.10E-03	3.05E-03	3.70E-03
0.04	1.30E-03	6.13E-04	7.86E-04	1.22E-03	1.85E-03	2.30E-03
0.05	8.56E-04	3.77E-04	4.93E-04	7.90E-04	1.24E-03	1.57E-03
0.06	6.02E-04	2.51E-04	3.34E-04	5.50E-04	8.87E-04	1.14E-03
0.07	4.45E-04	1.77E-04	2.38E-04	4.02E-04	6.66E-04	8.63E-04
0.08	3.42E-04	1.29E-04	1.77E-04	3.06E-04	5.18E-04	6.78E-04
0.09	2.70E-04	9.80E-05	1.36E-04	2.40E-04	4.14E-04	5.47E-04
0.10	2.19E-04	7.62E-05	1.07E-04	1.92E-04	3.39E-04	4.52E-04
0.20	5.46E-05	1.38E-05	2.10E-05	4.42E-05	9.09E-05	1.30E-04
0.25	3.49E-05	7.82E-06	1.23E-05	2.73E-05	5.93E-05	8.76E-05
0.30	2.42E-05	4.89E-06	7.87E-06	1.84E-05	4.17E-05	6.32E-05
0.40	1.35E-05	2.29E-06	3.87E-06	9.79E-06	2.39E-05	3.74E-05
0.50	8.58E-06	1.26E-06	2.20E-06	5.99E-06	1.54E-05	2.48E-05
0.60	5.89E-06	7.63E-07	1.38E-06	3.99E-06	1.07E-05	1.76E-05
0.70	4.26E-06	4.93E-07	9.24E-07	2.81E-06	7.84E-06	1.31E-05
0.80	3.21E-06	3.35E-07	6.47E-07	2.06E-06	5.95E-06	1.00E-05
0.90	2.49E-06	2.36E-07	4.70E-07	1.56E-06	4.65E-06	7.95E-06
1.00	1.98E-06	1.71E-07	3.52E-07	1.21E-06	3.72E-06	6.42E-06
2.00	3.98E-07	1.69E-08	4.40E-08	2.00E-07	7.77E-07	1.45E-06
3.00	1.32E-07	3.25E-09	9.71E-09	5.66E-08	2.54E-07	5.11E-07
5.00	2.89E-08	2.86E-10	1.05E-09	9.19E-09	5.33E-08	1.21E-07

TABLE C-6
1 HZ SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT BEAVER VALLEY 1 RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	3.44E-03	1.53E-03	2.00E-03	3.35E-03	5.00E-03	5.90E-03
0.02	9.16E-04	2.90E-04	4.09E-04	7.83E-04	1.46E-03	1.97E-03
0.03	3.99E-04	1.05E-04	1.54E-04	3.19E-04	6.64E-04	9.60E-04
0.04	2.01E-04	4.70E-05	7.08E-05	1.54E-04	3.41E-04	5.15E-04
0.05	1.13E-04	2.42E-05	3.72E-05	8.44E-05	1.95E-04	3.01E-04
0.06	6.94E-05	1.37E-05	2.15E-05	5.06E-05	1.21E-04	1.90E-04
0.07	4.54E-05	8.33E-06	1.33E-05	3.25E-05	8.00E-05	1.27E-04
0.08	3.13E-05	5.37E-06	8.71E-06	2.20E-05	5.58E-05	8.96E-05
0.09	2.26E-05	3.62E-06	5.97E-06	1.56E-05	4.06E-05	6.59E-05
0.10	1.69E-05	2.54E-06	4.24E-06	1.14E-05	3.06E-05	5.02E-05
0.20	2.83E-06	2.11E-07	4.27E-07	1.50E-06	5.24E-06	9.94E-06
0.25	1.66E-06	9.28E-08	2.03E-07	7.98E-07	3.06E-06	6.15E-06
0.30	1.08E-06	4.71E-08	1.10E-07	4.80E-07	1.99E-06	4.20E-06
0.40	5.69E-07	1.57E-08	4.16E-08	2.22E-07	1.04E-06	2.34E-06
0.50	3.53E-07	6.65E-09	1.97E-08	1.24E-07	6.40E-07	1.50E-06
0.60	2.43E-07	3.34E-09	1.08E-08	7.88E-08	4.38E-07	1.05E-06
0.70	1.79E-07	1.90E-09	6.66E-09	5.42E-08	3.21E-07	7.86E-07
0.80	1.39E-07	1.18E-09	4.39E-09	3.92E-08	2.46E-07	6.12E-07
0.90	1.10E-07	7.74E-10	3.05E-09	2.95E-08	1.94E-07	4.90E-07
1.00	8.95E-08	5.31E-10	2.19E-09	2.27E-08	1.56E-07	4.01E-07
2.00	1.87E-08	3.30E-11	1.87E-10	3.02E-09	2.88E-08	8.53E-08
3.00	6.19E-09	4.30E-12	3.06E-11	6.75E-10	8.37E-09	2.77E-08
5.00	1.35E-09	0.00E+00	2.23E-12	7.86E-11	1.46E-09	5.56E-09

TABLE C-7
0.5 HZ SPECTRAL ACCELERATION MEAN AND FRACTILE SEISMIC HAZARD AT BEAVER VALLEY 1 RB FOUNDATION LEVEL

SPECTRAL ACCELERATION [g]	ANNUAL FREQUENCY OF EXCEEDANCE					
	MEAN	5TH	16TH	50TH	84TH	95TH
0.01	1.54E-03	4.20E-04	6.16E-04	1.33E-03	2.63E-03	3.38E-03
0.02	3.86E-04	6.63E-05	1.05E-04	2.71E-04	7.00E-04	1.08E-03
0.03	1.55E-04	2.05E-05	3.43E-05	9.70E-05	2.85E-04	4.84E-04
0.04	7.32E-05	8.10E-06	1.41E-05	4.26E-05	1.34E-04	2.41E-04
0.05	3.87E-05	3.79E-06	6.74E-06	2.13E-05	7.12E-05	1.32E-04
0.06	2.25E-05	1.98E-06	3.61E-06	1.18E-05	4.17E-05	7.81E-05
0.07	1.40E-05	1.12E-06	2.09E-06	7.08E-06	2.62E-05	4.99E-05
0.08	9.21E-06	6.77E-07	1.29E-06	4.53E-06	1.74E-05	3.37E-05
0.09	6.35E-06	4.31E-07	8.32E-07	3.03E-06	1.21E-05	2.39E-05
0.10	4.56E-06	2.85E-07	5.63E-07	2.10E-06	8.66E-06	1.75E-05
0.20	6.21E-07	1.50E-08	3.63E-08	1.91E-07	1.04E-06	2.70E-06
0.25	3.41E-07	5.72E-09	1.48E-08	9.02E-08	5.39E-07	1.55E-06
0.30	2.18E-07	2.51E-09	6.91E-09	4.92E-08	3.30E-07	1.01E-06
0.40	1.13E-07	6.25E-10	1.98E-09	1.86E-08	1.58E-07	5.31E-07
0.50	6.72E-08	1.84E-10	6.67E-10	8.15E-09	8.59E-08	3.16E-07
0.60	4.37E-08	6.31E-11	2.63E-10	4.14E-09	5.18E-08	2.05E-07
0.70	3.03E-08	2.42E-11	1.16E-10	2.33E-09	3.35E-08	1.41E-07
0.80	2.19E-08	1.02E-11	5.54E-11	1.39E-09	2.26E-08	1.00E-07
0.90	1.64E-08	4.64E-12	2.82E-11	8.67E-10	1.57E-08	7.38E-08
1.00	1.27E-08	2.24E-12	1.50E-11	5.61E-10	1.12E-08	5.56E-08
2.00	1.96E-09	0.00E+00	1.64E-13	2.31E-11	9.61E-10	6.93E-09
3.00	6.07E-10	0.00E+00	8.34E-15	3.04E-12	1.98E-10	1.79E-09
5.00	1.17E-10	0.00E+00	0.00E+00	1.68E-13	2.03E-11	2.33E-10



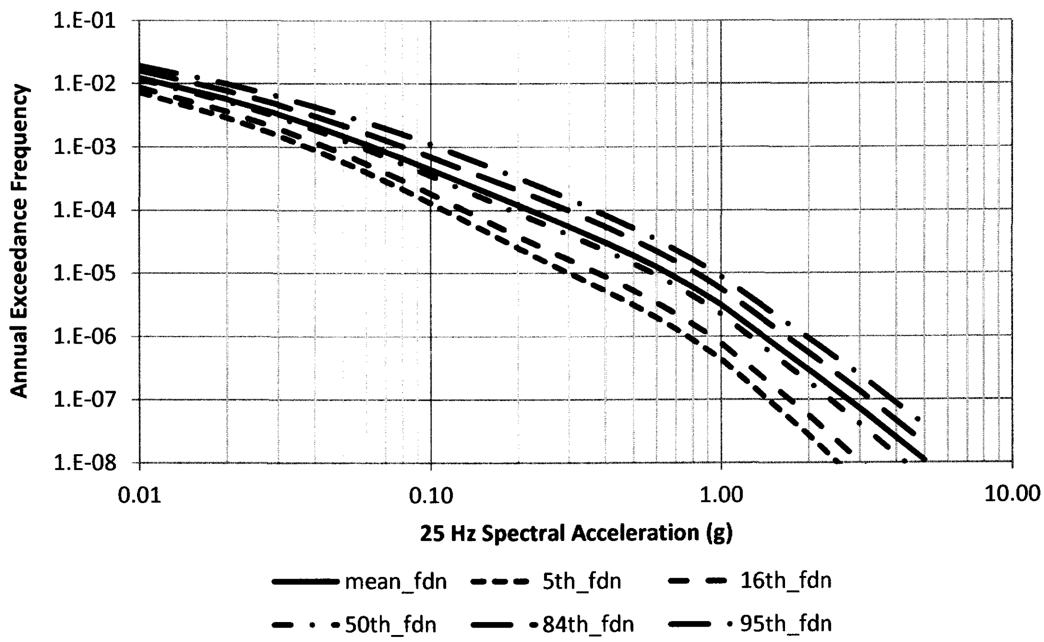
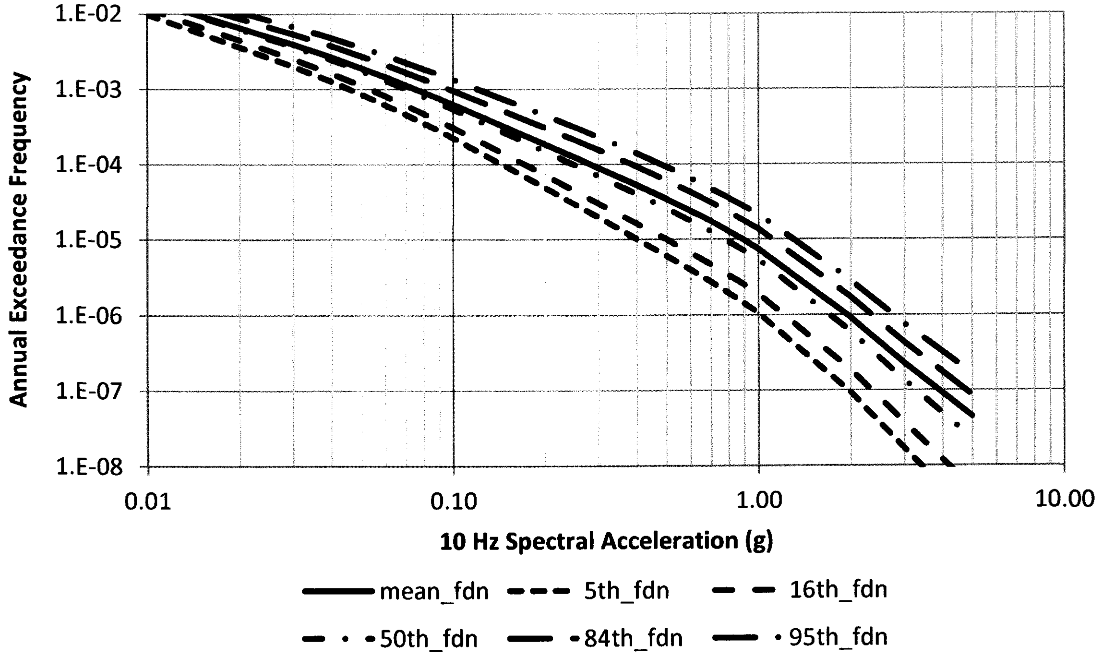


FIGURE C-1
BVPS-1 MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL (SA AT 100 HZ AND 25 HZ)



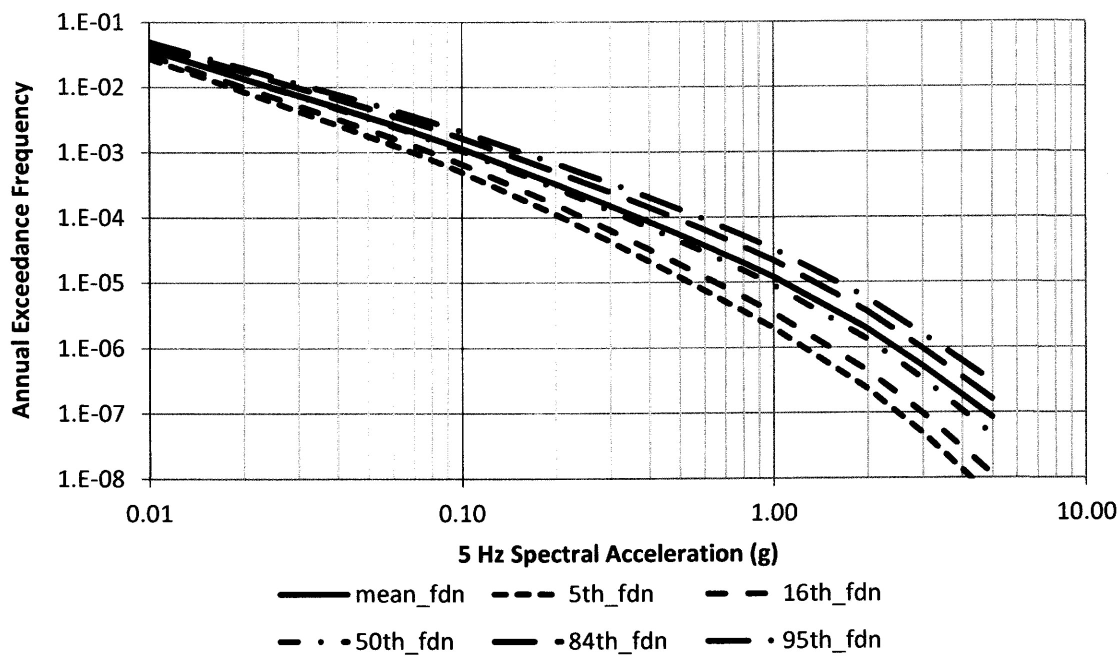
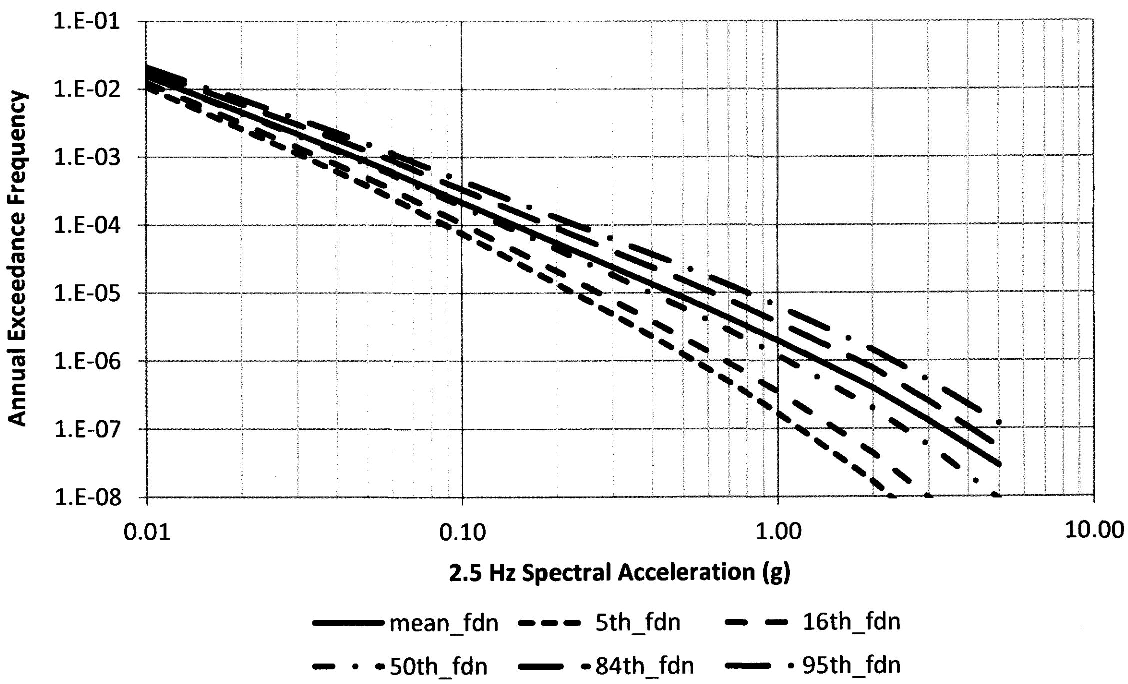


FIGURE C-2
BVPS-1 MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL (SA AT 10 HZ AND 5.0 HZ)



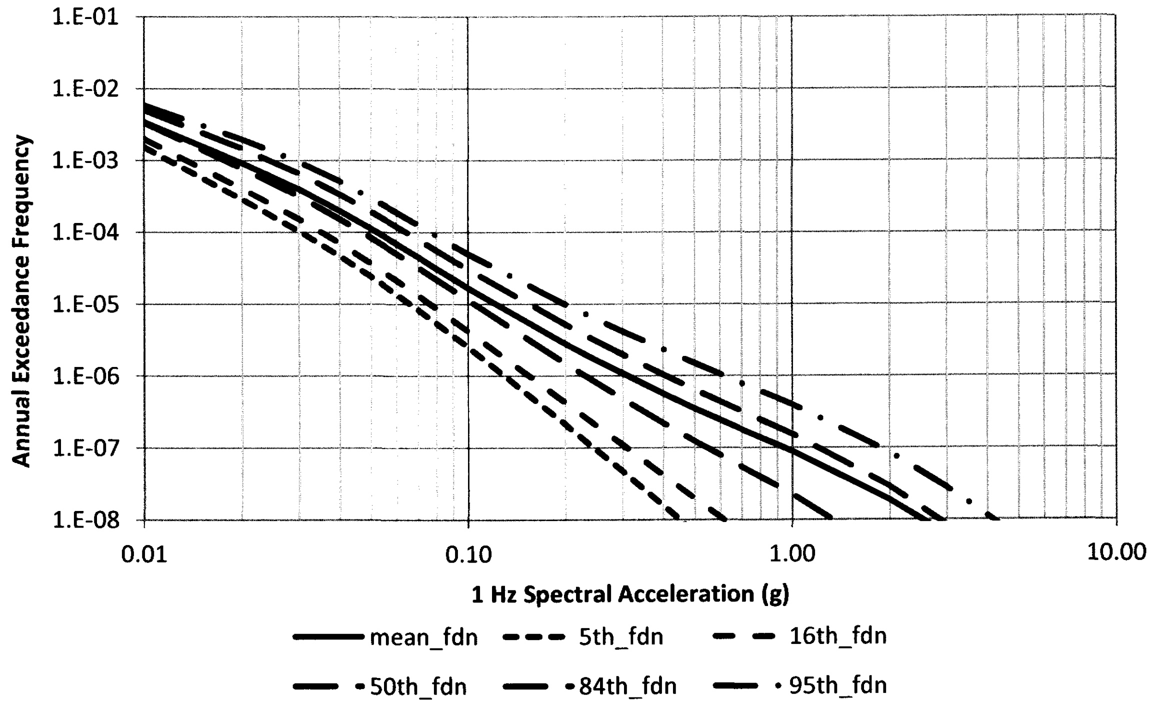


FIGURE C-3
BVPS-1 MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL (SA AT 2.5 HZ AND 1.0 HZ)

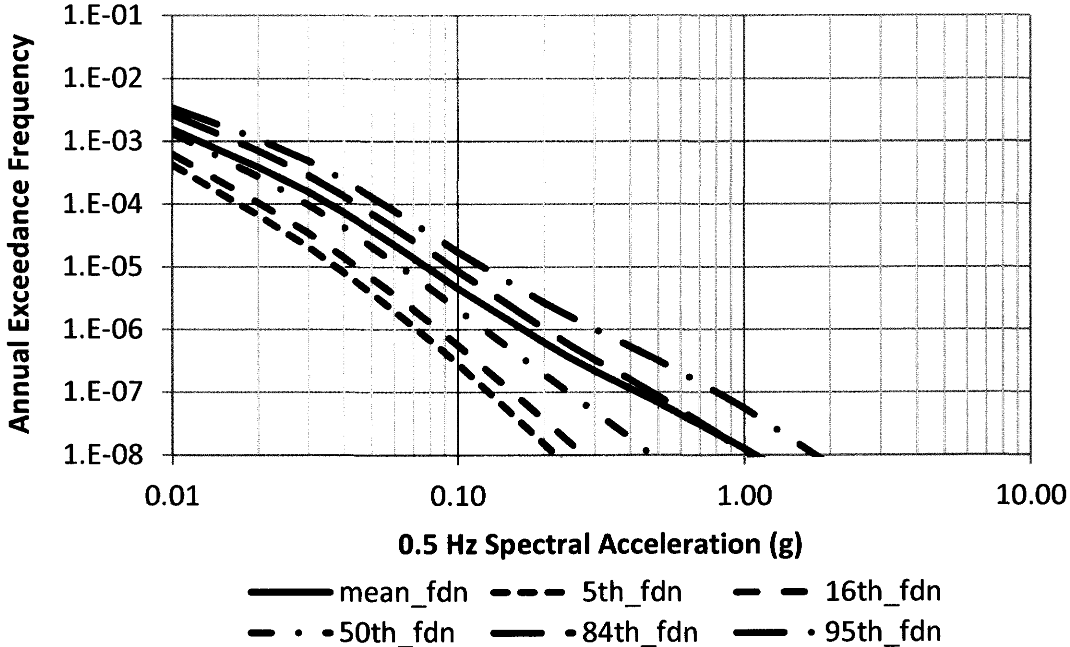


FIGURE C-4
BVPS-1 MEAN AND FRACTILE HAZARD CURVES AT RB FOUNDATION LEVEL (SA AT 0.5 HZ)