Exelon Generation

10 CFR 50.54(f)

RS-14-236
RA-14-071

August 21, 2014

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Clinton Power Station, Unit 1
Facility Operating License No. NPF-62
NRC Docket No. 50-461

Limerick Generating Station, Units 1 and 2
Facility Operating License Nos. NPF-39 and NPF-85
NRC Docket Nos. 50-352 and 50-353

Oyster Creek Nuclear Generating Station, Unit 1
Renewed Facility Operating License No. DPR-16
NRC Docket No. 50-219

Quad Cities Nuclear Power Station, Units 1 and 2
Renewed Facility Operating License Nos. DPR-29 and DPR-30
NRC Docket Nos. 50-254 and 50-265

Subject: Supplemental Information Regarding Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites) - Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident

References:

1. Exelon Generation Company, LLC, Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites), Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, dated March 31, 2014 (RS-14-066) [Clinton]
2. Exelon Generation Company, LLC, Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites), Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, dated March 31, 2014 (RS-14-069) [Limerick]

3. Exelon Generation Company, LLC, Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites), Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, dated March 31, 2014 (RS-14-070) [Oyster Creek]
4. Exelon Generation Company, LLC, Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites), Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, dated March 31, 2014 (RS-14-072) [Quad Cities]
5. Exelon Generation Company, LLC, Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident – 1.5 Year Response for CEUS Sites, dated September 12, 2013 (RS-13-205)
6. NRC Letter, Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, dated March 12, 2012
7. EPRI Report 1025287, Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic, February 2013
8. NRC Letter, Endorsement of Electric Power Research Institute Final Draft Report 1025287, "Seismic Evaluation Guidance," dated February 15, 2013
9. NRC Letter, Screening and Prioritization Results Regarding Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Re-Evaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, dated May 9, 2014
10. NRC Memorandum, Support Document for Screening and Prioritization Results Regarding Seismic Hazard Re-Evaluations for Operating Reactors in the Central and Eastern United States, dated May 21, 2014

In References 1, 2, 3, and 4, Exelon Generation Company, LLC (EGC) provided the Seismic Hazard and Screening Reports for Clinton Power Station, Unit 1, Limerick Generating Station, Units 1 and 2, Oyster Creek Nuclear Generating Station, and Quad Cities Nuclear Power Station, Units 1 and 2, respectively. In Reference 5, EGC provided the descriptions of subsurface materials and properties and base case velocity profiles for the EGC plant sites. These seismic hazard and screening reports, and the subsurface materials and properties and base case velocity profiles information, were provided in response to the NRC request for seismic hazard evaluation information (Reference 6). Reference 7 contains the industry guidance for performing the seismic hazard screening and describes the detailed information to be included in the seismic hazard evaluation and screening report submittals. NRC endorsed this industry guidance in Reference 8. The seismic hazard re-evaluation reports determined that these plants screen out based on the requirements of Section 3.2 of the SPID (Reference 7) and therefore, do not require further seismic risk assessment.

In Reference 9, the NRC issued the industry screening and prioritization results based on review of the March 31, 2014 seismic hazard re-evaluation reports. The NRC review of the

EGC plant sites identified that a final determination could not be made for Clinton Power Station, Unit 1, Limerick Generating Station, Units 1 and 2, Oyster Creek Nuclear Generating Station, and Quad Cities Nuclear Power Station, Units 1 and 2 and that additional interactions with the licensee is needed to reach resolution. The NRC staff determined these plants "conditionally screened-in" for the purposes of prioritizing and conducting additional evaluations. A meeting was held between the NRC and EGC on June 17, 2014 to discuss and understand the NRC basis for the conditional screen-in determination for the Exelon plants. At this meeting, EGC also provided additional information regarding development of the seismic hazard re-evaluation reports including the bases for the EGC screening results for the subject EGC plants.

The purpose of this letter is to provide supplemental information to address the NRC staff technical questions and issues resulting from the NRC's preliminary review of the seismic hazard re-evaluation reports provided for Clinton Power Station, Unit 1, Limerick Generating Station, Units 1 and 2, Oyster Creek Nuclear Generating Station, and Quad Cities Nuclear Power Station, Units 1 and 2, as discussed at the June 17, 2014 EGC/NRC meeting. This information provides additional detailed basis and justification for the inputs and parameters used in the EGC seismic hazard re-evaluation reports supporting the EGC determination that these plant sites meet the requirements of the NRC endorsed SPID criteria (References 7 and 8) and therefore screen out from further seismic risk assessment, as discussed at the June 17, 2014 EGC/NRC meeting.

This letter contains no new regulatory commitments. If you have any questions regarding this submittal, please contact Ron Gaston at (630) 657-3359.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 21st day of August 2014.

Respectfully submitted,

James Barstow
Director - Licensing & Regulatory Affairs
Exelon Generation Company, LLC

Attachments:

1. Clinton Power Station, Unit 1, Supplemental Information in Response to NRC Conditional Screen-In Evaluation
2. Limerick Generating Station, Units 1 and 2, Supplemental Information in Response to NRC Conditional Screen-In Evaluation
3. Oyster Creek Nuclear Generating Station, Supplemental Information in Response to NRC Conditional Screen-In Evaluation
4. Quad Cities Nuclear Power Station, Units 1 and 2, Supplemental Information in Response to NRC Conditional Screen-In Evaluation

cc: Director, Office of Nuclear Reactor Regulation
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Regional Administrator - NRC Region III
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NRC Senior Resident Inspector - Limerick Generating Station
NRC Senior Resident Inspector - Oyster Creek Nuclear Generating Station
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Site Vice President - Oyster Creek Nuclear Generating Station
Site Vice President – Quad Cities Nuclear Power Station
Vice President Operations Support
Regulatory Affairs Manager
Regulatory Assurance Manager - Clinton Power Station
Regulatory Assurance Manager - Limerick Generating Station
Regulatory Assurance Manager - Oyster Creek Nuclear Generating Station
Regulatory Assurance Manager – Quad Cities Nuclear Power Station
Severe Accident Management Director
Site Operations Director - Clinton Power Station
Site Operations Director - Limerick Generating Station
Site Operations Director - Oyster Creek Nuclear Generating Station
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Attachment 1

Clinton Power Station, Unit 1

Supplemental Information in Response to NRC Conditional Screen-In Evaluation

Reason for Evaluation / Scope:

In response to the 50.54(f) letter regarding Fukushima Near-Term Task Force (NTTF) Recommendation 2.1, Exelon performed a seismic hazard analysis and screening for Clinton Power Station (CPS) to develop a Ground Motion Response Spectrum (GMRS) for comparison with the Safe Shutdown Earthquake (SSE). The Exelon GMRS was developed in accordance with EPRI Report 1025287 (2012) "Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" (Ref. 1) that was endorsed by the Nuclear Regulatory Commission (NRC) (Ref. 2). The result of the screening process was that CPS screened out of performing a seismic risk assessment. Exelon submitted the seismic hazard and screening report to the NRC on March 31, 2014 (Ref. 3).

Subsequently, on May 9, 2014, the NRC issued the Screening and Prioritization Results letter (Ref. 4), and in that letter CPS was screened as "Conditional In." On May 21, 2014, the NRC issued by memorandum, "Support Document for Screening and Prioritization Results Regarding Seismic Hazard Re-evaluations for Operating Reactors in the Central and Eastern United States," (Ref. 5) and in that letter provided a plot of the CPS SSE, the Exelon new GMRS, and the NRC new GMRS (Fig. 1). The plot illustrated that the GMRS results of the re-evaluation performed by CPS were not in alignment with the results of the re-evaluation performed by the NRC. The differences were discussed in a public meeting between the NRC and Exelon at the NRC Offices in Rockville, MD on June 17, 2014 (Ref. 12). This paper discusses the bases for the differences in the analysis methods and technical judgments when comparing the re-evaluation performed by Exelon to the re-evaluation performed by the NRC as understood from the June 17, 2014 public meeting.

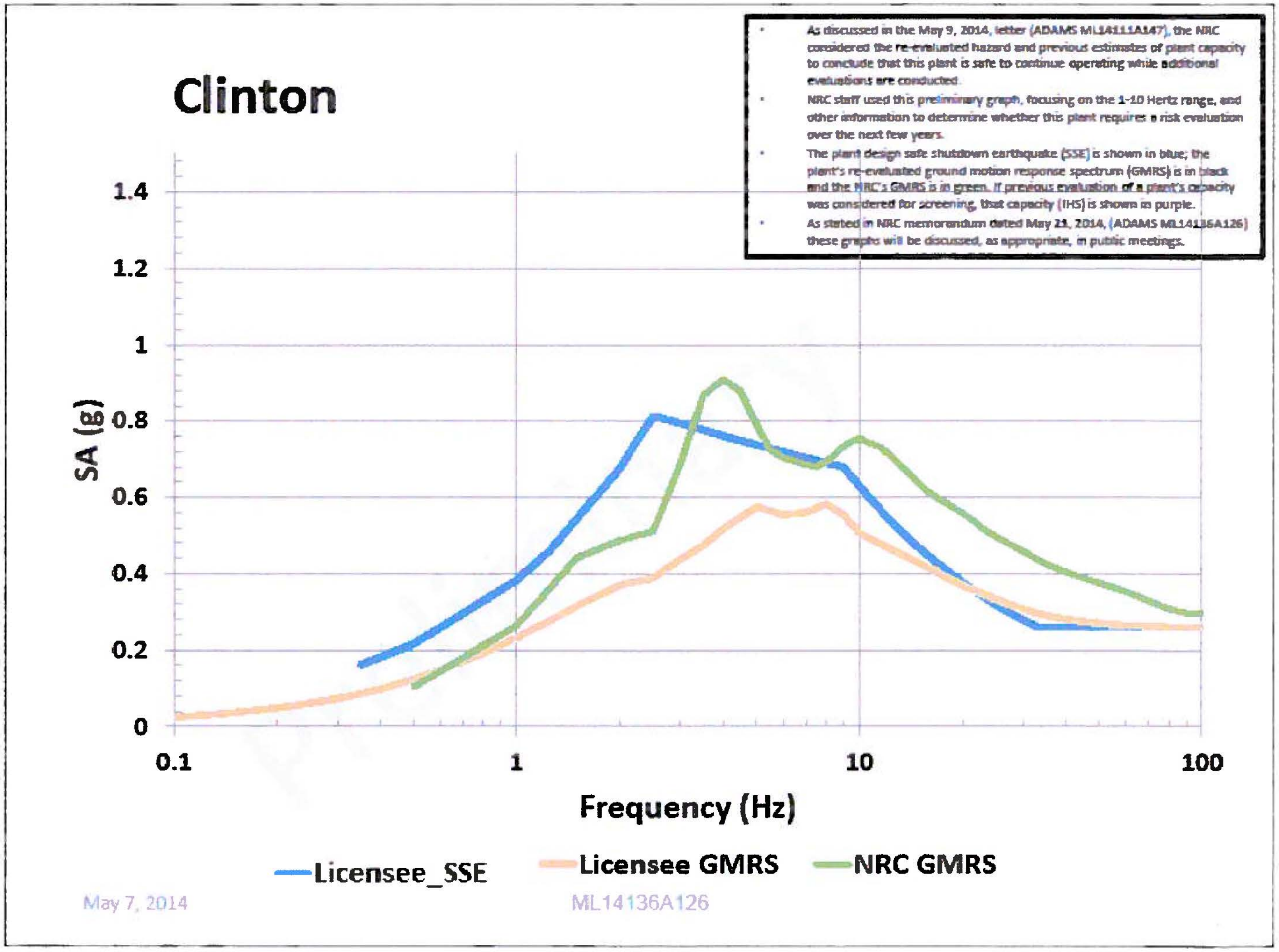

Clinton
• As discussed in the May 9, 2014, letter (ADAMS ML14111A147), the NRC considered the re-evaluated hazard and previous estimates of plant capacity to conclude that this plant is safe to continue operating while additional evaluations are conducted.
• NRC staff used this preliminary graph, focusing on the 1-10 Hertz range, and other information to determine whether this plant requires a risk evaluation over the next few years.
• The plant design safe shutdown earthquake (SSE) is shown in blue; the plant's re-evaluated ground motion response spectrum (GMRS) is in black and the NRC's GMRS is in green. If previous evaluation of a plant's capacity was considered for screening, that capacity (IHS) is shown in purple.
• As stated in NRC memorandum dated May 21, 2014, (ADAMS ML14136A126) these graphs will be discussed, as appropriate, in public meetings.
SA (g)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.1
1
10
100
Frequency (Hz)
Licensee_SSE
Licensee GMRS
NRC GMRS
May 7, 2014
ML14136A126

Figure 1

Detailed Evaluation:

The June 17, 2014 public meeting identified a number of differences between the GMRS developed in the Exelon re-evaluation and GMRS developed in the NRC re-evaluation efforts. The differences noted relate to the following items:

- Item No. 1: Base-case shear-wave velocity profile
- Item No. 2: Three base-case shear-wave velocity profiles versus one base-case shear-wave velocity profile
- Item No. 3: Kappa and low-strain damping values
- Item No. 4: Amplification functions

These items are addressed in the following sections. The Exelon understanding of the NRC approach regarding each item is presented based on the NRC presentation slides and public meeting discussions from the June 17, 2014 public meeting. The Exelon approach to development of the item is then presented, and followed by a comparison of the approaches.

Item No. 1: Base-Case Shear-Wave Velocity Profile

<u>NRC Shear-Wave Velocity Profile</u>

The NRC base-case shear-wave velocity profile was presented in the public meeting on June 17, 2014 (Ref. 9) and is shown below in Figure 2.

U.S.NRC
Protecting People and the Environment

NRC Velocities & Properties

Depth (ft)	Vs (ft/s)	Unit Weight (lb/ft^3)	G/G_{max}	Damping	Kappa (sec)
36	900	131	EPRI Soil (1993) & Peninsular	EPRI Soil (1993) & Peninsular	
57	1100	132	EPRI Soil (1993) & Peninsular	EPRI Soil (1993) & Peninsular	
160	2100	147	EPRI Soil (1993) & Peninsular	EPRI Soil (1993) & Peninsular	
188	2100	140	EPRI Soil (1993) & Peninsular	EPRI Soil (1993) & Peninsular	
267	2100	137	EPRI Soil (1993) & Peninsular	EPRI Soil (1993) & Peninsular	
290	2100	147	EPRI Soil (1993) & Peninsular	EPRI Soil (1993) & Peninsular	
308	3420	150	EPRI Soil (1993) & Peninsular	EPRI Soil (1993) & Peninsular	
398	4000	150	Linear	No Damping	Lower 0.010 Base 0.0123 Upper 0.016
448	4275	150	Linear	No Damping	
648	4650	150	Linear	No Damping	
1198	5500	155	Linear	No Damping	
1898	7200	155	Linear	No Damping	
5898	8200	160	Linear	No Damping	
Bedrock	9200	165		0.10%	0.006

Figure 2

Review of the NRC shear-wave velocity profile indicates that soil layers are based on the Clinton Early Site Permit (ESP) Site Safety Analysis Report (SSAR) data (Ref. 7) as illustrated in Figures 3 and 4.

Table 5-2 of Appendix A of the ESP SSAR (geotechnical evaluation) provides depth intervals at Boring B-2 and shear-wave and compression wave velocity test data for the stratigraphic soil units at the site to a depth of approximately 310 feet (Fig. 3). Top of firm rock is encountered at the ESP site at an approximate depth of 310 ft.

Review of the NRC shear-wave velocity data for soil stratigraphic units from the ground surface to 290 ft below the surface indicates that the values are based on the typical values from the USAR (Fig. 3). The shear-wave velocity data resulting from suspension logging shear-wave velocity tests (Boring B-2) and seismic cone tests (Boring CPT-2 and CPT-4) that were performed in the soil units for the ESP were not used. The balance of shear-wave velocity data (one soil unit and the balance are firm rock units) from 290 ft to 1,900 ft below the surface is based on the data presented in the ESP (Fig. 4).

Table 4.2-1 of Appendix B of the ESP SSAR (seismic hazard evaluation) provides depth range and shear-wave velocity for sedimentary rock from approximately 310 ft to 1,900 ft below the surface (Fig. 4). In Section 4.2.1 of Appendix B of the ESP, the report states that the "average" V_s values presented in Table 4.2-1 and Figure 4.2-1 (Ref. 7) "was configured to capture major trends in the measured velocity with depth. The median velocity profile was drawn smoothly through small scale variations in velocity measurements." Shear-wave velocity data in the firm rock layers are not based on deep borings at the CPS site or ESP site, but rather are based on regional data from deep well borings located within 10 miles of the site (Ref. 7). It should be noted that the equivalent damping ratio presented in Figure 4 for the firm rock ranges from 1.83% to 3.30%.

Below 1,898 ft, the NRC best estimate V_s is approximately 8,200 fps, which appears to have been obtained from the lower-bound dashed curve in Figure 17. This lower-bound curve was computed for the ESP using an estimated Poisson's ratio of 0.33, whereas the upper-bound dashed profile was computed using a Poisson's ratio of 0.25. At these depths, the ESP analysis accounted for uncertainty in V_s by randomizing profiles with a uniform distribution between the upper-bound and lower-bound profiles shown in Figure 17. By using the lower-bound profile from Figure 17 as their best estimate, the NRC has effectively biased the profile toward the lower end of the V_s range estimated in the ESP.

Based on this review, Exelon understands that the majority of shear-wave parameters used in the NRC analysis are based on the original geotechnical test program for Clinton site plus the regional deep well compression wave (V_p) measurements.

<u>Exelon Shear-Wave Velocity Profile</u>

As prescribed by section B2.0 of the SPID, Exelon considered soil data from the USAR, from the ESP, and from regional deep well V_p measurements in developing input parameters for the seismic hazard analysis. The soil profile data and ranges of parameters considering USAR and ESP soil data, plus regional V_p data, were submitted to the NRC on September 12, 2013 in Ref. 8. Exelon developed velocity ranges based on available data and measurements, and then computed the mean of those ranges as the base-case. The table was included in the seismic hazard and screening report (Ref. 3) as Table 2.3.1-1 (Fig. 5).

During the public meeting, Exelon presented numerous slides that were developed from USAR and ESP site cross-sections and regional cross-sections that illustrate the variability in the soil profile in the area of the Clinton site (Ref. 10). The slides are presented below in Figure 6 through Figure 12. The slides illustrate the following:

- Evidence of uncertainty by showing variability of soil profiles
- Variability of topography due to location of the site between two waterways
- Variability in layer thickness in soils
- Variability in firm rock layer thickness
- Variability in depth to top of firm rock
- Sloping surface at top of firm rock

The base-case soil profile thicknesses were developed based on a soil boring beneath the containment and ranges were developed using the available data. No weighting of the USAR and ESP data was used, as all available data was considered when the ranges were developed for Table 2.3.1-1 in Reference 3. The table shown in Figure 13 presented by Exelon (Ref. 10) illustrates the range in thicknesses for layers of soil.

Only four soil borings were made for the ESP study, which consisted of two borings to a depth of 100 ft, and two borings into the firm rock at an approximate depth of 310 ft. At the CPS site, the top of firm rock is encountered at an approximate depth of 240 ft as illustrated in the cross-section in Figure 10. The ESP SSAR explains that the geotechnical program for the ESP was developed to verify that the ESP site conditions were similar enough to the existing CPS site, so that the existing geotechnical data could be used for the ESP evaluation. Since the reactor plant design was not yet selected, a full geotechnical program in accordance with Regulatory Guide (R.G.) 1.132 (Ref. 11) and coordinated to the foundation design could not be developed and implemented at the time of the ESP. The ESP also explains that when a Combined License (COL) application would be developed, then the full R. G. 1.132 geotechnical requirements for COL application would have to be performed. Based on the discussion in the ESP SSAR, there is sufficient uncertainty in the data to warrant capturing a range of shear-wave velocities to account for epistemic uncertainty.

Comparison of NRC Base-case Shear-Wave Profile and Exelon Base-case Shear-Wave Profile

Based on the methodologies used and data considered to develop the base-case soil profile, there are differences between the NRC soil profile and the Exelon soil profile (noted as P1 in Ref. 3). A plot of the soil profiles was presented in the NRC public meeting presentation (Ref. 9), and is shown in Figure 14.

The NRC soil profile stratigraphic layer thicknesses appear to be based on the soil cross section from one soil boring from the ESP program, and the firm rock layers appear to be from data presented in the ESP. Neither of these data inputs appears to consider ranges of layer thickness.

The Exelon base-case soil profile stratigraphic layer thicknesses are based on the soil boring under the CPS containment building. The ranges of layer thicknesses for data at the ESP and CPS site were reported to show variability across the site. Exelon contends that ranges of data should be included to develop the base-case profile so that uncertainty is adequately considered in the re-evaluation.

The NRC selected shear-wave velocity data from typical values for soils down to approximately 290 ft from the CPS USAR, and then used tabulated values presented in the ESP for soil and firm rock layers below 290 ft which were based on regional V_p measurements and assumed Poisson's ratios.

The Exelon base-case shear-wave velocity profile considered the ranges of the shear-wave data considering data available in the test results of the ESP and the USAR in developing the base-case profile. Regional V_p measurements were also considered to develop the firm-rock shear-wave velocities using assumed Poisson's ratios.

The differences between the NRC and CPS best estimate base-case soil profiles, though not very significant, are expected to yield somewhat different GMRS curves even if Exelon had only used one base-case soil profile. However, this alone is not expected to be the main cause of the significant difference between the NRC and Exelon GMRS curves.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning the CPS mean base-case shear-wave velocity profile. Based on this review, Exelon concludes that the CPS profile submitted to the NRC on March 31, 2014 is appropriate and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation for the following reasons:

- The differences between the NRC and Exelon soil profiles are small and are not expected to significantly influence the seismic hazard results.
- The Exelon profile was developed using a systematic approach considering all available in-situ data. This approach is most representative of the geotechnical profile data available. This approach was used consistently across the CEUS fleet.

TABLE 5-2
Summary of Shear and Compression Wave Velocity Test Data

		EGC ESP Site Results								CPS Site Results			
		Suspension Logging Test at B-2 Receiver to Receiver Measurements				Seismic Cone Test at CPT-2		Seismic Cone Test at CPT-4		Uphole Survey at P-14		Downhole Survey at P-14	
		Compression Wave Velocity (fps)		Shear Wave Velocity (fps)		Shear Wave Velocity (fps)		Shear Wave Velocity (fps)		Compression Wave Velocity (fps)		Shear Wave Velocity (fps)	
Depth Interval at B-2 (ft bgs)	Stratigraphic Unit	Range	Average	Range	Average	Range	Average	Range	Average	Range	Typical	Range	Typical
0 to 42	Loess & Wisconsinan Till	1680 to 6030	4788	820 to 1340	975	703 to 1354	1034	641 to 1077	838	NA	4800	900 to 1100	900 to 1100
42 to 59	Interglacial Zone (Weathered Illinoian Till)	5720 to 7500	6465	860 to 1970	1343	1022 to 1231	1132	1006 to 1602	1256	NA	4800	NA	1100
59 to 162	Illinoian Till	5720 to 8880	7552	1100 to 3250	2188	NA	NA	NA	NA	NA	7400	NA	2100
162 to 190	Lacustrine	6080 to 8040	6971	1390 to 2670	1829	NA	NA	NA	NA	NA	7400	NA	2100
190 to 269	Pre-Illinoian Till	5270 to 8230	6925	1560 to 2800	2068	NA	NA	NA	NA	NA	7400	NA	2100
269 to 292	Pre-Illinoian Alluvial / Lacustrine	5270 to 7940	6579	1190 to 3310	2045	NA	NA	NA	NA	NA	7400	NA	2100
292 to 307	Weathered Bedrock	7850 to 8440	8096	3250 to 3880	3420	NA	NA	NA	NA	NA	12000	NA	5700

Figure 3

TABLE 4.2-1

NOMINAL DAMPING RATIOS FOR SEDIMENTARY ROCK CORRESPONDING TO κ = 0.013 SEC

Seismic Hazards Report for the EGC ESP Site

Depth Range[1] (ft)	**Average Shear Wave Velocity (fps)**	**Shear Wave Quality Factor Q_S**	**Equivalent Damping Ratio (%)**
310 - 400	4,000	15.2	3.30
400 – 450	4,275	16.2	3.08
450 – 650	4,650	17.6	2.84
650 – 1,200	5,500	20.9	2.40
1,200 – 1,900	7,200	27.3	1.83

[1] Depth range is depth below ground surface.

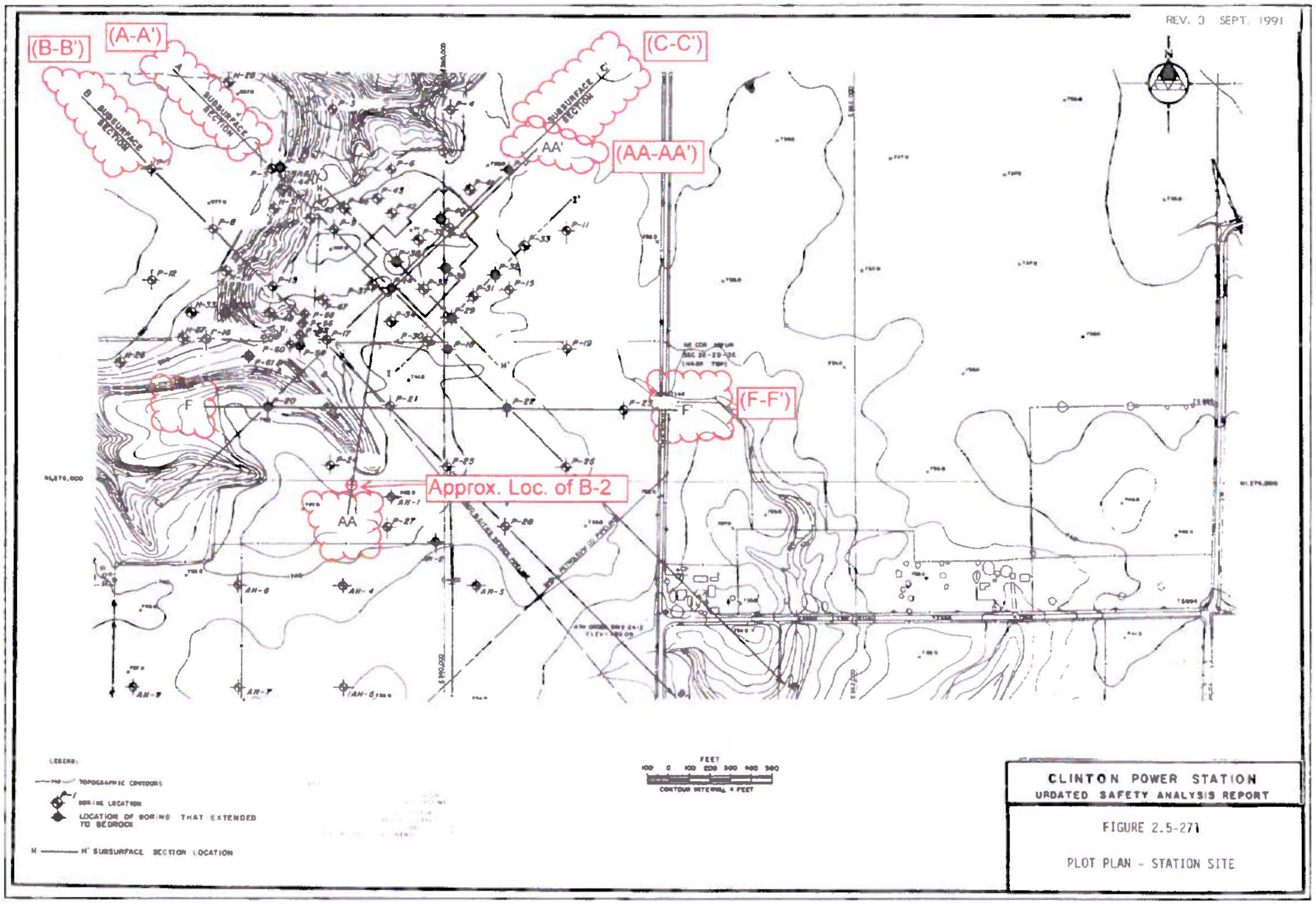
Figure 4

Table 2.3.1-1: Summary of geotechnical profile data for Clinton station (Reference 21)

Elevations of Layer Boundaries At Containment Buildings (feet, MSL)	Range in Thickness Across Site (feet)	Soil/Rock Description and Age	Density (pcf)	Shear Wave Velocity (fps)	Compressional Wave Velocity (fps)	Poisson's Ratio
736[a] to 732	4-10	Wisconsinan Richland Loess, soft, clayey silt	118-131	641-1354	1680-2875	0.37
732 to 702	20-55	Wisconsinan Wedron Formation, stiff to very stiff clayey sandy silt with lenses of stratified sand, gravel or silt	130-157	641-1354	4800-7300	0.48
702 to 680[b]	10-22	Illinoian weathered Glasford Formation, clayey silt with sand and gravel	120-160	860-1970	4800-7500	0.48
680 to 577	90-140	Illinoian unaltered Glasford Formation, hard sandy silt till with discontinuous layers of stratified sand, gravel or silt up to 3 feet thick in the uppermost part	140-160	1100-3250	5700-8900	0.46
577 to 560	0-17	Probably-Pre-Illinoian lacustrine deposit of clayey silt (reworked and weathered Pre-Illinoian glacial till)	133-142	1390-2670	7500	0.46-0.47
560 to 510	50-68	Pre-Illinoian silty clay and clayey silt with some sand and gravel	134-162	1560-2800	5270-8230	0.46-0.47
510 to 500	5-15	Pre-Illinoian lacustrine deposits of clayey silt and silty clay with sand and some gravel (reworked glacial till)	126-142	1190-3310	5270-7940	0.40-0.46
500 to 0	300-800	Pennsylvanian limestone, shale, sandstone, coal, and siltstone	160-166	3250-5700	7850-12000	0.29
0 to -500	500-600	Mississippian limestone, with lesser siltstone and shale	N/A	4500-6500	N/A	0.33
-500 to -700	150-250	Devonian shale and limestone	N/A	4500-8500	N/A	0.33
-700 to -1200	450-550	Silurian carbonates, some of which include reef structure	N/A	4500-8500	N/A	0.33
-1200 to -2300	1000-1500	Ordovician dolomite, sandstone, basal sandstone, limestone, and shales	N/A	6500-10500	N/A	0.25-0.33
-2300 to -5300	2900-3100	Cambrian siltstone, shale, sandstone, and dolomite	N/A	6500-10500	N/A	0.25-0.33
-5300 and below	N/A	Precambrian igneous rocks, dominantly granite with associated granodiorite, rhyolite, felsite, or granophyre of closely related composition	N/A	>9200	N/A	0.25

a Surface of finish grade is nominally at El. 736 feet MSL in the vicinity of the main power block. This is the control point elevation for the SSE and the IPEEE HCLPF.
b Bottom of the deepest foundation in the vicinity of the main power block is at El. 693 feet MSL, within the weathered Glasford Formation. Beneath the main power block, the native soils were excavated down to El. 680 feet MSL to the surface of the unaltered Glasford Formation. Type B structural fill is placed between El. 680 feet MSL and the bottom of the foundations. The structural backfill is described in UFSAR Section 2.5.4.5.1.5 (Reference 10).

Figure 5



Boring Locations and Cross Section Definitions
Figure 6

ESP Figure 5-5 below provides the ESP location relative to the plant (note boring B-2 is located approximately ¼ mile from plant).

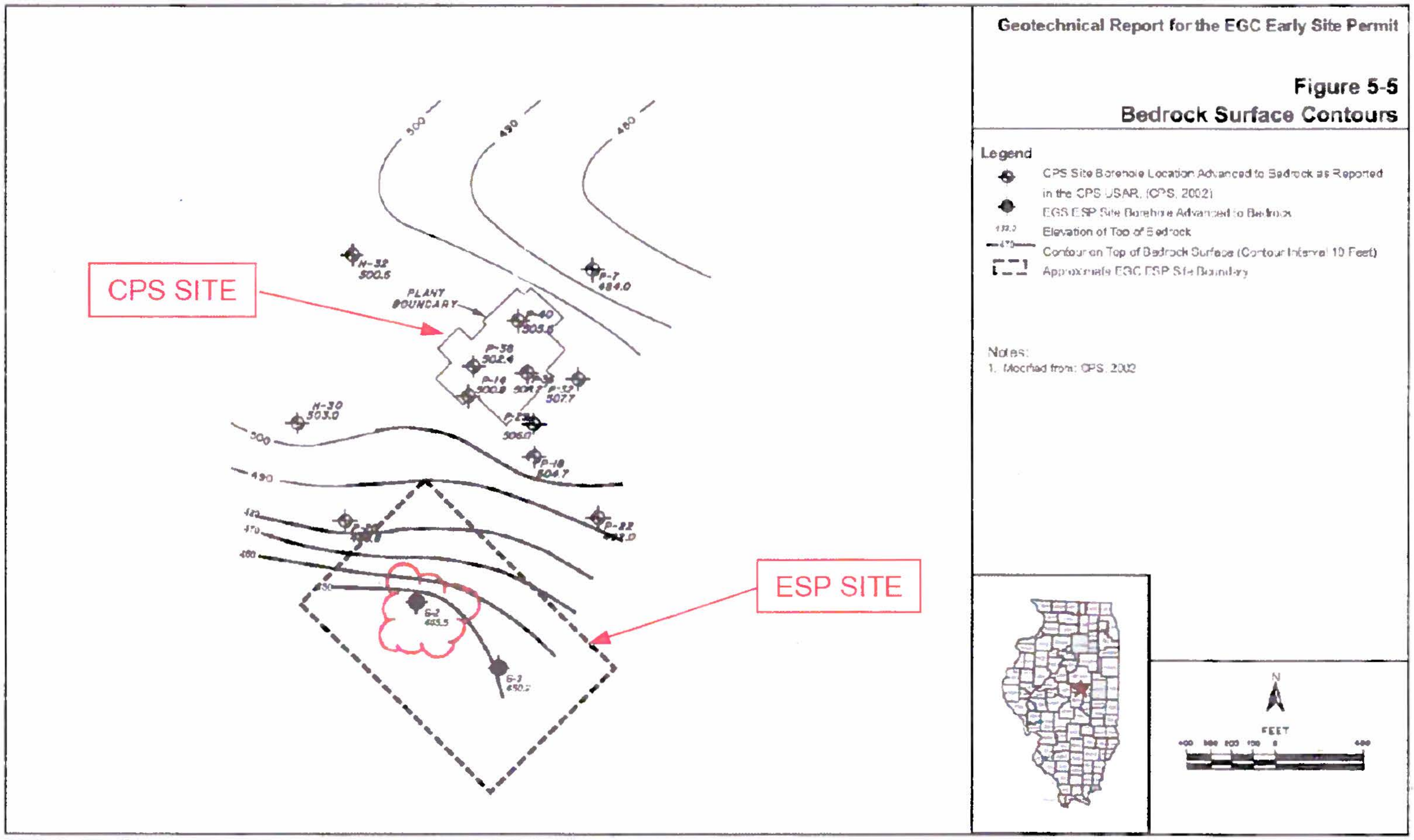


Figure 7

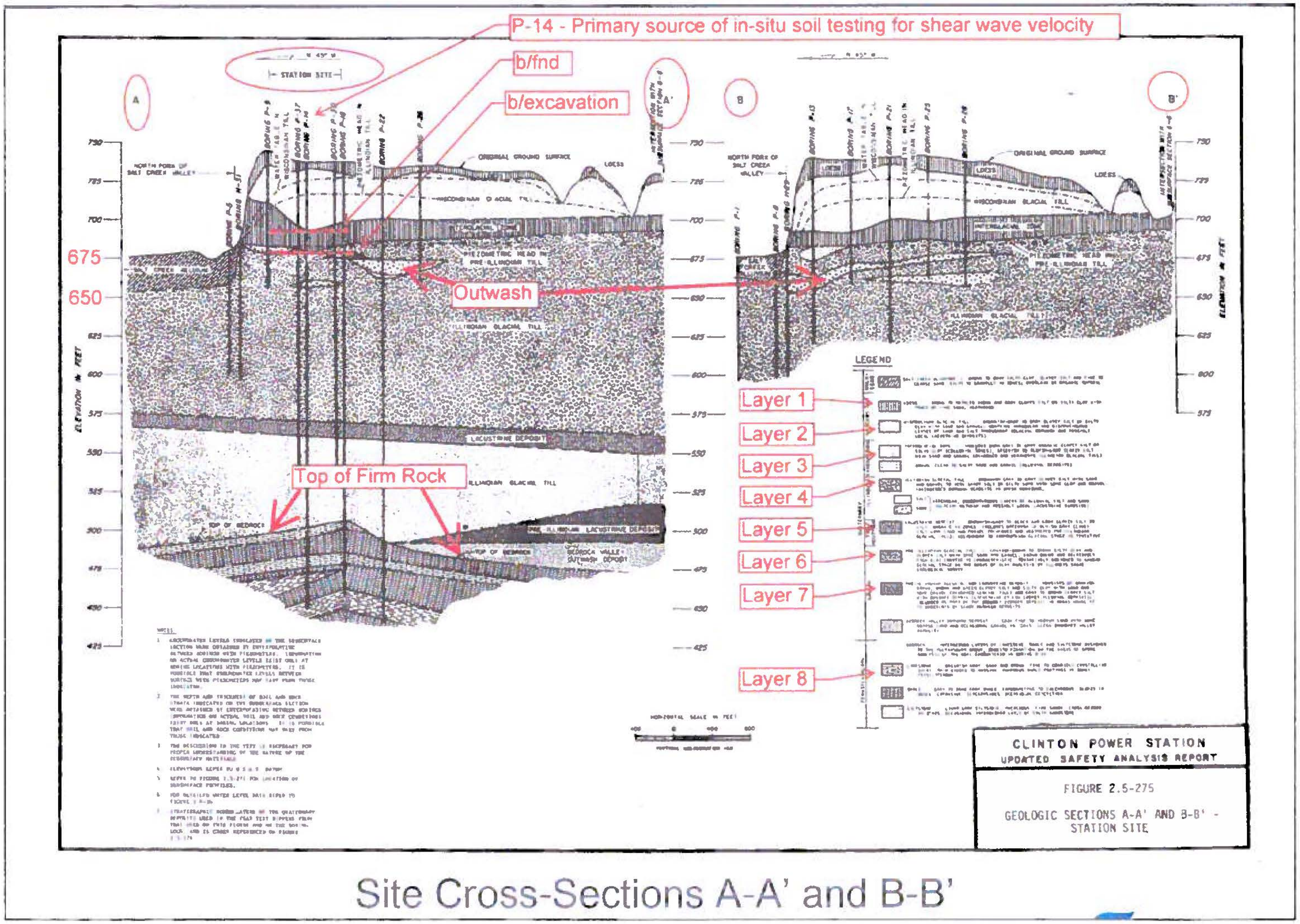

P-14 - Primary source of in-situ soil testing for shear wave velocity
b/fnd
b/excavation
675
650
Outwash
Top of Firm Rock
LEGEND
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
ELEVATION IN FEET
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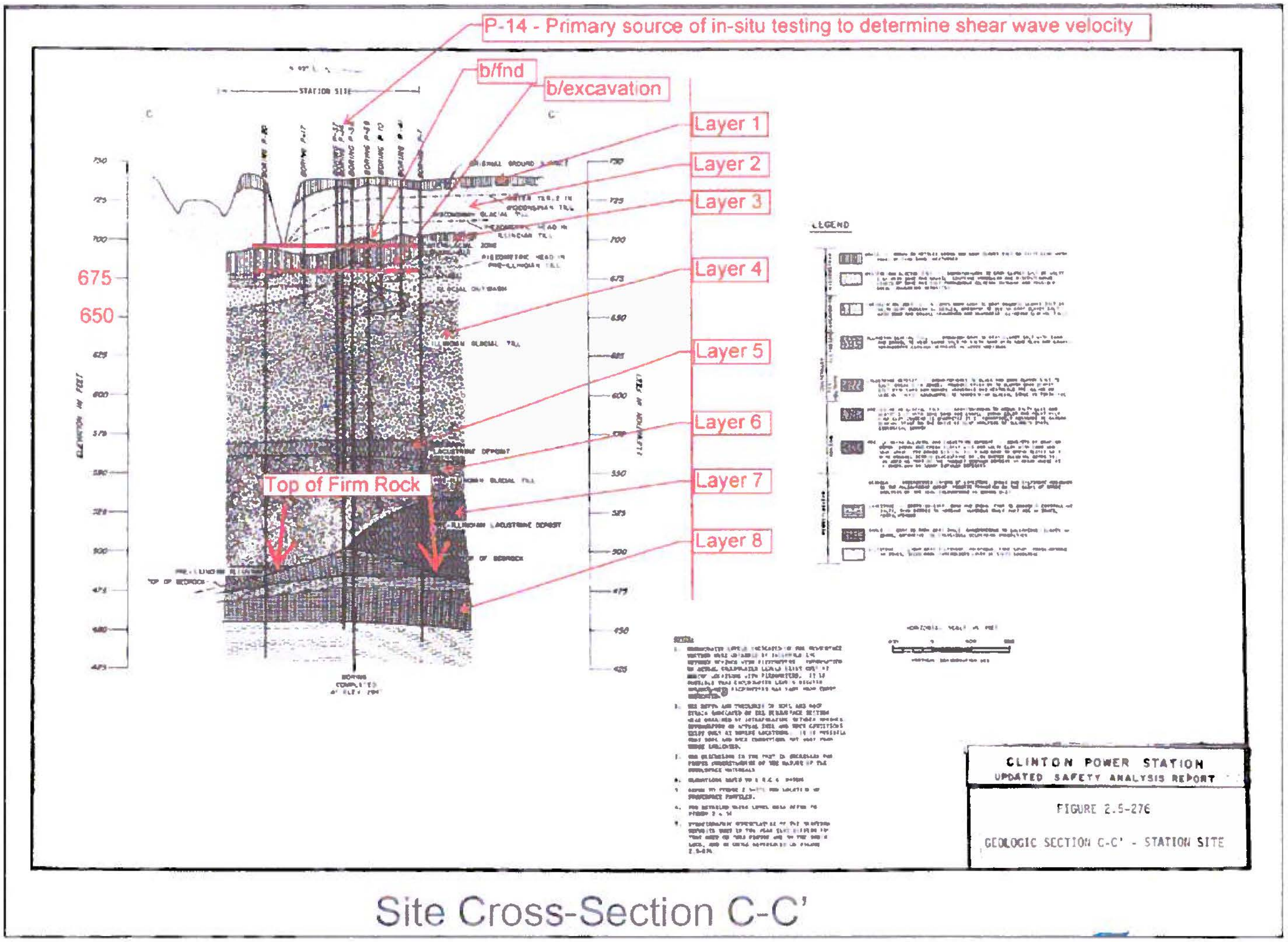
FIGURE 2.5-275
GEOLOGIC SECTIONS A-A' AND B-B' - STATION SITE
Site Cross-Sections A-A' and B-B'

Figure 8



Site Cross-Section C-C'

Figure 9

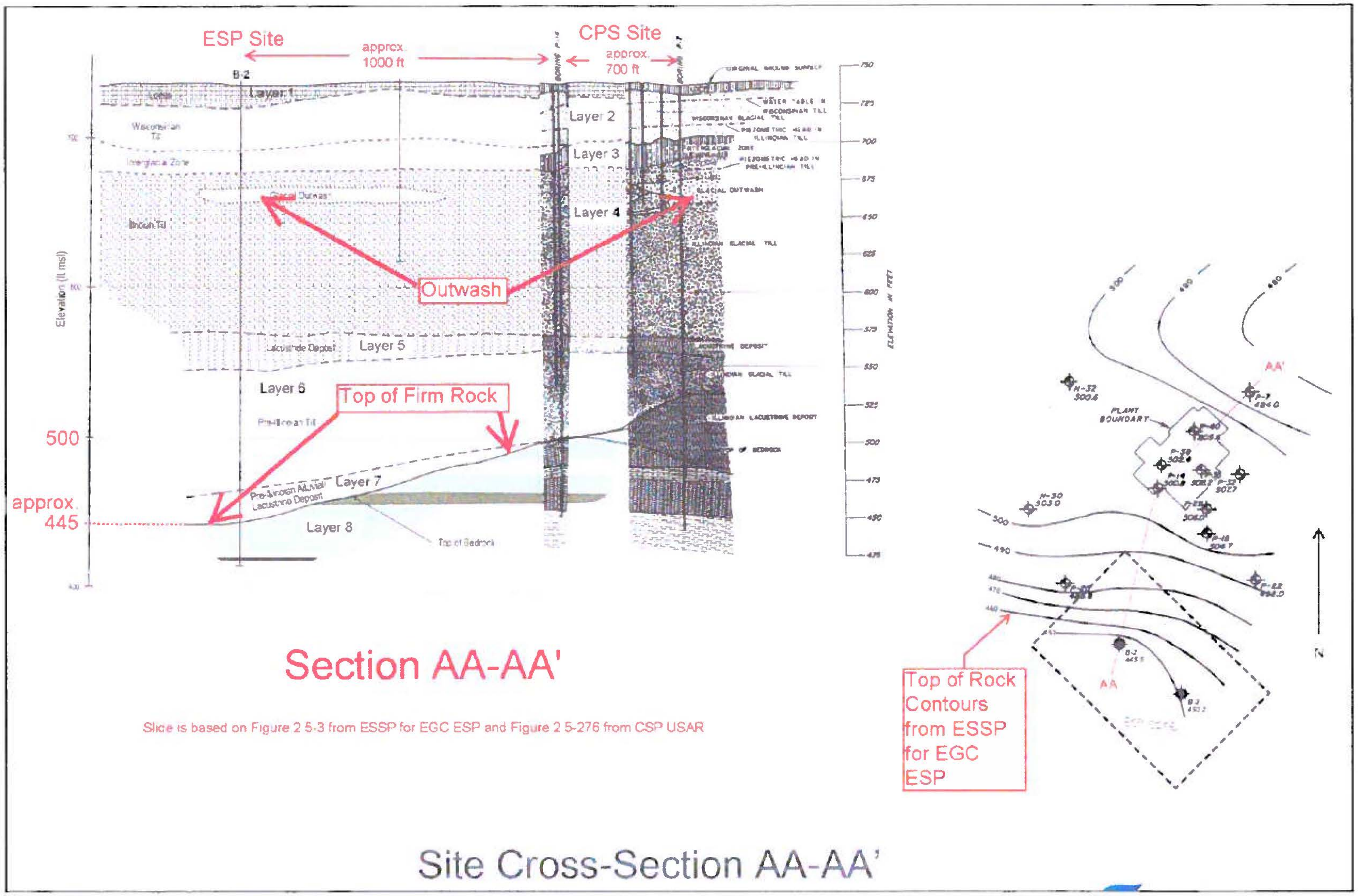
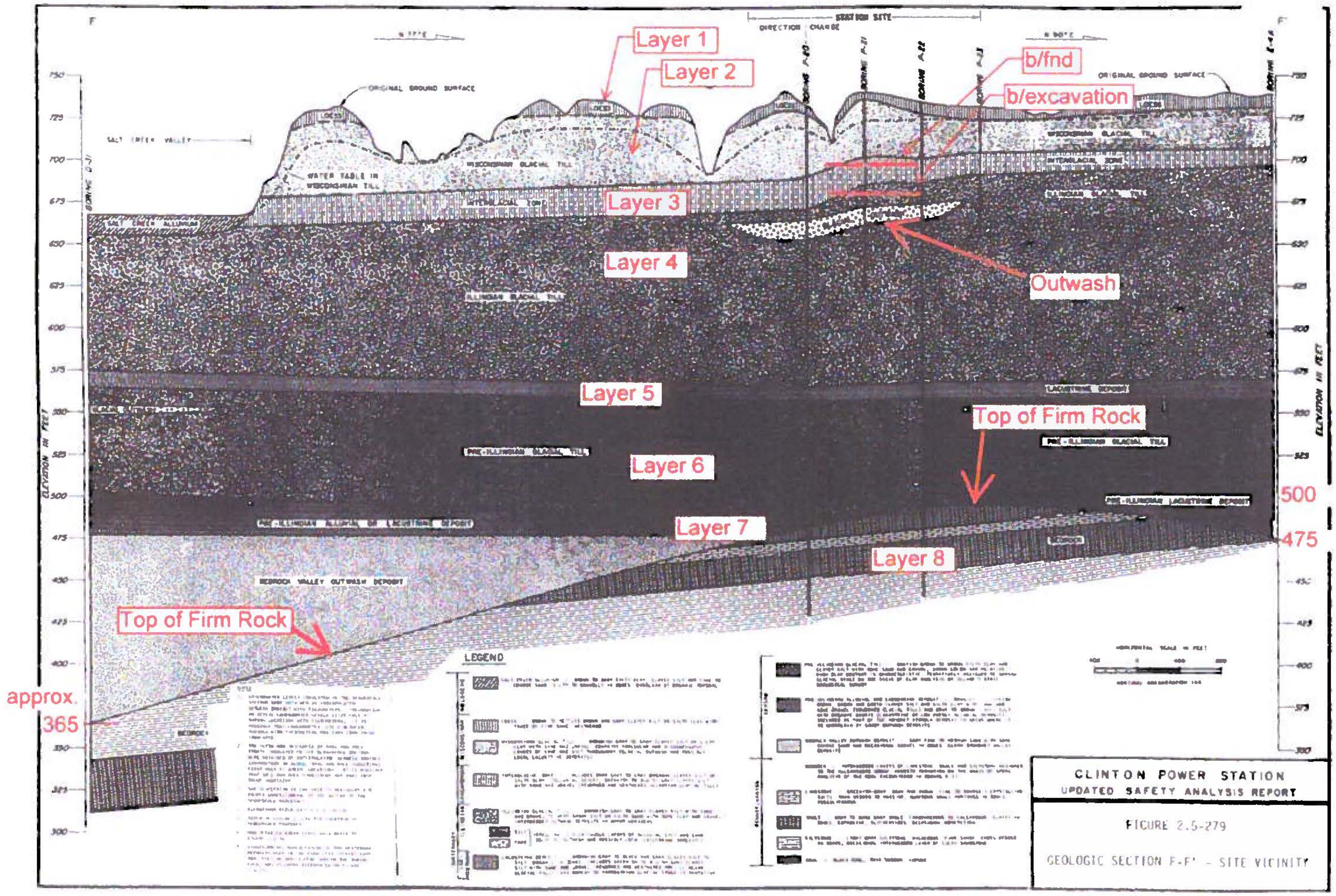
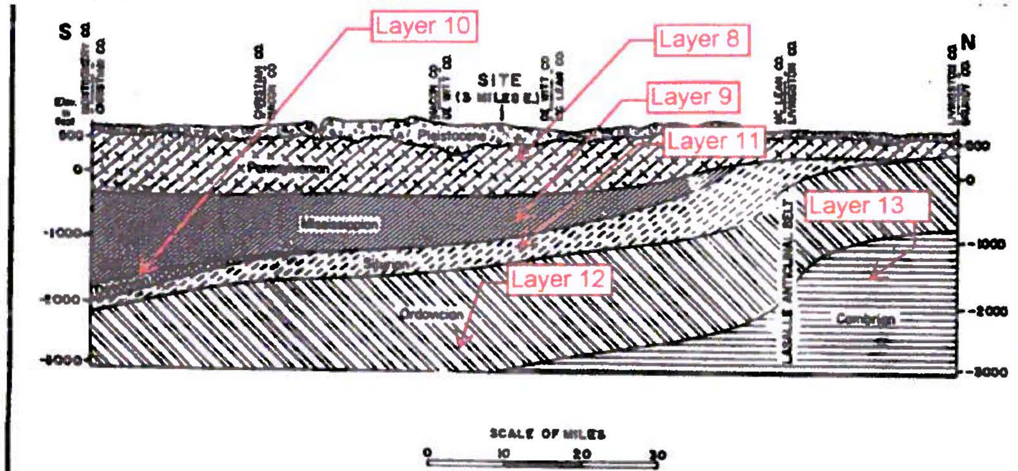

ESP Site
approx. 1000 ft
CPS Site
approx. 700 ft
Layer 1
Layer 2
Layer 3
Layer 4
Outwash
Layer 5
Layer 6
Top of Firm Rock
500
approx. 445
Layer 7
Layer 8
Section AA-AA'
Slice is based on Figure 2 5-3 from ESSP for EGC ESP and Figure 2 5-276 from CSP USAR
Top of Rock Contours from ESSP for EGC ESP
Site Cross-Section AA-AA'

Figure 10



Site Cross-Section F-F'

Figure 11



North-South Geologic Cross Section taken 3 miles west of the CPS site.

Cross sectional figure that illustrates the non-homogeneity of the firm rock layers and profile in the region of the Clinton site.

NOTES
1. REFER TO FIGURE 2.5-7 FOR LOCATION OF REGIONAL GEOLOGIC CROSS SECTION.
2. MODIFIED FROM: GROUNDWATER GEOLOGY IN EAST CENTRAL ILLINOIS BY L.F. SELKREGG AND J.P. KEMPTON, ILLINOIS STATE GEOLOGICAL SURVEY CIRCULAR 248, 1958.

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FIGURE 2.5-4

REGIONAL GEOLOGIC CROSS SECTIONS

Region Geologic Cross Section

Figure 12

- The following table shows overburden soil and rock thickness data.
  - Note the <u>large range in thicknesses</u> for layer Nos. 2, 5, 6, and 7.

Layer Number	Layer Name	Thickness of Stratigraphic Units							
		P-series Borings[1] (CPS Site)			B-2 Boring (ESP Site)	CPS USAR[3]			LCI
		ft		ft	ft	ft		ft	ft
1	Loess	3.4	to	13	13.5	N/A			4
2	Wisconsinan Till	20	to	42	30	N/A			30
3	Interglacial Zone	10	to	19	15	N/A			22
4	Illinoian Till (local zones of Glacial Outwash is present within this layer)	104	to	123	105	N/A			103
5	Lacustrine Deposit	0	to	17	27	N/A			17
6	Pre-Illinoian Till	16.5	to	70	78	N/A			50
7	Pre-Illinoian Alluvial/Lacustrine	0	to	24	23.5	N/A			10
8	Pennsylvanian Limestone, Shale, Sandstone, Coal and Shale	229.2[2]	to	252[2]	292[2]	300	to	800	500
9	Mississippian Limestone, with lesser Siltstone and Shale	Note 3				500	to	600	500
10	Devonian Shale and Limestone	Note 3				200	-	NA	200
11	Silurian Carbonates, some of which include reef structure	Note 3				450	-	NA	500
12	Ordovician Dolomite, Sandstone, Basal Sandstone, Limestone, and Shales	Note 3				1500	-	NA	1100
13	Cambrian Siltstone, Shale, Sandstone, and Dolomite	Note 3				3100	-	NA	3000
14	Precambrian Igneous Rock	Note 3				NA	-	NA	NA

1 P-series borings to rock are the only ones included in this summary (provided in CPS USAR).
2 Depth of top of rock surface reported, not thickness.
3 Actual data not obtained for these layers from the CPS or ESP subsurface exploration programs. Therefore approximate values discussed in the CPS USAR are reported in this table.

NA - Not Available
N/A - Not Applicable

Figure 13

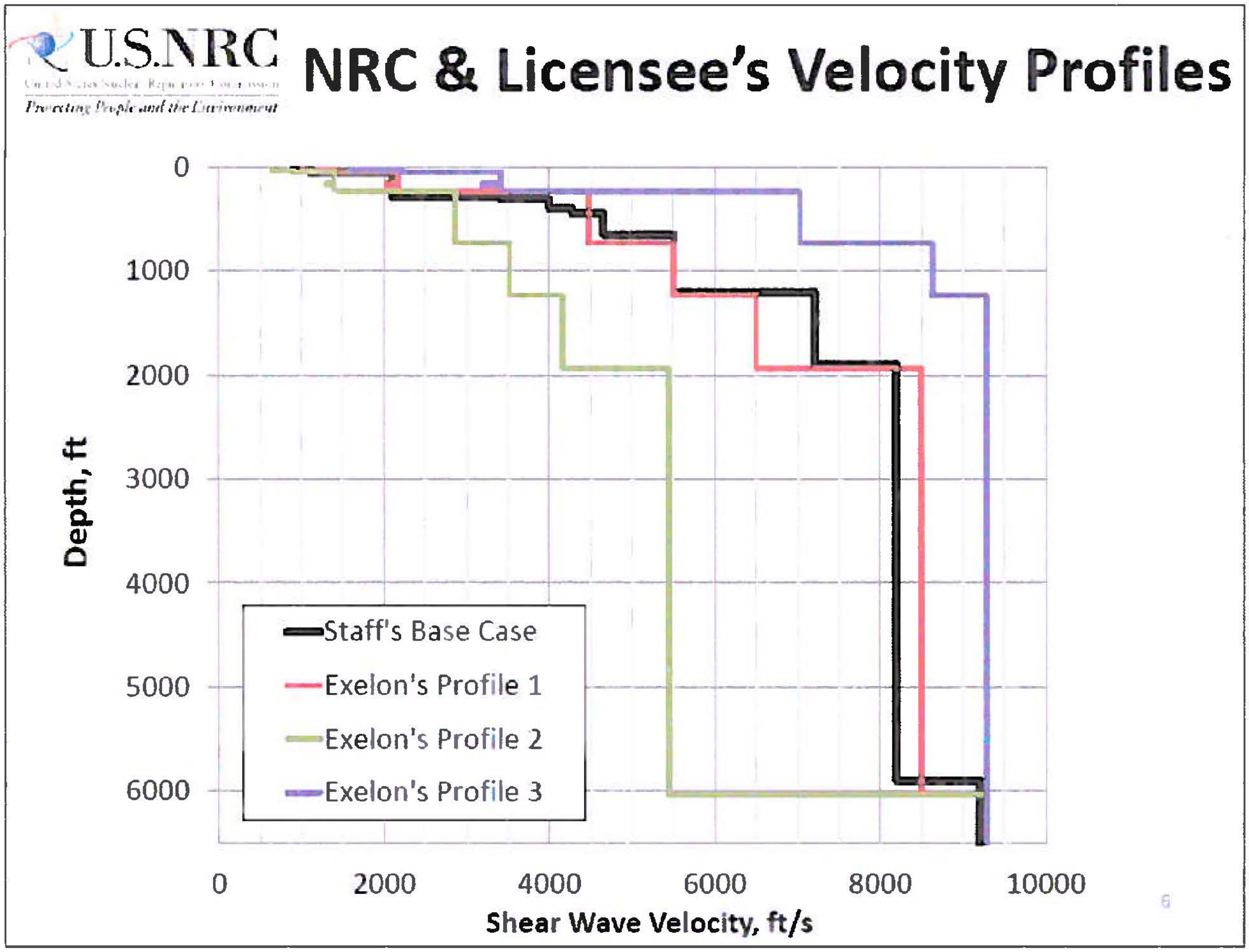
U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment
NRC & Licensee's Velocity Profiles
Depth, ft
0
1000
2000
3000
4000
5000
6000
Staff's Base Case
Exelon's Profile 1
Exelon's Profile 2
Exelon's Profile 3
0
2000
4000
6000
8000
10000
Shear Wave Velocity, ft/s
6

Figure 14

Item No. 2: Three Shear-Wave Velocity Profiles versus One Shear-Wave Velocity Profile

NRC Use of a Single Base-Case Shear-Wave Velocity Profile

The NRC has evaluated one base-case shear-wave velocity profile. Exelon understands that the use of a single profile is based on the fact that an ESP probabilistic seismic hazard analysis was performed for the Clinton site. It is understood that the NRC staff position is that the additional geotechnical and geophysical testing performed for the ESP development provides a level of confidence so that a base case plus upper bound and lower bound shear-wave profiles are not required to capture the epistemic uncertainty in the available material properties.

Consideration of a single base-case shear-wave velocity profile implies that there is zero epistemic uncertainty in the available data at a site. Section B2.1 in the SPID discusses epistemic uncertainty related to development of multiple base-case shear-wave profiles, and it states, "For well-characterized sites with abundant high-quality data this uncertainty would be reduced, possibly eliminating the need to vary some of the site parameters such as the site profile."

As discussed in the shear-wave velocity profile section above, the geotechnical program to develop the ESP used only four new soil borings and regional compression wave (V_p) data, and primarily used the data from the original CPS site geotechnical program for the ESP. Exelon understands that the NRC may consider that the original geotechnical data plus the supplemental ESP data results in Clinton being considered as a well-characterized site with abundant high-quality data. Exelon understands that for this reason, only a single base-case profile was selected by the NRC for re-evaluation of the seismic hazard.

The NRC base-case profile has a depth of about 6,000 feet, but there is no indication in the presentation that the analysis varied the depth to hard rock in the computations.

Exelon Use of Three Base-Case Shear-Wave Velocity Profiles

Exelon considered the available data from both the CPS site and the ESP site when developing the base-case soil profile and evaluating the quality of the data. As previously discussed, review of the site geotechnical cross-sections and the regional geologic cross-sections indicate that there is variability in understanding the soil and firm rock profile at the CPS site.

The available data is primarily from the original CPS construction. As discussed above, preparation of the ESP included only four soil borings, plus regional data that was compiled during the ESP process. Additional dynamic properties were tested using suspension logging at one of the bore holes to firm rock (Boring B-2), and cone penetrometer tests were performed in two bore holes to depths of approximately 45 ft. (Borings CPT-2 and CPT-4). The ESP states that the additional testing was performed to confirm that the soil at the ESP site was similar to the CPS site so that the CPS data could be used for the evaluation.

The ranges of shear-wave values from the existing test data were presented by Exelon at the public meeting (Ref. 10) and are shown in Figures 15 and 16. Additionally, Figure 17 (Ref. 7) presents a plot of firm rock layer shear-wave velocity (V_s) representative ranges based computing V_s from regional compression wave (V_p) data and estimated Poisson's ratios.

Sources of epistemic uncertainty in the shear-wave velocity profile for the site include:

- Layer thickness variations between ESP site and CPS site; throughout the region; and across the CPS site
- V_s variations throughout the region; across the ESP site and CPS site; and among the different test methods
- Lack of multiple, site-specific, state-of-the-art V_s measurements at the CPS site
- Conversion from V_p for firm rock using assumed Poisson's ratios
- Unknown depth to hard reference rock

As previously mentioned, the SPID (App. B, Section B2.1) (Ref. 1) discussed that for sites with abundant high-quality data, uncertainties would be reduced and varying the site profile could potentially be eliminated. Abundant high-quality data is not explicitly defined in the SPID, but it would potentially include:

- Multiple in-situ measurements with consistent results
- Direct V_s measurements rather than conversions from V_p measurements
- Site specific measurements rather than regional data

For new plant licensing, the requirements of Regulatory Guide 1.132 (Ref. 11) would apply.

The data suggest variability in the shear-wave velocity data such that the CPS site was not considered as having abundant high quality data, and therefore, the shear-wave profile could not be known with a high degree of certainty. Further, there is considerable epistemic uncertainty in the depth to hard rock due to a lack of knowledge of Poisson's ratios in the deeper firm rock layers as indicated by Figure 17. There is also significant dispersion in compressional wave velocity data from the regional deep borings. Since only regional deep boring data was available, there is epistemic uncertainty due to the lack of knowledge of site-specific firm rock wave velocities.

Based on the limited volume of high quality data from the ESP investigation and the range of values in material properties together with the variability in the soil profile, the methodology presented in the SPID was followed to evaluate the seismic hazard at CPS.

In accordance with Section B3.0 of the SPID, a best estimate base-case profile was developed. Lower-bound and upper-bound alternative profiles were developed to accommodate epistemic uncertainty in depth to hard rock conditions, soil layer thicknesses, and dynamic material properties (shear-wave velocity profiles and damping). Three shear-wave velocity profiles were used based on the levels of uncertainty that exist for the soil parameters described above and these profiles are considered to envelope the range of values in the soil and rock layers. The epistemic sigma of 0.35 was based on uncertainty regarding which V_s were measured at the site as opposed to being based on measured V_p and assumed Poisson's ratios.

The ESP used only one base-case profile, but Figure 4.2-8 in Appendix B of the ESP (Ref. 7) shows two alternate profiles with two different depths to hard rock. In the ESP site response calculations, epistemic uncertainty in depth to hard rock was modeled by randomized profiles with a uniform distribution on depth to hard rock varying from 2,000 ft to 6,000 ft. This uncertainty was captured in CPS base-case Profile 3, which has depth to hard rock on the order of about 1,200 ft, while Profiles 1 and 2 have depths to hard rock of 6,000 ft.

Comparison of NRC Approach and Exelon Approach

Based on the information exchanged in the June 17th meeting, the basis for the NRC approach is that the NRC staff considers the data presented in the ESP along with the original USAR data is "abundant high-quality data," therefore, only one base-case profile is considered.

Exelon review of available data from the ESP and original CPS programs concluded that the additional data developed in the ESP (four new borings and tests) did not raise the level of knowledge to "abundant high-quality data." Exelon, therefore, developed the re-evaluation as a site with limited data and followed the methodology in the SPID to develop three base-case shear-wave velocity profiles (best estimate, lower-bound, and upper-bound) to appropriately account for epistemic uncertainty.

Further review of determining one base-case profile versus three base-case profiles is under discussion between the NRC staff and EPRI. The expected result of those discussions is expected to be an industry white paper addressing the topic and developing alignment in the industry.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning the use of one base-case versus three base-case shear-wave velocity profiles in the CPS site response analysis. Based on this review, Exelon concludes that the three CPS base-case profiles submitted to the NRC on March 31, 2014 are appropriate and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation. We conclude the three Exelon profiles appropriately account for the following epistemic uncertainties in accordance with the NRC endorsed SPID (Ref. 1), whereas the single NRC profile does not for the following reasons:

- The soil shear-wave velocities at the CPS site are not well known because measurements of shear-wave velocity are only available at the ESP site (approximately 1,000 feet away) and must be inferred for geologic units that are laterally heterogeneous.
- The firm rock shear-wave velocities are not well known because the available data are not site specific, and because they were computed using assumed Poisson's ratios.
- As a result of the uncertainty in firm-rock shear-wave velocity, there is also uncertainty in depth to hard rock.
- The addition of four borings at the ESP site does not provide a basis for a determination of abundance of high quality data, and therefore, the shear-wave profile could not be known with a high degree of certainty.

- The following table shows the soil layer Vs measurements and estimates from the ESP and CPS sites
  - Green and Red values are Lower and Upper bounds of ranges reported in the Exelon submittal to NRC on 12 September 2013.
  - First eight layers shown here. Next slide describes the deeper, firm rock layers.

Layer Number	Layer Name	Shear Wave Velocities (ft/s)					
		ESP Site			CPS Site		
		Suspension Logging Borehole B-2[1]	Seismic Cone CPT-2[1]	Seismic Cone CPT-4[1]	Downhole Survey[1,2]	Tabulated Shear Wave Velocities[3,4]	Typical Geophysical Properties[3,5]
1	Loess	820 - 1340	703 - 1354	641 - 1077	900 - 1100	900 - 1100	900
2	Wisconsinan Till						900 - 1100
3	Interglacial Zone	860 - 1970	1022 - 1231	1006 - 1602	1100	-	1100
4	Illinoian Till (local zones of Glacial Outwash is present within this layer)	1100 - 3250	-	-	2100	2000 – 2100	2100
5	Lacustrine Deposit	1390 - 2670	-	-	2100	1800	
6	Pre-Illinoian Till	1560 - 2800	-	-	2100		
7	Pre-Illinoian Alluvial/Lacustrine	1190 - 3310	-	-	2100		
8	Pennsylvanian Limestone, Shale, Sandstone, Coal and Shale	3250 - 3880	-	-	5700	5300 - 5700	5700

Note 1 - In-situ measurement of shear wave velocity

Note 2 - Typical values reported in USAR

Note 3 - Estimates / recommended values used in design analyses

Note 4 - USAR Table 2.5-46

Note 5 - USAR Figure 2.5-369

Figure 15

- Firm rock layer Vs is estimated from compressional wave velocity (Vp) measurements at nine (9) regional deep borings within 10 mi of ESP and CPS sites.
  - Vp / Vs = 2.0 judged appropriate for Layers 9, 10 and 11 (Poisson's ratio 0.33)
  - Vs ranges for Layers 12 and 13 comprise values computed from Vp using Vp/Vs = 1.73 and Vp/Vs = 2.0 to reflect uncertainty in Poisson's ratio
  - Green and Red values are Lower and Upper bounds of ranges reported in Exelon submittal to NRC on 12 September 2013.
- Representative ranges are estimated from regional Vp data with large dispersion shown in figure on next slide

Layer Number	Layer Name	Representative Range of Shear Wave Velocities (ft/s)
9	Mississippian Limestone, with lesser Siltstone and Shale	4500 - 6500
10	Devonian Shale and Limestone	4500 - 8500
11	Silurian Carbonates, some of which include reef structure	4500 - 8500
12	Ordovician Dolomite, Sandstone, Basal Sandstone, Limestone, and Shales	6500 - 10500
13	Cambrian Siltstone, Shale, Sandstone, and Dolomite	6500 - 10500

Figure 16

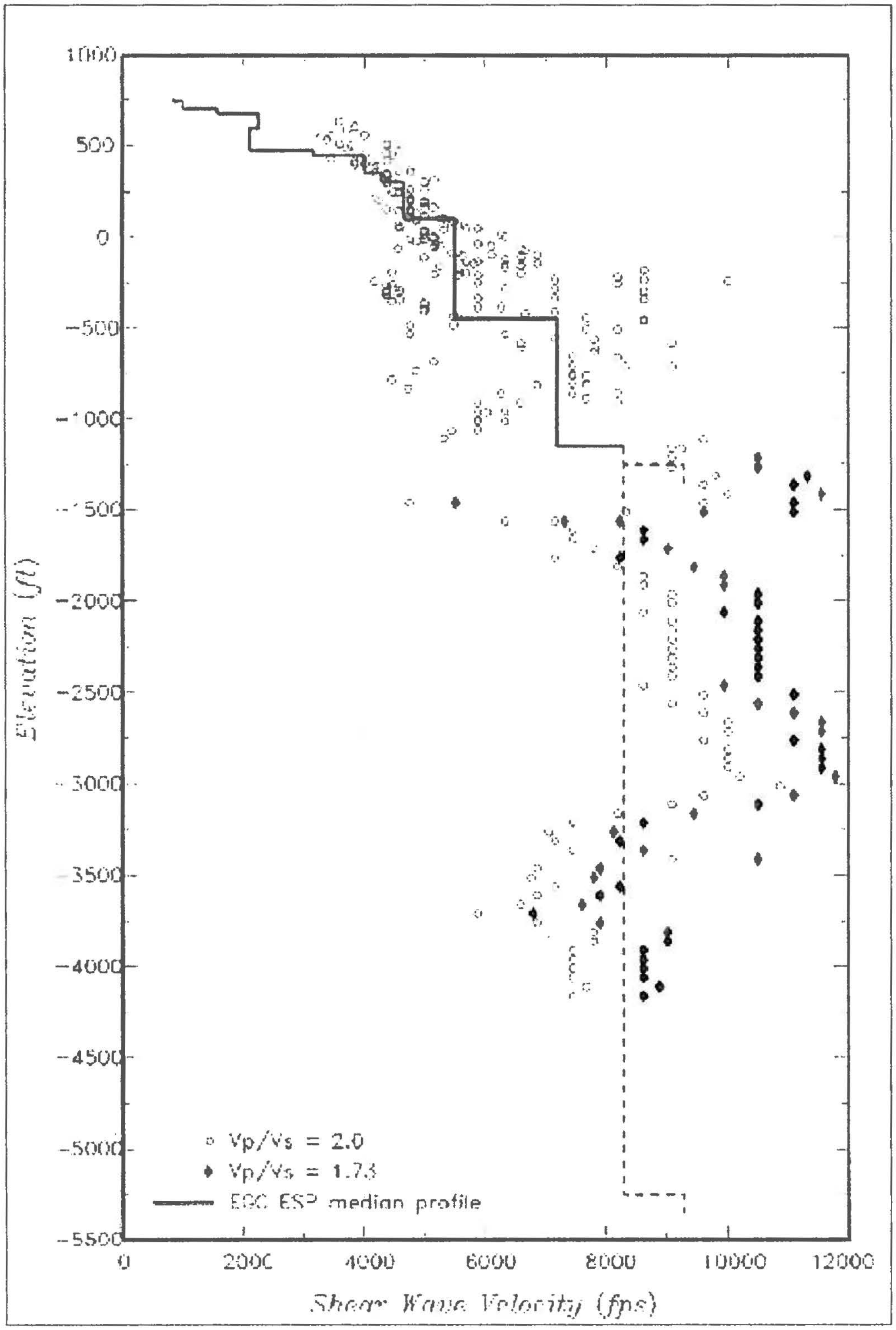
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
Elevation (ft)
0
2000
4000
6000
8000
10000
12000
Shear Wave Velocity (fps)
Vp/Vs = 2.0
Vp/Vs = 1.73
EGC ESP median profile

Figure 17

Item No. 3: Kappa and Low-Strain Damping

NRC Approach to Kappa and Low-Strain Damping

NRC considered non-linear behavior in the soil profile for the top approximately 310 feet. The top of firm rock is at approximately 310 ft from the surface. Linear behavior is considered in the firm rock from approximately 310 ft to Precambrian basement at a depth of approximately 6,000 ft. This is similar to the approach in the CPS ESP.

The NRC considered a Total Effective Kappa of approximately K = 0.023 s (Ref. 9) as shown in Figures 18. The NRC also presented their consideration of damping and Kappa values as shown in Figure 2.

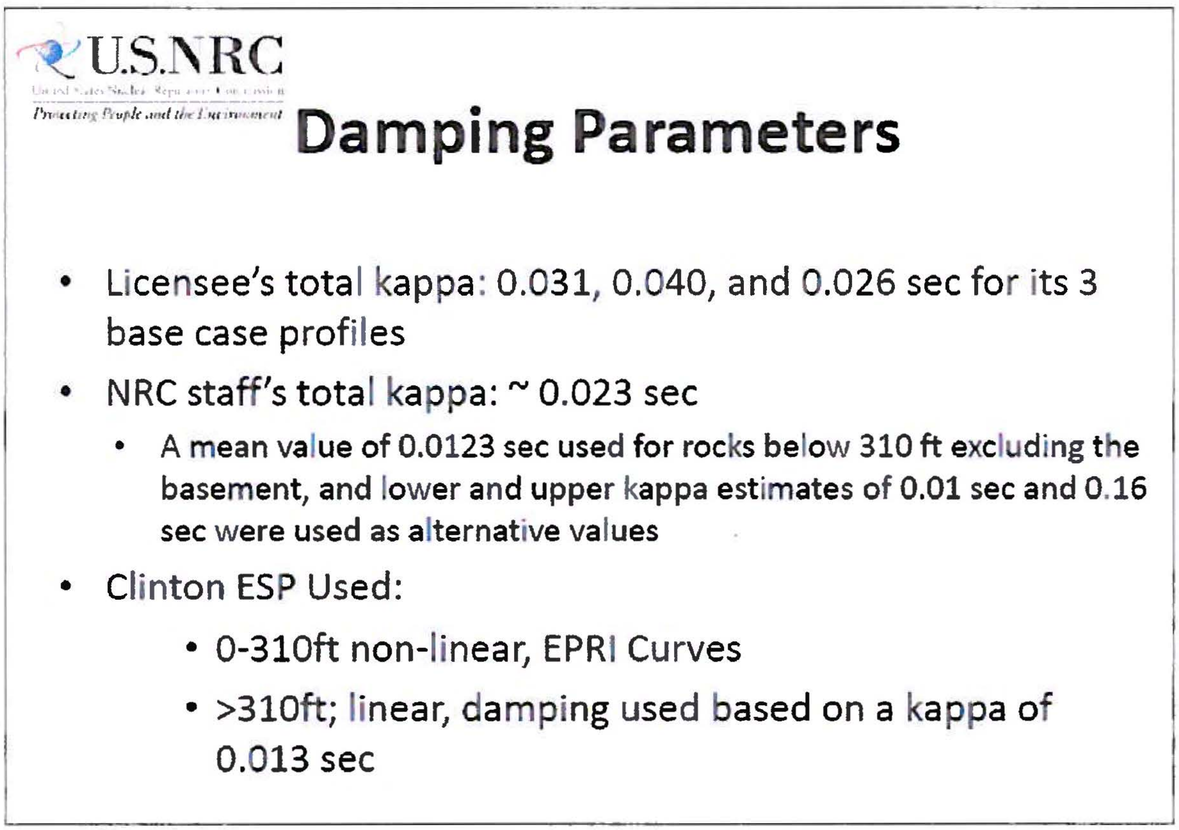

Figure 18

Based on the NRC slides in Figure 2 and Figure 18 above, Exelon understands that the NRC considered multiple cases for the Kappa contribution from firm rock. The NRC considered that there was "No Damping" contribution for the firm rock layers. It appears that there was a base-case profile with firm rock Kappa contribution of K = 0.0123 s, plus a lower-bound profile with firm rock Kappa of K = 0.01 s, and an upper bound profile with firm rock Kappa of K = 0.016 s. However, it is unclear how the lower-bound and upper-bound values were determined. Exelon understands that the NRC used the base-case firm rock Kappa, K = 0.0123 s, to calculate Total Effective Kappa.

The Kappa contribution from the hard rock basement was considered as K = 0.006 s.

The NRC considered EPRI soil curves to determine the Kappa contribution from the soil over the firm rock and considered that the soil was approximately 310 ft thick. The contribution from soil is not explicitly provided in the presentation, but can be back-calculated from the components to be:

Kappa soil, K = 0.023 s - 0.0123 s - 0.006 s = 0.0047 s

Therefore, Total Effective Kappa for base-case, lower-bound, and upper-bound can be computed. Exelon understands that the base-case Total Effective Kappa was K1 = 0.023 s, with lower-bound and upper-bound values of K2 = 0.021 s, and K3 = 0.027 s respectively. Exelon understands that the NRC evaluation considered one base-case soil profile and included multiple analysis runs with different Total Effective Kappa assigned, and then uncertainty in Total Effective Kappa at design loading levels for the base-case profiles was addressed with multiple shear modulus and hysteric damping curves.

Exelon Approach to Kappa and Low-Strain Damping

The profile at CPS site consists of 240 ft of soil over approximately 6,000 ft of firm rock. At the ESP site, the profile consists of 310 ft of soil over approximately 6,000 ft of firm rock. This profile represents a case that is not directly addressed in the SPID because it is not a rock site or a soil site. The SPID (section B-5.1.3.1) defines a rock site as one with at least 3,000 ft of firm sedimentary rock overlying hard rock; and it defines a soil site as one with at least 3,000 ft of soil over hard rock.

The SPID does not provide explicit guidance to calculate Total Effective Kappa for a site that has a significant soil layer (greater than 100 ft) overlying deep firm rock. Therefore, a hybrid approach that is based primarily on SPID recommendations for firm rock was used to calculate Total Effective Kappa. Estimates of Total Effective Kappa are based on summing the contributions from each layer of soil and rock considering damping, layer thickness, and V_s for the base-case soil profile are determined as follows:

- Top 500 feet is comprised of soil (240 ft) and rock (260 ft) and is considered a nonlinear zone using low-strain damping and EPRI soil curves from surface to approximately 240 ft, and then EPRI rock curves from 240 ft to 500 ft. Kappa contribution, K = 0.003 s.

- Below 500 feet to hard base rock the firm rock is considered a linear zone. Damping is fixed at 1.25% (Qs = 40). Kappa contribution, K = 0.022 s

- Hard base rock contribution to Kappa, K = 0.006 s

- Total Effective Kappa for base-case profile (Profile 1), K_T = 0.031 s

Uncertainty exists in estimating the low-strain Total Effective Kappa for the CPS site because of the variability in the site stratigraphy and the variability in the material properties because the firm rock properties are based on values from regional data and is not based on site-specific deep borings at the CPS site. Therefore, the uncertainty in low-strain Total Effective Kappa was addressed using three estimates that are based on the base-case profile (KP1 = 0.031 s), the upper-bound profile (KP2 = 0.040 s (maximum value allowed in the SPID)), and the lower-bound profile (KP3 = 0.026 s).

Uncertainty in Total Effective Kappa at design loading levels for each of the base-case profiles is addressed with multiple shear modulus and hysteric damping curves.

Comparison of NRC Approach and Exelon Approach

Review of the values computed for Kappa indicates that the primary difference between the NRC and the Exelon re-evaluations is the value of Kappa determined for the firm rock layers. It appears that the NRC considered a firm rock Kappa value of 0.0123 s for firm rock damping with alternative values of 0.010 s and 0.016 s. Considering the data presented in the ESP, the equivalent damping ratio ranges from 1.83% to 3.30% (Fig. 4). Exelon has considered equivalent damping of 1.25% in accordance with the SPID, and this level of damping would be judged as conservative considering the ESP damping. The NRC presentation states that no damping is considered, and this approach may be overly conservative considering the data presented in the ESP (Fig. 4).

Further review of the methods used to determine Kappa is under discussion between the NRC staff and EPRI. The expected result of those discussions is expected to be an industry white paper addressing the topic and developing alignment in the industry.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning computation of Kappa and low-strain damping properties. CPS is a site with a significant soil layer overlying deep firm rock. The SPID does not provide explicit guidance to compute the Total Effective Kappa for this type of site. Therefore, a hybrid approach that is based primarily on SPID recommendations for firm rock was used to compute Total Effective Kappa. Based on this review, Exelon concludes that the CPS Kappa and low-strain damping properties submitted to the NRC on March 31, 2014 are a more representative computation of damping properties based on the geotechnical conditions at the site and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation.

Item No. 4: Amplification Functions

NRC Approach to Amplification Functions

The NRC provided a plot of amplification functions in their presentation (Ref. 9). The plot is shown in Figure 19 below.

The NRC has not provided sufficient detail on the methods they used to develop the amplification functions. Therefore, Exelon cannot develop an understanding of the NRC amplification functions methodology.

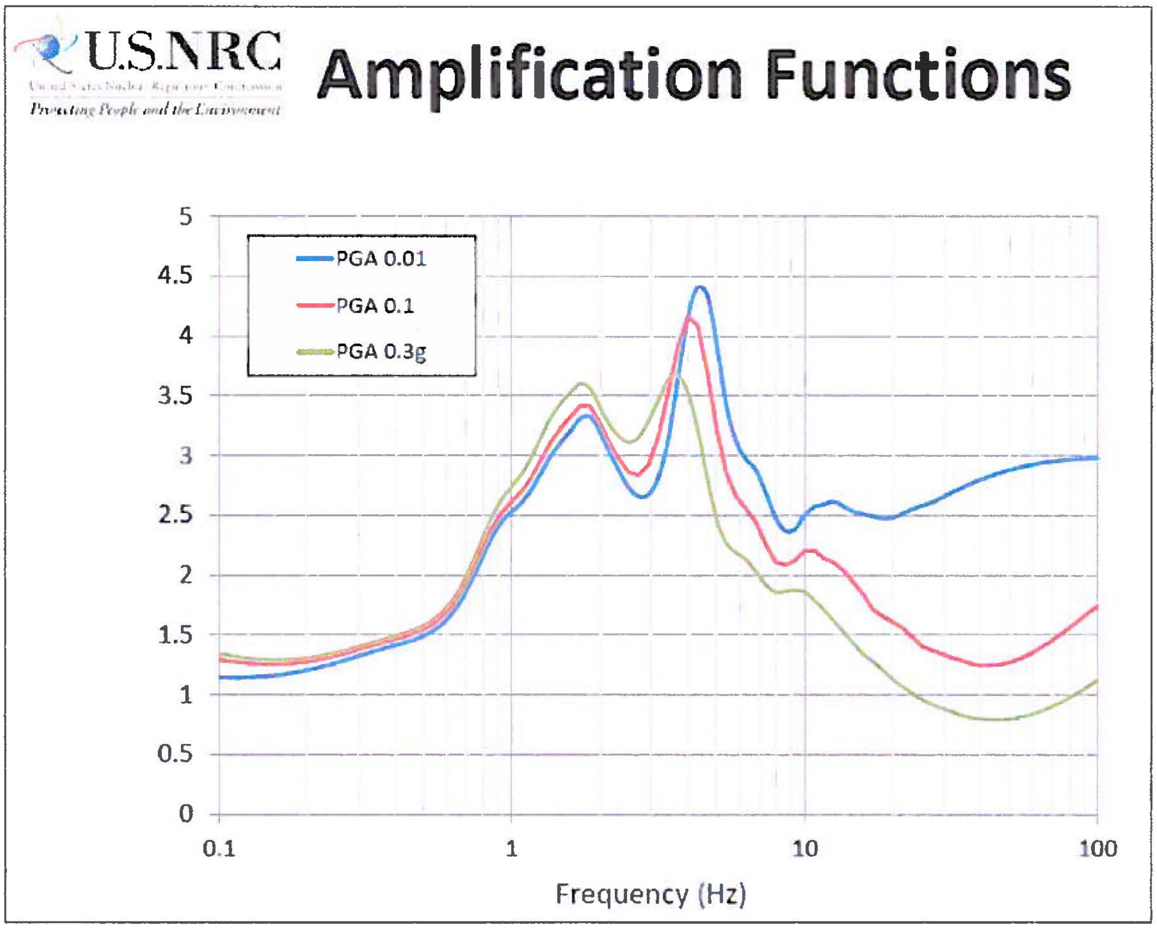

Figure 19

Exelon Approach to Amplification Functions

The results of the site response analysis are derived from amplification factors which describe the amplification (or deamplification) of hard reference rock motions as a function of frequency and input reference rock amplitude. The amplification factors are represented in terms of a median amplification value and an associated standard deviation for each oscillator frequency and input rock amplitude. A minimum median amplification value of 0.5 was used in the analysis in accordance with the SPID (Ref. 1, Section B-5.1.4.1). Eleven loading levels were parametized by the median hard rock peak acceleration (0.01g to 1.50g) for each profile and EPRI soil and firm rock G/G_{max} and hysteric damping curves.

The variability in the amplification factors results from variability in shear-wave velocity, depth to hard rock, and modulus reduction and hysteretic damping curves. The seismic hazard and screening report (Ref. 3), provided figures for more nonlinear behavior (Fig. 2.3.6-1, Ref. 3) and more linear behavior (Fig. 2.3.6-2, Ref. 3). Tabulated values of median amplification factors for PGA = 0.194g and PGA = 0.493g were provided in Table A-2b1 and Table A-2b2 of Reference 3.

Comparison of NRC Approach and Exelon Approach

The amplification functions are based on the dynamic material properties and unit weights of the materials overlying hard reference rock. Alignment of these properties between the NRC and Exelon is expected to result in acceptably close agreement between the NRC and Exelon estimates of the GMRS.

Further review of developing amplification functions is under discussion between the NRC staff and EPRI. The expected result of those discussions is expected to be an industry white paper addressing the topic and developing alignment in the industry.

Exelon has reviewed and reconsidered the Exelon position communicated in the June 17, 2014 public meeting concerning computations of amplification functions. Based on this review, Exelon concludes that the amplification functions submitted to the NRC on March 31, 2014 are appropriate and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation.

Conclusions / Findings:

Item No. 1: Base-Case Shear-Wave Velocity Profile

The NRC soil profile stratigraphic layer thicknesses appear to be based on the soil cross section from one soil boring from the ESP program, and the firm rock layers appear to be from data presented in the ESP. Neither of these data inputs appears to consider ranges of layer thickness.

The Exelon base-case soil profile stratigraphic layer thicknesses are based on the soil boring under the CPS containment building. The ranges of layer thicknesses for data at the ESP and CPS site were reported to show variability across the site. Exelon contends that ranges of data should be included to develop the base-case profile so that uncertainty is adequately considered in the re-evaluation.

The NRC selected shear-wave velocity data from typical values for soils down to approximately 290 ft from the CPS USAR, and then used tabulated values presented in the ESP for soil and firm rock layers below 290 ft which were based on regional V_p measurements and assumed Poisson's ratios.

The Exelon base-case shear-wave velocity profile considered the ranges of the shear-wave data considering data available in the test results of the ESP and the USAR in developing the base-case profile. Regional V_p measurements were also considered to develop the firm-rock shear-wave velocities using assumed Poisson's ratios.

The differences between the NRC and Exelon best estimate base-case soil profiles, though not very significant, are expected to yield somewhat different GMRS curves even if Exelon had only used one base-case soil profile. However, this alone is not expected to be the main cause of the significant difference between the NRC and Exelon GMRS curves.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning the CPS mean base-case shear-wave velocity profile. Based on this review, Exelon concludes that the CPS profile submitted to the NRC on March 31, 2014 is appropriate and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation for the following reasons:

- The differences between the NRC and Exelon profiles are small and are not expected to significantly influence the seismic hazard results.
- This approach is most representative of the geotechnical profile data available. The Exelon profile was developed using a systematic approach that was used consistently across the CEUS fleet.

Item No. 2: Three Shear-Wave Velocity Profiles versus One Shear-Wave Velocity Profile

The NRC appears to consider that the data available from the ESP and the original CPS programs creates a condition of "abundant high-quality data." Therefore, epistemic uncertainty was not included through the use of lower-bound and upper-bound profiles.

Exelon review of the ESP data indicates that limited scope geotechnical work (four new soil borings) was performed to verify similarity between soils at the ESP location and the CPS site so that original data could be used for the ESP. Exelon judged that the additional data resulting from the four new borings did not result in a level of knowledge that could be characterized as "abundant high-quality data." Exelon performed the seismic hazard evaluation in accordance with the SPID and considered best estimate, lower-bound, and upper-bound shear-wave velocity profiles in order to account for epistemic uncertainty in available data.

Further review of determining one base-case profile versus three base-case profiles is under discussion between the NRC staff and EPRI. The expected result of those discussions is expected to be an industry white paper addressing the topic and developing alignment in the industry.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning the use of one or three base-case shear-wave velocity profiles in the CPS site response analysis. Based on this review, Exelon concludes that the three CPS base-case profiles submitted to the NRC on March 31, 2014 are appropriate and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation. We conclude the three Exelon profiles appropriately account for the following epistemic uncertainties in accordance with the NRC endorsed SPID (Ref. 1), whereas the single NRC profile does not for the following reasons:

- The soil shear-wave velocities at the CPS site are not well known because measurements of shear-wave velocity are only available at the ESP site (approximately 1,000 feet away) and must be inferred for geologic units that are laterally heterogeneous.
- The firm rock shear-wave velocities are not well known because the available data are not site specific, and because they were computed using assumed Poisson's ratios.
- As a result of the uncertainty in firm-rock shear-wave velocity, there is also uncertainty in depth to hard rock.
- The addition of four borings at the ESP site does not provide a basis for a determination of abundance of high quality data, and therefore, the shear-wave profile could not be known with a high degree of certainty.

Item No. 3: Kappa and Low-Strain Damping

The primary difference between the NRC approach and the Exelon approach to computation of Kappa is in the way Kappa is determined in the firm rock layers.

It appears that the NRC considered a firm rock Kappa value of 0.0123 s for firm rock damping with alternative values of 0.010 s and 0.016 s.

Exelon developed the magnitude of Kappa using low-strain damping in soils and firm rock to 500 feet, and then 1.25% below 500 feet, plus 0.006 s for hard reference rock. This approach appears to be an extremely conservative underestimate of Kappa considering the range of effective damping magnitudes of 1.83% to 3.30% for the firm rock that is presented in the ESP.

Currently, methodology associated with computation of Kappa is under discussions between EPRI industry experts and the NRC staff. The results of those discussions are expected to result in industry alignment on the approach to compute Kappa.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning computation of Kappa and low-strain damping properties. CPS is a site with a significant soil layer overlying deep firm rock. The SPID does not provide explicit guidance to compute the Total Effective Kappa for this type of site. Therefore, a hybrid approach that is based primarily on SPID recommendations for firm rock was used to compute Total Effective Kappa. Based on this review, Exelon concludes that the CPS Kappa and low-strain damping properties submitted to the NRC on March 31, 2014 are a more representative computation of damping properties based on the geotechnical conditions at the site and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation.

Item No. 4: Amplification Functions

The amplification functions are based on the dynamic material properties and unit weights of the materials overlying hard reference rock. Alignment of these properties between the NRC and Exelon is expected to result in acceptably close agreement between the NRC and Exelon estimates of the GMRS.

Currently, methodology associated with computation of amplification functions is under discussions between EPRI industry experts and the NRC staff. The results of those discussions are expected to result in industry alignment on the approach to compute amplification functions.

Exelon has reviewed and reconsidered the Exelon position communicated in the June 17, 2014 public meeting concerning computations of amplification functions. Based on this review, Exelon concludes that the amplification functions submitted to the NRC on March 31, 2014 are appropriate and should be used in the seismic hazard analysis for the NTTF 2.1 screening evaluation.

Summary Conclusion

In response to the 50.54(f) letter regarding Fukushima Near-Term Task Force Recommendation 2.1, Exelon performed a seismic hazard analysis and screening for CPS to develop a GMRS for comparison with the site SSE. The Exelon GMRS was developed in accordance the NRC endorsed SPID (Ref. 1) guidelines. The result of the screening process was that CPS screened out of performing a seismic risk assessment. Exelon submitted these results in the seismic hazard and screening report to the NRC on March 31, 2014 (Ref. 3).

Subsequently, on May 9, 2014, the NRC issued the Screening and Prioritization Results letter (Ref. 4), and in that letter CPS was screened as "Conditional In." On May 21, 2014, the NRC issued by memorandum, "Support Document for Screening and Prioritization Results Regarding Seismic Hazard Re-evaluations for Operating Reactors in the Central and Eastern United States," (Ref. 5) and in that letter provided a plot of the CPS SSE, the Exelon new GMRS, and the NRC new GMRS (Fig. 1). The plot illustrated that the results of the re-evaluation performed by CPS were not in alignment with the results of the re-evaluation performed by the NRC. The differences were discussed in a public meeting between the NRC and Exelon at the NRC offices in Rockville, MD on June 17, 2014.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning the differences in the analysis methods and technical judgments for the following items:

- Item No. 1: Base-case shear-wave velocity profile
- Item No. 2: Three base-case shear-wave velocity profiles versus one base-case shear-wave velocity profile
- Item No. 3: Kappa and low-strain damping values
- Item No. 4: Amplification functions

Based on this review, Exelon concludes that the CPS GMRS submitted to the NRC on March 31, 2014 (Ref. 3) was developed in accordance with the NRC endorsed SPID (Ref. 1) and was appropriately used for the NTTF 2.1 screening evaluation of GMRS-to-SSE comparison. In accordance with the results reported in the March 31, 2014 report (Ref. 3), Exelon has reconfirmed the conclusion that CPS screens out of further seismic risk assessments.

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6. Clinton Power Station Unit 1, Updated Safety Analysis Report (USAR), Revision 16

7. Clinton Early Site Permit Application, Site Safety Analysis Report, Revision 4

8. Clinton Power Station, Unit 1, "Descriptions of Subsurface Material and Properties and Base Case Velocity profiles," September 12, 2013, ML13256A070

9. Nuclear Regulatory Commission, Public Meeting presentation slides, June 17, 2014, ML14167A320

10. Exelon, Public Meeting presentation slides, June 17, 2014, ML14167A053

11. Nuclear Regulatory Commission, Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants," ML032790474

12. Nuclear Regulatory Commission, Letter to Exelon Generation Company and Omaha Public Power District, "Summary of the June 17, 2014, Category 1 Public Meeting with Exelon and Omaha Public Power District to Discuss Seismic Hazard Reevaluations Associated with Implementation of Japan Lessons-Learned Near-Term Task Force Recommendation 2.1, Seismic," August 11, 2014, ML14175A518

Attachment 2

Limerick Generating Station, Units 1 and 2

Supplemental Information in Response to NRC Conditional Screen-In Evaluation

Reason for Evaluation / Scope

On March 31, 2014, Exelon submitted the results of the comparison of the Ground Motion Response Spectrum (GMRS) developed by the Electric Power Research Institute (EPRI) to the current Limerick Generating Station (LGS) licensing basis Safe Shutdown Earthquake (SSE) response spectra [Ref. 1] in response to Near-Term Task Force (NTTF) Recommendation 2.1: Seismic per the March 12, 2012 50.54(f) request for information letter [Ref. 2]. As indicated in this Seismic Hazard and Screening report, Limerick was determined to "screen out" from the need to perform a seismic risk assessment based on the seismic screening guidance provided in EPRI 1025287, titled "Seismic Evaluation Guidance – Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima NTTF Recommendation 2.1: Seismic" (hereafter referred to as the SPID) [Ref. 3]. Additionally, Limerick was determined to "screen out" from the need to perform an additional interim evaluation under the Expedited Seismic Evaluation Program (ESEP) based on guidance provided in EPRI 3002000704, titled "Seismic Evaluation Guidance – Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic" [Ref. 4].

On May 9, 2014 the Nuclear Regulatory Commission (NRC) issued Screening and Prioritization Results related to seismic hazard reevaluations for the Central and Eastern United States (CEUS) nuclear plant sites [Ref. 5]. Based on this effort, the NRC determined that Limerick screened "conditional in" and was conditionally placed into Prioritization Group 3. Subsequent to this letter, the NRC identified to Exelon certain technical differences noted between underlying inputs of independent GMRS developed by Exelon and NRC. These areas are categorized as two discrete items: 1) kappa (including site-specific wave scattering and low-strain damping of near-surface material); and 2) shear-wave velocity profile. These differences were discussed between Exelon and the NRC at a public meeting on June 17, 2014 [Ref. 6]. During this meeting, various pieces of information were shared between Exelon and NRC guided by presentations from both parties [Refs. 7 and 8] aimed at developing a common understanding of the source of differences between Exelon and NRC GMRS used for NTTF 2.1: Seismic screening.

The GMRS independently developed by Exelon and NRC are shown together in Figure 1 below, as presented by the NRC [Ref. 8]. It is important to note that, despite the acknowledged technical differences of certain underlying inputs, the GMRS from both Exelon and NRC are rather similar.

The purpose of this technical evaluation is to document Exelon's review and consideration of the information shared by the NRC during the public meeting on June 17, 2014, to provide supplemental detail regarding the information shared by Exelon, and to determine whether a revision to the GMRS submitted by Exelon is warranted for the purposes of NTTF 2.1: Seismic screening. This evaluation is intended to assist the NRC in their final determination of NTTF 2.1: Seismic screening and prioritization of the Limerick site.

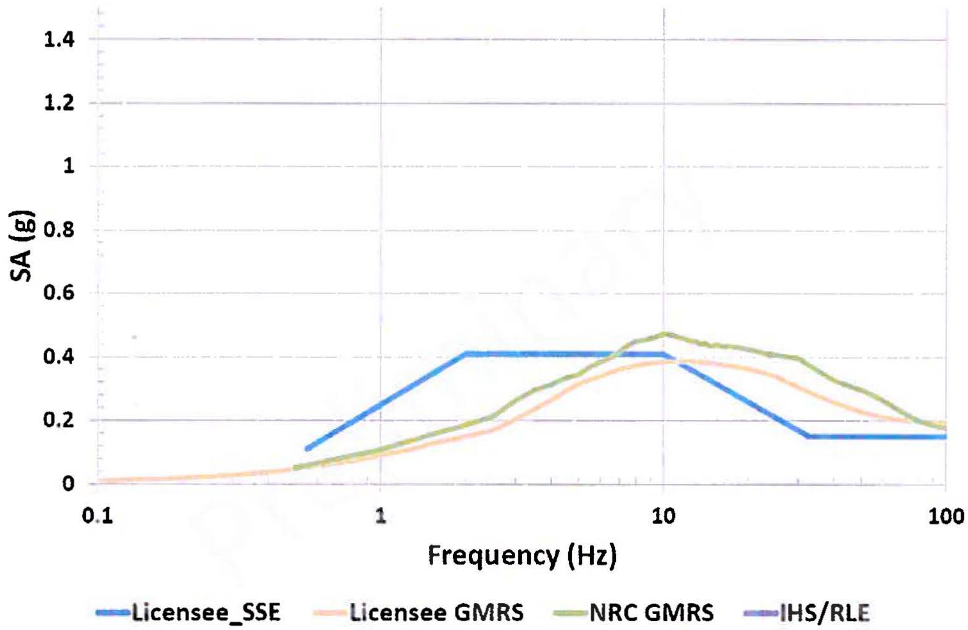

Figure 1: Limerick GMRS Differences between Exelon and NRC [Ref. 8]

1. Detailed Evaluation

1.1 Item #1 – Kappa

During the June 17, 2014 public meeting [Ref. 6], the NRC and Exelon communicated a difference in methodology for consideration of low-strain damping in total effective kappa, and have utilized different values for the low-strain damping in the characterization of the dynamic properties of geotechnical materials (i.e. rock). Specific differences are discussed below.

<u>*Exelon Characterization*</u>

Per the SPID Section B-5.1.3 [Ref. 3], kappa in the context of site amplification for NTTF 2.1: Seismic screening GMRS development refers to profile damping contributed by both intrinsic hysteretic damping as well as wave scattering due to wave propagation in heterogeneous material. As a result, the kappa estimates reflect values that would be expected to be measured based on empirical analyses of wavefields propagating throughout the profiles at low loading levels and reflect the effective damping or “effective” Q_s (seismic quality factor of S-waves) within the profile. In other words, the “total effective kappa” estimated based on the SPID Section B-5.1.3 [Ref. 3] includes the contribution from the material nonlinear zone small strain damping (intrinsic attenuation or anelasticity) plus the contribution of the underlying profile layers due to scattering attenuation resulting from heterogeneities along the travel path [Ref. 9].

For the Limerick site, Exelon determined the total effective kappa estimates of the three base-case profiles using Section B-5.1.3.1 of the SPID [Ref. 3] for a firm CEUS rock site [Ref. 1]. The classification of Limerick as a rock site is consistent with historical interpretations (see for example [Ref 14]). More specifically, application of the SPID to the characterization of the Limerick site as 8,000 feet of firm sedimentary rock overlying hard basement bedrock prescribes a direct relationship between total effective kappa and the average shear-wave velocity over the

upper 100 feet of the site profile. Per the SPID Section B-5.1.3.1, this prescriptive relationship is applicable "for rock sites with at least 3,000 ft (1000 m) of firm sedimentary rock (V_{S30} > 500 m/s) overlying hard rock" [Ref. 3]. The values for total effective kappa used at Limerick are repeated from the site-specific Seismic Hazard and Screening Report [Ref. 1] in Table 1 below:

Table 1: Kappa (κ) used by Exelon for Limerick

Profile	V_{s100} (fps)	κ (sec)
P1	3475	0.023
P2	2223	0.036
P3	5974	0.012

Based on the definition of this kappa as a "total effective kappa" described above, these values are intended to include the contribution of the low-strain damping from nonlinear near-surface layers. For Limerick, two dynamic material models were considered in the upper 500 feet of the profile: EPRI rock and linear response [Ref. 1]. In both cases, low-strain damping is approximately 3% of critical (damping ratio about 0.03) as depicted in SPID Figure B-11 [Ref. 3].

Epistemic uncertainty in kappa was considered to be adequately reflected based on the range (upper and lower ranges, P3 and P2) about the best estimate base-case value (profile P1) being roughly a multiplier of 1.6 [Ref. 1]. This use of multiple estimates of total effective kappa provided for epistemic uncertainty in kappa (low-strain damping) below 500 feet, where greater uncertainty in damping exists. The shallow portion of the firm rock profile (with lower shear-wave velocity) is the zone where highest damping may be expected to occur.

NRC Characterization

NRC reported their estimation of kappa for each base case profile as provided in Table 2 below [Ref. 8]. These values appear to correspond with the relationship prescribed in the SPID [Ref. 3] for rock sites having at least 3,000 feet of sedimentary rock overlying hard rock, computed using the shear-wave velocity profiles estimated by NRC as shown in slides presented during the public meeting [Ref. 8]. (Note that the average shear-wave velocities of the upper 100 feet identified in the table below are estimates from the shear-wave velocity profiles for Limerick presented by NRC [Ref. 8], and may differ somewhat from the actual values used by NRC.)

Table 2: Kappa (κ) used by NRC for Limerick

Profile	V_{s100} (fps)	κ (sec)
BC	2900	0.027
LBC	2200	0.035
UBC	4000	0.019

Additionally, NRC presented two versions of the GMRS based on two different possible interpretations of dynamic material properties of the near-surface layers [Ref. 8]. In NRC version R1, one model considered EPRI rock for the top 475 feet and linear response with no damping for the layers below 475 feet, and the second model considered linear response with 1% damping for the top 1700 feet and linear response with no damping for the layers below 1700 feet. In NRC version R2, one model considered EPRI rock for the top 123 feet and linear response with no damping in the layers below 123 feet, and the second model considered linear response with 1% damping in the top 475 feet and linear response with no damping in the

layers below 475 feet. NRC considered epistemic uncertainty in low-strain damping to be addressed by this application of different damping values to the near-surface layers [Ref. 8].

Discussion of Differences

The values of kappa reported by Exelon and NRC are very similar (0.023 vs 0.027, 0.036 vs. 0.035, and 0.012 vs 0.019). However, both the NRC GMRS (version R1 and R2) were reported to be somewhat higher than the Exelon GMRS. Discussion during the public meeting clarified that NRC attributed this phenomenon to the difference in low-strain damping applied to the near-surface layers between NRC and Exelon based on a sensitivity run demonstrating that an adjustment of low-strain damping from 1% to about 3% brought the NRC GMRS very close to the Exelon GMRS. However, given the SPID definition of kappa as a "total effective kappa" including the effects of both low-strain damping in the near-surface layers as well as scattering attenuation from heterogeneities [Ref. 3], and considering minimal non-linear response in the near-surface layers at loading levels of interest, it is not clear how the GMRS would be appreciably sensitive to independent adjustment of the low-strain damping value.

The first caveat to the statement above relates to total effective kappa. Because the total effective kappa is estimated by a direct relationship and includes the effect of both low-strain damping of the near-surface layers and the scattering attenuation [Ref. 3], a change to one component would be counteracted by the requisite change to the other in order to maintain the same total effective kappa. For example, consider a simplified characterization of the Limerick site with the top 500 feet comprised of a uniform layer with constant damping and shear-wave velocity of 3000 fps:

- Using the relationship for total effective kappa of a deep rock site in the SPID Section B-5.1.3.1 [Ref. 3] kappa is estimated to be 0.026 seconds (= 10^[2.218-1.0930*log(3000)]).
- First consider a constant damping in the near-surface layer of 3% ($\zeta = 0.03$). Then, the contribution from low-strain damping of the near-surface layer can be estimated utilizing the relationship between V_s, Q, and kappa [Ref. 10]. In this case, the kappa contribution from low-strain damping of the near-surface layer would be 0.01 seconds ($= H/(QV_s) = 2\zeta H/V_s$ = [2*0.03*500/3000]). Thus, the kappa attributed to the profile below the near-surface layer would be 0.016 seconds (=0.026-0.01).
- Next consider a constant damping in the near-surface layer of 1% ($\zeta = 0.01$). Then, the contribution from low-strain damping of the near-surface layer can be estimated as approximately 0.003 seconds (= 2*0.01*500/3000). Thus, the kappa attributed to the profile below the near-surface layer would be 0.023 seconds (= 0.026-0.003).
- In both cases, note that the total effective kappa remains constant at 0.026 seconds.

The implication of this point is that, all other things being equal (and minimal non-linear response), a change in low-strain damping of the near-surface layer is not expected to appreciably impact the resulting GMRS. In development of the amplification function, the kappa contribution from deeper layers shows up in the diminution function convolved with the reference rock motion, whereas the contribution of the low-strain damping of the near-surface layers shows up in the generation of soil motions [Refs. 3, 10 and 11]. This methodology accounts for the estimated total effective kappa. Details of how the low-strain damping is

distributed with depth can affect the linear (low loading level) amplification but its potential impact is expected to be relatively small.

The other caveat relates to having minimal non-linear response. For material models with non-constant damping (i.e. EPRI rock per the SPID Section B-3.3), the material damping increases at higher loading levels. Therefore, the total effective kappa tends to increase at very high loading levels due to increasing contribution from near-surface damping combined with constant kappa contribution from the deeper layers. However, significant nonlinearity in the soft-to-firm rock materials is largely confined to the very high loading levels (e.g. ≥0.75g) per the SPID Section B-3.3 [Ref. 3]. For Limerick, the GMRS is most strongly influenced by loading around 0.20g (as evidenced by the GMRS anchor point PGA) [Ref. 1] which does not exhibit appreciable non-linear response, as evidenced by the similarity in amplification functions between both dynamic material models at loading level near 0.20g (see Figures 2.3.6-1 and 2.3.6-2 of the Limerick Seismic Hazard and Screening Report [Ref. 1]). Therefore, the Limerick GMRS is not expected to be strongly influenced by potential nonlinear response of the near-surface layers and corresponding increases in damping at high loading levels.

Note that additional discussion and detail regarding the methodology for estimating site-specific kappa (including how distribution of low-strain damping with depth can affect linear amplification), generalized across the industry, is expected to be provided in the coming months. This forthcoming supplemental information ("industry white paper") may provide additional clarity regarding the total effective kappa at Limerick and apparent differences in approach between NRC and Exelon.

In addition to the technical discussion above, it should be noted that the approach utilized by Exelon for kappa estimation and applicable damping from the dynamic material properties of the near-surface layers is a direct application of the SPID Appendix B [Ref. 3]. Quantitative differences with the NRC approach could be considered deviations from the SPID. For example (and perhaps most notably), use of 1% low-strain damping in the near-surface rock layers is a deviation from the SPID approach to use EPRI rock properties, which have about 3% low-strain damping [Ref. 3]. As another example, consideration of 1700 feet and 123 feet as the near-surface depth for application of dynamic materials is a deviation from the depth of 500 feet referred to in Section B-4.0 of the SPID [Ref. 3].

1.2 Item #2 – Shear Wave Velocity Profile

During the June 17, 2014 public meeting [Ref. 6], differences in shear-wave velocity profiles for Limerick between Exelon and NRC were discussed as being based on differences in approaches for utilizing available site-specific data and for quantitatively estimating a geotechnical profile where site-specific measurements are not available. Specific differences are discussed below.

Exelon Characterization

Exelon has characterized the Limerick site as having 8,000 feet of sound Triassic sedimentary rocks (hard siltstone, sandstone, and shale) overlying hard crystalline basement rock [Ref. 1]. This general interpretation is based primarily on local site exploration programs (including foundation explorations for original plant construction) and regional data contained in the plant UFSAR [Ref. 12], as consolidated and reported by SGH [Ref. 13].

Exelon has characterized the shear-wave velocity profile as a constant shear-wave velocity gradient from the surface to the depth of basement bedrock [Ref. 1]. This constant gradient utilized for the best-estimate base case profile is consistent with the 0.5 m/s/m gradient prescribed in the SPID Section B-3.1 [Ref. 3] for firm rock sites resembling those composed of Cenozoic or Paleozoic sedimentary rocks such as shales, sandstones, siltstones, or similar rock types.

Exelon has characterized the shallow (near-surface) shear-wave velocity of the base case profiles based on site-specific measurements from the top portion (approximately 100 feet) of the firm rock [Ref. 1]. For the best-estimate base case profile, the average of relatively recent near-surface shear-wave velocity data from the nearby Independent Spent Fuel Storage Installation (ISFSI) was used (3,452 fps). The lower range base-case profile scaled the best estimate by a scale factor of 1.57 representative of epistemic uncertainty (2,209 fps). The upper range base-case profile used the average of near-surface shear-wave velocity data reported in the plant UFSAR (5,952 fps).

NRC Characterization

NRC has characterized the site as approximately 5,000 feet of soft red shale, siltstones, and sandstones overlying basement bedrock [Ref. 8].

NRC has characterized the shear-wave velocity profile as a near-surface portion (approximately 80 feet deep) based on site-specific data extended to basement bedrock using a template profile [Ref. 8]. The near-surface portion was developed based on ISFSI and General Atomics (1974) data [Ref. 8]. The template profile appears to be based on those suggested in the SPID Section B-3.1 [Ref. 3] for soil and soft rock sites with sparse or very limited information regarding dynamic material properties available.

NRC has characterized the lower and upper range base case profiles based on a scale factor of 1.3 for the near-surface profile and a scale factor of 1.57 below the near-surface profile to represent epistemic uncertainty in the shear-wave velocity profile [Ref. 8].

Discussion of Differences

The Exelon and NRC shear-wave velocity profiles are based on similar interpretation of largely the same data. Graphs illustrating both the Exelon and NRC profiles presented by the NRC during the June 17 public meeting [Ref. 8] are repeated below as Figure 2. Although qualitatively similar, visible differences between Exelon and NRC shear-wave velocity profiles include the granularity of the near-surface data applied, the shape of the extrapolated profile from the near-surface to bedrock, and the depth to bedrock. The NRC shear wave velocity is slightly lower at the shallower depth (<500ft) and greater at the deeper layers than Exelon.

The near-surface data applied by the NRC includes a somewhat significant jump in shear-wave velocity data, which would be expected to result in potential resonances at high-frequency, perhaps accompanied by increased amplification compared to the shear-wave velocity profile applied by Exelon. Based on the varying geologic and geotechnical data available at the Limerick site from both original plant licensing as well as ISFSI implementation [Ref. 13], it is unclear whether such a geologic structure is representative of the complete Limerick site and therefore applicable to the GMRS calculation discussed herein.

It is understood that the differences between NRC and Exelon estimates of shear-wave velocity profile at Limerick were informally judged during the NRC public meeting on June 17 [Ref. 6] as

relatively inconsequential to the ultimate GMRS calculation given the general similarity of the profiles and specific site characteristics. Staff and consultants from both NRC and Exelon appeared to be in agreement regarding this judgment.

For purposes of NTTF 2.1: Seismic screening, additional study to evaluate the specific impact of these differences on GMRS amplitude would be warranted only if the GMRS incorporating resolution of kappa is very close to the plant SSE spectra.

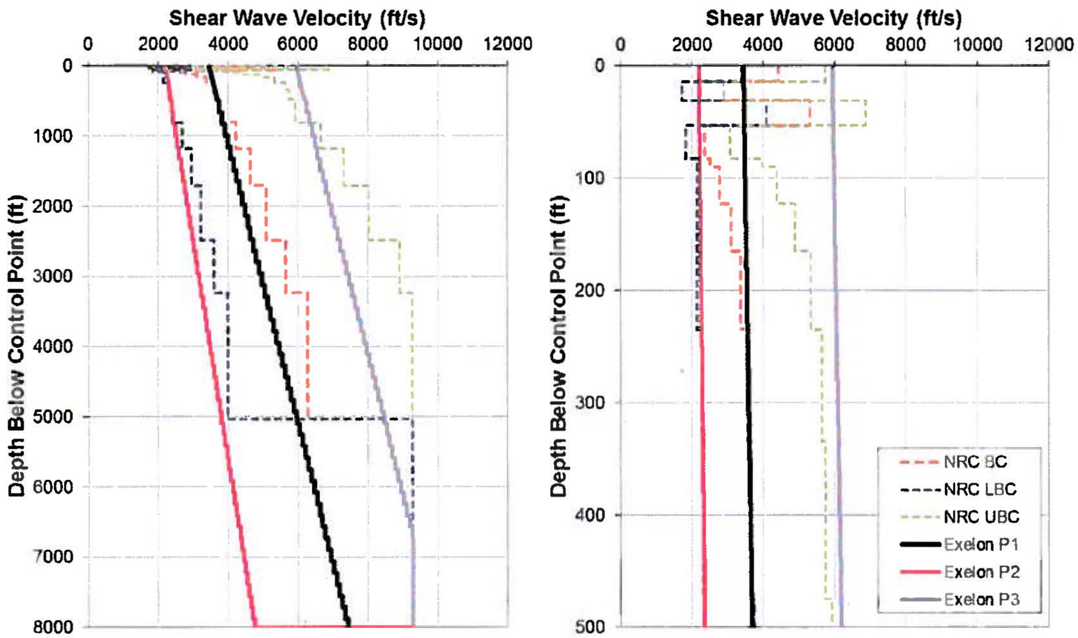

Figure 2: Comparison of Limerick Shear-Wave Velocity Profiles Developed by NRC and EPRI [Ref. 8]

2. Conclusions / Findings

Exelon and NRC met during a public meeting on June 17, 2014 aimed at developing a common understanding of the source of differences between Exelon and NRC GMRS used for NTTF 2.1: Seismic screening, noting that the Exelon and NRC GMRS curves themselves were quite close already. Differences in GMRS were categorized as relating to kappa and shear-wave velocity profile. Exelon has considered the alternative information shared by the NRC and assessed the differences with corresponding information used by EPRI in development of the Exelon GMRS.

Regarding kappa, primary differences between Exelon and NRC relate to the consideration of low-strain damping in the near-surface material and its contribution to total effective kappa, as well as the difference in magnitude of assumed material damping in the near-surface layers (i.e. 1% versus approximately 3%). The methodology utilized by Exelon is consistent with the SPID and supporting literature, and is believed to be appropriate for the Limerick site. Additional discussion and detail regarding the methodology for estimating site-specific kappa is expected to be provided in the coming months, which may provide additional clarity regarding the total effective kappa at Limerick and apparent differences in approach between NRC and Exelon.

Regarding the shear-wave velocity profile, primary differences between Exelon and NRC relate to the interpretation of site-specific data for extrapolating to depths where site-specific data is unavailable, and to the granularity of interpreted near-surface shear-wave velocity data. The

specific differences noted are not expected to appreciably affect the GMRS in the context of NTTF 2.1: Seismic screening.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting [Ref. 6] concerning the Limerick kappa values and shear-wave velocity profile. Based on this review, Exelon concludes that the GMRS-to-SSE comparison submitted to NRC on March 31, 2014 [Ref. 1] is appropriate and should be used in the NTTC 2.1: Seismic screening evaluation. Therefore, Exelon is proceeding based on this conclusion and subsequently will not complete a seismic risk assessment or ESEP for Limerick.

3. References

1. Exelon Generation Company, LLC letter to the NRC, *Seismic Hazard and Screening Report (Central and Eastern United States (CEUS) Sites), Response to NRC Request for Information Pursuant to 10 CFR 50.54(f) Regarding Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident*, dated March 31, 2014 (RS-14-069)
2. NRC (E. Leeds and M. Johnson) Letter to All Power Reactor Licensees at al., *Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3, of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident*, March 12, 2012
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7. Exelon Presentation Slides, "Exelon Response to May 9, 2014 Letter on Site Seismic Hazard Screening Items," ML14167A053, June 17, 2014
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13. Simpson, Gumpertz and Heger (SGH) Report No. 128018-R-01, Revision 1, *Review of Existing Site Response Data for the Exelon Nuclear Fleet*, July 2012 [Exelon AR01550669-02, Rev. 0]

14. EPRI NP-6395-D, "Probabilistic Seismic Hazard Evaluation at Nuclear Plant Sites in the Central and Eastern United States: Resolution of the Charleston Earthquake Issue," April 1989

Attachment 3

Oyster Creek Nuclear Generating Station

Supplemental Information in Response to NRC Conditional Screen-In Evaluation

REASON FOR EVALUATION/SCOPE

On March 31, 2014, Exelon submitted a Seismic Hazard and Screening Report (Reference 3) for the Oyster Creek Nuclear Generating Station in response to the NRC 50.54(f) Information Request Regarding Fukushima Near-Term Task Force Recommendation 2.1: Seismic. This report provided a comparison between the Ground Motion Response Spectra (GMRS) generated by Exelon for the Oyster Creek site and the site Safe Shutdown Earthquake (SSE). The information contained in the report was developed using guidance from the NRC endorsed Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (Reference 1).

Based on the comparison between the GMRS generated by Exelon and the Oyster Creek SSE as shown in the Seismic Hazard and Screening Report, Oyster Creek is shown to "screen-out" from the requirement to perform a seismic risk assessment or the Expedited Seismic Evaluation Process (ESEP). However, Oyster Creek will need to perform additional limited scope evaluations as described in the Exelon submittal of March 31, 2014 (Reference 3).

On May 9, 2014, the NRC issued Screening and Prioritization Results (Reference 4) for Oyster Creek. This report states that based on a comparison between GMRS generated by the NRC for the Oyster Creek site and the SSE identified by the NRC for Oyster Creek, Oyster Creek conditionally screens "in" with respect to the need to complete a seismic risk assessment. Furthermore, this document conditionally classifies Oyster Creek as Priority Group 2.

During a public meeting held between the NRC and Exelon on June 17, 2014, the NRC provided further information related to the generation of the NRC GMRS and the SSE used by the NRC for their comparison to the GMRS. During this meeting, Exelon provided additional information supporting the information contained in their submittal of March 31, 2014 (Reference 3). While a formal presentation was made at the meeting, some of this information was provided verbally. The purpose of this evaluation is to formally provide Exelon's complete basis for our screening conclusions to the NRC along with supporting documentation. Additionally, this report will document Exelon's review and conclusions of the NRC information provided as well as consideration of the verbal discussion from the June 17, 2014 public meeting. This information is being provided to the NRC to assist them in making a final determination of the need for Oyster Creek to complete a seismic risk assessment (Seismic PRA or Seismic Margins Assessment) and an Expedited Seismic Evaluation Process (ESEP).

This evaluation contains information that shows that the GMRS developed by EPRI for Exelon/Oyster Creek are consistent with the guidelines provided in the SPID and that the SSE spectra used by Exelon for comparison to the GMRS for Oyster Creek are the appropriate spectra to be used for this comparison. Therefore, the information provided in this evaluation demonstrates that Oyster Creek screens "out" and that a seismic risk assessment and ESEP are not required.

DETAILED EVALUATION

Background/Introduction

On March 31, 2014, Exelon submitted the results of the comparison of the Ground Motion Response Spectrum (GMRS) generated by Exelon to the current Oyster Creek Safe Shutdown Earthquake Response Spectra (Reference 3). As indicated in this Seismic Hazard and Screening report, Oyster Creek was determined to screen out from the need to perform a seismic risk assessment or the Expedited Seismic Evaluation Process (ESEP) based on guidance provided in the Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near Term Task Force Recommendation 2.1: Seismic (Reference 1).

On May 9, 2014, the NRC issued Screening and Prioritization Results related to seismic hazard reevaluations for the Central and Eastern United States (CEUS) nuclear plant sites (Reference 4). Based on this effort, the NRC determined that Oyster Creek "conditionally screened-in" and was conditionally placed into Priority Group 2. Subsequent to this letter, the NRC raised 4 items related to differences between the results obtained by Exelon and submitted on March 31, 2014 (Reference 3) and the results obtained by the NRC and issued on May 9, 2014 (Reference 4) and on May 21, 2014 (Reference 29). These items were: 1) the soil velocity profile for soil layers more than approximately 350 feet below the surface used by the NRC was determined to be different from the soil velocity profile used by Exelon; 2) the value of kappa used by the NRC was determined to be different from the kappa value used by Exelon; 3) the Safe Shutdown Earthquake (SSE) used by Exelon was different than the SSE that the NRC felt should have been used based on information available to them; and, 4) the Control Point was changed from bottom of the main building foundation to the free field surface. In addition, during the public meeting held between Exelon and the NRC on June 17, 2014, the NRC indicated that they were not able to duplicate the GMRS generated by EPRI for Exelon/Oyster Creek, even using the inputs reported to have been used by EPRI. This will be addressed as Item 5.

These five items were discussed between Exelon and the NRC in the public meeting held on June 17, 2014. During this meeting, various pieces of information were shared and presentations on these points were made by Exelon and the NRC. The purpose of this transmittal is to provide further documentation of the information presented by Exelon in the public meeting and to address the items raised by the NRC and to provide supplemental information related to the five items discussed previously. Information related to each of the five items is provided in the following paragraphs to assist the NRC in their final determination of screening and prioritization of the Oyster Creek site.

Item 1: Differences in Soil Velocity Profiles more than 350 Feet below the Surface

Basis for Exelon Position

Based on information presented in the Oyster Creek UFSAR and other sources, Oyster Creek is classified as a deep soil site. Section B-5.1.3.1 of the SPID (Reference 1) defines a soil site as sites with at least 3000 feet of soil above hard rock. The Oyster Creek UFSAR (Reference 2) states that there are 3700 feet of soil above hard rock at the Oyster Creek site (see later discussion of UFSAR information). Therefore, the Oyster Creek site meets the definition of a deep soil site.

Information on soil properties in the vicinity of the site are only available for the soil from the surface to approximately 350 feet below the surface. For deep soil sites where information is only available for soil layers near the surface, the SPID (Reference 1) provides a template for use in developing a soil profile for the deeper layers. Exelon used the template from the SPID to develop the soil profiles for the soil layers from approximately 350 feet below the surface to the top of rock. This approach is consistent with the SPID and with the available site information contained in the Oyster Creek UFSAR.

Information on soil velocity profiles for the in-situ soil at Oyster Creek is available for the soil layers from grade to approximately 350 feet below grade as indicated in the Exelon submittal on March 31, 2014 (Reference 3). Based on information in the Oyster Creek UFSAR, Exelon has characterized the site as a deep soil site, with Coastal Plain sediments overlying Precambrian basement rock. As stated in Section 2.5.1.2 of the Oyster Creek UFSAR (Reference 2), the New Jersey coastal plain is underlain by a sequence of unconsolidated to semi-consolidated sedimentary deposits. These sediments vary in thickness from 800 feet at Sandy Hook to 6000 feet at Cape May. In the vicinity of the site, the sediments are estimated to be approximately 3700 feet thick.

In addition, Table 2-10 in NUREG-1742 (Reference 26) defines Oyster Creek as a soil site. NRC Information Notice 2010-18 (Reference 27) refers to a study prepared by the NRC related to Generic Issue 199. Pages B-8 and B-6 of Appendix B of this study also define Oyster Creek as a soil site.

Exelon has established the top 350 feet of the site-specific base-case shear wave velocity profile based on shear-wave velocities extracted from existing site-specific exploration programs. From 350 feet to basement bedrock, Exelon adopted a representative template profile from the SPID scaled to match the shallow velocity estimates provided at the site. This template matching process directly follows the process prescribed in the SPID (Reference 1) for soil sites where shear wave velocity measurements are available only at shallow depths (see SPID Section 2.4.1 and B-3.1 for additional detail). Per the SPID Section B-3.1, the template profiles are appropriate for "both soil and soft rock sites" and can be used for "deep soil" sites "to provide a rational basis to extrapolate the profile to the required depth."

Epistemic uncertainty at depths below the top 350 feet is addressed by Exelon in generating the GMRS by using three base-case shear-wave velocity profiles (best estimate, upper bound, and lower bound) to account for the limited knowledge of the Oyster Creek site stratigraphy. This treatment of epistemic uncertainty ensures that possible moderate differences from the estimated shear-wave velocity profiles are accounted for in the GMRS development.

<u>Consideration of NRC Position</u>
In the public meeting of June 17, 2014, the NRC characterized the site as soil overlying older layers resembling soft rock grading to firm rock. The NRC reported that this characterization is based primarily on existing Oyster Creek site-specific measurements at shallow depths coupled with site-specific measurements from the PSEG Nuclear site (Salem and Hope Creek Nuclear Generating Stations) in Lower Alloways Creek, NJ.

The NRC established the top 350 feet of the base-case shear wave velocity profile based on shear-wave velocities extracted from existing site-specific exploration programs. These velocity profiles were obtained from data reported in the Oyster Creek UFSAR and closely match the

profiles used by Exelon in generating the GMRS. From 350 feet to just over 1200 feet below the surface, it appears that the NRC developed profile layers based on the NRC PSEG velocity model developed from combined operating license (COL) application data. The technical rationalization for this extrapolation of information from another site was summarized by the NRC as follows: although approximately 80 miles apart, the Oyster Creek and PSEG sites are both in the Coastal Plain Province of New Jersey, which has been reported to have relatively continuous strata based on information provided by Sugarman et al. (Reference 28). From just over 1200 feet below the surface to basement bedrock, NRC adopted a gradient profile. The use of a constant gradient profile is prescribed in the SPID for firm rock such as Cenozoic or Paleozoic sedimentary shales, sandstones siltstones or similar rock types (see SPID Section 2.4.1 and B-3.1 for additional detail). The technical rationalization described by the NRC for interpreting the deeper layers at Oyster Creek as firm rock is based on the reported age of these deeper formations within the Coastal Plain strata, as stated by the NRC during the public meeting.

A slide from the June 17 public meeting with the NRC is shown in Figure 1. This slide (from Reference 31) presents the NRC base case and the best case, upper bound and lower bound shear-wave velocity profiles used by Exelon on the same graph. The graph also shows the gradient for firm rock sites as defined in Section B-3.1 and shown in Figure B-6 of the SPID (Reference 1). The differences in shear-wave velocity profile between NRC and Exelon can be described for three distinct depth ranges: shallow near-surface (top 350 feet), intermediate depth (between 350 feet and approximately 1200 feet below the surface), and deep layers (between approximately 1200 feet below the surface and basement bedrock).

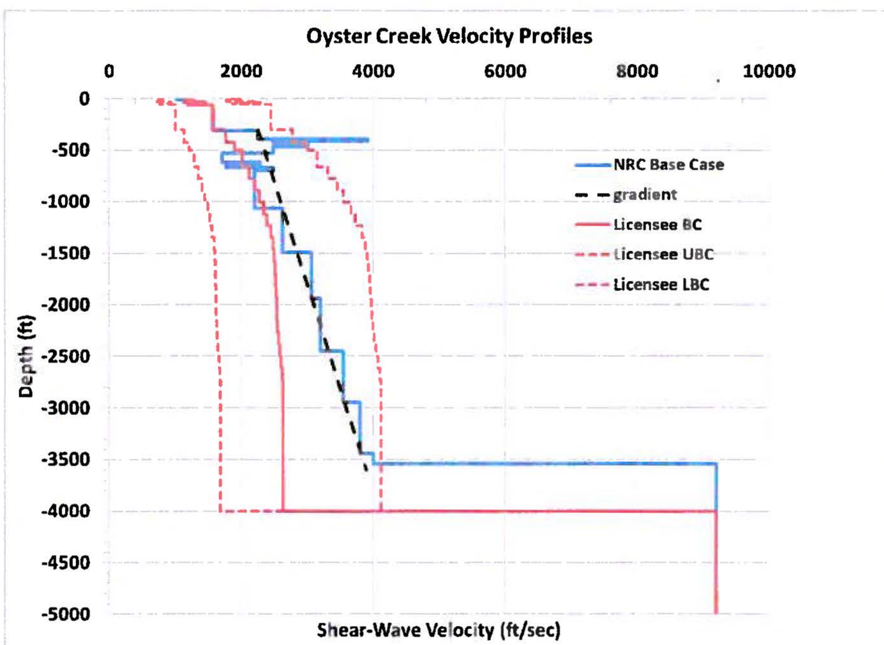


Figure 1

In the shallow-near-surface depth range, the NRC and Exelon shear-wave velocity profiles are nearly identical, with the exception being related to the control point elevation (see separate discussion on control point in Item 4). This implies that site-specific data has been interpreted equivalently by both NRC and Exelon for soil in the top 350 feet below the surface.

In the intermediate depth range, the NRC and Exelon shear-wave velocity profiles are similar, except that the NRC profile has more granular layering and greater variation from the equivalent mean. The other exception is that the NRC profile includes a thin dense sand layer at approximately 450 feet depth that is stiffer than the layers above and below. This stiffness discontinuity phenomenon appears to be a result of the extension of site-specific PSEG data to the Oyster Creek site. This profile, with a significant jump in velocity near a depth of about 400 feet would be expected to potentially result in resonances which may have increased amplification over the smoother EPRI profiles. It is unclear whether such a discontinuity exists at the Oyster Creek site, and would require additional detailed geotechnical exploration to better understand and confirm whether or not PSEG data is directly applicable.

In the deep layers, the NRC and Exelon shear-wave velocity profiles diverge, with the NRC profile being stiffer at deeper depths. This difference appears to result from the NRC applying a gradient profile below the intermediate depths, whereas Exelon applied a template profile below the shallow layers that extends through the intermediate and deeper layers. As described above, the SPID indicates that template profile estimates are applicable for soil and soft rock sites, whereas a gradient profile estimate is applicable for firm rock sites.

Conclusions for Item 1

As stated in the discussion, the shear-wave velocity profiles used by Exelon and the NRC are nearly identical for the top 350 feet below the surface. Below this depth, the soil profiles used by the NRC diverge from those used by Exelon. The differences appear to be due to the Exelon characterization of the site as a deep soil site and the NRC characterizing the site as rock below a relatively shallow depth. The basis for the NRC characterization appears to be judgment based on age of the deposits and information from the Salem/Hope Creek sites. This use of information from a site that is a significant distance from Oyster Creek does not appear to be appropriate given the information in the Oyster Creek UFSAR and the past characterization of the site as a deep soil site.

The soil profile used by Exelon for the top 350 feet below the surface is based on information provided in the Oyster Creek UFSAR (Reference 2). This soil profile is essentially identical to the soil profile used by the NRC for the top 350 feet below the surface as shown in Figure 1. At depths greater than 350 feet below the surface, Exelon used template guidance from Appendix B of the SPID (Reference 1) for deep soil sites to develop a soil profile and then included a lower bound and upper bound estimate to account for uncertainty with respect to the soil properties.

Due to the relatively large uncertainty, a factor of 1.57 was applied to the best estimate to develop both the upper bound and lower bound profiles. This factor is consistent with guidance provided in Appendix B of the SPID (Reference 1) for developing upper and lower bound soil profiles where data is limited or not available and was applied by Exelon to all layers above hard rock. Given the lack of specific information for the Oyster Creek site at these depths, this approach is consistent with the guidance provided in the SPID. Oyster Creek is a deep soil site

as stated in the Oyster Creek UFSAR (Reference 2) and the other documents cited herein and the approach used by Exelon to develop the best case soil profile is also consistent with the SPID for deep soil sites. In conclusion, the soil velocity profiles used by Exelon to generate the GMRS are developed consistent with available site-specific information and the guidance in the NRC endorsed SPID (Reference 1).

Item 2: Differences in Kappa Values

Basis for Exelon Position

Oyster Creek is a deep soil site as described in the discussion related to Item 1. Based on guidance in the SPID (Reference 1), a kappa value of 0.04s is appropriate for deep soil sites. Exelon used a value for kappa of 0.04s for all three soil profiles to generate the GMRS as discussed in Item 1. This estimation of kappa is consistent with the SPID since all three soil profiles meet the SPID definition for soil or soft rock. It should be noted that the use of 0.04s for kappa for deep soil sites is conservative based on sparse observations as referred to in the SPID (Reference 1).

Exelon considered the Oyster Creek site to be a deep soil site (defined in Section B-5.1.3.1 of the SPID as sites with a depth of soil exceeding 3000 feet to hard rock), consistent with previous characterizations of the site as deep soil. For deep soil sites, Section B-5.1.3.1 of the SPID prescribes a mean base-case kappa of 0.04s. Exelon applied this kappa value for each of the three soil profiles (best estimate, upper bound and lower bound) discussed in Item 1, and considered epistemic uncertainty in damping to be accommodated at design loading levels by the multiple sets of G/G_{max} and hysteretic damping curves. All three soil profiles used in the generation of the GMRS (best estimate, upper bound and lower bound) meet the SPID definition for soil/soft rock, for which the SPID (Reference 1) recommends a kappa of 0.04s.

Consideration of NRC Position

During the June 17, 2014 public meeting, the NRC described their characterization of the Oyster Creek site as soil over soft rock grading to firm rock overlying hard basement bedrock. For this condition, the SPID prescribes a different formulation for the estimate of kappa than it does for deep soil sties. Based on this characterization of the site, the NRC estimated a base-case kappa of 0.037s rather than the value of 0.04s used by Exelon. The NRC then explicitly addressed epistemic uncertainty in kappa by estimating kappa of 0.04s and 0.027s for the upper bound and lower bound profiles, respectively. During the meeting, both the NRC and Exelon judged, based on experience, that the differences in kappa would have only minimal impact on the resulting GMRS calculation. It was judged that the difference in soil profiles resulting from different characterizations of the site has a larger impact.

Conclusion for Item 2

The differences between the kappa values used by Exelon and the values used by the NRC for the Oyster Creek site are primarily due to a difference in interpretation of the physical geotechnical conditions at the plant site for depths below 350 feet below the surface where site-specific measurements are not available. Exelon used a value of kappa of 0.04s as stated in the SPID for deep soil and soft rock sites. Since the best estimate, upper bound and lower bound soil profiles developed by Exelon using guidance in the SPID for deep soil sites all fall into the definition of soil or soft rock, Exelon used a value of 0.04s for kappa for all three soil profiles. This approach is consistent with the SPID guidance for deep soil sites. Based on our

review of available soil information from the Oyster Creek site and the guidance in the SPDI, Exelon concludes that the kappa values used in the March 31, 2014 submittal are appropriate and should be used for the NTTF 2.1 seismic screening evaluations. Further discussion related to estimates of kappa, soil velocity profiles and the approach used to account for epistemic uncertainty is intended to be addressed in a generic white paper that is currently being developed.

Item 3: Appropriate SSE to be used for comparison to the Exelon GMRS

Basis for Exelon Position

The Safe Shutdown Earthquake (SSE) spectrum for Oyster Creek used by Exelon in their submittal of March 31, 2014 (Reference 3) for comparison to the GMRS generated by EPRI for Oyster Creek is the current licensing and design basis for Oyster Creek as specified in the Oyster Creek UFSAR (Reference 2). This Site Specific Response Spectrum (SSRS) was developed by Weston Geophysical and is anchored at 0.184g. The spectrum is provided in Figure 3.7-18 of the Oyster Creek UFSAR. The use of this spectrum for the plant design and licensing basis was approved by the NRC in their SER dated March 18, 1992 (Reference 11). This spectrum was used to develop in-structure response spectra (ISRS) for the main plant buildings and this spectrum along with the associated ISRS have been used since 1995 for all evaluations, designs and analyses performed at the site. The SSRS developed by Weston Geophysical and anchored at 0.184g is the current design and licensing basis SSE spectrum for the Oyster Creek site and is the appropriate spectrum for comparison to the GMRS generated by EPRI for Exelon/Oyster Creek. A copy of this spectrum is provided at the end of the discussion of this item.

Section 3.7.1 of the Oyster Creek UFSAR (Reference 2) states:

> Beginning in September, 1995, equipment, components, supports and structural subsystems are designed on the basis of the SSE design response spectra shown in Figures 3.7-18 and 3.7-19 and contained in Reference 6. The response spectra were developed by Weston Geophysical Corporation using the 84 percent non-exceedance probability from 67 horizontal records and the corresponding 34 vertical records. The SSE Site Specific Response Spectra (SSRS) have a peak ground acceleration of 0.184g horizontal and 0.0952g vertical. These spectra were approved by US NRC in March, 1992.

Section 3.7.3.4 of the Oyster Creek UFSAR (Reference 2) states,

> Beginning in September, 1995, equipment and seismic subsystems are analyzed, evaluated, and designed using the new EQE response spectra described in Reference 8 and contained in Reference 10. These spectra are used in conjunction with damping values specified in US NRC Regulatory Guide 1.61 or in ASME Code case N-411 for piping.

Section 3.7 of the Oyster Creek UFSAR (Reference 2) states:

The original seismic design for the Oyster Creek Nuclear Generating Station critical structures and equipment is based on dynamic analyses using acceleration response spectrum curves which were based on a peak ground acceleration of 0.11g for the Operating Basis Earthquake (OBE) and 0.22g for the Safe Shutdown Earthquake (SSE). Beginning in September, 1995, seismic design of equipment and structures is based on a peak ground acceleration of 0.092g for the OBE and 0.184g for the SSE.

Sections 3.9 and 3.10 of the Oyster Creek UFSAR (Reference 2) provide the requirements for design of Category 1 mechanical and electrical equipment, respectively. Section 3.9.3.1.2 states, "The seismic loads are specified to be the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE) in accordance with the seismic response spectra, as specified in the UFSAR Section 3.7.3.4." Section 3.10 refers to section 3.7, which also requires an OBE and SSE assessment, for seismic design requirements. The EQE report that provides the ISRS for the Reactor building includes both OBE and SSE spectra.

Oyster Creek received its provisional operating license (POL) on April 9, 1969, and began electric power generation on December 23, 1969 as stated in NUREG-1382 (Reference 5). The initial design of Class I structures and major pieces of equipment at Oyster Creek was based on a dynamic analysis using the acceleration response spectrum curves shown in the Oyster Creek UFSAR (Reference 2) Figure 3.7-1, as recommended by Dr. George W. Housner. The Housner SSE horizontal response spectra were anchored at a peak ground acceleration (PGA) of 0.22g as shown in UFSAR Section 3.7. The UFSAR did not specify vertical response spectra so the same spectra were used for both horizontal and vertical. The Housner ground motion response spectra were used as input to design of systems and components at every elevation in every building. No ISRS were developed using the Housner ground spectra. Damping values to be used in conjunction with the Housner response spectrum were provided in UFSAR Table 3.7-2. Damping values for equipment, steel substructures, bolted, welded or riveted assemblies and components were specified to be 1% or 2% of critical. Damping values for piping were specified to be ½% of critical. The Housner ground motion anchored at 0.22g along with the damping values in Table 3.7-2 of the UFSAR was the design and licensing basis of the plant from the beginning of the design effort until September 1995 when the Oyster Creek UFSAR was updated to specify that the Weston Geophysical SSRS and associated ISRS would be used as the design and licensing basis SSE going forward.

An application was filed to convert the POL for Oyster Creek to a full-term operating license on March 6, 1972. In 1977, NRC included all facilities with POL in Phase II of the Systematic Evaluation Process (SEP) as stated in NUREG-1382 (Reference 5). The intent of the SEP was to determine if plants that were designed prior to the issuance of the Standard Review Plan (SRP) (Reference 6) would have adequate margin to withstand the design requirements of the SRP. To address the SEP requirements related to seismic, ground motion response spectra were developed based on the standard ground motion shape provided in Regulatory Guide 1.60 (Reference 7) anchored at 0.22g, consistent with the original Oyster creek UFSAR (Reference 2). The same spectra were developed for both horizontal and vertical inputs, consistent with the original Housner spectra which were the same for both horizontal and vertical components. These spectra are provided in UFSAR Figures 3.7-5 and 3.7-6 (horizontal and vertical SSE, respectively) and in UFSAR Figures 3.7-7 and 3.7-8 (horizontal and vertical OBE, respectively)

(Reference 2). These curves were never part of the design or licensing basis for the plant and were only used for limited analyses as part of the SEP effort.

In addition, Weston Geophysical was contracted to develop a site specific response spectrum (SSRS) to be used in the SEP effort. This spectrum was anchored at 0.165g and was provided to GPUN by the NRC in letter LS05-81-06-068 (Reference 8). This spectrum was only used for evaluations conducted as part of the SEP effort and for design of the Recirculation system. As stated later in the discussion of this item, the recirculation system has been reanalyzed using the current licensing basis SSE (Weston Geophysical spectrum anchored at 0.184g).

Various analyses were performed by the NRC and their consultants and by GPUN using one or both of these "SEP" spectra. ISRS were developed as part of the SEP effort and various components were evaluated using these ISRS. The purpose of these evaluations was to demonstrate that the existing structures, systems and components (SSCs) had sufficient margin to perform their intended functions during and/or after the earthquake represented by these spectra. The results of these various analyses are discussed in NUREG/CR-1981 (Reference 9) and in NUREG-1382 (Reference 5). Neither of these spectra were ever part of the design or licensing basis for Oyster Creek (except that the 0.165g spectra were used for design of the reactor recirculation system, as discussed).

NUREG-1382 (SER supporting the issuance of Full Term Operating License to Oyster Creek) was issued by the NRC in January 1991 (Reference 5). This NUREG discusses various evaluations that were performed at Oyster Creek as part of the SEP effort and other programs. In Section 3.7.3 of NUREG-1382, the NRC summarized the seismic design and evaluation of the structures, systems and components at Oyster Creek and concluded that Oyster Creek can continue to be operated until the ultimate resolution of USI A-46 without endangering the health and safety of the public. Furthermore, due to the fact that several different floor response spectra had been used for different purposes, in July 1987, GPUN had proposed to develop new site specific response spectra and new standardized ISRS. NUREG 1382 states that as of January 1991, development of the new seismic floor response spectra continues, and they will be reviewed by the staff when they are submitted.

In the SER dated February 23, 1995 (Reference 13), the NRC approved the use of the ISRS developed by EQE for the resolution of USI A-46, and for any future designs, analyses and evaluations. The NRC did not impose any condition on this use except that the Oyster Creek UFSAR shall be amended to reflect the proposed changes. In the SER dated January 19, 2000 (Reference 14), the NRC concluded that USI A-46 has been adequately resolved. Based on the above SERs the safety issues of all Oyster Creek SSCs have been fully addressed without re-evaluation using the new seismic spectra with the exception of the safety related piping systems as discussed in sections 3.7.2 and 3.9.1 of NUREG-1382 (Reference 5).

During the resolution of USI A-46, GPUN reviewed the various ground motion response spectra that had been used in previous evaluations and determined that new site specific response spectra (SSRS) and conservative state-of-the-art design ISRS needed to be developed to properly assess the plant equipment. To accomplish this, GPUN contracted Weston Geophysical to develop the new SSRS. To develop these spectra, Weston Geophysical obtained actual time history recordings of earthquakes from sites around the world with soil profiles matching or consistent with the in-situ soil profile at Oyster Creek. The criteria for selecting the earthquakes, including magnitude and distance as well as the sites to be included

were established by the NRC and the 67 actual horizontal earthquake records (and the 34 corresponding vertical records provided by Weston Geophysical to EQE in Reference 10) used in the development of the SSRS were approved by the NRC as stated in their SER provided in a letter dated March 18, 1992 (Reference 11).

The SSRS developed by Weston Geophysical are provided in a letter from Weston Geophysical to EQE (Reference 10) and are shown in UFSAR (Reference 2) Figures 3.7-18 and 3.7-19 for the horizontal and vertical components, respectively. These spectra were approved for use in developing ISRS in a letter from Alexander Dromerick of the NRC to John Barton of GPUN dated March 18, 1992 (Reference 11). In this letter, the NRC states, "we consider the methodology and the resulting site specific response spectra acceptable." In the SER attached to this letter, the NRC concludes that "the staff considers the SSRS based on the 67-record data set acceptable for use in the SSI analysis." Further, this SER states the following:

> When performing the SSI analysis the procedures indicated in the Standard Review Plan (NUREG-0800 Revision 2, 1989) should be adhered to. The most significant of these procedures pertaining to an SSI analysis are:
>
> 1. The SSRS or an equivalent time history shall be applied at a "free field" location at plant grade elevation. The de-convolved spectral amplitudes at the foundation depth of the "free field" location shall not be less than 60% of SSRS spectral amplitudes defined at plant grade free field elevation.
> 2. The soil properties shall consist of:
>   a) An average (or best estimate) soil property derived from in-situ geophysical and geotechnical data,
>   b) An upper bound soil property equal to twice the average soil property, and
>   c) A lower bond(*sic*) soil property equal to half the average soil property
> 3. The material damping assumed for the soil shall not exceed 15%

Subsequent to this approval, GPUN contracted EQE to generate ISRS for the Reactor Building, Turbine Building, Emergency Diesel Generator Building and Intake Structure. The resulting ISRS for the Reactor Building, Turbine Building and Intake Structure are provided in EQE Report 50069-R-001 (Reference 12) and ISRS for the Emergency Diesel Generator Building are provided in EQE Report 50124-R-001 (Reference 23). As indicated in these reports, the SSRS developed by Weston Geophysical were used as input and the requirements from the NRC SER, including the placement of the motion at grade in the free field and the use of in-situ soil properties, were met. Pages 8 and 20 of EQE Report 50069-R-001 indicate that the input motion was applied at plant grade. Soil properties were provided by Geomatrix in Report 1957-1 (Reference 20) and were obtained from investigation of the in-situ soil conditions as specified in this report. Thus, the ISRS were developed by applying the SSRS at grade in the free field and using in-situ soil properties to develop foundation input response spectra (FIRS). The criteria used by EQE to develop the in-structure response spectra are provided in an EQE

Design Criteria document (Reference 21). Following generation of these ISRS, GPUN received an SER from the NRC approving the use of the EQE ISRS in a letter from Alexander Dromerick of the NRC to John Barton of GPUN dated February 23, 1995 (Reference 13).

In the SER attached to the NRC letter of February 23, 1995 (Reference 13), the NRC determined that the approach and methodology used by EQE to generate ISRS complied with the requirements established by the NRC in their letter dated March 18, 1992 (Reference 11). They also concurred with the soil properties used in this analysis, which were based on measurements of the in-situ soil properties. In their SER dated February 23, 1995 (Reference 13), the NRC approved the use of the ISRS developed by EQE using the SSRS produced by Weston Geophysical for the resolution of USI A-46, and "for any future designs, analyses and evaluations, provided that the Oyster Creek UFSAR is amended to reflect the proposed changes for future work. Also, the ISRS may be used in conjunction with damping values specified in Regulatory Guide 1.61 and ASME Code Case N-411 subject to the conditions specified in Regulatory Guide 1.84". The NRC SER also concluded that the approach used for generation of in-structure response spectra was consistent with the provisions of NRC Standard Review Plan Section 3.7.1, 3.7.2, and 3.7.3. As directed by the NRC SER dated February 23, 1995, the Oyster Creek UFSAR was amended in accordance with 10 CFR 50.59 to incorporate the new seismic design basis approved by the NRC based on the GPUN submittals referenced in the NRC SER.

In April 1997, the Oyster Creek UFSAR (Reference 2) was updated to include the new ISRS developed by EQE and the SSRS produced by Weston Geophysical. The UFSAR states that beginning in September 1995, all equipment, components, supports and structural sub-systems will be designed using the EQE ISRS. Section 3.7.3.4 of the Oyster Creek UFSAR states that beginning in September 1995, equipment and seismic sub-systems are analyzed, evaluated and designed using the EQE response spectra. The Oyster Creek UFSAR was also updated to specify that damping values consistent with those specified in Regulatory Guide 1.61 and ASME Code Case N411 were to be used in conjunction with the new EQE ISRS for evaluations, designs and analyses of SSCs. As stated in section 3.7 of the UFSAR, both OBE and SSE were to be evaluated using the Weston Geophysical SSRS.

As stated previously, in their SERs dated March 18, 1992 and February 23, 1995 (References 11 and 13, respectively) the NRC did not impose any restrictions on use of the new EQE ISRS and did not require GPUN to reevaluate any existing SSCs using the new ISRS (except for safety-related piping systems, which have all subsequently been reevaluated using the EQE ISRS as input). In addition, as stated in NUREG 1382 (Reference 5), the NRC had concluded that the plant SSCs were seismically adequate and that the plant could continue to operate pending successful resolution of USI A-46 and evaluation of safety-related piping systems.

It should be noted that the new EQE ISRS plotted at 5% damping were lower or nearly the same as the original Housner ground response spectra plotted at 2% damping at all elevations in the Reactor Building below elevation 75'-3". All internal SSCs had previously been evaluated using the Housner ground spectra at either 1% or 2% damping. Damping values consistent with Regulatory Guide 1.61 are used with the EQE spectra as stated by the NRC in their SER of February 23, 1995 (Reference 13). In general, at floors where the 2% damped Housner spectra is higher than the 5% damped EQE spectra, equipment qualified to the Housner spectra using the damping values specified in the Oyster Creek UFSAR for use with the Housner curve are also qualified to the EQE ISRS, using the damping specified in the Oyster Creek UFSAR

(Reference 2) for use with the EQE curve. Graphs showing a comparison between the EQE ISRS at 5% and the Housner ground motion at 2% damping for a selection of floors in the Oyster Creek Reactor Building are provided in Figures 2 through 5. Note that Figures 2 through 5 show the comparisons for the North-South direction. The East-West curves are slightly higher than the North-South curves but the conclusions remain the same. The Housner ground spectra at 2% damping is higher than the EQE ISRS at 5% damping up to elevation 23'-6" and is only slightly lower than the EQE ISRS at elevation 51'-3".

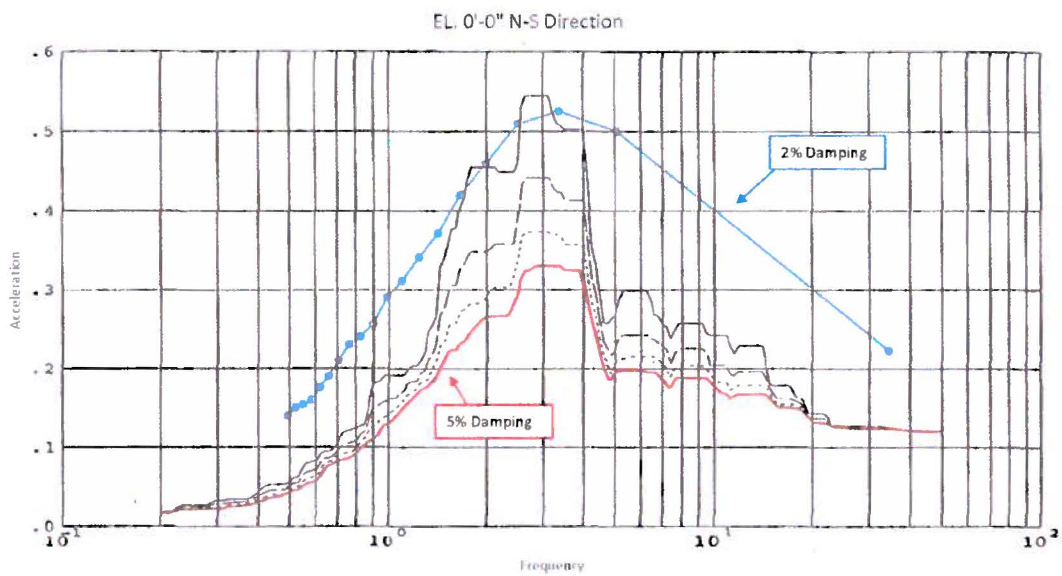


Figure 2

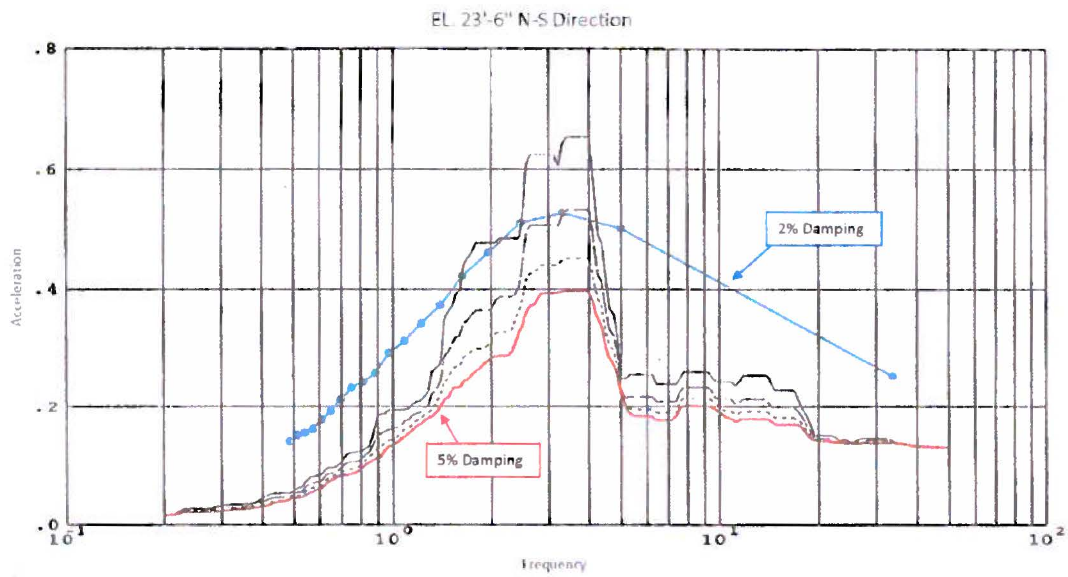

EL. 23'-6" N-S Direction
.8
.6
.4
.2
.0
Acceleration
2% Damping
5% Damping
10^{-1}
10^{0}
10^{1}
10^{2}
Frequency

Figure 3

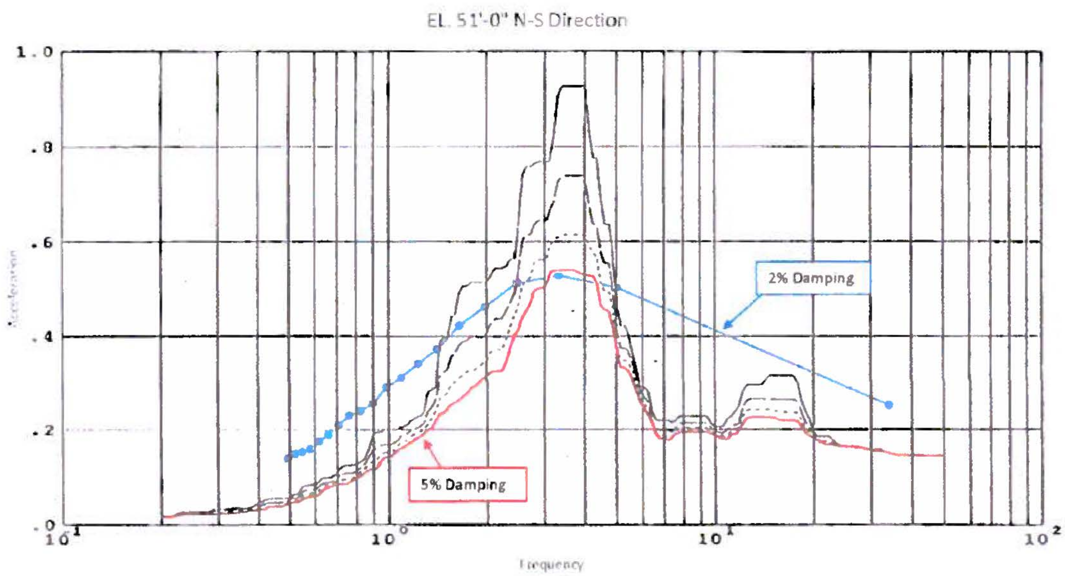

EL. 51'-0" N-S Direction
1.0
.8
.6
.4
.2
.0
10^-1
10^0
10^1
10^2
2% Damping
5% Damping

Figure 4

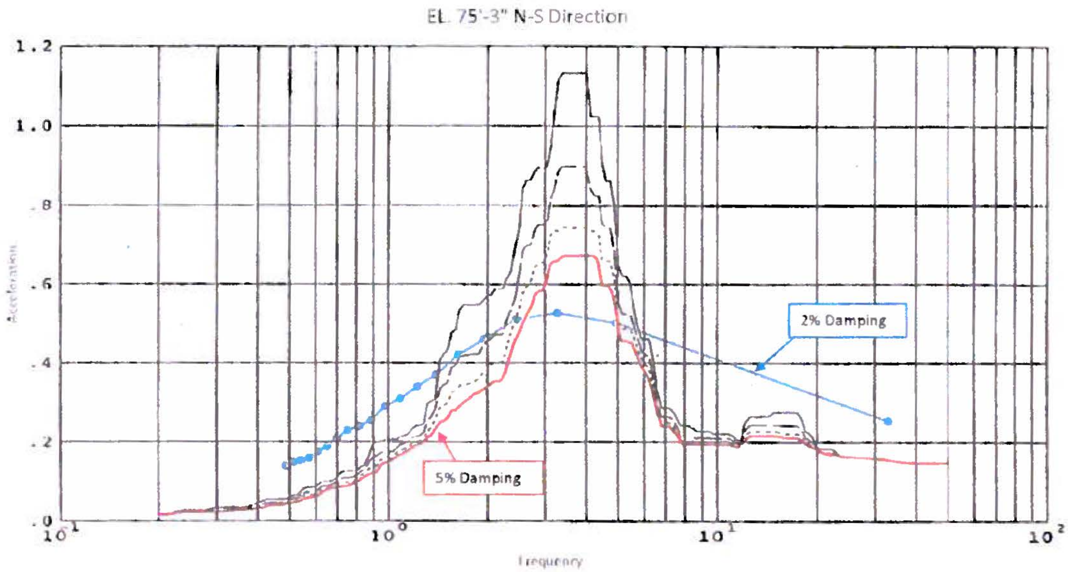


Figure 5

As shown in these graphs, the 2% damped Housner ground response spectra envelopes (or nearly envelopes) the 5% damped EQE in-structure response spectra at all elevations below elevation 75'-3". Essentially all the major safety-related structures, systems or components in the plant located in the Reactor Building are at elevation -19.0', 0.0', 23.5' or 51.0' There are relatively few safety-related components located at elevation 75.25 feet or above.

Prior to submitting the Weston Geophysical SSRS anchored at 0.184g to the NRC for approval as the licensing basis ground motion, various analyses had been performed to assess the seismic adequacy of the Oyster Creek SSCs. In particular, during the SEP effort, GPUN, the NRC and the NRC's consultants (Lawrence Livermore) performed analyses of a significant sample of safety-related components. These evaluations were performed using various seismic inputs but the result was a determination by the NRC in NUREG 1382 (Reference 5) that the plant was safe to operate pending resolution of USI A-46 and open issues related to design of safety-related piping systems. These assessments, performed over a period of 14 years along with the comparison between the Housner ground motion and the EQE ISRS as shown in Figures 2 to 5 were considered sufficient to demonstrate that the plant was seismically

adequate and that no reevaluations of existing SSCs were required (with the exception of safety-related piping).

On January 19, 2000, the NRC issued "Safety Evaluation Report for USI A-46 Program Implementation at Oyster Creek Nuclear Generating Station" (Reference 14). On page 12 of the report, the NRC concluded that "the licensee's actions provide sufficient basis to close the USI A-46 review at the facility", and "the licensee's implementation program to resolve USI A-46 at the facility has adequately addressed the purpose of the 10CFR 50.54(f) request".

On February 8, 2001, the NRC issued review of Oyster Creek IPEEE submittal (Reference 15). In the attached SER, the NRC states that the plant SSE has a peak ground acceleration of 0.18g (approximately 0.184g). On page 2 of the letter, the NRC states, "On the basis of the screening review, the staff concludes that the licensee's IPEEE process is capable of identifying the most likely severe accidents and severe accident vulnerabilities and, therefore, that the Oyster Creek IPEEE has met the intent of Supplement 4 to GL 88-20."

In the 22 years since the Weston Geophysical SSRS were approved by the NRC and the 19 years since the EQE ISRS were approved by the NRC, virtually all the major components and seismic sub-systems at the plant have been evaluated, analyzed and/or designed using the EQE ISRS as the seismic demand input to the assessment as the result of plant programs and upgrades. This includes but is not limited to:

- All equipment evaluated in response to Unresolved Safety Issue (USI) A46
- All equipment evaluated in response to the Individual Plant Examination for External Events
- All safety-related piping systems within the scope of IE Bulletin 79-14 and associated pipe supports within the scope of IE Bulletin 79-02 (see further discussion in the following paragraphs with respect to safety-related piping systems)
- All structures, systems and components which have been modified or reanalyzed since 1995
- All components included in the walk-downs in response to Near Term Task Force Recommendation 2.3, Seismic were qualified using the EQE response spectra

With respect to safety-related piping systems, various assessments were performed between 1979 and 2000 using different methodologies and different seismic inputs. As a result of these analyses, modifications were made to a large number of supports and certain supports were scheduled for additional modification. Due to changes in criteria and inputs, the piping systems were analyzed several times. To resolve on-going concerns related to the seismic adequacy of the piping due to the different inputs and methodologies used in the different evaluations and to resolve the open item identified in NUREG 1382 (Reference 5), a reanalysis of all of the safety-related piping systems was performed beginning in 2000. This reanalysis was performed using the EQE ISRS as input and all applicable design basis load combinations, including those involving OBE and SSE, were considered in the analysis. In all cases, piping and supports were shown to meet applicable design and licensing basis allowable limits using the EQE ISRS as input. The piping systems included in this analysis were the 11 piping systems within the scope of IE Bulletin 79-14 listed below (note that this includes the reactor recirculation system):

1. Liquid Poison
2. Shutdown Cooling
3. Core Spray
4. Emergency Service Water
5. Control Rod Drive/Scram Discharge Volume
6. Containment Spray
7. Isolation Condenser
8. Feed Water
9. Cleanup Demineralizer
10. Main Steam
11. Reactor Recirculation

From UFSAR Section 3.7.3.2.2 (Reference 2), the dynamic analyses of the Seismic Class I piping systems described in Section 3.9.1 of NUREG-1382 (Reference 5) are governed by the rules described in Section 3.9.3.1 of the UFSAR. Section 3.9.3.1.2 of the UFSAR references UFSAR Section 3.7.3.4, which describes the new EQE ISRS as the applicable seismic response spectra. All 11 piping systems listed above were reanalyzed in accordance to this criteria beginning in 2000.

In addition to evaluations of structural sub-systems, systems and components, a large portion of the Oyster Creek Reactor Building was reanalyzed using the EQE ISRS as input. The purpose of this reanalysis was to assess the structural adequacy of the Oyster Creek Reactor Building for loads associated with movement of a dry fuel transfer cask during a plant SSE. An analysis of the operating floor at elevation 119'-0", including the beams and columns along the designated cask haul path is contained in Exelon calculation C-1302-153-E310-129 (Reference 16). An analysis of the floor slab in the truck bay at elevation 23'-6" is contained in Exelon calculation C-1302-153-E310-114 (Reference 17) and in Exelon calculation C-1302-153-E310-116 (Reference 18). As shown in these calculations, the Reactor Building is adequate without modification for loads associated with the dry fuel transfer cask while resting on the floor at elevation 119' or at elevation 23'-6" during a plant SSE. Further, as part of the implementation of dry fuel storage, Oyster Creek replaced the overhead Reactor Building Crane with a new single-failure-proof crane. This crane and the crane support structure were also reanalyzed using the EQE response spectra as input. The reanalysis of the crane is contained in EQE calculation 302067-C-001 (Reference 19).

Consideration of NRC Position

In the NRC public meeting on June 17, 2014, the NRC stated that the SSE for Oyster Creek should be taken as the spectrum contained in their letter of May 21, 2014 (Reference 29). This response spectrum does not match any response spectrum contained in current or earlier versions of the Oyster Creek UFSAR. The spectrum appears to be anchored at 0.165g. While some evaluations performed as part of the SEP used a spectrum anchored at 0.165g, the SSE contained in the NRC letter dated May 21, 2014 does not appear to match the SEP spectrum. Furthermore, the 0.165g SEP spectrum was never part of the design or licensing basis for Oyster Creek. There does not appear to be any technical or licensing basis for considering this spectrum as the SSE for Oyster Creek.

Conclusion for Item 3

The Site Specific Response Spectra (SSRS) developed by Weston Geophysical and approved by the NRC in their SER of March 18, 1992 (Reference 11) are the current licensing basis and design basis SSE for the Oyster Creek site. The horizontal Weston Geophysical Response Spectra are anchored at 0.184g and are shown in Figure 3.7-18 of the Oyster Creek UFSAR (Reference 2). As stated, the NRC was involved in discussion with Weston Geophysical and GPUN during development of the SSRS and the actual 67 record data set used to develop the SSRS was approved by the NRC in their SER of March 18, 1992. The SSRS were used to develop ISRS using guidance provided by the NRC in their SER dated March 18, 1992 (Reference 11). The SSRS were applied at grade in the free field and in-situ soil properties were used to develop the Foundation Input Response Spectra (FIRS) for input to the soil-structure interaction analysis. This is consistent with the direction provided by the NRC in their SER dated March 18, 1992.

The ISRS developed by EQE using the SSRS developed by Weston Geophysical are the current design and licensing basis for Oyster Creek. These spectra were generated using criteria specified by the NRC in their SER dated March 18, 1992 (Reference 11). The EQE ISRS were approved by the NRC in their SER dated February 23, 1995 (Reference 13) for all future designs, analyses and evaluations.

The EQE ISRS have been used since September 1995 for all designs, analyses and evaluations performed at Oyster Creek, including risk assessments performed in response to the Individual Plant Examination for External Events and the resolution of USI A-46. Virtually all the major Class 1 components and structural sub-systems have been evaluated due to various plant programs or upgrades using these spectra over the past 19 years and major portions of the Reactor Building have been reevaluated using the spectra as input. The spectra are currently being used for on-going modifications related to various lessons learned from the Fukushima Dai-Ichi seismic event. Therefore, these spectra are the appropriate spectra to be used for comparison to the GMRS generated by Exelon for screening and prioritization.

The current licensing and design basis Site Specific Response Spectrum from Figure 3.7-18 in the Oyster Creek UFSAR (Reference 2) developed by Weston Geophysical and anchored at 0.184g is provided in Figure 7. This spectrum was approved by the NRC in their SER dated March 18, 1992 (Reference 11) for all future analyses, designs and evaluations for Oyster Creek. No limitations on the use of the Weston Geophysical SSRS were imposed. Furthermore, no restrictions were imposed on use of the EQE ISRS generated using the Weston Geophysical SSRS for future designs, evaluation or analyses. These ISRS were approved by the NRC in their SER of February 23, 1995 (Reference 13). No reevaluations of existing structures, systems or components were required by the NRC in their SER approving the EQE ISRS (Reference 13). Sufficient analyses were performed over time using various seismic criteria to provide assurance that the SSCs at Oyster Creek were seismically adequate and that a reevaluation of the existing SSCs was not necessary to change the licensing basis to the Weston Geophysical SSRS anchored at 0.184g.

A timeline showing the events related to the SSE for Oyster Creek is provided in Figure 6 and a copy of the Weston Geophysical SSRS anchored at 0.184g from the Oyster Creek UFSAR (Reference 2) is provided in Figure 7.

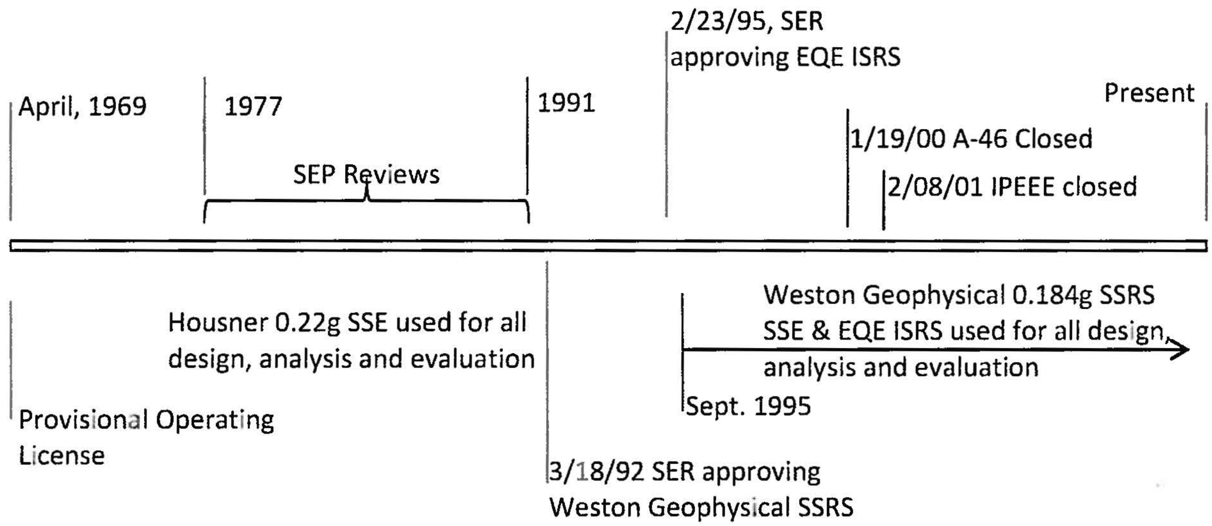
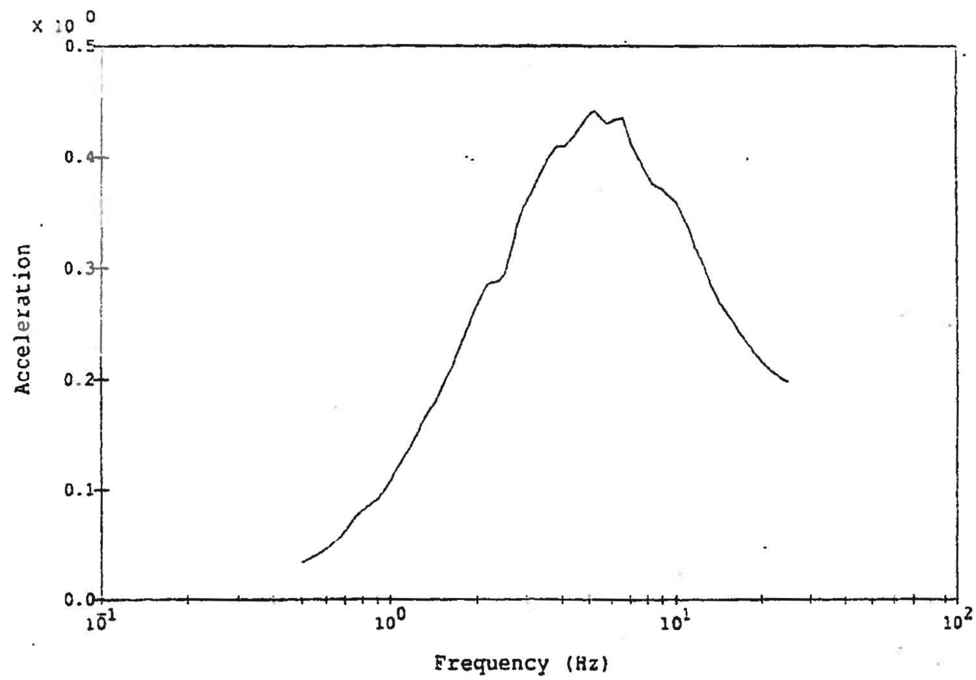


Figure 6



Notes:
Accelerations in g's
Spectral Damping 5%
PGA = 0.184g

Figure 3.7-18: **OCNGS Site Specific Response Spectra, Horizontal Component, 5% Damping**

Figure 7

Item 4:Control Point Location

Basis for Exelon Position

In the Exelon submittal of March 31, 2014 (Reference 3), Exelon reported that the GMRS were generated by Exelon using grade in the free field as the Control Point and using in-situ soil profiles for the soil layers. Based on a review of the Weston Geophysical and EQE reports, this approach has been determined to be consistent with the Control Point and soil properties used to develop the Oyster Creek SSE spectra. In addition, based on the directions provided by the NRC in their SERs dated March 18, 1992 and February 23, 1995 (References 11 and 13, respectively), this approach is consistent with guidance provided by the NRC. Therefore, it is appropriate to consider grade in the free field as the Control Point and to use in-situ soil properties to generate the GMRS.

During the NRC public meeting held on June 17, 2014 the NRC raised a concern that the control point location had been changed after the Exelon submittal of information on September 12, 2013 (Reference 22). In their submittal of September 12, 2013 (Reference 22), Exelon stated on page 1 of Attachment 7 that the control point elevation was not well defined and therefore the soil profile was modeled up to the elevation where the best estimate shear wave velocity exceeds 1000 feet per second. This elevation was stated to be in the Cohansey Formation, where the Oyster Creek Reactor Building is founded. The bottom of the Reactor Building foundation was reported on page 2 of Attachment 7 to be at elevation -29', in the Cohansey Formation. The elevation of the control point was subsequently changed by Exelon as stated in their submittal of March 31, 2014 (Reference 3)

In generating the GMRS, EPRI, at the request of Exelon, used a control point location as top of grade based on input provided by Exelon subsequent to the September 2013 submittal to the NRC. This control point location was provided to the NRC in the March 31, 2014 submittal (Reference 3) which provides results of the comparison of the GMRS generated by Exelon to the Oyster Creek SSE. The object of the discussion related to this item is to provide a basis for the change in Control Point Elevation.

As stated in the response to item 3, the original design of Oyster Creek was based on a site specific response spectrum developed by George Housner and anchored at a peak ground acceleration of 0.22g as stated in the Oyster Creek UFSAR (Reference 2). The control point elevation for this spectrum was not provided in the UFSAR because the site ground motion response spectra were not used to develop in-structure response spectra. The ground response spectra were used, along with very low damping values for evaluations of all structures, systems and components at every elevation in every building. Consistent with the fact that the original FSAR did not specify a control point location, when the UFSAR was revised to add the Weston Geophysical Site Specific Response Spectra (SSRS) anchored at 0.184g, the control point elevation was also not specified in the UFSAR. Thus, no information regarding the elevation or location of the control point was available based on a review of the Oyster Creek UFSAR (Reference 2).

When the location of the control point is not known or provided, the SPID (Reference 1) states that the control point elevation should be taken as the foundation of the major structures at the site. In the September 2013 submittal, Exelon reported that the control point should be the bottom of the foundation of the Reactor Building, or elevation -29 in the Cohansey Formation.

Subsequently, Exelon performed more in-depth reviews of available documentation related to development of the SSRS that form the basis of the Oyster Creek SSE. Based on this review, it was determined that the proper location of the control point for comparison between the GMRS and the SSE is at plant grade. This conclusion is based on the following information.

As stated in the discussion related to Item 3, the current licensing and design basis SSE for Oyster Creek is the Weston Geophysical SSRS approved by the NRC in their SER dated March 18, 1992 (Reference 11). This SSRS was developed from actual earthquake recordings in the free field at sites with soil velocity profiles similar to those found at Oyster Creek. The SSRS were developed from actual recordings from 34 earthquakes that occurred around the world at "deep soil" sites. As indicated in the SER received from the NRC on March 18, 1992, the soil profiles associated with 18 of these 34 records closely matched the soil profile at Oyster Creek. The remaining records were associated with "deep soil" sites where soil velocity profiles were not available. The NRC approved all records used in the development of the SSRS. Since the SSRS was developed based on instruments located at grade in the free field, it is appropriate that the control point location for the SSRS be taken as grade.

As stated in the discussion related to Item 3, the NRC approved the use of the SSRS developed by Weston Geophysical for use in developing in-structure response spectra. In the SER received from the NRC on March 18, 1992 approving the Weston Geophysical SSRS (Reference 11), the NRC stated the following:

> When performing the SSI analysis the procedures indicated in the Standard Review Plan (NUREG-0800 Revision 2, 1989) should be adhered to. The most significant of these procedures pertaining to an SSI analysis are:
>
> 1. The SSRS or an equivalent time history shall be applied at a "free field" location at plant grade elevation. The de-convolved spectral amplitudes at the foundation depth of the "free field" location shall not be less than 60% of SSRS spectral amplitudes defined at plant grade free field elevation.
> 2. The soil properties shall consist of:
>   a) An average (or best estimate) soil property derived from in-situ geophysical and geotechnical data,
>   b) An upper bound soil property equal to twice the average soil property, and
>   c) A lower bond(*sic*) soil property equal to half the average soil property
> 3. The material damping assumed for the soil shall not exceed 15%

As stated in the NRC SER (Reference 11), the SSRS developed by Weston Geophysical were to be applied at grade elevation in the free field. As stated in the EQE report (see subsequent paragraphs), the SSRS developed by Weston Geophysical were input at grade elevation in the free field for use in developing ISRS. Thus, establishing the control point as grade elevation for

the purpose of generating the new GMRS is consistent with the development and use of the SSRS developed by Weston Geophysical.

As stated on pages 8 and 20 of EQE Report 50069-R-001 (Reference 12) the control point location is at grade in the free field. This is consistent with the provisions contained in the NRC SER dated March 18, 1992 (Reference 11). In Report 50069-R-001 (Reference 12), in order to determine the Foundation Input Response Spectra (FIRS), EQE used the in-situ properties of the soil to de-convolve and re-convolve the input motion. This is also consistent with the NRC SER as stated previously. Thus, it is appropriate that the in-situ soil properties be used to develop the Exelon GMRS to be used for comparison with the site SSE.

To account for uncertainty in the soil properties, three separate soil models were used to develop the in-structure response spectra. The best estimate soil properties were based on information provided in the Oyster Creek and as specified by Geomatrix in Report 1957-1, (Reference 20). The lower bound estimate was then taken as ½ the best estimate and the upper bound was taken as 2 times the best estimate as specified in Exelon Document 990-2191 (Reference 21) and with the NRC SER (Reference 11). To develop the lower and upper bound properties, the shear modulus values for each of the soil layers were multiplied and divided by two (2). The resulting in-structure response spectra from the best estimate case were broadened +/- 15% and the spectra for the upper and lower bound cases were each broadened +/- 10%. The three resulting spectra were then enveloped to provide the design basis ISRS.

Note that while the NRC stated that the input motion should be applied at grade elevation in the free field, and EQE Report 50069-R-001 (Reference 12) states that the input motion was applied at grade, the lower bound soil properties of the top three feet of soil were not used in the development of the ISRS. Since the top three feet of soil had very low shear wave velocities (best estimate of approximately 300 feet per second), the lower bound properties of the top three feet of soil were not used in the analysis. However, since the next layer down has a shear wave velocity of 600 feet per second, the lower bound values for this layer (½ the best estimate) are essentially the same as the best estimate of the properties of the upper layer. Therefore, the properties of this layer were used for the top three-foot layer. While the lower-bound properties of the upper layer were not specifically included in the development of the lower bound, the thickness and overburden impact of this layer were included in the analysis. Thus, the input motion was effectively applied at grade. Since the variation in soil properties (one half and two times the best estimate) considered in developing the ISRS is sufficient to capture the properties of the top layer and since the other effects of the top layer were incorporated into the analysis, it is appropriate to set the control point at the ground surface for development of the GMRS. In addition, since the in-situ soil properties were used to determine the Foundation Input Response Spectra (FIRS) as specified by the NRC, it is appropriate to use in-situ soil properties to generate the GMRS.

Consideration of NRC Position

During the NRC public meeting held on June 17, 2014, the NRC questioned the fact that the Control Point was established at grade level and that in-situ soil properties were used by Exelon to generate the GMRS. As stated previously, the SSE for Oyster Creek is the Site Specific Response Spectra (SSRS) developed by Weston Geophysical, anchored at 0.184g and provided in the Oyster Creek UFSAR (Reference 2) as Figure 3.7-18. These spectra are the current design and licensing basis SSE for Oyster Creek as stated in the Oyster Creek UFSAR.

The spectra have been, since September 1995, and are currently being used for all analyses, designs and evaluations being performed for the Oyster Creek site. These spectra were developed at grade elevation and the in-situ soil properties were taken into account in selection of sites to use for the development of the spectra. In addition, the NRC specifically stated in their SER accepting these spectra as the design basis for Oyster Creek that the spectra were to be applied at grade in the free field and that in-situ soil properties were to be used in the soil-structure interaction analysis to develop in-structure response spectra. Thus, establishing the control point at grade and using in-situ soil properties are consistent with the methodology used to develop the SSE and consistent with the NRC stipulations for use of the Weston Geophysical spectra to develop ISRS.

Conclusion for Item 4

The current SSE for Oyster Creek is the SSRS developed by Weston Geophysical and approved by the NRC in their SER of March 18, 1992 (Reference 11). This response spectrum was developed from actual earthquake records measured at grade in the free field at sites similar to the Oyster Creek site. In their SER from March 18, 1992, the NRC specified that the input motion be applied at grade in the free field and that in-situ soil properties be used to develop the in-structure response spectra. ISRS were developed in accordance with the conditions specified in the NRC SER, which specified that input motions be applied at grade and in-situ soil properties as developed by Geomatrix and reported in the UFSAR be used. Since the SSE spectra were developed and applied at grade, it is appropriate to use grade elevation and in-situ soil properties in generating the new GMRS for comparison to the SSE. Furthermore, the SPID states that the control point should be established at the bottom of the foundation of the main plant buildings if the location of the control point used to define the SSE is not known. When the control point used to define and develop the SSE is known, the same control point is to be used to generate the GMRS, per the SPID guidance. Since the control point for developing the SSE is known, the GMRS provided by Exelon in the submittal of March 31, 2014 (Reference 3) is appropriate for comparison to the Oyster Creek SSE.

Item 5:Inability to Replicate the Exelon GMRS Using Exelon Inputs

Basis for Exelon Position

The GMRS generated by Exelon used guidance provided in the SPID (Reference 1). The inputs and methodology used to generate the GMRS are consistent with the SPID and available site information. Exelon has re-confirmed that the inputs used to generate the GMRS submitted on March 31, 2014 (Reference 3) are correct and consistent with the SPID (Reference 1).

During the public meeting held on June 17, 2014, the NRC indicated that they were not able to replicate the GMRS presented by Exelon in their submittal of March 31, 2014 (Reference 3) even using the inputs reported to have been used by Exelon. This appears to be true for both the amplification functions used as input to the GMRS and to the GMRS themselves.

During the public meeting held on June 17, 2014, Exelon stated that it appeared that the differences in the amplification functions were similar to the differences in the GMRS. Therefore, it appears the differences between the GMRS generated by the NRC and the GMRS generated by Exelon are primarily due to differences in their respective amplification functions.

As a result of the comments provided by the NRC, EPRI has reviewed the GMRS provided in their report of December 23, 2013 (Reference 30) and has determined that the amplification functions and GMRS presented in the report were generated correctly and in accordance with the SPID (Reference 1) and that the inputs used in generating the amplification functions and GMRS are as described in the report.

The GMRS is defined at specific discrete frequencies (0.5, 1.0 2.5, 5.0 10.0, 25.0, and 100.0 Hz). As a result, the differences between the NRC GMRS and the Exelon GMRS may be exaggerated due to differences in interpolation. Acceptable convergence of the NRC and EPRI GMRS, conditional on identical inputs, is intended to be addressed in a generic white paper that is currently being developed.

Consideration of NRC Position

At the NRC public meeting held on June 17, 2014, the NRC presented a comparison between the GMRS generated by Exelon and the GMRS generated independently by the NRC. The GMRS generated by Exelon were provided to the NRC in Exelon's submittal on March 31, 2014 (Reference 3). The GMRS generated by the NRC were issued in their memo of May 21, 2014 (Reference 29). As noted during the meeting on June 17, there are differences between the GMRS generated by the NRC and the GMRS generated by Exelon. As discussed previously, differences in estimations of kappa and differences in soil velocity profiles directly led to differences in the GMRS. However, as shown in the NRC slides (Reference 31), the GMRS generated by the NRC are different from the ones generated by Exelon even when the NRC used the inputs reported to have been used by Exelon. During the meeting on June 17, the NRC presented GMRS that had been generated using the same inputs as those reported to have been used by Exelon. This slide demonstrates that the NRC was not able to duplicate the GMRS provided by Exelon in the March 31 submittal (Reference 3) even using the same inputs as those used by EPRI. The relevant NRC slide is shown in Figure 8.

U.S.NRC

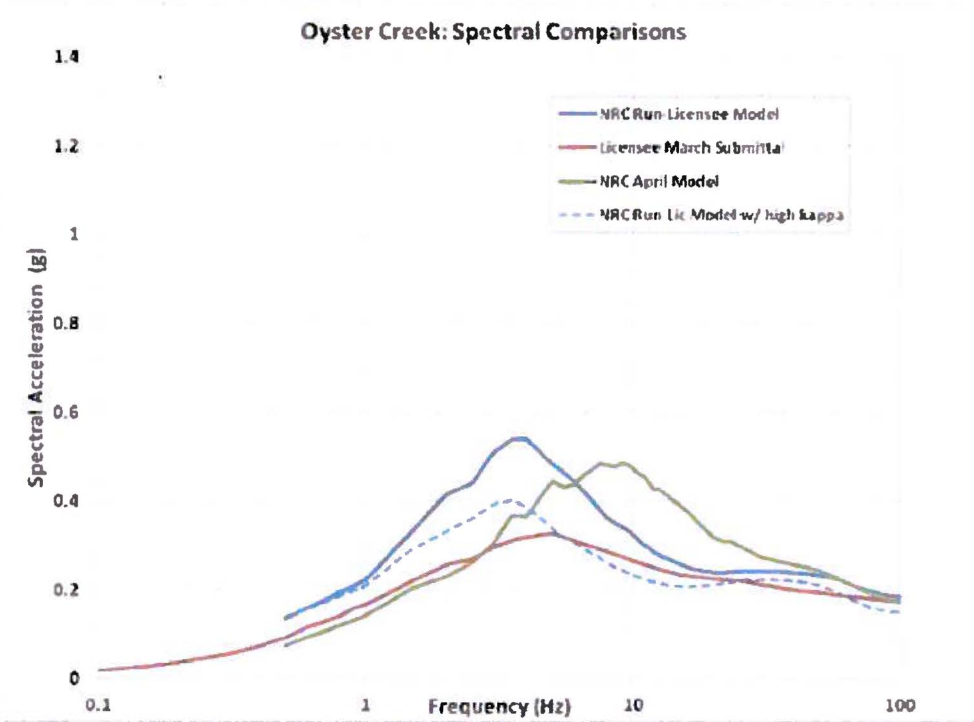


Figure 8

From Figure 8, it is apparent that the GMRS generated by Exelon (red) and the GMRS generated by the NRC (dashed blue) are characteristically different in shape as well as amplitude. As part of the discussion of the differences in the GMRS generated by the NRC and the GMRS generated by Exelon, the NRC also presented comparisons of the amplification functions developed by Exelon and those developed by the NRC using the inputs reported to have been used by Exelon. The comparisons of amplification functions are provided in the NRC slides from the public meeting of June 17, 2014 (Reference 31) and in Figures 9 and 10.

Confirmation: NRC Run of Licensee Profile

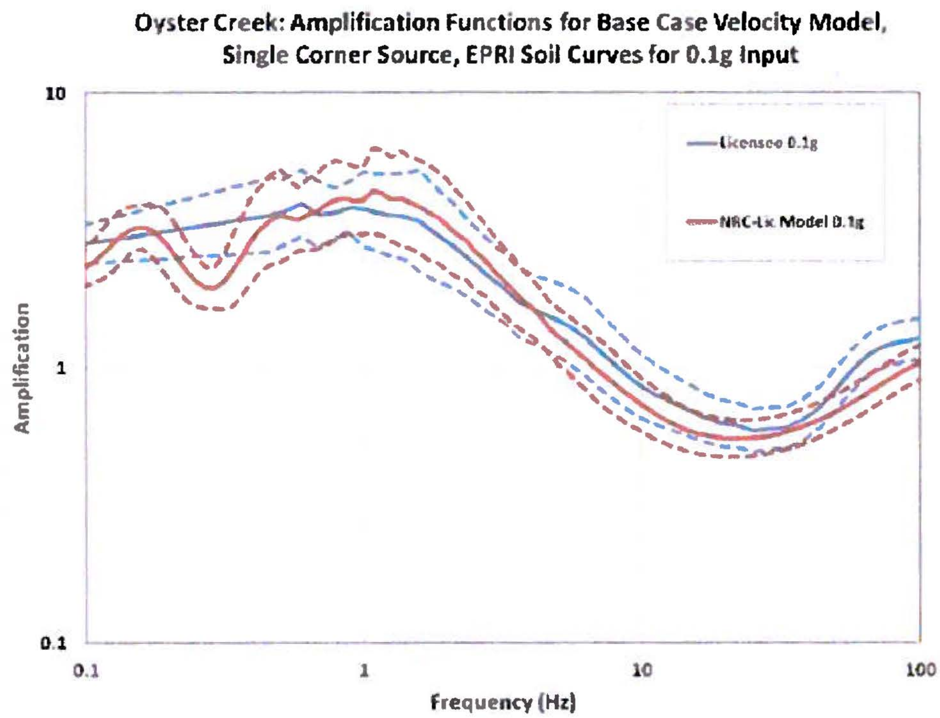


Figure 9

U.S.NRC

Confirmation: NRC Run of Licensee Profile

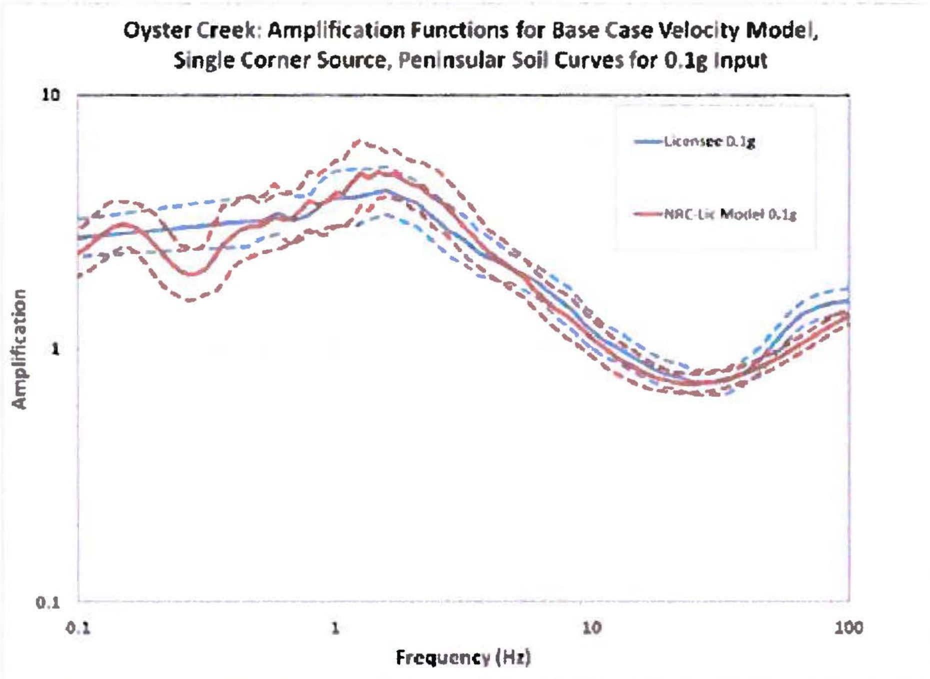


Figure 10

Based on Figures 9 and 10, it is apparent that the amplification functions developed by Exelon to generate the GMRS for the Oyster Creek site are different from the amplification functions developed by the NRC using the same inputs. As was pointed out by Exelon during the meeting of June 17, given that the amplification function axes are logarithmic, the characteristics of the amplification function differences match those of the GMRS differences. That is, in the frequency ranges where the NRC amplification functions are higher than the EPRI amplification functions, the NRC GMRS is also higher than the EPRI GMRS. The difference in shape and amplitude is in line with the differences in the amplification functions. Thus, it appears that the difference in GMRS is due to difference in development of the amplification functions.

Conclusion for Item 5

EPRI has reviewed the information presented by the NRC with respect to both the amplification functions and the GMRS and has not identified any issues in the methodology Exelon used to generate the GMRS that should have led to the observed differences in amplification functions and GMRS. As stated, EPRI has reviewed the GMRS produced in their report of December 23, 2013 (Reference 30) and has determined that the amplification functions and GMRS presented in the report were generated correctly and in accordance with the SPID (Reference 1) and that the inputs used in generating the amplification functions and GMRS are as described in the report. Therefore, the GMRS submitted by Exelon in the submittal of March 31, 2014 (Reference 3) are appropriate and consistent with the NRC endorsed guidance provided in the

SPID (Reference 1). Further discussion related to convergence of the NRC and EPRI GMRS, conditional on identical inputs, is intended to be addressed in a generic white paper that is currently being developed.

CONCLUSION

The soil velocity profiles and estimation of kappa used by Exelon to generate the GMRS for Oyster Creek are based on information provided in the Oyster Creek UFSAR (Reference 2) and are consistent with the applicable portions of the NRC endorsed SPID (Reference 1). Oyster Creek has consistently been characterized as a deep soil site and the soil profiles used by Exelon for depths at which data is not available are consistent with the SPID guidance for deep soil sites. The estimation of kappa used by Exelon for generation of the GMRS is also consistent with the SPID for deep soil sites.

The appropriate SSE spectra for comparison to the GMRS generated by EPRI are the site specific response spectra developed by Weston Geophysical, anchored at 0.184g. These spectra have been used since 1995 and are currently being used for all designs, analyses and evaluations at the plant. These spectra are the current design and licensing basis spectra for the plant and since they became the design and licensing basis, virtually all plant structures, systems and components have been evaluated using these spectra as input. As specified by the NRC in their SER of March 18, 1992 (Reference 11), the SSE spectra were developed and applied at grade in the free field and in-situ soil properties were used to develop the in-structure response spectra. As such, it is appropriate that the control point for the GMRS generated by EPRI be at grade in the free field and that in-situ soil properties be used for generating the GMRS.

Based on available information and on the guidance provided in the NRC endorsed SPID (Reference 1), the GMRS and the SSE provided in the Exelon submittal of March 31, 2014, (Reference 3) are appropriate and consistent with the applicable SPID guidance. Using these spectra as inputs, the Oyster Creek SSE envelopes the EPRI GMRS in the frequency range from 1 to 10 Hz, except for some exceedances classified as low-frequency exceedances.

Exelon has reviewed and reconsidered the positions that the NRC and Exelon communicated in the June 17, 2014 public meeting concerning the Oyster Creek kappa values and shear wave velocity profile and the appropriate SSE and control point location for comparison to the GMRS generated by Exelon. Based on our review, we conclude that the GMRS-to-SSE comparison submitted to NRC on March 31, 2014 is appropriate and should be used in the NTTF 2.1 screening evaluation.

As stated in the Exelon submittal of March 31, 2014, Oyster Creek will complete both a high frequency and a low frequency confirmation. The approach, scope and schedule for completing the high and low frequency confirmation are provided in the Exelon report submitted on March 31, 2014 (Reference 3) in Response to the 50.54(f) Information Request Regarding Fukushima Near Term Task Force Recommendation 2.1: Seismic.

CONCLUSIONS/FINDINGS

As shown in this evaluation, the methodology used by Exelon to generate the Ground Motion Response Spectra (GMRS) for the Oyster Creek site is consistent with the guidance provided in the Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near Term Task Force Recommendation 2.1: Seismic (Reference 1). Oyster Creek has consistently been characterized as a deep soil site and the guidance from the SPID for deep soil sites was used to develop soil profiles and to estimate kappa. The epistemic uncertainties associated with soil properties for depths for which there is not available site-specific information are adequately accounted for in the methodology used by Exelon in developing best estimate, upper bound and lower bound soil profiles and in their use of kappa with the different soil profiles.

On March 31, 2014, Exelon submitted a report that provides a comparison between the GMRS generated by Exelon and the Oyster Creek SSE. The GMRS generated by Exelon were compared to the current design and licensing basis Safe Shutdown Earthquake (SSE) ground response spectra for Oyster Creek. These Site Specific Response Spectra (SSRS) were developed by Weston Geophysical from a statistical analysis of actual earthquake records from sites that were judged by the NRC and Weston Geophysical to be similar to the Oyster Creek site. The spectra were applied at grade elevation in the free field for development of in-structure response spectra. The placement of the control point at grade elevation in the free field was specified by the NRC in their SER approving the use of the spectra for all future designs, analyses and evaluations for the Oyster Creek Nuclear Generating Station (Reference 11). In addition, in-situ soil properties were used in conjunction with these spectra to develop in-structure response spectra. The use of in-situ soil properties for the development of in-structure response spectra was also specified by the NRC in their SER (Reference 11).

Therefore, the use of in-situ soil properties to generate the GMRS and the use of grade elevation in the free field as the control point for generation of the GMRS are consistent with the development and application of the SSE spectra for development of ISRS. The GMRS and the SSE spectra used by Exelon for screening of Oyster Creek are appropriate for performing the screening in accordance with the SPID (Reference 1). As shown in the Exelon submittal of March 31, 2014 (Reference 3), using the GMRS generated by EPRI and the current plant SSE, Oyster Creek "screens-out" from the need to perform a seismic risk assessment or the Expedited Seismic Evaluation Process.

As stated in the Exelon submittal of March 31, 2014, Oyster Creek will complete both a high frequency and a low frequency confirmation. The approach, scope and schedule for completing the high and low frequency confirmation are provided in the Exelon report submitted on March 31, 2014 (Reference 3) in Response to the 50.54(f) Information Request Regarding Fukushima Near Term Task Force Recommendation 2.1: Seismic.

REFERENCES

1. "Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near Term Task Force Recommendation 2.1: Seismic", EPRI Report 1025287, February 2013
2. Oyster Creek UFSAR, Revision 16, October 2009
3. "Seismic Hazard and Screening Report in Response to the 50.54(f) Information Request Regarding Fukushima Near Term Task Force Recommendation 2.1: Seismic for the Oyster Creek Nuclear Generating Station Unit 1", Transmitted to the NRC on March 31, 2014.
4. "Screening and Prioritization Results Regarding Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Re-Evaluations for Recommendation 2.1 of the Near Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident", Letter from the NRC dated May 9, 2014.
5. NUREG-1382, "Safety Evaluation Report related to the full-term operating license of Oyster Creek Nuclear Generating Station"
6. NUREG-0800, "U. S. Nuclear Regulatory Commission Standard Review Plan"
7. Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants"
8. NRC Letter LS05-81-06-068, dated June 17, 1981
9. NUREG/CR-1981, "Seismic Review of the Oyster Creek Nuclear Power Plant as Part of the Systematic Evaluation Program"
10. "Site Specific Response Spectra – Oyster Creek Nuclear Generating Station (M68217)", Letter from George Klimkiewicz of Weston Geophysical to A. P. Asfura of EQE, dated October 14, 1992.
11. "Review and Evaluation of the Site Specific Response Spectra – Oyster Creek Nuclear Generating Station (M68217)", Letter from Alexander Dromerick of the USNRC to John J. Barton of GPU Nuclear Corporation, dated March 18, 1992
12. EQE Report 50069-R-001, "Design Basis Seismic Response Analyses for the Oyster Creek Nuclear Generating Station Reactor, Intake and Turbine Buildings", September 1995
13. "Review and Evaluation of the Soil Structure Interaction Analysis and Approach for Generation of In-Structure Spectra (TAC No. M69467)", Letter from Alexander Dromerick of the USNRC to John J. Barton of GPU Nuclear Corporation, dated February 23, 1995
14. "Safety Evaluation Report for USI A-46 Program Implementation at Oyster Creek Nuclear Generating Station (TAC No. M69467)", dated January 19, 2000
15. "Review of Oyster Creek Nuclear Generating Plant (Oyster Creek) Individual Plant Examination of External Events (IPEEE) Submittal (TAC No. M83652), dated February 8, 2001

16. Calculation C-1302-153-E310-129, "Structural Evaluation of Reactor Building El. 119'-3" Floor Concrete Beams Along Spent Fuel Cask Safe Load Path", February 7, 2014

17. Calculation C-1302-153-E310-114, "OC RB Elevation 23'-6"Floor Analysis for Spent Fuel Cask Load", Revision 0

18. Calculation C-1302-153-E310-116, "RB Air Lock Floor Elevation 23'-6" Analysis for Spent Fuel Cask Load"

19. Calculation 302067-C-001, "Seismic Qualification of OCGS Reactor Bldg. Crane", EQE

20. Report No. 1957-1, "Soil Profile and Dynamic Soil Properties for Soil-Structure Interaction Analysis of Reactor Building, Oyster Creek Nuclear Generating Station, New Jersey", Geomatrix October 1991

21. Exelon Document 990-2191, "Design Criteria for Soil-Structure Interaction Analysis of the Reactor/Containment Building at GPUN Oyster Creek Nuclear Generating Station", EQE June 1993

22. "Exelon Generation Company, LLC Response to NRC Request for Information Pursuant to 10CFR50.54(f) Regarding the Seismic Aspects of Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident – 1.5 Year Response for CEUS Sites", Dated September 12, 2013

23. EQE Report 50124-R-001, "In-Structure Response Spectra for the Oyster Creek Nuclear Generating Station, Compilation of Response Spectra for use in USI A-46 Program", May 1994

24. letter LS05-81-06-068, dated June 17, 1981

25. Not Used

26. NUREG 1742, Volume 2, "Perspectives Gained from the Individual Plant Examination of External Events (IPEEE) Program", April 2010

27. NRC Information Notice 2010-18, "Generic Issue 199, 'Implication of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants'", September 2, 2010

28. "Hydrostratigraphy of the New Jersey Coastal Plain: Sequences and facies predict continuity of aquifers and confining units", Sugarman, et al, *Stratigraphy*, Volume 2, Number 3, 2005).

29. "Support Document for Screening and Prioritization Results Regarding Seismic Hazard Re-evaluations for Operating Reactors in the Central and Eastern United States" Memorandum from David Skeen of the NRC, dated May 21, 2014.

30. EPRI RSM-121313-039, *Oyster Creek Seismic Hazard and Screening Report*, dated December 23, 2013.

31. Nuclear Regulatory Commission, Public Meeting Presentation Slides, meeting of June 17, 2014, ML14167A320.

Attachment 4

Quad Cities Nuclear Power Station, Units 1 and 2

Supplemental Information in Response to NRC Conditional Screen-In Evaluation

EC Evaluation No. 398962, Rev. 0

Title: Supplemental Information for Quad Cities Station, Submitted to NRC in Response to the NRC 50.54(f) Information Request Regarding Fukushima Near Term Task Force Recommendation 2.1: Seismic

Reason for Evaluation/Scope:

In response to the 50.54(f) letter regarding Fukushima near-term task force (NTTF) recommendation 2.1, a seismic hazard reevaluation for Quad Cities station was performed to develop a Ground Motion Response Spectrum (GMRS) for comparison with the Safe Shutdown Earthquake (SSE). Quad Cities reevaluation (Reference 1) provides spectra associated with both Golden Gate and Housner, normalized to 0.24g (SSE) and at 5% damping representing the existing SSE. By contrast, the preliminary graph documenting the NRC's review of Quad Cities, as provided in NRC memorandum dated May 21, 2014 (Reference 6) used only the Housner curve to represent the existing SSE. This difference was discussed at the public meeting between the NRC and Exelon at the NRC Offices in Rockville, MD on June 17, 2014. This paper outlines Exelon's basis for including both Golden Gate and Housner curves as representing the existing Licensing Basis for Quad Cities Station. Consistent with Reference 6, this evaluation will focus on the 1 – 10 Hz range.

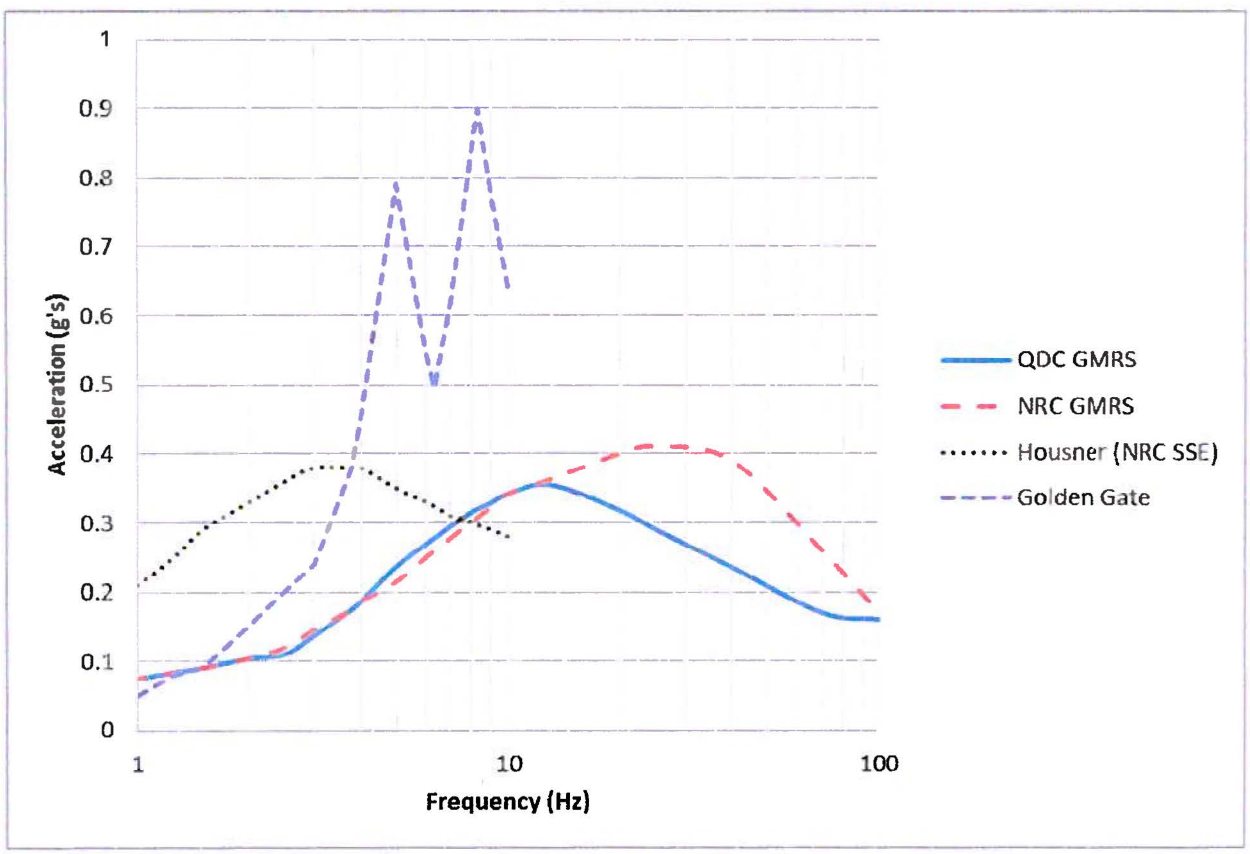


Figure 1 – Safe Shutdown Earthquake Comparison: GMRS to Licensing Basis

Note: All spectra included in this evaluation, in Figures 1 through 4, represent the Safe Shutdown Earthquake at 5% damping.

Detailed Evaluation:

Golden Gate Spectrum

Quad Cities licensing basis earthquake is discussed in the Quad Cities UFSAR (Section 3.7) describing structures and equipment qualification where "the Class I structures, piping, and equipment (with the exception of the drywell) were initially seismically analyzed with the earthquake input corresponding to the Golden Gate Park South 80° East (S80E) component of the 1957 San Francisco earthquake normalized to 0.12g at the base of the reactor building." The magnitude of 0.12g is for the Operating Basis Earthquake (OBE). The Safe Shutdown Earthquake (SSE) was defined as twice the OBE, or the input normalized to 0.24g.

The UFSAR provides additional discussion on the curves used as follows: "For structures and equipment analyzed using the response spectrum method, smoothed curves such as those shown in Figure 3.7-1 were used. For structures and equipment analyzed using the time history method, the actual Golden Gate Park record was normalized to 0.12g and used in the analysis; the unsmoothed response spectrum of this time history is shown in Figure 3.7-2."

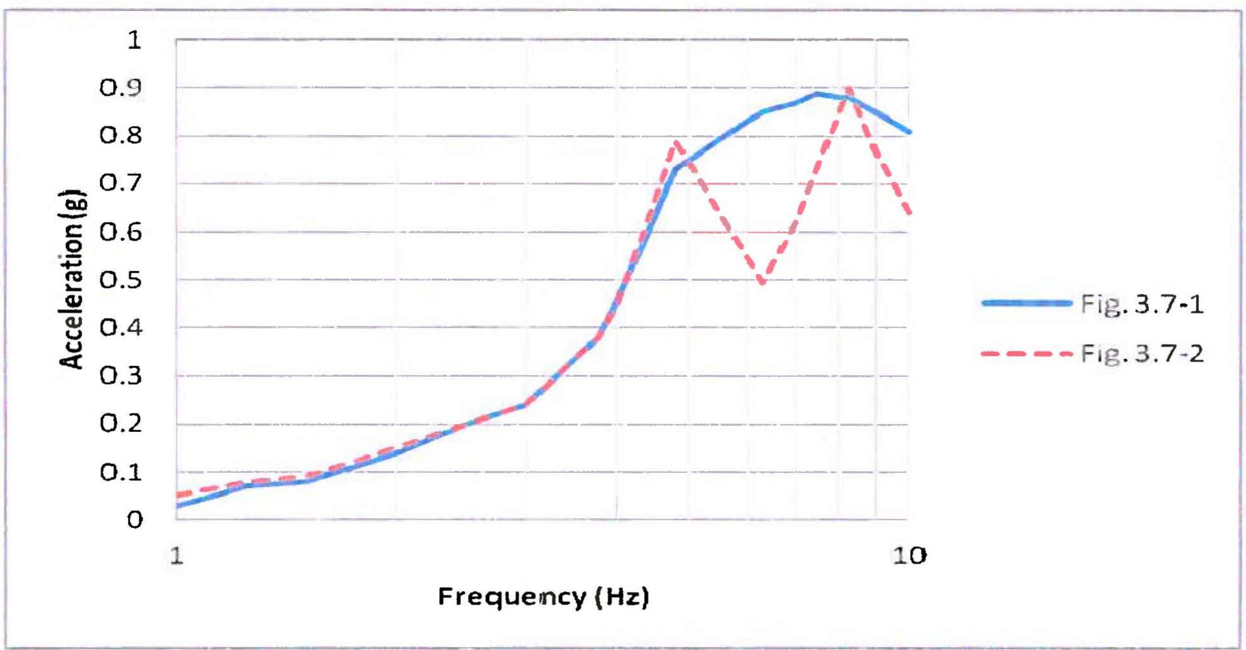


Figure 2 – Comparison of Two Different Golden Gate Profiles from UFSAR

As can be seen from a comparison between the curves from Figures 3.7-1 and 3.7-2 in Figure 2, both curves are comparable, and for the purposes of a clear, conservative comparison, the Figure 3.7-2 profile is used in ensuing discussions as representative for the Golden Gate profile.

Housner Spectrum Addition

During initial licensing (References 3 - 5), it was identified that the Housner spectra was greater in the low frequency range, and as a result, as discussed in the UFSAR: "All Class I structures,

piping, and equipment were re-evaluated to ensure that the results of the original analyses, based on Golden Gate Park and El Centro inputs, adequately enveloped those of the Housner input. For systems analyzed to the Golden Gate Park spectrum with fundamental periods less than 0.265 seconds, the spectral accelerations from the original analysis were higher than the corresponding spectral accelerations from the Housner event; therefore, the original analyses were acceptable. For those structures where the Housner event may control, reanalysis using the Housner input was performed." The structures "whose periods fall in the range where the Housner spectral accelerations exceed those of the Golden Gate Park earthquake were reanalyzed using the Housner spectrum and were evaluated using the higher seismic loads obtained from either of the two analyses."

The inclusion of both spectra in the Quad Cities licensing basis is documented in the original SER that approves operation of Quad Cities (Reference 5), which states: "In order to predict the most conservative value of force inputs in the dynamic analyses of Class I structures and equipment over a range of natural frequencies, two earthquake response spectra were used." Golden Gate S80E was used "for seismic design of stiff structures whose natural frequencies were greater than 4 cycles per second", and Housner was used "for more flexible structures whose natural frequencies were less than 4 cycles per second."

Comparison to New GMRS

A comparison of both of the bounding curves used for SSE - Golden Gate (GG) and Housner (H) - are shown below in comparison to the new GMRS over the period of interest of 1-10 Hz. The original Golden Gate curve is bounding at all frequencies greater than 1.5 Hz, maintaining significant margin (roughly over twice the new GMRS at frequencies greater than 3 Hz and less than 10 Hz). Structures with significant low-frequency response (less than 3.77 Hz) were covered by the Housner analysis. The original Housner curve is bounding at all frequencies less than 7 Hz, maintaining significant margin (roughly over twice the new GMRS at frequencies between 1 Hz and 4 Hz).

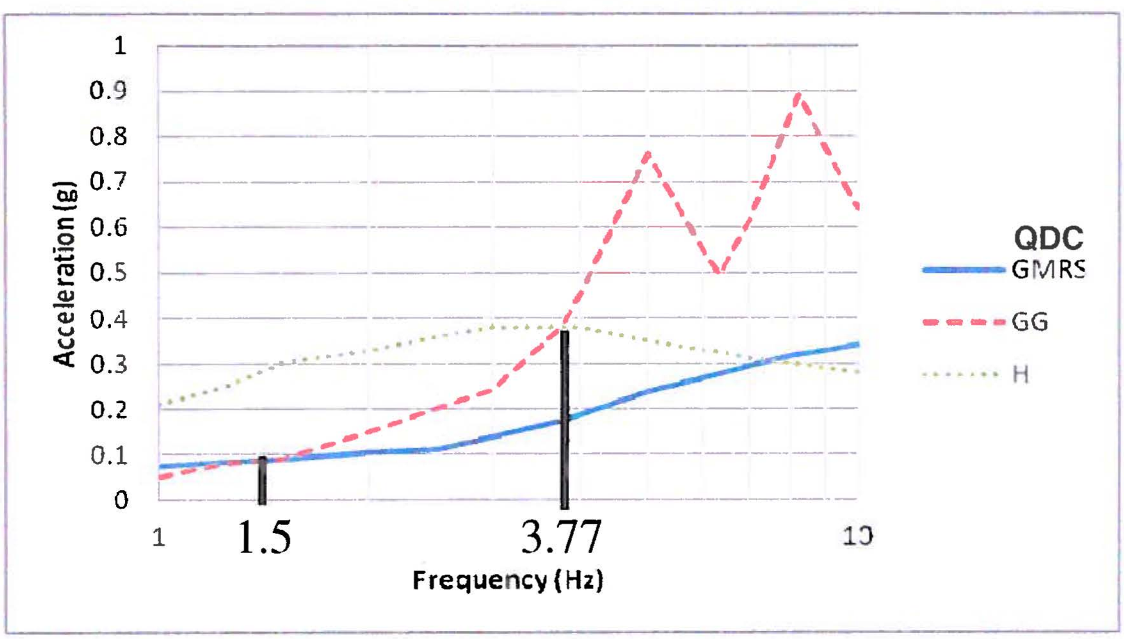


Figure 3 – Comparison of QDC GMRS to Licensing Basis Spectra

Quad Cities Design and Licensing Basis Spectra

When new equipment, piping or structures are designed, such as piping analyses performed for Extended Power Uprate, they are typically evaluated to a design spectrum per Topical Design Basis Document TDBD-DQ-1 that bounds both Golden Gate (GG) and Housner (H), as shown below in Figure 4. At a minimum, though, any existing or new structure meets the bounding spectrum as discussed in the original and current licensing basis – the higher loads from either Golden Gate or Housner. This is confirmed from the fact that this is the original licensing basis approved in 1971 (Reference 5) and is also the current licensing basis as described in the Quad Cities UFSAR (Reference 2).

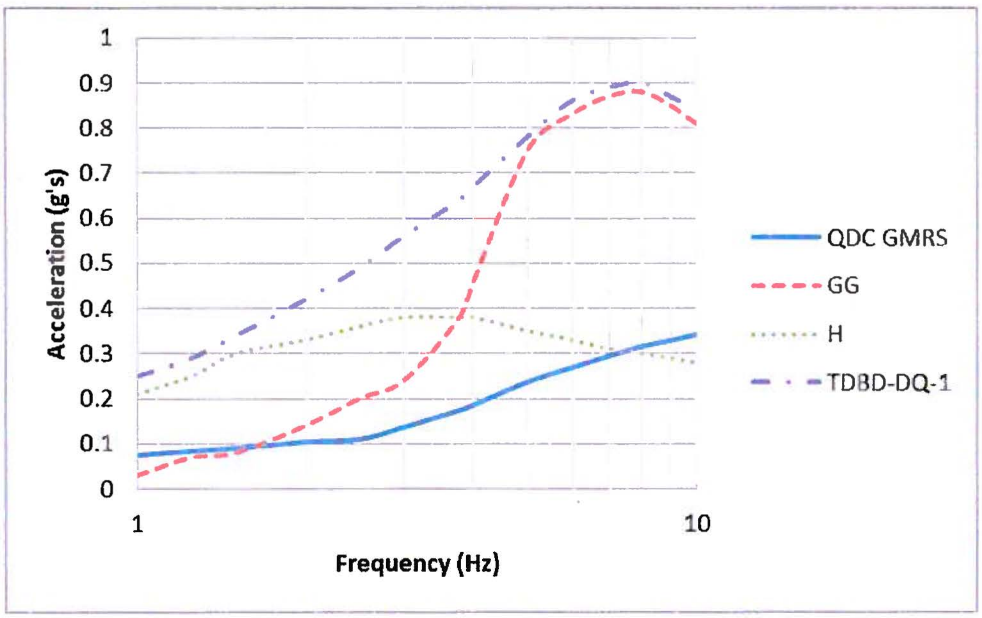


Figure 4 – GMRS Comparison including TDBD-DQ-1 Profile

Quad Cities Drywell Seismic Licensing Basis

Since the aforementioned portion of UFSAR Section 3.7 excludes the drywell from equipment originally designed to the Golden Gate spectrum, additional discussion is provided to put this statement in context. As discussed later in UFSAR Section 3.7, "the Quad Cities drywell was evaluated using the results of the Dresden drywell analysis. The seismic input for the Dresden plant was the north-south component of the 1940 El Centro earthquake, normalized to 0.10g."

"John A. Blume and Associates reviewed the Quad Cities drywell with respect to the Dresden drywell including considerations of site geology, input earthquakes, and building arrangements. The review resulted in using the Dresden drywell seismic envelopes of shear, moment, and displacement as design values for Quad Cities.

"The primary factors in the selection of the Dresden drywell analyses as being applicable to Quad Cities are that, below elevation 652 feet 8 inches the shear values for the empty condition are essentially constant and independent of elevation, and the Dresden reactor-turbine building

displacements are greater than the corresponding Quad Cities displacements. The drywell seismic inertia contribution is small in comparison to the effects of seismic building movements as indicated from the nearly constant shear values at elevations below 652 feet 8 inches. This indicated that the critical load source is displacement of the reactor-turbine building. The Dresden displacements are 120 and 70 mils in the north-south and east-west direction at the shear lug elevation, whereas the corresponding Quad Cities displacements are 65 and 55 mils. Hence, use of the Dresden design parameters results in a more conservative design than if a detailed drywell analysis for Quad Cities had been used."

Therefore, while the Quad Cities drywell analysis is based on the Dresden El Centro spectra, this was done because it yielded more conservative results than if a specific analysis would have been performed for Quad Cities based on the bounding Golden Gate / Housner spectra. Therefore, a comparison of the new spectrum against the Golden Gate and Housner spectra is sufficient to ensure the Quad Cities drywell is not impacted by the new GMRS.

Conclusions/Findings:

Quad Cities licensing basis is based on two curves, Golden Gate and Housner. This was the original licensing basis of the plant as approved in the 1971 SER and remains the existing licensing basis in effect as described in the UFSAR. The licensing basis specifies the use of Golden Gate for items where the natural frequency is greater than 3.77 Hz and Housner where the natural frequency is less than 3.77 Hz. The Golden Gate curve dips slightly below the new GMRS between 1-1.5 Hz and the Housner curve dips slightly below the new GMRS curve between 7-10 Hz, but both curves supplement each other and bound the new GMRS by roughly a factor of two in their period of interest. Since each curve maintains significant margin over the new GMRS in the range of interest, Quad Cities concluded that the licensing basis bounds the new GMRS.

References:

1. EC EVAL 397663, Rev. 0, Quad Cities Seismic Hazard and Screening Report.
2. Quad Cities UFSAR, Rev. 12, Section 3.7, including Figures 3.7-1 and 3.7-2.
3. Quad Cities Final Safety Analysis Report (FSAR) dated August 30, 1968.
4. Quad Cities FSAR Amendment 13, dated November 6, 1970, Section 12, Question 12.1.
5. AEC Safety Evaluation Report (SER) for Quad Cities, dated August 25, 1971.
6. NRC Memorandum from S. Flanders to D. Skeen, Support Document for Screening and Prioritization Results Regarding Seismic Hazard Re-Evaluation for Operating Reactors in the Central and Eastern United States (ADAMS ML14136A126).