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PSEG
Power LLC

ND-2013-0018
July 17, 2013

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

Subject: **PSEG Early Site Permit Application**
Docket No. 52-043
Response to Request for Additional Information, RAI No. 70, Stability of Subsurface Materials and Foundations

References:
1) PSEG Power, LLC Letter No, ND-2013-0006 to USNRC, Submittal of Revision 2 of the Early Site Permit Application for the PSEG Site, dated March 27, 2013

2) RAI No. 70, SRP Section: 02.05.04 – Stability of Subsurface Materials and Foundations, dated June 6, 2013 (eRAI 7121)

3) PSEG Power, LLC Letter No, ND-2013-0008 to USNRC, Response to Request for Additional Information, RAI No. 69, Stability of Subsurface Materials and Foundations, dated April 4, 2013

4) PSEG Power, LLC Letter No, ND-2012-0044 to USNRC, Documents in Support of Application Early Site Permit for the PSEG Site, dated August 9, 2012

The purpose of this letter is to provide a response to the request for additional information (RAI) provided in Reference 2 above. This RAI addresses the Stability of Subsurface Materials and Foundations, as described in Subsection 2.5.4 of the Site Safety Analysis Report (SSAR), as submitted in Part 2 of the PSEG Site Early Site Permit Application, Revision 2.

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NRO

Enclosure 1 provides our response for RAI No. 70, Question No. 02.05.04-28.

If any additional information is needed, please contact David Robillard, PSEG Nuclear Development Licensing Engineer, at (856) 339-7914.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 17th day of July, 2013.

Sincerely,

James Mallon
Early Site Permit Manager
Nuclear Development
PSEG Power, LLC

Enclosure 1: Response to NRC Request for Additional Information, RAI No. 70, Question No. 02.05.04-28, SRP Section: 02.05.04 – Stability of Subsurface Materials and Foundations

cc: USNRC Project Manager, Division of New Reactor Licensing, PSEG Site (w/enclosures)
USNRC Environmental Project Manager, Division of New Reactor Licensing (w/enclosures)
USNRC Region I, Regional Administrator (w/enclosures)

PSEG Letter ND-2013-0018, dated July 17, 2013

ENCLOSURE 1

Response to RAI No. 70

Question No.
02.05.04-28
SRP Section: 02.05.04 –
Stability of Subsurface Materials and Foundations

Response to RAI No. 70, Question 02.05.04-28:

In Reference 2, the NRC staff asked PSEG for information regarding the Stability of Subsurface Materials and Foundations, as described in Subsection 2.5.4 of the Site Safety Analysis Report. The specific request for Question 02.05.04-28 was:

Supplemental RAI

> *In an April 4, 2013, response to RAI 69, Question 02.05.04-27, you selected results from condition 1 in table RAI 69-1 to support your conclusion stated in SSAR Section 2.5.4.8.3, "SPT-Based Liquefaction Assessment," Rev. 2, that "The SPT-based screening calculation results indicate that potentially liquefiable soils in the Vincentown Formation are isolated pockets surrounded by denser materials, not a continuous layer. Thus, liquefaction of granular soils below the top of the competent layer is not likely to occur." Results from the updated liquefaction analysis, based on a higher input Peak Ground Acceleration (PGA), indicate a considerable increase in the number of samples with factors of safety (FS) less than or equal to 1.1. According to Table RAI-69-1, most of the points with FS equal to or less than 1.1 are located within the Vincentown formation (foundation bearing layer) and are from samples taken from Borings NB-1, NB-2, NB-3 and NB-4. This consistent pattern might indicate a potentially weak liquefiable zone. Section 3.2, "Factor of Safety Against Liquefaction," of Regulatory Guide 1.198, "Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites," indicates that, in general, soil elements with low FS (FS=< 1.1) would achieve conditions wherein soil liquefaction should be considered to have been triggered. In compliance with 10 CFR 100.23 (d) (4), please justify your conclusion given the considerable number of samples with FS equal to or lower than 1.1 encountered at the site, and the limited extent of field investigation performed at the site.*

PSEG Response to NRC RAI

Evaluation of potential for liquefaction under Regulatory Guide (RG) 1.198 includes consideration of the geologic setting and age of the formations at the site as well as conducting screening using the SPT methodology and, if necessary, detailed study using site-specific testing. In this response, site information on geologic aging, historical information from the Hope Creek licensing studies, and evaluation of liquefaction potential using shear wave velocity screening are presented in support of the conclusion in the response to RAI No. 69 (Reference 3).

Geologic Considerations

In SSAR Reference 2.5.4.8-2, the increase of resistance to liquefaction with age is acknowledged:

"Sediments deposited within the past few thousand years are generally much more susceptible to liquefaction than older Holocene sediments; Pleistocene sediments are even more resistant; and pre-Pleistocene sediments are generally immune to liquefaction."

Also, in RG 1.198, it is stated that "*Most liquefaction risk is associated with recent Holocene deposits and uncompacted fills. There have, however, been a few observed cases of liquefaction of Pleistocene and even Pre-Pleistocene deposits. Particular caution should be used in dealing with very loose types of these soils (e.g. dune sands, talus) and with extremely loose collapsible soils (e.g. loess).*"

The Vincentown Formation is of pre-Pleistocene age (Paleocene; 60 Ma) as stated in SSAR Subsection 2.5.1.2.2.1.2.3. Thus, according to the literature, it would be considered generally immune to liquefaction. Furthermore, the Vincentown Formation consists of marine sediments and does not contain dune sands, talus or loess.

As discussed in SSAR Subsection 2.5.4.1.3, the upper portion of the Vincentown Formation was exposed for a long period of time subsequent to its deposition. Weathering and erosion caused development of an oxidized zone that is indicated by presence of orange-stained sands. Aging effects should be considered to begin after disturbance by weathering or other processes has ceased. In the case of the Vincentown Formation, the deposition of the Kirkwood Formation would mark the end of the Vincentown Formation disturbances. The Kirkwood Formation has been age-dated to approximately 25 Ma (SSAR Subsection 2.5.4.1.3), which is pre-Pleistocene (Reference RAI-70-1). Thus, even considering possible disturbance after deposition, the Vincentown Formation is within the materials considered by SSAR Reference 2.5.4-8 as being "generally immune to liquefaction".

Eight borings were drilled on the PSEG Site for the ESP investigation with spacings on the order of 300 to 600 feet or more. The boring logs (SSAR Appendix 2AA) show that Standard Penetration Test (SPT) N-values less than 30 were noted in the uppermost portion of the Vincentown Formation in all borings. These lower N-values were often associated with evidence of oxidation. Review of Hope Creek boring logs shows that similar lower blow counts were encountered in 29 out of 57 borings with penetration into the Vincentown Formation. In 15 of the borings, these lower blow counts were found in the upper portion and oxidized portion of the Vincentown Formation, above elevation –67 ft. NAVD, and the materials were removed as part of the foundation excavation work based on inspection at the time of construction. In the other 14 borings, the lower blow counts were typically isolated instances of one or two in any one boring.

SSAR Subsection 2.5.1.4.1.2.3.2 notes that the Vincentown Formation is composed of predominately sandy soils with zones of cemented sands ranging from 0.1 to 1 foot in thickness. The logs of the eight borings performed for the ESP exploration note presence of cemented and friable zones. Review of boring logs from the Hope Creek FSAR shows that cemented zones were present in the Vincentown Formation soils encountered by those borings. The cemented zones act as a form of reinforcement for the soils, increasing their strength to resist cyclic shear stresses.

Although instances of lower blow counts were encountered in the widely-spaced and limited number of ESP boring studies which, by themselves, can be associated with low values for factors of safety against liquefaction, they do not indicate a continuous layer of such conditions across the PSEG Site. This conclusion is based on review of the more numerous, more closely spaced Hope Creek borings. In addition, half of the ESP borings do not show low factors of safety. As noted in SSAR Table 2.5.4.7-3, shear wave velocities from P-S suspension logging in the Vincentown and Hornerstown Formations are above 2000 ft/sec, indicating soils are stiffer than indicated by the SPT N-values.

The RAI question points to borings NB-1, NB-2, NB-3, and NB-4, all spaced 550 to 700 feet apart, as possibly indicating an areal zone of potential liquefaction using the SPT-based screening methodology. For comparison, a closer boring to NB-1 (NB-5, 325 feet north) does not indicate potential liquefaction in the SPT-based screening methodology. In addition to the ESP boring data, there are 10 borings from the Hope Creek FSAR exploration located in the area between NB-4 and NB-8 and extending approximately 800 feet south of these two borings spaced approximately 300 ft apart. There are also two borings from the Salem FSAR exploration located in the central portion of the PSEG Site (SSAR Figure 2.5.4.1-2). Review of the logs for these borings shows that samples below elevation -67 ft (NAVD) had blow counts less than 30 in six of the 11 borings (one boring did not include penetration testing). There was generally only one blow count less than 30 in each boring. Thus, existing information from more closely-spaced borings indicates borings with lower blow counts are an isolated condition.

In addition, an exploration was performed in 2002 for the Hope Creek/Salem ISFSI, directly south of the south boundary of the PSEG Site that included 12 borings on approximate 150- to 200-foot spacings. The borings extended into the Vincentown Formation. Blow counts below elevation -67 ft (NAVD) were less than 30 in only two of the 12 borings, and only for one sample in each of those two borings.

Based on the historical information from borings on closer spacings than performed for the ESP, the Vincentown Formation does have some instances where looser soils are encountered, but the instances appear to be isolated and near the oxidized upper layer of the formation, and not representative of a continuous stratum.

The geotechnical investigation of the PSEG Site during the COL stage will include more borings and more closely-spaced borings in accordance with Regulatory Guide 1.132. The additional boring information obtained during this stage will be analyzed to determine if zones of lower blow counts, which might suggest potential for liquefaction, are present below what is identified in the ESP as the "competent layer." As described in SSAR Subsection 2.5.4.12, the excavation for the foundations will be inspected for presence of unsuitable materials which will be removed and replaced. Although the preponderance of the literature indicates pre-Pleistocene deposits are not likely to liquefy, a prior commitment (COL 2.5-1; Reference 4) acknowledges the presence of some low N-values and commits to removing such soils to attain a competent base for the foundation.

Conservatism in application of SPT-based liquefaction screening methodology

The calculation of factors of safety against liquefaction includes consideration of the overburden pressures, variables in performing the SPT, adjustment factor for earthquake magnitude, and potentially adjustment for formation age. The existing SSAR calculations applied conservatism in the factor of safety calculation in the following manner:

- A lower-bound magnitude scaling factor was applied (tends to decrease factor of safety);
- Overburden correction factors were calculated using the ground surface as a reference point, (tends to decrease the factor of safety),
- No consideration was given for effects of fill material that will ultimately be placed above the present ground surface (approximately elevation 10 ft NAVD) to create an exterior grade at approximately elevation 36.5 ft, (added confining pressure tends to increase factor of safety), and
- No age-correction factor was applied (tends to decrease factor of safety).

While SSAR Reference 2.5.4.8-2 recognized the influence of age in increasing resistance to liquefaction, no quantitative age correction factor was proposed. More recent publications have incorporated use of an age-correction factor (Reference RAI-70-2). Based on the information in Reference RAI-70-4, an age correction factor of 1.5 is appropriate for geologic formations 1 million years or older. As discussed earlier, the Vincentown Formation has been undisturbed for over 25 million years; hence, not applying an age correction factor can be considered an overly conservative approach to determine factors of safety.

Table RAI-70-1 shows the results of factor of safety calculations using the age correction factor of 1.5. Table RAI-69-2, in the response to RAI No. 69 (Reference 3), contains 15 safety factors less than or equal to 1.1 and 13 safety factors greater than 1.1 and less than 1.4 in the Vincentown Formation. When age is considered, there is one factor of safety less than or equal to 1.1 and two factors of safety greater than 1.1 and less than 1.4 in the Vincentown Formation.

Shear wave velocity screening

Only the SPT-based screening methodology was used in calculations because early papers discussing use of shear wave velocity as a screening tool indicated available case history data limited its use to Holocene age materials and to a depth of approximately 10 m (Reference RAI-70-3). In Reference RAI-70-4, an approach to extend the shear wave velocity screening to deeper depths and to older geologic formations is presented. The approach includes correcting shear wave velocities for overburden pressures and applying an age correction factor to the cyclic resistance ratio, CRR. Corrected shear wave velocities are compared to a limiting value determined from study of case histories and relationships between N-value and shear wave velocity. As described in Reference RAI-70-3, the limiting value of shear wave velocity is related to the fines content (FC) of the soils and ranges from 200 m/s (FC>=35%), to 215 m/s (FC <=5%). If the shear wave velocities, appropriately adjusted for overburden pressure, are greater than the limiting value, then liquefaction is not indicated.

Shear wave velocity data from P-S Suspension logging were obtained at intervals of approximately 1.65 ft (vertically) from two borings on the PSEG Site and also from two borings performed east of the PSEG Site. Application of the methodology as described in Reference RAI-70-4 found that only two of 158 shear wave velocities within the Vincentown Formation indicate the potential for liquefaction, and those two values are in the top (weathered zone) of the Vincentown Formation in the area east of the PSEG Site.

Conclusion

In an ESP investigation, the borings are widely spaced and fewer than the number of borings that will be conducted for the COL to meet the requirements of RG 1.132. Adjustments in the position of the competent layer may result from the additional boring studies performed during COLA development. Based on geologic age, the Vincentown Formation as a geologic stratum is not susceptible to liquefaction. When the age of the Vincentown Formation is addressed in liquefaction screening by including an age correction factor, only two instances of low factors of safety against liquefaction are calculated and these are isolated to the upper portion of the Vincentown Formation.

Based on current literature, the inclusion of an age correction factor is appropriate in the calculation of factor of safety. Therefore, the conclusion in RAI No. 69 that, "*potentially liquefiable soils in the Vincentown Formation are isolated pockets surrounded by denser materials, not a continuous layer. Thus, liquefaction of granular soils below the top of the competent layer is not likely to occur.*" is still valid. Even if the additional borings and analyses performed during COLA development identify some areas where potential for liquefaction may be present below the currently estimated competent layer, the SSAR acknowledges, both in SSAR Subsection 2.5.4.12 and in COL Action Item 2.5-1, that such materials will be removed and replaced with competent material.

References

RAI-70-1 United States Geological Survey, "Divisions of Geologic Time – Major Chronostratigraphic and Geochronologic Units", Fact Sheet 2010-3059, July, 2010.

RAI-70-2 Arango, I., Lewis, M. R., and Kramer, C. "Updated Liquefaction Potential Analysis Eliminates Foundation Retrofitting of Two Critical Structures", Soil Dyn. Earthquake Eng. 20, 17-25, 2000

RAI-70-3 Andrus, R. D., and Stokoe, II, K. H., "Liquefaction Resistance of Soils From Shear-Wave Velocity", *J. Geotech. Geoenviorn. Eng.*, ASCE, 126 (11), 1015-1025, November 2000.

RAI-70-4 Andrus, R. D., Stokoe, II, K. H., and Juang, C.H., "Guide for Shear-Wave Based Liquefaction Potential Evaluation", Earthquake Spectra, 20(2), 285-305, 2004.

Associated PSEG Site ESP Application Revisions:

None.

Table RAI-070-1
Summary of Liquefaction Safety Factors (FS) for each Geologic Formation Considering Age Correction Factor

Formation Number	Formation Name	Distribution of Safety Factors [a]		
		FS<=1.1	1.1<FS<1.4	1.4<=FS
4	Vincentown	1	2	73
5	Hornerstown	0	0	33
6	Navesink	0	0	44
7	Mount Laurel	0	0	90
8	Wenonah	0	0	1
9	Mashalltown	0	0	5
10	Englishtown	0	0	1
11	Woodbury	0	0	0
12	Merchantville	0	0	0
13	Magothy	0	0	3
14	Potomac	0	0	3
	Total =	1	2	253

Note - Values of r_d computed from elevation -67 ft., a_{max} is 0.225g (based on NUREG-2115) at elevation -67 ft. NAVD, and overburden stresses are referenced to ground surface.
(a) Safety factors based on lower bound Magnitude Scaling Factor and age correction factor of 1.5.