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June 18, 2012

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

Subject: Duke Energy Carolinas, LLC
William States Lee III Nuclear Station – Docket Nos. 52-018 and 52-019
AP1000 Combined License Application for the
William States Lee III Nuclear Station Units 1 and 2
Response to Request for Additional Information (eRAI 6497)
Ltr# WLG2012.06-07

Reference: Letter from Brian Hughes (NRC) to James Thornton (Duke Energy), Request for Additional Information Letter No. 106 Related to SRP Section 02.05.04, Stability of Subsurface Materials and Foundations for William States Lee III Units 1 and 2 Combined License Application, dated May 17, 2012 (ML12138A118)

This letter provides the Duke Energy response to the Nuclear Regulatory Commission's request for additional information (RAI) item 02.05.04-017, included in the referenced letter.

The response to the NRC information request described in the referenced letter is addressed in a separate enclosure, which also identifies associated changes, when appropriate, to be made in a future revision of the Final Safety Analysis Report for the Lee Nuclear Station.

If you have any questions or need any additional information, please contact James R. Thornton, Nuclear Plant Development Licensing Manager (Acting), at (704) 382-2612.

Sincerely,

John W. Pitesa

John W. Pitesa
Senior Vice President
Nuclear Operations

D093
NRO

Enclosure:

1) Lee Nuclear Station Response to Request for Additional Information (RAI) Letter No. 106, RAI 02.05.04-017

xc (w/out enclosure):
Frederick Brown, Deputy Regional Administrator, Region II

xc (w/ enclosure):
Brian Hughes, Senior Project Manager, DNRL

AFFIDAVIT OF JOHN W. PITESA

John W. Pitesa, being duly sworn, states that he is Senior Vice President, Nuclear Operations, Duke Energy Carolinas, LLC, that he is authorized on the part of said Company to sign and file with the U. S. Nuclear Regulatory Commission this combined license application for the William States Lee III Nuclear Station, and that all the matter and facts set forth herein are true and correct to the best of his knowledge.

John W. Pitesa

John W. Pitesa, Senior Vice President
Nuclear Operations

Subscribed and sworn to me on June 18, 2012

Teresa D. Neely

Notary Public

My commission expires: 9/2/2015

SEAL

TERESA D. NEELY
NOTARY PUBLIC
GASTON COUNTY, NC
MY COMMISSION EXPIRES 09/02/2015

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI Letter No. 106

NRC Technical Review Branch: Geosciences and Geotechnical Engineering Branch 2 (RGS2)

Reference NRC RAI Number(s): 2.5.4-017

NRC RAI:

On April 9-11, 2012, NRC staff conducted an audit on site response and soil-structure interaction (SSI) calculations performed by Westinghouse Electric Corporation (WEC) in supporting of the design of William Lee Nuclear Station (WLS).

During the audit, the applicant indicated that the GW, GP and SW type of soils, as defined by Unified Soil Classification system, were considered as back fill in its site response and SSI analyses. The applicant also plans to utilize a gabion/MSE wall to support fill adjacent to the nuclear island (NI). However, the staff notes that the FSAR Section 2.5.4 does not specify the soil classification of the backfill soil to be placed around Category I and adjacent Category II structures. Similarly, staff finds that there is no mention of the MSE wall in FSAR Section 2.5.4.

To address these issues and to ensure compliance with 10 CFR 100.23 and 10 CFR Part 50, Appendix S, please: 1) specify the type of soil to be used as backfill material with its classification and static and dynamic properties; 2) discuss how to ensure that as-placed backfill properties are comparable to those assumed in site-specific analyses; 3) provide details of MSE wall design; and 4) discuss its impact on side fill compaction and structural stability analyses so that the staff can conduct a full evaluation of foundations/structures stability.

Duke Energy Response:

1. As described in FSAR Subsection 2.5.4.5.1, the type of soil to be used as backfill will be granular material likely to be obtained from an off-site source such as an operating rock quarry. As stated in FSAR Subsection 2.5.4.5.3.5, the granular fill obtained from a quarry will conform to SCDOT gradation and plasticity limits. Two SCDOT granular products, namely Macadam Base Course (MBC) and Washed Screenings are selected for consideration. Two specific gradations within the range for MBC and a third specific gradation within the range for Washed Screenings are used to predict static and dynamic properties that are considered to be typical of the range for these materials. Duke Energy intends to maintain the option of having either or both of these materials available for consideration pending selection of the quarry source and performance of a test program to confirm compatibility with the estimated properties. The factors that determine if a particular granular quarry aggregate has static and dynamic properties comparable to those estimated for these two materials will be the results of the suite of laboratory tests listed in FSAR Table 2.5.4-222. For MBC granular fill, the material passing the No. 4

sieve shall have a liquid limit (LL) no greater than 25 and a plasticity index (PI) no greater than 6 as determined in accordance with ASTM D 4318. Therefore, the classification symbols for the MBC granular fill, depending on the specific fill gradation of a given specimen within the permissible range could be GW, GP, GW-GM, GP-GM, GW-GC, or GP-GC. The classification symbol for a given specimen of Washed Screenings could be SW or SP.

2. The as-placed backfill properties will be assessed for compatibility with the properties assumed in the site-specific analyses by the testing program outlined in FSAR Subsection 2.5.4.5.3.5. As stated, the suite of laboratory tests listed in FSAR Table 2.5.4-222 is conducted to confirm that the chosen backfill has properties compatible with those used in the site-specific analyses. This is followed by a "test fill" pad being constructed on-site using the equipment and granular fill materials to be used in constructing the backfill. Before the production backfill commences, an engineering report will exist that concludes that the equipment and methods used to construct the test fill are capable of producing acceptable and consistent results.

   A program of in-place measurements of shear wave velocity in the granular backfill is performed to confirm that shear wave velocities (and thus small strain shear modulus) of the as-placed granular backfill are comparable to those used in the site-specific analyses. The in-place shear wave velocity will be determined by SASW measurements when backfill accumulation has risen to heights of approximately 1/3, 2/3 and approximately full height of the backfill. A second method of shear wave velocity measurement will be utilized when the backfill has reached approximately full height (e.g., crosshole, downhole, or p-s logging). FSAR Table 2.5.4-222 is revised to include these measurements of in-place shear wave velocity (see Attachment 2).

3. For construction/convenience, a system of MSE walls will be constructed to surround the nuclear islands. The available details of the MSE wall design are contained in Attachment 1. These walls facilitate construction of the nuclear islands. Backfill behind the MSE walls subsequently provides support for construction cranes used in constructing the nuclear islands. Per Attachment 1, these MSE walls will likely consist of geogrids to reinforce the backfill and a facing. These MSE walls are not faced with modular precast concrete panels but rather the facing consists of welded wire forms within which the geogrids and a geotextile are wrapped to retain the granular fill at the face. (Note that the MSE wall facing is not technically a "gabion", which is a welded wire basket filled with larger rock pieces. The MSE facing contains the same granular particle sizes as the remainder of the granular fill and is compacted to the same minimum degree.) The MSE wall, including its facing, is thus a structure whose mass properties such as unit weight, shear strength and shear wave velocity are determined by the properties of the granular fill. The MSE wall facing thus does not form a possible subsurface "hard spot" that might adversely affect the distribution of stresses on the overlying building foundations. The space between the facing of the MSE wall and the below grade nuclear island wall, after its construction, is backfilled with the same granular backfill material used in the general granular fill.

The granular backfill is compacted as described in FSAR Subsection 2.5.4.5.3.5. The granular materials are spread in lift thicknesses that are appropriate for the type of compaction equipment. FSAR Subsection 2.5.4.5.3.5 notes that hand-guided compactors are used within confined areas (where larger mechanized equipment cannot effectively operate) or within 5 ft of the nuclear island walls. As will be demonstrated by the test fill, the hand-guided compactors will have sufficient weight and striking power to produce the specified degree of compaction that is obtained in the general granular fill by the mechanized equipment.

4. Due to the use of compaction equipment and associated lift thicknesses appropriate for the equipment, the granular backfill in confined spaces such as the side fill between the below grade nuclear island wall and the face of the MSE wall is compacted to the same degree as the granular backfill within and behind the MSE wall facing. The degree of compaction achieved is documented by the tests outlined in FSAR Table 2.5.4-222. Therefore, the presence of the MSE wall does not adversely affect the degree of compaction achieved in the side fill. The static and dynamic properties of the side fill are the same as those of the general granular fill, and thus the presence of the MSE wall does not adversely impact the static or dynamic response of the structures founded on the granular fill or the side fill adjacent to the nuclear island.

   The mat foundations of structures adjacent to the nuclear island are underlain by the side fill, the MSE wall and its facing, and by the general granular backfill. Both the side fill (with its degree of compaction as specified) and the presence of the MSE wall (with its facing of wire forms and geogrids with geotextile fabric) have no adverse effect on the structural stability, foundation bearing capacity or settlement analyses of these structures.

   Note that the FSAR Subsection 2.5.4.5.3.5 states the following:

   "The granular fill is compacted to a minimum of 96 percent of the maximum dry density determined in accordance with the modified Proctor test method (ASTM D 1557) with a moisture content that is not more than 2 percentage points above the optimum moisture content, nor less than the optimum."

   In retrospect, note that for cohesionless soils such as the granular fill, control of moisture in the material is to facilitate compaction. If the compacted density meets the requirements, moisture present during compaction is controlled only for compaction efficiency and not as an engineering requirement. Nonconformance to recommended compaction moisture content does not alter the engineering properties of the cohesionless fill and should not form the basis for rejection of the constructed material.

   To promote the constructability of the granular fill without affecting its static or dynamic engineering properties, the FSAR is revised to state that the moisture content of the fill at the time of compaction should be within ±3% of the optimum moisture content determined in accordance with ASTM D1557. The following wording will replace the existing wording in the FSAR Subsection 2.5.4.5.3.5 (see Attachment 2):

"The granular fill is compacted to a minimum of 96 percent of the maximum dry density determined in accordance with the modified Proctor test method (ASTM D 1557) with a moisture content that is generally within 3 percentage points above or below the optimum moisture content. If the compacted density meets the requirements, moisture present during compaction is controlled only for compaction efficiency and not as an engineering requirement. Nonconformance to recommended compaction moisture content does not alter the engineering properties of the cohesionless fill and should not form the basis for rejection of the constructed material."

FSAR Subsection 2.5.4.5.3.5 is revised to clarify that the anticipated material types are Macadam Base Course and Washed Screenings and that they are expected to meet the Atterberg Limits and Los Angeles Abrasion criteria of the South Carolina Department of Transportation Specifications (see Attachment 2). FSAR Table 2.5.4-222 is revised to remove "GW, GP and SW" from the title since the granular fill may possess a different USCS classification symbol from the three gradations used to predict the static and dynamic properties for the granular fill materials. FSAR Table 2.5.4-222 is also revised to reflect that the anticipated granular materials are Macadam Base Course and Washed Screenings and to add the Atterberg Limits requirements for these materials (see Attachment 2).

References:

None

Associated Revision to the Lee Nuclear Station Final Safety Analysis Report:

FSAR Subsection 2.5.4.5.3.5

FSAR Table 2.5.4-222

Attachments:

1) Conceptual MSE Wall Fill Material and Design
2) Revisions to FSAR Subsection 2.5.4.5.3.5 and Table 2.5.4-222

Attachment 1

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI 02.05.04-017

Conceptual MSE Wall Fill Material and Design

Conceptual MSE Wall Fill Material and Design

MSE Wall Fill Material:

The fill material used for construction of the MSE wall surrounding the nuclear islands will be the same engineered granular fill materials that will be used to backfill adjacent to the nuclear island walls and underneath adjacent power block structures.

As stated in FSAR Subsection 2.5.4.5.3.5, Granular Backfill Outside the Nuclear Island, these granular materials will meet the gradation requirements for Macadam Base Course, defined in Subsection 305.2.5.5 of the South Carolina Department of Transportation (SCDOT) Standard Specifications for Highway Construction, and Washed Screenings, defined in Subsection 408.2.2. The Macadam Base Course materials are also expected to meet the plasticity limits specified in Section 305.2.5.5 of the SCDOT specifications. Thus, these granular fill materials will consist of granular soils (gravels and sands) having limited amounts of fines (i.e., no more than 12 percent), a maximum liquid limit of 25, and a maximum plasticity index of 6.

The upper- and lower-bound gradation limits of the Macadam Base Course are shown on Figure 1.

Washed Screenings are defined in the SCDOT Standard Specifications for Highway Construction, Subsection 408.2.2. Washed Screenings are comprised generally of medium and fine sand, as most of the material passes the No. 10 (2.00-mm) sieve and is retained on the No. 200 (0.075 mm) sieve. The upper- and lower-bound gradation limits of the Washed Screenings are shown in Figure 2.

Conceptual MSE Wall Design:

During construction of Lee Nuclear Station Units 1 and 2, a retaining wall will be constructed within each power block excavation to facilitate construction of the nuclear islands. These retaining walls are planned as mechanically stabilized earth (MSE) walls and will remain in place after construction is complete, becoming a permanent part of the subsurface profile. As shown in Figures 3 and 4, each MSE wall is anticipated to be located approximately 15 ft from the nuclear island. At least 6 ft of working space will be provided at the base of the nuclear island. Assuming that the slope of the MSE wall face will be approximately 1 horizontal to 18 vertical, the setback from the nuclear island at the top of the MSE wall (at plant grade Elevation 589.0) will be approximately 17 ft. Note, however, that the top of the MSE wall may be established taking into consideration the subgrade bearing elevation of the adjacent power block structures, which will be slightly below Elevation 589.0. The space between the face of the MSE walls and the below grade portion of the nuclear island walls will be backfilled prior to construction of the power block structures located adjacent to or on top of the MSE walls.

MSE walls are internally stabilized retaining structures consisting of alternating layers of compacted fill and a reinforcing material, such as metal strips, wire mesh, geotextiles, or geogrids. The weight of the soil and the internal shear resistance provided by the reinforcement material create a flexible, yet stable, structure. The MSE wall supplier typically performs the MSE wall design with respect to the geometry and internal stability of the structure, giving consideration to external loading conditions, performance criteria, and construction constraints.

The external and overall (global) stability of the wall is typically determined by the geotechnical engineer-of-record.

For this construction application, the MSE walls are anticipated to be designed as reinforced soil structures comprised of compacted granular fill and geogrid reinforcement. The MSE wall will have a welded wire form (WWF) facing with geotextile wrap to maintain face alignment, prevent loss of fill material, and allow for drainage. A conceptual MSE wall cross section is depicted in Figure 4. The minimum base width and length of geogrid reinforcement required will be on the order of 70 percent of the wall height, or approximately 30 ft for a 40-ft-high wall. The minimum embedment depth for MSE walls is based on bearing capacity, settlement, and stability considerations. A minimum embedment depth of 2 ft below grade will be assumed for portions of the MSE walls bearing on granular fill or partially weathered rock surrounding the nuclear islands. Embedment may not be required where the MSE walls bear directly on rock or concrete.

As shown in Figure 5, geotextile fabric will be looped around the WWF facing to contain the fill material and form the exposed face of each MSE wall. These geosynthetic wrapped facings are flexible and advantageous for use in temporary applications, and are designed to prevent excessive bulging as the granular fill behind the facing elements compresses due to compaction stresses and fill self weight. The anticipated 4" x 4" W4.0 x W4.0 WWF to be used consists of 4-inch by 4-inch welded wire mesh having wire support struts spaced every 2 ft. The wires are smooth and the cross-sectional area is 0.04 square inches in both the longitudinal and transverse directions, which equates to a wire diameter of approximately 0.225 inches. For temporary applications, facing units are fabricated typically using conventional black steel. As previously stated, the MSE walls are considered to be a temporary application to facilitate construction of the nuclear islands. Note that the MSE walls will no longer function as a wall once side fill is placed between the below grade nuclear island walls and the face of the MSE walls.

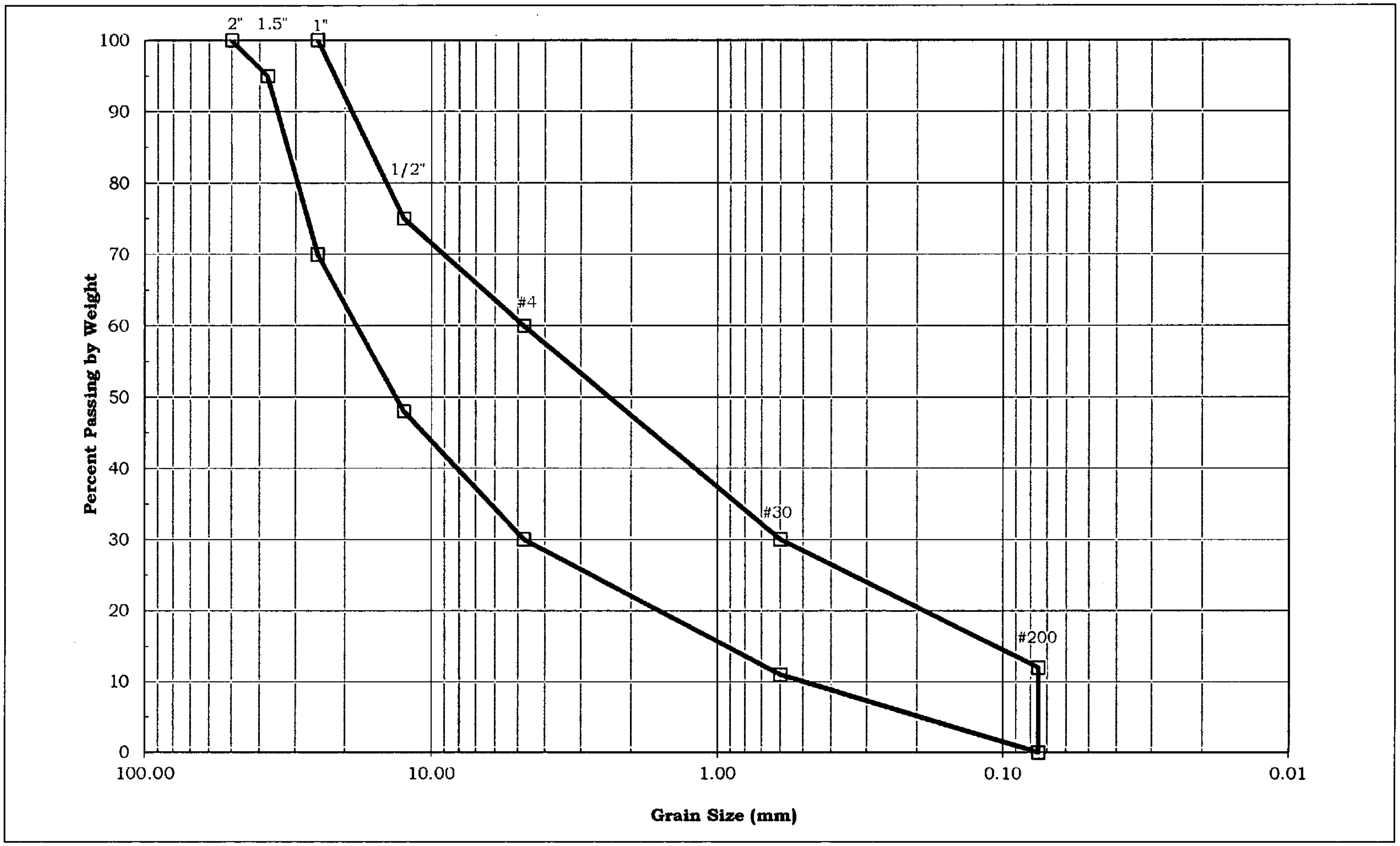

Figure 1, SCDOT 305.2.5.5 Macadam Base Course Gradation Limits

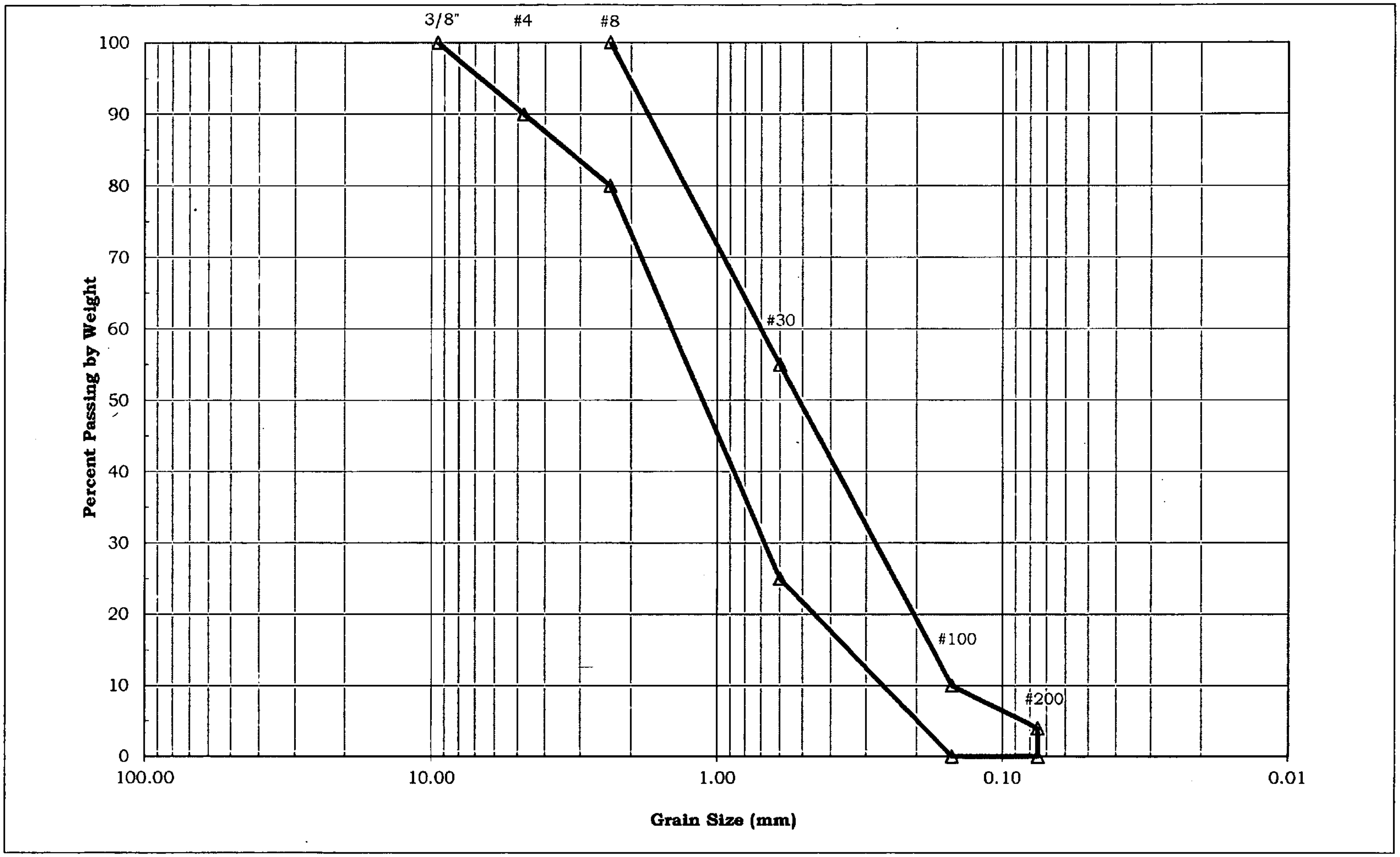

Figure 2, SCDOT 408.2.2 Washed Screenings Gradation Limits

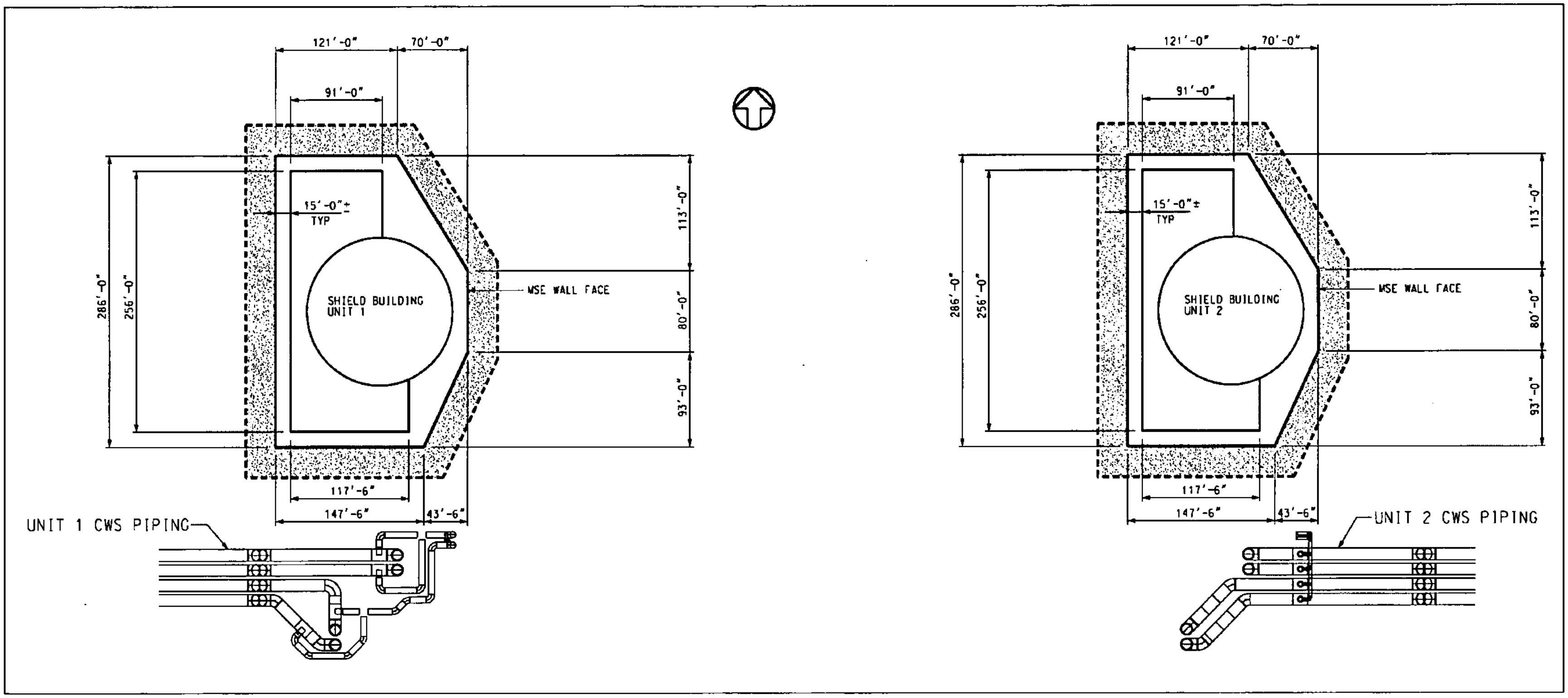

Figure 3, Conceptual Location of Nuclear Island MSE Wall

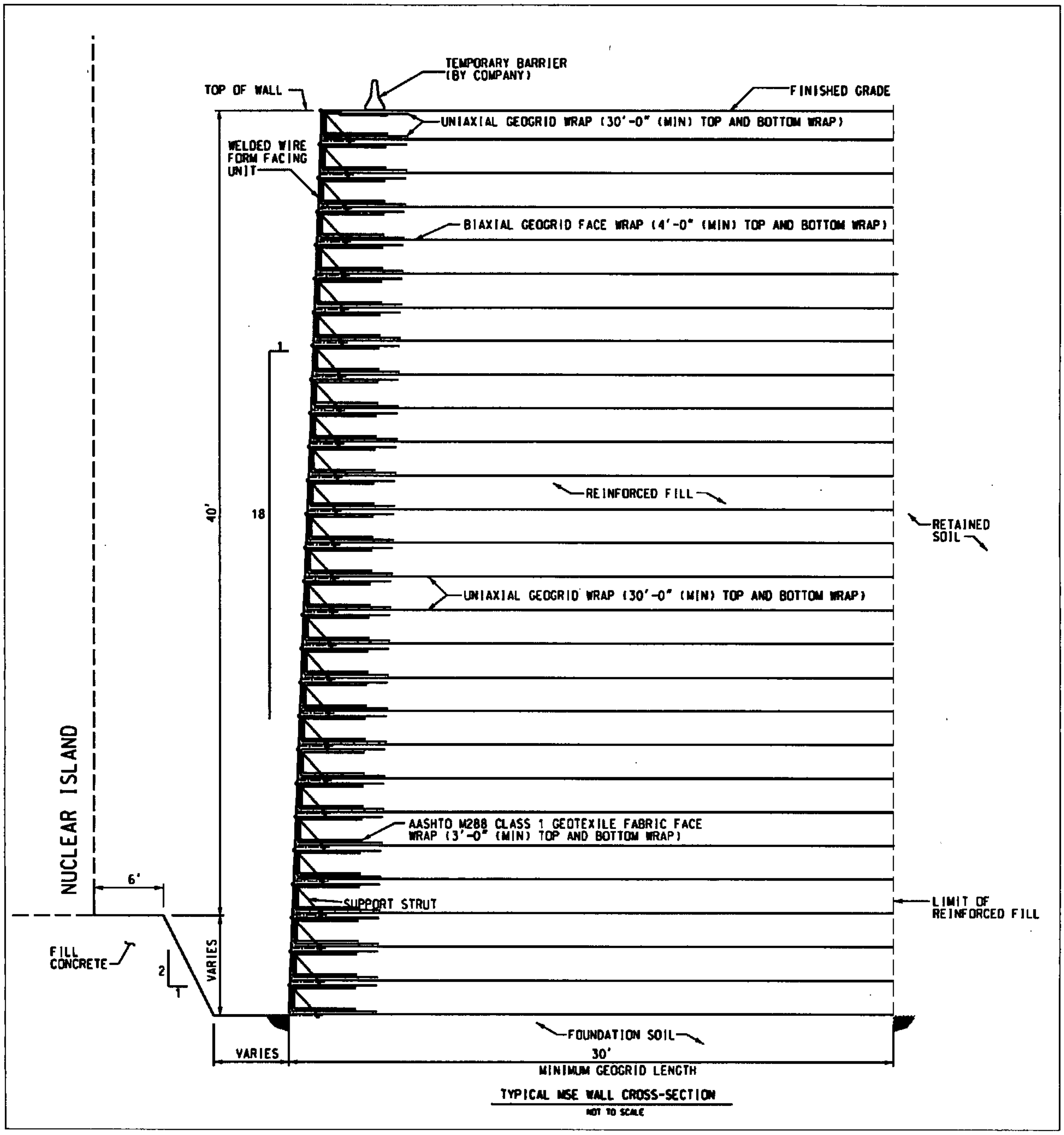

Figure 4, Conceptual MSE Wall Cross-Section

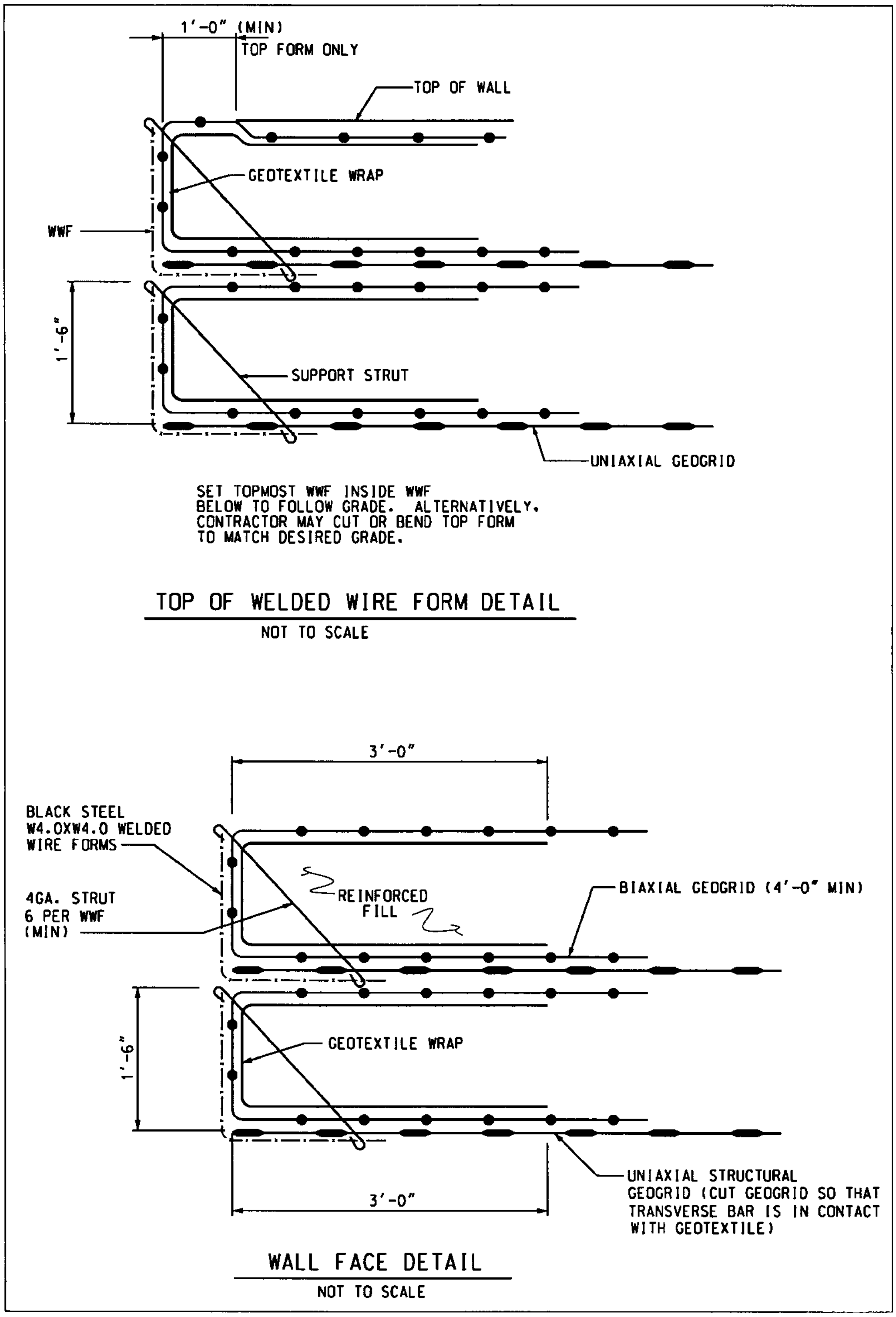

Figure 5, Conceptual MSE Wall Facing Details

Attachment 2

Lee Nuclear Station Response to Request for Additional Information (RAI)

RAI 02.05.04-017

Revisions to FSAR Subsection 2.5.4.5.3.5

Revisions to FSAR Table 2.5.4-222

COLA Part 2, FSAR Chapter 2, Section 2.5.4.5.3.5 is revised to read:

2.5.4.5.3.5 Granular Backfill Outside the Nuclear Island

Outside the below grade nuclear island walls (Units 1 and 2), a granular backfill will be placed up to approximately the yard elevation or to the underside of the adjacent buildings. The backfill adjacent to the nuclear island walls and extending outward to form the foundation support of the adjacent buildings (radwaste, annex, and turbine buildings) will be an engineered granular backfill. Outside the limits of the granular fill, soil backfill will be used. This subsection describes the specifications and controls of granular fill materials. The soil backfill placed beyond the granular fill limits is non safety-related and the placement specifications will be developed as part of construction.

Static properties of typical granular backfill materials are discussed in Subsection 2.5.4.2. Dynamic properties of typical granular backfill materials are discussed in Subsection 2.5.4.7.

Quality control for granular backfill includes verification that the material was obtained from an approved source (e.g., an approved quarry). The maximum dry density and optimum moisture content are determined according to the modified Proctor (ASTM D 1557) method. For gradation and moisture content testing, the test samples are obtained after placing the material but before compaction. Measurement of in-place dry density of each lift after compaction is performed using the sand cone (ASTM D 1556) or rubber balloon (ASTM D 2167) method. The nuclear gauge (ASTM D 6938) method is used to augment (but not completely replace) the other methods.

A quality control sampling and testing program for the granular backfill inclusive of the items provided by Table 2.5.4-222 is implemented during construction of the granular backfill. This quality control sampling and testing program verifies that the granular backfill is constructed in accordance with the parameters described in this subsection. To ensure that the engineering properties of the backfill meet the values used to calculate the static and dynamic lateral earth pressures, and the values used to establish seismic requirements for the Category II structures (annex building and turbine building Bay 1), the backfill will be tested in the laboratory. Testing to be performed on granular backfill before construction begins is also provided by Table 2.5.4-222. Prior to constructing the backfill around the nuclear island structures, a "test fill" pad will be constructed on-site using the equipment and granular fill materials to be used in the backfill. Before the production backfill commences, an engineering report will exist that concludes that the equipment and methods used to construct the "test fill" are capable of producing acceptable and consistent results.

The non safety-related structures adjacent to the nuclear island (radwaste, annex, and turbine buildings) will be supported on the granular fill. The following criteria are required for granular backfill placed adjacent to the nuclear island walls and extending outward to form the supporting material for the adjacent structures:

- The granular fill is obtained from a quarry and will conform to SCDOT gradation limits (Reference 224, SCDOT, 2007). Anticipated material types are Macadam Base Course and Washed Screenings.
- The material is from an approved source (e.g., a quarry) and meets the assigned gradation requirements after the material is hauled and placed (before compaction).
- The coarse particles (materials retained on and above the No. 4 sieve) have an abrasion loss no more than ~~40~~65 percent (Reference 224) when subjected to the Los Angeles Abrasion Test (ASTM C 131) and has an apparent specific gravity (ASTM C 127) that is greater than or equal to approximately 2.65.

- The material has a defined moisture-density relationship to allow a maximum dry density to be determined in accordance with ASTM D 1557 (modified Proctor) for compaction control.
- Care is taken to prevent segregation of the materials during handling and placement.
- ~~To achieve the required degree of compaction, the moisture content is maintained at or near the~~The moisture content is maintained generally within 3 percentage points above or below the optimum moisture content as determined by the modified Proctor (ASTM D 1557) laboratory compaction test. Moisture contents outside this range do not cause rejection of the constructed material providing compaction requirements are achieved.
- The lift thickness is appropriate for the type of compaction equipment, but generally does not exceed about 8 inches (compacted thickness) for mechanized equipment nor about 4 inches for hand-guided compactors. Lift thicknesses may vary from the above values depending on the capability of the equipment being used.
- Steel wheel tandem drum rollers weighing on the order of 10 tons are generally effective for compacting granular fill materials.
- Within confined areas, or within 5 feet of the nuclear island walls, hand-guided compactors are used to prevent excessive lateral pressures against the walls from the residual soil stress caused by heavy compactors. The compactors have sufficient weight and striking power to produce the same degree of compaction that is obtained on the other portions of the fill by the rolling equipment, as specified.
- The granular fill is compacted to a minimum of 96 percent of the maximum dry density determined in accordance with the modified Proctor test method (ASTM D 1557) with a moisture content that is ~~not more than 2 percentage points above~~generally within 3 percentage points above or below the optimum moisture content~~, nor less than the optimum~~. If the compacted density meets the requirements, moisture present during compaction is controlled only for compaction efficiency and not as an engineering requirement. Nonconformance to recommended compaction moisture content does not alter the engineering properties of the cohesionless fill and should not form the basis for rejection of the constructed material. This relative compaction is selected to produce a granular fill equivalent to a relative density of 80 percent (Reference 225), and thus highly resistant to liquefaction.

Lateral pressures applied against the below grade nuclear island walls are evaluated and discussed in Subsection 2.5.4.10.3. Evaluation and discussion of liquefaction issues related to the backfill materials is provided in Subsection 2.5.4.8.

TABLE 2.5.4-222 (Sheet 1 of 4)
QUALITY CONTROL RECOMMENDATIONS FOR GENERIC ENGINEERED GRANULAR BACKFILL~~— GW, GP, AND SW~~

WLS COL 2.5-6
WLS COL 2.5-7

Material	Test	Minimum Sampling and Testing Frequency
Granular Backfill	Field Density	Minimum 1 sample per lift per 10,000 square feet. One test for every 250 square feet per lift when manually operated compactors are used. Use sand cone (ASTM D 1556) or rubber balloon (ASTM D 2167) for at least 33% of field density measurements. Nuclear gauge (ASTM D 6938) may be used for 67% of measurements. The sand cone or rubber balloon test shall be performed at the location of at least two of the nuclear gauge tests (if used) for each day's work.
	Moisture	One test for each sand cone or rubber balloon test. (ASTM D 2216)
	Moisture-Density Relationship (Modified Proctor)	One test for every borrow source and material type and any time material type changes. Additional test for every 40 Field Density tests, or as directed by geotechnical engineer in responsible charge. (ASTM D 1557)
	Gradation	One test for each Moisture-Density test. (ASTM D 422 and D 1140)
	Atterberg Limits	One test for each Moisture-Density test. (ASTM D 4318)
	Material Type	Granular fill must come from an approved borrow source (e.g. a quarry) and be the approved material for the project.

TABLE 2.5.4-222 (Sheet 2 of 4)
QUALITY CONTROL RECOMMENDATIONS FOR GENERIC
ENGINEERED GRANULAR BACKFILL ~~— GW, GP, AND SW~~

The following laboratory tests will be performed on samples of the proposed granular fill materials before they are approved for use.

Test	Minimum No. of Tests	Criterion for Acceptance Unless Approved by Engineer of Record
All below		An engineering report exists that concludes the granular fill material will produce a backfill having acceptable engineering properties.
Grain Size ASTM D 6913	1 per material type per source as-is, and 1 per material type per source scalped if necessary	Complies with SCDOT Specifications for Material Type (Reference 224) (may differ on some sieve sizes with approval of Engineer of Record). Anticipated material types are Macadam Base Course and Washed Screenings.
Atterberg Limits ASTM D 4318	1 per material type per source	Complies with SCDOT Specifications for Material Type (Reference 224)
Specific Gravity ASTM D 854	1 per material type per source	
Modified Proctor ASTM D 1557 and ASTM D 4718	1 per material type per source	Maximum Dry Density $\geq$ 124 lb/ft^3.
Constant Head Permeability ASTM D 2434	1 per material type per source	
pH ASTM G 51	1 per material type per source	
Chloride Content EPA SW-846 9056/300.0	1 per material type per source	

TABLE 2.5.4-222 (Sheet 3 of 4)
QUALITY CONTROL RECOMMENDATIONS FOR GENERIC ENGINEERED GRANULAR BACKFILL ~~– GW, GP, AND SW~~

Test	Minimum No. of Tests	Criterion for Acceptance Unless Approved by Engineer of Record
Sulfate Content EPA SW-846 8056/300.0	1 per material type per source	
Resistivity ASTM G 57	1 per material type per source	
Consolidated Drained Triaxial Shear USACE EM-1110-2-1906 Appendix X (30 Nov. 70)	1 per material type per source (scalped) (minimum 2 confining pressures per material type)	$\phi' \geq 35°$
Consolidation ASTM D 2435	1 per material type per source (up to 50 kip/ft2 effective vertical stress)	
Resonant Column Torsional Shear University of Texas Procedure PBRCTS-1	1 per material type per source (scalped) Test at 4 to 6 isotropic confining stress values	Maximum shear modulus, modulus ratio, and damping ratio consistent with upper range and lower range values used for site response calculation to determine compatibility with site response for Category II structures (Annex Building and Turbine Building Bay 1).
Free-Free Resonant Column Test University of Texas Procedure Fr-Fr-1	1 per material type per source (scalped) Test free-free resonance and direct travel time tests	

TABLE 2.5.4-222 (Sheet 4 of 4)
QUALITY CONTROL RECOMMENDATIONS FOR GENERIC ENGINEERED GRANULAR BACKFILL ~~— GW, GP, AND SW~~

In addition to other tests performed during construction, the following field measurements of shear wave velocity of the in-place fill will be performed.

Test	Minimum No. of Tests	Criterion for Acceptance Unless Approved by Engineer of Record
Spectral Analysis of Surface Waves (SASW) University of Texas Procedure GR-07	When approximately 1/3, 2/3 and approximately full height of granular backfill is in-place.	Maximum shear modulus consistent with values used for site response calculations for Category II structures.
Crosshole Seismic Testing (ASTM D 4428), Downhole Seismic Testing (ASTM D 7400) or PS Suspension Seismic Velocity Logging (GeoVision Procedure for OYO P-S Suspension Seismic Velocity Logging)	When approximately full height of granular backfill is in-place.	