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

RAI Letter No. 067

NRC Technical Review Branch: **Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)**

Reference NRC RAI Number(s): **RAI 03.07.01-004**

NRC RAI:

This RAI is follow-up RAI related to 3.07.01-002

RAI 3.07.01-002 (eRAI system RAI 1003, Q3500) addresses the seismic analysis of the Annex Building. The AP1000 DCD, Section 3.7.2.8, states that the Annex Building is a Seismic Category II building that is analyzed/designed to Seismic Category I design criteria for a range of soil conditions as given in DCD Section 3.7.1.4. The FSAR states that the Annex Building will not fail/collapse onto NI structures. The RAI questioned whether the range of analyses referenced in DCD Section 3.7.1.4 properly envelopes the soil conditions at Lee Station.

The applicant responded to RAI 3.07.01-002 in a letter dated December 17, 2008 [ML083570396]. The applicant stated that significant margin exists between the site-specific FIRS and the CSDRS except in the high frequency range, which the Applicant states is of little significance since high frequency seismic motion is of limited, or negligible, structural damage potential.

The staff believes that the applicant's response does not address the concern that the range of soil conditions analyzed for the DCD envelope the soil conditions at Lee Station.

The concern is that the Annex Building is largely, possibly entirely, founded on artificial fill based on the review of FSAR Figures 2.5.4-233 through -239. The soil depths (soil column heights) vary between approximately 30 and 50 ft., which is significantly less than the soil depths studied in DCD Section 3.7.1.4. These relatively shallow soil columns under the Annex Building can amplify the seismic motion since they are stiffer than the deeper depth soil columns studied in the DCD. The soil properties of the artificial fill are also not known or specified. The overall concern is that actual seismic motion experienced by the Annex Building may be greater than what was studied in DCD Section 3.7.1.4.

While margin does indeed exist between the CSDRS and the GMRS itself, the actual seismic demand for the Annex Building may be greater than the CSDRS for Lee Station given (1) that the GMRS is defined at the NI foundation elevation and (2) the shallow soil conditions and fill soil properties.

The staff requests the applicant to clarify that the backfill soil amplification below the annex building is bounded by the analyses considered in the DCD and provide appropriate analytical data to support this conclusion.

Duke Energy Supplemental Response:

In Reference 5, Duke Energy presented an initial response to RAI 03.07.01-004. Reference 6 supplemented that response, providing additional detail and presenting a more bounding assessment of the site-specific requirements for Seismic Category II buildings adjacent to the nuclear island. Reference 6 described development of a suite of performance-based surface response spectra (PBSRS) for the representative profiles, individually considering each of the three candidate granular fill materials (soil classifications GW, GP, and SW), as well as a range

of groundwater levels (mid, high, and low), and a variety of profiles A2, A3, A4 (Unit 1), C1, C2, and C3 (Unit 2), and B3-7, B3-8, B3-9 and B3-10 (Unit 1 northwest corner). Reference 6 compares the resulting PBSRS to the inputs used in developing requirements for the AP1000 Standard Plant Seismic Category II buildings.

Reference 6 concludes that the Lee Nuclear Station site complies with the criteria of DCD Subsection 3.7.2.8.4 for a hard rock site, including uniformity of support, appropriate backfill configuration and material, and adequate bearing capacity for the materials supporting Seismic Category II buildings, and a site GMRS that is enveloped by the AP1000 HRHF response spectrum.

To resolve any potential concerns about differences from the support configurations considered in the AP1000 DCD, and any minor exceedances in the site-specific PBSRS surface spectra compared to those considered in the DCD, Reference 6 stated that Duke Energy would perform detailed site-specific soil-structure interaction analyses of adjacent Seismic Category II buildings. This supplemental response provides those site-specific soil-structure interaction analyses.

From the candidate granular fill materials described in FSAR Subsection 2.5.4, Duke Energy has determined that Macadam Base Course material provides properties appropriate for precluding interaction of Seismic Category II buildings with the nuclear island. Duke Energy has selected the static and dynamic properties described in FSAR Subsection 2.5.4 as well-graded gravel (GW) to represent that Macadam Base Course material.

Attachment 37 is Westinghouse Electric Company Report WLG-1000-S2R-804 Revision 2, describing the site-specific analyses of adjacent Seismic Category II buildings and confirming that all DCD criteria have been satisfied. FSAR Subsection 3.7.2.8.4 is revised to reflect these site-specific analyses as shown in Attachment 38 to this enclosure, and will be incorporated into a future revision of the Final Safety Analysis Report. Attachment 38 also presents associated minor edits to FSAR Subsection 2.5.4.

As described in FSAR Subsection 2.5.4.5.1, the source for the granular fill material (Macadam Base Course) supporting the Seismic Category II buildings has not yet been identified. Once a source for the granular fill material has been selected, the static and dynamic properties of the material supporting Seismic Category II buildings will be verified as compatible with Lee Nuclear Station site response analyses.

References:

Note: For clarity, all references used in the initial response and subsequent supplemental responses are shown.

1. Letter from Bryan J. Dolan (Duke Energy) to Document Control Desk, U.S. Nuclear Regulatory Commission, Supplemental Response to Request for Additional Information (RAI Nos. 1874, 1881, and 2098), Ltr# WLG2009.10-02, dated October 30, 2009 (ML093080101)
2. Letter from Bryan J. Dolan (Duke Energy) to Document Control Desk, U.S. Nuclear Regulatory Commission, Response to Request for Additional Information (RAI Nos. 1003 and 1004), Ltr# WLG2008.12-25, dated December 17, 2008 (ML083570396)
3. Letter from Robert Sisk (Westinghouse Electric Company) to Document Control Desk, U.S. Nuclear Regulatory Commission, AP1000 Response to Request for Additional Information (SRP 3), dated July 28, 2010 (Letter DCP_NRC_002981, ML102160322)
4. Letter from Bryan J. Dolan (Duke Energy) to Document Control Desk, U.S. Nuclear Regulatory Commission, Transmittal of Unit 1 Foundation Input Response Spectra (FIRS) Horizontal and Vertical Component Analysis, Ltr# WLG2010.02-01, dated February 22, 2010 (ML100550350)
5. Letter from Bryan J. Dolan (Duke Energy) to Document Control Desk, U.S. Nuclear Regulatory Commission, Response to Request for Additional Information (RAI No. 2350), Ltr# WLG2010.08-02, dated August 24, 2010 (ML102380042)
6. Letter from John W. Pitesa (Duke Energy) to Document Control Desk, U.S. Nuclear Regulatory Commission, Supplemental Response to Request for Additional Information (RAI No. 2350), Ltr# WLG2012.02-03, dated February 28, 2012 (ML12060A377)

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

1. Subsection 2.5.4.2.4.1
2. Subsection 2.5.4.2.4.1.8
3. Subsection 2.5.4.5.1
4. Subsection 3.7.2.8.4
5. Subsection 3.7.6

Attachments:

Note: Attachments 1 through 11, Attachment 13, Attachments 15 through 24, and Attachment 26 are presented in Reference 5. Attachment 12 (Revised), Attachment 14 (Revised), Attachment 25 (Revised), and Attachments 27 through 36 are presented in Reference 6.

37. Westinghouse Electric Company Report WLG-1000-S2R-804, Revision 2, *William S. Lee Site Specific Adjacent Building Seismic Evaluation Report*
38. Revisions to Lee Nuclear Station Final Safety Analysis Report, Subsections 2.5.4.2.4.1, 2.5.4.2.4.1.8, 2.5.4.5.1, 3.7.2.8.4, and 3.7.6

Lee Nuclear Station

Supplemental Response to Request for Additional Information (RAI)

Attachment 37 to RAI 03.07.01-004

Westinghouse Electric Company Report

WLG-1000-S2R-804, Revision 2

William S. Lee Site Specific Adjacent Building Seismic Evaluation Report

WLG-1000-S2R-804
Revision 2
July 2012

AP1000
William S. Lee Site Specific Adjacent Building Seismic Evaluation Report

Westinghouse Electric Company LLC
Nuclear Power Plants
Post Office Box 355
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Record of Revisions

Rev	Date	Revision Description
0	See EDMS	Original Issue
1	8/2010	Revised to add Duke Energy comments and Appendix A HRHF response spectra comparisons.
2	7/2012	Updated Duke Lee Units 1 and 2 Seismic Category II adjacent structures 2D parametric SSI analyses including updated well-graded gravel (GW) backfill soil properties, envelop performance-based surface response spectra (PBSRS) and corresponding time histories to evaluate the response of the Unit 1 and Unit 2 SCII adjacent structures to site-specific subsurface conditions. Pertinent report sections and results summaries were updated accordingly.

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1.0 Introduction and Purpose

The Duke Energy (Duke) William States Lee Nuclear Station (Lee) will consist of twin AP1000 power plant units located at the site of the former, partially-constructed Cherokee Nuclear Station (CNS). Westinghouse Energy Company (WEC) understands that the existing site will be developed and allow for the placement of the AP1000 units in their standard configurations; however, there are subsurface and foundation site characteristics that differ from the generic site conditions for which the AP1000 Seismic Category II (SCII) adjacent buildings have been designed. This plant-specific site analysis addresses these differences.

As shown in Figure 2.1-1, the preferred locations for the two AP1000 units align the new Unit 1 with the old CNS Unit 1 centerline, and the new Unit 2 with the old CNS Unit 3 centerline. The location of the AP1000 units assumes partial demolition of the existing CNS structures and subsequent placement and compaction of select granular backfill material to grade.

Nuclear Regulatory Commission (NRC) RAI 3.07.01-004 addresses the seismic analysis of the Annex Building, which expresses concern that the range of soil conditions analyzed for the WEC Design Control Document (DCD) envelope does not address the existing and proposed site/soil conditions at Duke Lee. The NRC staff's concern is that the Annex Building is largely, possibly entirely founded on artificial fill based on their review of FSAR Figures 2.5.4-233 through -239. The soil depths (soil column heights) vary between approximately 30 and 50 feet, which are significantly less than the soil studied in AP1000 DCD Section 3.7.1.4. While margin exists between the AP1000 Certified Seismic Design Response Spectra (CSDRS), Hard Rock High Frequency (HRHF), and Duke Lee Ground Motion Response Spectra (GMRS), the NRC Staff's concern is that the actual seismic demand for the Annex Building may be greater than the CSDRS for Duke Lee given that:

1. The FIRS is defined at the Nuclear Island (NI) foundation elevation; and
2. The shallow soil conditions and fill soil properties are not addressed in the DCD envelope.

Therefore, the NRC staff has requested clarification that the backfill soil amplification below the Annex Building is bounded by the analyses considered in the DCD and provide appropriate analytical data to support this conclusion.

WEC previously prepared report WLG-1000-S2R-804 Rev. 1 in August 2010 documenting a site specific soil-structure interaction (SSI) analysis of the Duke Lee Units 1 and 2 SCII Turbine Building First (1st) Bay and SCII portion of the Annex Building. These two-dimensional (2D) parametric SSI analyses evaluated a total of five (5) models and one (1) backfill soil case. The input time history for these analyses was the Lee Nuclear Island (NI) foundation interface response spectra (FIRS).

Previous SSI analyses were performed utilizing strain compatible soil properties provided by Duke in Reference 1 and seismic input and time histories, which were also provided by Duke at the Nuclear Island AP1000 elevation (El.) 60.5. The SSI results indicated the Duke Lee in-structure floor response spectra (FRS) exceed the generic AP1000 SCII SCII portion of the Annex Building and Turbine Building 1st Bay envelope FRS. WEC noted that

these exceedences were likely due to the inconsistency between the NI FIRS seismic input and the backfill dynamic soil properties, which yielded overly conservative SSI analyses results.

Subsequently, changes to the Lee Nuclear Station site specific configuration and supporting documentation were made including the development of numerous backfill material and ground water dependent GMRS curves including well-graded gravel (GW), poorly-graded gravel (GP) and well-graded sand (SW). A total of four (4) site response scenarios were determined by Duke to represent the enveloping model, backfill, and groundwater cases including:

1. Unit 2 East-West and North-South profile with 30 feet of backfill soil (10' less than DCD);
2. Unit 2 East-West and Unit 1 North-South profile with 40 feet of backfill soil (similar to DCD);
3. Unit 1 East-West profile with 50 feet of backfill soil (10' more than DCD); and
4. Unit 1 East-West in the Northwest corner with location specific backfill/concrete soil conditions.

Preliminary SSI analyses of the various backfill thickness/material scenarios indicated that a well-graded gravel (GW) backfill provided the best soil-structure response as it pertains to the Turbine Building 1st Bay and SCII portion of the Annex Building in-structure FRS and all of the proposed 30-, 40-, and 50-foot backfill scenarios, including the concrete and soil Northwest corner scenario. Therefore, the WEC approach and methodology used in this updated SSI analysis utilizes the GW strain-compatible material properties with the profile geometry and corresponding site characteristic information for the four model scenarios above including the three (3) generalized backfill soil thicknesses of 30, 40 and 50 feet, and the Northwest corner geometry. Also the specific GW surface GMRS envelops are used to develop surface input motions (time histories) to evaluate the response of the Duke Lee SCII Turbine 1st Bay and SCII portion of the Annex Building structures with GW backfill material.

Therefore, the purpose of the revised analyses was to address the following:

Perform two-dimensional (2D) parametric studies to:

- Evaluate the extent of subsurface characterization, site response and surface motions;
- Analyze the site-specific dynamic profiles and foundation medium underlying the Units 1 and 2 SCII adjacent building footprints;
- Assess the effect of the Unit 1 Northwest (NW) corner site-specific conditions on the seismic response; and
- Compare the Duke Lee 2D horizontal and vertical in-structure FRS to the AP1000 2D SCII FRS envelops at the base of the SCII portion of the Annex Building and Turbine Building 1st Bay.
- Compare the Duke Lee SCII adjacent structures axial and shear forces and moments at the base of the structure(s);
- Compare relative displacements between the NI and the Annex and Turbine building foundations as well as at the top of the structure; and
- Estimate the maximum bearing pressure demand for each SCII adjacent structure.

The 2D SSI analyses were performed using the computer code SASSI2000 (Reference 4) specifically modules SITE, POINT, HOUSE, ANALYS, MOTION and STRESS. All 2D SASSI SSI analyses performed and described in this report utilized the SASSI Direct Method for computing in-structure FRS.

WEC conducted the site-specific SSI analysis for Duke Lee Units 1 & 2 SCII adjacent structures using the Duke Lee site-specific backfill dynamic soil profiles and surface GMRS envelops provided by Duke in DUK010-FSAR-2.5.2-CALC-015 (Reference 7) and DUK010-FSAR-2.5.2-CALC-014 (Reference 6), respectively.

1.1 SSI Analysis Observations

Based on the Duke Lee 2D site-specific parametric SSI analyses results described in Section 6.0, the site specific Duke Lee in-structure FRS comparison to the AP1000 SCII design envelops for the adjacent structures indicate the following:

Turbine Building:

The SSI analysis results for the Duke Lee Units 1 and 2 Turbine Building 1st Bay indicate that the FRS for the 40- and 30-foot backfill cases, respectively, and GW backfill material, with a range of upper and lower bound dynamic soil properties are enveloped by the AP1000 Turbine Building FRS envelop.

The axial and base shear forces and moments associated with the 40- and 30-foot backfill case and GW backfill material are also enveloped by the generic CSDRS Turbine Building forces and moments, which control the design of the structure. The relative displacements for this case and backfill material are within the tolerance of 2-inches at the foundation and 4 inches at the top of the structures. The maximum bearing demand for the Turbine Building is estimated at 12.14 kips per square foot (ksf) as compared to the Turbine Building bearing capacity of 43.74 ksf.

Annex Building

The SSI analysis results for the 40- and 30-foot backfill cases associated with the Unit 1 and 2 SCII portion of the Annex Building, respectively with GW backfill are also enveloped by the AP1000 generic FRS envelop. The forces and moments associated with the Units 1 and 2 Centerline 40- and 30-foot backfill cases and GW fill are enveloped by the generic CSDRS Annex Building forces and moments. The relative displacements for the 40- and 30-foot cases and GW backfill are within the limits of 2-inches at the foundation and 4 inches at the top of the structures.

The SSI results for the 50-foot backfill case at the South end of the Unit 1 Annex Building with GW backfill are enveloped by the AP1000 generic FRS envelop spectra. The forces and moments associated with the Unit 1 South 50-foot backfill case and GW fill are enveloped by the generic CSDRS Annex Building forces and moments, and the relative displacements for this case are also within the limits of 2-inch at the foundation and 4 inches at the top of the structure. The SSI analyses results for the concrete and backfill case at the Northwest corner of the Unit 1 Annex Building with GW backfill are enveloped by the AP1000 generic envelop spectra. The maximum bearing demand for the Annex Building is 16.83 ksf as compared to the Annex Building bearing capacity of 32.05 ksf.

Finally, WEC notes that the analytical results presented and observations noted may not preclude the use of the GP and/or SW candidate backfill materials, as the results of this 2D SSI parametric study, with further refinement and additional parametric evaluation of the data could also yield favorable FRS comparisons for these backfill materials.

2.0 Duke Lee Site Characteristics Including SCII Adjacent Structures

The Duke Lee site characteristics at the location of the two AP1000 units are described in the Foundation Interface Report DUK-010-PR-012 (Reference 1) and Final Safety Analysis Report (FSAR) (Reference 2). The Unit 1 NI basemat is founded predominately on fill concrete at El. 550.5 feet (AP1000 El. 60.5 feet), and the Unit 2 NI basemat is founded on hard rock also at El. 550.5 feet. The final grade level for both units is at EL 590.0 feet (AP1000 El. 100.0 feet). The following sections summarize the subsurface conditions, cross-sections and soil profiles used to develop the 2D embedded and 3D surface models for evaluation of the Duke Lee Units 1 and 2 seismic response.

2.1 Summary of Duke Lee SCII Adjacent Structures Subsurface Conditions

As shown in Figure 2.1-1, the new AP1000 Unit 1 will utilize portions of the former CNS Unit 1 footprint and it is planned to overlie portions of the CNS existing foundation. Similarly, the new AP1000 Unit 2 will occupy portions of the former CNS Unit 3 footprint area, and will overlie native rock. Both AP1000 Nuclear Island (NI) structures are founded on hard rock, and both Units 1 and 2 under this configuration will require some additional minor excavation for the development of Duke Lee site. The placement and compaction of engineered fill is required to backfill the existing excavations and develop a level plant grade at an approximate elevation (El.) of 589.5 feet mean sea level (MSL). This elevation corresponds to the AP1000 plant grade at El. 99.5 feet, which is 6 inches below the AP1000 floor El. 100.0 feet.

It should be noted that Duke Energy has recently decided to revise the height of the top of the engineered fill material adjacent to the NI from El. 589.5 feet (AP1000 El. 99.0 feet). The elevation of the NI is unchanged. This small change in site grading adjacent to the NI will have negligible effect on these evaluations.

Duke Energy will use granular fill material beside the NI and beneath the structures adjacent to the NI, including the SCII portion of the Annex Building and Turbine Building 1st Bay. WEC understands the source of the granular fill has not yet been identified, and a range of candidate granular materials has been considered corresponding to the Unified Soil Classification System (USCS) soil classifications of well-graded gravel (GW), poorly-graded gravel (GP) and well-graded sand (SW). However, preliminary SSI analyses of the various backfill thickness/material scenarios indicated that a well-graded gravel (GW) backfill provided a suitable soil-structure response as it pertains to the SCII Turbine Building 1st Bay and SCII portion of the Annex Building in-structure FRS, and all of the proposed 30-, 40-, and 50-foot backfill scenarios, including the concrete and soil Northwest corner scenario.

Figure 2.1-1 presents a plan view of the Duke Lee site and the relative locations of Units 1 and 2, previous CNS units and the cross-section locations used to develop the site-specific SSI models. Figure 2.1-2 presents a plan view of the Unit 1 Northwest corner. The foundation conditions and geologic profiles vary between the Duke Lee Units 1 and 2, and locally at the Northwest corner of Unit 1. A total of five (5) site-specific SSI models were developed with corresponding dynamic soil profiles to represent the varied

conditions and backfill beneath the Duke Lee Units 1 and 2 NI and Annex and Turbine Buildings. The following cross-sections were modeled including:

1. Cross-Section B-B, Unit 1 Centerline including NI and Annex Building (Figure 2.2-1);

2. Cross-Section B-B, Unit 2 Centerline including NI and Annex Building (Figure 2.2-2);

3. Cross-Section Y-Y and Cross-Section U-U, Unit 1 North including Northwest Corner NI and Annex Building (Figure 2.3-1 and Figure 2.3-2);

4. Cross-Section Z-Z, Unit 1 South including NI and Annex Building (Figure 2.4-1); and

5. Cross-Section F-F, Unit 2 Centerline including NI, Turbine and Radwaste Buildings (Figure 2.5-1).

A brief description of the models and site conditions are summarized below and the various cross-sections are presented in Figures 2.2-1 through Figure 2.5-1.

2.2 Units 1 and 2 Centerline, Cross-Section B-B

Cross-Section B-B (Figure 2.2-1) represents bedrock conditions at the centerline of both the Unit 1 and Unit 2 NI, which includes the Annex Building. The new Unit 1 NI basemat will be constructed over an average of about 15 feet of existing fill concrete and structural basemat concrete from the former CNS Unit 1 plant foundation, and the Annex Building is constructed on approximately 50 feet of engineered backfill. The Unit 2 NI basemat is founded on hard rock and the Annex Building is constructed on about 30 feet of engineered fill. The Unit 1 rock shear wave velocity for this section ranges from about 9297 fps to about 9559 fps as shown in Base Case A1 (Figure 2.5-2), and Unit 2 rock shear wave velocity for this section ranges from about 8391 fps to about 9890 fps as shown in Profile C (Figure 2.5-4).

2.3 Unit 1 Northwest Corner, Cross-Sections Y-Y and U-U

Cross-Section Y-Y (Figure 2.3-1) and Cross-Section U-U (Figure 2.3-2) represent bedrock conditions at the Northwest corner of the NI and Annex Building. In this area, the Duke Lee Unit 1 NI overlies a localized zone of weathered and fractured rock, extending approximately 15 to 25 feet deep, below the Unit 1 basemat footprint El. 550.5 feet. This minor localized weathered zone of rock exhibits lower Vs velocities, ranging from approximately 4500 to 6000 fps, than the underlying and adjacent sound rock with average Vs of approximately 9,500 fps. Excavation of this isolated lower velocity material to continuous rock at the Northwest corner of Duke Lee Unit 1 nuclear island to a depth of 15 to 25 feet below basemat will remove a significant portion of the lower velocity weathered rock, and extend the excavation deeper within the support zone beyond the Duke Lee Unit 1 nuclear island footprint. Engineered fill beneath the Annex Building is

approximately 60 to 70 feet deep, and is underlain by fill concrete below the NI basemat. The Unit 1 rock shear wave velocity for the Northwest section ranges from about 5348 fps to approximately 9242 fps as shown in Base Case B3-1 (Figure 2.5-3). Cross-section U-U is presented in Figure 2.3.2, which indicates the pertinent borings within the Unit 1 NW corner area where engineered fill strain compatible dynamic properties were derived in DUK010-FSAR-2.5.2-CALC-015 (Reference 7).

2.4 Unit 1 South, Cross-Section Z-Z

Cross-Section Z-Z (Figure 2.4-1) represents bedrock conditions beneath the southern end of the Unit 1 NI and Annex Building. The new NI basemat will bear on a thin layer of fill concrete, which bears directly on high-velocity rock. The rock shear wave velocity ranges from about 8,000 fps to 9,800 fps. The Annex Building bears on approximately 50 feet of engineered fill and a portion of an approximately 10-foot thick concrete CNS foundation. The Unit 1 rock shear wave velocity for this section ranges from about 6,000 fps to about 9,800 fps as shown in Base Case A1 (Figure 2.5-2).

2.5 Unit 2 Centerline with Turbine Building Cross-Section F-F

Cross-Section F-F (Figure 2.5-1) represents bedrock conditions beneath the Unit 2 NI and Turbine Building. The Unit 2 NI basemat is founded on hard rock and the Turbine Building is constructed on about 30 feet of engineered fill. The Unit 2 rock shear wave velocity for this section ranges from about 8391 fps to about 9890 fps as shown in Profile C (Figure 2.5-4).

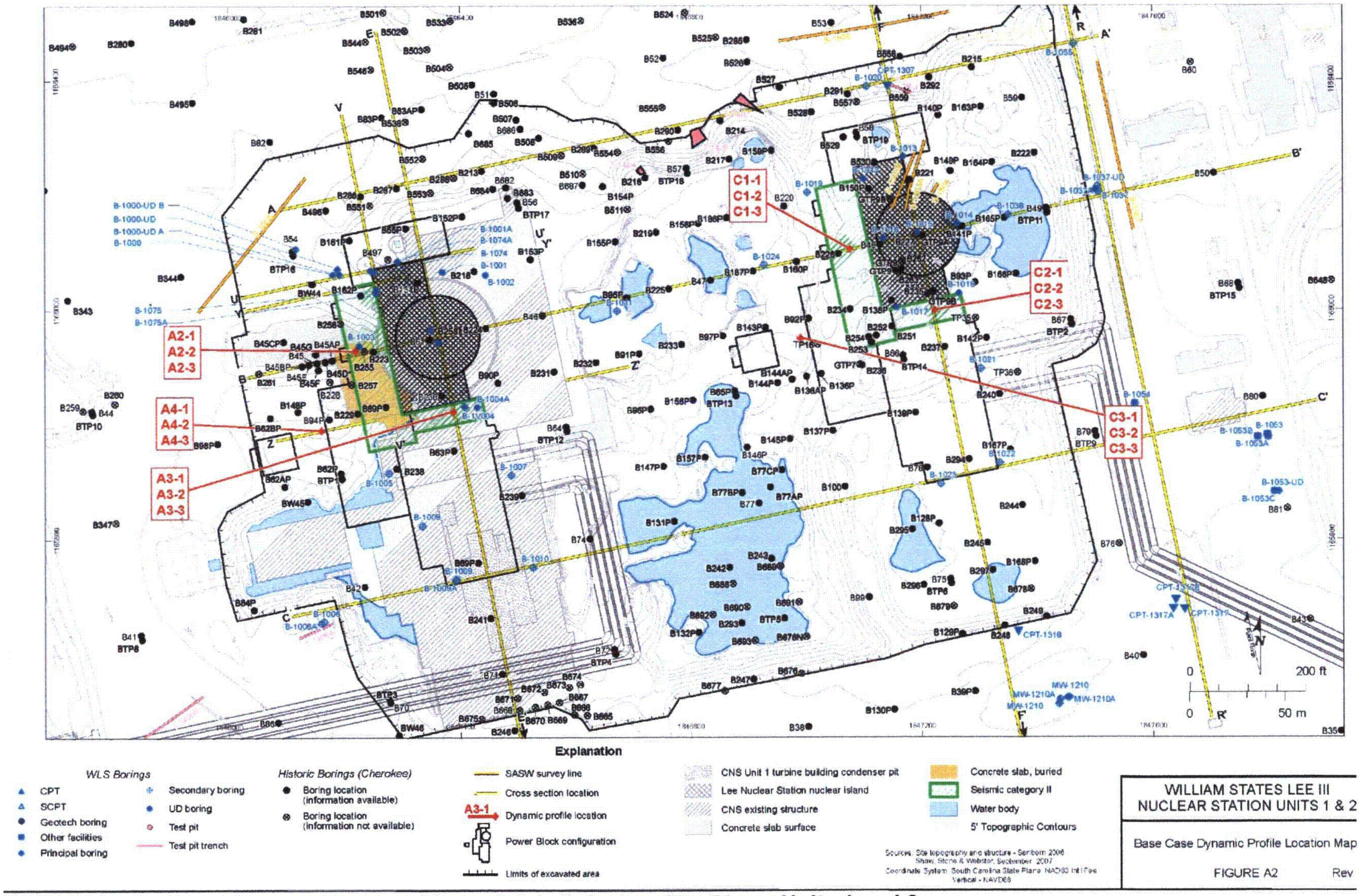

Figure 2.1-1: Duke Lee Site Plan – Units 1 and 2

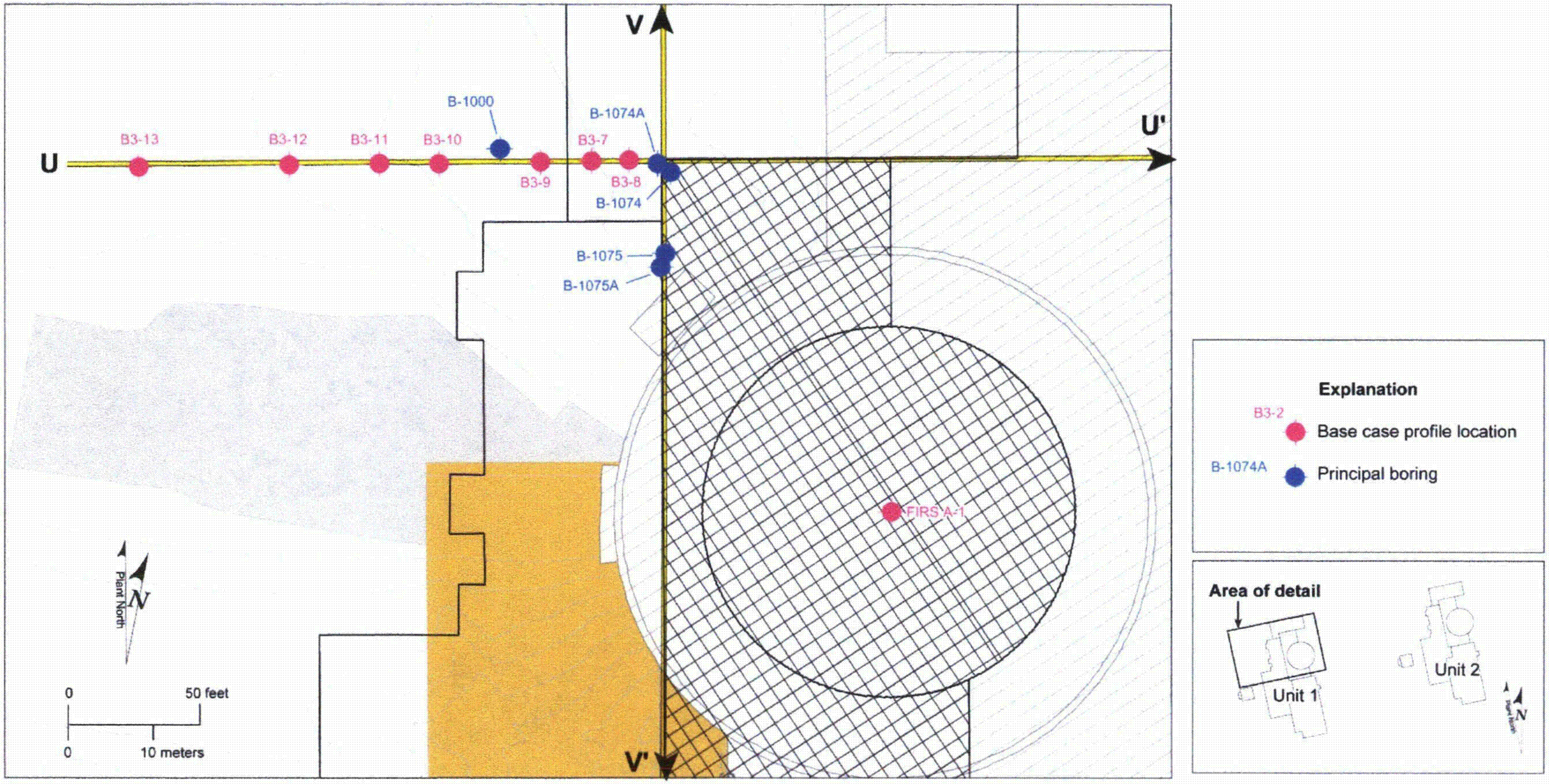

Figure 2.1-2: Duke Lee Site Plan – Unit 1 Northwest Corner

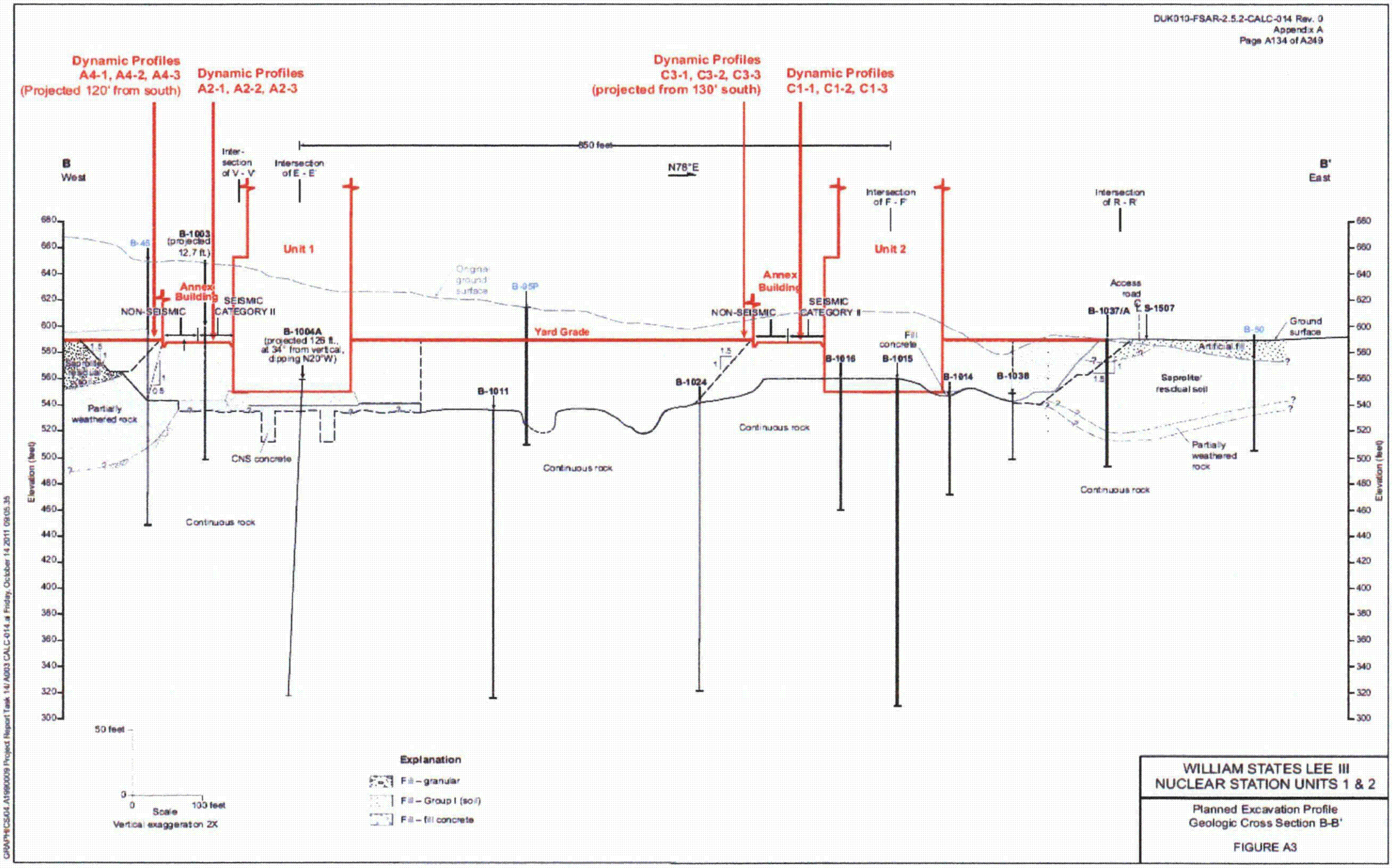

Figure 2.2-1: Cross-Section B-B

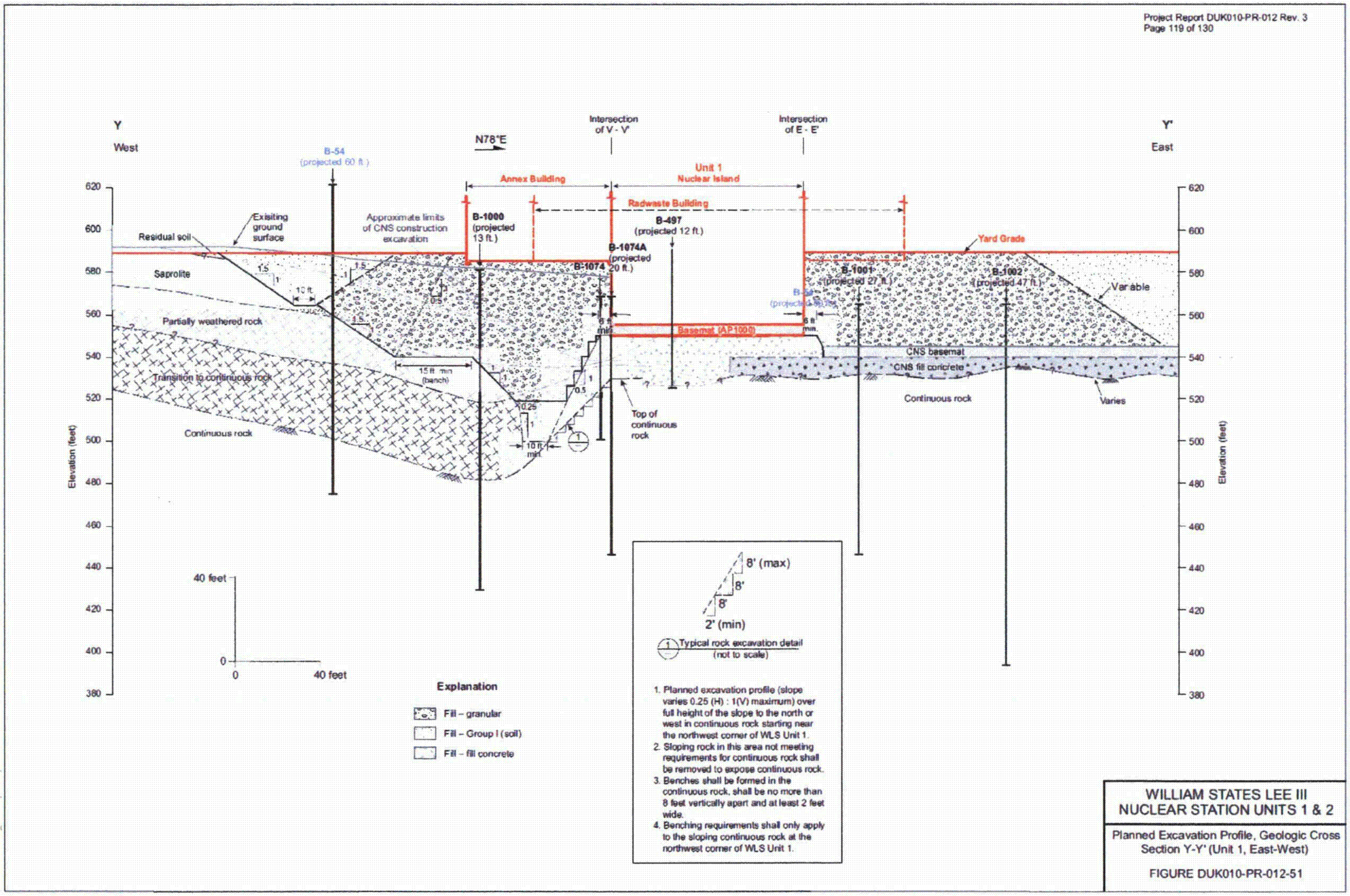

Figure 2.3-1: Cross-Section Y-Y

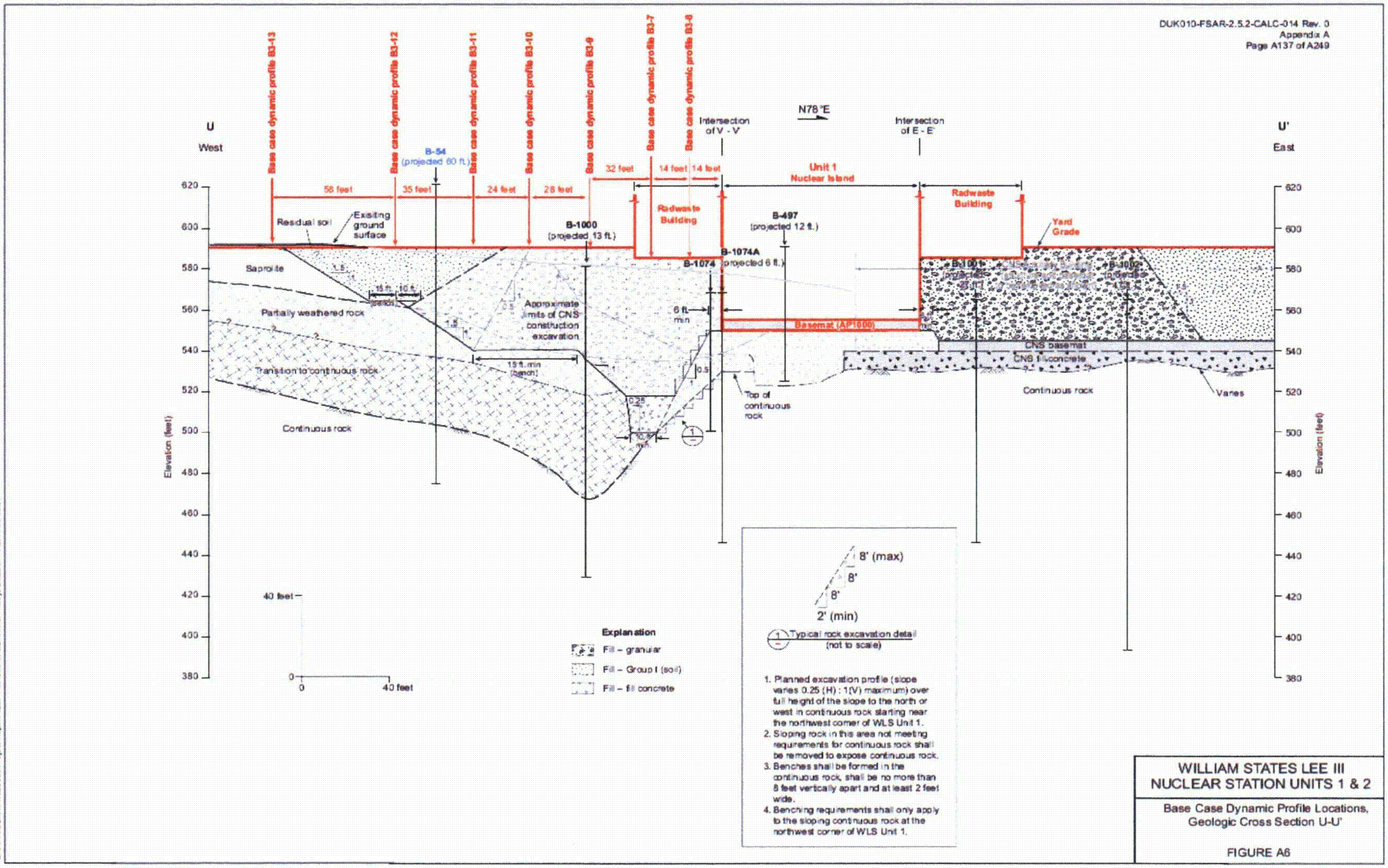

Figure 2.3-2: Cross-Section U-U

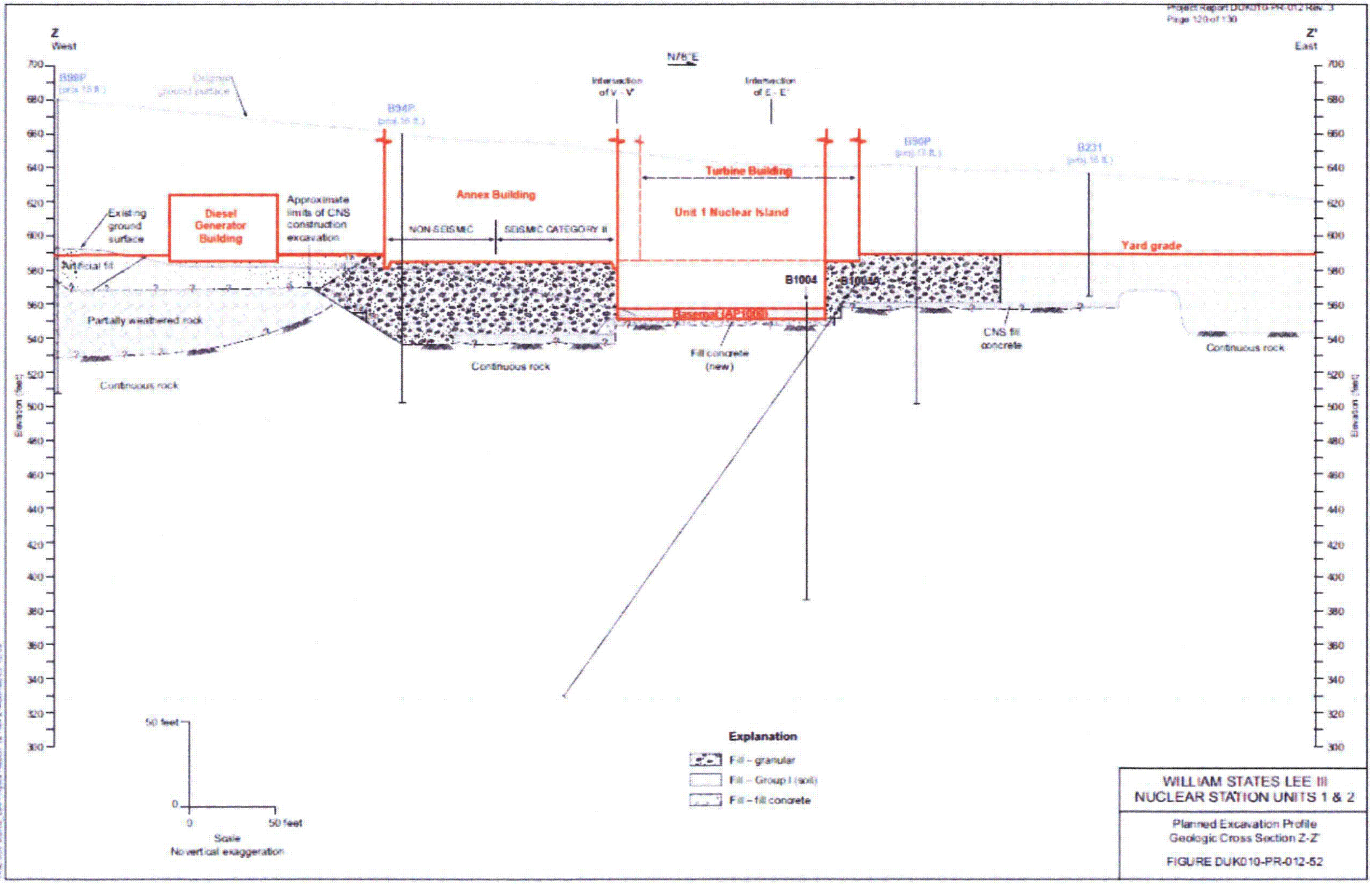

Figure 2.4-1: Cross-Section Z-Z

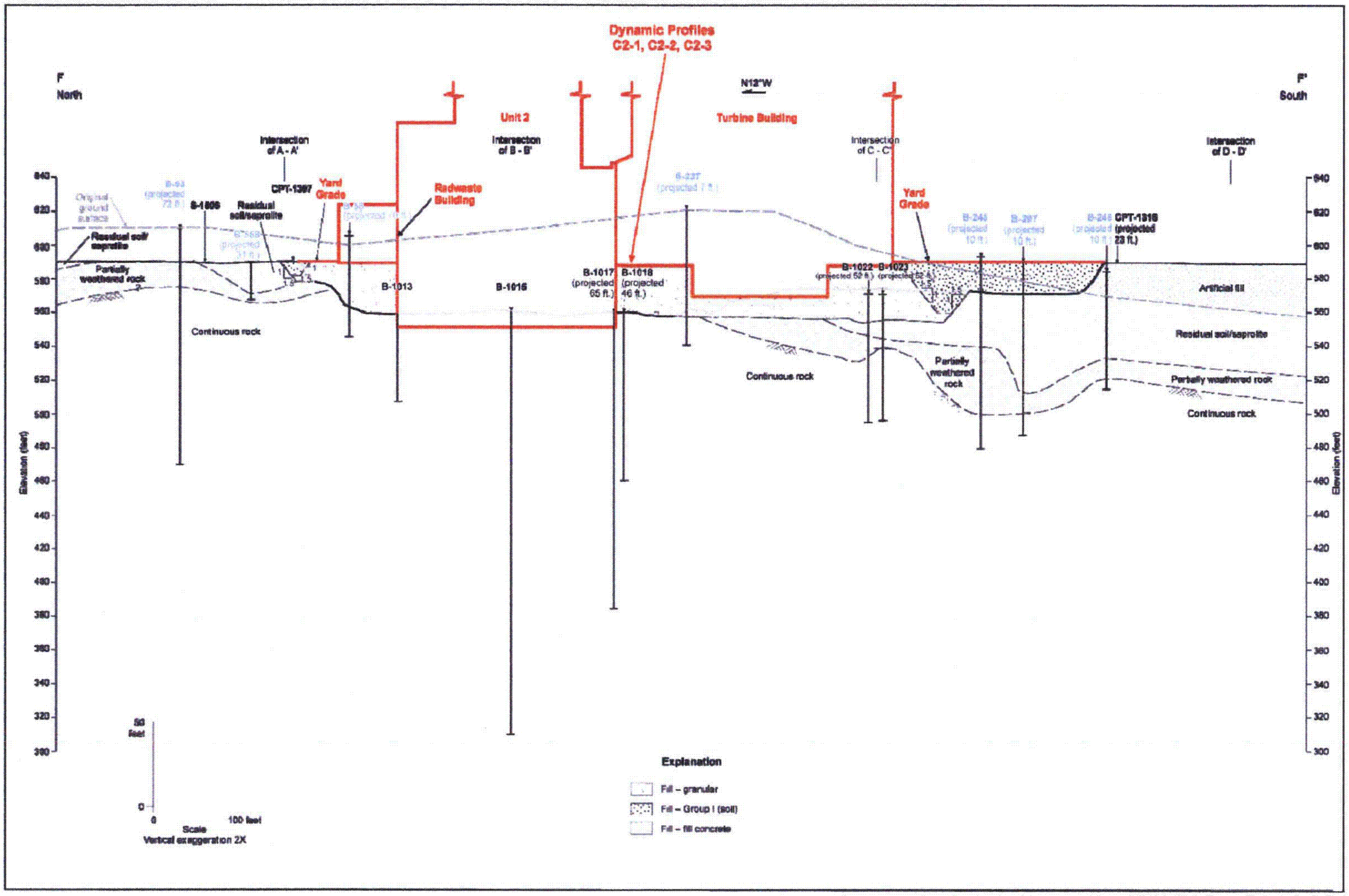

Figure 2.5-1: Cross-Section F-F

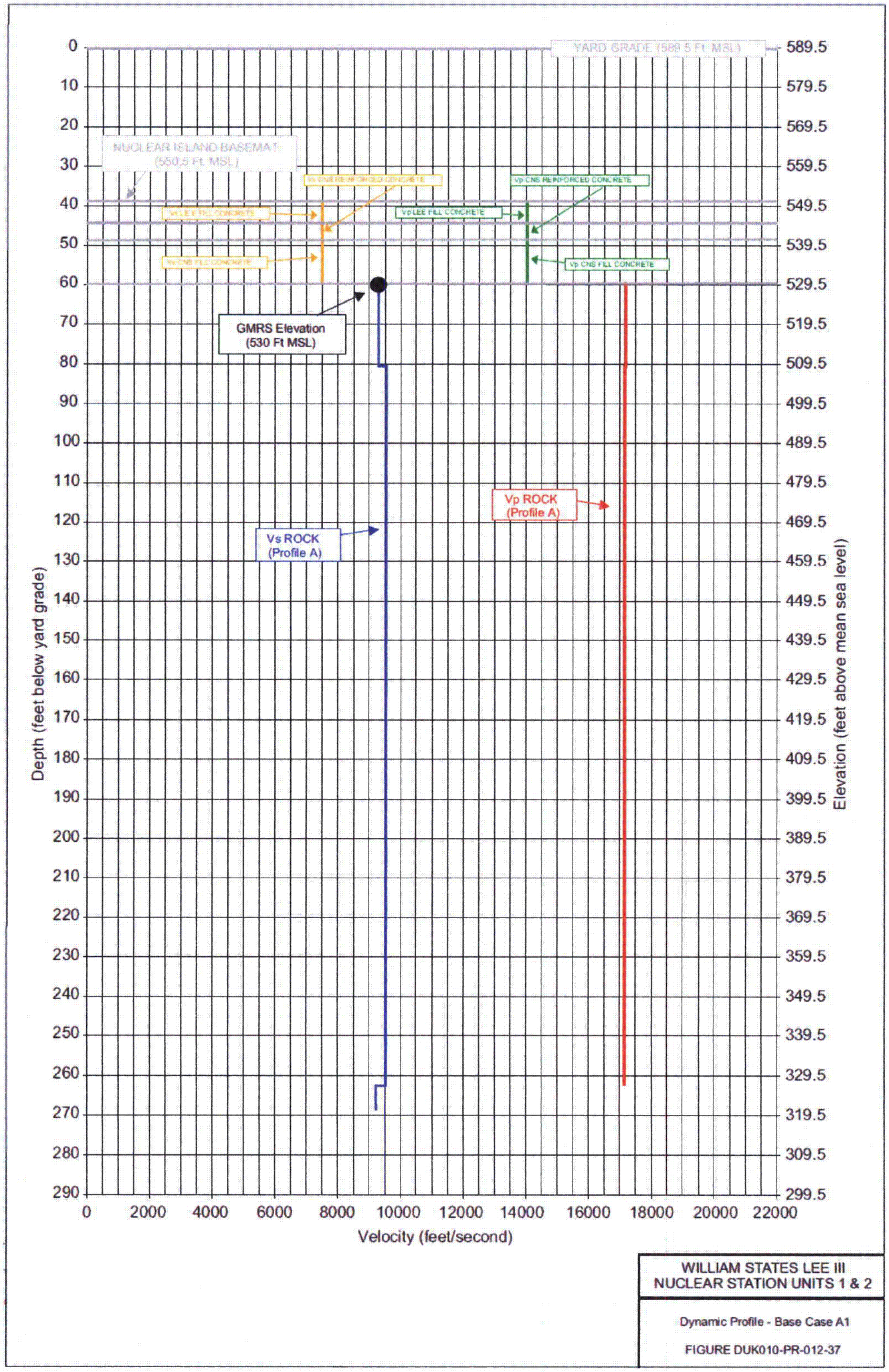

Figure 2.5-2: Base Case A1 Dynamic Profile – Unit 1 NI Centerline

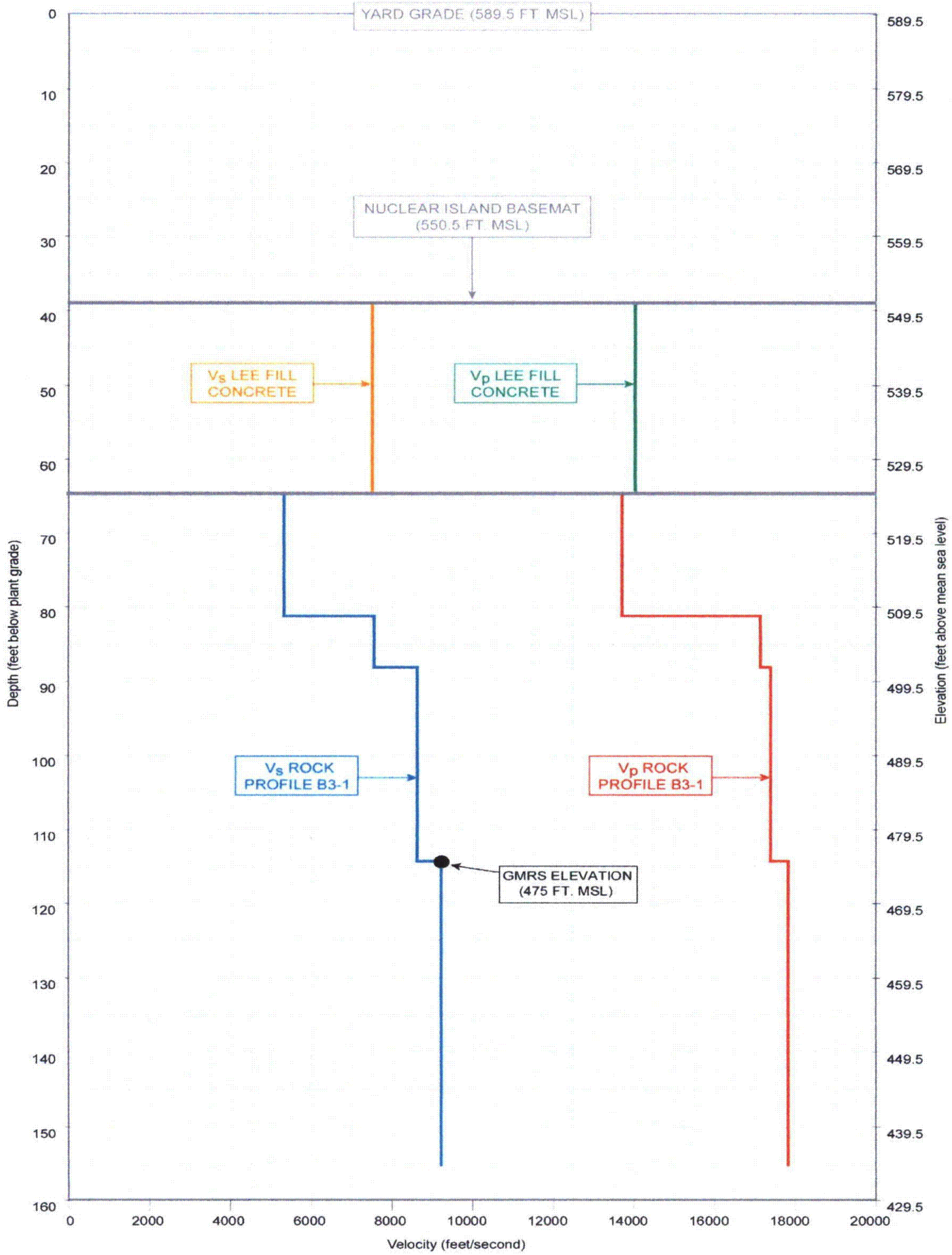

Figure 2.5-3: Base Case B3-1 Dynamic Profile – Unit 1 Northwest Corner

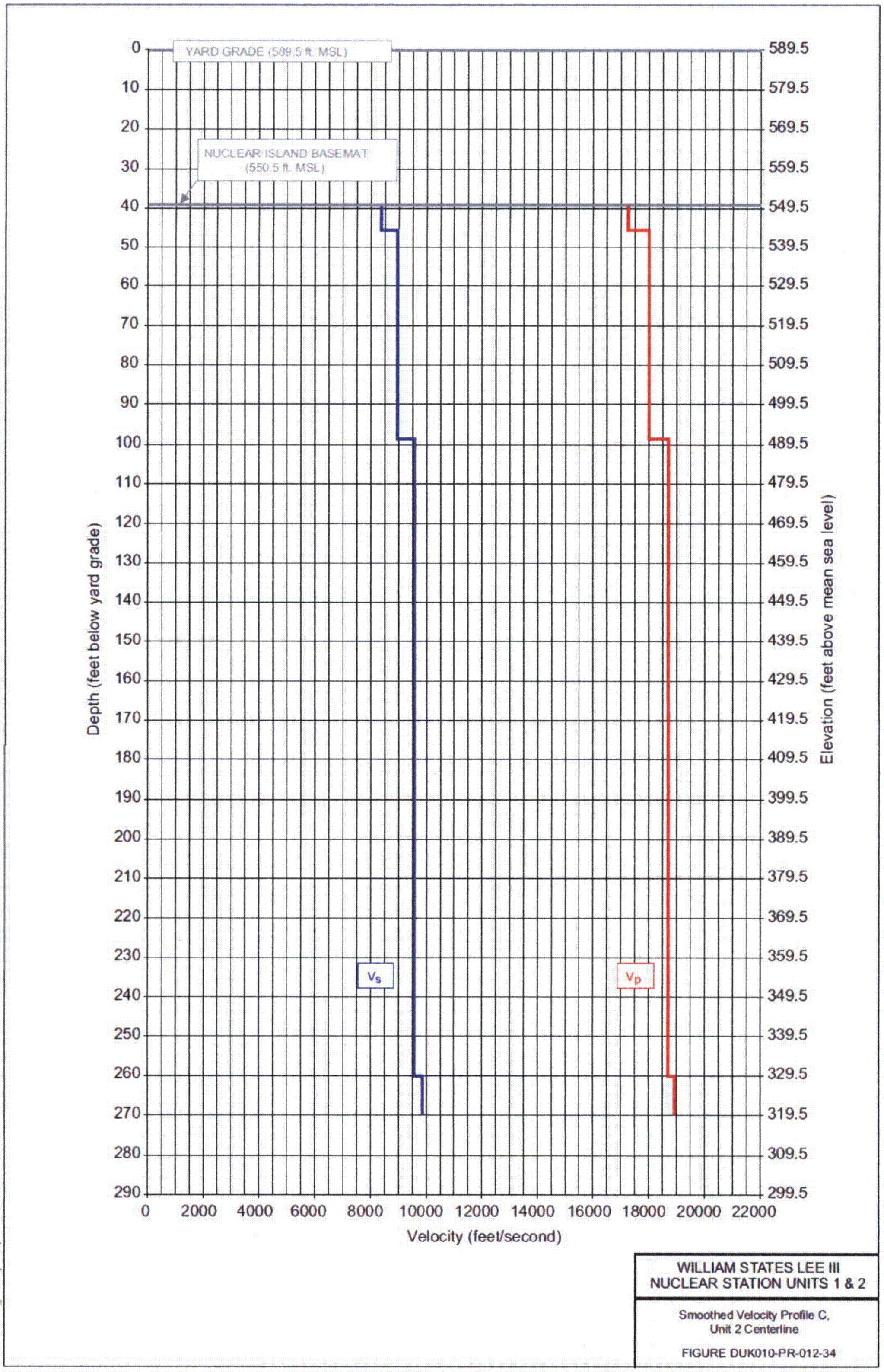

Figure 2.5-4: Smoothed Velocity Profile C, Unit 2 Centerline

3.0 WLS Analysis Dynamic Soil Properties

Three candidate backfill materials were initially proposed beneath the Duke Lee Units 1 and 2 SCII adjacent structures. Backfill material properties and their uncertainty as used to calculate site response surface spectra and strain compatible soil properties was addressed in various calculations provided by Duke.

Of particular interest for the Duke Lee SCII adjacent structures SSI analysis is the range of uncertainty and the Coefficient of Variability (COV) of nonlinear dynamic properties associated with planned GW granular engineered fill placed adjacent to the NI and extending outwards to form the foundation support for the SCII Annex Building and Turbine Building 1st Bay, and the non-seismic portions of the Annex, Turbine and Radwaste buildings. WEC understands that the best-estimate (BE) granular fill dynamic material properties were developed using published typical engineering values as no granular fill test samples have been tested in the laboratory.

As described in Reference 10 Technical Requirements Document provided by Duke, the development of maximum shear modulus, modulus ratio and damping ratio of granular fill material is presented. This reference also presents the methods used to derive empirical maximum shear modulus, corresponding shear wave velocity, the elastic modulus values and corresponding Poisson's ratio and compression wave velocities for engineered granular fill that will be used to support foundations for the SCII structures. The values presented include Best Estimate (BE) (mean) parameters. The bounding values are Lower Bound Estimate (LB) = BE/(1+COV) and Upper Bound Estimate (UB) = BE*(1+COV) with COV = σ (mean). This approach results in a wide distribution of UB and LB values that is intended to encompass the complete range of soil variability.

The BE dynamic soil properties initially used in site response analysis involving granular fill are consistent with BE material properties described in calculation package DUK010-FSAR-2.5.4-CALC-015, Rev. 1 maximum shear modulus, modulus ratio and damping ratio of granular fill material. However, in the development of performance-based surface response spectra, DUK010-FSAR-2.5.2-CALC-014 Rev. 0 applied a COV higher than 0.5 (shear modulus) which was considered to be conservative for determining the LB and UB properties of the granular fill.

In the case of Duke Lee, uncertainties associated with site conditions are well characterized based on detailed site investigations, including in situ and laboratory testing, and planned controls on post-construction configuration. These detailed evaluations coupled with the planned placement of a well-controlled engineered granular fill, compacted to a minimum relative compaction of 96 percent of the modified Proctor maximum dry density, in critical foundation support areas (e.g., beneath SCII structures) should be considered as a factor in assigning site uncertainty values (COV) to dynamic material properties used in SSI evaluations of SCII structures for the Duke Lee site.

For well investigated sites, such as the Duke Lee site, consideration for reducing the uncertainty (COV) assigned to granular fill dynamic material properties is supported in NUREG-0800, SRP Section 3.7.2. SRP Section 3.7.2 allows for a COV of no less than 0.5 for well-investigated sites (refer to RGs 1.132 and 1.138). A COV = 0.5 can be justified for the granular fill at the Duke Lee site. In no case did the material soil damping as expressed by the hysteretic damping ratio exceed 15 percent.

Tables 3-1 to 3-4 present average BE strain-compatible dynamic soil properties for the cited base cases (e.g., A3, C3) for the various low, medium and high groundwater conditions, which were used to develop the lower bound and upper bound ranges of properties for GW engineered granular backfill, and is further described in Section 5.3. The soil unit weight of the GW backfill was 150 pounds per cubic foot (pcf) and provided in Reference 1. Table 3-5 presents BE properties of the concrete for the existing CNS basemat and the existing CNS concrete fill of the former CNS Unit 1, as well as the new fill concrete for construction of the Duke Lee Units 1 and 2.

Table 3-1: GW 40-Foot BE Site-Specific Dynamic Soil Properties

		GW40 BE	A3, C3	Low, Med, High - AVERAGE	
LAYER	THICK(FT)	DEPTH(FT)	MED. VS(FT/SEC)	MED. VP(FT/SEC)	MED. DAMPS(%)
1	0.492	0.246	735.603	1327.450	1.047
2	4.987	2.986	550.118	2578.950	5.978
3	2.494	6.726	543.007	2768.133	7.712
4	2.494	9.22	474.897	2768.133	8.941
5	2.494	11.714	615.385	4058.150	8.114
6	2.494	14.208	572.175	4058.150	8.847
7	2.247	16.578	663.495	5371.683	8.462
8	2.247	18.825	633.640	5371.683	8.952
9	3.117	21.507	630.775	4992.550	9.327
10	1.411	23.772	606.470	4992.550	9.680
11	1.706	25.33	590.465	4992.550	9.897
12	3.281	27.823	567.230	4992.550	10.196
13	0.492	29.71	552.700	4992.550	10.389
14	2.494	31.203	688.210	4979.300	9.768
15	1.969	33.435	670.248	4979.300	9.998
16	2.264	35.551	655.193	4979.300	10.182
17	2.297	37.832	641.638	4979.300	10.338
18	0.427	39.194	634.833	4979.300	10.414
19	0.066	39.44	633.832	4979.300	10.426
20	0.492	39.719	4507.462	11038.200	5.752
21	0.525	40.228	4573.277	11105.400	5.169
22	0.689	40.835	4571.933	11105.400	5.184
23	0.886	41.622	7246.350	14563.500	0.500
24	3.412	43.771	7246.350	14563.500	0.500
25	0.066	45.51	7246.350	14563.500	0.500
26	1.509	46.298	6963.200	13783.000	0.500
27	2.822	48.463	6963.200	13783.000	0.500
28	1.312	50.53	6963.200	13783.000	0.500
29	0.558	51.465	7558.150	14653.500	0.500
30	0.853	52.171	7893.800	15236.500	0.500
31	5.99	55.592	7909.433	15206.000	0.500
32	3.281	60.228	8546.850	16419.000	0.500

Table 3-2: GW 30-Foot BE Site-Specific Dynamic Soil Properties

LAYER	THICK(FT)	GW30 BE DEPTH(FT)	C1, C2 Low, Med, High - AVERAGE MED. VS(FT/SEC)	MED. VP(FT/SEC)	MED. DAMPS(%)
1	0.492	0.246	674.195	1230.400	1.259
2	4.987	2.986	455.068	1842.550	7.347
3	2.494	6.726	455.757	2557.150	9.234
4	2.494	9.22	394.765	2557.150	10.369
5	2.494	11.714	616.102	4100.600	8.581
6	2.494	14.208	573.770	4100.600	9.305
7	2.247	16.578	566.037	5096.767	9.335
8	2.247	18.825	536.993	5096.767	9.740
9	5.611	22.755	638.293	5073.650	9.630
10	3.904	27.512	605.568	5073.650	10.045
11	1.706	30.317	4089.628	10324.350	5.171
12	3.281	32.81	4080.543	10324.350	5.286
13	0.492	34.697	7787.100	16003.000	0.500
14	2.494	36.19	7787.100	16003.000	0.500
15	1.969	38.421	7787.100	16003.000	0.500
16	2.264	40.538	7787.100	16003.000	0.500
17	2.297	42.818	7787.100	16003.000	0.500
18	0.427	44.18	7787.100	16003.000	0.500
19	0.066	44.427	7787.100	16003.000	0.500
20	0.492	44.706	7787.100	16003.000	0.500
21	0.525	45.215	7787.100	16003.000	0.500
22	54.866	72.91	8181.650	16644.500	0.500
23	3.281	101.984	8698.000	17684.500	0.500

Table 3-3: GW 50-Foot BE Site-Specific Dynamic Soil Properties

LAYER	THICK(FT)	GW50 BE DEPTH(FT)	MED. VS(FT/SEC)	A2, A4 Low, Med, High - AVERAGE MED. VP(FT/SEC)	MED. DAMPS(%)
1	0.492	0.246	740.910	1336.633	1.024
2	4.987	2.986	557.930	1948.517	5.691
3	2.494	6.726	520.057	2679.983	7.744
4	2.494	9.22	453.385	2679.983	8.952
5	2.494	11.714	603.155	3967.583	8.223
6	2.494	14.208	560.168	3967.583	8.979
7	2.247	16.578	568.372	4934.433	9.177
8	2.247	18.825	539.900	4934.433	9.638
9	3.117	21.507	647.637	4972.317	9.086
10	1.411	23.772	623.052	4972.317	9.466
11	1.706	25.33	607.487	4972.317	9.700
12	3.281	27.823	584.522	4972.317	10.028
13	0.492	29.71	569.673	4972.317	10.242
14	2.494	31.203	673.815	4866.133	9.798
15	1.969	33.435	655.447	4866.133	10.039
16	2.264	35.551	639.628	4866.133	10.239
17	2.297	37.832	624.395	4866.133	10.423
18	0.427	39.194	616.227	4866.133	10.520
19	0.066	39.44	614.858	4866.133	10.536
20	0.492	39.719	613.345	4866.133	10.555
21	2.165	41.048	741.488	4957.378	9.554
22	2.33	43.295	728.340	4957.378	9.707
23	2.592	45.756	732.957	5012.283	9.699
24	3.412	48.758	4750.117	10234.189	3.748
25	0.066	50.497	6788.317	12927.500	0.500
26	1.509	51.285	7375.183	13782.167	0.500
27	2.822	53.45	7703.017	14351.167	0.500
28	3.988	56.855	7968.267	14681.000	0.500
29	3.281	60.49	9424.583	17495.000	0.500

Table 3-4: GW NW BE Site-Specific Dynamic Soil Properties

LAYER	THICK(FT)	GWNW BE DEPTH(FT)	B3-7, B3-8, B3-9, B3-10 Low, Med, High - AVERAGE MED. VS(FT/SEC)	MED. VP(FT/SEC)	MED. DAMPS(%)
1	0.492	0.246	731.167	1319.275	1.052
2	2.494	1.739	613.806	1319.275	3.920
3	2.494	4.233	481.830	1319.275	7.373
4	2.494	6.727	562.793	2777.700	7.597
5	2.494	9.221	495.926	2777.700	8.843
6	2.494	11.715	616.913	4022.825	8.127
7	2.494	14.209	573.101	4022.825	8.878
8	2.247	16.579	629.134	5235.575	8.671
9	2.247	18.826	599.338	5235.575	9.130
10	3.336	21.618	667.653	5075.308	9.061
11	3.336	24.954	633.771	5075.308	9.587
12	3.335	28.289	604.733	5075.308	10.022
13	3.336	31.625	677.384	4906.075	9.889
14	3.336	34.961	652.488	4906.075	10.233
15	3.335	38.296	630.142	4906.075	10.521
16	3.336	41.632	709.275	4853.550	10.042
17	3.336	44.968	689.455	4853.550	10.285
18	3.335	48.303	671.795	4853.550	10.491
19	3.336	51.639	1362.086	5713.625	7.514
20	3.336	54.975	1349.928	5713.625	7.658
21	3.335	58.31	3602.465	8834.750	2.947
22	3.336	61.646	3664.683	8959.450	2.542
23	3.336	64.982	3660.822	8959.450	2.588
24	3.335	68.317	3657.508	8959.450	2.627
25	1.509	70.739	3139.510	8861.975	2.649
26	18.013	80.5	7638.200	15768.500	0.500
27	22.965	100.989	7877.025	15932.750	0.500
28	3.281	114.112	9267.825	17270.750	0.500

Table 3-5: Additional Site-Specific Dynamic Properties

Concrete Dynamic Properties					
Total Unit Wt. (kcf)	Vs (fps)	Damping (%)	Vp (fps)	Damping (%)	Materials
0.150	7500	0.5	14031	0.5	Fill Concrete (New)
0.150	7500	0.5	14031	0.5	Existing CNS Fill Concrete
0.150	7500	0.5	14031	0.5	Existing CNS Basemat

4.0 Duke Lee Site-Specific Seismic Inputs

As described in Section 1.0, changes to the Duke Lee site specific configuration and supporting documentation were made since the last revision including the development of numerous backfill material and ground water dependent GW backfill surface PBSRS curves. Figures 4-1 and 4-2 present the dynamic property profile trees used to develop the various 30, 40, 50 and Northwest corner envelop profiles and corresponding PBSRS envelops.

Backfill/ground water dependent PBSRS curves were provided by Duke in DUK010_PR-040 Rev. 1 (Reference 8). A total of four (4) site response scenarios were determined by Duke to represent the enveloping model, backfill, and groundwater cases including:

1. Unit 2 East-West and North-South profile with 30 feet of backfill soil (10' less than DCD);
2. Unit 2 East-West and Unit 1 North-South profile with 40 feet of backfill soil (similar to DCD);
3. Unit 1 East-West profile with 50 feet of backfill soil (10' more than DCD); and
4. Unit 1 East-West in the Northwest corner with location specific backfill/concrete soil conditions.

DUK010-PR-040 Rev. 1 (Reference 8) and DUK010-FSAR-2.5.2-CALC-014 Rev. 1 (Reference 6) present the methodology for development of the PBSRS envelops, and the corresponding PBSRS for the backfill material and depths. The PBSRS envelop data was developed for three scenarios including:

PBSRS envelope for profiles with granular fill profiles less than the WEC DCD;
PBSRS envelope for profiles with granular fill profiles similar to WEC DCD;
PBSRS envelope for profiles with granular fill profiles greater than the WEC DCD;

Per Table 4-1, the 'thickness less than WEC DCD' envelope considered profiles with fill thickness of approximately 30 feet (C1 and C2), the 'thickness similar to WEC DCD' envelope considered profiles of approximately 40 feet (A3 and C3) and the 'thickness greater than WEC DCD' envelop considered profiles with fill thicknesses of 50 feet (A2 and A4). An additional envelop considered the Northwest corner of the Unit 1 Annex Building and the site-specific backfill and concrete materials, which considered profiles B3-7, B3-8, B3-9 and B3-10.

The following summarizes the various backfill material and envelop scenario PBSRS designations used to develop surface motion time histories presented in Section 4.1 and used in the corresponding SSI analyses.

Table 4-1: Duke Lee Envelop, Backfill and PBSRS Summary

Comparison to 39.5' WEC DCD Profile	Duke Lee Profiles	Backfill Envelope Thickness (feet)	Backfill Material	PBSRS Components
Thickness Less than WEC DCD	C1 and C2	30	GW	Horizontal (H) and Vertical (V)
Thickness Similar to WEC DCD	A3 and C3	40	GW	H, V
Thickness Greater than WEC DCD	A 2 and A4	50	GW	H, V
Northwest Corner	B3-7, B3-8, B3-9 and B3-10	Varies	GW	H, V

Figures 4-3 to 4-10 presents plots of the Duke Lee horizontal and vertical envelop PBSRS for the various envelop thickness and GW backfill material. PBSRS envelops for GP and SW are shown for information.

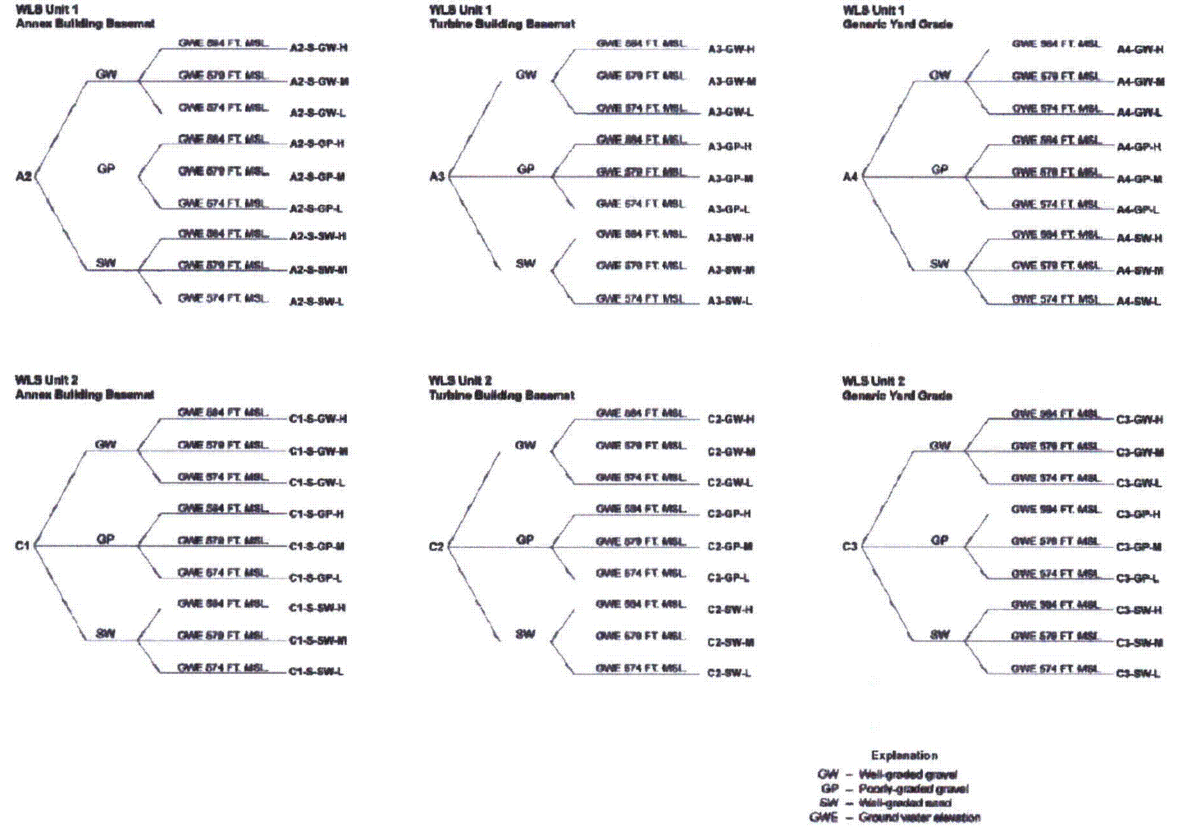

Figure 4-1: Dynamic Profile Parameter Trees – A2, A-3, A-4, C-1, C-2 and C-3

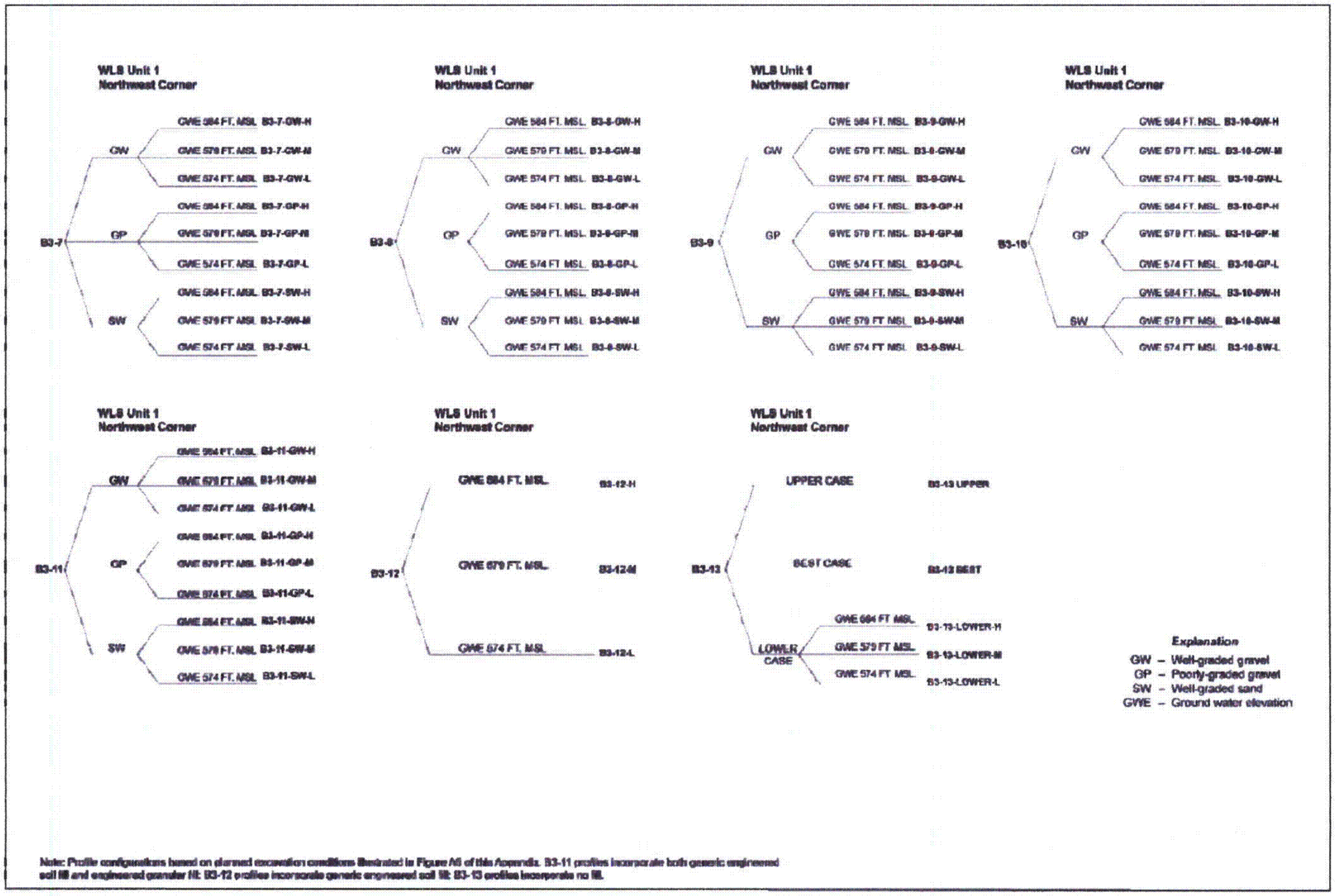

Figure 4-2: Dynamic Profile Parameter Trees – B3-7, B3-8, B3-9 and B3-10

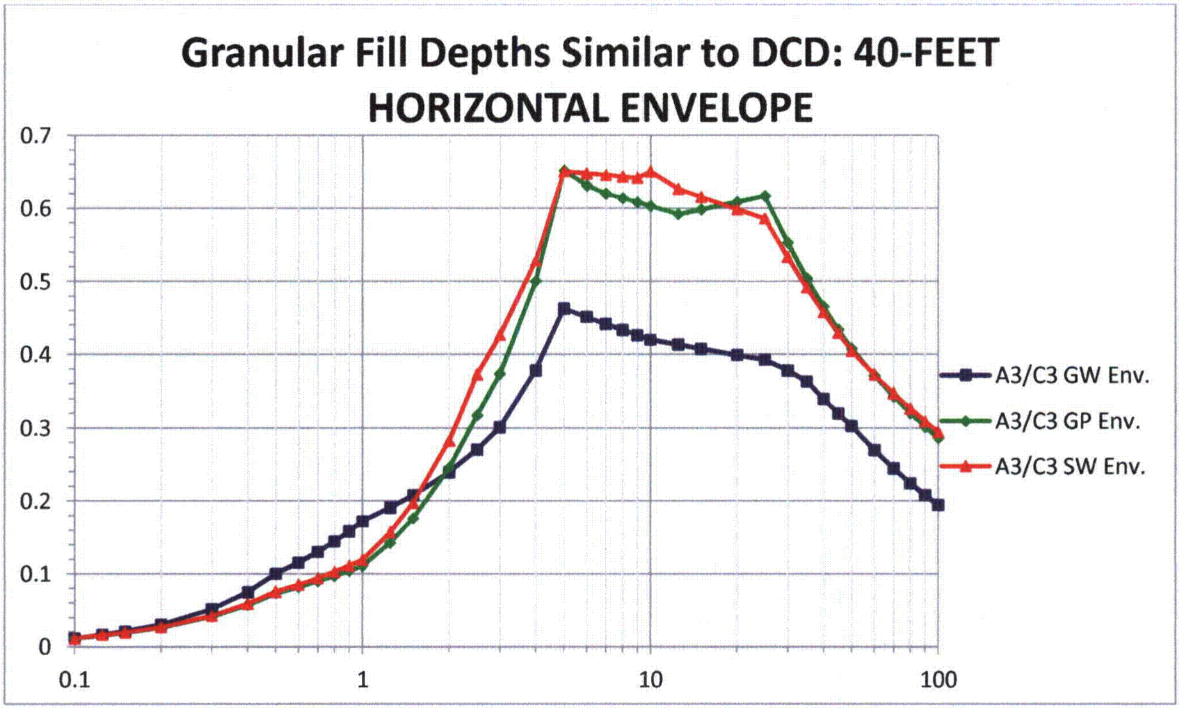

Figure 4-3: Duke Lee Unit 1 Center 40-Foot Backfill Soil Horizontal Surface FIRS at 5% Damping

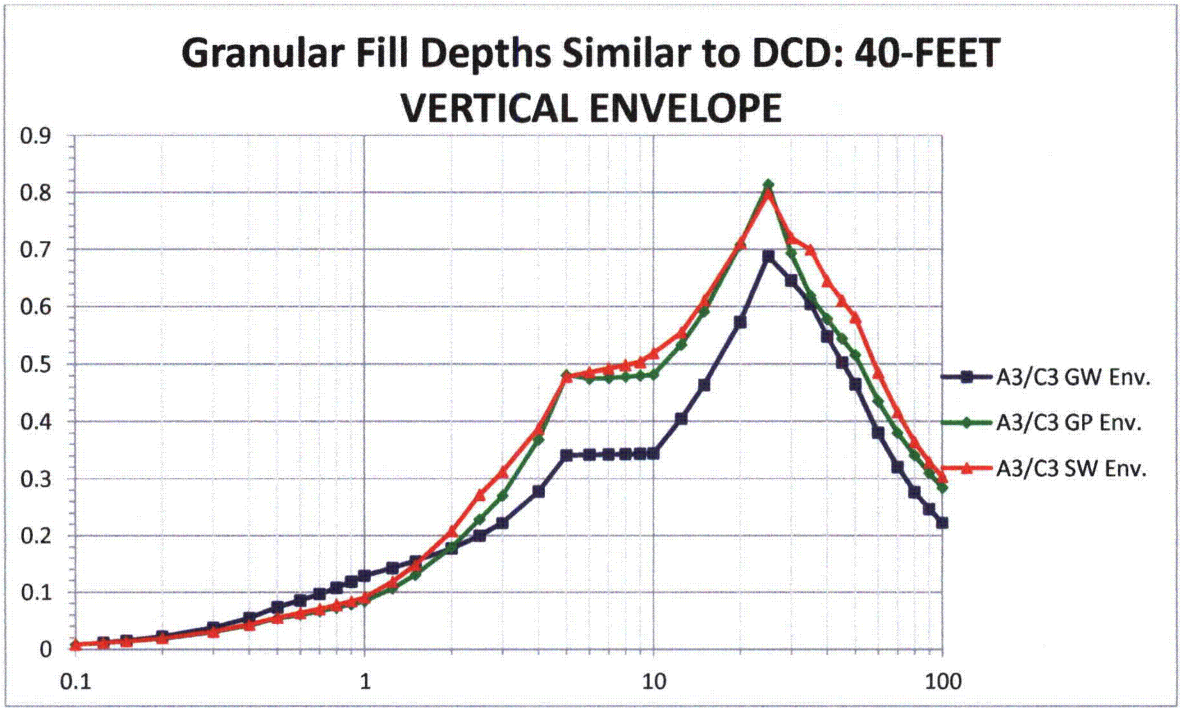

Figure 4-4: Duke Lee Unit 1 Center 40-Foot Backfill Soil Vertical Surface FIRS at 5% Damping

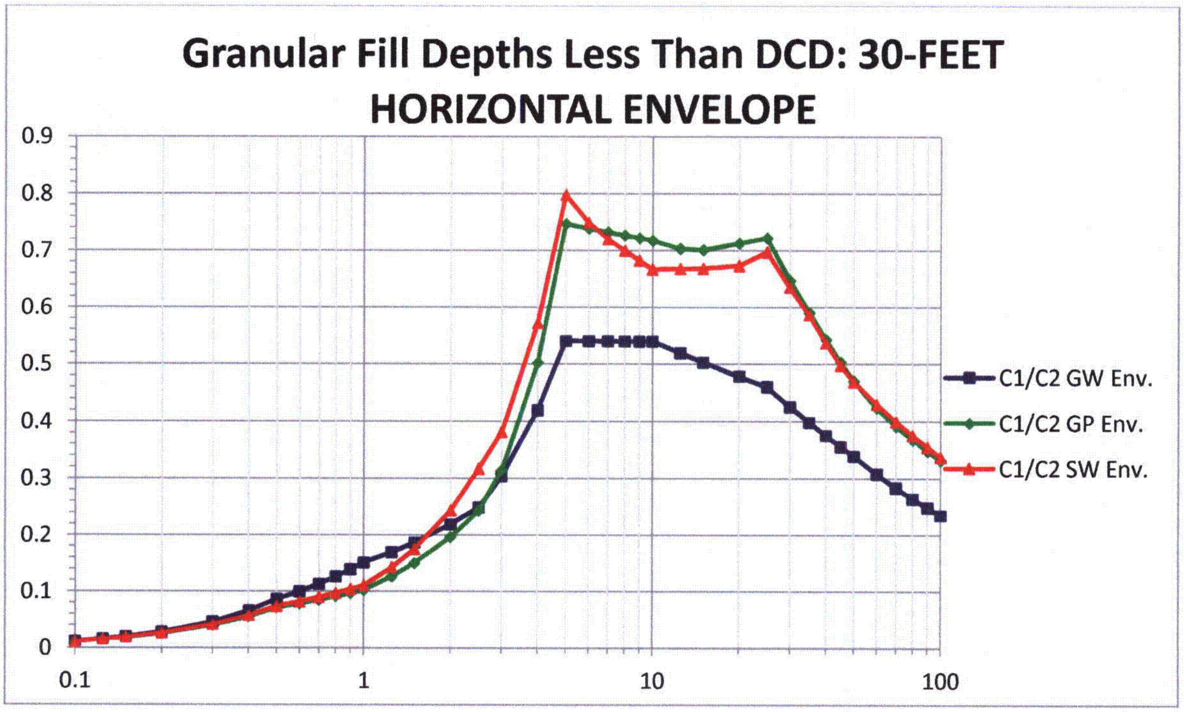

Figure 4-5: Duke Lee Unit 2 Center 30-Foot Backfill Soil Horizontal Surface FIRS at 5% Damping

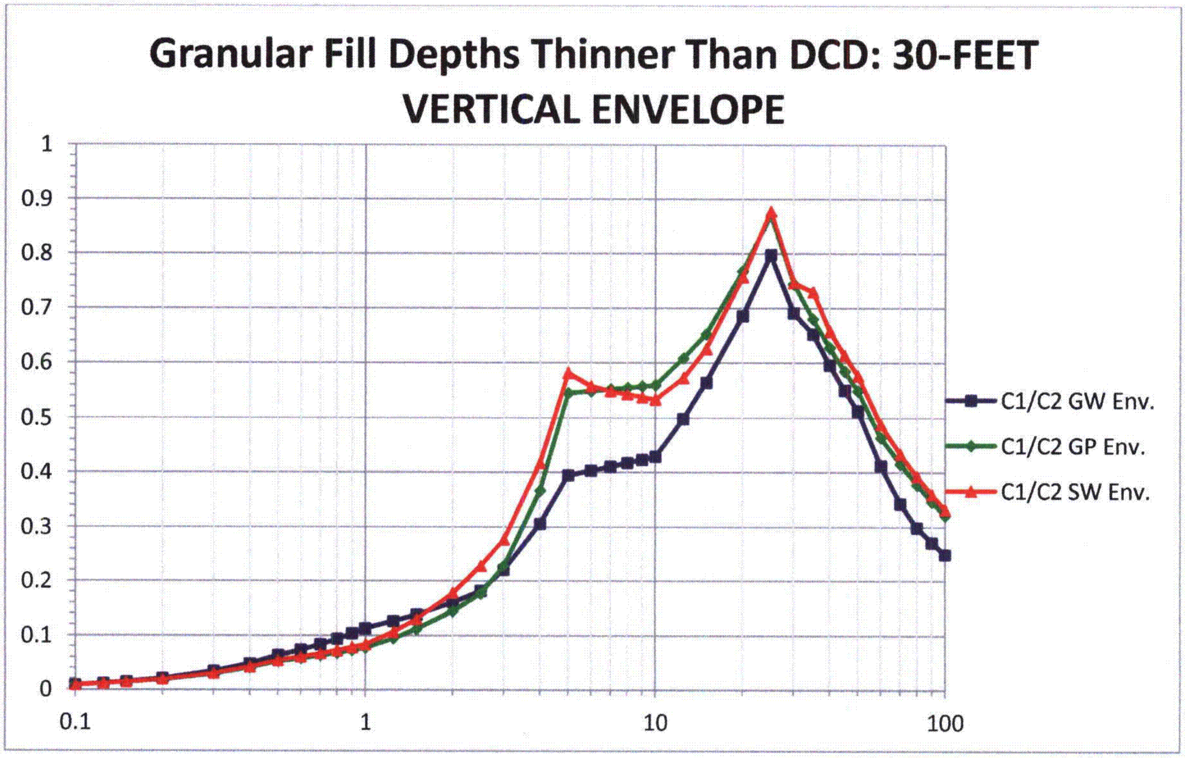

Figure 4-6: Duke Lee Unit 2 Center 30-Foot Backfill Soil Vertical Surface FIRS at 5% Damping

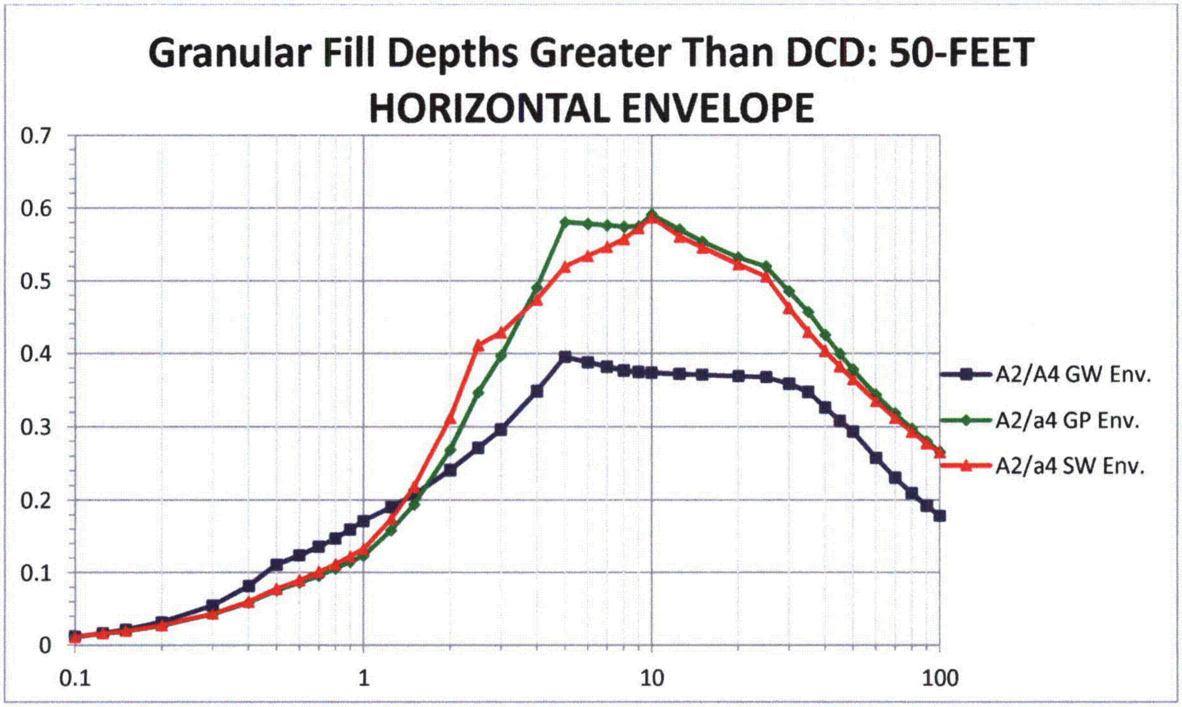

Figure 4-7: Duke Lee Unit 1 South 50-Foot Backfill Soil Horizontal Surface FIRS at 5% Damping

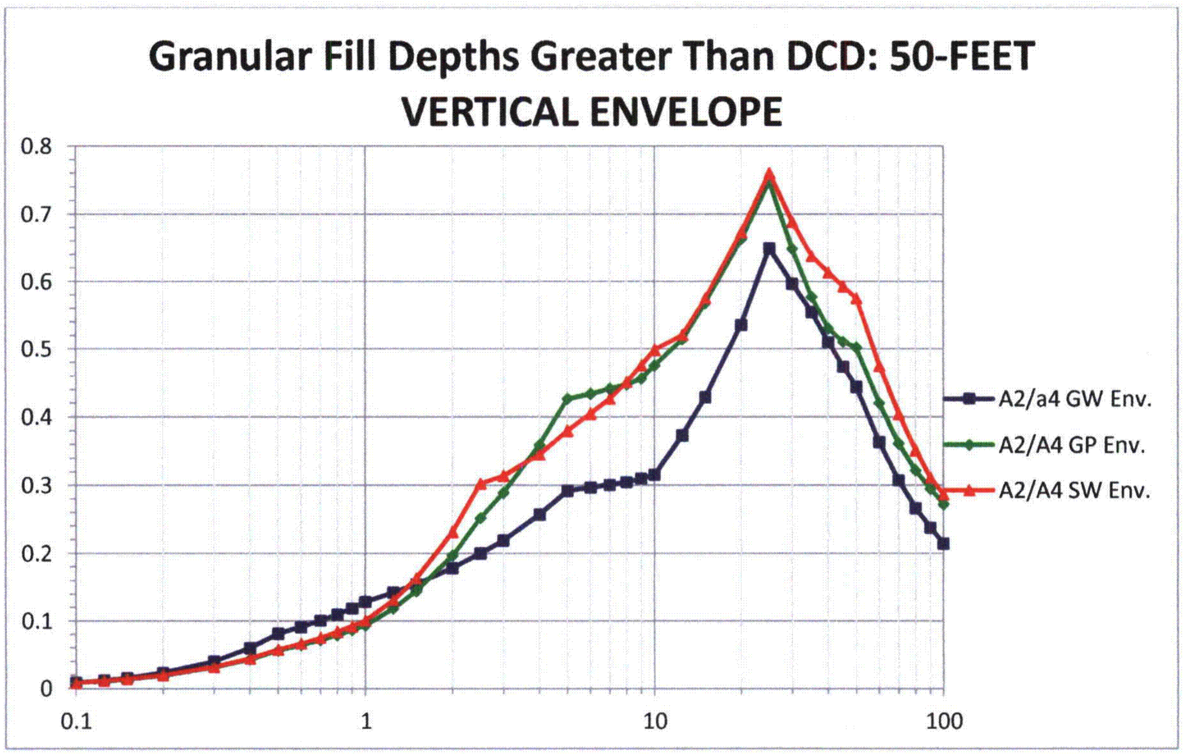

Figure 4-8: Duke Lee Unit 1 South 50-Foot Backfill Soil Vertical Surface FIRS at 5% Damping

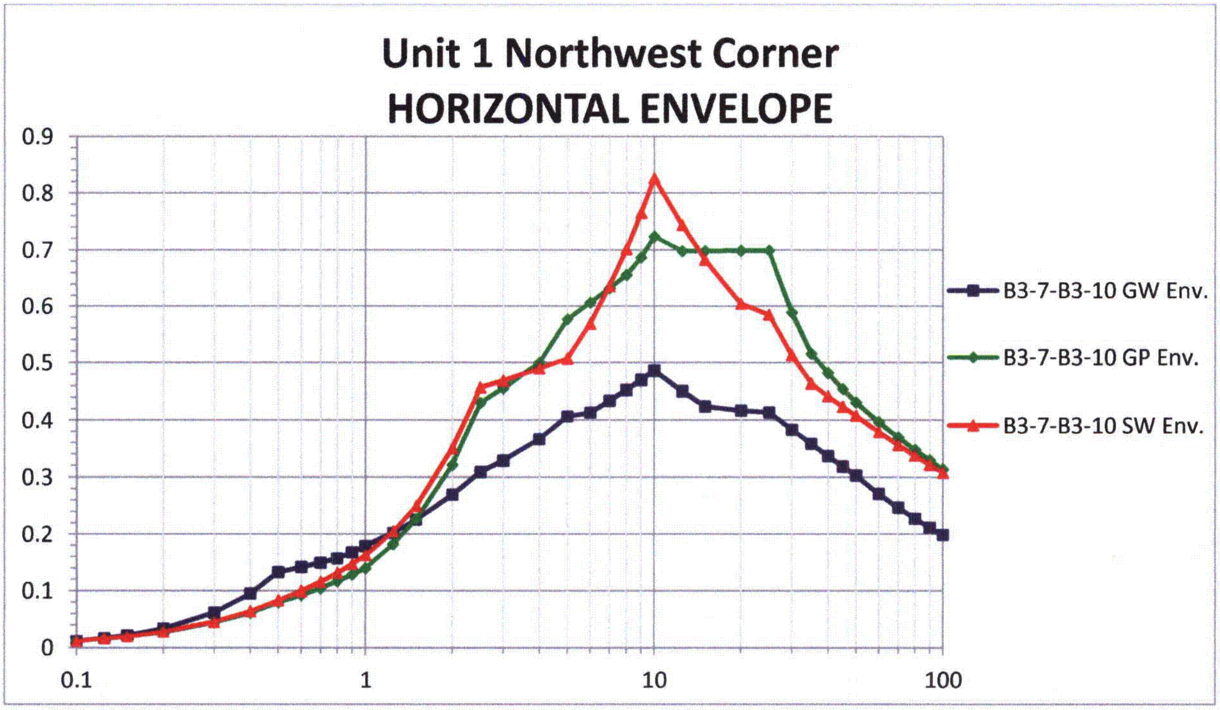

Figure 4-9: Duke Lee NW Corner Horizontal Surface FIRS at 5% Damping

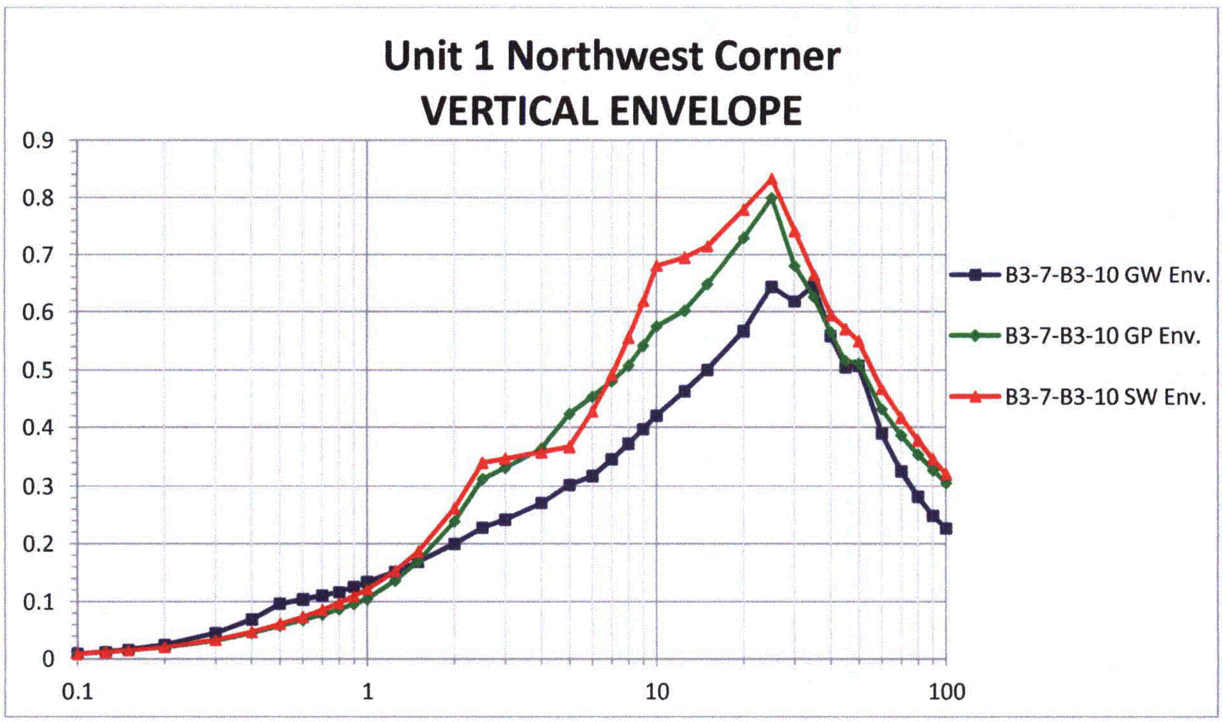

Figure 4-10: Duke Lee NW Corner Vertical Surface FIRS at 5% Damping

4.1 Time History Inputs – Surface Founded SCII Adjacent Structures

The Duke Lee surface PBSRS for the various backfill materials and thickness were provided by Duke and presented in Section 4.0. The corresponding acceleration time histories for the adjacent structures were developed by WEC and are presented in Figures 4.1-1 through 4.1-12. The input time histories are used as seismic input in two orthogonal directions at the ground surface (AP1000 El. 100) in the respective SSI analyses (X and Z for the Turbine building first bay, and Y and Z for the Annex Building).

Two horizontal and one vertical artificial time history components compatible with the various Duke Lee horizontal and vertical PBSRS were developed by WEC for each of the backfill material and fill thickness scenarios. The same 3-component ground motion record (seed) used in the development of the NI FIRS time histories in DUK-001-CALC-01 Rev. 0 (Reference 3) was used for the development of the Duke Lee SCII adjacent structures time histories. The NSK record from the 1999 Chi-Chi Taiwan earthquake (M7.6, distance 64.5 km) was used as the seed time history for both the NI and adjacent structures artificial time histories, which is part of the NRC Time History Library as noted in Reference 3.

The seed time history was modified for each component using spectral matching software RSPMatch (2009). Each spectrally-matched component was checked to meet the requirements for Approach 2 in SRP 3.7.1 (Reference 9). The cross-correlation coefficients between the three components of acceleration were checked and do not exceed the criterion of 0.16 for statistical independence. Input time histories contain 8192 discrete values with a time step of 0.005 seconds for a duration of 40.96 seconds.

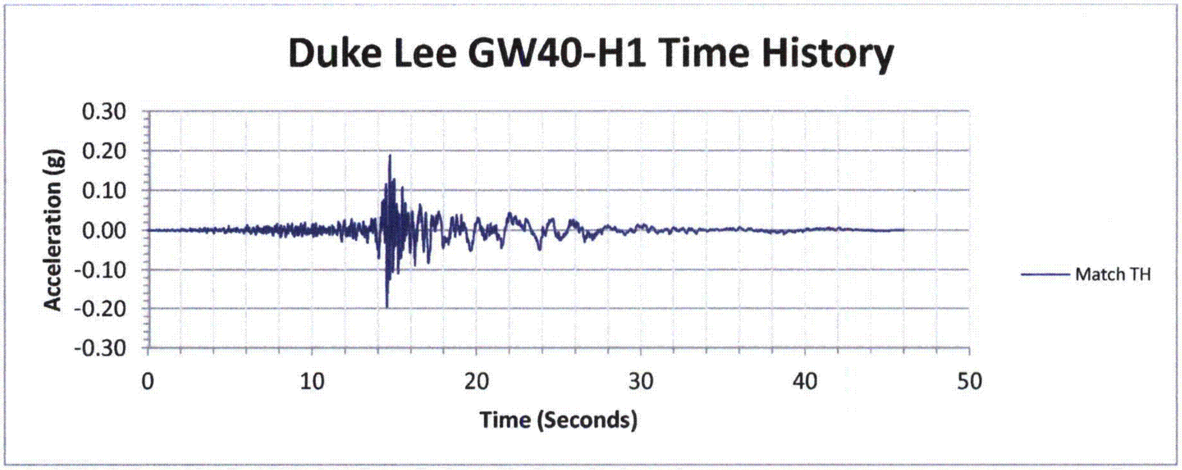

Figure 4.1-1: Duke Lee GW40 North-South H1 Time History

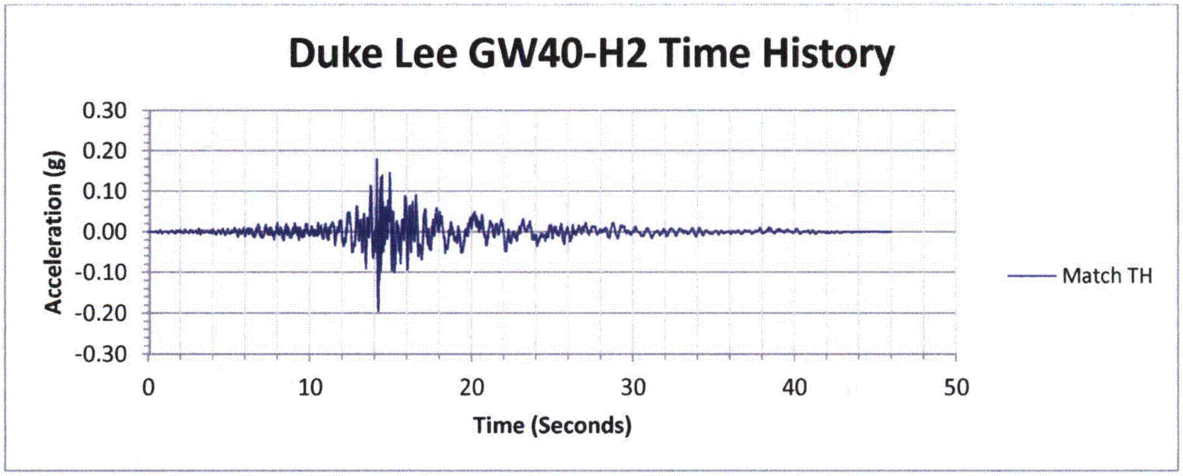

Figure 4.1-2: Duke Lee GW40 East-West H2 Time History

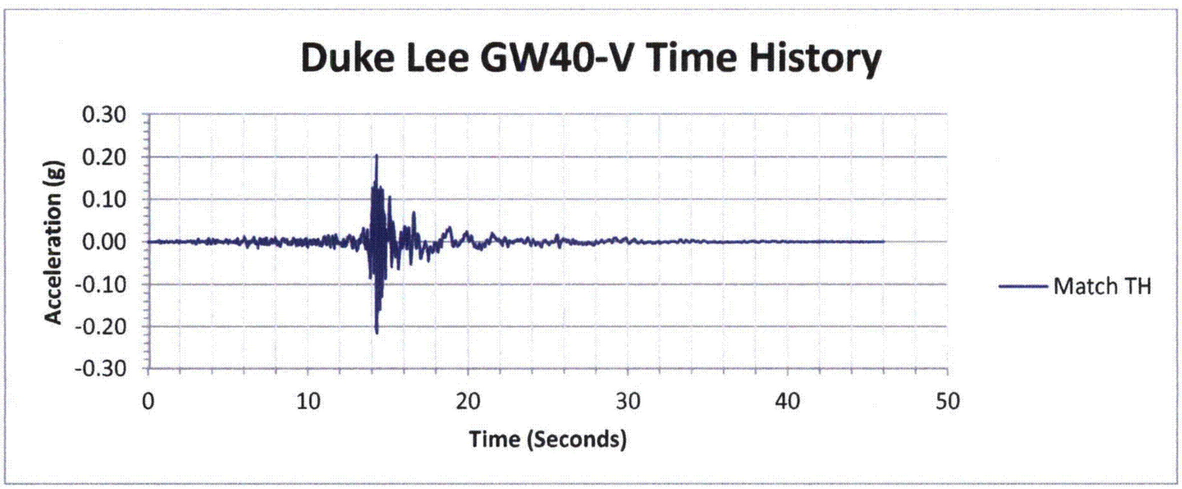

Figure 4.1-3: Duke Lee GW40 Vertical V Time History

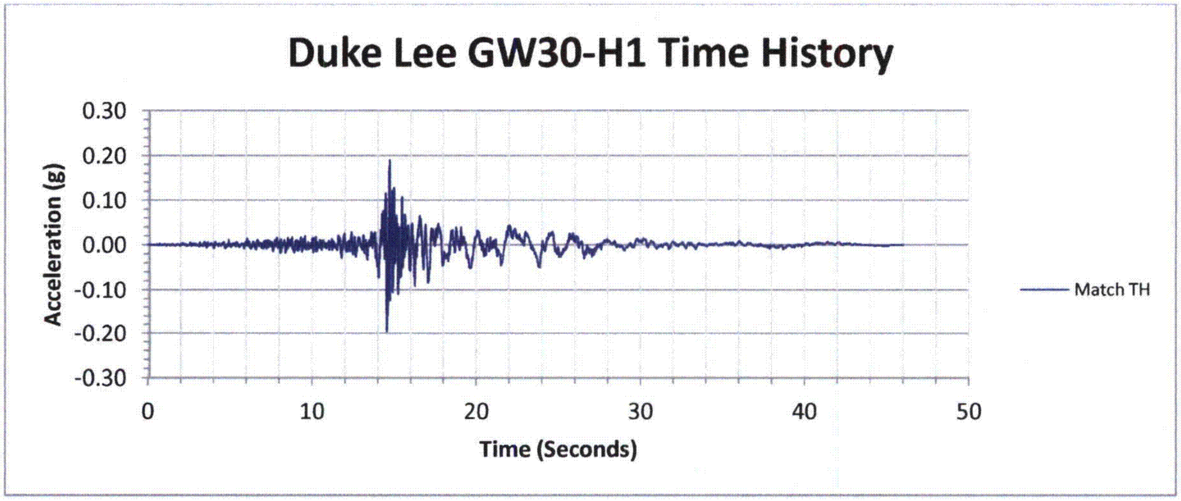

Figure 4.1-4: Duke Lee GW30 North-South H1 Time History

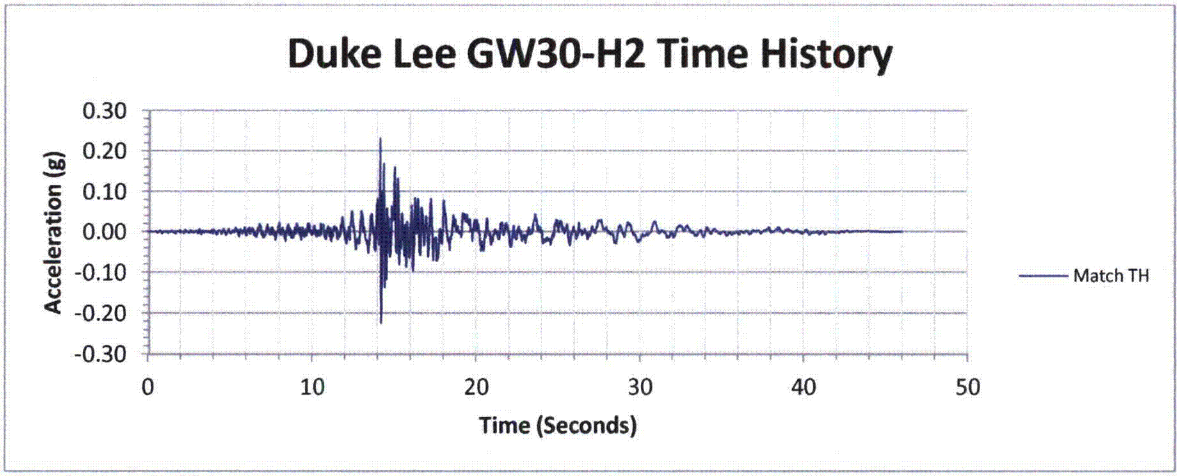

Figure 4.1-5: Duke Lee GW30 East-West H2 Time History

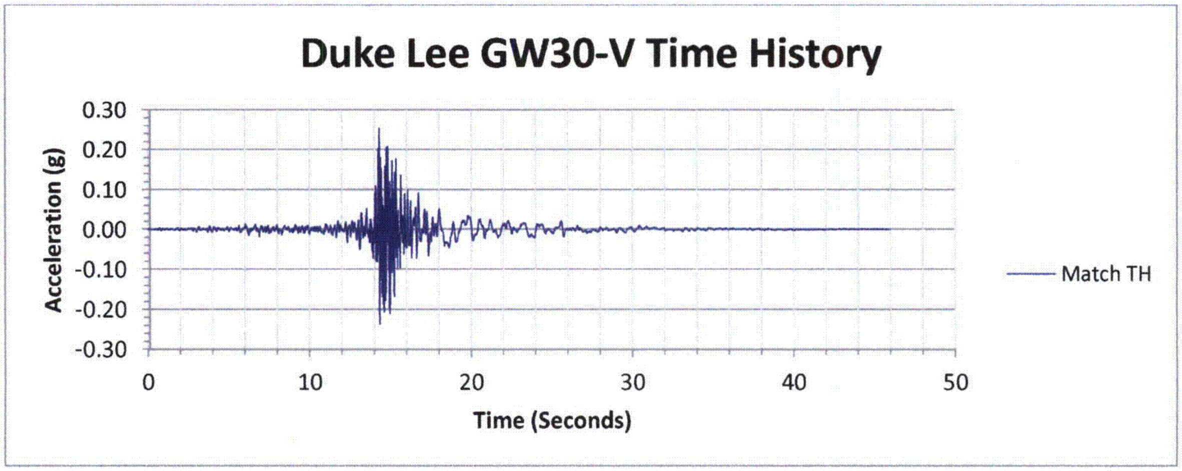

Figure 4.1-6: Duke Lee GW30 Vertical V Time History

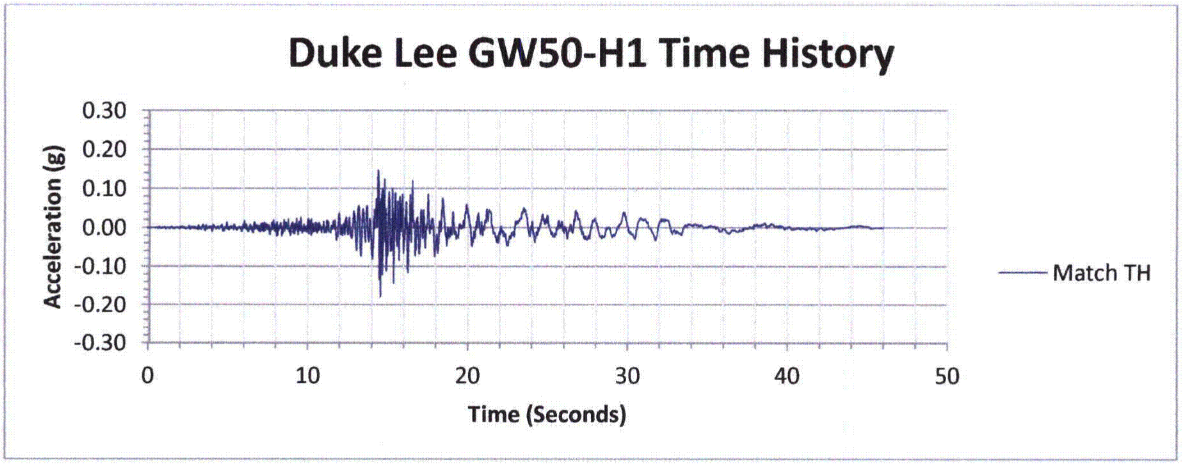

Figure 4.1-7: Duke Lee GW50 North-South H1 Time History

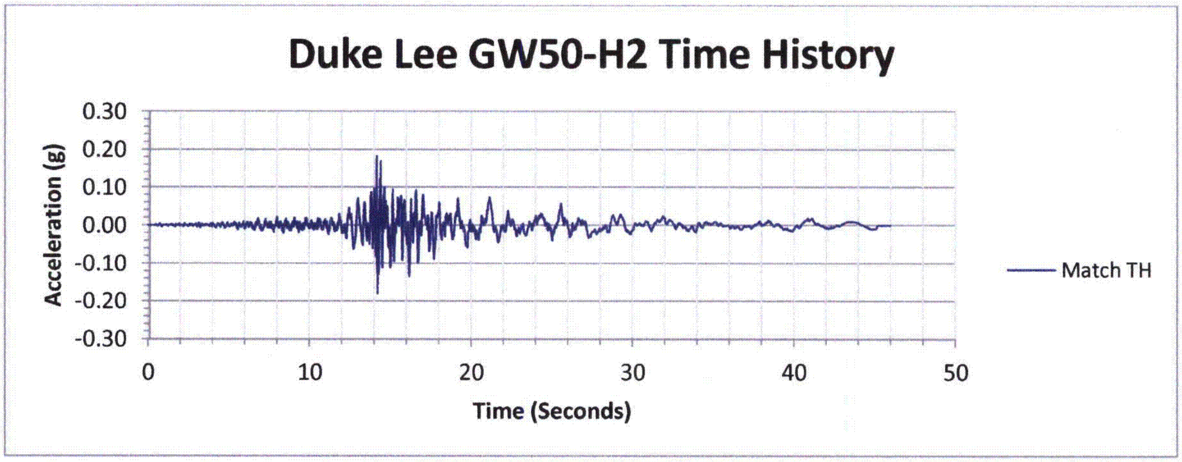

Figure 4.1-8: Duke Lee GW50 East-West H2 Time History

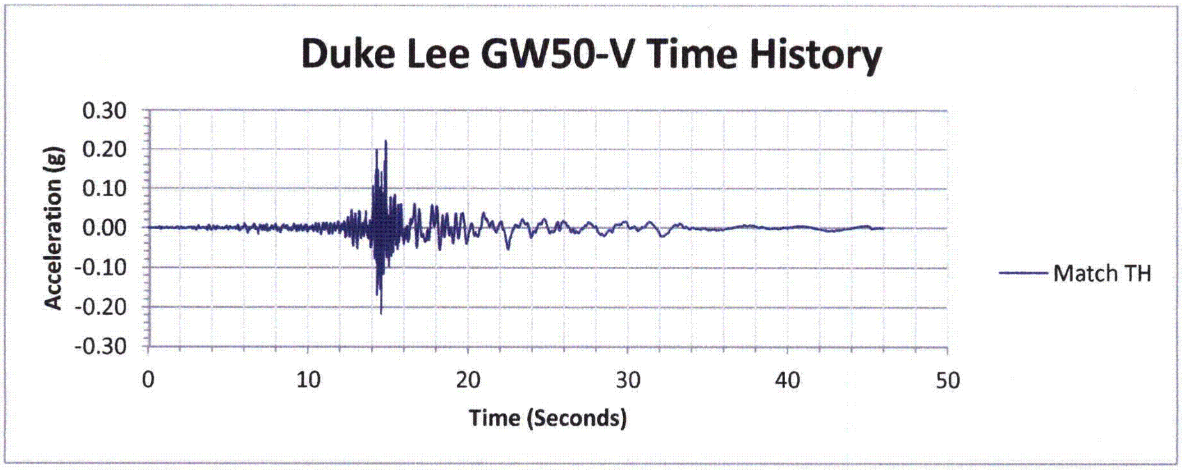

Figure 4.1-9: Duke Lee GW50 Vertical V Time History

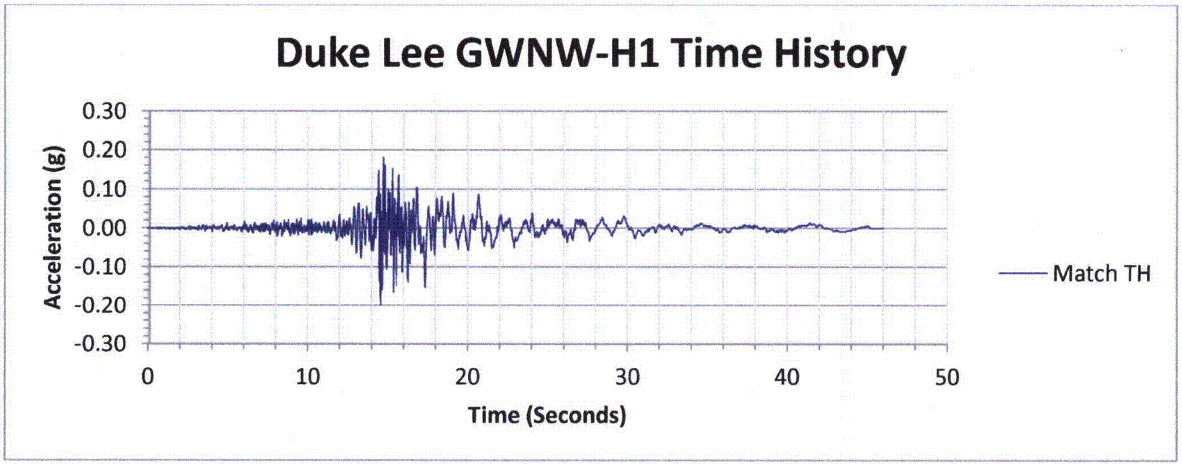

Figure 4.1-10: Duke Lee GWNW North-South H1 Time History

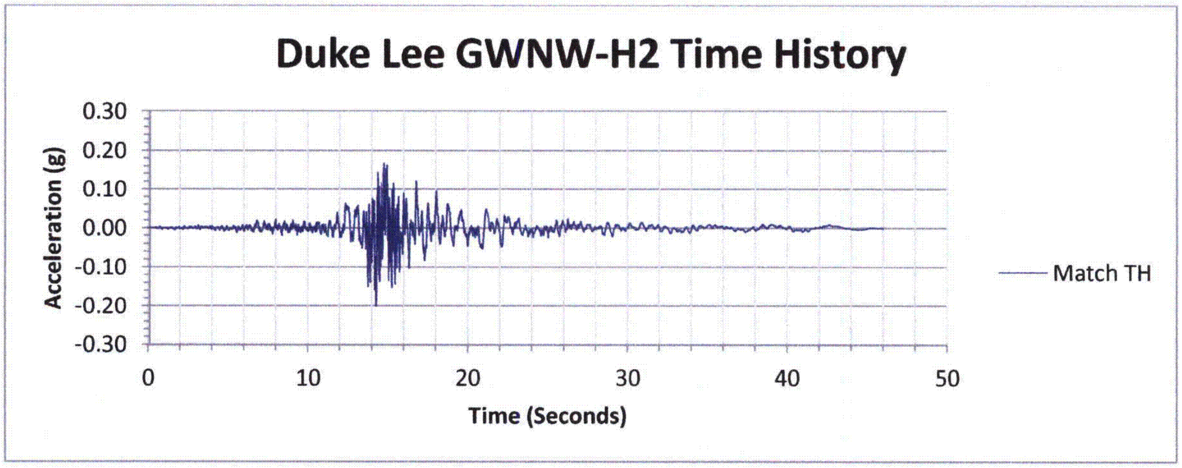

Figure 4.1-11: Duke Lee GWNW East-West H2 Time History

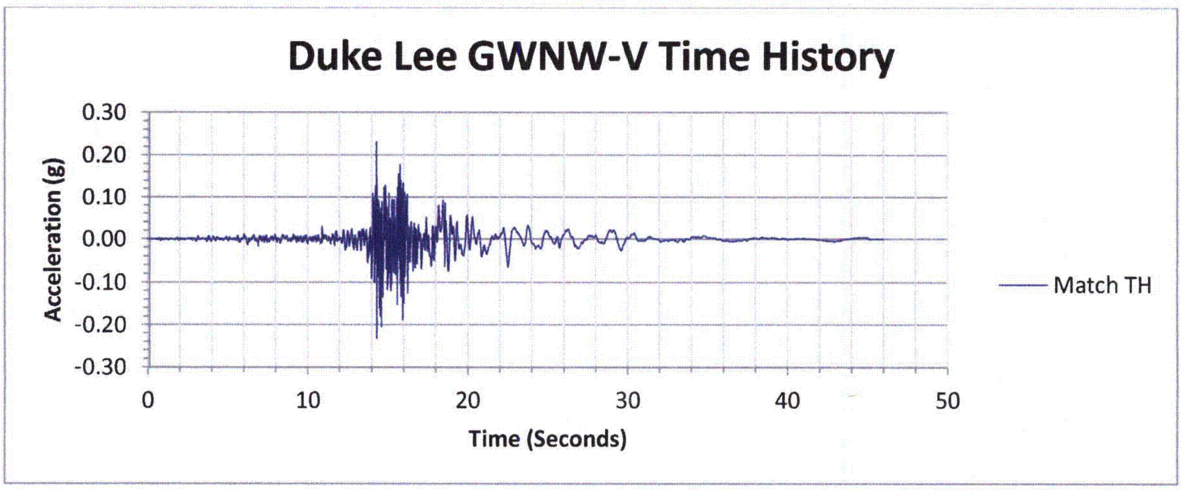

Figure 4.1-12: Duke Lee GWNW Vertical V Time History

5.0 SASSI Parametric Studies

Parametric studies were performed to address and define the following;

(1) The extent of subsurface characterization and site response characteristics
(2) The effects of the foundation medium underlying the adjacent building
(3) Effects of NW corner backfill on seismic response

5.1 SASSI Stick Model

The 2D models of the NI and Annex Building are developed as shown in Figure 5.1-1. Nuclear Island sticks include the Auxiliary Shield Building (ASB) stick, the Steel Containment Vessel (SCV) stick, and the Containment Internal Structure (CIS) stick. It is noted that in Figure 5.1-2, the different stick models for the ASB, SCV, and CIS are collocated, and therefore, appear as one stick even if there are three sticks present. The 2D models of the NI and Annex Building are considered in conjunction with their foundation and supporting media to form a SSI model. From the analysis using the 2D models, the important modes of the structure and seismic interaction between the NI structures, adjacent building and supporting media are obtained.

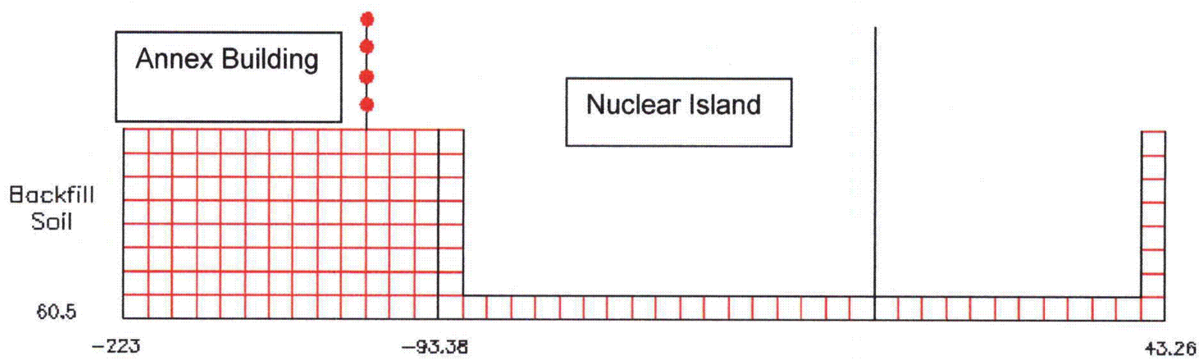

Figure 5.1-1: Generalized 2D East-West (NI and Annex Building) SSI Model

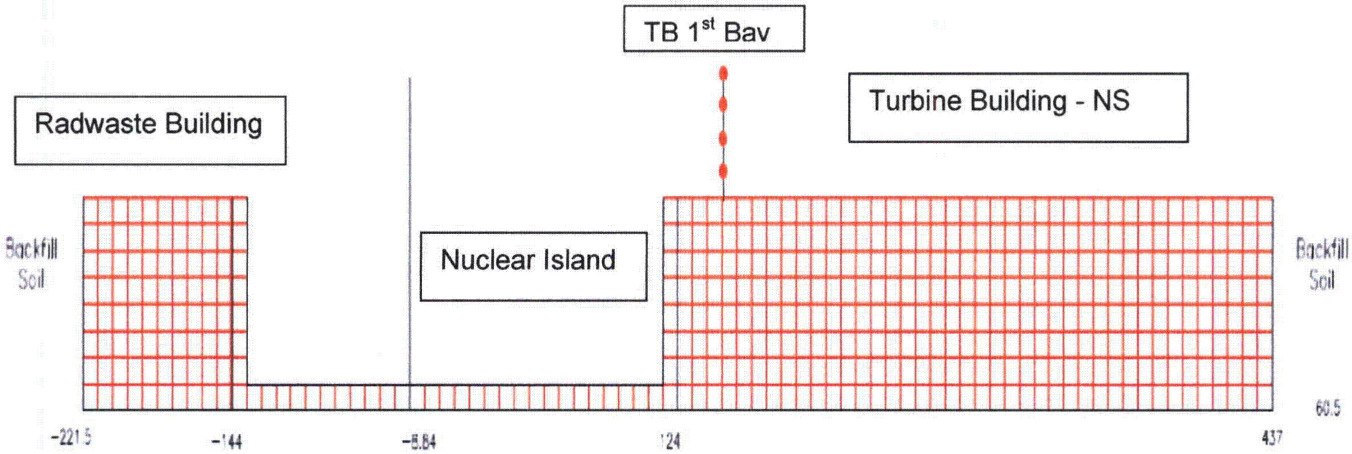

Figure 5.1-2: Generalized 2D North-South (NI and Turbine/Radwaste Building) SSI Model

5.2 SASSI Parametric Studies

The 2D SASSI Finite Element Models were developed to represent five cross sections of the Duke Lee Units 1 and 2. The Cross Sections were described as follows:

1. Cross-Section B-B, Unit 1 Centerline including NI and Annex Building (Figure 2.2-1);
2. Cross-Section B-B, Unit 2 Centerline including NI and Annex Building (Figure 2.2-1);
3. Cross-Sections Y-Y and U-U, Unit 1 North including Northwest Corner NI and Annex Building (Figures 2.3-1 and 2.3-2);
4. Cross-Section Z-Z, Unit 1 South including NI and Annex Building (Figure 2.4-1); and
5. Cross-Section F-F, Unit 2 Centerline including NI, Turbine and Radwaste Buildings (Figure 2.5-1).

The 2D SASSI East-West (E-W) finite element models are shown in Figures 5.2-1 through Figure 5.2-4. The Unit 1 2D NI E-W stick model is used to analyze the effect of NW corner with new fill concrete and backfill soil (Figure 5.2-3). The 2D NI E-W model is shifted 105 ft northward to accommodate the Northwest corner soil condition. The same model is shifted 132 ft southward to accommodate the Unit 1 South soil condition (Figure 5.2-4). These models resulted in conservative ZPA values that do not represent the true response level of the NI and Annex Building, but are presented for information. The Unit 2 E-W centerline model, which includes the Annex Building is as shown in Figure 5.2-2, and the Unit 2 North-South (N-S) centerline model including the Turbine Building first bay is presented in Figure 5.1-2.

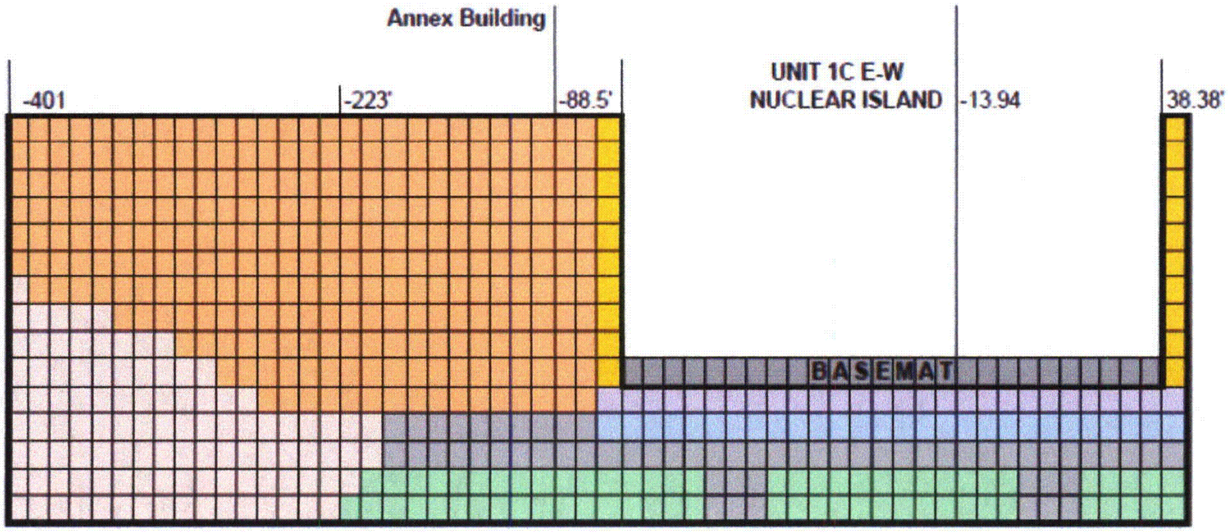

Figure 5.2-1: 2D SASSI East-West Model for Duke Lee Unit 1 Center (Section B-B)

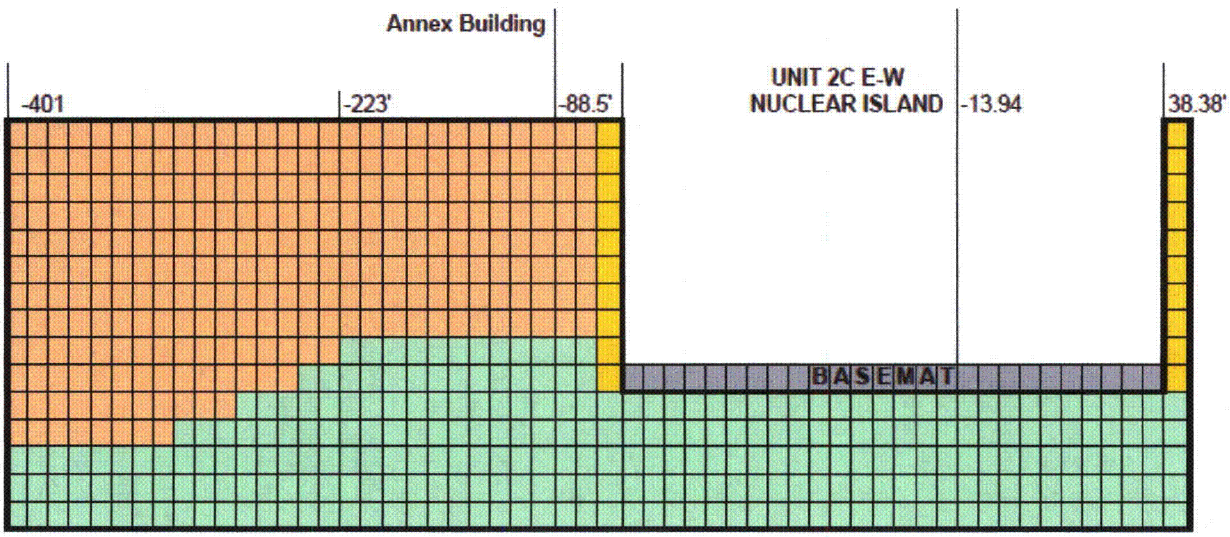

Figure 5.2-2: 2D SASSI East-West Model for Duke Lee Unit 2 Center (Section B-B)

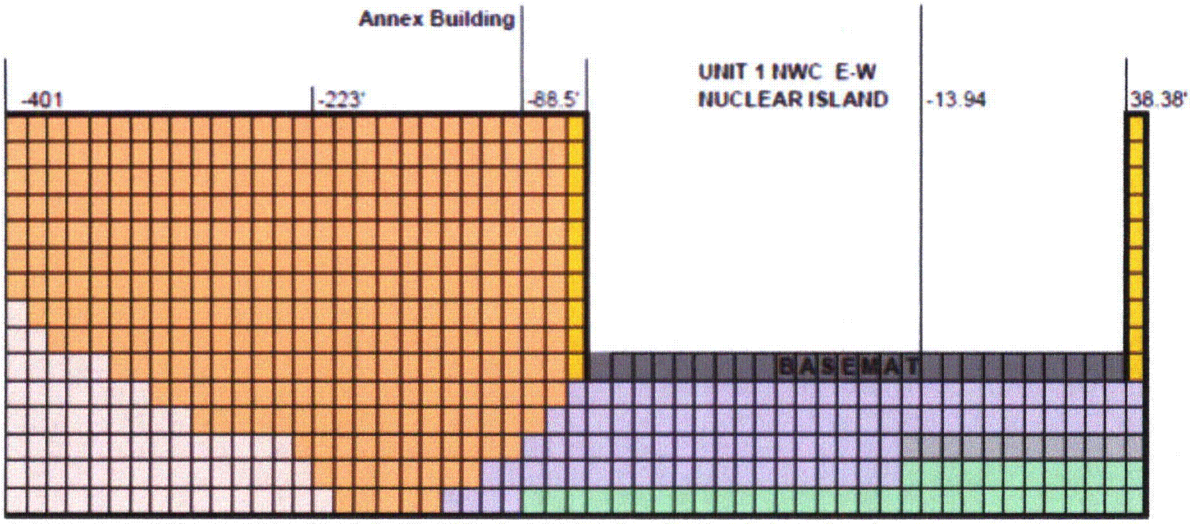

Figure 5.2-3: 2D SASSI Finite Element Model for Duke Lee Unit 1 NW Corner (Section Y-Y)

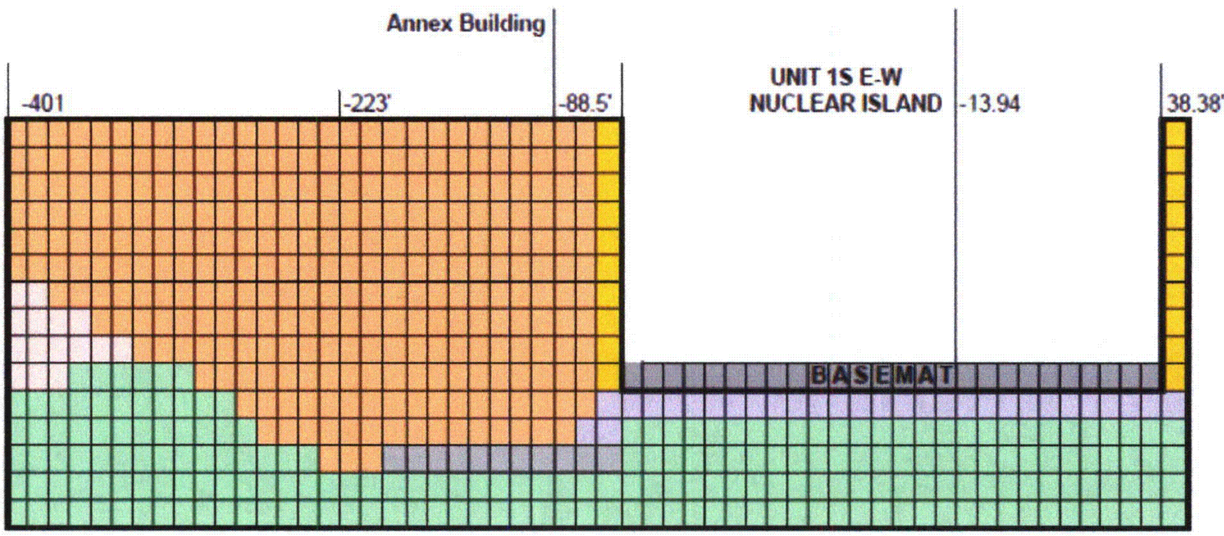

Figure 5.2-4: 2D SASSI East-West Model for Duke Lee Unit 1 South (Section Z-Z)

5.3 Duke Lee SSI Analysis Dynamic Soil Properties

Utilizing the BE strain compatible soil profiles presented in Tables 3-1 through 3-4, Lower Bound (LB) and Upper Bound (UB) soil profiles were developed. The development of dynamic soil properties and the COV are described in Section 3.0.

As recommended in Reference 10, WEC implemented the use of revised COV=0.5 for granular fill materials to reflect a reduced uncertainty is site dynamic profile consistent with acceptable NRC standards. The revised COV is justified considering the planned placement of a well-controlled engineered granular fill in critical foundation support areas (e.g., beneath SCII structures).

WEC developed soil profile pairings and used existing BE values to determine LB and UB values based on the COV for shear wave velocity, damping, and shear modulus parameters as outlined below:

- For Vs BE, apply BE damping and BE shear modulus properties for SSI evaluations;
- For revised Vs UB, apply revised LB damping and UB modulus properties for SSI evaluations;
- For revised Vs LB, apply revised UB damping and LB modulus properties for SSI evaluations;
- For revised damping associated with Vs LB, use BE damping*(1+COV); and
- For revised damping associated with Vs UB, use BE damping/(1+COV).

The SASSI SITE layer thickness, shear wave velocity (Vs), compression wave velocity (Vp), and damping ratio from the ground surface to the simulated halfspace are presented in Tables 5.3-1 to 5.3-12. Figures 5.3-1 to 5.3-4 graphically present the SSI Vs profiles within the site soil profile depth.

Table 5.3-1: Duke Lee GW40 BE Dynamic Soil Properties

GW40 BE A3, C3 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	642.9	1953.2	3.5	39.6	3.25	96.75	0.44
2	3.5	546.6	2673.5	6.8	31.2	6.75	93.25	0.48
3	3.5	474.9	2768.1	8.9	27.1	10.25	89.75	0.48
4	3.5	615.4	4058.2	8.1	35.2	13.75	86.25	0.49
5	3.5	572.2	4058.2	8.8	32.7	17.25	82.75	0.49
6	3.5	648.6	5371.7	8.7	37.1	20.75	79.25	0.49
7	3.5	609.2	4992.6	9.6	34.8	24.25	75.75	0.49
8	3.5	567.2	4992.6	10.2	32.4	27.75	72.25	0.49
9	5.75	637.1	4983.7	10.1	22.2	33.5	66.5	0.49
10	6	641.4	4979.3	10.3	21.4	39.5	60.5	0.49
11	5.5	5629.1	12475.2	3.4	204.7	45	55	0.37
12	5	7034.0	13978.1	0.5	281.4	50	50	0.33
13	5	7787.1	15032.0	0.5	311.5	55	45	0.32
14	5	8546.9	16419.0	0.5	341.9	60	40	0.31
15	5	8546.9	16419.0	0.5	341.9	65	35	0.31

Table 5.3-2: Duke Lee GW40 LB Dynamic Soil Properties

GW40 LB A3, C3 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	524.9	1594.8	2.3	32.3	3.25	96.75	0.44
2	3.5	446.3	2182.9	4.6	25.5	6.75	93.25	0.48
3	3.5	387.8	2260.2	6.0	22.2	10.25	89.75	0.48
4	3.5	502.5	3313.5	5.4	28.7	13.75	86.25	0.49
5	3.5	467.2	3313.5	5.9	26.7	17.25	82.75	0.49
6	3.5	529.6	4386.0	5.8	30.3	20.75	79.25	0.49
7	3.5	497.4	4076.4	6.4	28.4	24.25	75.75	0.49
8	3.5	463.1	4076.4	6.8	26.5	27.75	72.25	0.49
9	5.75	520.2	4069.2	6.7	18.1	33.5	66.5	0.49
10	6	523.7	4065.6	6.9	17.5	39.5	60.5	0.49
11	5.5	4596.1	10186.0	2.3	167.1	45	55	0.37
12	5	5743.2	11413.1	0.3	229.7	50	50	0.33
13	5	6358.2	12273.6	0.3	254.3	55	45	0.32
14	5	6978.5	13406.1	0.3	279.1	60	40	0.31
15	5	6978.5	13406.1	0.3	279.1	65	35	0.31

Table 5.3-3: Duke Lee GW40 UB Dynamic Soil Properties

GW40 UB A3, C3 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	787.3	2392.2	5.3	37.4	3.25	96.75	0.44
2	3.5	669.4	3274.4	10.3	34.0	6.75	93.25	0.48
3	3.5	581.6	3390.3	13.4	34.1	10.25	89.75	0.48
4	3.5	753.7	4970.2	12.2	37.9	13.75	86.25	0.49
5	3.5	700.8	4970.2	13.3	36.9	17.25	82.75	0.49
6	3.5	794.3	6578.9	13.1	37.4	20.75	79.25	0.49
7	3.5	746.2	6114.6	14.5	41.5	24.25	75.75	0.49
8	3.5	694.7	6114.6	15.3	40.5	27.75	72.25	0.49
9	5.75	780.2	6103.8	15.1	25.4	33.5	66.5	0.49
10	6	785.5	6098.4	15.5	24.3	39.5	60.5	0.49
11	5.5	6894.2	15278.9	5.1	212.7	45	55	0.37
12	5	8614.8	17119.6	0.8	279.9	50	50	0.33
13	5	9537.2	18410.4	0.8	311.3	55	45	0.32
14	5	10467.7	20109.1	0.8	329.5	60	40	0.31
15	5	10467.7	20109.1	0.8	329.5	65	35	0.31

Table 5.3-4: Duke Lee GW30 BE Dynamic Soil Properties

GW30 BE C1, C2 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	564.6	1536.5	4.3	34.7	3.25	96.75	0.42
2	3.5	455.4	2199.9	8.3	26.0	6.75	93.25	0.48
3	3.5	394.8	2557.2	10.4	22.6	10.25	89.75	0.49
4	3.5	616.1	4100.6	8.6	35.2	13.75	86.25	0.49
5	3.5	573.8	4100.6	9.3	32.8	17.25	82.75	0.49
6	3.5	551.5	5096.8	9.5	31.5	20.75	79.25	0.49
7	3.5	638.3	5073.7	9.6	36.5	24.25	75.75	0.49
8	3.5	605.6	5073.7	10.0	34.6	27.75	72.25	0.49
9	5.75	4085.1	10324.4	5.2	142.1	33.5	66.5	0.41
10	6	7787.1	16003.0	0.5	259.6	39.5	60.5	0.34
11	5.5	7787.1	16003.0	0.5	283.2	45	55	0.34
12	25	8181.7	16644.5	0.5	65.5	70	30	0.34
13	30	8698.0	17684.5	0.5	58.0	100	0	0.34

Table 5.3-5: Duke Lee GW30 LB Dynamic Soil Properties

GW30 LB C1, C2 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	461.0	1254.5	2.9	28.4	3.25	96.75	0.42
2	3.5	371.8	1796.2	5.5	21.2	6.75	93.25	0.48
3	3.5	322.3	2087.9	6.9	18.4	10.25	89.75	0.49
4	3.5	503.0	3348.1	5.7	28.7	13.75	86.25	0.49
5	3.5	468.5	3348.1	6.2	26.8	17.25	82.75	0.49
6	3.5	450.3	4161.5	6.4	25.7	20.75	79.25	0.49
7	3.5	521.2	4142.6	6.4	29.8	24.25	75.75	0.49
8	3.5	494.4	4142.6	6.7	28.3	27.75	72.25	0.49
9	5.75	3335.5	8429.8	3.5	116.0	33.5	66.5	0.41
10	6	6358.1	13066.4	0.3	211.9	39.5	60.5	0.34
11	5.5	6358.1	13066.4	0.3	231.2	45	55	0.34
12	25	6680.3	13590.2	0.3	53.4	70	30	0.34
13	30	7101.9	14439.3	0.3	47.3	100	0	0.34

Table 5.3-6: Duke Lee GW30 UB Dynamic Soil Properties

GW30 UB C1, C2 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	691.5	1881.8	6.5	37.4	3.25	96.75	0.42
2	3.5	557.8	2694.3	12.4	34.0	6.75	93.25	0.48
3	3.5	483.5	3131.9	15.6	34.1	10.25	89.75	0.49
4	3.5	754.6	5022.2	12.9	37.9	13.75	86.25	0.49
5	3.5	702.7	5022.2	14.0	36.9	17.25	82.75	0.49
6	3.5	675.5	6242.2	14.3	37.4	20.75	79.25	0.49
7	3.5	781.7	6213.9	14.4	41.5	24.25	75.75	0.49
8	3.5	741.7	6213.9	15.1	40.5	27.75	72.25	0.49
9	5.75	5003.2	12644.7	7.8	25.4	33.5	66.5	0.41
10	6	9537.2	19599.6	0.8	24.3	39.5	60.5	0.34
11	5.5	9537.2	19599.6	0.8	24.3	45	55	0.34
12	25	10020.4	20835.3	0.8	24.3	70	30	0.34
13	30	10652.8	21659.0	0.8	24.3	100	0	0.34

Table 5.3-7: Duke Lee GW50 BE Dynamic Soil Properties

GW50 BE A2, A4 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	649.4	1642.6	3.4	40.0	3.25	96.75	0.41
2	3.5	520.1	2680.0	7.7	29.7	6.75	93.25	0.48
3	3.5	453.4	2680.0	9.0	25.9	10.25	89.75	0.49
4	3.5	603.2	3967.6	8.2	34.5	13.75	86.25	0.49
5	3.5	560.2	3967.6	9.0	32.0	17.25	82.75	0.49
6	3.5	554.1	4934.4	9.4	31.7	20.75	79.25	0.49
7	3.5	635.3	4972.3	9.3	36.3	24.25	75.75	0.49
8	3.5	596.0	4972.3	9.9	34.1	27.75	72.25	0.49
9	5.75	633.0	4901.5	10.0	22.0	33.5	66.5	0.49
10	6	623.8	4866.1	10.4	20.8	39.5	60.5	0.49
11	5.5	704.0	4948.3	9.9	25.6	45	55	0.49
12	5	5769.2	11580.8	2.1	230.8	50	50	0.33
13	5	7539.1	14066.7	0.5	301.6	55	45	0.30
14	5	8696.4	16088.0	0.5	347.9	60	40	0.29

Table 5.3-8: Duke Lee GW50 LB Dynamic Soil Properties

GW50 LB A2,A4 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	530.2	1341.2	2.2	32.6	3.25	96.75	0.41
2	3.5	424.6	2188.2	5.2	24.3	6.75	93.25	0.48
3	3.5	370.2	2188.2	6.0	21.2	10.25	89.75	0.49
4	3.5	492.5	3239.5	5.5	28.1	13.75	86.25	0.49
5	3.5	457.4	3239.5	6.0	26.1	17.25	82.75	0.49
6	3.5	452.4	4028.9	6.3	25.9	20.75	79.25	0.49
7	3.5	518.8	4059.9	6.2	29.6	24.25	75.75	0.49
8	3.5	486.6	4059.9	6.6	27.8	27.75	72.25	0.49
9	5.75	516.8	4002.1	6.7	18.0	33.5	66.5	0.49
10	6	509.3	3973.2	7.0	17.0	39.5	60.5	0.49
11	5.5	574.8	4040.3	6.6	20.9	45	55	0.49
12	5	4710.5	9455.7	1.4	188.4	50	50	0.33
13	5	6155.6	11485.4	0.3	246.2	55	45	0.30
14	5	7100.6	13135.8	0.3	284.0	60	40	0.29

Table 5.3-9: Duke Lee GW50 UB Dynamic Soil Properties

GW50 UB A2,A4 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	795.4	2011.7	5.0	37.4	3.25	96.75	0.43
2	3.5	636.9	3282.3	11.6	34.0	6.75	93.25	0.47
3	3.5	555.3	3282.3	13.4	34.1	10.25	89.75	0.47
4	3.5	738.7	4859.3	12.3	37.9	13.75	86.25	0.49
5	3.5	686.1	4859.3	13.5	36.9	17.25	82.75	0.49
6	3.5	678.7	6043.4	14.1	37.4	20.75	79.25	0.49
7	3.5	778.1	6089.8	13.9	41.5	24.25	75.75	0.49
8	3.5	730.0	6089.8	14.8	40.5	27.75	72.25	0.49
9	5.75	775.2	6003.1	15.0	25.4	33.5	66.5	0.49
10	6	764.0	5959.8	15.6	24.3	39.5	60.5	0.49
11	5.5	862.3	6060.4	14.8	212.7	45	55	0.37
12	5	7065.8	14183.6	3.2	279.9	50	50	0.33
13	5	9233.5	17228.1	0.8	311.3	55	45	0.32
14	5	10650.9	19703.7	0.8	329.5	60	40	0.31

Table 5.3-10: Duke Lee GWNW BE Dynamic Soil Properties

GWNW BE B3-7, B3-8, B3-9, B3-10 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	672.5	1319.3	2.5	41.4	3.25	96.75	0.32
2	3.5	522.3	2048.5	7.5	29.8	6.75	93.25	0.47
3	3.5	495.9	2777.7	8.8	28.3	10.25	89.75	0.48
4	3.5	595.0	4022.8	8.5	34.0	13.75	86.25	0.49
5	3.5	629.1	5235.6	8.7	36.0	17.25	82.75	0.49
6	3.5	633.5	5155.4	9.1	36.2	20.75	79.25	0.49
7	3.5	633.8	5075.3	9.6	36.2	24.25	75.75	0.49
8	3.5	604.7	5075.3	10.0	34.6	27.75	72.25	0.49
9	5.75	677.4	4906.1	9.9	23.6	33.5	66.5	0.49
10	6	641.3	4906.1	10.4	21.4	39.5	60.5	0.49
11	5.5	699.4	4853.6	10.2	25.4	45	55	0.49
12	5	671.8	4853.6	10.5	26.9	50	50	0.49
13	5	1356.0	5713.6	7.6	54.2	55	45	0.47
14	5	3633.6	8897.1	2.7	145.3	60	40	0.40
15	5	3660.8	8959.5	2.6	146.4	65	35	0.40
16	15	4811.7	11196.6	1.9	64.2	80	20	0.39
17	25	7877.0	15932.8	0.5	63.0	105	-5	0.34
18	15	9267.8	17270.8	0.5	123.6	120	-20	0.30

Table 5.3-11: Duke Lee GWNW LB Dynamic Soil Properties

GWNW LB B3-7, B3-8, B3-9, B3-10 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	549.1	1077.2	1.7	33.8	3.25	96.75	0.32
2	3.5	426.5	1672.6	5.0	24.4	6.75	93.25	0.47
3	3.5	404.9	2268.0	5.9	23.1	10.25	89.75	0.48
4	3.5	485.8	3284.6	5.7	27.8	13.75	86.25	0.49
5	3.5	513.7	4274.8	5.8	29.4	17.25	82.75	0.49
6	3.5	517.2	4209.4	6.1	29.6	20.75	79.25	0.49
7	3.5	517.5	4144.0	6.4	29.6	24.25	75.75	0.49
8	3.5	493.8	4144.0	6.7	28.2	27.75	72.25	0.49
9	5.75	553.1	4005.8	6.6	19.2	33.5	66.5	0.49
10	6	523.6	4005.8	6.9	17.5	39.5	60.5	0.49
11	5.5	571.0	3962.9	6.8	20.8	45	55	0.49
12	5	548.5	3962.9	7.0	21.9	50	50	0.49
13	5	1107.2	4665.2	5.1	44.3	55	45	0.47
14	5	2966.8	7264.5	1.8	118.7	60	40	0.40
15	5	2989.0	7315.4	1.7	119.6	65	35	0.40
16	15	3928.8	9142.0	1.3	52.4	80	20	0.39
17	25	6431.6	13009.0	0.3	51.5	105	-5	0.34
18	15	7567.1	14101.5	0.3	100.9	120	-20	0.30

Table 5.3-12: Duke Lee GWNW UB Dynamic Soil Properties

GWNW UB B3-7, B3-8, B3-9, B3-10 Low, Med, High - AVERAGE								
Layer	Thickness (feet)	Vs (fps)	Vp (fps)	Damping (%)	Frequency (Hz)	Depth (feet)	Elevation (feet)	Poissons Ratio (dim)
1	3.25	823.6	1615.8	3.0	50.7	3.25	96.75	0.32
2	3.5	639.7	2508.9	9.2	36.6	6.75	93.25	0.47
3	3.5	607.4	3402.0	10.8	34.7	10.25	89.75	0.48
4	3.5	728.7	4926.9	10.4	41.6	13.75	86.25	0.49
5	3.5	770.5	6412.2	10.6	44.0	17.25	82.75	0.49
6	3.5	775.9	6314.1	11.1	44.3	20.75	79.25	0.49
7	3.5	776.2	6216.0	11.7	44.4	24.25	75.75	0.49
8	3.5	740.6	6216.0	12.3	42.3	27.75	72.25	0.49
9	5.75	829.6	6008.7	12.1	28.9	33.5	66.5	0.49
10	6	785.4	6008.7	12.7	26.2	39.5	60.5	0.49
11	5.5	856.5	5944.4	12.4	31.1	45	55	0.49
12	5	822.8	5944.4	12.8	32.9	50	50	0.49
13	5	1660.8	6997.7	9.3	66.4	55	45	0.47
14	5	4450.2	10896.7	3.4	178.0	60	40	0.40
15	5	4483.6	10973.0	3.2	179.3	65	35	0.40
16	15	5893.2	13713.0	2.4	78.6	80	20	0.39
17	25	9647.3	19513.6	0.6	77.2	105	-5	0.34
18	15	11350.7	21152.3	0.6	151.3	120	-20	0.30

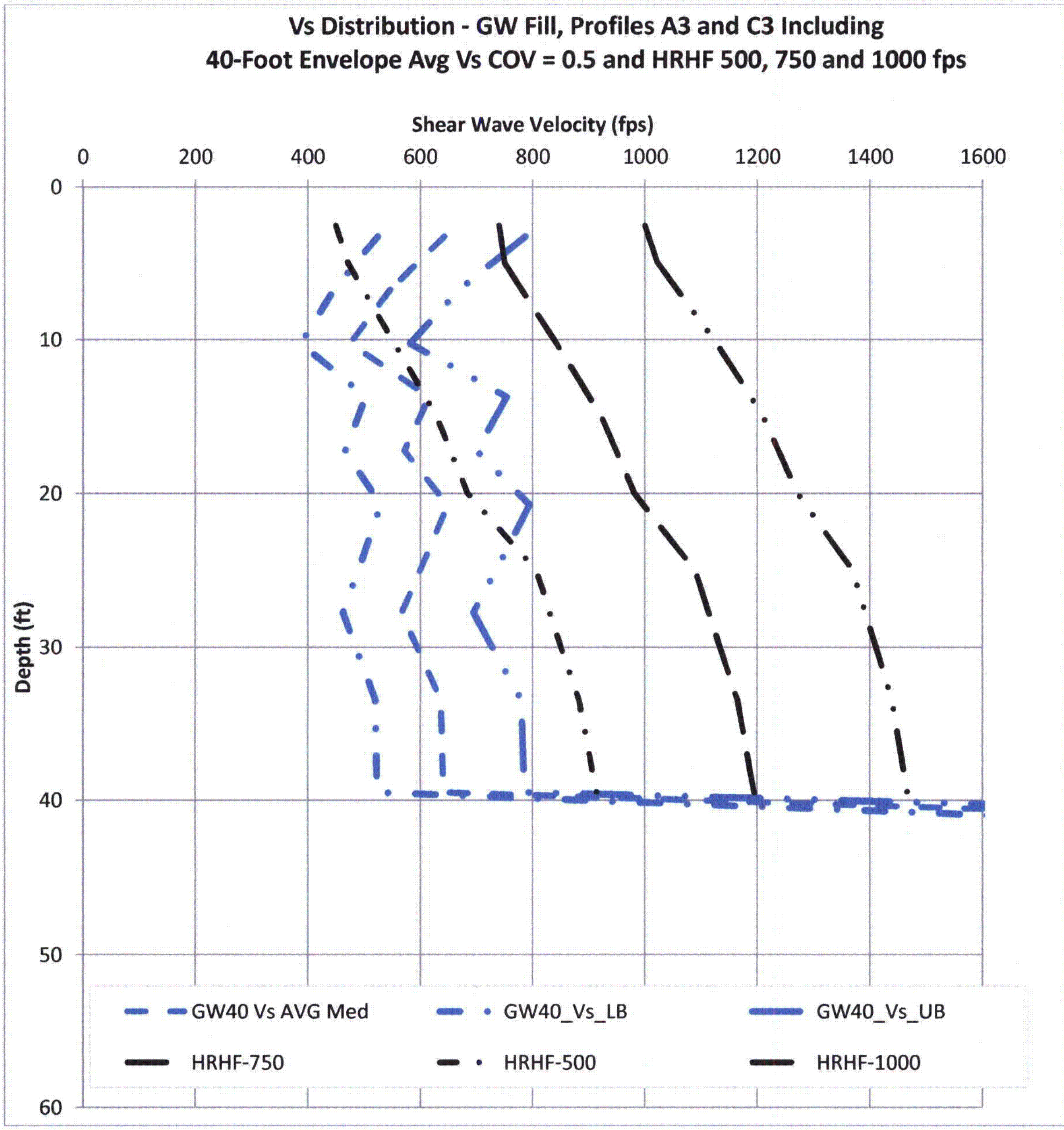

Figure 5.3-1: Duke Lee Unit 1 Center SSI – 40-Foot Envelope GW BE, LB and UB Soil Profiles

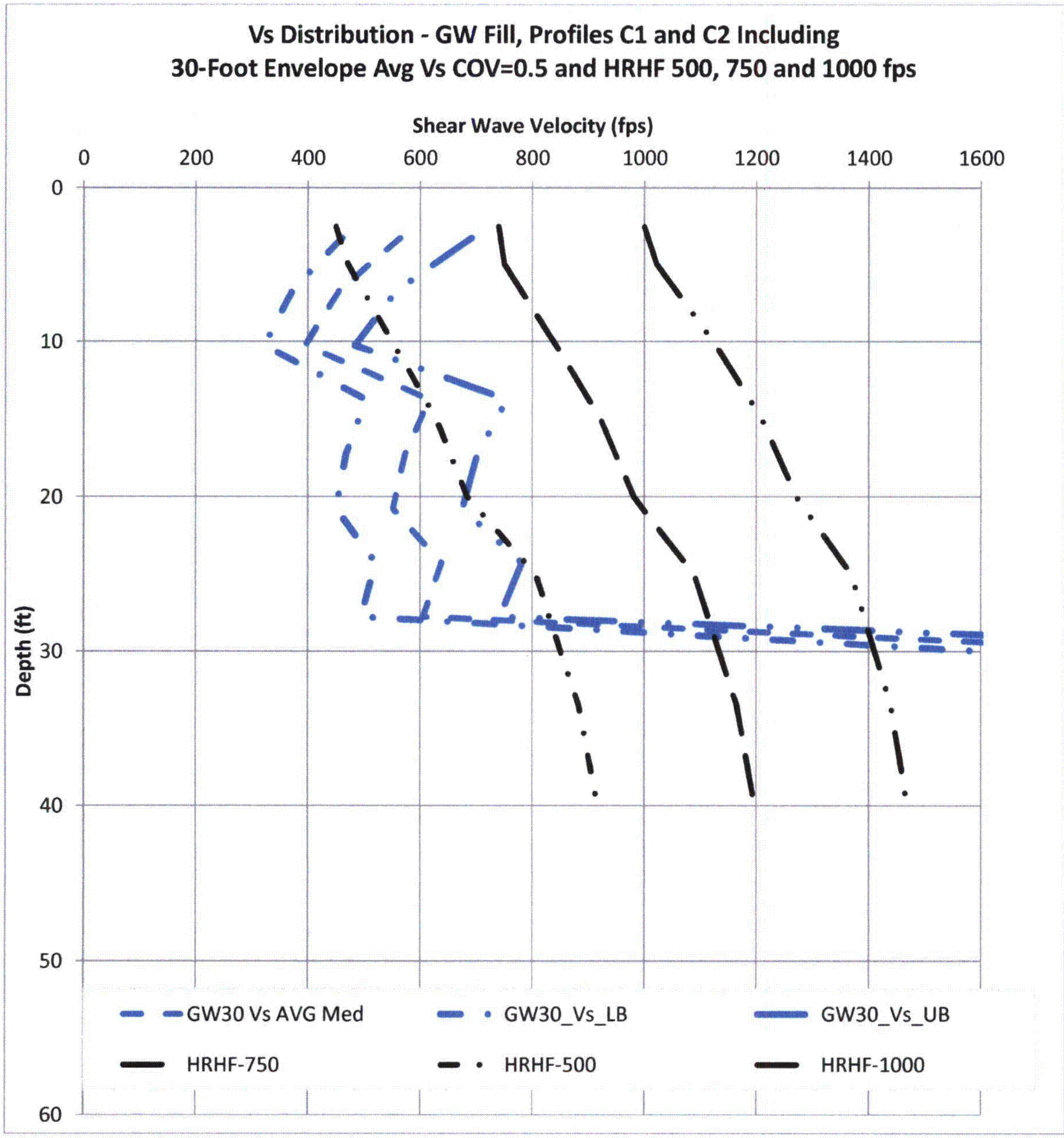

Figure 5.3-2: Duke Lee Unit 1 Center SSI – 30-Foot Envelope GW BE, LB and UB Soil Profiles

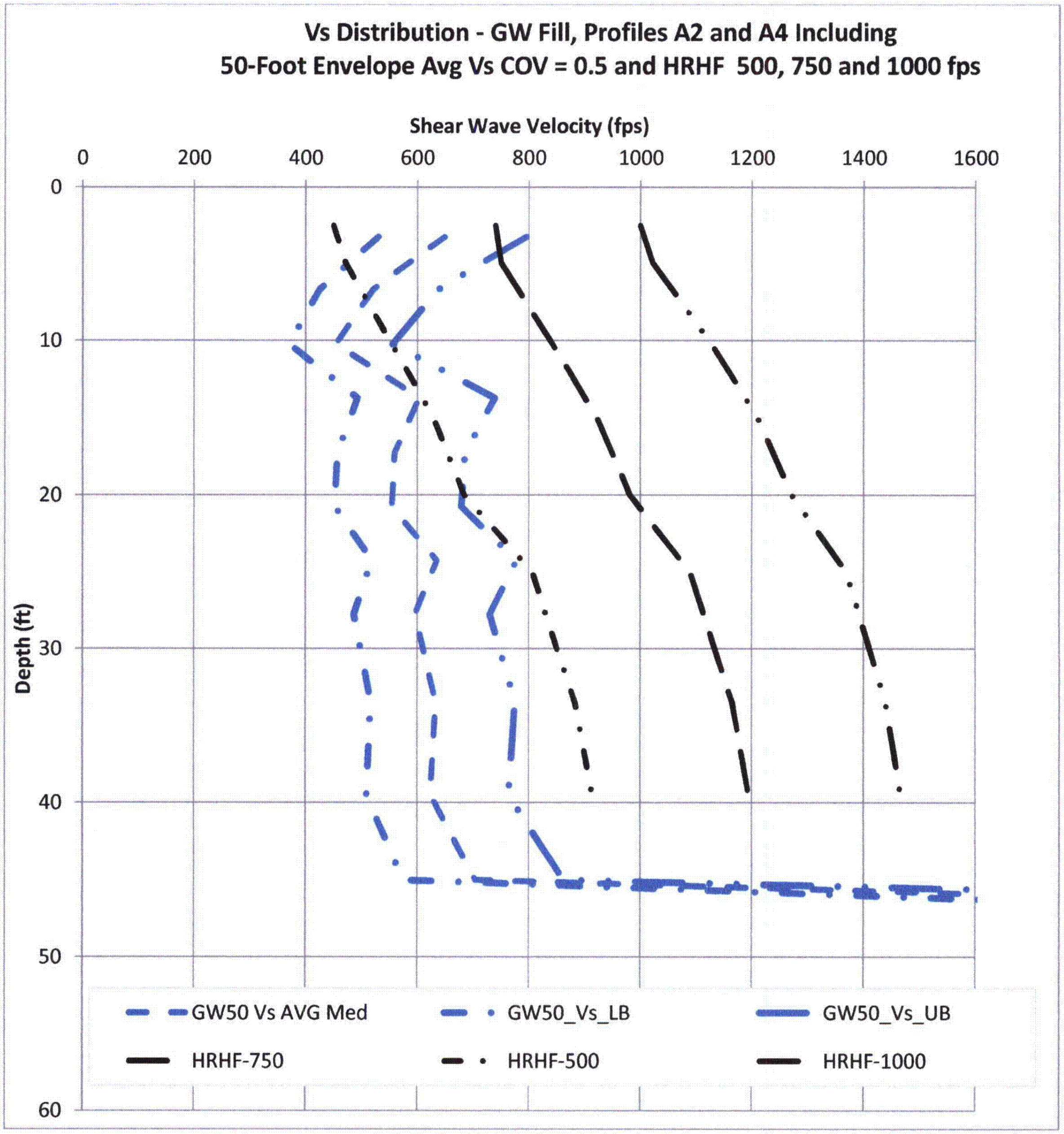

Figure 5.3-3: Duke Lee Unit 1 Center SSI – 50-Foot Envelope GW BE, LB and UB Soil Profiles

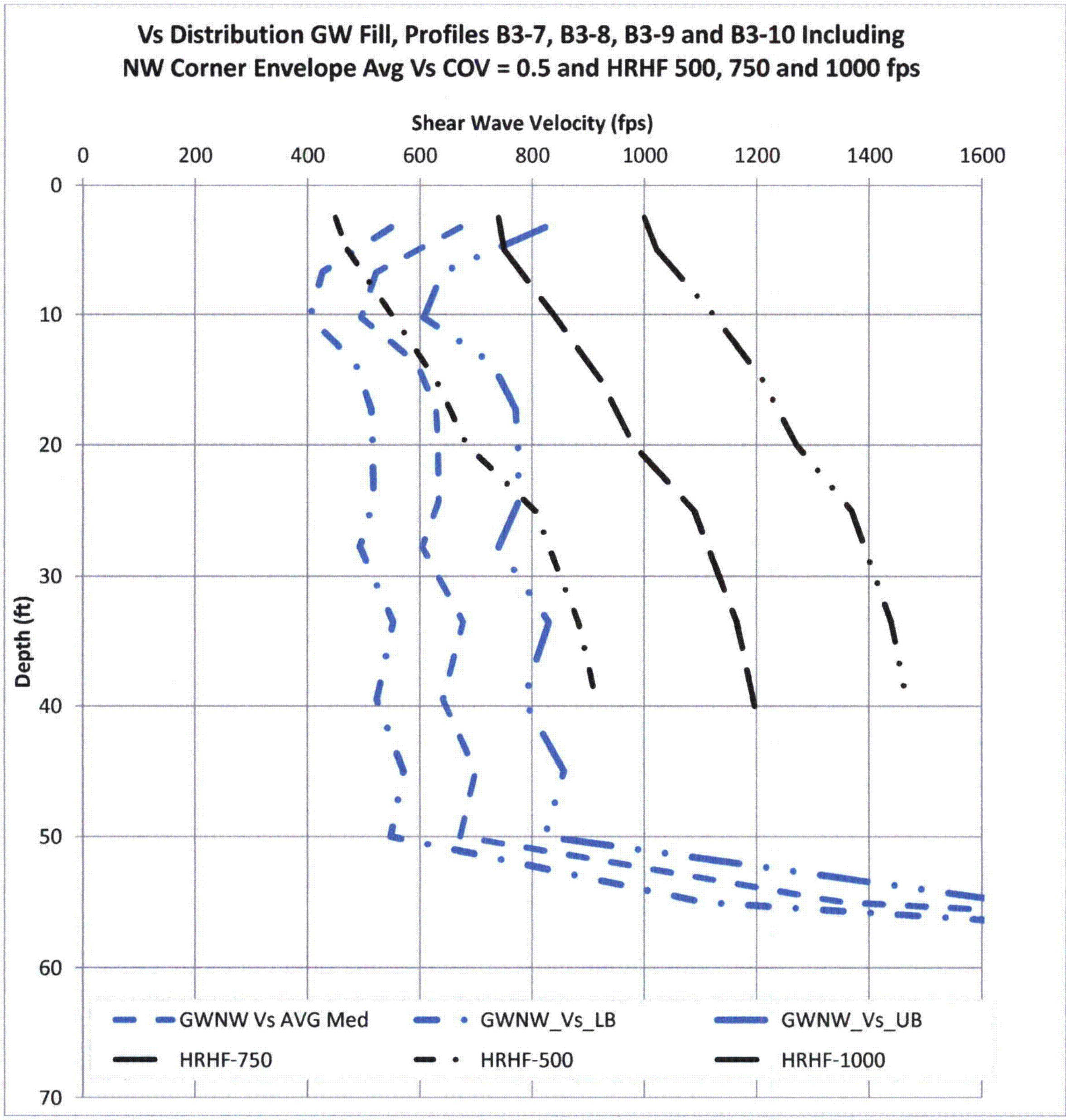

Figure 5.3-4: Duke Lee Unit 1 Center SSI – NW Corner Envelope GW BE, LB and UB Soil Profiles

6.0 2D SASSI Analysis Results

Three locations of the Duke SCII Turbine Building 1st Bay are selected for comparison to the AP1000 SCII Turbine Building 1st Bay factored envelop (WEC Node 2955) as shown in Table 6-1, including Nodes 2947, 2951 and 2955 corresponding to the inner and outer edge and the base of the Turbine Building first bay stick model at El 100.0.

Table 6-1: Turbine Building Locations Selected for Comparison

Location	WEC Elevation (ft)	2D SASSI Duke Node	AP1000 General Area
Turbine Building	100	2947	North End
	100	2951	Turbine 1st Bay Stick Base
	100	2955	South End
Note: AP1000 North corresponding to Duke Lee Plant South			

Three locations of the Duke SCII Annex Building are selected for comparison to the AP1000 SCII Annex Building factored envelop (WEC Node 2942) as shown in Table 6-2, including Nodes 3523, 3526 and 3531 corresponding to the outer and inner edge and the base of the Annex Building stick model at El 100.0.

Table 6-2: Annex Building Locations Selected for Comparison

Location	WEC Elevation (ft)	2D SASSI Envelop/Duke Node	AP1000 General Area
Annex Building	100	3523	East End
	100	3526	Annex Stick Base
	100	3531	West End
Note: AP1000 North corresponding to Duke Lee Plant South			

6.1 Duke Lee 2D SSI Adjacent Building Analysis Results

The Duke Lee adjacent building SSI analyses were performed to present FRS at the ground surface of the Turbine Building 1st Bay and SCII portion of the Annex Building for the backfill soil case enveloped by the AP1000 SCII Turbine Building 1st Bay and SCII Annex Building envelops. Also, a comparison of relative displacements to assess the interaction between the adjacent structures and the NI, axial and shear forces and moments compared to the AP1000 CSDRS/HRHF design envelope, and bearing demand for the structures are presented in Sections 6.2, 6.3 and 6.4, respectively.

Duke Lee SCII time history seismic analyses were performed in one horizontal and one vertical direction (X and Z for the Turbine Building model, and Y and Z for the Annex Building model). The input surface time histories for the various analyses are presented in Section 4.1 and were input into SASSI in conjunction with the SASSI Direct method. FRS for 5 percent damping were obtained at the ground surface.

Figures 6.1-1 through 6.1-6 present the Duke SCII Turbine Building 1st Bay horizontal and vertical FRS envelops for the GW backfill soil case and 30-, 40-foot backfill thickness compared to the AP1000 SCII Turbine Building 1st Bay FRS envelop at the ground surface (AP1000 El. 100.0').

Figures 6.1-7 through 6.1-12 present the SCII portion of the Duke Annex Building horizontal and vertical FRS envelops for the GW backfill soil case and 30-, 40-, and 50-foot backfill thickness as well as the Duke SCII Annex Building Northwest corner scenario compared to the AP1000 SCII Annex Building FRS envelop at the ground surface (AP1000 El. 100.0').

As shown, the AP1000 Turbine Building 1st Bay and Annex Building FRS envelop the Duke Lee site specific SCII Turbine Building 1st Bay and Annex Building FRS for the GW backfill and 30-, 40-, 50-foot, and Northwest corner backfill thickness geometry. Figure 6.1-8 suggests a very slight exceedence in the vertical direction at Node 3523 for the Unit 1 Annex Building Northwest corner; however, this model scenario over-estimates the proximity of the NI to the Northwest corner and this minor exceedence is considered to be negligible.

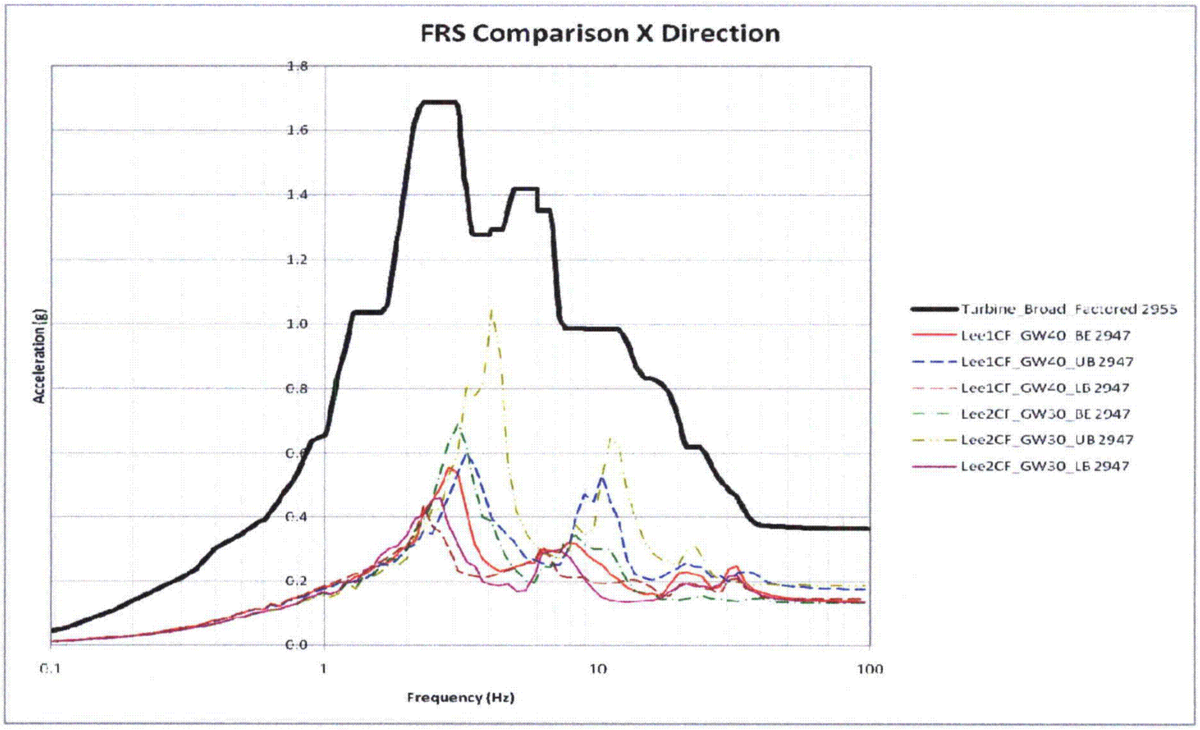

Figure 6.1-1: Unit 1 and 2 Turbine Building FRS Comparison in X-Dir. – GW Backfill – Node 2947

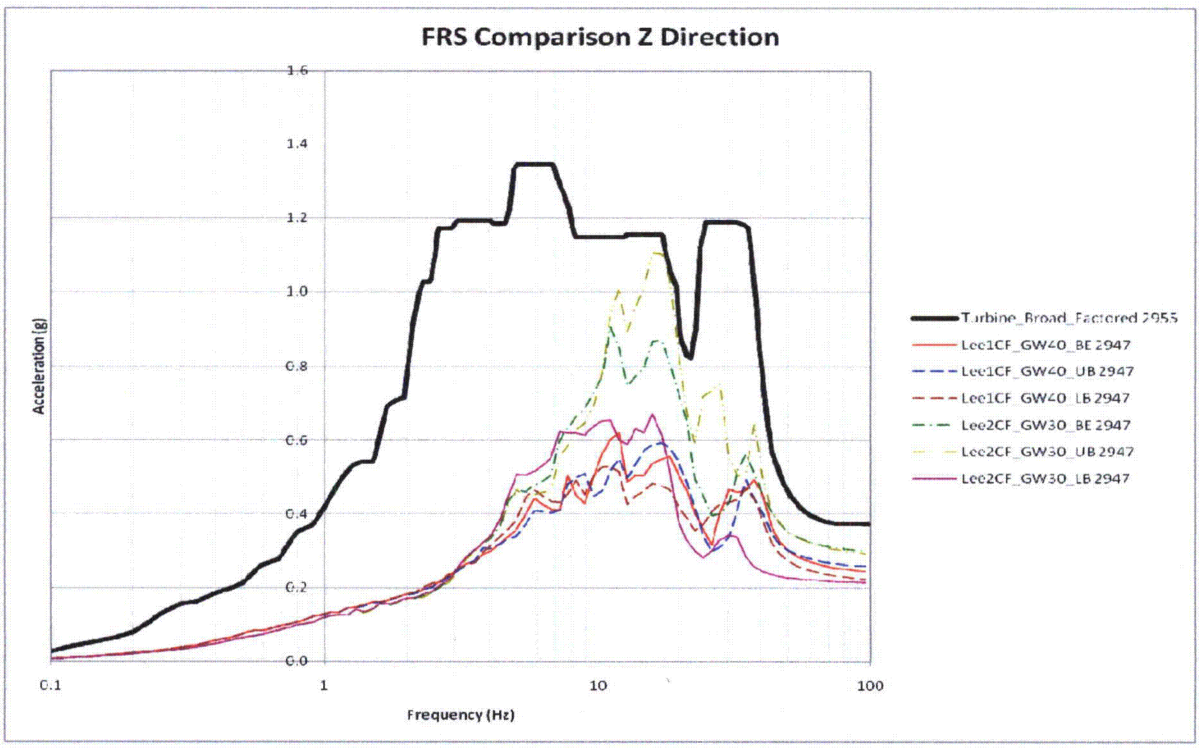

Figure 6.1-2: Unit 1 and 2 Turbine Building FRS Comparison in Z-Dir. – GW Backfill – Node 2947

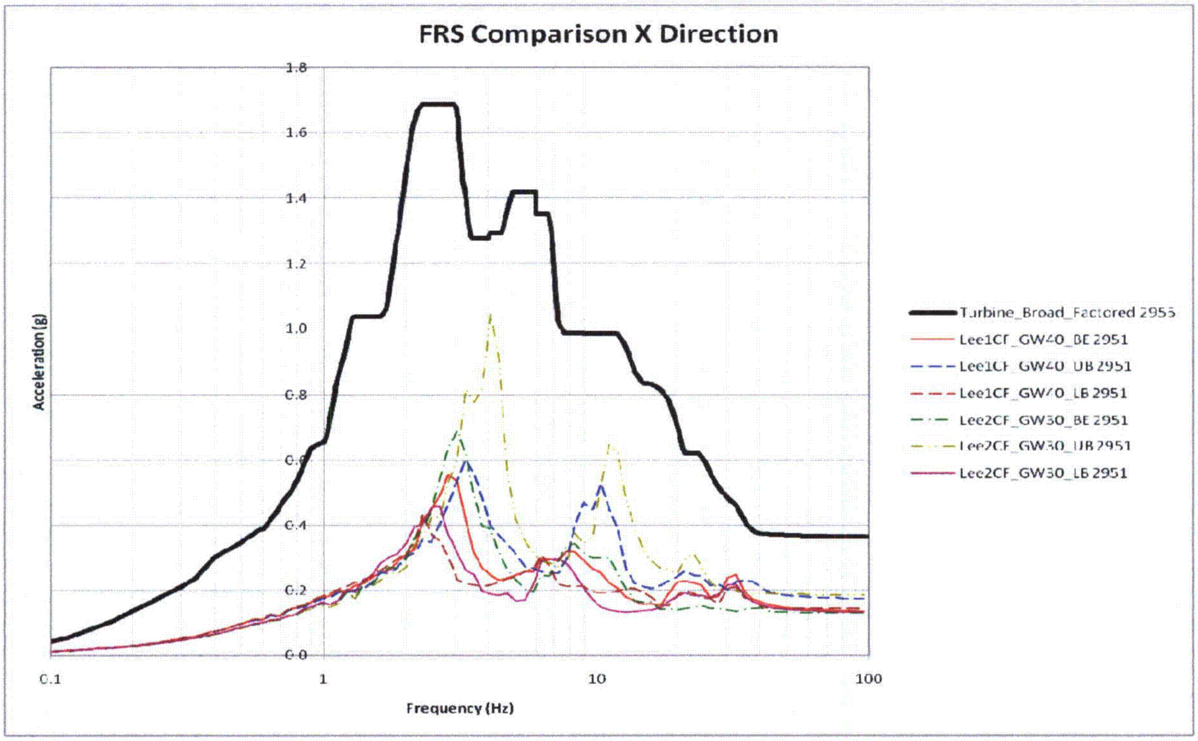

Figure 6.1-3: Unit 1 and 2 Turbine Building FRS Comparison in X-Dir. – GW Backfill – Node 2951

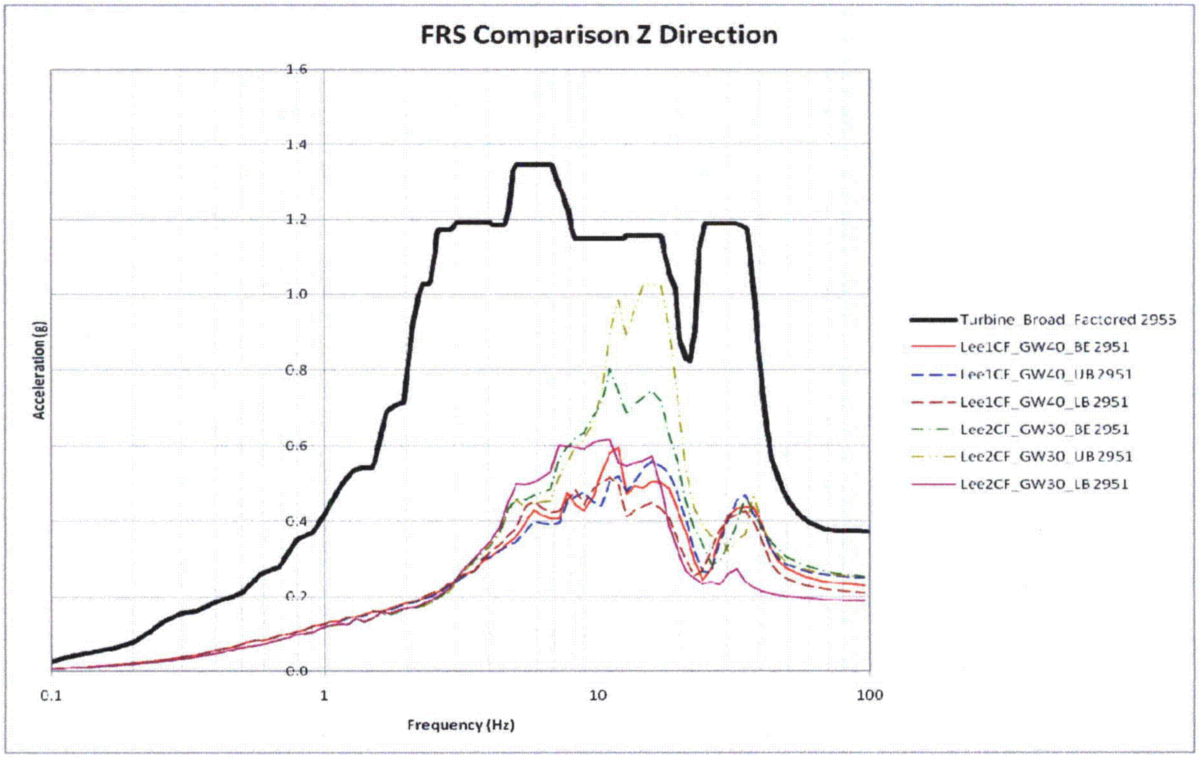

Figure 6.1-4: Unit 1 and 2 Turbine Building FRS Comparison in Z-Dir. – GW Backfill – Node 2951

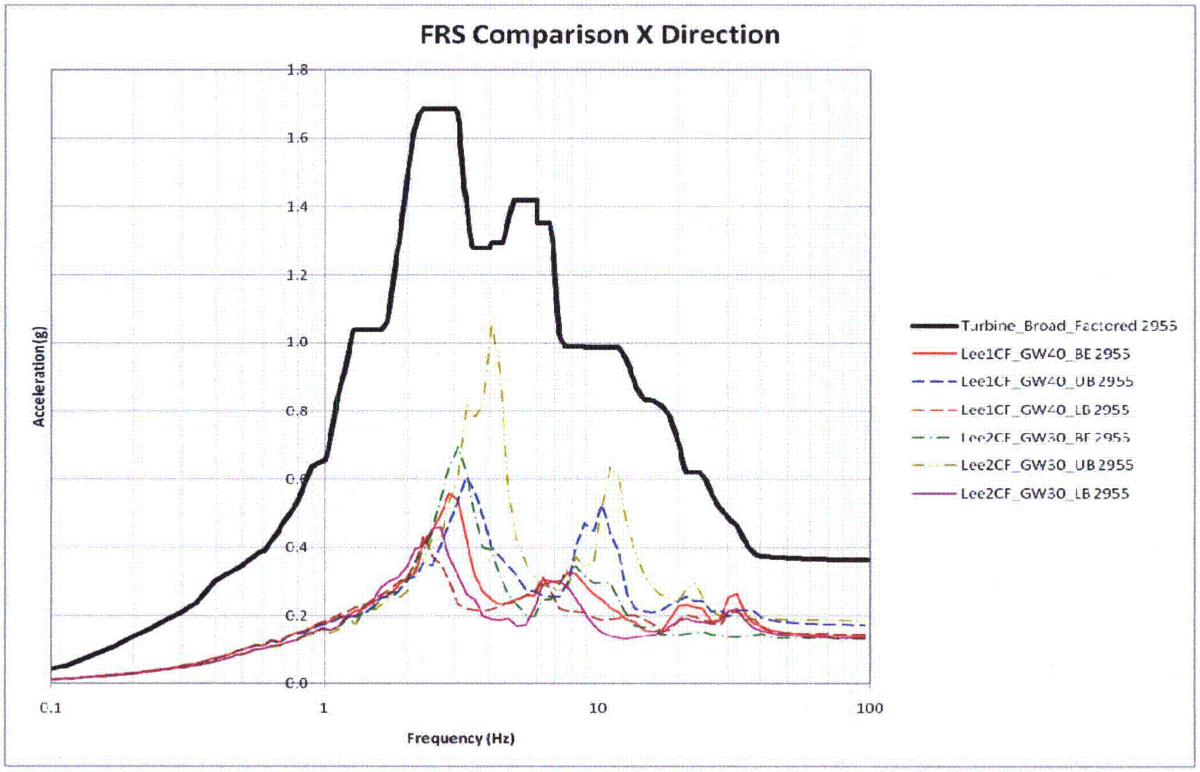

Figure 6.1-5: Unit 1 and 2 Turbine Building FRS Comparison in X-Dir. – GW Backfill – Node 2955

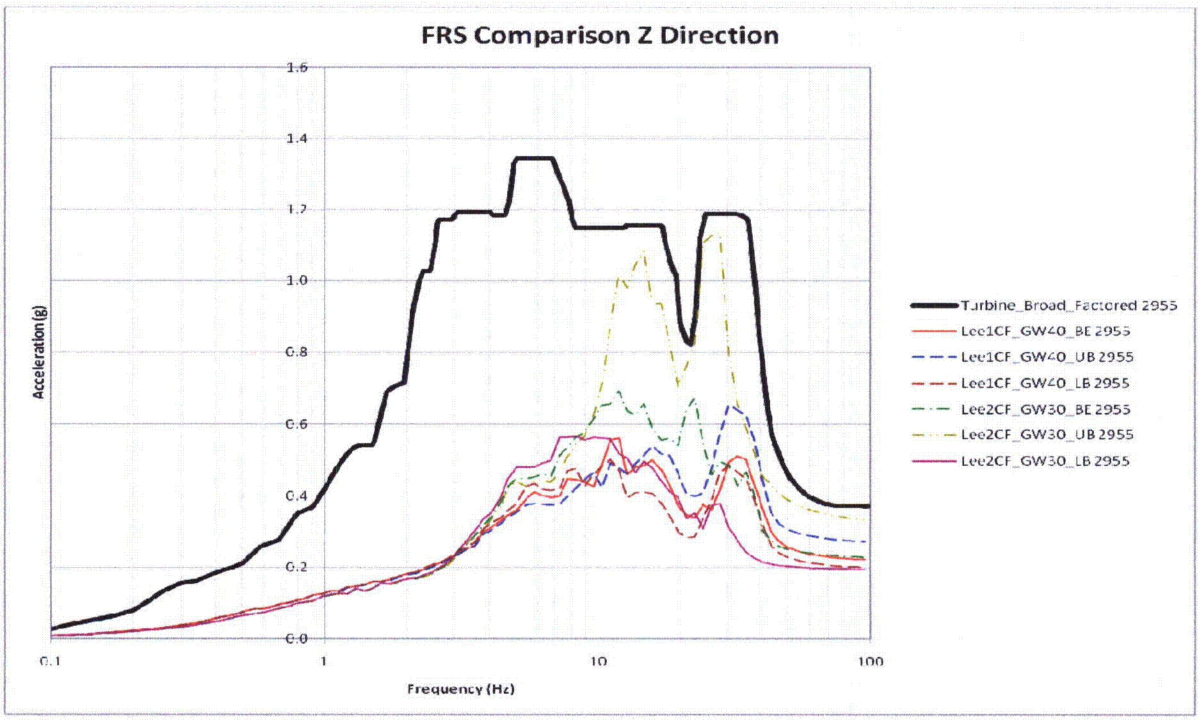

Figure 6.1-6: Unit 1 and 2 Turbine Building FRS Comparison in Z-Dir. – GW Backfill – Node 2955

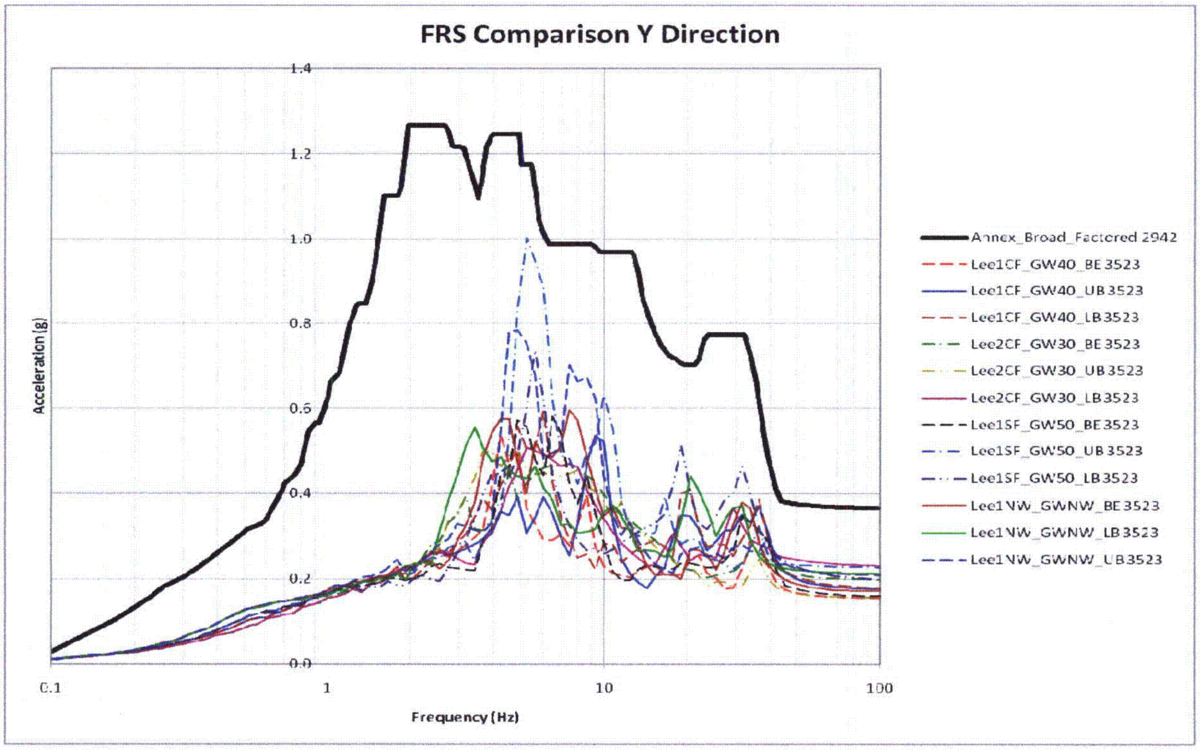

Figure 6.1-7: Unit 1 and 2 Annex Building FRS Comparison in Y-Dir. – GW Backfill – Node 3523

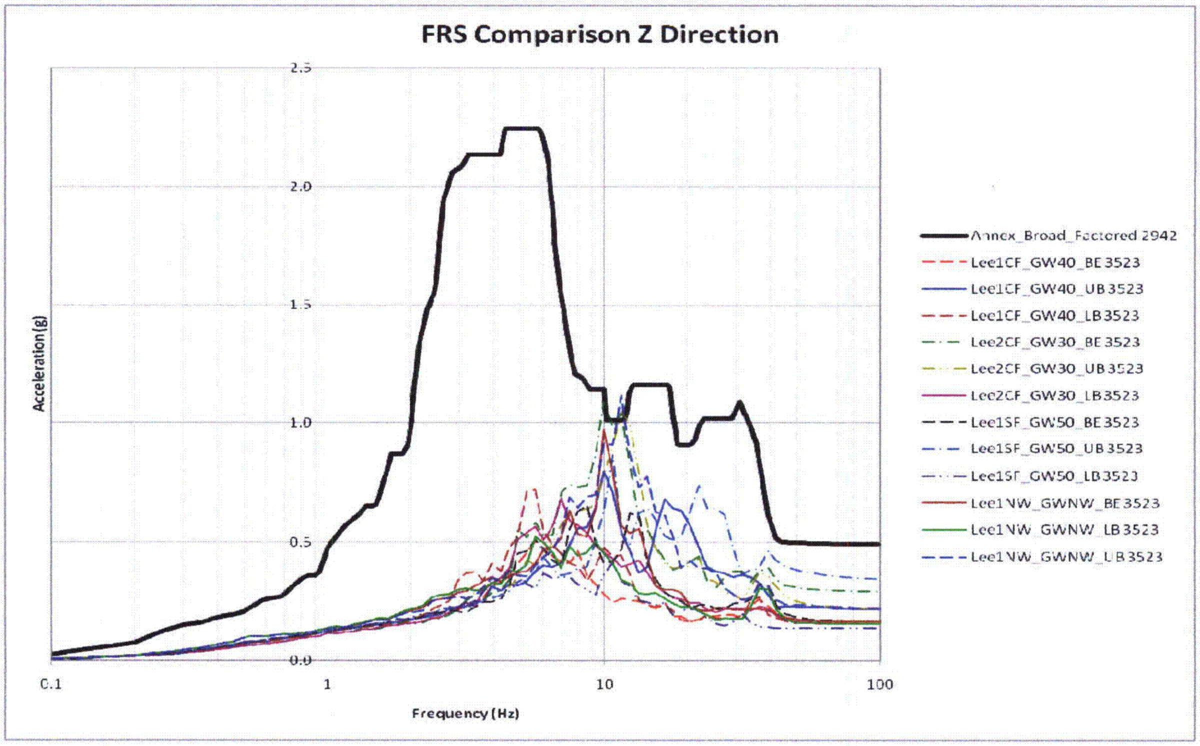

Figure 6.1-8: Unit 1 and 2 Annex Building FRS Comparison in Z-Dir. – GW Backfill – Node 3523

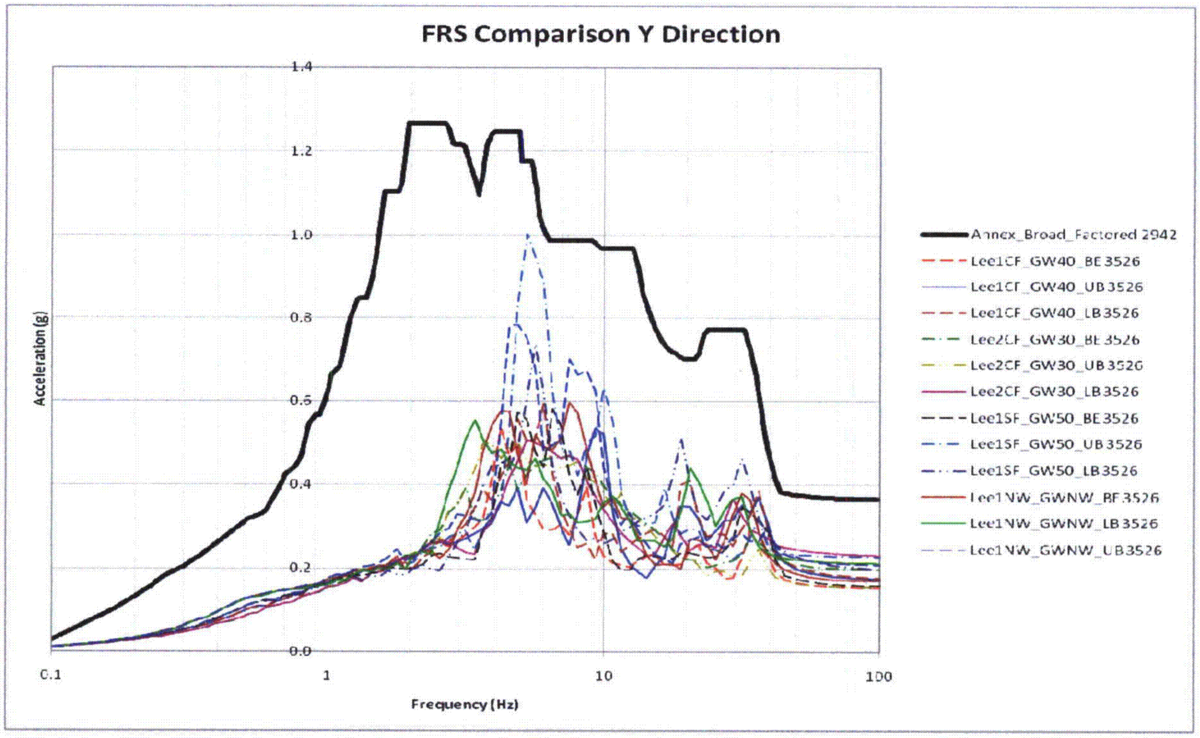

Figure 6.1-9: Unit 1 and 2 Annex Building FRS Comparison in Y-Dir. – GW Backfill – Node 3526

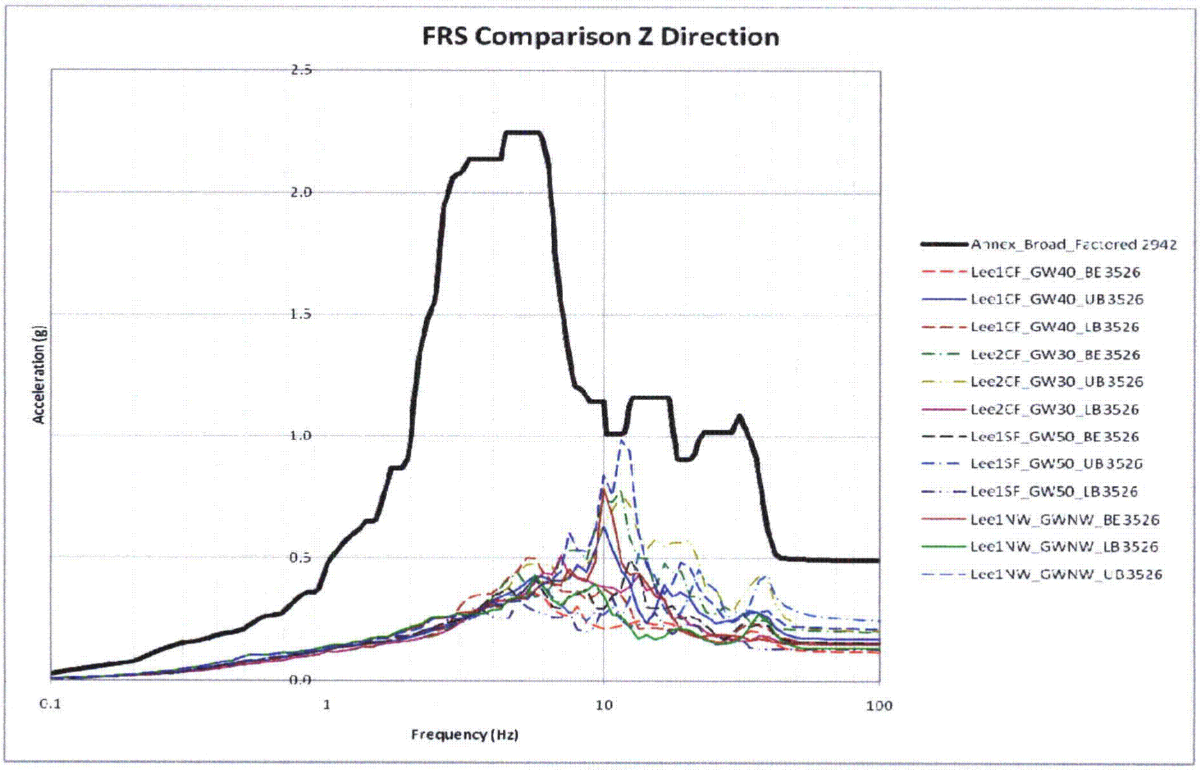

Figure 6.1-10: Unit 1 and 2 Annex Building FRS Comparison in Z-Dir. – GW Backfill – Node 3526

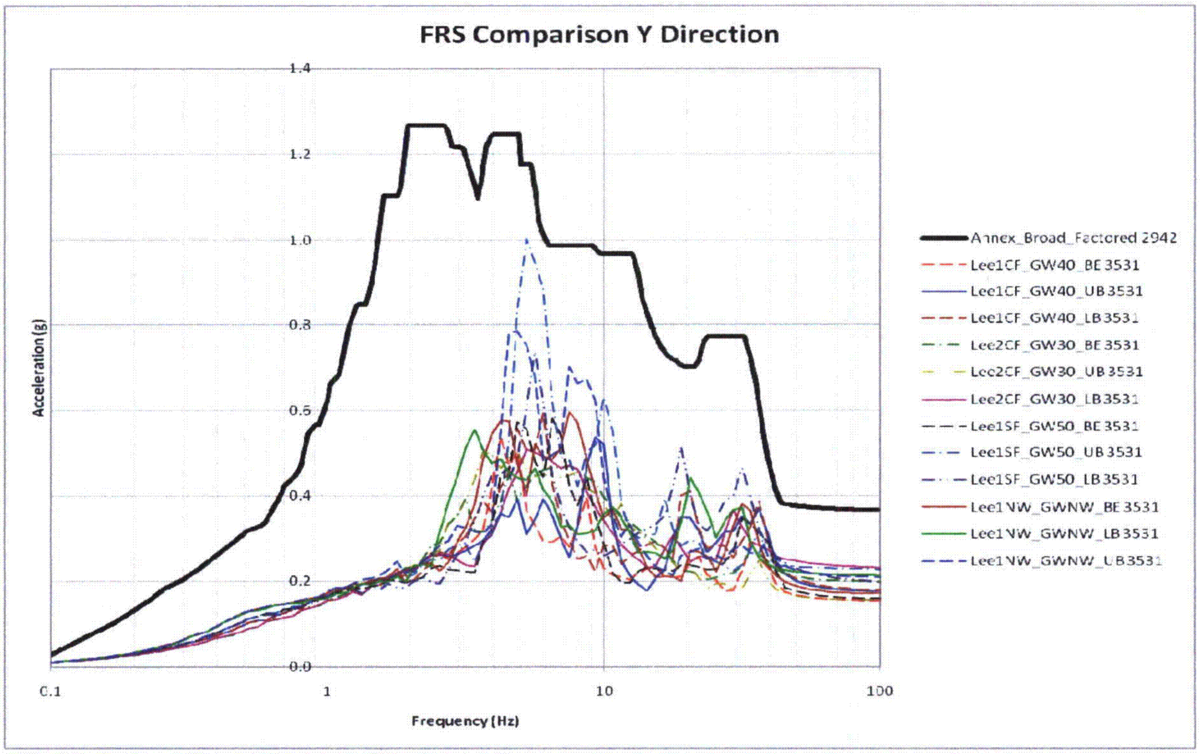

Figure 6.1-11: Unit 1 and 2 Annex Building FRS Comparison in Y-Dir. – GW Backfill – Node 3531

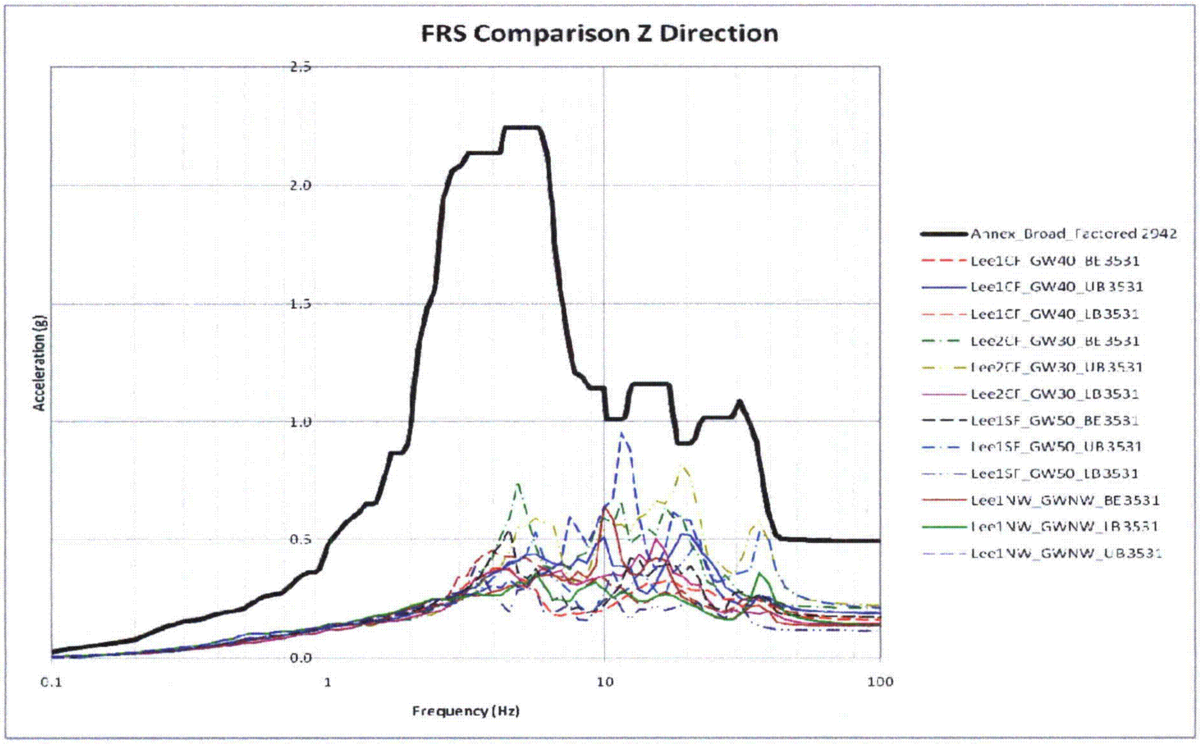

Figure 6.1-12: Unit 1 and 2 Annex Building FRS Comparison in Z-Dir. – GW Backfill – Node 3531

6.2 Adjacent Structure Relative Displacements

The Duke Lee 2D NS and EW models were used to obtain the relative displacements at the locations listed below:

- Turbine Building Foundation to Nuclear Island
- Top of Turbine Building to Nuclear Island (El.170)
- Annex Building Foundation to Nuclear Island
- Top of Annex Building to Nuclear Island (El.180)

The relative displacements were calculated to ensure that there is no contact between the structures at the foundations or at the superstructure. To prevent contact, the relative displacements between the NI and the foundations of the adjacent buildings must be less than 2 inches. To avoid contact between the NI and the Top of the Turbine Building (elevation 170') and Top of the Annex Building (elevation 180'), the relative displacement between the superstructures must be less than 4 inches. The relative displacements, shown in Tables 6.2-1, 6.2-2 and 6.2-3 are less than the space allocated; therefore there is no contact between the NI and the adjacent structures. It is noted that relative displacements for the Northwest corner scenario were not included since the NI is not actually directly adjacent this section as conservatively modeled.

Table 6.2-1: Unit 1 GW 40-Foot Backfill Relative Displacements

	Duke SCII Unit 1 N-S Model (inches)			Duke SCII Unit 1 E-W Model (inches)	
Backfill Envelope Soil Case	Radwaste Building Foundation to Nuclear Island	Turbine Building Foundation to Nuclear Island	Top of Turbine Building to Nuclear Island (El.169)	Annex Building Foundation to Nuclear Island	Top of Annex Building to Nuclear Island (El.180)
GW 40 BE	0.057	0.109	0.284	0.085	0.151
GW 40 LB	0.081	0.178	0.268	0.113	0.131
GW 40 UB	0.041	0.097	0.386	0.060	0.113

Table 6.2-2: Unit 2 GW 30-Foot Backfill Relative Displacements

	Duke SCII Unit 2 N-S Model (inches)			Duke SCII Unit 2 E-W Model (inches)	
Backfill Envelope Soil Case	Radwaste Building Foundation to Nuclear Island	Turbine Building Foundation to Nuclear Island	Top of Turbine Building to Nuclear Island (El.169)	Annex Building Foundation to Nuclear Island	Top of Annex Building to Nuclear Island (El.180)
GW 30 BE	0.045	0.120	0.344	0.066	0.080
GW 30 LB	0.063	0.155	0.249	0.108	0.107
GW 30 UB	0.038	0.121	0.502	0.043	0.121

Table 6.2-3: Unit 1 GW 50-Foot Backfill Relative Displacements

	Duke SCII Unit 1S E-W Model (inches)	
Backfill Envelope Soil Case	Annex Building Foundation to Nuclear Island	Top of Annex Building to Nuclear Island (El.180)
GW 50 BE	0.066	0.080
GW 50 LB	0.108	0.107
GW 50 UB	0.043	0.121

6.3 Axial and Base Shear Forces and Moments Comparison

Axial and base shear forces and moments acting in the basemat elements of the Turbine Building 1st Bay and SCII portion of the Annex Building are obtained. Forces and moments are determined in the X (N-S) and Y (E-W) directions due to the X or Y and Z direction accelerations from which the maximums are determined. Forces and moments for the 40-, 30-foot and 50-foot backfill envelope cases as well as the Northwest corner case are presented in Tables 6.3-1, 6.3-2, 6.3-3 and 6.3-4, respectively. Forces and moments from the corresponding AP1000 generic SCII SSI analysis of the CSDRS and HRHF are also presented for comparison, and as shown, the Duke SCII forces and moments are bounded by the AP1000 CSDRS values.

Table 6.3-1: Unit 1 40-Foot GW Backfill Soil Forces and Moments Comparison

Backfill Soil Case	Axial (kips)	Shear (kips)	Moment (kips-ft)	Generic Case	Axial (kips)	Shear (kips)	Moment (kips-ft)
Turbine Building							
GW 40 LB, BE, UB	3564	2585	111782	CSDRS	10288	8384	222229
				HRHF	5569	4758	164407
Annex Building							
GW 40 LB, BE, UB	10733	11704	243407	CSDRS	23189	16795	637565
				HRHF	7602	13311	403706

Table 6.3-2: Unit 2 30-Foot GW Backfill Forces and Moments

Backfill Soil Case	Axial (kips)	Shear (kips)	Moment (kips-ft)	Generic Case	Axial (kips)	Shear (kips)	Moment (kips-ft)
Turbine Building							
GW 30 LB, BE, UB	4043	3459	146884	CSDRS	10288	8384	222229
				HRHF	5569	4758	164407
Annex Building							
GW 30 LB, BE, UB	9457	10408	328114	CSDRS	23189	16795	637565
				HRHF	7602	13311	403706

Table 6.3-3: Unit 1 50-Foot GW Backfill Forces and Moments

Backfill Soil Case	Axial (kips)	Shear (kips)	Moment (kips-ft)	Generic Case	Axial (kips)	Shear (kips)	Moment (kips-ft)
Annex Building							
GW NW LB, BE, UB	6650	14291	329127	CSDRS	23189	16795	637565
				HRHF	7602	13311	403706

Table 6.3-4: Unit 1 NW Corner GW Backfill Forces and Moments

Backfill Soil Case	Axial (kips)	Shear (kips)	Moment (kips-ft)	Generic Case	Axial (kips)	Shear (kips)	Moment (kips-ft)
Annex Building							
GW NW LB, BE, UB	10267	7329	171360	CSDRS	23189	16795	637565
				HRHF	7602	13311	403706

6.4 Dynamic Bearing Pressure

Additional elements have been created under the Annex and Turbine 1st Bay basemat to obtain soil pressures. Total bearing pressures acting in the soil elements under the basemat combine the deadweight and seismic pressures to yield a maximum bearing pressure.

Since SASSI is a SSI dynamic analysis program, the stress time history due to dead load is obtained by simulating a static dead weight. This is done by running a seismic analysis of the soil structure interaction model excited by one cycle of a 40.96 second harmonic time history with 1g of amplitude; thus, this seismic motion is equivalent to a pseudo-static applied force of value 1g. As shown, the bearing demand for the SCII Annex Building and Turbine Building 1st Bay compare favorably with the Duke Lee site capacities for GW backfill shown in the Duke Lee Foundation Interface Report, Table DUK010-PR-012-23.

Table 6.4-1: Unit 1 and 2 Maximum Bearing Demand/Capacity

Duke Unit 1 and 2	
SCII Annex Building (ksf)	SCII Turbine Building 1st Bay (ksf)
16.83/32.05	12.14/43.74

7.0 Conclusions

Based on the Duke Lee 2D site-specific parametric SSI analyses results described in Section 6.0, the site specific Duke Lee in-structure FRS comparison to the AP1000 SCII design envelops for the adjacent structures indicate the following:

Turbine Building:

The SSI analysis results for the Duke Lee Units 1 and 2 Turbine Building 1st Bay indicate that the FRS for the 40- and 30-foot backfill cases, respectively, and GW backfill material, with a range of upper and lower bound dynamic soil properties are enveloped by the AP1000 Turbine Building FRS envelop.

The axial and base shear forces and moments associated with the 40- and 30-foot backfill case and GW backfill material are also enveloped by the generic CSDRS Turbine Building forces and moments, which control the design of the structure. The relative displacements for this case and backfill material are within the tolerance of 2 inches at the foundation and 4 inches at the top of the structures. The maximum bearing demand for the Turbine Building is estimated at 12.14 ksf as compared to the Turbine Building bearing capacity of 43.74 ksf.

Annex Building

The SSI analysis results for the 40- and 30-foot backfill cases associated with the Unit 1 and 2 SCII portion of the Annex Building, respectively with GW backfill are also enveloped by the AP1000 generic FRS envelop. The forces and moments associated with the Units 1 and 2 Centerline 40- and 30-foot backfill cases and GW fill are enveloped by the generic CSDRS Annex Building forces and moments. The relative displacements for the 40- and 30-foot cases and GW backfill are within the limits of 2 inches at the foundation and 4 inches at the top of the structures.

The SSI results for the 50-foot backfill case at the South end of the Unit 1 Annex Building with GW backfill are enveloped by the AP1000 generic FRS envelop spectra. The forces and moments associated with the Unit 1 South 50-foot backfill case and GW fill are enveloped by the generic CSDRS Annex Building forces and moments, and the relative displacements for this case are also within the limits of 2-inch at the foundation and 4 inches at the top of the structure. The SSI analyses results for the concrete and backfill case at the Northwest corner of the Unit 1 Annex Building with GW backfill are enveloped by the AP1000 generic envelop spectra. The maximum bearing demand for the Annex Building is 16.83 ksf as compared to the Annex Building bearing capacity of 32.05 ksf.

Finally, WEC notes that the analytical results presented and observations noted may not preclude the use of the GP and/or SW candidate backfill materials, as the results of this 2D SSI parametric study, with further refinement and additional parametric evaluation of the data could also yield favorable FRS comparisons for these backfill materials.

8.0 References

1. DUK-010-PR-012, "Project Report for Duke Lee Combined Operating License Project, Foundation Interface Report," Enercon Services, Inc., Rev. 3, 1/25/10.

2. William S. Lee Nuclear Power Plant Unit 1 and 2 COL Application, Part 2, Final Safety Analysis Report, Revision 6.

3. Fugro Consultants, Inc. DUK-001-CALC-01 Rev. 0, "Development of Artificial Time Histories for Lee Unit 1 – Concrete Structures", October 2010.

4. SASSI2000, User's Manual, A System for Analysis of Soil-Structure Interaction, Rev. 1, November 1999, Geotechnical Engineering Division Civil Engineering Department, University of California, Berkeley, CA 94720.

5. Enercon Services, Inc. DUK010-FSAR-2.5.2-CALC-010 Rev. 0, "Lee Unit 1 Nuclear Island Northwest Corner Site Response Sensitivity Analysis for Horizontal Motions."

6. Enercon Services, Inc. DUK010-FSAR-2.5.2-CALC-014 Rev. 1, "Calculation of Location-Specific Performance-Based Surface Response Spectra (PBSRS) for Lee Units 1 and 2."

7. Enercon Services, Inc. DUK010-FSAR-2.5.2-CALC-015 Rev. 1, "Calculation of Location-Specific Hazard-Consistent Strain Compatible Property (HCSCP) Data for Lee Units 1 and 2."

8. ENERCON Services, Inc. (2012c), DUK010-PR-040, Rev. 1, Performance-Based Surface Response Spectra (PBSRS) Envelopes for Lee Units 1 and 2.

9. U.S. Nuclear Regulatory Commission Standard Review Plan (SRP) 3.7.1, Seismic Design Parameters, NUREG-0800, Revision 3, March 2007.

10. Technical Requirements Document, WLR-4000.55-03-004 Rev. 2 including "Memorandum from Fugro Consultants, Inc. (Robert Turner [FCL] and Michael Gray [LCI] to Enercon Services (Tom Slavonic and Fred Redwanz), Uncertainty associated with material dynamic properties used in calculation of site response analysis and hazard consistent strain compatible properties for Duke Energy William States Lee III COLA Project, dated June 11, 2012."

Lee Nuclear Station

Supplemental Response to Request for Additional Information (RAI)

Attachment 38 to RAI 03.07.01-004

Revisions to Lee Nuclear Station Final Safety Analysis Report

Subsections 2.5.4.2.4.1, 2.5.4.2.4.1.8, 2.5.4.5.1, 3.7.2.8.4, and 3.7.6

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.4.2.4.1 is revised as follows:

2.5.4.2.4.1 Geotechnical Model

A geotechnical model of the site was developed in the Cherokee Nuclear Station Preliminary Safety Analysis Report document prepared in the early to mid-1970s. This model has been adopted for use at the Lee Nuclear Station Site to maintain consistency with the work completed during Cherokee Nuclear Station construction activities. The conditions at the site are amenable to being classified into a geotechnical model that consists of existing engineered fill soils, alluvial soils, residual soils, saprolite, partially weathered rock (PWR), existing concrete, and rock. Also added to the model is the granular backfill material placed around the nuclear islands and beneath Seismic Category II structures adjacent to the nuclear islands.

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.4.2.4.1.8 is revised as follows:

2.5.4.2.4.1.8 Granular Backfill

No safety-related structures will be placed on granular fill. Granular fill composed of select materials from a quarry rock crushing product will be placed and compacted around the walls of the nuclear islands and extending outward to form the support for the structures adjacent to the nuclear islands. These select granular materials will be compacted to a minimum relative compaction of 96 percent of the modified Proctor (ASTM D 1557-02) maximum dry density. FSAR Subsection 3.7.2.8.4 describes the material property characteristics of the granular fill used to support Seismic Category II structures adjacent to the nuclear island.

COLA Part 2, FSAR, Chapter 2, Subsection 2.5.4.5.1 is revised as follows:

2.5.4.5.1 Sources and Quantities

WLS COL 2.5-6
WLS COL 2.5-7

The Lee Nuclear Station Site requires granular backfill material described in Subsection 2.5.4.5.3.5 to fill the area around the below-grade nuclear island walls out to the extents shown on Figures 2.5.4-245 and 2.5.4-246, and 2.5.4-260 through 2.5.4-265. This backfill also forms the yard elevation and supporting materials for the power block structures outside but adjacent to the nuclear island.

The source for the granular fill is not identified. At a rock quarry, material is crushed to form granular product consisting of a mixture of gravel, sand, and some fines. The granular fill material will likely be obtained from an off-site source such as an operating rock quarry. Imported granular fill intended to be placed adjacent to Seismic Category I structures or beneath other important adjacent facilities will be verified as compatible with Lee Nuclear Station site response calculations. FSAR Subsection 3.7.2.8.4 describes the material property characteristics of the granular fill used to support Seismic Category II structures adjacent to the nuclear island.

COLA Part 2, FSAR, Chapter 3, Subsection 3.7.2.8.4, is revised as follows:

3.7.2.8.4 Seismic Modeling and Analysis of Seismic Category II Building Structures

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Add the following information to the end of DCD Subsection 3.7.2.8.4:

WLS SUP 3.7-4 The foundation conditions beneath most of the Unit 1 Annex Building are very uniform, and are in fact similar to those described in the AP1000 DCD, except that the fill material supporting the Annex Building is a few feet thicker. In the northernmost end of the Unit 1 Annex Building, the top-of-continuous-rock slopes away, but the overall character of the building support remains quite uniform. This is illustrated in FSAR Figures 2.5.4-246, 2.5.4-260, and 2.5.4-264. Since the entire Seismic Category II portion of the Annex Building is on a common base mat and will behave as a unit, these localized differences in the support conditions will not significantly affect overall response of the Unit 1 Annex Building, or the potential for interaction with the nuclear island.

FSAR Figure 2.5.4-260 also illustrates the support conditions beneath the Unit 2 Annex Building. Though final excavation profiles to support construction of Unit 2 have not been established, the foundation support provided by the existing rock excavation provide uniform support at a depth about ten feet less than the configuration described in the AP1000 DCD.

The foundation conditions beneath the Seismic Category II portion of the Unit 1 and Unit 2 Turbine Buildings are also very uniform and are in fact similar to those described in the AP1000 DCD, except that the supporting rock or fill concrete will be a few feet above the level considered for the standard design.

As shown in FSAR Subsection 3.7.1.1.1, the Lee GMRS and Unit 1 FIRS are enveloped by the AP1000 HRHF response spectrum. The properties of the granular fill material that will be placed above continuous rock, presented in FSAR Table 2.5.4-211 and FSAR Tables 2.5.4-224A through 2.5.4-224F, are consistent with those used by Westinghouse in developing design criteria for adjacent Seismic Category II structures and include having a shear wave velocity greater than 500 fps.

Lee site-specific performance-based surface response spectra at the ground surface of the granular fill supporting the adjacent Seismic Category II buildings have been developed, considering the effects of the different thicknesses of granular fill material beneath the adjacent buildings. For frequencies above 5 Hz, these site-specific spectra are generally lower than the AP1000 generic plant-grade spectra for a Hard Rock High Frequency site that were considered in developing design criteria for the Seismic Category II buildings and any isolated exceedances of the AP1000 generic plant-grade spectra would not result in any change to the standard design criteria for the AP1000 Seismic Category II buildings. For frequencies below 5 Hz, the design of Seismic Category II structures is governed by the CSDRS.

From the candidate granular fill materials described in FSAR Subsection 2.5.4, Duke Energy has determined that Macadam Base Course material provides properties appropriate for precluding interaction of Seismic Category II buildings with the nuclear island. Duke Energy has selected the static and dynamic properties described in FSAR Subsection 2.5.4 as well-graded gravel (GW) to represent that Macadam Base Course material.

Westinghouse has performed a site-specific analysis of Seismic Category II structures supported by granular fill material with the static and dynamic properties associated with well-graded gravel (GW), and has concluded that all DCD criteria have been met . This analysis is presented in Reference 205. The calculated site-specific relative displacements of adjacent buildings are less than the building separation, so there is no contact between the nuclear island

and adjacent buildings. The calculated foundation input response spectra at the base of the Annex Building and at the base of the first bay of the Turbine Building are less than those considered in the AP1000 standard design of those structures. The maximum site-specific bearing demand (approximately 13.06 ksf for the Annex Building and 7.75 ksf for the Turbine Building) is significantly less than the site-specific allowable bearing pressure shown in FSAR Table 2.5.4-228 (approximately 32.05 ksf for the Annex Building and 43.74 ksf for the Turbine Building). The base shears and moments for those two structures are also significantly less than those considered in the AP1000 standard design of the Seismic Category II structures for the CSDRS.

As described in FSAR Subsection 2.5.4.5.1, the source for the granular fill material (Macadam Base Course) supporting the Seismic Category II buildings has not yet been identified. Once a source for the granular fill material has been selected, the static and dynamic properties of the material supporting Seismic Category II buildings will be verified as compatible with Lee Nuclear Station site response analyses.

~~The Lee site-specific bearing capacity for the granular fill material supporting the Seismic Category II structures (shown in FSAR Table 2.5.4-228) is greater than the generic AP1000 bearing demand for these structures.~~

The site-specific analysis presented in Reference 205 demonstrates that the ~~The~~ Lee site provides uniform support for the Seismic Category II buildings; site-specific fill material is consistent with that considered in establishing generic AP1000 design criteria for these buildings; and the site-specific seismic demands on the Seismic Category II buildings are less than those considered in the AP1000 standard design.

COLA Part 2, FSAR, Chapter 3, FSAR Subsection 3.7.6 is revised to add a new reference as follows:

205. Westinghouse Electric Company Report WLG-1000-S2R-804, Revision 2, William S. Lee Site Specific Adjacent Building Seismic Evaluation Report, July 2012.