STP Nuclear Operating Company
South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

December 21, 2010
U7-C-STP-NRC-100274

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Supplemental Response to Request for Additional Information

Attached is a supplemental response to the NRC staff question included in Request for Additional Information (RAI) letter number 349 related to Combined License Application (COLA) Part 2, Tier 2, Section 3.7. The attachment provides the supplemental response to the RAI question listed below:

03.07.01-27

Where there are COLA markups, they will be made at the first routine COLA update following NRC acceptance of the RAI response. There are no commitments in this letter.

If you have any questions regarding this response, please contact me at (361) 972-7136, or Bill Mookhoek at (361) 972-7274.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 12/21/10

Scott Head
Manager, Regulatory Affairs
South Texas Project Units 3 & 4

jep

Attachment:

RAI 03.07.01-27, Supplement 1

D091
NRO

STI 32802268

cc: w/o attachments and enclosure except*

(paper copy)

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RAI 03.07.01-27, Supplement 1

QUESTION:

Follow-up Question to RAI 03.07.01-19 (STP-NRC-100093)

1. 10CFR50, Appendix S requires that evaluation for SSE must take into account soil-structure interaction (SSI) effects and the expected duration of vibratory motion. In the response to the first paragraph of RAI 03.07.01-19, the applicant has presented its approach for developing the input motion for the SSI analysis and design of the DGFOSV that takes into account the impact of the nearby heavy RB and RSW Pump House structures. The applicant also stated that *"Conservatively, a 3-dimensional SAP2000 response spectrum analysis was used to obtain the safe-shutdown earthquake (SSE) design forces due to structure inertia. The seismic induced dynamic soil pressure on DGFOSV walls were computed using the method of ASCE 4-98, Subsection 3.5.3.2"* The response, however, does not provide details as to how the SSI analysis of the DGFOSV are performed and how the input motion developed are subsequently specified in the SSI analysis of DGFOSV to develop the structural response and in-structure response spectra for any equipment and subsystems within DGFOSV. From the response it appears that the applicant has not included explicitly DGFOSV structural model in the SASSI model of the RB and RSW Pump House structures to properly evaluate the SSSI effect on the DGFOSV. In order for the staff to determine if the evaluation of DGFOSV for SSE has appropriately accounted SSI effects, the applicant is requested to provide in the FSAR the following information:

   (a) Describe in detail the method used for the SSI analysis of DGFOSV including the procedures for treatment of strain dependent backfill material properties in the model, input motion used and how it is specified in the analysis, variation of soil properties, and the computer programs used for SSI analysis.

   (b) Describe in detail how SAP2000 analysis of DGFOSV was performed including, how foundation soil/backfill material was represented, how many modes were extracted, what modal damping values were used, how the input motion was specified, and what type of boundary conditions were used.

   (c) Demonstrate that the DGFOSV foundation response spectra and dynamic soil pressure (on DGFOSV basement walls using ASCE 4-98 criteria) used in the design of DGFOSV will envelop the results of structure to structure (SSSI) interaction analysis which explicitly models DGFOSV structure in the SSI model of RB and the RSW Pump House structure.

   (d) Describe in detail if there is any Category I tunnel structure for transporting Diesel Fuel Oil between DGFOSV and the Diesel Generator located in other buildings including its layout and configuration and seismic analysis and design method.

2. In the response to Item 2 of RAI 03.07.01-19, the applicant has stated that the P-wave damping ratios are assigned the same values as those calculated for the S-wave damping ratios because of the **upcoming** recommendations of ASCE 4-09 standards. It is further stated that this recommendation is based on the recent observation of earthquake data and the realization that the waves generated due to SSI effects are mainly surface and shear waves. It is noted that the NRC has not endorsed ASCE 4-09 for estimating the P-wave damping. In general, the P-wave damping is primarily associated with the site response rather than SSI effects. Because the Pwave energy for the most part will travel in water within the saturated soil media at relatively high propagation speed and is not affected by shear strains of degraded soil, the P-wave damping will be small. As such, the applicant is requested to provide quantitative assessment by performing sensitivity analysis that shows that seismic responses of Category I structures are not adversely affected to a lower P-wave damping.

SUPPLEMENTAL RESPONSE:

The response to Part 2 of this RAI was submitted with STPNOC letter U7-C-STP-NRC-100208 dated September 15, 2010. The response to Part 1(d) is currently scheduled to be provided in January 2011. This supplemental response provides the response to Parts 1(a) through 1(c).

1a) Soil-Structure Interaction (SSI) Analysis of Diesel Generator Fuel Oil Storage Vaults (DGFOSV)

The DGFOSV are reinforced concrete structures, located below grade with an access room above grade. The DGFSOV house fuel oil tanks and transfer pumps. The locations of the DGFOSV and nearby structures are shown in Figure 3H.6-221 (see Enclosure 1).

The following two types of SSI analyses are performed for DGFOSV:

- 3D SSI analyses of DGFOSV alone for calculating in-structure response spectra and design accelerations/forces of the structure. These analyses were performed considering both full and empty fuel oil tanks.
- 2D structure-soil-structure interaction (SSSI) analysis of DGFOSV and adjacent structures to obtain seismic soil pressures.

3D SSI Analysis

The SSI analyses of the 3D model of DGFOSV are performed using SASSI2000 computer program (using subtraction method).

Structural Model:

The structural part of the model consists of shell elements to model the exterior walls, and the roof slabs and 3D solid elements to model the basemat and the mud mat. Structure self weight and other applicable weights of equipment, live load, piping, metal

decking, missile barrier cover are included in the structural model. The fuel tank is modeled with the fuel and tank weight lumped at the center of gravity of the tank and the tank lumped weight rigidly connected to the base mat at tank saddle locations. The fuel tank procurement specification will require that the fuel tank with fuel in it should have predominant frequencies greater than 33 Hz in horizontal and vertical directions. The fuel tank portion of the model has been assigned a damping value of 0.5%. For the other parts of the structure two damping values are used; 7% damping and 4% damping. The results from the 7% structural damping are used for design of the DGFOSV. The results from the 4% damping are used for generation of in-structure response spectra. Both full and empty fuel oil tank conditions are considered in the analysis. Figure 3H.6-222 (see Enclosure 1) shows the typical 3D structural model of the DGFOSV for various SSI analyses. The following provides the details of the SSI model and method of analysis.

Strain Dependent Soil Properties Used in SSI Analyses:

The strain dependent soil properties used in the model are in accordance with the properties provided in COLA Part 2, Tier 2 Table 3H.6-1 for the in-situ soil and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers is adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

Analysis Cases, Passing Frequency and Cutoff Frequency for the SSI Analyses:

- The following cases are analyzed for both 4% and 7% structural damping values:

  For full fuel oil tank case:

  - Lower Bound (LB) in-situ soil
  - Mean in-situ Soil
  - Upper Bound (UB) in-situ soil
  - LB backfill over LB in-situ soil
  - Mean backfill over mean in-situ soil
  - UB backfill over UB backfill
  - UB in-situ soil with soil separation
  - UB in-situ soil with cracked concrete

  For Empty fuel oil tank case:

  - UB in-situ soil with empty fuel tank

  Note: For soil separation, cracked concrete and empty fuel oil tank cases, the UB in-situ soil is used because the UB in-situ soil case in general governed.

- A cut-off frequency of 35 Hz was used for all SSI analyses for transfer function calculation.
- Vertical direction passing frequencies (based on one fifth of shear wave length criterion and considering lower bound in-situ soil) are equal to or greater than 33 Hz.
- Horizontal direction passing frequencies are equal to or greater than 33 Hz, except at following locations:

  - For LB in-situ soil, the passing frequency for the top 4 ft soil layer is 30.3 Hz.
  - At the foundation toe, the passing frequencies for in-situ soil are 20 Hz for LB, 25.8 Hz for mean, 31.6 Hz for UB; and for backfill are 23.1 Hz for LB, 28.3 Hz for mean and 34.7 Hz for UB.

To evaluate the effect of 20 Hz passing frequency for LB in-situ case, the foundation toe was divided into two elements, thus increasing the passing frequency to 40 Hz. This refined model with LB in-situ soil properties was analyzed and 5% damped spectra from this model were compared with the spectra from the original model with passing frequency of 20 Hz. The spectra comparison plots are shown in Figures 03.07.01-27.1 through 03.07.01-27.24. The comparison shows that:

- In the X direction, there is insignificant difference between the response spectra from the two models
- In the Y direction, the response spectra from the two models matched well except at frequency of about 3.8 Hz where the refined model produced higher spectra. However, spectra from both the models are enveloped by the spectra for UB in-situ soil case
- In the vertical direction, the spectra from the two models matched well (insignificant difference)

Based on the above evaluation it is concluded that the horizontal direction passing frequencies are acceptable.

Input Motion:

As described in COLA Part 2, Tier 2 Section 3H.6.7, the input motion considers the impact of the nearby Reactor Building (RB) and UHS/RSW Pump House. From the procedure described in this COLA section it was determined that the 0.3g Regulatory Guide 1.60 spectra envelop all other spectra derived from the SSI analyses to take into account the impact of nearby large structures. Therefore, in this SSI analysis, acceleration time histories consistent with 0.3g Regulatory Guide 1.60 spectra are used as input at the grade elevation.

Response Combination, Enveloping and Spectra Peak Widening:

For all analysis cases, the responses due to two horizontal directions and vertical direction input motions are combined using square-root sum of squares (SRSS) method.

Then, the responses from all analysis cases and all locations considered for spectra generation are enveloped to determine one set of un-widened horizontal and vertical response spectra. Finally, per Regulatory Guide 1.122, the enveloped un-widened response spectra are peak widened by plus-minus 15% on the frequency scale to obtain the final response spectra for DGFOSV. The resulting enveloping response spectra for DGFOSV are shown in Figures 3H.6-223 and 3H.6-224 (see Enclosure 1).

2D SSSI Analysis

Two 2D SSSI models are developed and analyzed to evaluate the effects of nearby structures on the three DGFOSV and to calculate the seismic soil pressures on the structures.

The first SSSI model is for a section cut in the North-South direction, consisting of UHS/RSW Pump house, RSW Piping Tunnel, DGFOSV 1B, DGFOSV 1C and RB. The details of this SSSI analysis have been provided in the response to RAI 03.07.02-24, Supplement 1, submitted with STPNOC letter U7-C-STP-NRC-100253 dated November 29, 2010.

The second SSSI model is for a section cut in the East-West direction consisting of diesel generator fuel oil tunnel (DGFOT), DGFOSV 1A and the Crane Foundation Retaining Wall. The model for this SSSI analysis is shown in Figure 3H.6-225 (see Enclosure 1). The model details of the SSSI analysis is provided below.

Structural Models:

DGFOSV Model:

East-West direction of 2D DGFOSV model is idealized by a stick model of beam elements. Axial, flexural, and shear deformation effects are included in beam element stiffness. The fuel oil tank is also modeled using beam elements and its mass is lumped at its CG. The basemat and the mud mat are modeled using four node plain strain elements. The model properties (stiffness and mass) for the 2D plane analysis correspond to per unit depth (one foot dimension in the out-of-plane direction) of the DGFOSV.

DGFOT Model:

Four node plane strain elements are used to model the exterior walls, base slab, the top slab and the mud mat. Applicable weights are included at appropriate locations in the model. The structural model properties (stiffness and mass) for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

Crane Wall:

The Crane Wall is modeled using beam elements with nodes located 17 ft away from the DGFOSV east wall (clear distance between the DGFOSV 1A exterior wall face and the west face of the Crane Wall). Beam section properties (stiffness and mass) for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

The SSSI analysis of the 2D model of DGFOSV with other structures, which affects the DGFOSV in the East-West direction, is performed using SASSI2000 computer program, using subtraction method. The following provides the details of the SSSI analysis.

Strain Dependent Soil Properties Used in SSSI Model:

The strain dependent soil properties used in the model are in accordance with the properties provided in COLA Part 2, Tier 2 Table 3H.6-1 for the in-situ soil, and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers is adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

To evaluate the effects of the soil variation, five soil cases are considered:

- UB in-situ soil with UB backfill between the structures.
- LB in-situ soil with LB backfill between the structures.
- Mean in-situ soil with Mean backfill between the structures.
- Mean in-situ soil with LB backfill between the structures.
- Mean in-situ soil with UB backfill between the structures.

Passing Frequency and Cut-off Frequency for SSSI Model:

- Cut-off frequency of 33 Hz is used in the analysis.
- Vertical direction passing frequencies are equal to or greater than 33.5 Hz.
- Horizontal direction passing frequencies are equal to or greater than 30.48 Hz.

Input Motion:

STP 3&4 site specific SSE motion, as described in COLA Part 2, Tier 2 Subsection 3H.6.5.1.1.2, is applied at the grade elevation, in the East-West direction.

Comparison of DGFOSV Foundation Spectra from 3D SSI analysis and 2D SSSI Analysis:

Figures 03.07.01-27.25, 03.07.01-27.26 and 03.07.01-27.27 show the comparisons between the DGFOSV foundation level 5% damped response spectra obtained from the

3D SSI analysis (enveloped for all soil cases and used for the design of the DGFOSV) and the 5% damped foundation spectra obtained from 2D SSSI analyses. The comparisons show that the design spectra obtained from the 3D SSI analyses envelop the spectra obtained from the 2D SSSI analyses. Note that the input motion for the 3D SSI analysis corresponds to 0.3g Regulatory Guide 1.60 spectra, and the input motion for 2D SSSI analysis is the site specific SSE.

1b. The SAP2000 response spectrum analysis described in response to RAI 03.07.01-19, submitted with letter U7-C-STP-NRC-100093, dated April 29, 2010, is no longer used. The revised SSI analyses are described in Part 1a above. All in-structure response spectra and maximum accelerations for DGFOSV are based on this revised SSI analysis. The design of DGFOSV has also been revised and the seismic loads are conservatively determined using equivalent static method. The details for this equivalent static method will be provided in the response to RAI 03.08.04-30, Supplement 1, which is currently scheduled to be submitted in January 2011.

1c. The comparison of the DGFOSV foundation response spectra from 3D SSI analysis and 2D SSSI analysis is provided in Part 1a above.

The structural analysis and design of the DGFOSV have been revised to consider seismic soil pressures from the SSSI analysis described in part 1a above. Figures 3H.6-226 through 3H.6-231 show a comparison of the SSSI soil pressures and the ASCE 4-98 soil pressures and the total soil pressure used in the design of DGFOSV walls. The revised design results for the DGFOSV will be provided in the response to RAI 03.08.04-30, Supplement 1, which is currently scheduled to be submitted in January 2011.

Revision 4 of COLA Part 2, Tier 2 Section 3H.6 will be revised as shown in Enclosure 1.

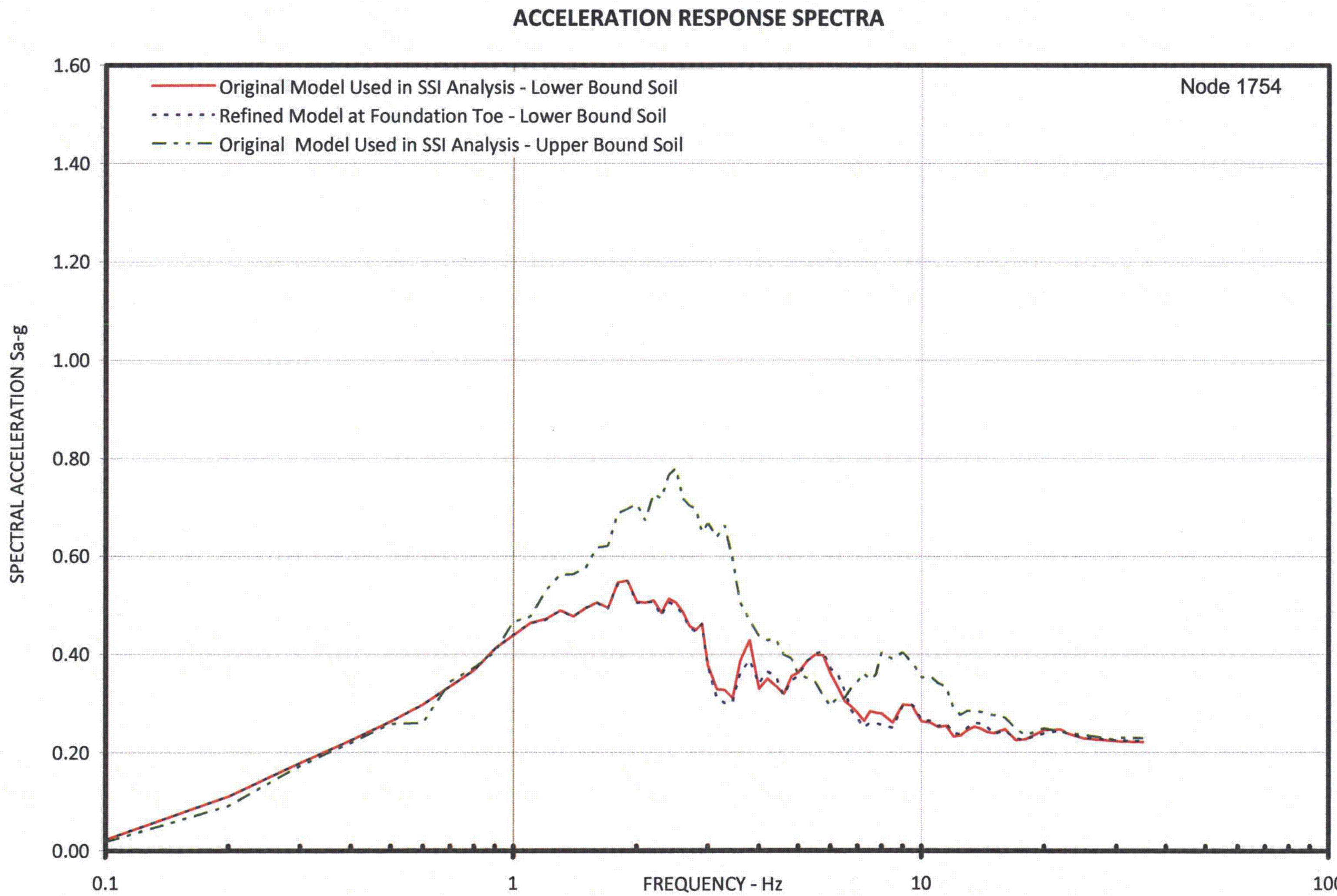

Figure 03.07.01-27.1 - 5% Damped Spectral Comparison in X Direction at Top of Foundation (Center), El. -3.0 ft

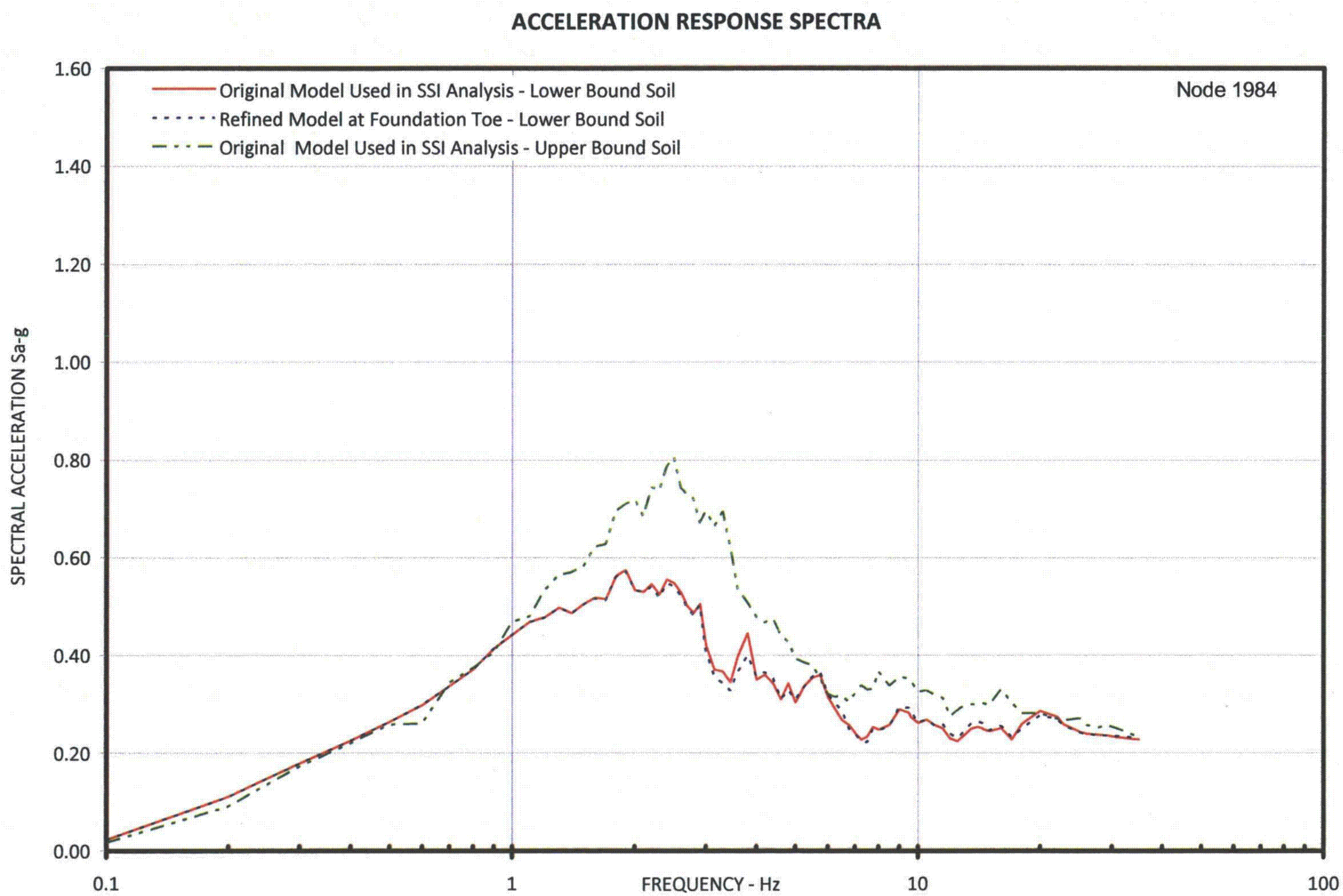

Figure 03.07.01-27.2 - 5% Damped Spectral Comparison in X Direction at C.G. of Oil Tank

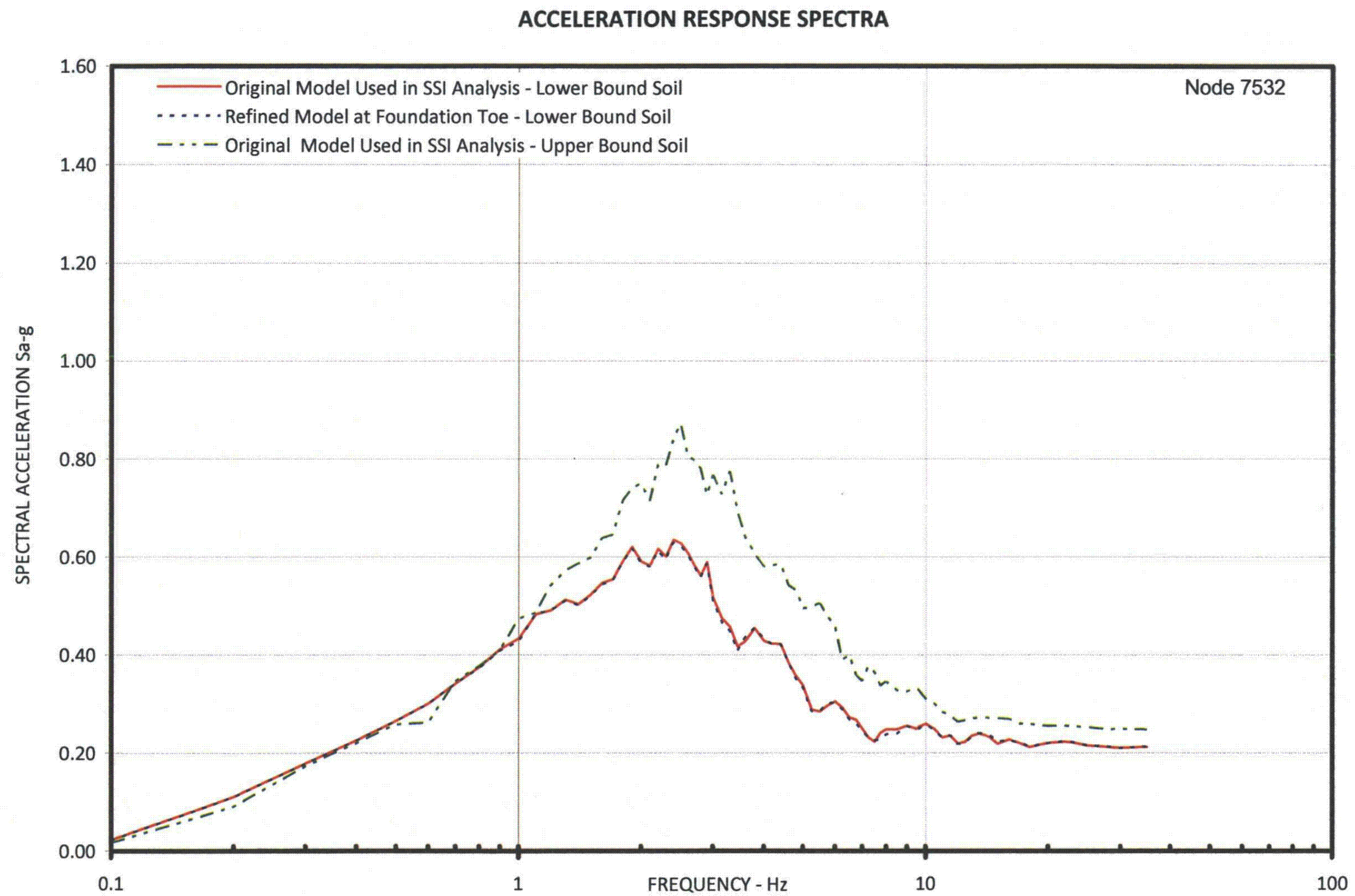

Figure 03.07.01-27.3 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Corner away from access room), El. 30.0 ft

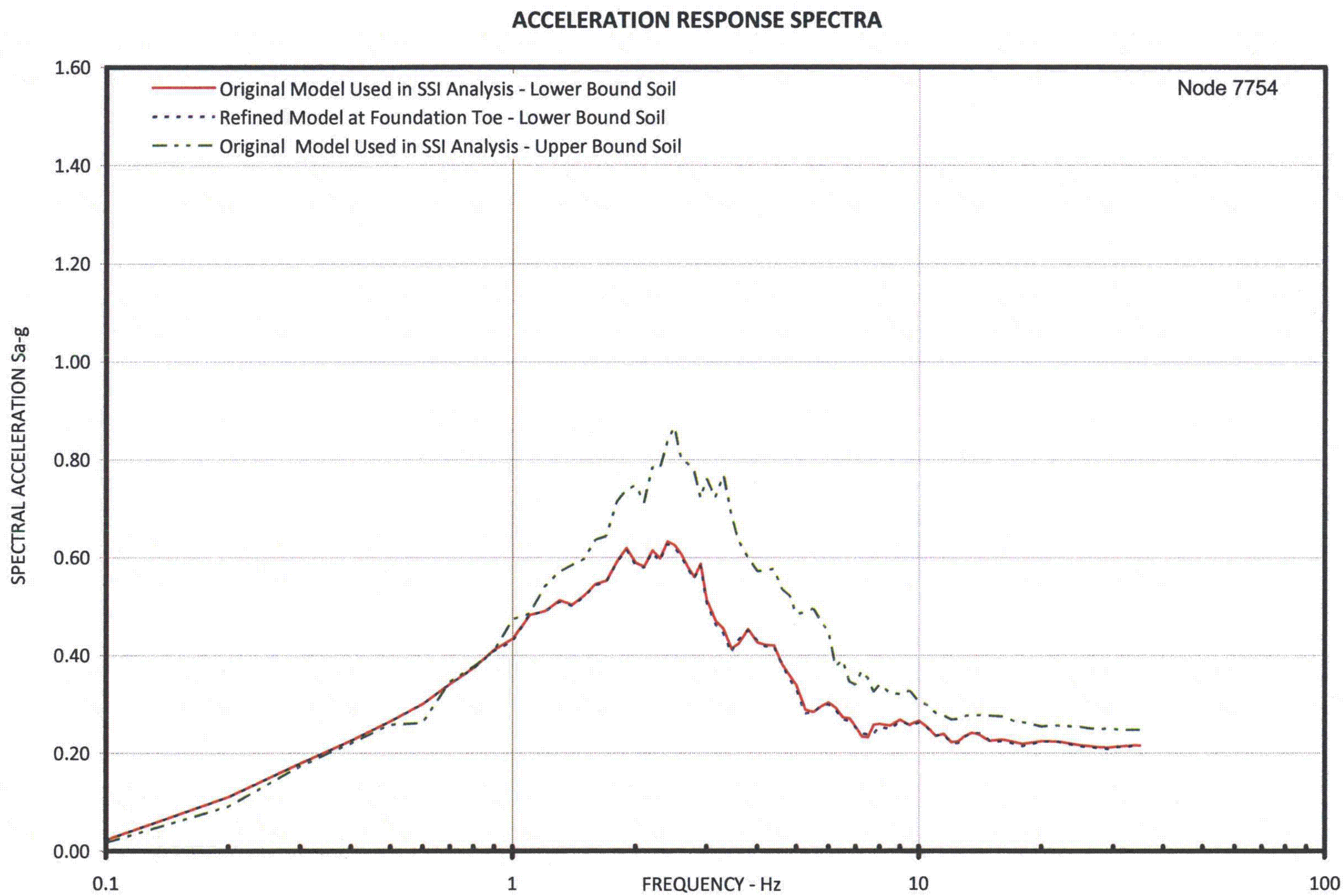

Figure 03.07.01-27.4 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Center), El. 30.0 ft

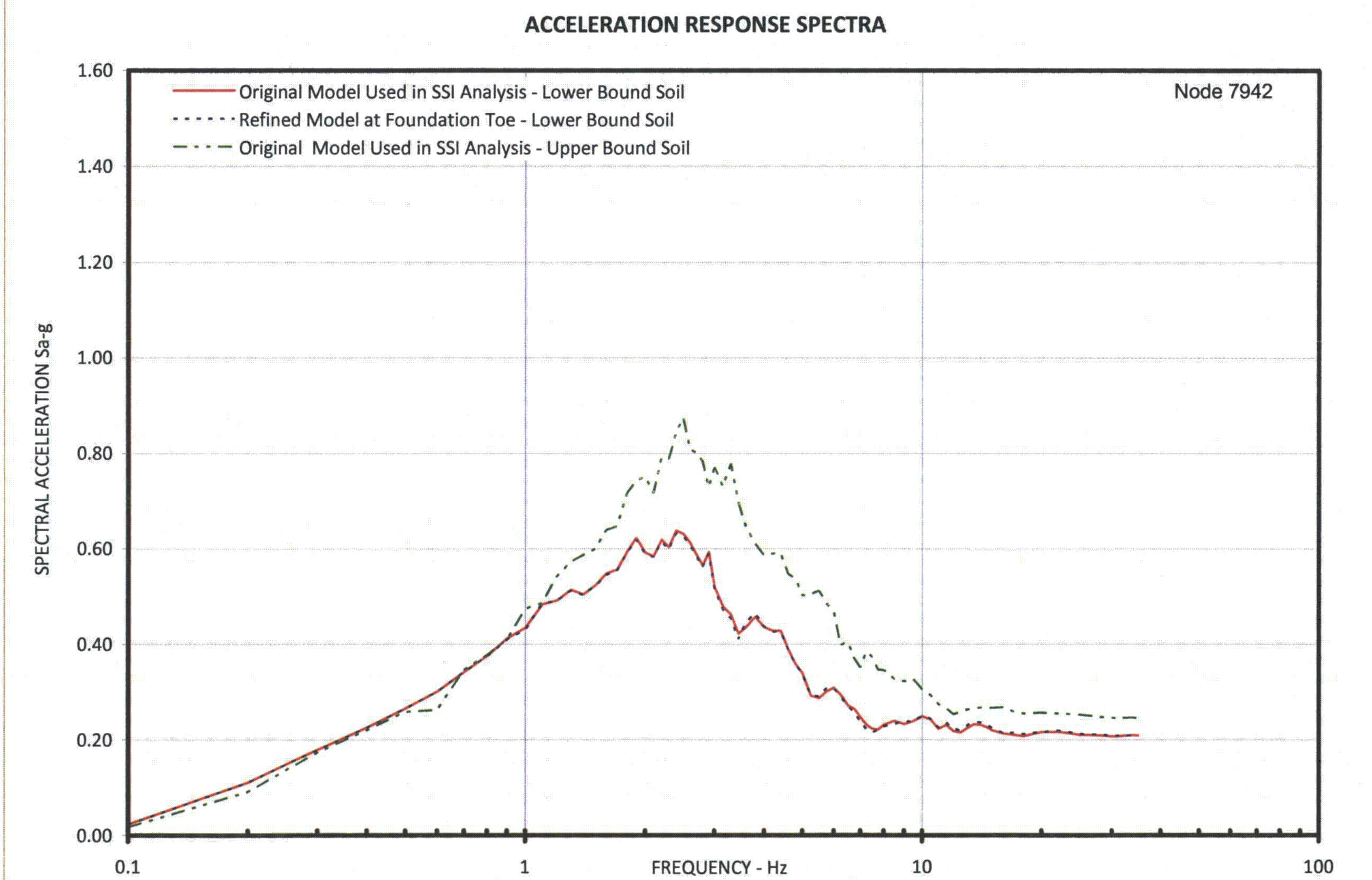

Figure 03.07.01-27.5 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Corner near access room), El. 30.0 ft

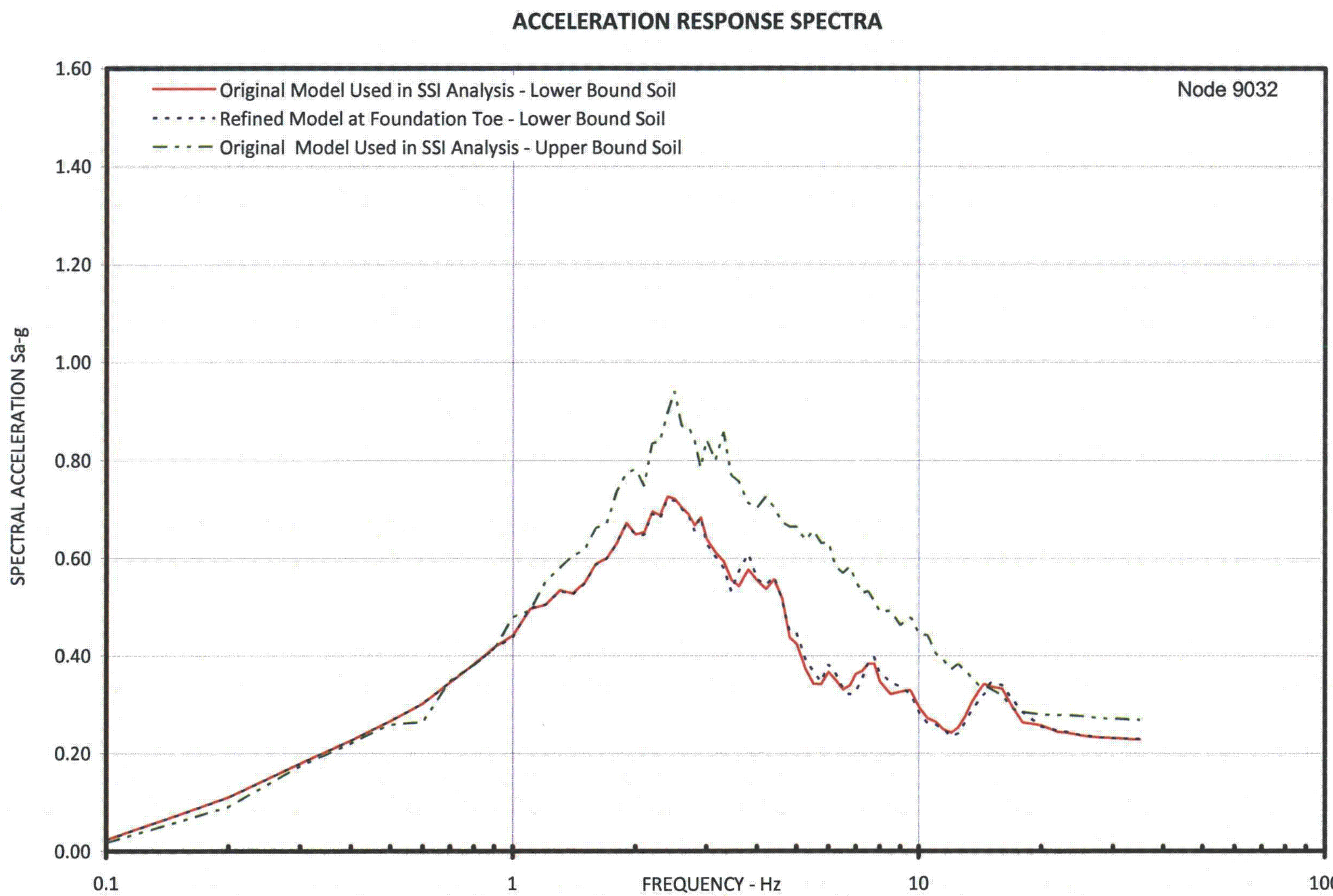

Figure 03.07.01-27.6 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Corner), El. 50.0 ft

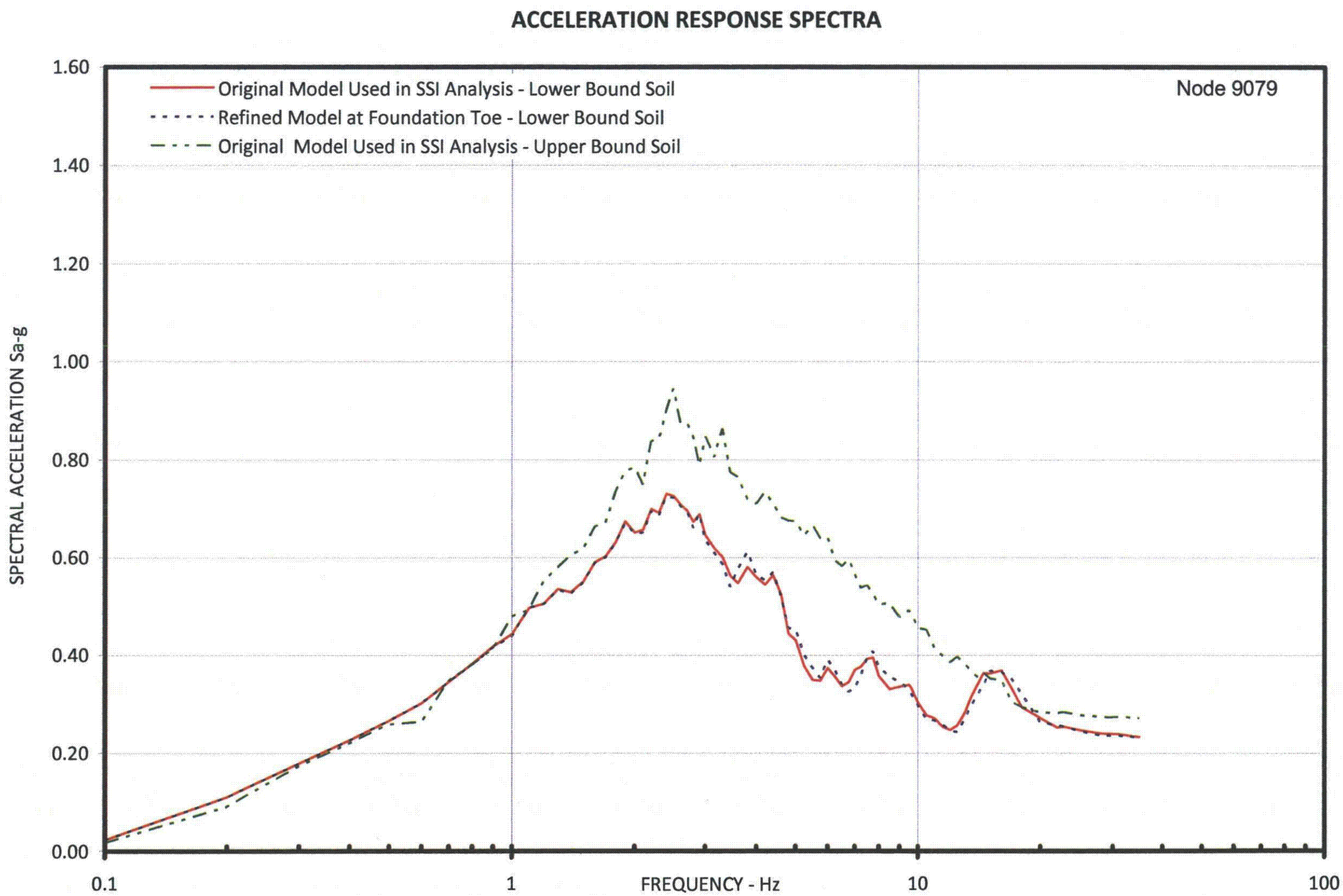

Figure 03.07.01-27.7 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Center), El. 50.0 ft

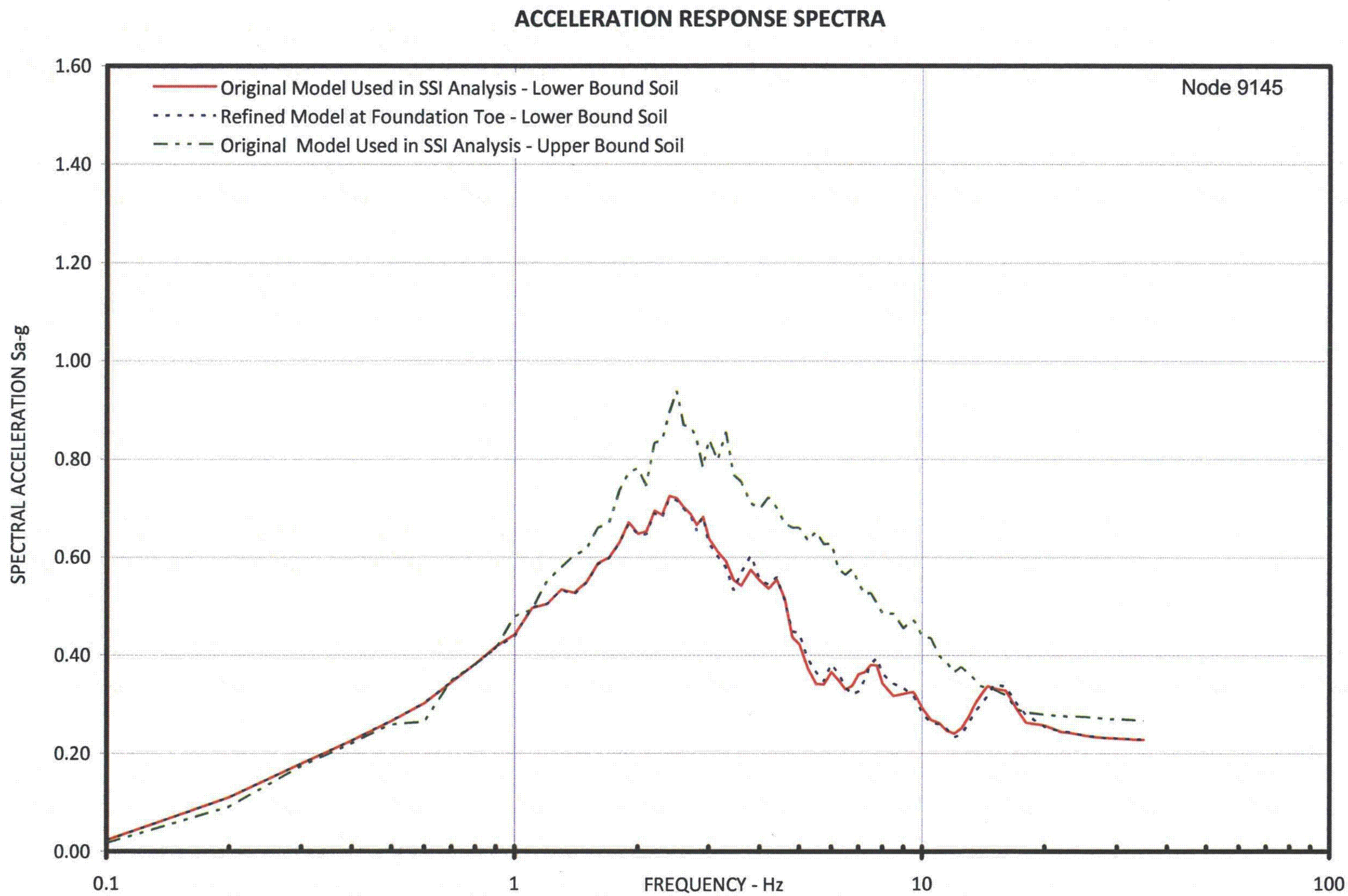

Figure 03.07.01-27.8 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Building corner), El. 50.0 ft

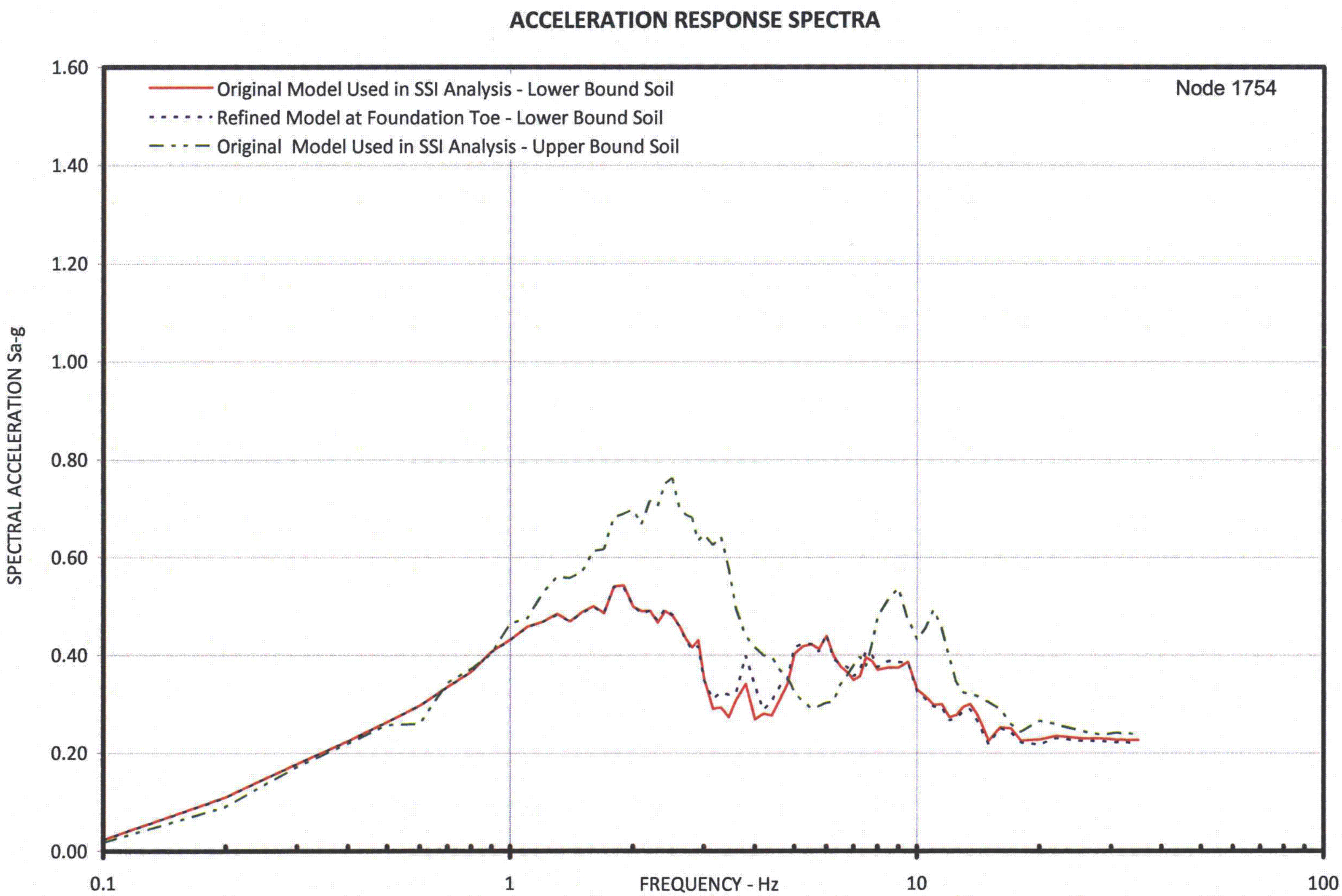

Figure 03.07.01-27.9 - 5% Damped Spectral Comparison in Y Direction at Top of Foundation (Center), El. -3.0 ft

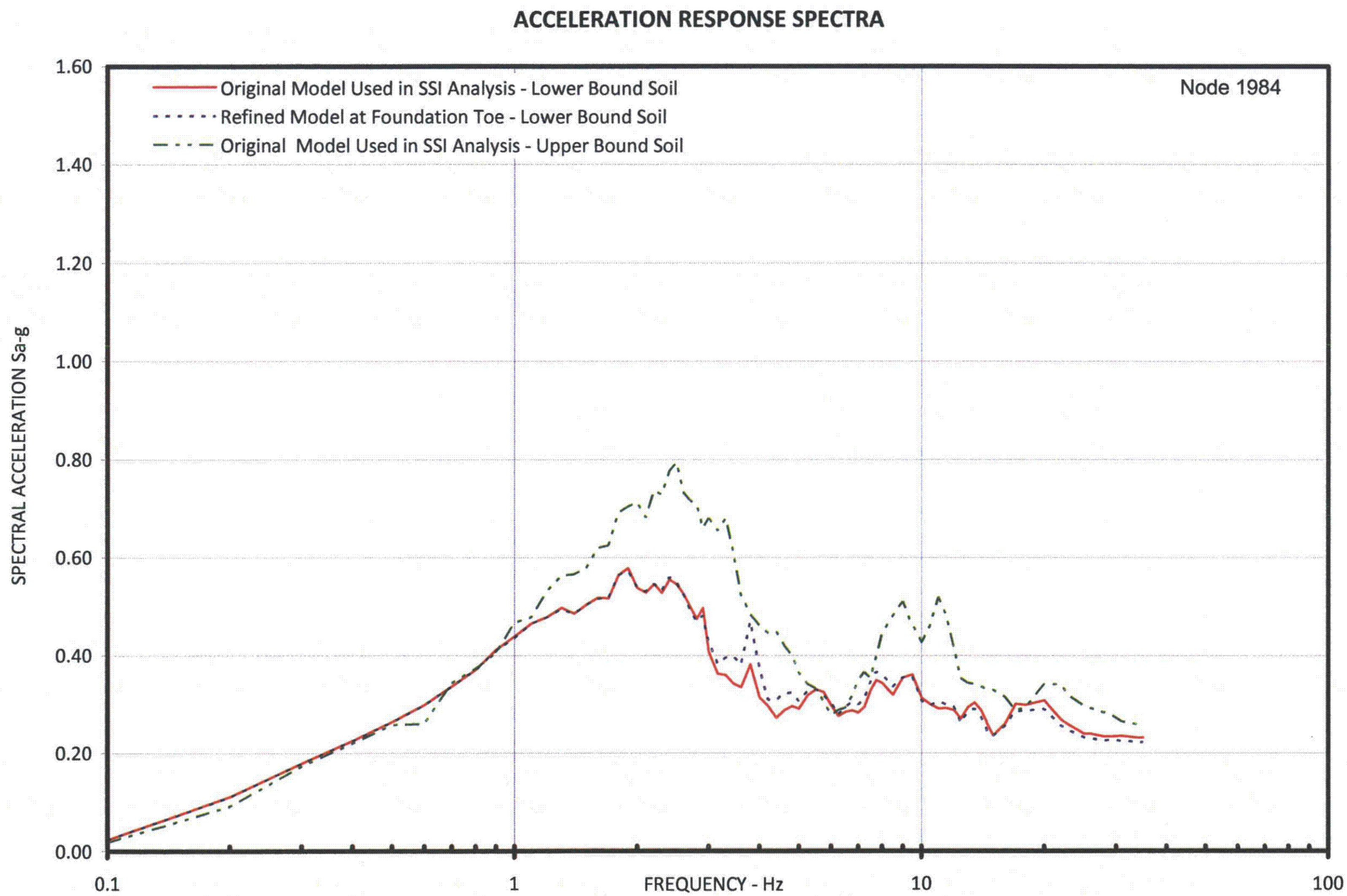

Figure 03.07.01-27.10 - 5% Damped Spectral Comparison in Y Direction at C.G. of Oil Tank

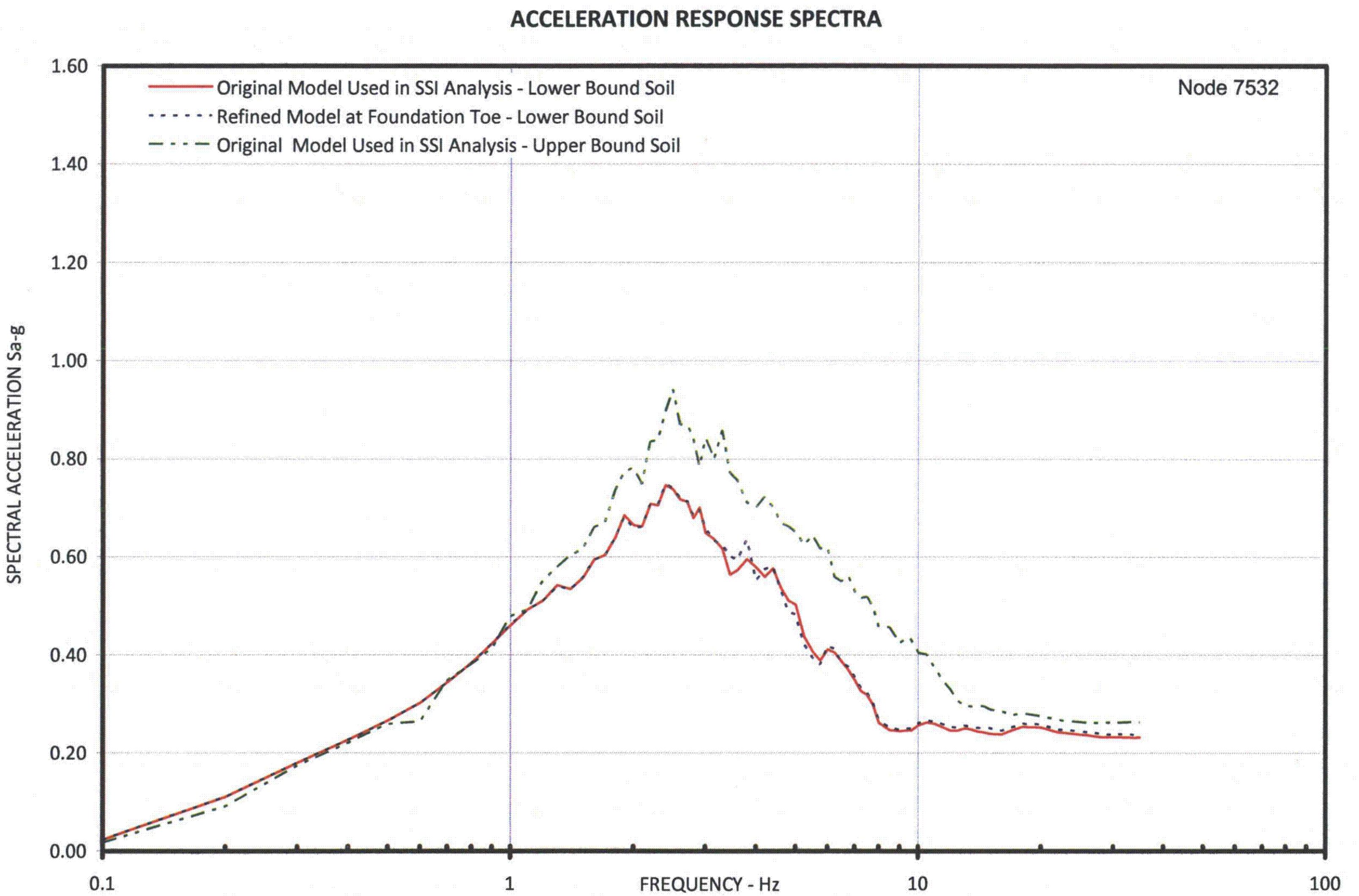

Figure 03.07.01-27.11 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Corner away from access room), El. 30.0 ft

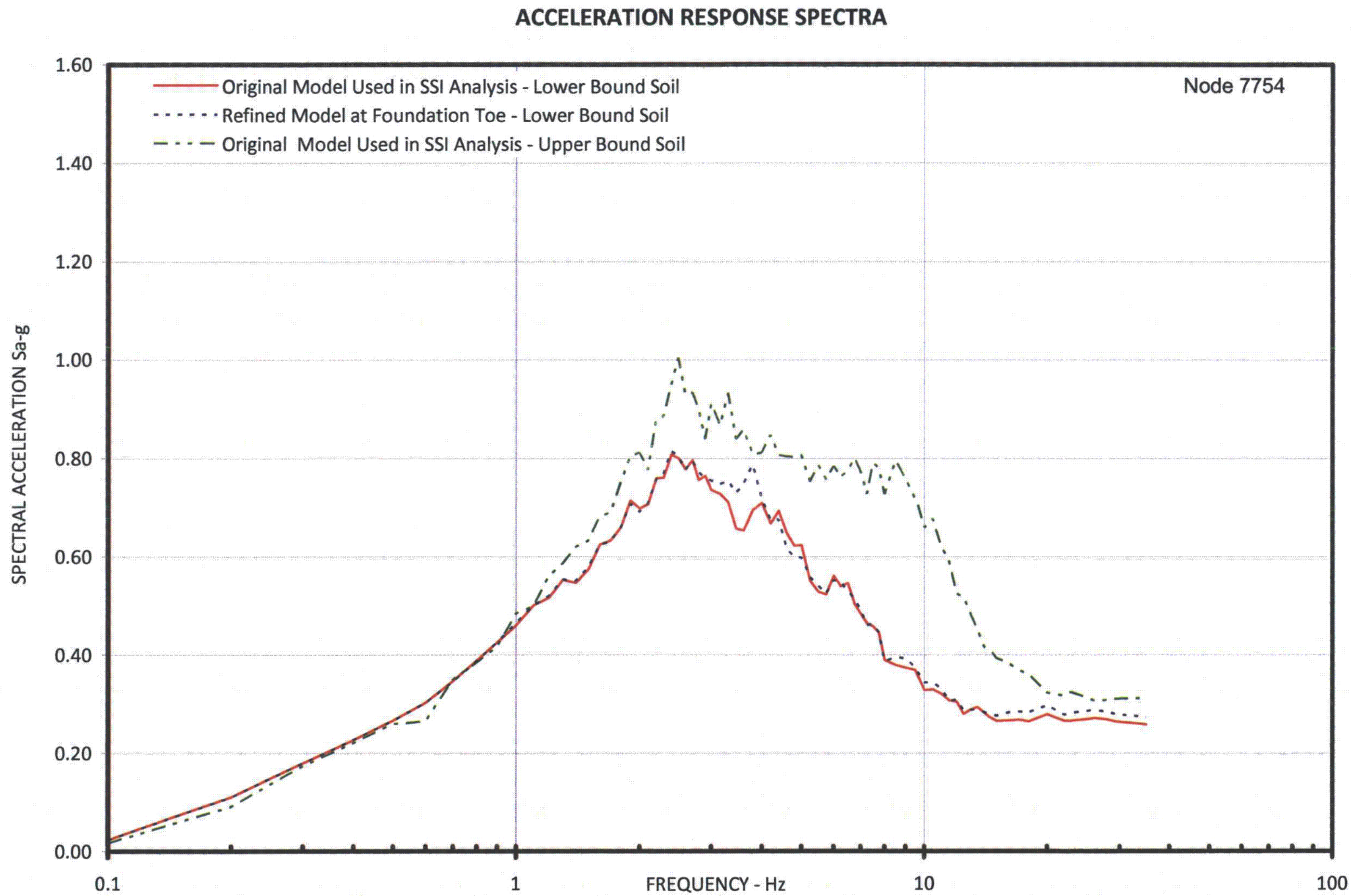

Figure 03.07.01-27.12 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Center), El. 30.0 ft

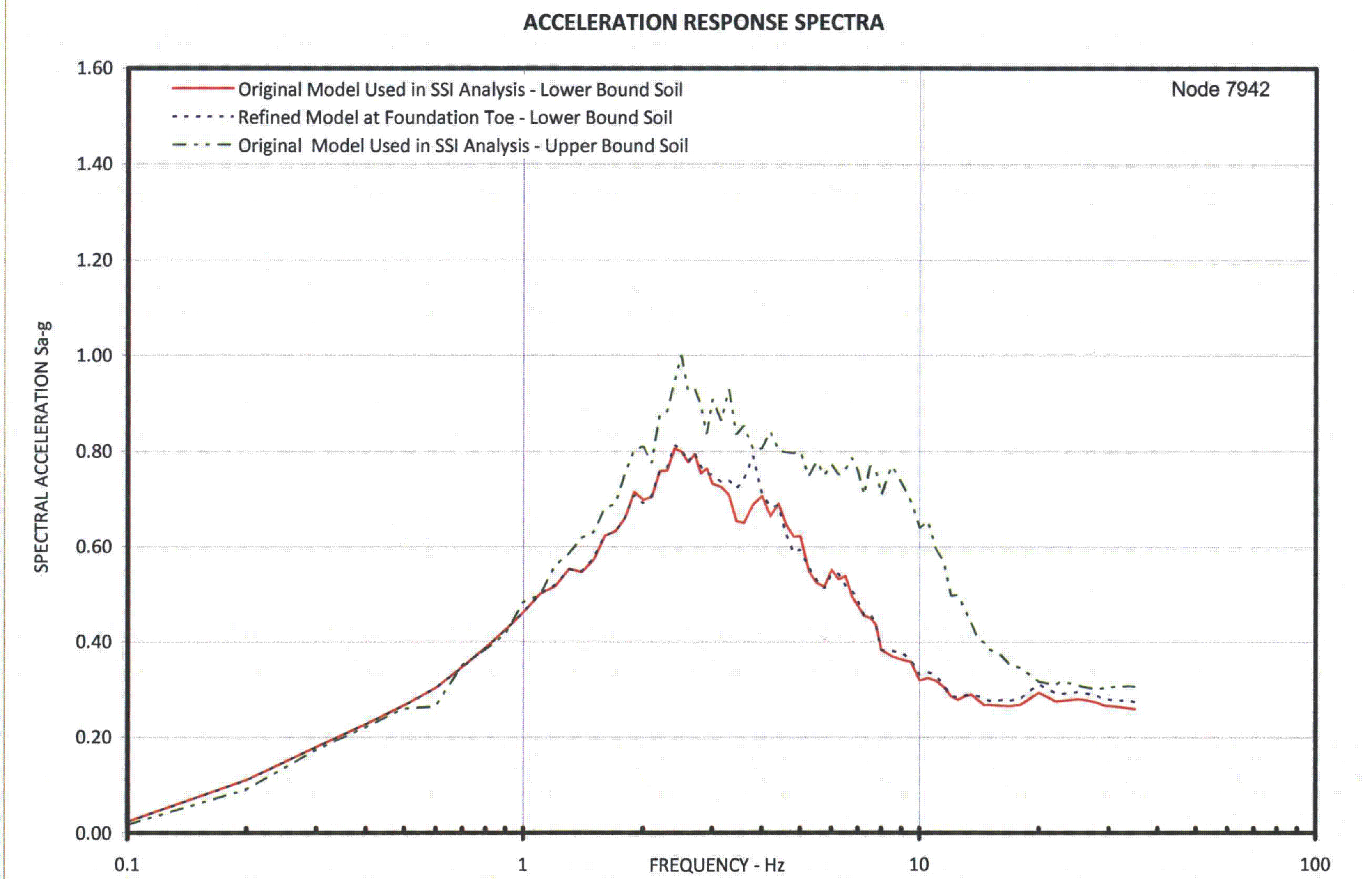

Figure 03.07.01-27.13 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Corner near access room), El. 30.0 ft

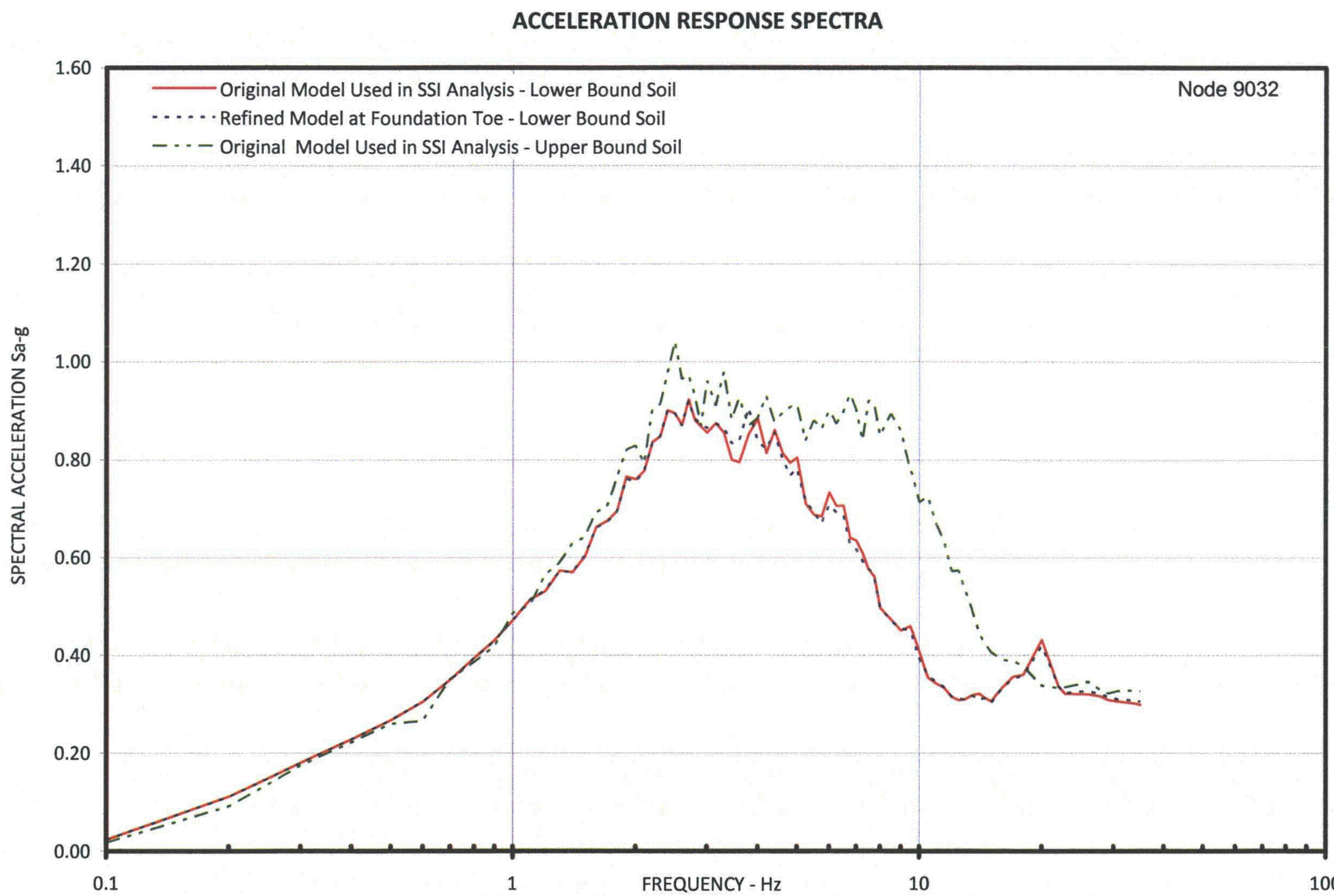

Figure 03.07.01-27.14 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Corner), El. 50.0 ft

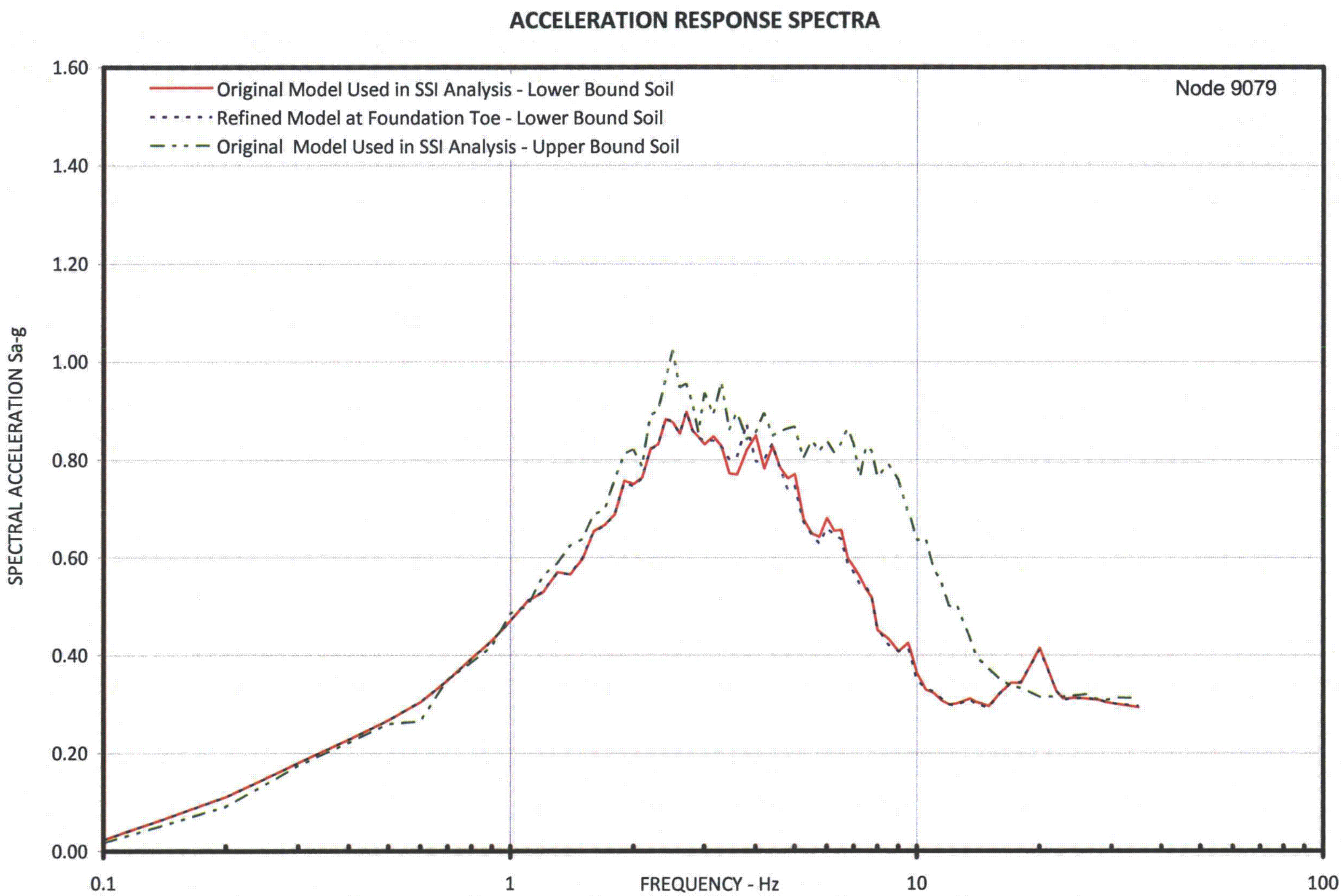

Figure 03.07.01-27.15 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Center), El. 50.0 ft

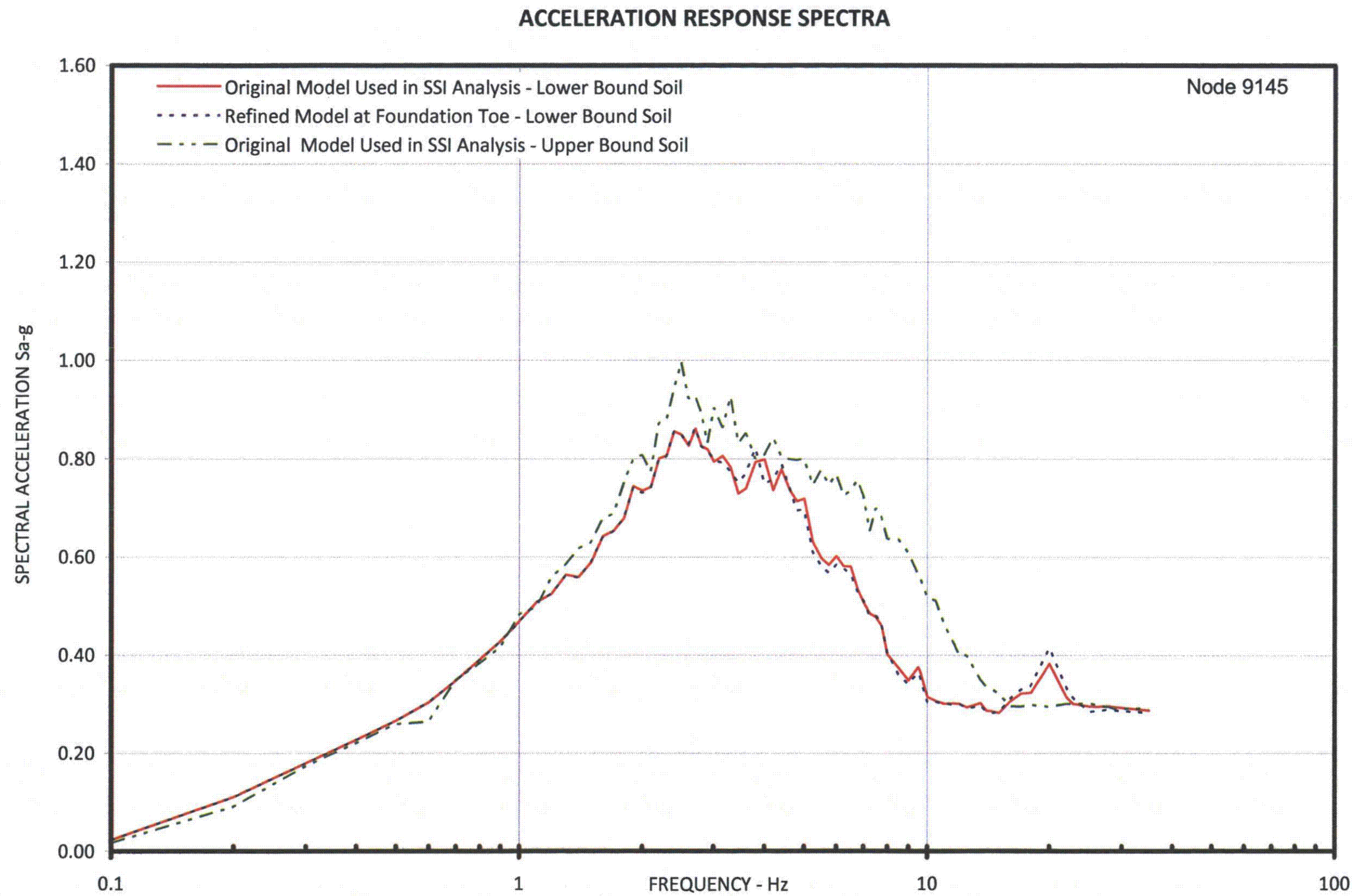

Figure 03.07.01-27.16 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Building corner), El. 50.0 ft

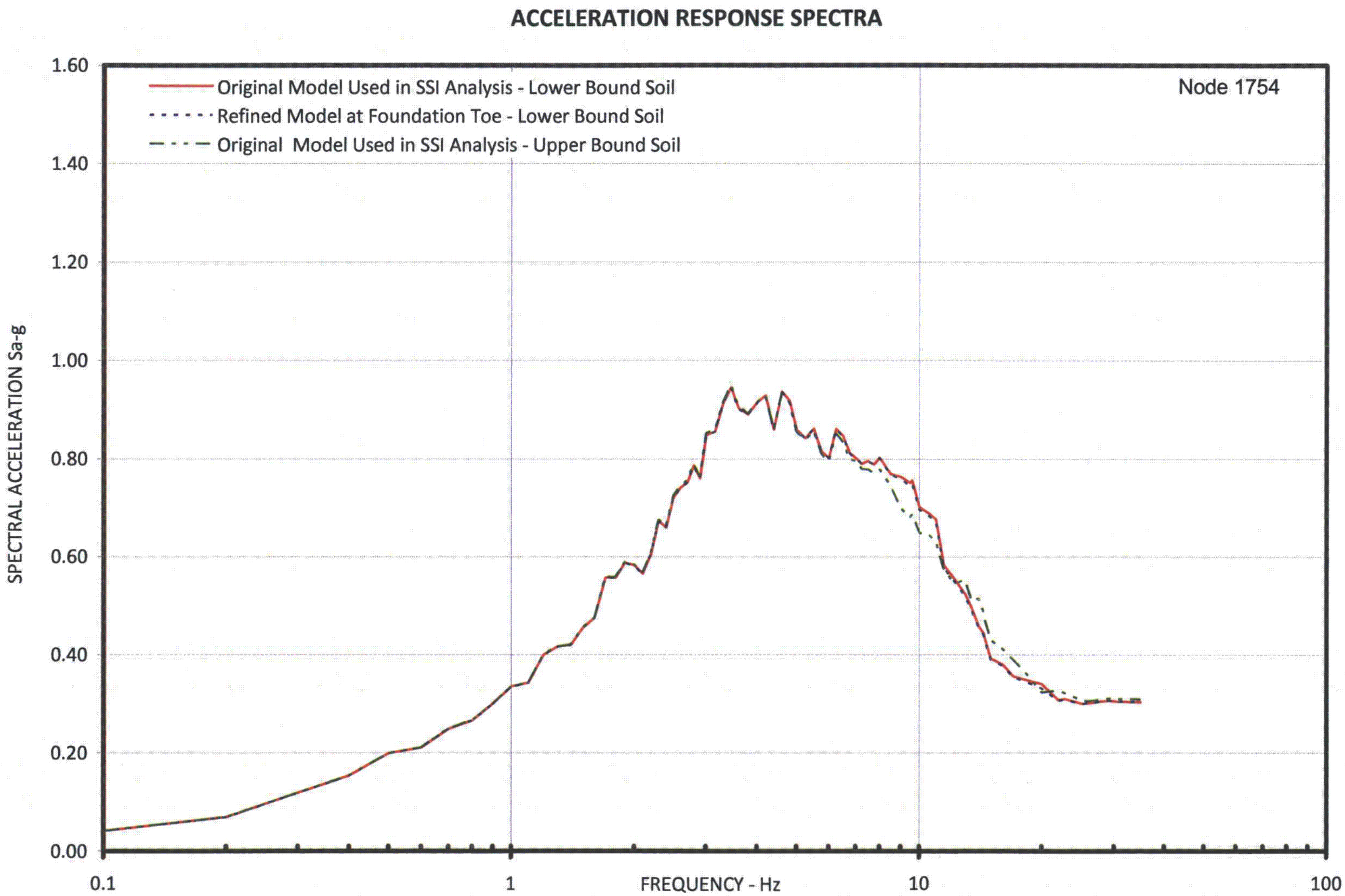

Figure 03.07.01-27.17 - 5% Damped Spectral Comparison in Vertical Direction at Top of Foundation (Center), El. -3.0 ft

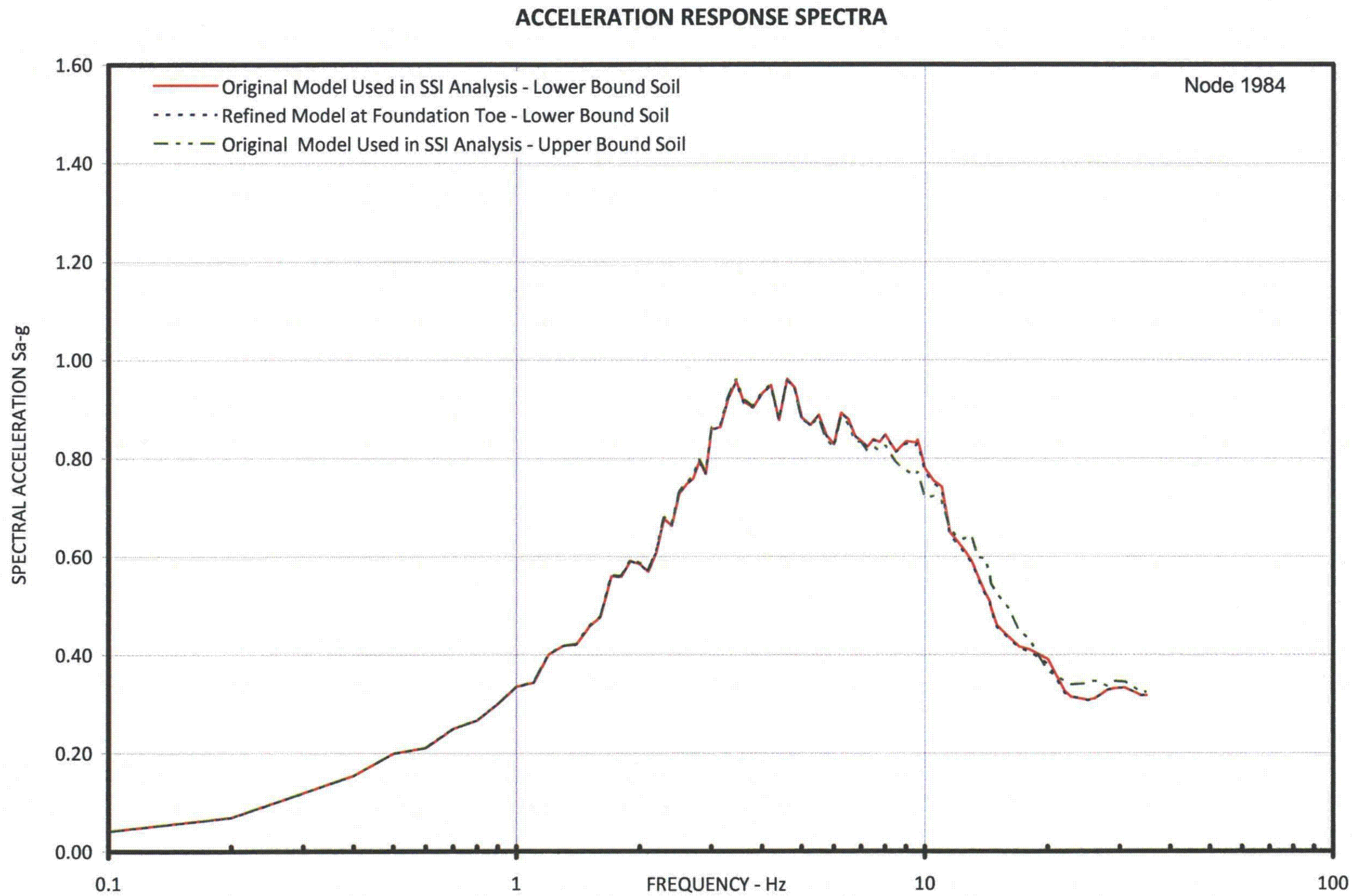

Figure 03.07.01-27.18 - 5% Damped Spectral Comparison in Vertical Direction at C.G. of Oil Tank

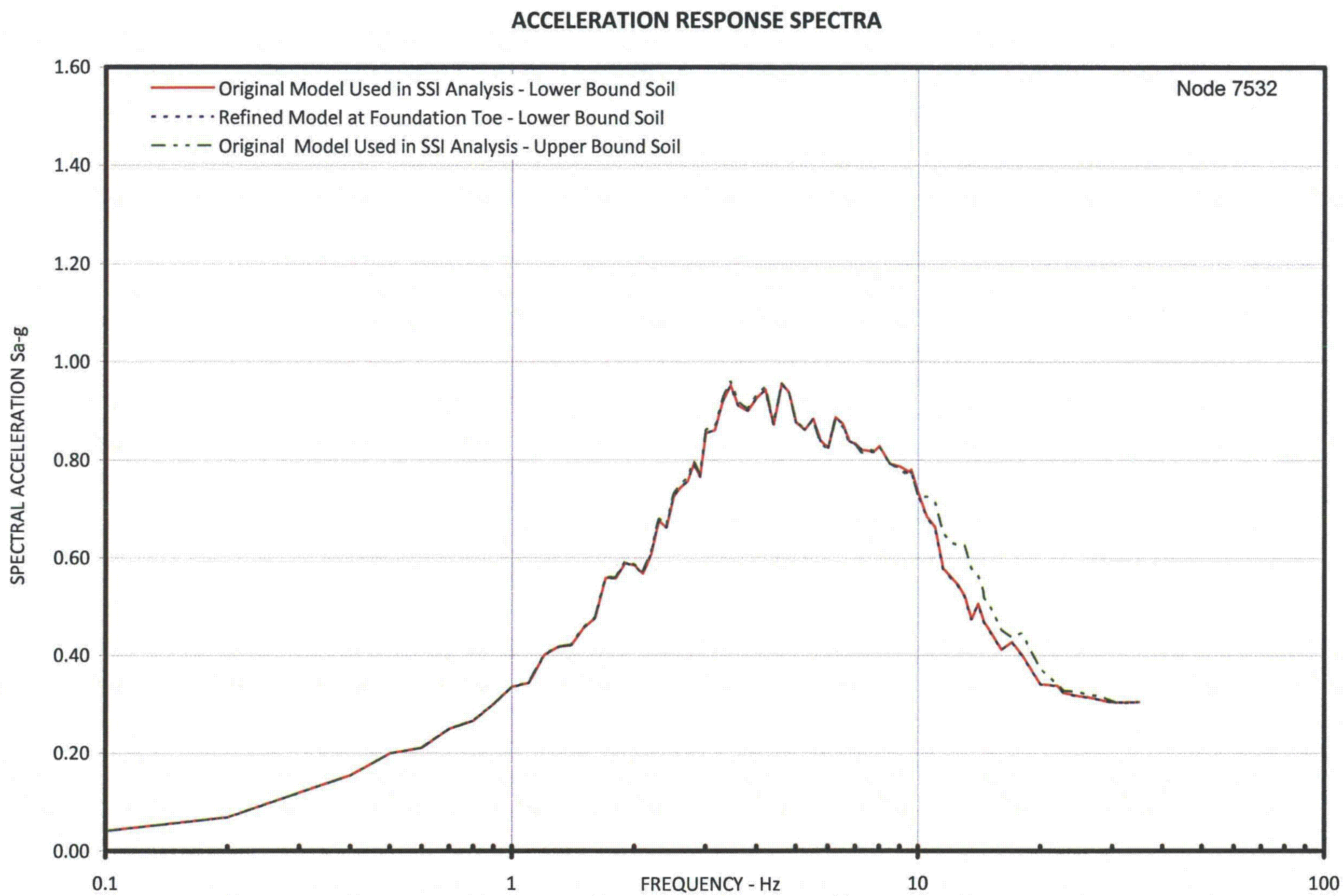

Figure 03.07.01-27.19 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Corner away from access room), El. 30.0 ft

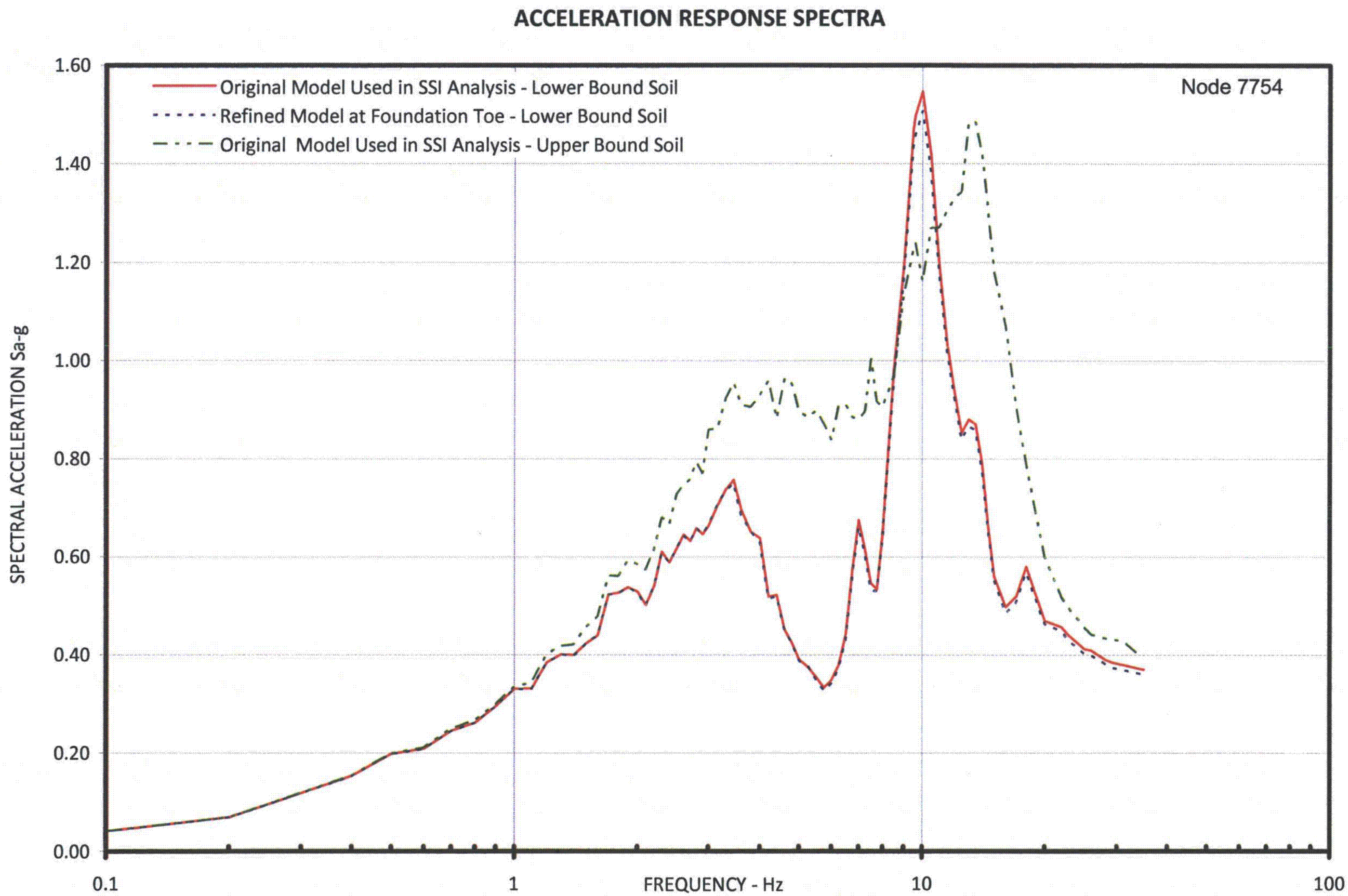

Figure 03.07.01-27.20 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Center), El. 30.0 ft

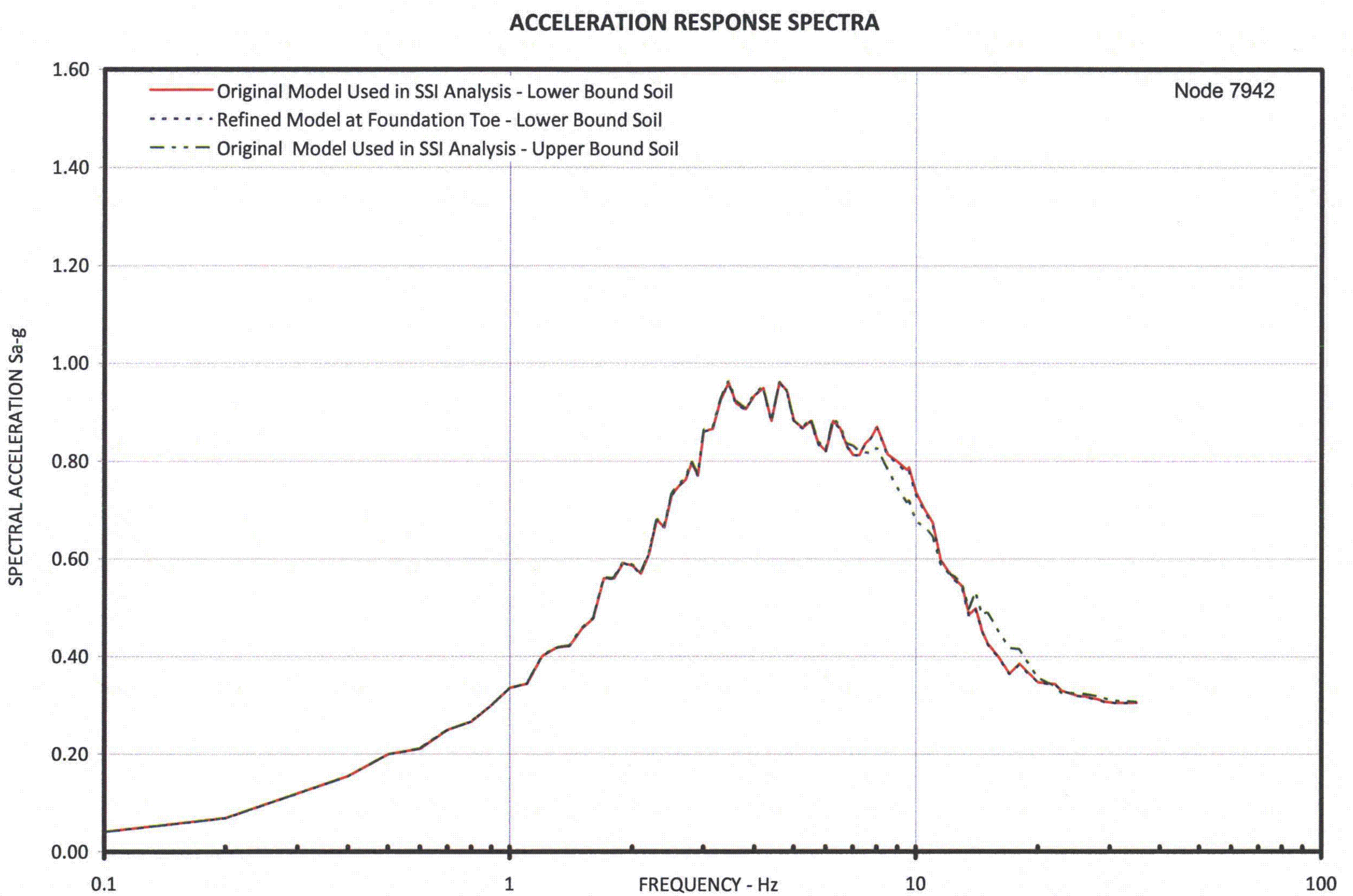

Figure 03.07.01-27.21 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Corner near access room), El. 30.0 ft

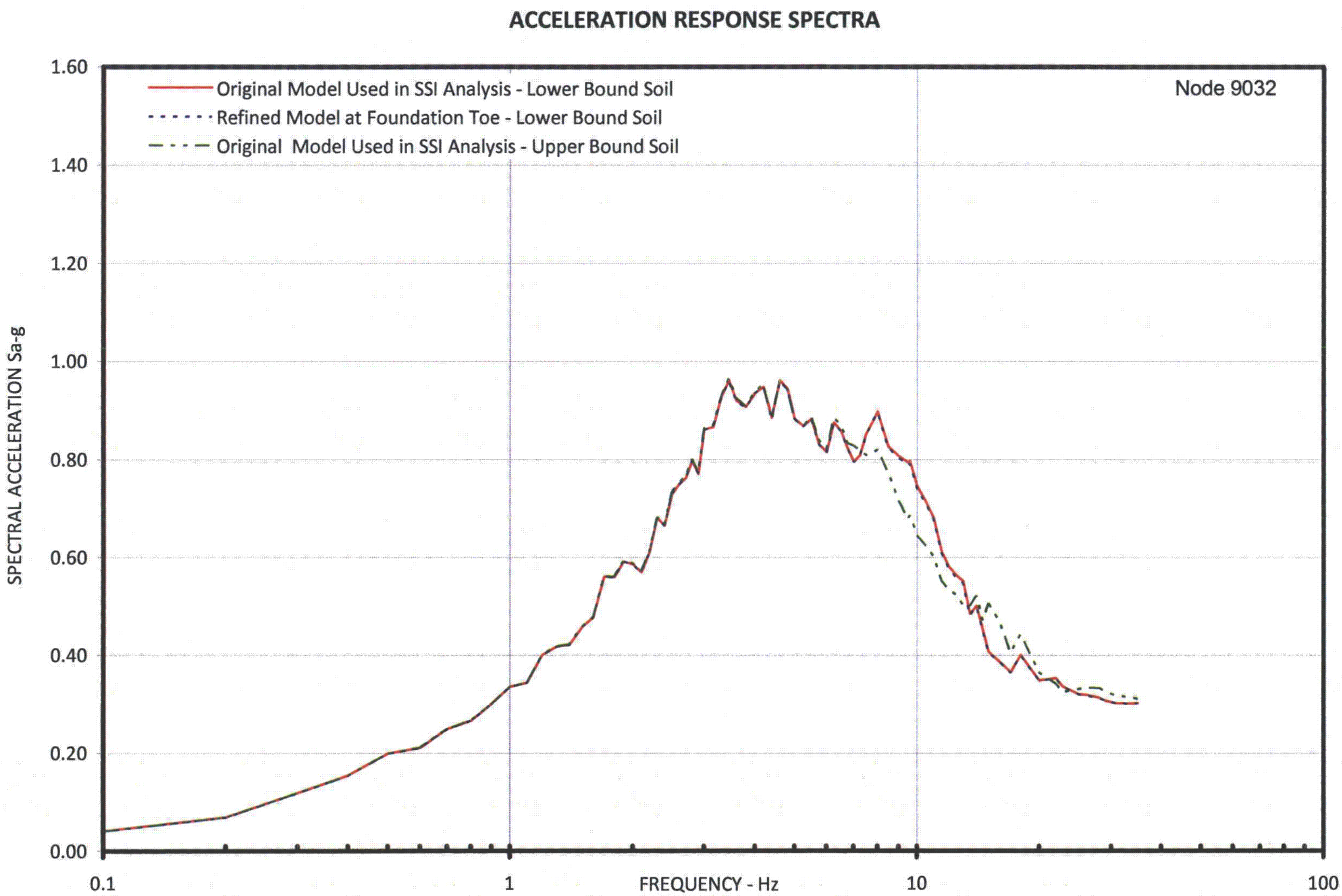

Figure 03.07.01-27.22 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Corner), El. 50.0 ft

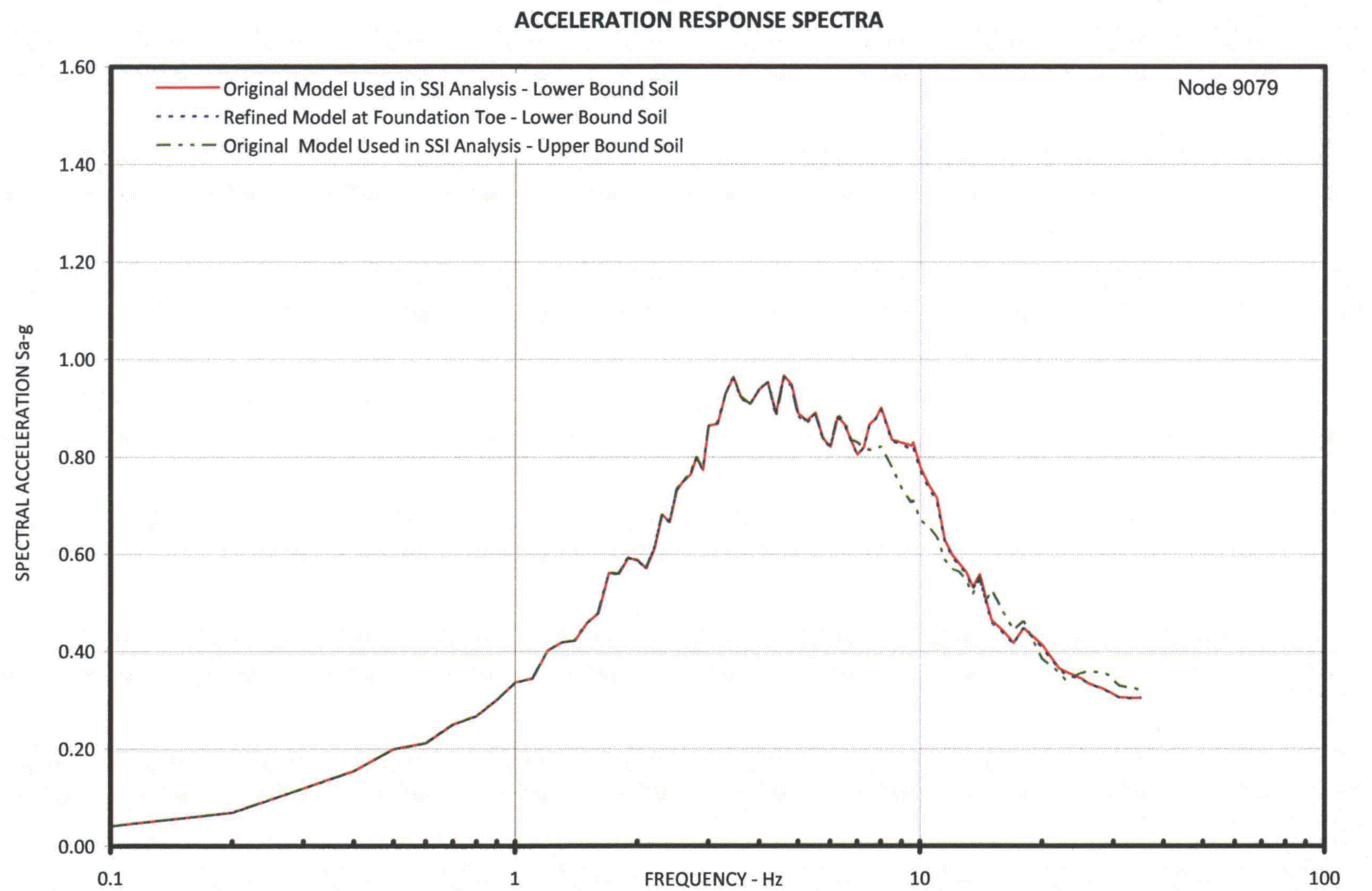

Figure 03.07.01-27.23 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Center), El. 50.0 ft

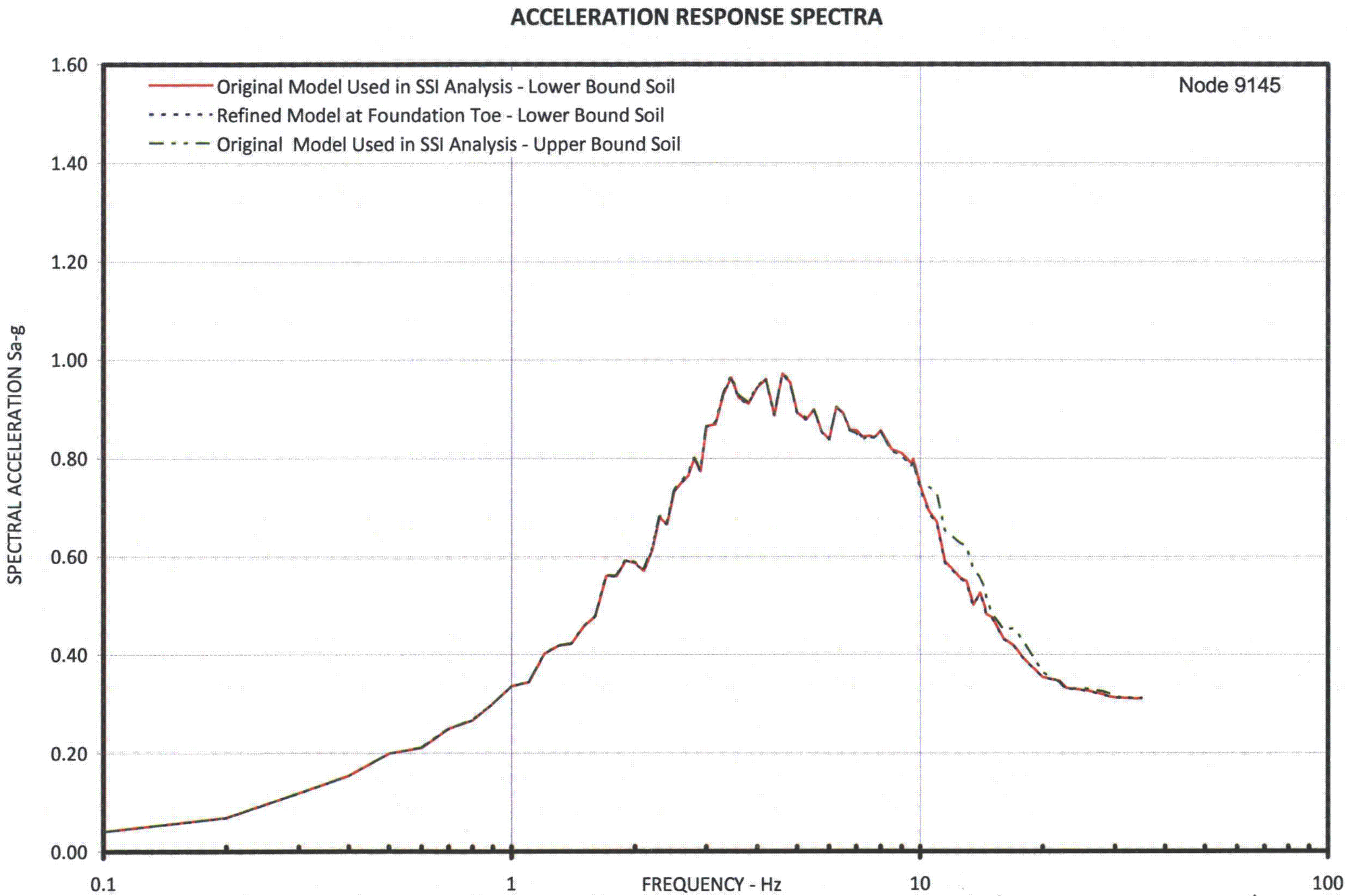

Figure 03.07.01-27.24 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Building corner), El. 50.0 ft

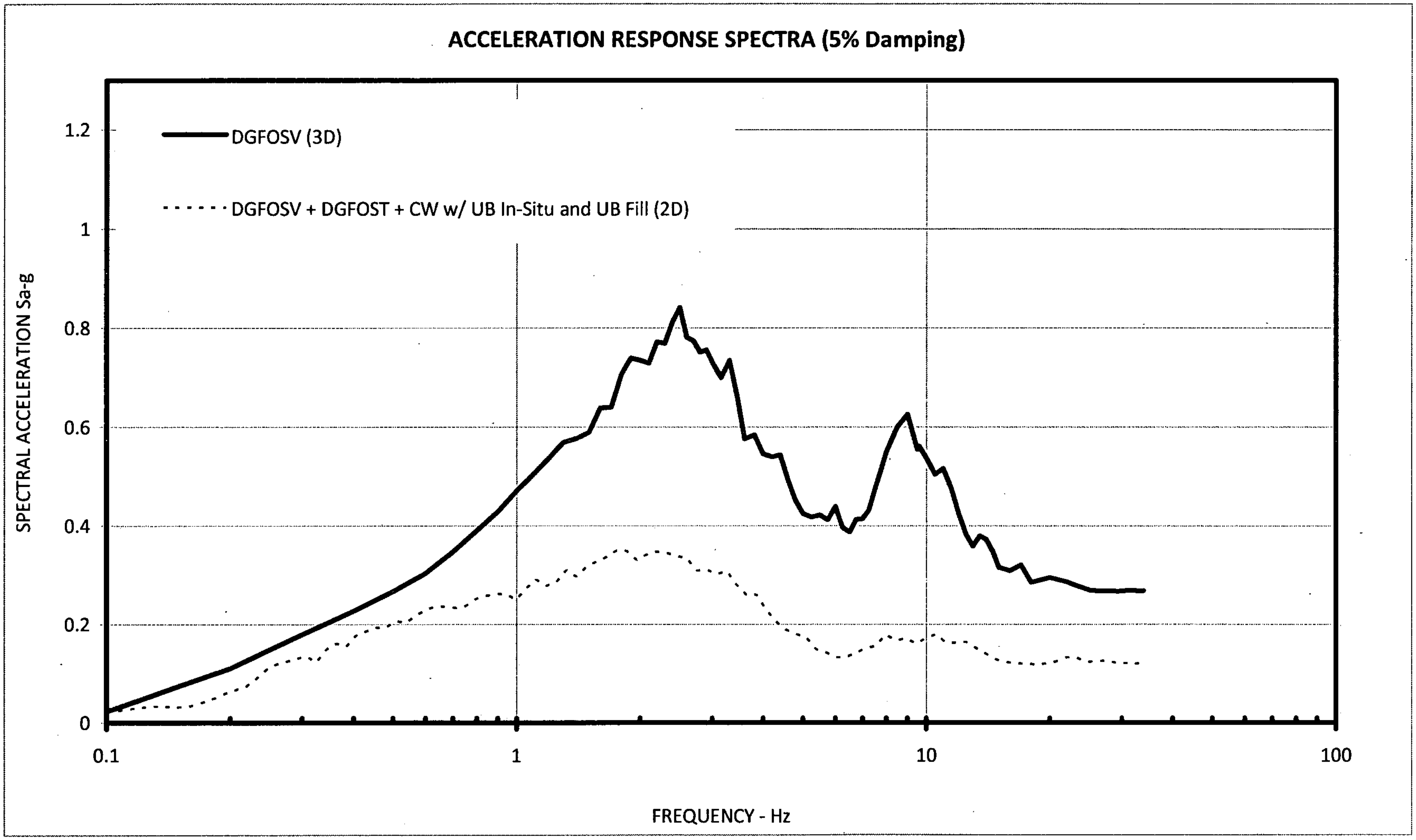

Figure 03.07.01-27.25: Comparison of Horizontal Response Spectra at DGFOSV 1A Basemat Top

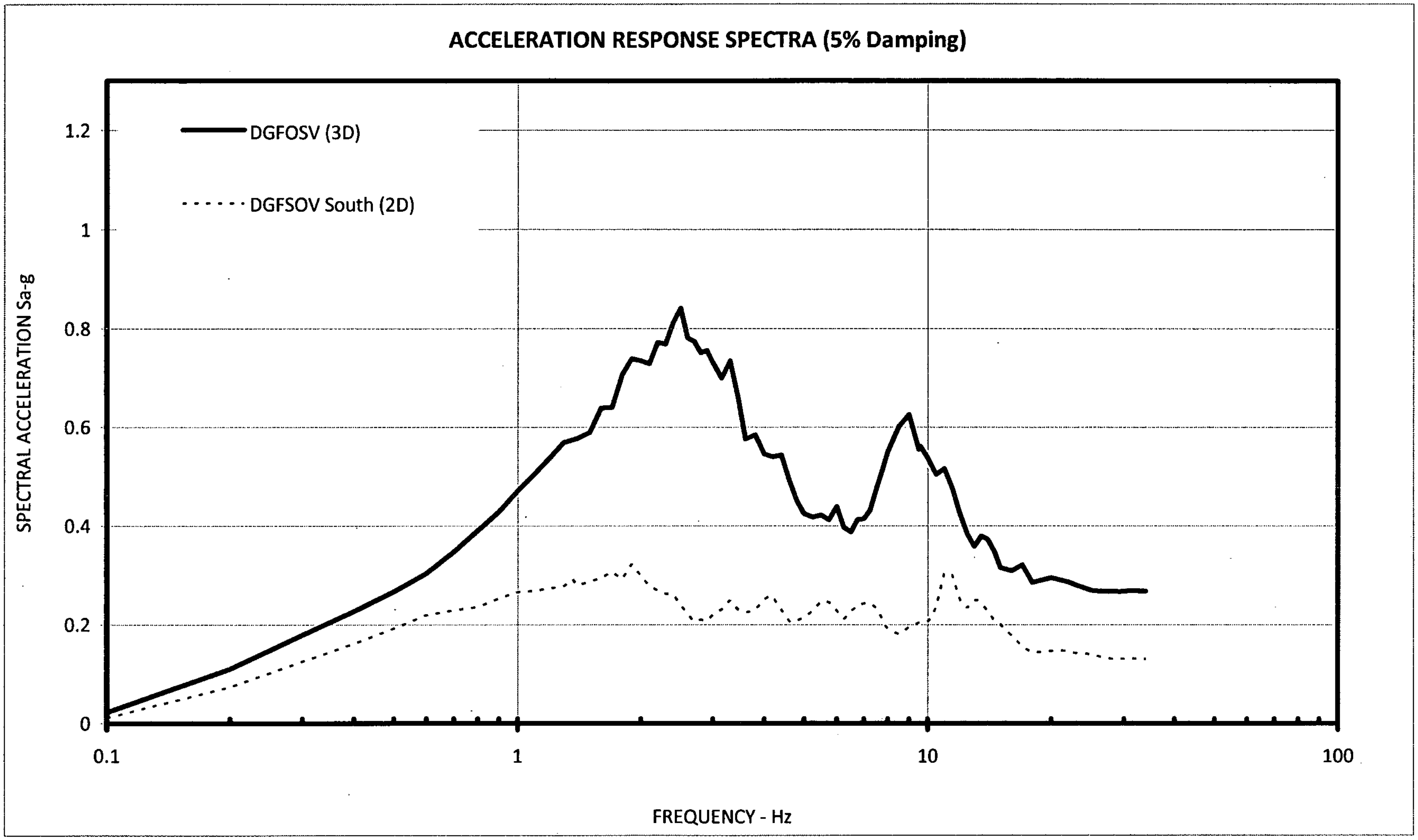

Figure 03.07.01-27.26: Comparison of Horizontal Response Spectra at DGFOSV 1C Basemat Top

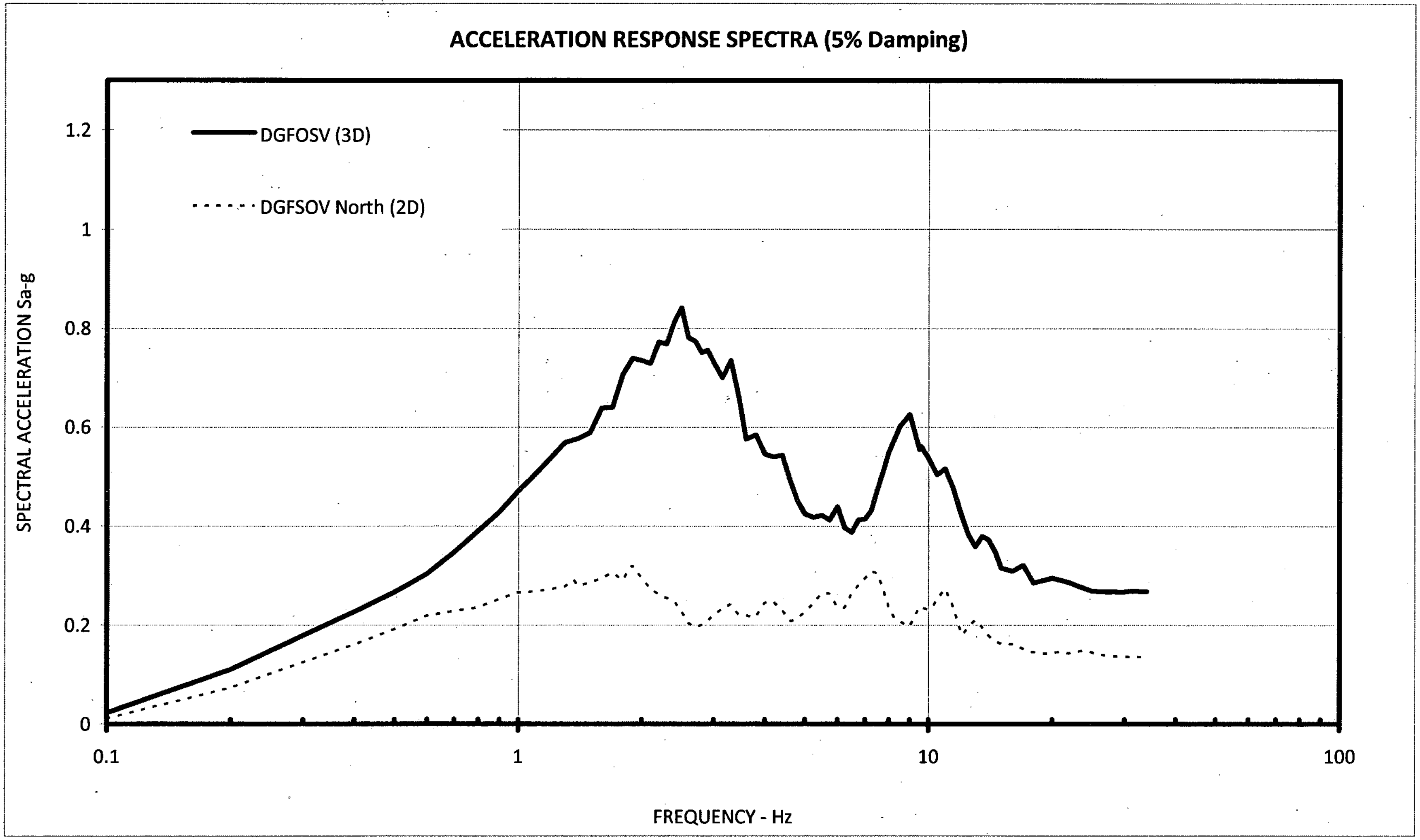

Figure 03.07.01-27.27: Comparison of Horizontal Response Spectra at DGFOSV 1B Basemat Top

RAI 03.07.01-27, Supplement 1
Enclosure 1

Revisions to COLA Section 3H.6

3H.6.7 Diesel Generator Fuel Oil Storage Vaults (DGFOSV)

The Diesel Generator Fuel Oil Storage Vaults (DGFOSV) are reinforced concrete structures, located below grade with an access room above grade. The DGFOSV house fuel oil tanks and transfer pumps. The DGFOSV are buried in the structural back-fill. The embedment depth to the bottom of the 2 ft thick mudmat is approximately 45 ft, the maximum height from the bottom of the mudmat is approximately 61 ft, and the basemat dimensions are approximately 81.5 ft by 48 ft. Properties of the backfill are described in Section 3H.6.5.2.4. ~~A 3-dimensional SAP2000 response spectrum analysis was used to obtain the SSE design forces due to structure inertia. The seismic induced dynamic soil pressures on DGFOSV walls and roof were computed using the method of ASCE 4-98, Subsection 3.5.3.2.~~

Two DGFOSV are located about ~~50~~53feet away from the south face of the Reactor Building (RB), which is a heavy multistory structure. The third DGFOSV is located approximately ~~38~~40 feet away from the north face of the Reactor Service Water (RSW) Pump House. Figure 3H.6-221 shows the DGFOSV locations relative to other structures. Considering the soil profile at the STP Units 3 & 4 site, the induced acceleration at the foundation level of the DGFOSV during a safe-shutdown earthquake (SSE) event may be amplified due to their close proximity to the RB (for the two) or the RSW Pump House (for the third). To establish the input motion for the soil-structure interaction (SSI) analysis of the DGFOSV, considering the impact of the nearby heavy RB (for the two) and RSW Pump House (for the third) structures, an analysis as described below was performed.

Five interaction nodes at the ground surface and five at the depth corresponding to the bottom elevation of the DGFOSV foundations are added to the three dimensional SSI SASSI2000 model of the RB for obtaining free field responses for the two DGFOSV close to the RB. These five nodes correspond to the four corners and the center of the DGFOSV. This RB SSI model is analyzed for the STP site-specific SSE. For each of these two DGFOSV, first an average of the spectra at five nodes at the surface and foundation each is calculated and then envelope of the two average spectra is calculated. A similar SSI analysis is performed for the third DGFOSV close to the RSW Pump House. Since the diesel oil tank is a standard plant equipment, the input motion for the SSI analysis should also consider the 0.3g Regulatory Guide 1.60 response spectra. ~~Finally~~Therefore, the envelope of the envelope average spectra for the three DGFOSV and the 0.3g Regulatory Guide 1.60 response spectr~~um~~a ~~is~~are used as the input response spectra for the SSI analysis of the DGFOSV. The 0.3g Regulatory Guide 1.60 response spectra were found to be the bounding spectra. The DGFOSV and the equipment and components inside the vault are designed using the results of the SSI analysis.

The comparison of response spectra (the minimum required 0.1g Regulatory Guide 1.60 spectra, the FIRS, and the deconvolved SHAKE outcrop spectra for the site-specific SSE specified at the ground surface) at the foundation level of the DGFOSV is presented in Figures 3H.6-11d through 3H.6-11L. As can be seen from these figures, the deconvolved SHAKE outcrop spectra envelop the minimum required spectra and FIRS for the three sets of soil properties.

The following two types of soil-structure interaction (SSI) analyses are performed for DGFOSV:

- 3D SSI analyses of DGFOSV alone for calculating in-structure response spectra and design accelerations/forces of the structure. These analyses were performed considering both full and empty fuel oil tanks.
- 2D structure-soil-structure interaction (SSSI) analysis of DGFOSV and adjacent structures to obtain seismic soil pressures.

3D SSI Analysis

The SSI analyses of the 3D model of DGFOSV are performed using SASSI2000 computer program (using subtraction method).

Structural Model:

The structural part of the model consists of shell elements to model the exterior walls and the roof slabs and 3D solid elements to model the basemat and the mud mat. Structure self weight and other applicable weights of equipment, live load, piping, metal decking, missile barrier cover are included in the structural model. The fuel tank is modeled with the fuel and tank weight lumped at the center of gravity of the tank and the tank lumped weight rigidly connected to the base mat at tank saddle locations. The fuel tank procurement specification will require that the fuel tank with fuel in it should have predominant frequencies greater than 33 Hz in horizontal and vertical directions. The fuel tank portion of the model has been assigned a damping value of 0.5%. For the other parts of the structure two damping values are used; 7% damping and 4% damping. The results from the 7% structural damping are used for design of the DGFOSV. The results from the 4% damping are used for generation of in-structure response spectra. Both full and empty fuel oil tank conditions are considered in the analysis. Figure 3H.6-222 shows the typical 3D structural model of the DGFOSV for various SSI analyses. The following provides the details of the SSI model and method of analysis.

Strain Dependent Soil Properties Used in SSI Analyses:

The strain dependent soil properties used in the model are in accordance with the properties provided in Table 3H.6-1 for the in-situ soil and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers are adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

Analysis Cases, Passing Frequency and Cutoff Frequency for the SSI Analyses:

- The following cases are analyzed for both 4% and 7% structural damping cases:

  For full fuel oil tank case:

  - Lower Bound (LB) in-situ soil
  - Mean in-situ Soil
  - Upper Bound (UB) in-situ soil

- LB backfill over LB in-situ soil
- Mean backfill over mean in-situ soil
- UB backfill over UB backfill
- UB in-situ soil with soil separation
- UB in-situ soil with cracked concrete

For Empty fuel oil tank case:

- UB in-situ soil with empty fuel tank

Note: For soil separation, cracked concrete and empty fuel oil tank cases, the UB in-situ soil is used because the UB in-situ soil case in general governed.

- A cut-off frequency of 35 Hz was used for all SSI analyses for transfer function calculation.
- Vertical direction passing frequencies (based on one fifth of shear wave length criterion and considering lower bound in-situ soil) are equal to or greater than 33 Hz.
- Horizontal direction passing frequencies are equal to or greater than 33 Hz, except at following locations:

  - For LB in-situ soil, the passing frequency for the top 4 ft soil layer is 30.3 Hz.
  - At the foundation toe, the passing frequencies for in-situ soil are 20 Hz for LB, 25.8 Hz for mean, 31.6 Hz for UB; and for backfill are 23.1 Hz for LB, 28.3 Hz for mean and 34.7 Hz for UB.

To evaluate the effect of 20 Hz passing frequency for LB in-situ case, the foundation toe was divided into two elements, thus increasing the passing frequency to 40 Hz. This refined model with LB in-situ soil properties was analyzed and 5% damped spectra from this model were compared with the spectra from the original model with passing frequency of 20 Hz. The comparison shows that:

- In the X direction, there is insignificant difference between the response spectra from the two models
- In the Y direction, the response spectra from the two models matched well except at frequency of about 3.8 Hz where the refined model produced higher spectra. However, spectra from both the models are enveloped by the spectra for UB in-situ soil case
- In the vertical direction, the spectra from the two models matched well (insignificant difference)

Based on the above evaluation it is concluded that the horizontal direction passing frequencies are acceptable.

Input Motion:

In the SSI analysis, acceleration time histories, consistent with 0.3g Regulatory Guide 1.60, are used as input at the grade elevation. The response spectra from these time histories envelop the amplified response spectra at the DGFOSV locations considering the effect of nearby heavy RB and UHS/RSW Pump House structures.

Response Combination, Enveloping and Spectra Peak Widening:

For all analysis cases, the responses due to two horizontal directions and vertical direction input motions are combined using square-root sum of squares (SRSS) method. Then, the responses from all analysis cases and all locations considered for spectra generation are enveloped to determine one set of un-widened horizontal and vertical response spectra. Finally, per Regulatory Guide 1.122, the enveloped un-widened response spectra are peak widened by plus-minus 15% on the frequency scale to obtain the final response spectra for DGFOSV. The resulting enveloping response spectra for DGFOSV are shown in Figures 3H.6-223 and 3H.6-224.

2D SSSI Analysis

Two 2D SSSI models are developed and analyzed to evaluate the effects of nearby structures on the three DGFOSV and to calculate the seismic soil pressures on the structures.

The first SSSI model is for a section cut in the North-South direction, consisting of UHS/RSW Pump house, RSW Piping Tunnel, DGFOSV 1B, DGFOSV 1C and RB. The details of this SSSI analysis are provided in Section 3H.6.5.3.

The second SSSI model is for a section cut in the East-West direction consisting of diesel generator fuel oil tunnel (DGFOT), DGFOSV 1A and the Crane Foundation Retaining Wall. The model for this SSSI analysis is shown in Figure 3H.6-225 and the details of the model are provided below.

Structural Models:

DGFOSV Model:

East-West direction of 2D DGFOSV model is idealized by a stick model of beam elements. Axial, flexural, and shear deformation effects are included in beam element stiffness. The fuel oil tank is also modeled using beam elements and its mass is lumped at its CG. The basemat and the mud mat are modeled using four node plain strain elements. The model properties (stiffness and mass) for the 2D plane analysis correspond to per unit depth (one foot dimension in the out-of-plane direction) of the DGFOSV.

DGFOT Model:

Four node plane strain elements are used to model the exterior walls, base slab, the top slab and the mud mat. Applicable weights are included at appropriate locations in the model. The structural model properties (stiffness and mass) for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

Crane Wall:

The Crane Wall is modeled using beam elements with nodes located 17 ft away from the DGFOSV east wall (clear distance between the DGFOSV 1A exterior wall face and the west face of the Crane Wall). Beam section properties (stiffness and mass), for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

The SSSI analysis of the 2D model of DGFOSV with other structures, which affects the DGFOSV in the East-West direction is performed using SASSI2000 computer program, using subtraction method. The following provides the details of this SSSI analysis.

Strain Dependent Soil Properties Used in SSSI Model:

The strain dependent soil properties used in the model are in accordance with the properties provided in Table 3H.6-1 for the in-situ soil, and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers are adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

To evaluate the effects of the soil variation, five soil cases are considered:

- UB in-situ soil with UB backfill between the structures.
- LB in-situ soil with LB backfill between the structures.
- Mean in-situ soil with Mean backfill between the structures.
- Mean in-situ soil with LB backfill between the structures.
- Mean in-situ soil with UB backfill between the structures.

Passing Frequency and Cut-off Frequency for SSSI Model:

- Cut-off frequency of 33 Hz is used in the analysis.
- Vertical direction passing frequencies are equal to or greater than 33.5 Hz.
- Horizontal direction passing frequencies are equal to or greater than 30.48 Hz.

Input Motion:

STP 3&4 site specific SSE motion, as described in Subsection 3H.6.5.1.1.2, is applied at the grade elevation, in the East-West direction.

The applicable codes, standards, and specifications from Section 3H.6.4 are used for analysis and design of the DGFOSV.

The DGFOSV are designed to the applicable loads and load combinations specified in Section 3H.6.4.

Lateral soil pressures used in design are shown in Figures 3H.6-226 through 3H.6-231.

The settlement information on the DGFOSV is included in Section 2.5S.4.10.

The forces and moments at critical locations in the DGFOSV along with the provided

longitudinal and transverse reinforcement are included in Table 3H.6-11 in conjunction with Figures 3H.6-140 through 3H.6-208.

The calculated factors of safety against sliding, overturning, and flotation for the DGFOSV are included in Table 3H.6-12.

The tornado missile impact evaluation results for the DGFOSV are included in Table 3H.6-13.

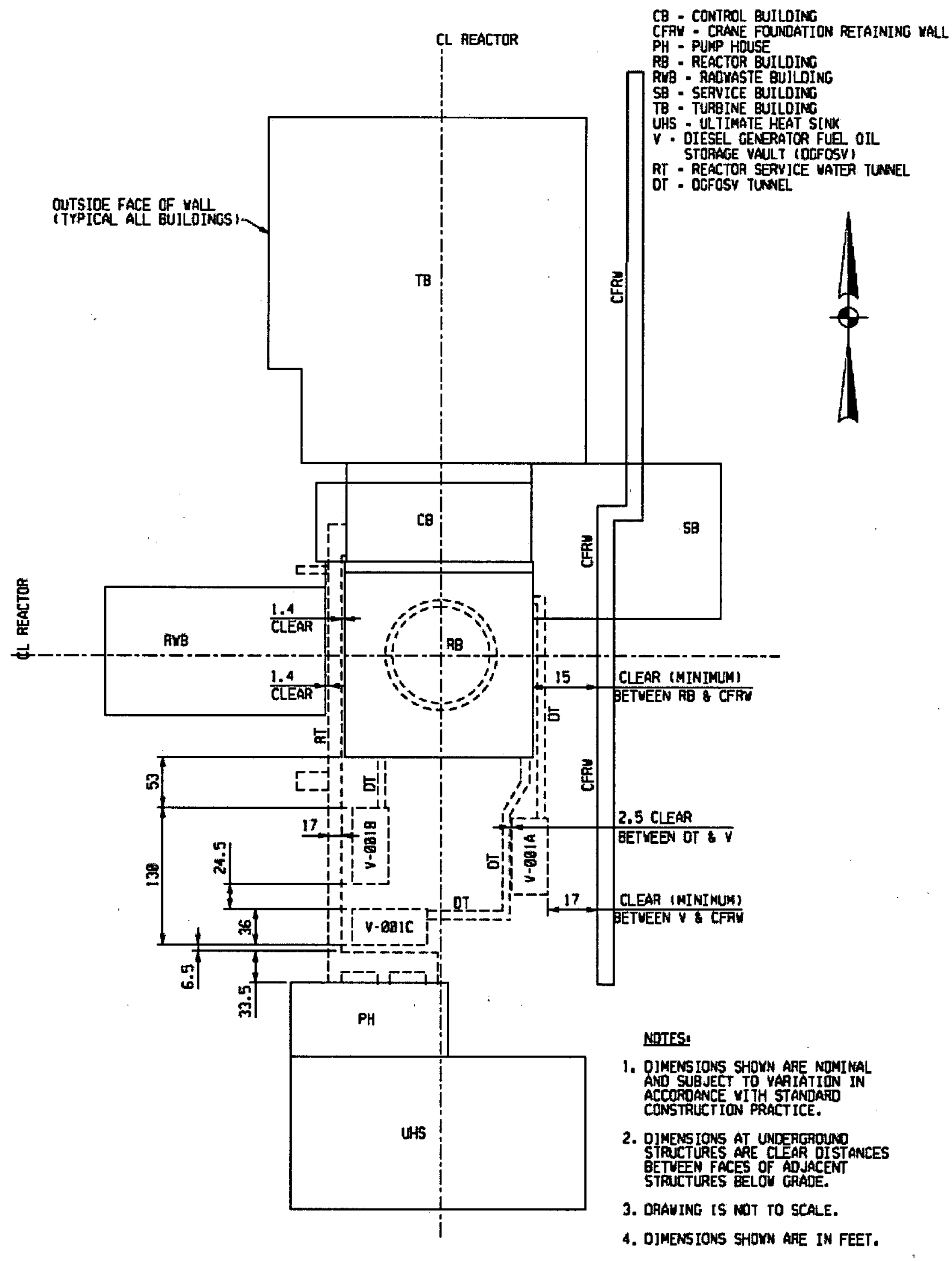

Figure 3H.6-221: Partial Site Plan

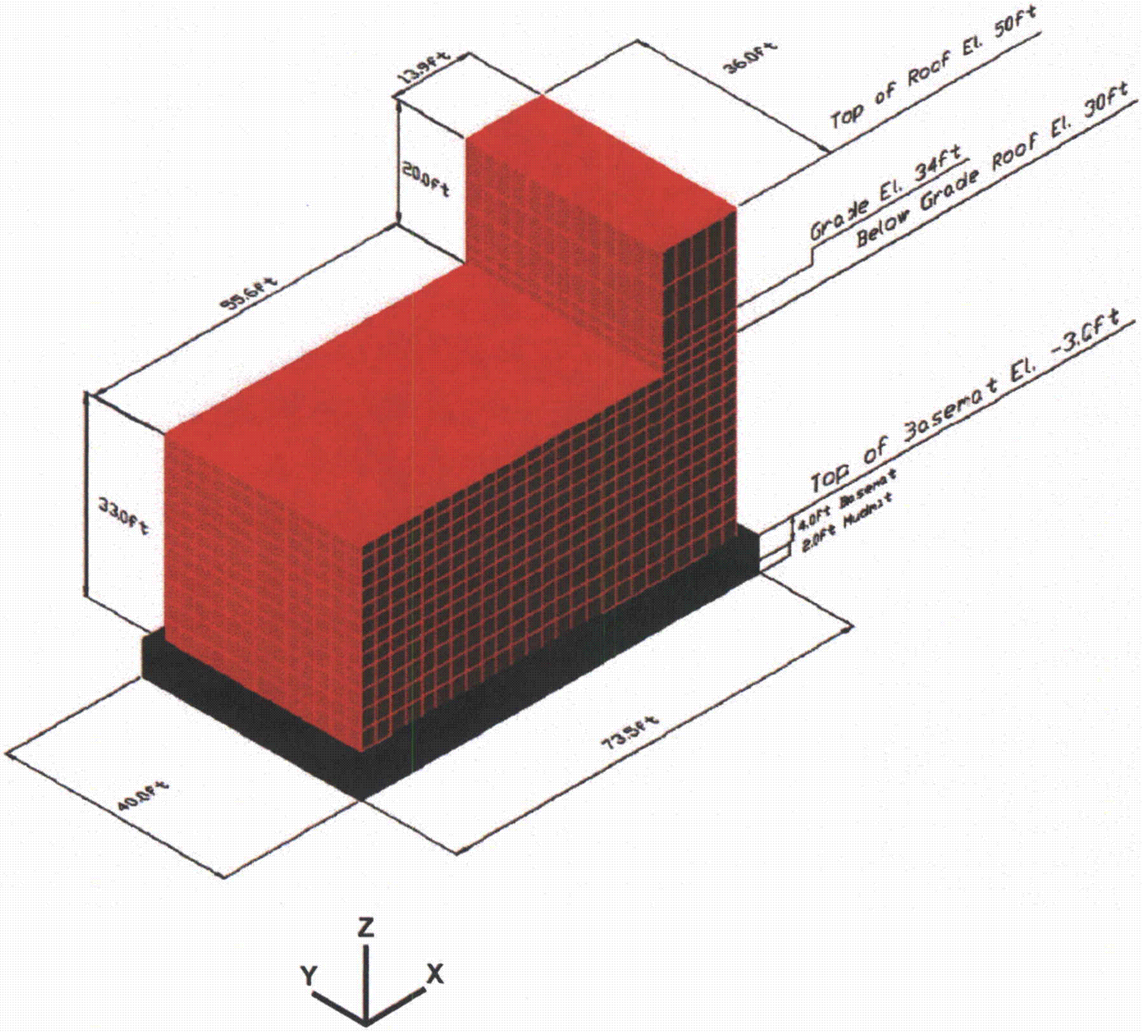

Figure 3H.6-222: 3D Model of DGFOSV for SSI Analysis

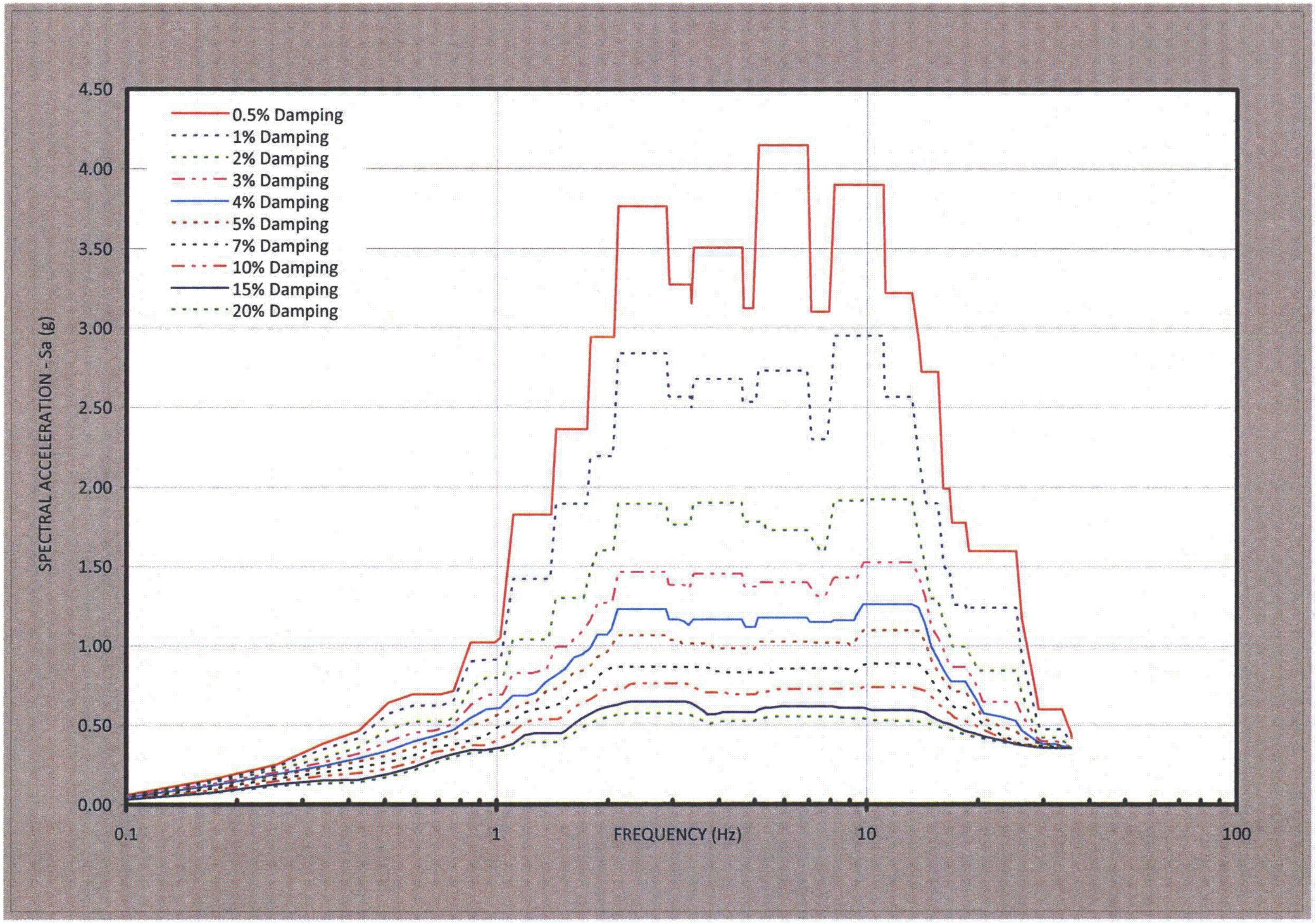

Figure 3H.6-223: Enveloped Broadened Horizontal Direction Response Spectra for DGFOSV

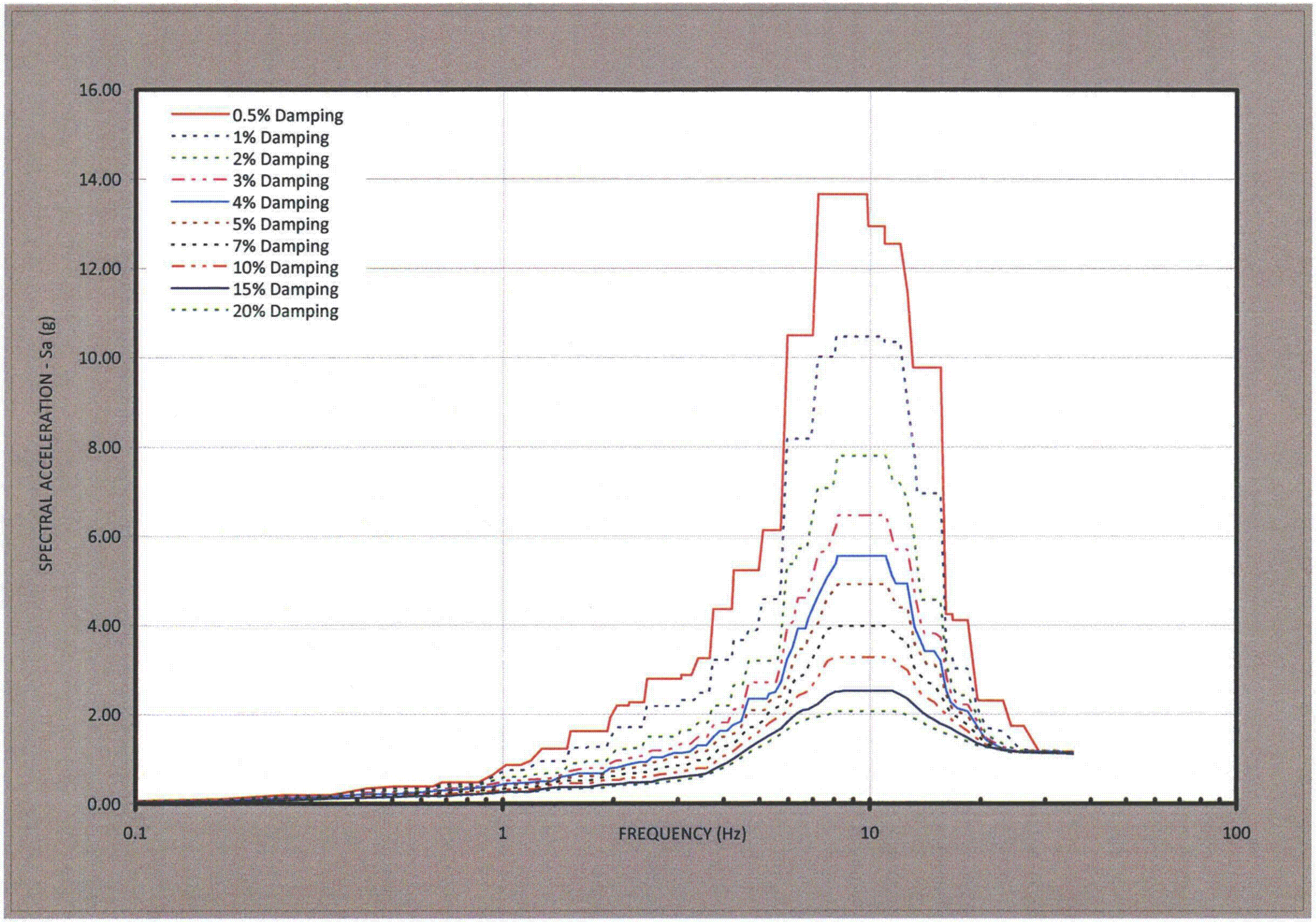

Figure 3H.6-224: Enveloped Broadened Vertical Direction Response Spectra for DGFOSV

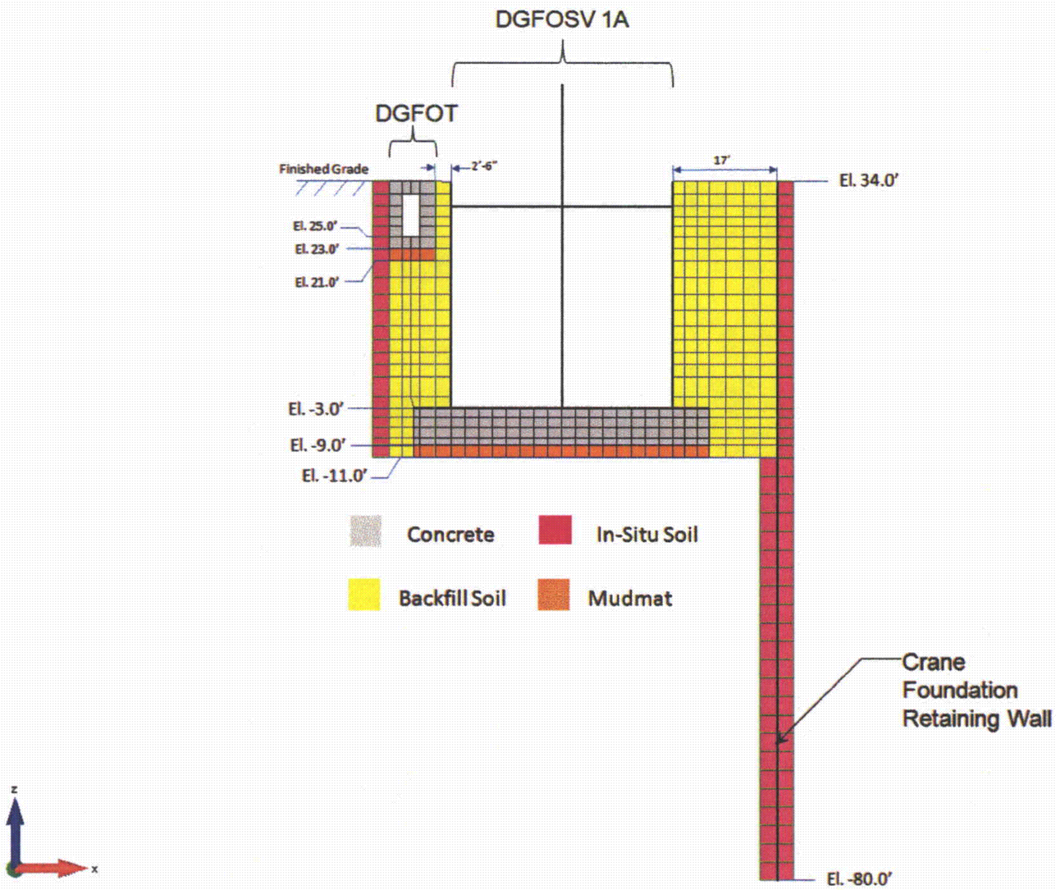

Figure 3H.6-225: 2D SSSI Model of DGFOT, DGFOSV and Crane Foundation Retaining Wall

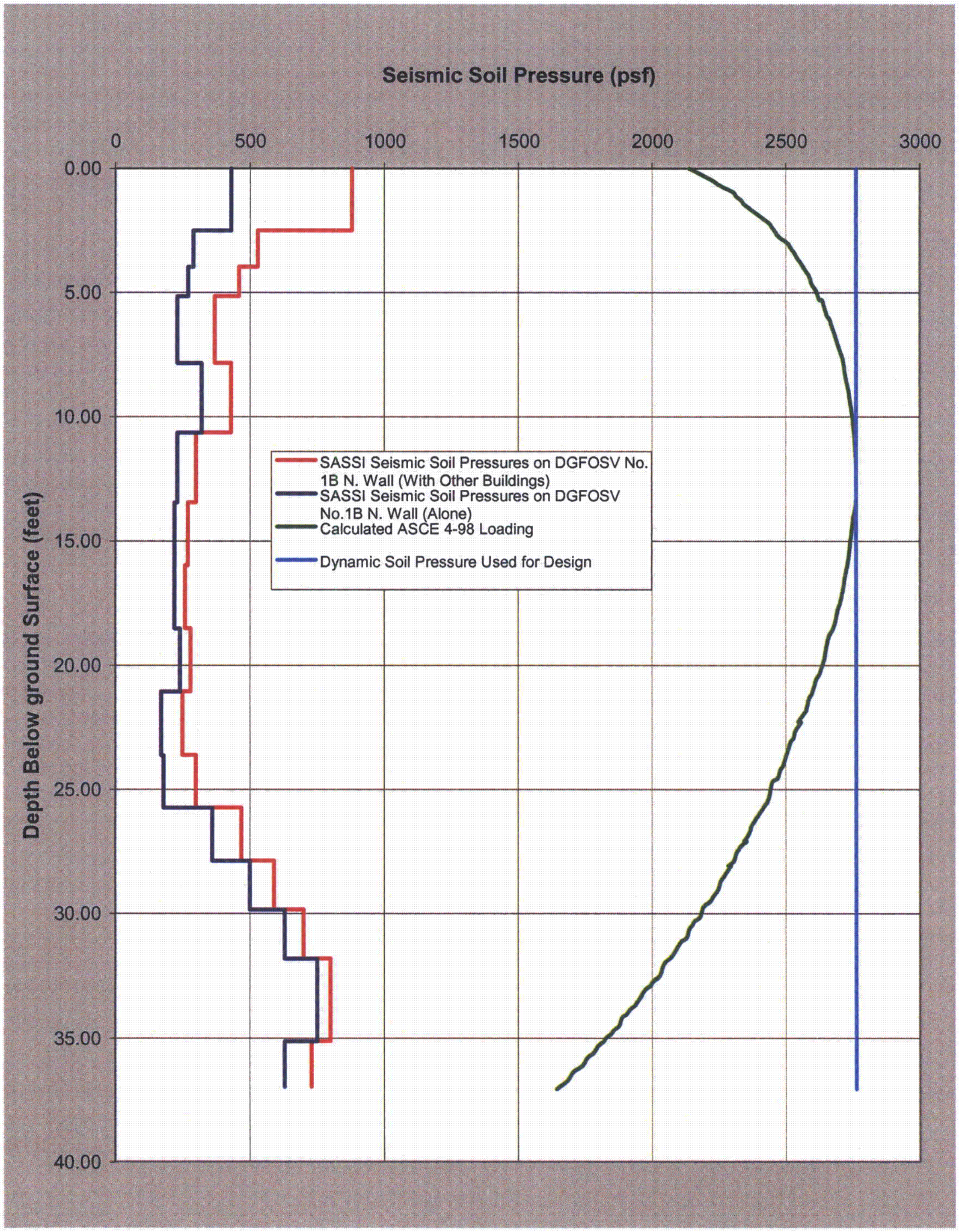

Figure 3H.6-226: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1B North Wall

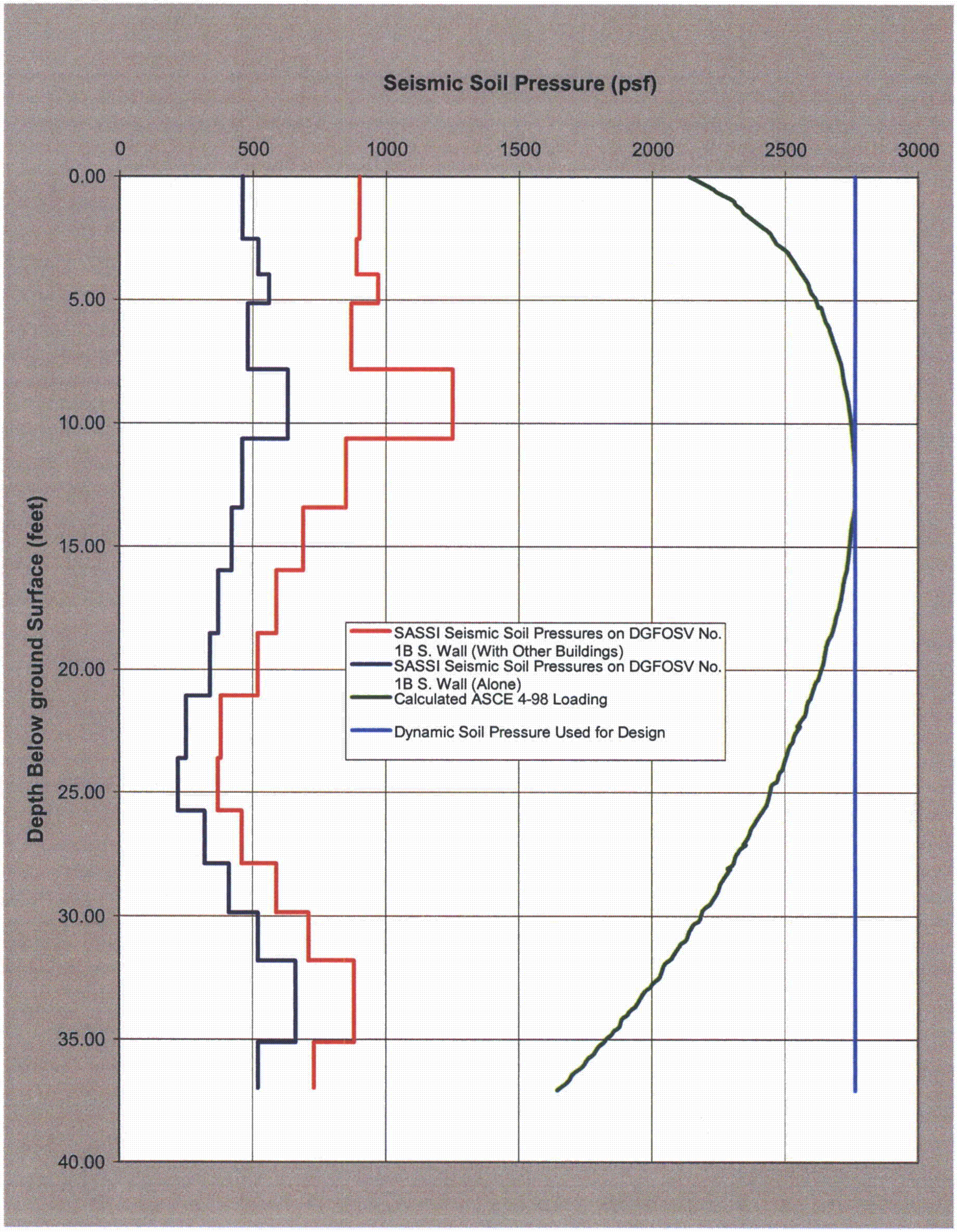

Figure 3H.6-227: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1B South Wall

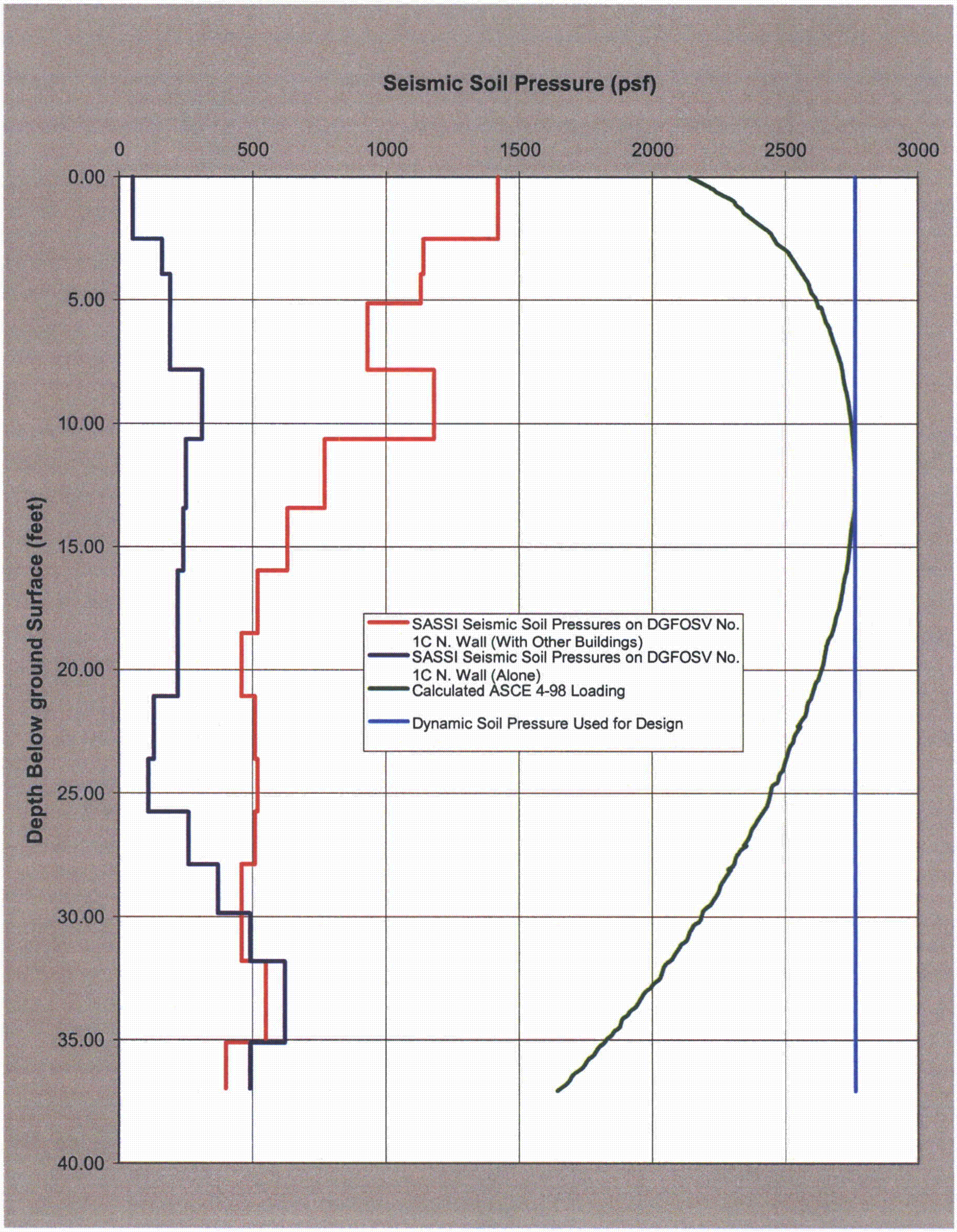

Figure 3H.6-228: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1C North Wall

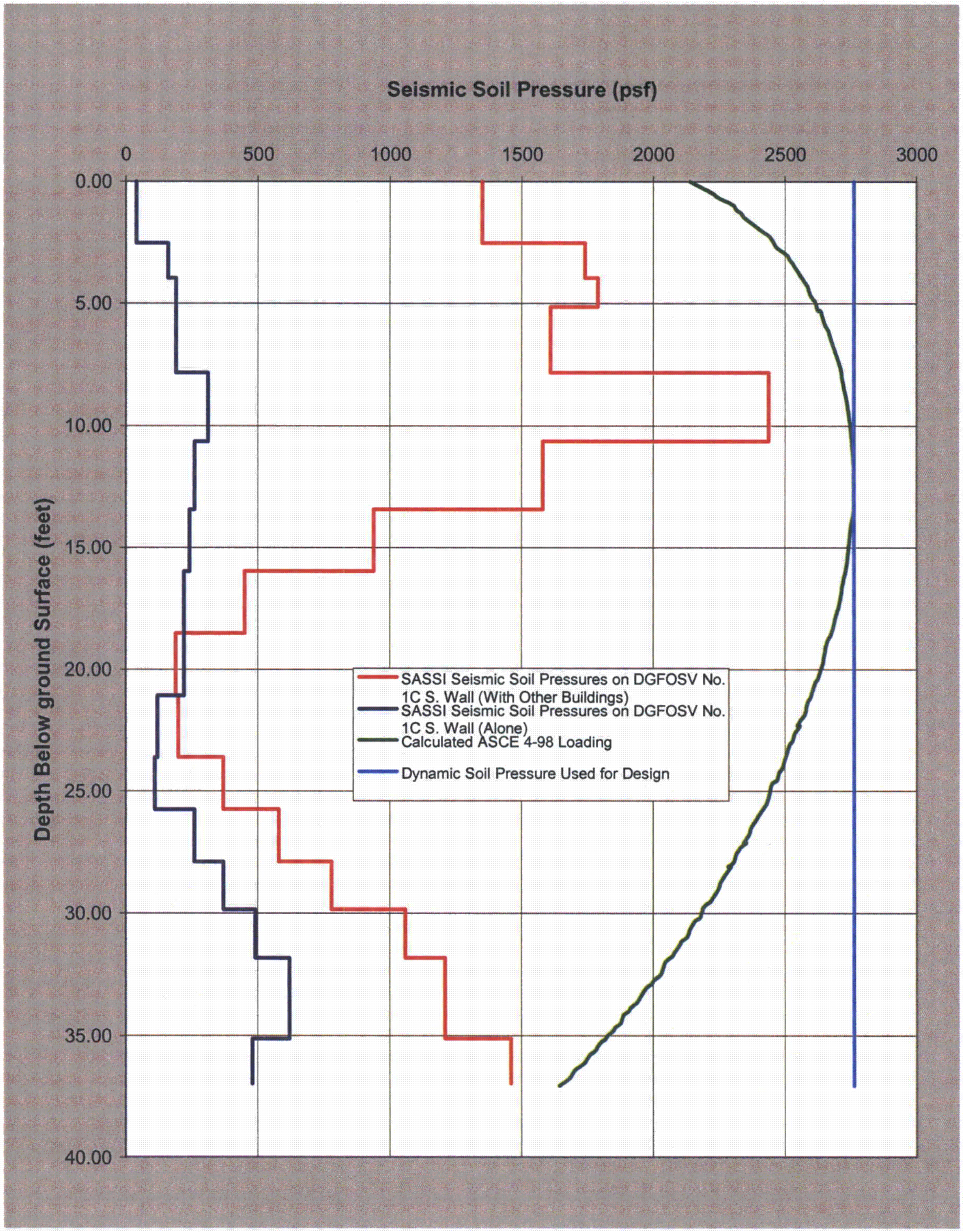

Figure 3H.6-229: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1C South Wall

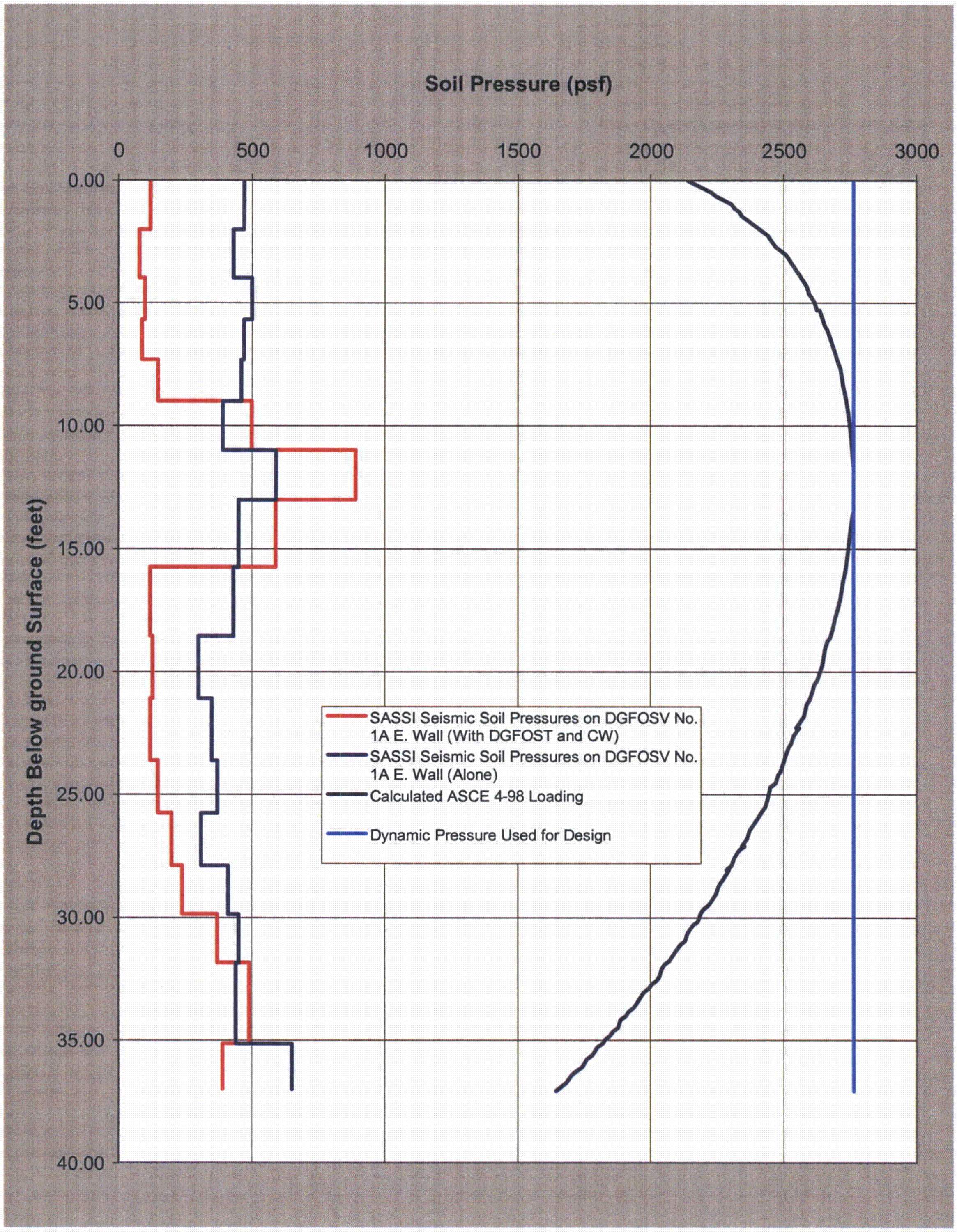

Figure 3H.6-230: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1A East Wall

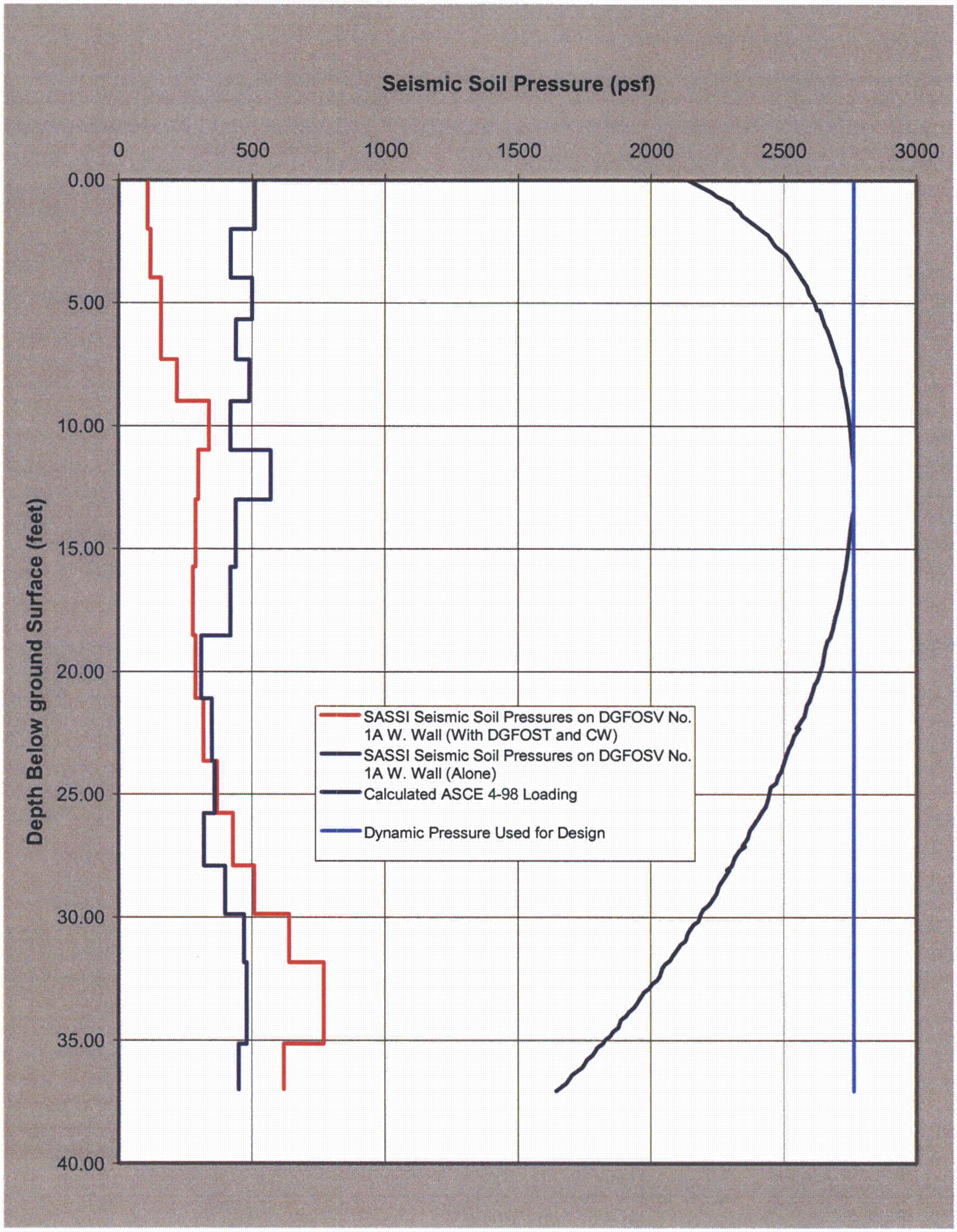

Figure 3H.6-231: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1A West Wall