Alaskan Way Viaduct & Seawall Replacement Program

U.S. Department of Transportation Federal Highway Administration | WSDOT | King County | City of Seattle

Seismic Ground Motion Study Supplement

1,000-Year Ground Motion

Submitted to:
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The Alaskan Way Viaduct & Seawall Replacement Program

Seismic Ground Motion Study Supplement

1,000-Year Ground Motion

Agreement No. Y-9594

Task AF

The Alaskan Way Viaduct & Seawall Replacement Program is a joint effort between the Federal Highway Administration (FHWA), the Washington State Department of Transportation (WSDOT), and the City of Seattle. To conduct this project, WSDOT contracted with:

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1.0 INTRODUCTION

The Washington State Department of Transportation (WSDOT) and the Alaskan Way Viaduct and Seawall Replacement Program (AWVSRP) Design Team are performing final design to replace the existing Alaskan Way viaduct (State Route [SR] 99) from S. Holgate Street to Harrison Street (see Figure 1-1). This report is a supplement to the seismic ground motion study that was performed for the project in 2004 and presents additional studies that were performed for the 1,000-year site-specific earthquake ground motions. This Seismic Ground Motion Study Report (SGMSR) supplement does not include detailed explanations of our analysis methods and background data. This supplement includes references to various appendices of the 2004 SGMSR for further information.

1.1 Purpose and Background

In 2004, bridge seismic design was based on dual ground motion / performance level approach as outlined in the Recommended LRFD Guidelines for the Seismic Design of Highway Bridges, Part I: Specifications and Part II: Commentary and Appendices, 2003 Edition, published by the Applied Technology Council and Multidisciplinary Center for Earthquake Engineering Research (ATC-49). We performed probabilistic seismic hazard analyses and site-specific ground (soil) response studies for the AWVSRP. The results of our studies were presented in a SGMSR submitted in October 2004 (Shannon & Wilson, 2004). Site-specific ground response analyses results and design spectra were provided in the SGMSR for two ground motion levels (in accordance with ATC-49) in the area south of Pine Street as follows:

- Expected Earthquake (EE) – Ground motions with 50 percent probability of exceedance in 75 years (108-year return period).
- Rare Earthquake (RE_{2500}) – Ground motions with a 3 percent probability of exceedance in 75 years (2,500-year return period).

Based on the results of the site ground response studies, the area south of Pine Street was divided into two zones, Zone A and Zone B, with each zone having its own site-specific EE and RE_{2500} design spectra. The locations of these zones are shown in Figure 1-2.

Subsequent to publication of the SGMSR, the dual level ATC-49 approach for bridge design was replaced by the American Association of State Highway and Transportation Officials (AASHTO) Guide Specifications for Load and Resistance Factor Design (LRFD) Seismic Bridge Design (AASHTO, 2007) and its modifications per WSDOT Design Memorandum dated February 18, 2008 (WSDOT, 2008). AASHTO (2007) has a single design earthquake ground motion level that is defined as:

- 1,000-year ground motion - Ground motions with a 7 percent probability of exceedance in 75 years (1,000-year return period).

Additional deep borings and shear wave velocity measurements were performed following the completion of the SGMSR. The results of these explorations are included in the December 2008 Geotechnical and Environmental Data Report (GEDR) prepared for the S. Holgate Street to S. King Street Viaduct Replacement Project (Shannon & Wilson, 2008). The locations of the explorations are shown in Figure 1-3.

In our 2004 studies, the project study area extended from Pine Street south along the downtown Seattle waterfront to about 400 feet south of S. Atlantic Street. The study area was divided into two zones, Zone A and Zone B, based on the subsurface conditions. In 2008, the additional subsurface information and extension of the project to S. Holgate Street resulted in the creation of a third zone, Zone C. The locations of Zones A, B, and C are shown in Figure 1-2.

This report provides recommended equivalent-linear design spectra for Zones A, B, and C. The report also provides recommended non-linear effective stress design spectra estimated for Zones B and C. These non-linear effective stress design spectra consider the effects of pore pressure generation on the design ground motions. Non-linear effective stress site response was not performed for Zone A. In our opinion, and considering the relative shallow thickness of Holocene soil above glacial soil, the Zone A equivalent-linear design spectrum would be similar to the non-linear effective stress spectrum for this zone.

1.2 Limitations

Within the limitations of scope, schedule, and budget, the analyses, conclusions, and recommendations presented in this report were prepared in accordance with generally accepted professional geologic and geotechnical engineering principles and practices in this area at the time this report was prepared. We make no other warranty, either express or implied. The conclusions are based on our understanding of the project as described in this report.

This report was prepared for the exclusive use of WSDOT, the City of Seattle, and the AWVSRP design team members for the evaluation of ground motion hazards and the understanding of the basis of seismic design ground motions for the project.

2.0 1,000-YEAR SOFT ROCK GROUND MOTION

The soft rock input time histories used for the 1,000-year ground motion analyses were modified from the three RE_{2500} time history sets (each set consists of two horizontal pairs) that were developed and used in 2004 (see Appendix D of the SGMSR). To modify the time histories, we developed a soft rock target spectrum for the 1,000-year uniform hazard spectrum from the results of the peer-reviewed probabilistic seismic hazard analyses (PSHA) performed in 2004 (see Appendix B of the SGMSR). The 1,000-year soft rock target spectrum included near-fault directivity and basin effects.

Specifically, we developed a rock uniform hazard spectrum (UHS) from the results of the SGMSR PSHA. The UHS was then modified using the same basin amplification scaling factors used in 2004 and described in Appendix E of the SGMSR. The target spectrum was also modified for potential near-fault directivity effects using approximately one-half of the amplification indicated by the average-directivity-effects amplification factors used in Figure B-13 in Appendix B of the SGMSR. The directivity-effects amplification factors in the SGMSR are deterministic and are based on movement of the Seattle Fault. For the RE_{2500}, most of the ground motion hazard is from the Seattle Fault, so the directivity factors were used without any scaling. However, for the 1,000-year ground motion, the Seattle Fault only contributes about 50 percent of the ground motion hazard (see Figures B-17 to B-19 in Appendix B of the SGMSR). Therefore, only one-half of the fault-directivity amplification was used for the 1,000-year ground motion.

The acceleration, velocity, and displacement soft rock spectrum for the 1,000-year ground motion are presented in Figures 2-1, 2-2, and 2-3.

The RE_{2500} horizontal rock time histories were arithmetically scaled to match the 1,000-year ground motion rock target response spectrum. After scaling, the time histories were spectrally matched to the 1,000-year ground motion rock target response spectrum using the procedures described in 2004 (see Appendix D of the SGMSR). Three sets of spectrum-compatible horizontal rock time histories were developed to match the 1,000-year soft rock spectrum.

Plots of the seed and spectrum-compatible rock time histories, and plots of the time history response spectra before and after spectral matching are presented in Appendix A, in Figures A-1 through A-24.

3.0 SOIL GROUND MOTIONS

3.1 Equivalent Linear Site Response Analyses

3.1.1 Analysis Method

We performed equivalent linear site response analyses for the 1,000-year ground motion in Zones A, B, and C. We performed the analysis using the programs Pro-Shake (EduPro Civil Systems, 1999) and SHAKE2000 (GeoMotions, 2009a), which are modified versions of the original program SHAKE (Schnabel, 1972). The program uses an equivalent linear, total stress analysis procedure to compute the response of a one-dimensional, horizontally layered, visco-elastic system subjected to vertically propagating shear waves. The 1,000-year spectrum-compatible rock time histories described in Section 2.0 were used as input motions in the analyses of the various site response models.

The equivalent linear method models the nonlinear variation of the soil shear moduli and damping as a function of shear strain using input shear modulus degradation and damping versus strain curves. Given an initial estimate of the shear strains, the program determines values of dynamic moduli and damping ratios corresponding to the "effective" strain. An iterative procedure is used to arrive at moduli and damping values compatible with the calculated "effective" strains. The equivalent linear approach has been validated by many back-analyses of previous earthquakes, and the method generally provides representative results at low to moderate levels of shaking.

Input properties for equivalent linear analysis include the shear wave velocity and soil unit weight along with shear modulus degradation and damping versus strain curves. The published curves used in our analyses included those by EPRI (1993) for sand, Vucetic and Dobry (1991) and Vucetic and Hsu (2004) for silt, and Peninsular Range (Silva and others, 1997) for deep soil deposits.

Shear wave velocities in the equivalent linear soil model are based on downhole velocity measurements in the following borings: EB-18B, H-9-93, SDC-001, SDC-002, and SDC-003 in 2004; and IB-240, IB-258, and IB-263 in 2008. The measurements from borings performed for previous studies (EB-18B, H-9-93, SDC-001, SDC-002, and SDC-003) are presented in Appendix G of the SGMSR. The measurements at recent borings (IB-240, IB-258, and IB-263) are presented in the December 2008 GEDR (Shannon & Wilson, 2008). For the three 2008 borings and considering the previous analyses, site response models were developed utilizing the results of subsurface explorations, field measurements of shear wave velocity, and laboratory measurements of engineering index soil properties. For the five boring locations included in the 2004 study, we used the original site response models presented in the SGMSR. The eight shear wave velocity (Vs) profiles, the model velocity profiles, and the geologic soil models are presented in Appendix B in Figures B-1 through B-8.

To provide a representation of the potential variability in subsurface conditions, the measured (or best estimate) shear wave velocity profile was varied by 30 percent (in log space) in the upper 350 feet. This estimate of variability is based on our experience and variability estimated for the western United States (McGuire and others, 2001). These shear wave velocity profiles that were varied by 30 percent were termed the lower-bound and upper-bound estimates of Vs and are shown on Figures B-1 through B-8 in Appendix B.

3.1.2 Analysis Results

We calculated site-specific free-field, horizontal ground surface motions using equivalent linear site response methods for the model borings located in Zones A, B, and C. The zones and corresponding model borings are follows:

- Zone A: Borings EB-18B and H-9-93
- Zone B: Borings SDC-001, SDC-002, SDC-003, and IB-240
- Zone C: Borings IB-258 and IB-263

The calculated geometric mean free-field horizontal ground surface response spectra for all the model borings are presented together in Figure 3-1. The calculated geometric mean free-field horizontal ground surface response spectra are divided up by zone location in Figures 3-2 through 3-4. The individual ground surface response spectra from each input motion at individual boring location are presented in Appendix B.

3.2 Non-Linear Site Response Analyses

3.2.1 Analysis Method

The soil profiles obtained from borings drilled in Zones B and C were analyzed for effective stress conditions using the fully nonlinear computer code, D-MOD2000 (GeoMotions, 2009b). D-MOD2000 computes the dynamic response of a layered soil profile to vertically propagating shear waves using a nonlinear stress-strain model. The program also incorporates a pore pressure generation model for sand and a pore water pressure/cyclic degradation model for clay to simulate pore water pressure response in the effective stress analysis.

Similar to the equivalent linear analyses and to provide a representation of the potential variability in subsurface conditions, the measured (or best estimate) shear wave velocity profile was varied by 30 percent (in log space) in the upper 350 feet. The shear wave velocity measurements obtained from borings SDC-001, SDC-002, and SDC-003 were considered in the soil profile developed for the IB-240 analyses.

Non-linear effective stress site response was not performed for Zone A. In our opinion, and considering the relative shallow thickness of Holocene soil above glacial soil, the Zone A equivalent-linear design spectrum would be similar to the non-linear effective stress spectrum for this zone.

For effective stress analyses using D-MOD2000, the pore water pressure generation models include: (a) Dobry et al. (1985) and Vucetic and Dobry (1988) for sand and (b) Matasović and Vucetic (1995) for clay. These models were developed from the results of strain-controlled laboratory testing. Cyclic direct simple shear, cyclic triaxial, or torsional shear strain-controlled laboratory testing could be used to provide some constants and parameters of pore water pressure generation models. However, for this project, values of parameters attributed to typical materials and available in literature and the matching procedure described below were used. Results from the cyclic direct simple shear tests performed for this portion of the alignment (Shannon & Wilson, 2008) were in general agreement with the values published in the literature.

We developed input parameters for the nonlinear MKZ soil model using a curve fitting procedure developed by N. Matasović. The procedure determines parameters β and S to match target shear modulus degradation and damping curves for given input shear wave velocity and reference shear strain values. The pore pressure generation model for sand was used for all soil layers in the nonlinear effective stress analysis. According to program recommendations, the sand model is applicable for granular materials and low to medium plasticity fine-grained soil. This is consistent with the site soils. Input hydraulic conductivity values were selected based on field and published values for the corresponding soil. Threshold shear strain values were determined using values provided in Hsu and Vucetic (2006). Other model parameters were based on typical values recommended in D-MOD2000 documentation.

3.2.2 Analysis Results

We calculated site-specific free-field, horizontal ground surface motions using D-MOD2000 fully non-linear site response methods for boring IB-240 located in Zone B, and borings IB-258 and IB-263 located in Zone C. The calculated geometric mean free-field horizontal ground surface response spectra for all three model borings in the two zones are presented together in Figure 3-5. The individual ground surface response spectra from each input motion at individual boring locations are presented in Appendix B.

4.0 DESIGN GROUND MOTIONS

Site-specific design spectra are provided for seismic design of structures located within Zones A, B, or C. The boundaries between these zones are approximate. Where proposed structures approach a zone boundary, the structural design should be checked with the spectra from the zones on either side of the boundary.

4.1 Horizontal Spectra

We have divided the project into three zones for design based on similarities and differences among the results of the equivalent linear and nonlinear site-specific ground response analyses in Appendix B. Specifically, for each soil model, we calculated the response spectra for each time history and each shear wave velocity variation. We then calculated the geometric mean of all the response spectra for each soil model; compared the soil models geometric mean spectra; and divided the project into zones based on similarities and differences among the geometric mean spectra. This approach, of calculating and comparing geometric mean spectra for each soil model to divide the project into zones, was the same approach used in the SGMSR. Geometric mean spectra plots of the soil model for the 1,000-year ground motion are shown in Figure 4-1. Based on this plot, we divided the project into three zones, designated as Zone A, B and C. The locations of these zones are shown in Figure 1-2. Zone A consists of soil model profiles EB-18B and H-9-93; Zone B consists of soil model profiles SDC-001, SDC-002, SDC-003, and IB-240; Zone C consists of soil model profiles IB-258 and IB-263. For comparison, the AASHTO design spectrum (using peak ground acceleration [PGA], S_S, and S_1 from the PSHA in Appendix B) for Site Class E is shown in Figure 4-1.

Acceleration, velocity, and displacement spectra with geometric mean for the equivalent linear case are presented for Zone A, B, and C in Figures 4-2, 4-3, and 4-4, respectively. Acceleration, velocity, and displacement spectra with geometric mean for the non-linear effective stress case are presented in Figure 4-5. The recommended smoothed horizontal design response spectra for Zone A, B, and C are also shown in Figures 4-2, 4-3, 4-4, and 4-5. Numerical values for these spectra are provided in Tables 4-1 through 4-4. The amplitudes of the spectra were selected to generally envelope the geometric mean site response results for the model profiles in a particular zone. Smoothed recommended horizontal response spectra for design are also shown together in Figure 4-6. The amplitude of the spectra in Figure 4-6 are equal to or greater than two-thirds of the ASSHTO T3 code Site Class E spectrum.

Vertical Response Spectra

The 1,000-year site-specific vertical design response spectra were developed from deterministic vertical-to-horizontal (V/H) spectral ratios. Vertical ground motion attenuation equations have not been published for intraslab and interplate earthquakes. However, vertical ground motion attenuation equations are available for crustal earthquakes. Therefore, deterministic estimates of the soil V/H ratios were developed using vertical crustal attenuation equations. To be consistent with the PSHA in the 2004 SGMSR, deterministic median V/H ratios for soil were calculated using the soil ground motion attenuation relationships by Abrahamson and Silva (1997), Campbell and Bozorgnia (2003a, b, c), and Sadigh et al. (1993) for deep soil conditions. Results of the 1,000-year deaggregation were used to guide selection of the magnitude and distance used in the attenuation relations. Figure 4-7 presents the V/H ratios that were applied to the recommended horizontal design spectra presented in Figure 4-6. Figure 4-8 shows the resulting equivalent linear and non-linear vertical design response spectra for Zones A, B, and C. Numerical values for these spectra are provided in Tables 4-1 through 4-4. For locations along the alignment where site-specific response analyses for horizontal ground motions were not performed, the V/H ratios should be applied to the code horizontal design spectra to develop a vertical design spectrum.

4.2 Ground Motions Parameters for Liquefaction Analyses

In addition to peak ground accelerations, earthquake magnitude or duration is typically required for liquefaction and lateral spread analyses. We recommend that an earthquake magnitude of 6.8 be used for liquefaction analyses and the AASHTO

1,000-year ground motion. The peak ground acceleration for analyses in Zones A through C are provided in Table 4-1 through 4-3.

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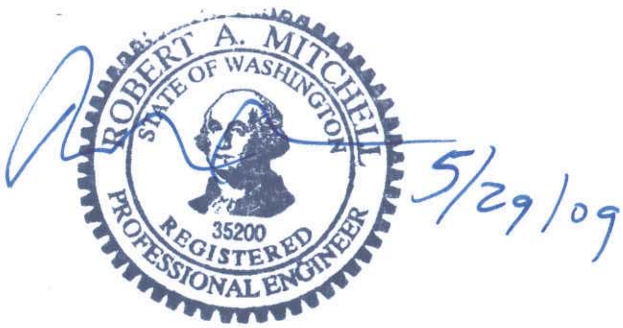

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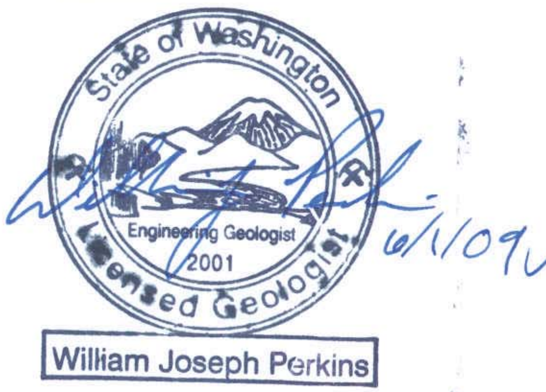

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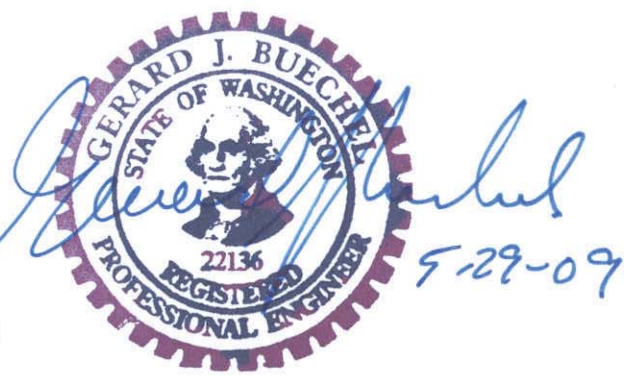

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5.0 REFERENCES

Abrahamson, N.A. and Silva, W.J., 1997, Empirical response spectral attenuation relations for shallow crustal earthquakes: Seismological Research Letters, v. 68, no. 1, p. 94-127.

Applied Technology Council (ATC) and Multidisciplinary Center for Earthquake Engineering (MCEER), 2003, Recommended LRFD guidelines for the seismic design of highway bridges, part I: specifications and part II: commentary and appendices: Redwood, Calif., ATC Report MCEER/ ATC-49, 2 vol.

American Association of State Highway and Transportation Officials (AASHTO), 2007, Guide Specifications for LRFD Seismic Bridge Design, 249 pages.

Campbell, K.W., and Bozorgnia, Y., 2003a, Updated near-source ground-motion (attenuation) relations for the horizontal and vertical components of peak ground acceleration and acceleration response spectra: Bulletin of the Seismological Society of America, v. 93, no. 1, p. 314-331.

Campbell, K.W., and Bozorgnia, Y., 2003b, Updated near-source ground-motion (attenuation) relations for the horizontal and vertical components of peak ground acceleration and acceleration response spectra (errata): Bulletin of the Seismological Society of America, v. 93, no. 3, p. 1413.

Campbell, K.W., and Bozorgnia, Y., 2003c, Updated near-source ground-motion (attenuation) relations for the horizontal and vertical components of peak ground acceleration and acceleration response spectra (errata): Bulletin of the Seismological Society of America, v. 93, no. 4, p. 1872.

Dobry, R.; Piece, W.G.; Dyvik, R.; and others 1985, Pore pressure model for cyclic straining of sand: Troy, N.Y., Rensselaer Polytechnic Institute, Civil Engineering Department Research Report, 56 p.

EduPro Civil Systems, 1999, ProShake: Sammamish, Wash., EduPro Civil Systems, Inc.

Electric Power Research Institute (EPRI), 1993, Guidelines for determining design basis ground motions: Palo Alto, Calif., Electric Power Research Institute Report TR-102293, 5 v.

GeoMotions, LLC, 2009a, SHAKE2000 a computer program for the 1-D analysis of geotechnical earthquake engineering problems: Lacey, Wash., GeoMotions, LLC.

GeoMotions, LLC, 2009b, D-MOD2000, a computer program for seismic response analysis of horizontally layered soil deposits, earthfill dams and solid waste landfills: Lacey, Wash., GeoMotions, LLC.

Hsu, C.-C., and Vucetic, Mladen, 2006, Threshold shear strain for cyclic pore-water pressure in cohesive soils: Journal of Geotechnical and Geoenvironmental Engineering, v. 132, no. 10, p. 1325-1335.

Matasović, Neven, and Vucetic, Mladen, 1995, Generalized cyclic-degradation – pore-pressure generation model for clays: Journal of Geotechnical Engineering, v. 121, no. 1, p. 33-42.

McGuire, R.K.; Silva, W.J.; and Constantino, C.J., 2001, Technical basis for revision of regulatory guidance on design ground motions: hazard- and risk-consistent ground motion spectra guidelines: Washington, D.C., U.S. Nuclear Regulatory Commission, Report no. NUREG/CR-6728.

Sadigh, K.; Chang, C. Y.; Abrahamson, N. A.; and others, 1993, Specification of long period ground motions: updated attenuation relationships for rock site conditions and adjustment factors for near fault effects:, in ATC-17-1 Seminar on seismic isolation, passive energy dissipation, and active control, San Francisco, Calif., 1993, Proceedings: Redwood City, Calif., Applied Technology Council, v. 1., p. 59-70.

Schnabel, P.B.; Lysmer, J.; and Seed, H.B., 1972, SHAKE: a computer program for earthquake response analysis of horizontally layered sites: Berkeley, Calif., Earthquake Engineering Research Center Report No. EERC 72-12, 46 p.

Shannon & Wilson, Inc., 2004, Seismic ground motion study report, SR-99: Alaskan Way viaduct project, Seattle, Washington: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., 21-1-09490-929, for WSDOT, Federal Highway Administration and City of Seattle, Seattle, Wash., October, 2 v.

Shannon & Wilson, Inc., 2008, Geotechnical and environmental data report - S. Holgate Street to S. King Street viaduct replacement project, SR 99: Alaskan Way viaduct and seawall replacement program, Seattle, Washington: Report prepared by Shannon & Wilson, Inc., Seattle, Wash., 21-1-20840-007, for WSDOT and City of Seattle, Seattle, Wash., December.

Silva, W.J., Abrahamson, N., Toro, G., and Constantino, C., 1997, Description and validation of the stochastic ground motion model: submitted to Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York.

Vucetic, Mladen, and Dobry, Ricardo, 1988, Cyclic triaxial strain-controlled testing of liquefiable sands in Donaghe, R.T.; Chaney, R.C.; and Silver, M.L. eds., Advanced triaxial testing of soil and rock: Philadelphia, Penn., ASTM International, Special Technical Publication no. 977, p. 475-485.

Vucetic, Mladen, and Dobry, Ricardo, 1991, Effect of soil plasticity on cyclic response: Journal of the Geotechnical Engineering Division, v. 117, no. 1, p. 89-107.

Vucetic, Mladen., and Hsu, C., 2004, Results of seven cyclic simple shear tests on five soils conducted for Shannon & Wilson, Inc.: Los Angeles, Calif., University of California.

Washington State Department of Transportation (WSDOT), 2008, Design memorandum: implementation of LRFD guidelines for seismic bridge design: Memorandum from Bijan Khaleghi, February 18, 10 p.

Table 4-1
1,000-YEAR GROUND MOTION
ZONE A EQUIVALENT LINEAR DESIGN SPECTRA

Period (sec.)	Horizontal Design Spectrum			Vertical Design Spectrum		
	Sa (g's)	Sv (fps)	Sd (ft)	Sa (g's)	Sv (fps)	Sd (ft)
0.01	0.650	0.03	0.00	0.714	0.04	0.00
0.02	0.700	0.07	0.00	0.768	0.08	0.00
0.03	0.730	0.11	0.00	0.901	0.14	0.00
0.05	0.780	0.20	0.00	1.120	0.29	0.00
0.07	0.830	0.30	0.00	1.234	0.44	0.00
0.10	0.910	0.47	0.01	1.227	0.63	0.01
0.20	1.450	1.49	0.05	1.104	1.13	0.04
0.30	1.450	2.23	0.11	0.756	1.16	0.06
0.40	1.450	2.97	0.19	0.616	1.26	0.08
0.50	1.450	3.72	0.30	0.517	1.32	0.11
0.60	1.450	4.46	0.43	0.483	1.49	0.14
0.70	1.243	4.46	0.50	0.394	1.41	0.16
0.80	1.088	4.46	0.57	0.332	1.36	0.17
1.00	0.870	4.46	0.71	0.250	1.28	0.20
1.20	0.725	4.46	0.85	0.207	1.27	0.24
1.30	0.669	4.46	0.92	0.190	1.27	0.26
1.40	0.621	4.46	0.99	0.176	1.26	0.28
1.60	0.544	4.46	1.14	0.155	1.27	0.32
1.80	0.483	4.46	1.28	0.140	1.29	0.37
2.00	0.435	4.46	1.42	0.129	1.32	0.42
2.25	0.363	4.18	1.50	0.112	1.29	0.46
2.50	0.302	3.87	1.54	0.097	1.24	0.49
3.00	0.225	3.46	1.65	0.076	1.17	0.56
3.25	0.198	3.30	1.71	0.070	1.16	0.60
3.50	0.175	3.14	1.75	0.064	1.14	0.64
4.00	0.141	2.90	1.85	0.054	1.11	0.71

NOTES:

1. See text of report for an explanation of the design spectra.
2. See Figure 4-6 and Figure 4-8 for plots of the horizontal and vertical spectra.
3. g = acceleration of gravity.

Table 4-2
1,000-YEAR GROUND MOTION
ZONE B EQUIVALENT LINEAR DESIGN SPECTRA

Period (sec.)	Horizontal Design Spectrum			Vertical Design Spectrum		
	Sa (g's)	Sv (fps)	Sd (ft)	Sa (g's)	Sv (fps)	Sd (ft)
0.01	0.370	0.02	0.00	0.406	0.02	0.00
0.02	0.396	0.04	0.00	0.434	0.04	0.00
0.03	0.408	0.06	0.00	0.504	0.08	0.00
0.05	0.434	0.11	0.00	0.623	0.16	0.00
0.07	0.459	0.16	0.00	0.683	0.25	0.00
0.10	0.498	0.25	0.00	0.671	0.34	0.01
0.20	0.625	0.64	0.02	0.476	0.49	0.02
0.30	0.753	1.16	0.06	0.392	0.60	0.03
0.40	0.880	1.80	0.11	0.374	0.77	0.05
0.50	0.880	2.25	0.18	0.314	0.80	0.06
0.60	0.880	2.71	0.26	0.293	0.90	0.09
0.70	0.880	3.16	0.35	0.279	1.00	0.11
0.80	0.880	3.61	0.46	0.269	1.10	0.14
1.00	0.880	4.51	0.72	0.252	1.29	0.21
1.18	0.880	5.32	1.00	0.250	1.51	0.28
1.33	0.880	6.00	1.27	0.249	1.70	0.36
1.40	0.836	6.00	1.34	0.237	1.70	0.38
1.60	0.732	6.00	1.53	0.208	1.71	0.43
1.80	0.650	6.00	1.72	0.189	1.74	0.50
2.00	0.585	6.00	1.91	0.174	1.78	0.57
2.25	0.520	6.00	2.15	0.161	1.85	0.66
2.50	0.468	6.00	2.39	0.150	1.93	0.77
2.72	0.430	6.00	2.60	0.142	1.98	0.86
3.00	0.354	5.45	2.60	0.120	1.85	0.88
3.25	0.302	5.03	2.60	0.106	1.77	0.91
3.50	0.260	4.67	2.60	0.095	1.70	0.95
4.00	0.199	4.08	2.60	0.076	1.57	1.00

NOTES:

1. See text of report for an explanation of the design spectra.
2. See Figure 4-6 and Figure 4-8 for plots of the horizontal and vertical spectra.
3. g = acceleration of gravity.

Table 4-3

1,000-YEAR GROUND MOTION
ZONE C EQUIVALENT LINEAR DESIGN SPECTRA

Period (sec.)	Horizontal Design Spectrum			Vertical Design Spectrum		
	Sa (g's)	Sv (fps)	Sd (ft)	Sa (g's)	Sv (fps)	Sd (ft)
0.01	0.37	0.02	0.0000	0.41	0.02	0.0000
0.02	0.40	0.04	0.0001	0.43	0.04	0.0001
0.03	0.41	0.06	0.0003	0.50	0.08	0.0004
0.05	0.43	0.11	0.001	0.62	0.16	0.001
0.07	0.46	0.16	0.002	0.68	0.25	0.003
0.10	0.50	0.25	0.004	0.67	0.34	0.005
0.20	0.61	0.63	0.02	0.46	0.48	0.02
0.30	0.68	1.05	0.05	0.36	0.55	0.03
0.40	0.68	1.40	0.09	0.29	0.60	0.04
0.50	0.68	1.75	0.14	0.24	0.62	0.05
0.60	0.68	2.10	0.20	0.23	0.70	0.07
0.70	0.68	2.45	0.27	0.22	0.78	0.09
0.80	0.68	2.80	0.36	0.21	0.86	0.11
1.00	0.68	3.50	0.56	0.20	1.00	0.16
1.18	0.68	4.13	0.78	0.19	1.17	0.22
1.33	0.68	4.66	0.99	0.19	1.32	0.28
1.40	0.68	4.90	1.09	0.19	1.39	0.31
1.60	0.68	5.60	1.43	0.19	1.59	0.41
1.80	0.68	6.30	1.80	0.20	1.83	0.52
2.00	0.68	7.00	2.23	0.20	2.08	0.66
2.25	0.61	7.00	2.51	0.19	2.16	0.77
2.50	0.55	7.00	2.79	0.18	2.25	0.89
2.72	0.50	7.00	3.03	0.17	2.31	1.00
3.00	0.46	7.00	3.34	0.15	2.37	1.13
3.25	0.42	7.00	3.62	0.15	2.46	1.27
3.50	0.39	7.00	3.90	0.14	2.55	1.42
4.00	0.34	7.00	4.46	0.13	2.68	1.71

NOTES:

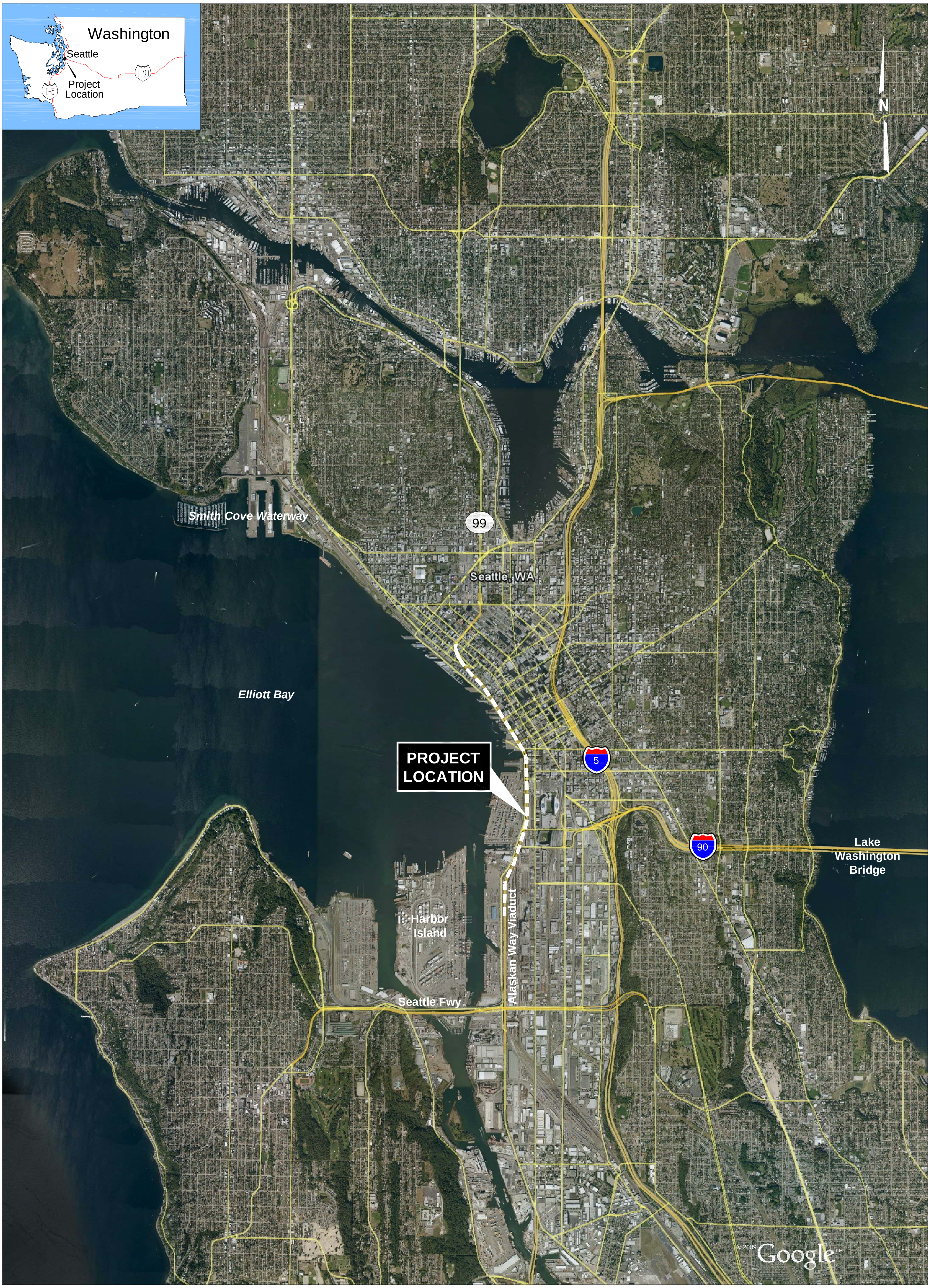
1. See text of report for an explanation of the design spectra.
2. See Figure 4-4 and Figure 4-8 for plots of the horizontal and vertical spectra.
3. g = acceleration of gravity.

Table 4-4
1,000-YEAR GROUND MOTION
ZONE B AND ZONE C EFFECTIVE STRESS DESIGN SPECTRA

Period (sec.)	Horizontal Design Spectrum			Vertical Design Spectrum		
	Sa (g's)	Sv (fps)	Sd (ft)	Sa (g's)	Sv (fps)	Sd (ft)
0.01	0.26	0.01	0.0000	0.29	0.01	0.0000
0.02	0.28	0.03	0.0001	0.31	0.03	0.0001
0.03	0.29	0.05	0.0002	0.36	0.06	0.0003
0.05	0.33	0.08	0.001	0.47	0.12	0.001
0.07	0.36	0.13	0.001	0.54	0.19	0.002
0.10	0.41	0.21	0.003	0.56	0.29	0.005
0.13	0.46	0.31	0.01	0.52	0.35	0.01
0.22	0.61	0.68	0.02	0.43	0.47	0.02
0.30	0.61	0.94	0.04	0.32	0.49	0.02
0.40	0.61	1.25	0.08	0.26	0.53	0.03
0.50	0.61	1.56	0.12	0.22	0.56	0.04
0.60	0.61	1.88	0.18	0.20	0.63	0.06
0.70	0.61	2.19	0.24	0.19	0.69	0.08
0.80	0.61	2.50	0.32	0.19	0.76	0.10
0.90	0.61	2.81	0.40	0.18	0.83	0.12
1.08	0.61	3.38	0.58	0.17	0.97	0.17
1.25	0.53	3.38	0.67	0.15	0.96	0.19
1.50	0.44	3.38	0.81	0.12	0.96	0.23
1.70	0.39	3.38	0.91	0.11	0.97	0.26
2.00	0.33	3.38	1.08	0.10	1.00	0.32
2.20	0.30	3.38	1.18	0.09	1.04	0.36
2.50	0.26	3.38	1.34	0.08	1.09	0.43
2.70	0.24	3.38	1.45	0.08	1.11	0.47
3.00	0.22	3.38	1.61	0.07	1.15	0.55
3.50	0.19	3.38	1.88	0.07	1.23	0.69
4.00	0.16	3.38	2.15	0.06	1.30	0.82

NOTES:

1. See text of report for an explanation of the design spectra.
2. See Figure 4-5 and Figure 4-8 for plots of the horizontal and vertical spectra.
3. g = acceleration of gravity.



NOTE

Map adapted from aerial imagery provided by Google Earth Pro, Image © 2009 DigitalGlobe, and Image © 2009 City of Bellevue, reproduced by permission granted by Google Earth ™ Mapping Service.

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Seattle, Washington

VICINITY MAP

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FIG. 1-1

FIG. 1-1

Filename: J:\211\20840-041\21-1-20840-041 SGMS Spectra (Current).dwg Layout: Spectra 041 Date: 04-21-2009 Login: Sandy Cottrell

NOTE

This figure is based on measurements in the field and on City of Seattle GIS data files *topo.dwg*, *st_names.dwg*, and *paveedge.dwg*, received 3-11-02.

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SITE SPECIFIC DESIGN RESPONSE SPECTRA ZONES

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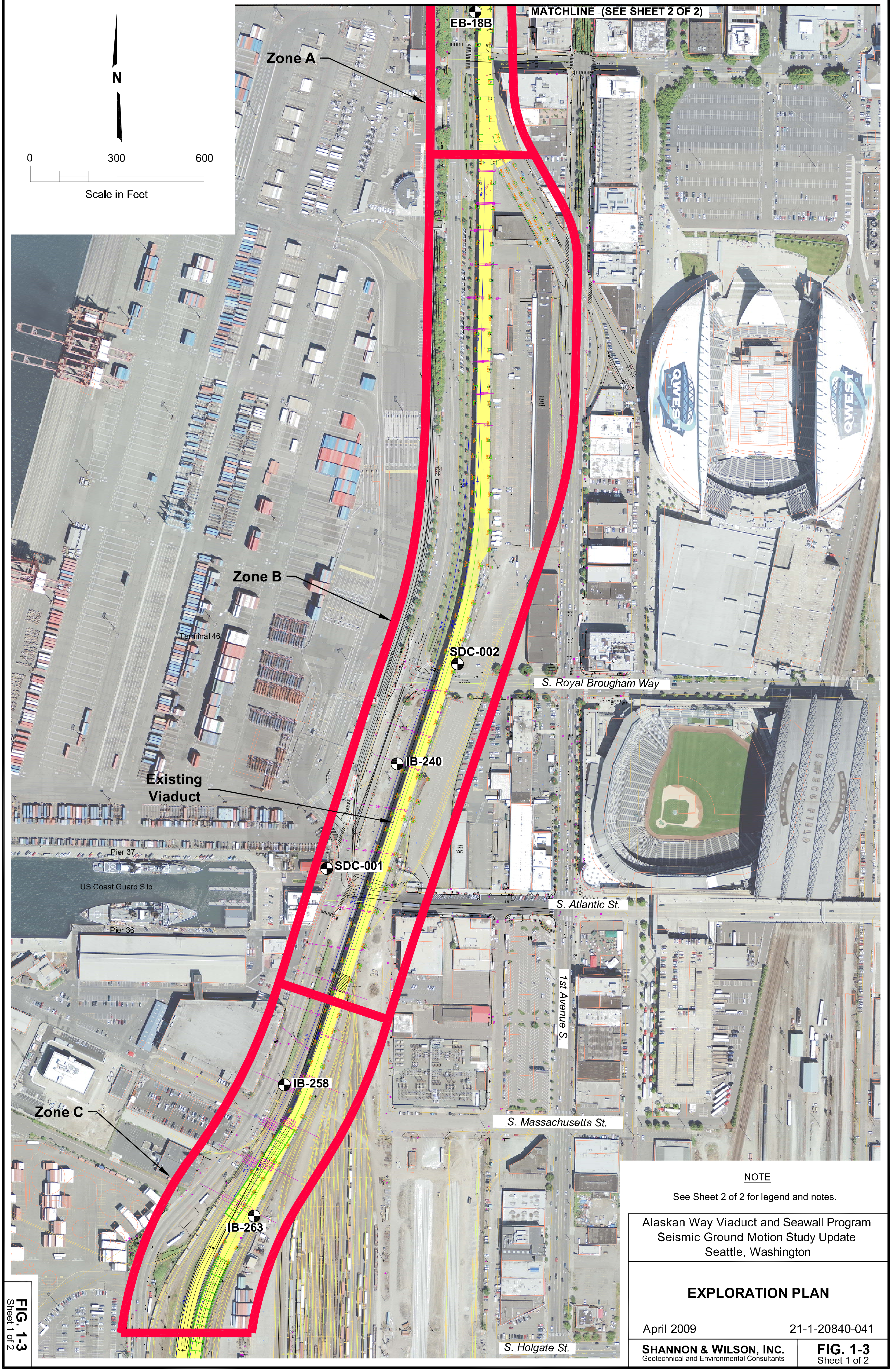
FIG. 1-2

FIG. 1-2



NOTE

See Sheet 2 of 2 for legend and notes.

Alaskan Way Viaduct and Seawall Program
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EXPLORATION PLAN

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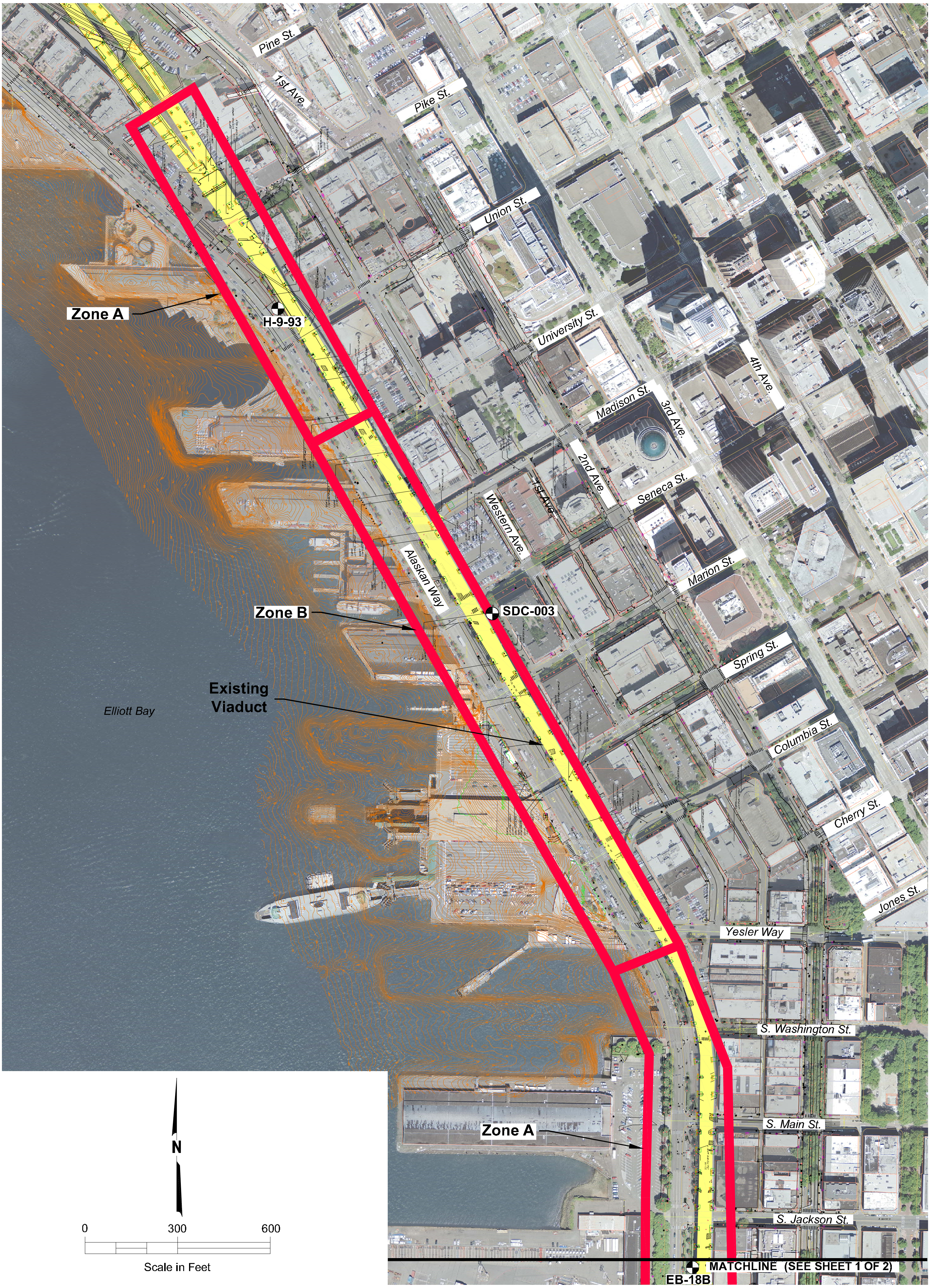
FIG. 1-3
Sheet 1 of 2



LEGEND

Soil Borings with Shear Wave Velocity Measurements Obtained

NOTES

1. Base map is adapted from City of Seattle GIS data files *topo_all.dwg*, *st_names.dwg*, and *paveedge.dwg*, received 3-11-02; City of Seattle GIS data file *buildings.dwg*, received 3-6-02; and Parsons Brinckerhoff AutoCAD files *BSMP_SO.dwg*, received 11-30-01, and *rail.dwg*, received 5-15-03.
2. Image received 1-17-08 from Parsons Brinckerhoff.

FIG. 1-3
Sheet 2 of 2

Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
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EXPLORATION PLAN

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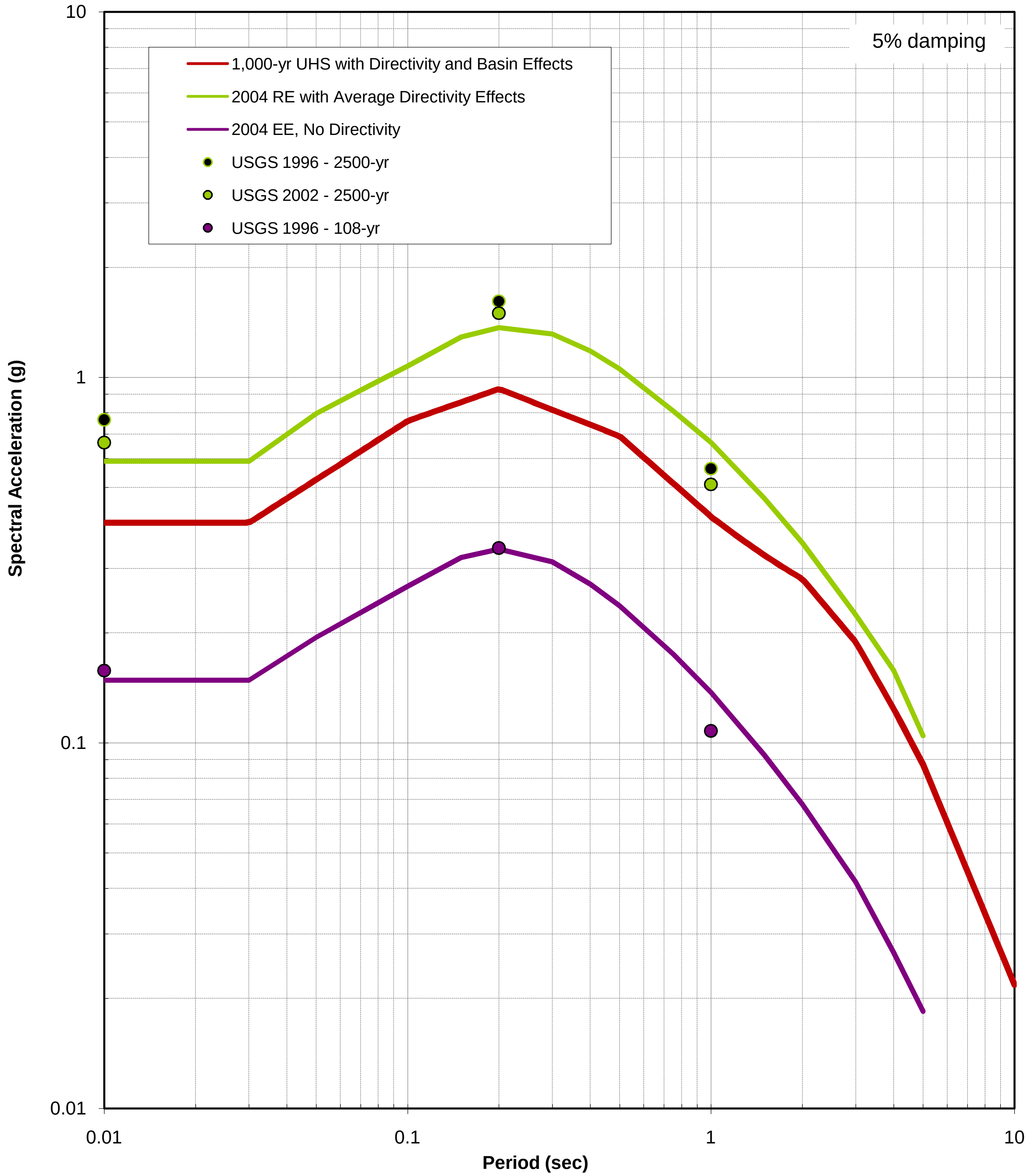
FIG. 1-3
Sheet 2 of 2



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SOFT ROCK UHS
ACCELERATION SPECTRA

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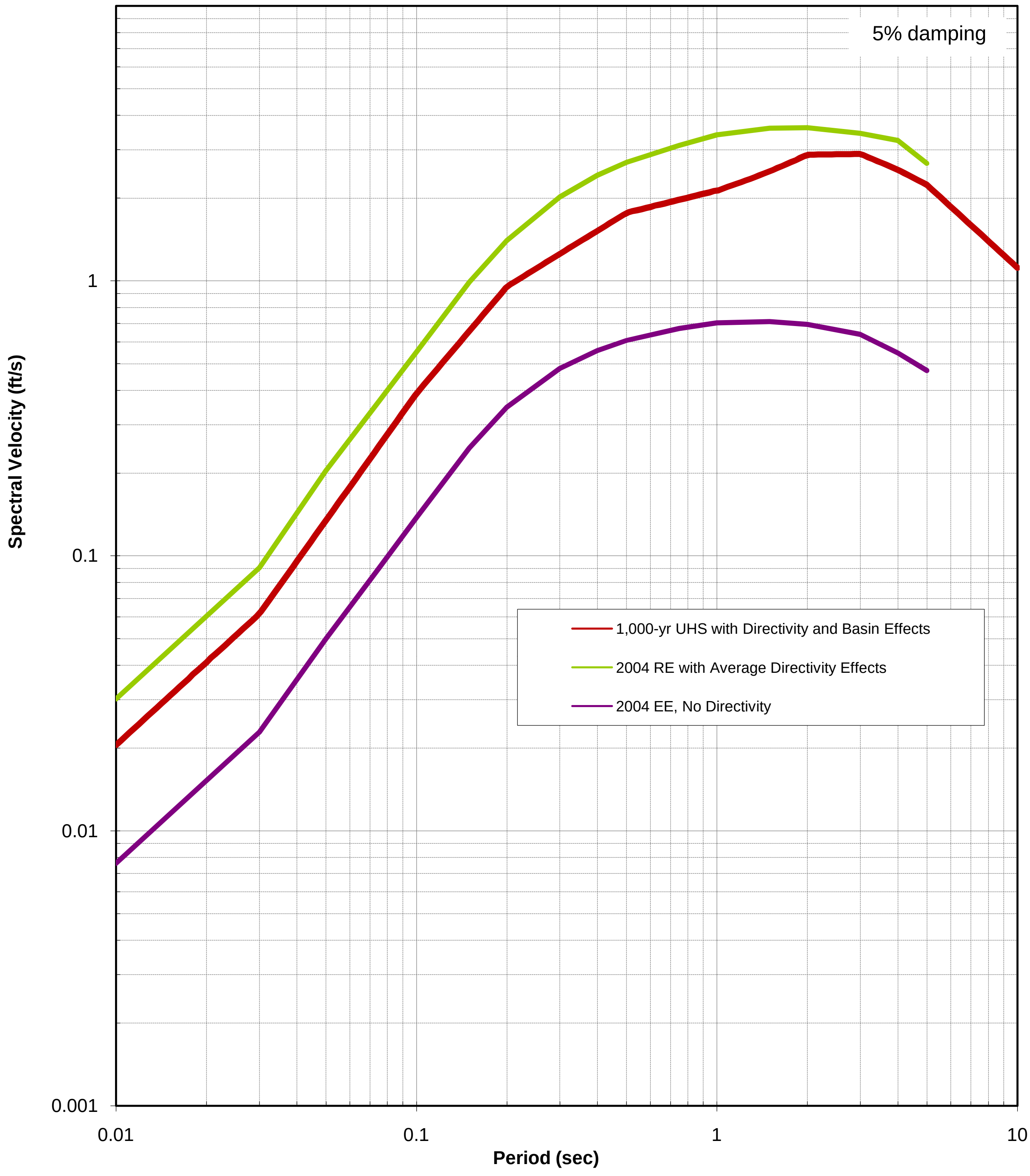
FIG. 2-1



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SOFT ROCK UHS
VELOCITY SPECTRA

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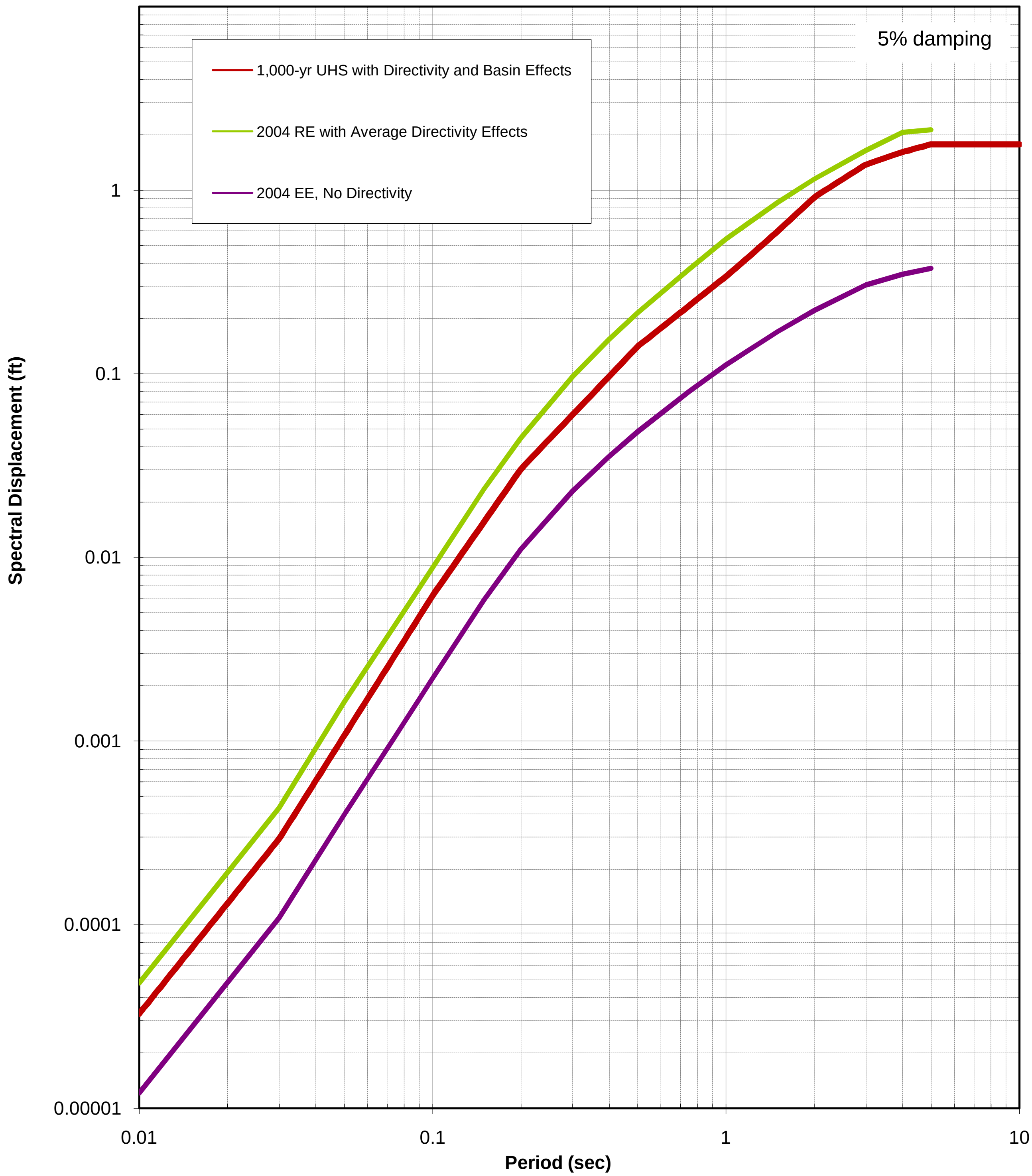
FIG. 2-2



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SOFT ROCK UHS
DISPLACEMENT SPECTRA

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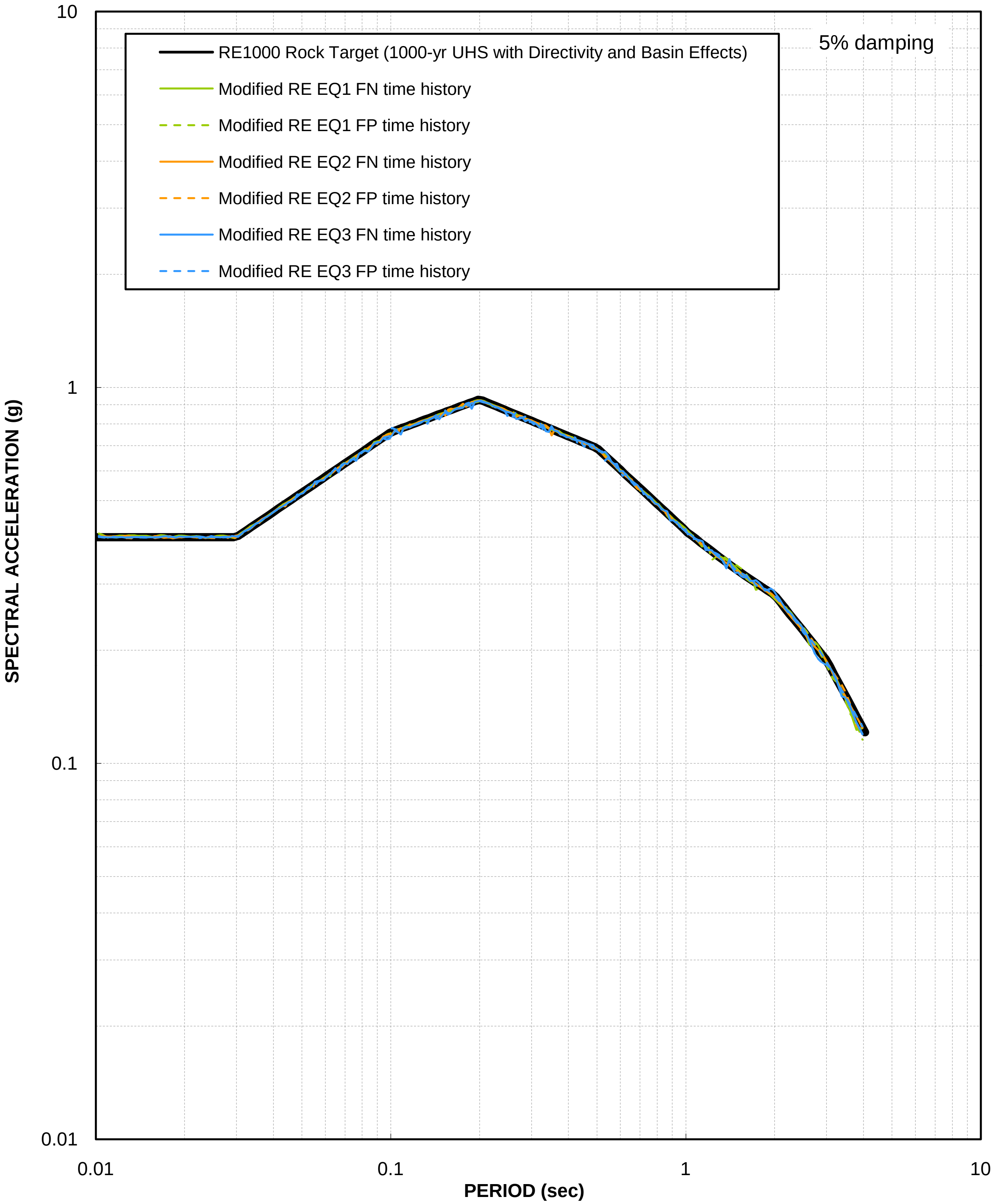
FIG. 2-3



NOTES:

1. See text of report for an explanation of the plot shown above.

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1,000-YEAR RETURN PERIOD TARGET ROCK SPECTRUM AND INPUT ROCK TIME HISTORIES

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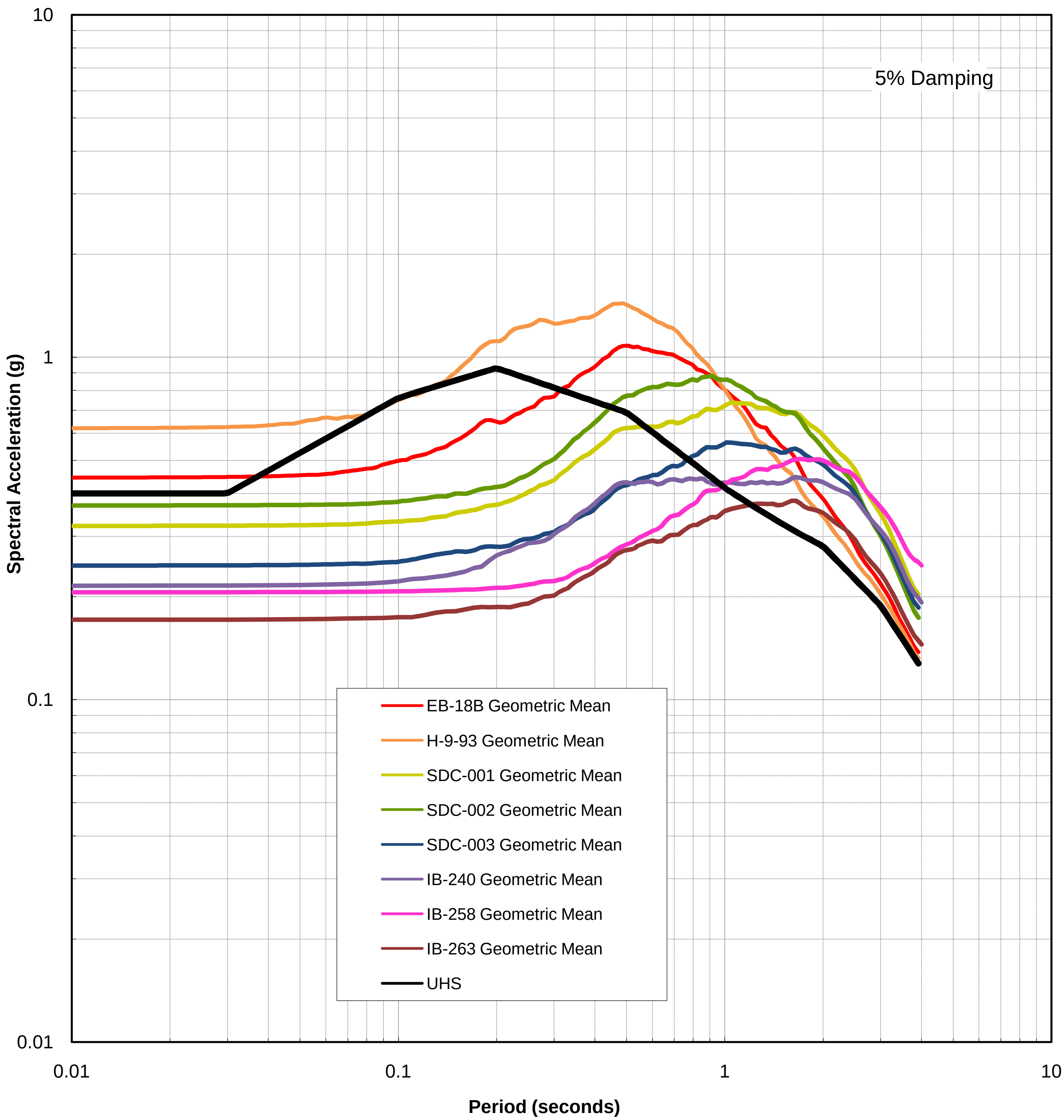
FIG. 2-4



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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ALL ZONES

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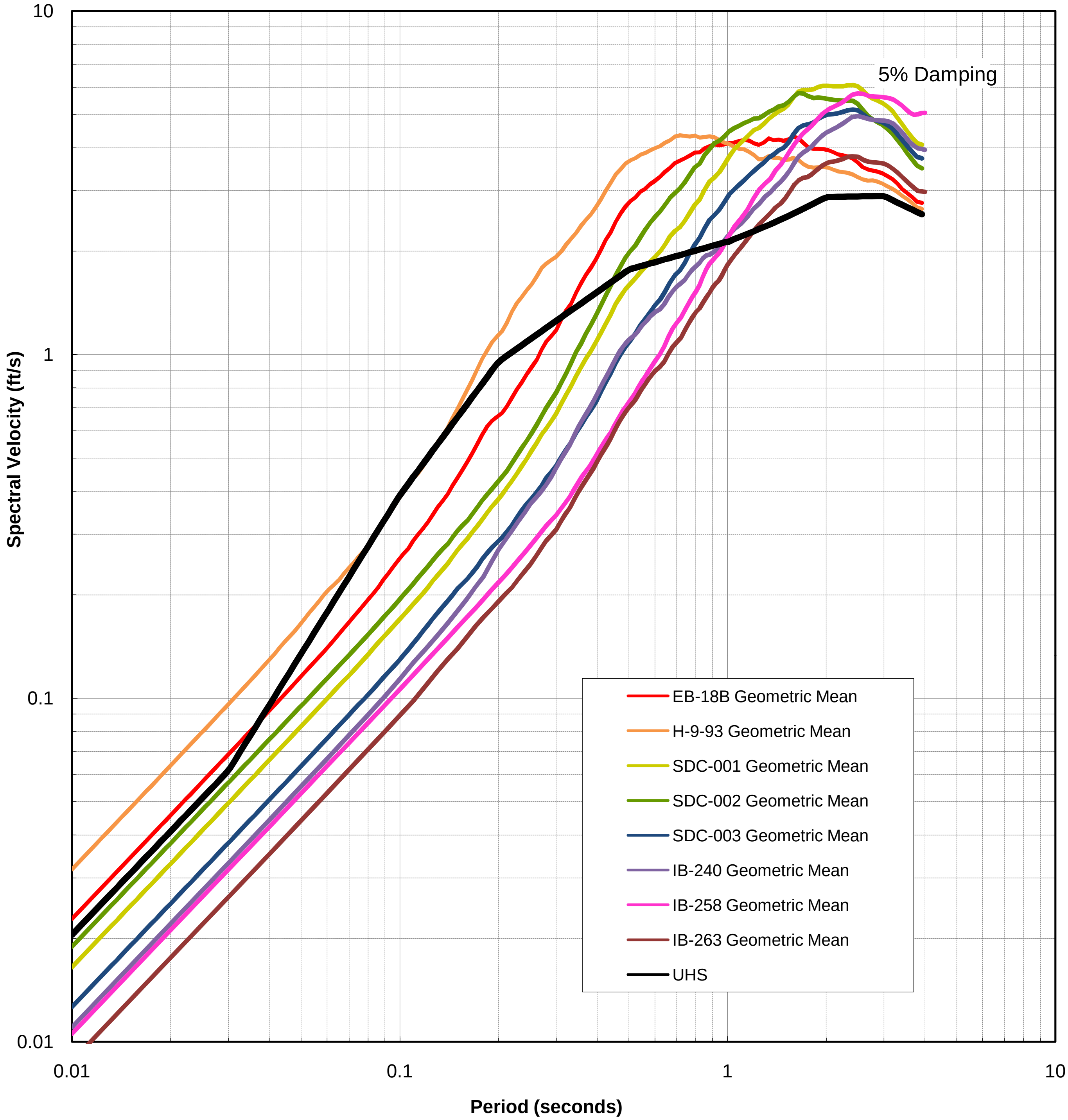
FIG. 3-1A



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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ALL ZONES

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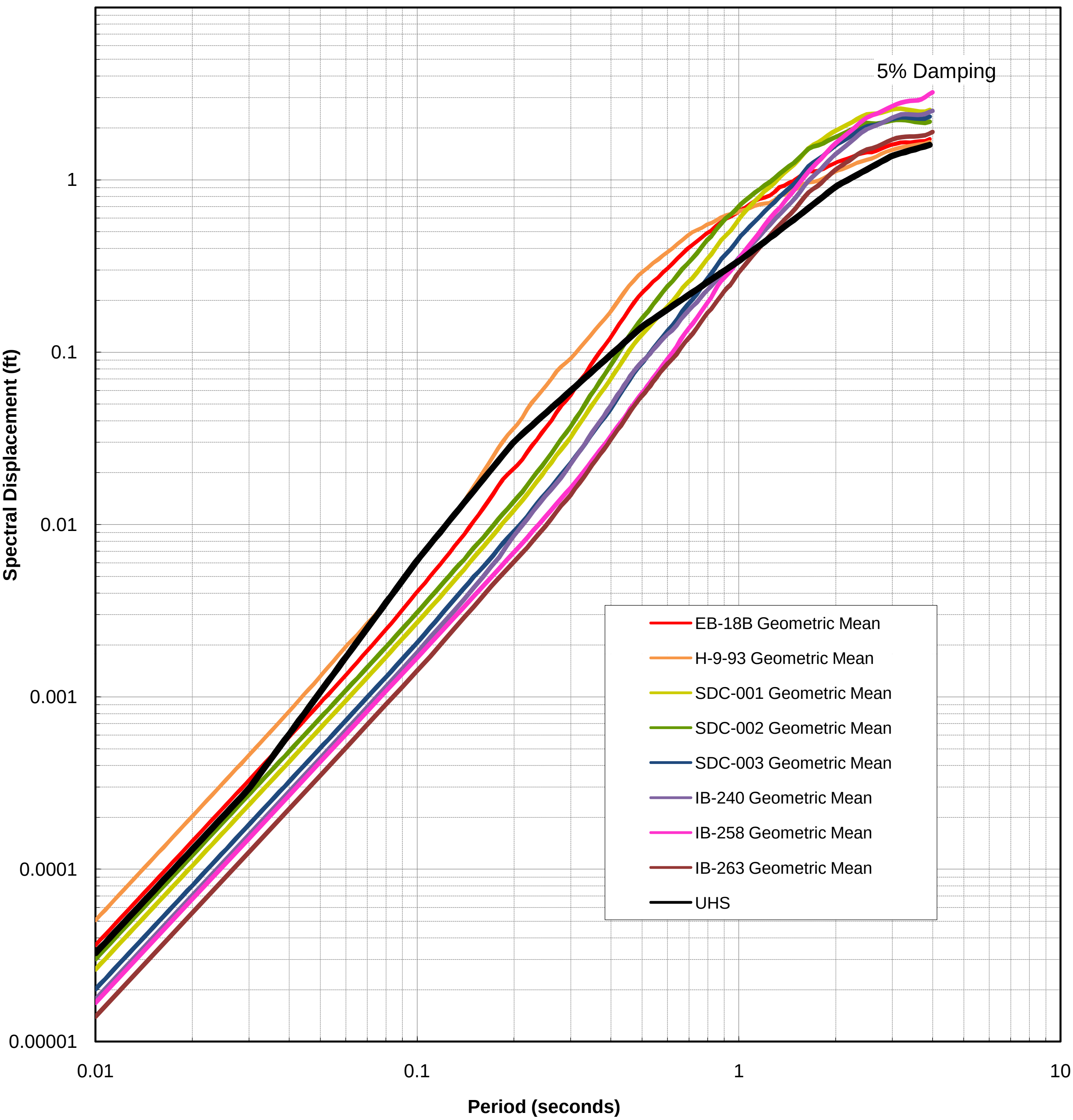
FIG. 3-1B



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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ALL ZONES

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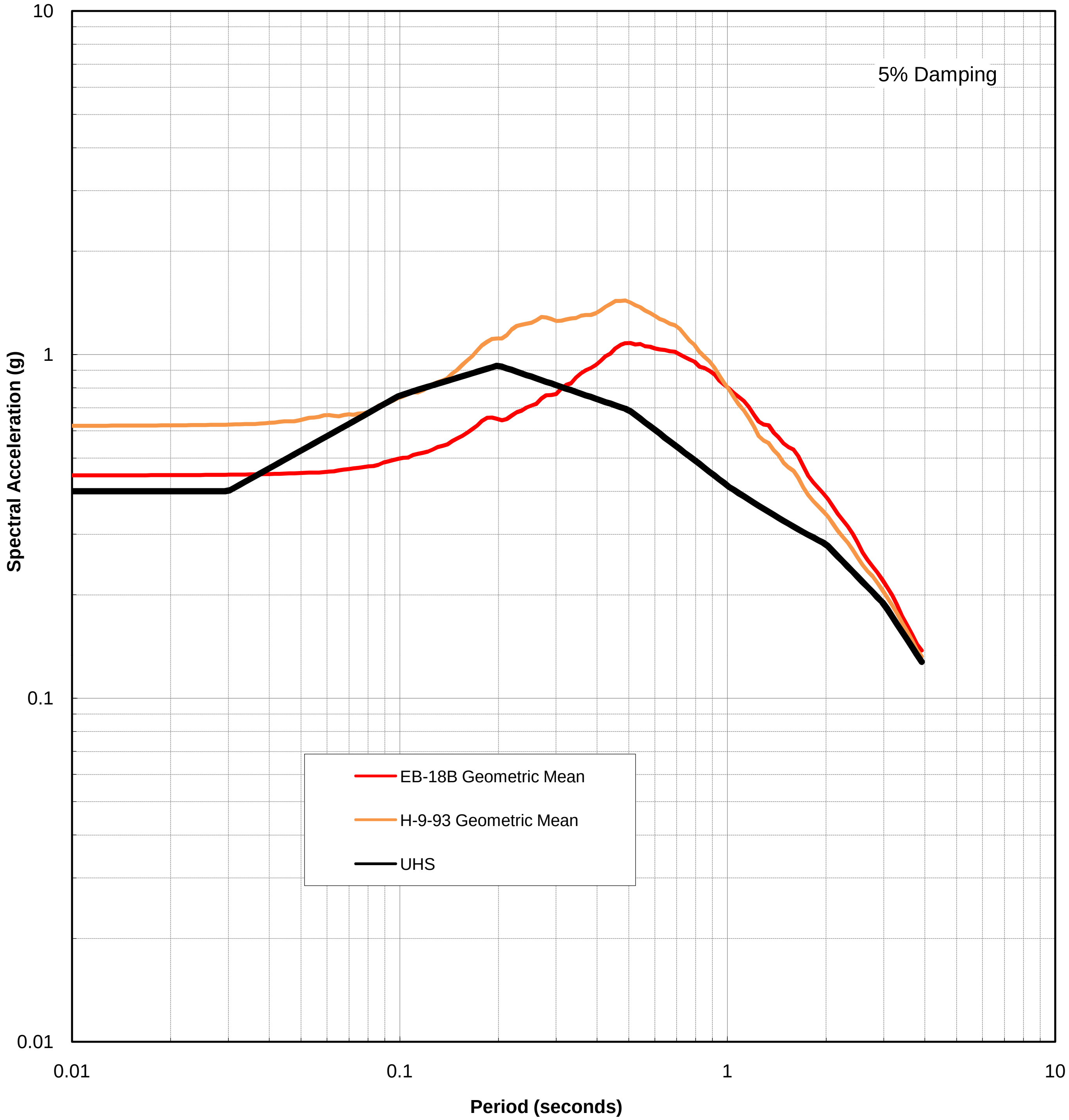
FIG. 3-1C



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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE A

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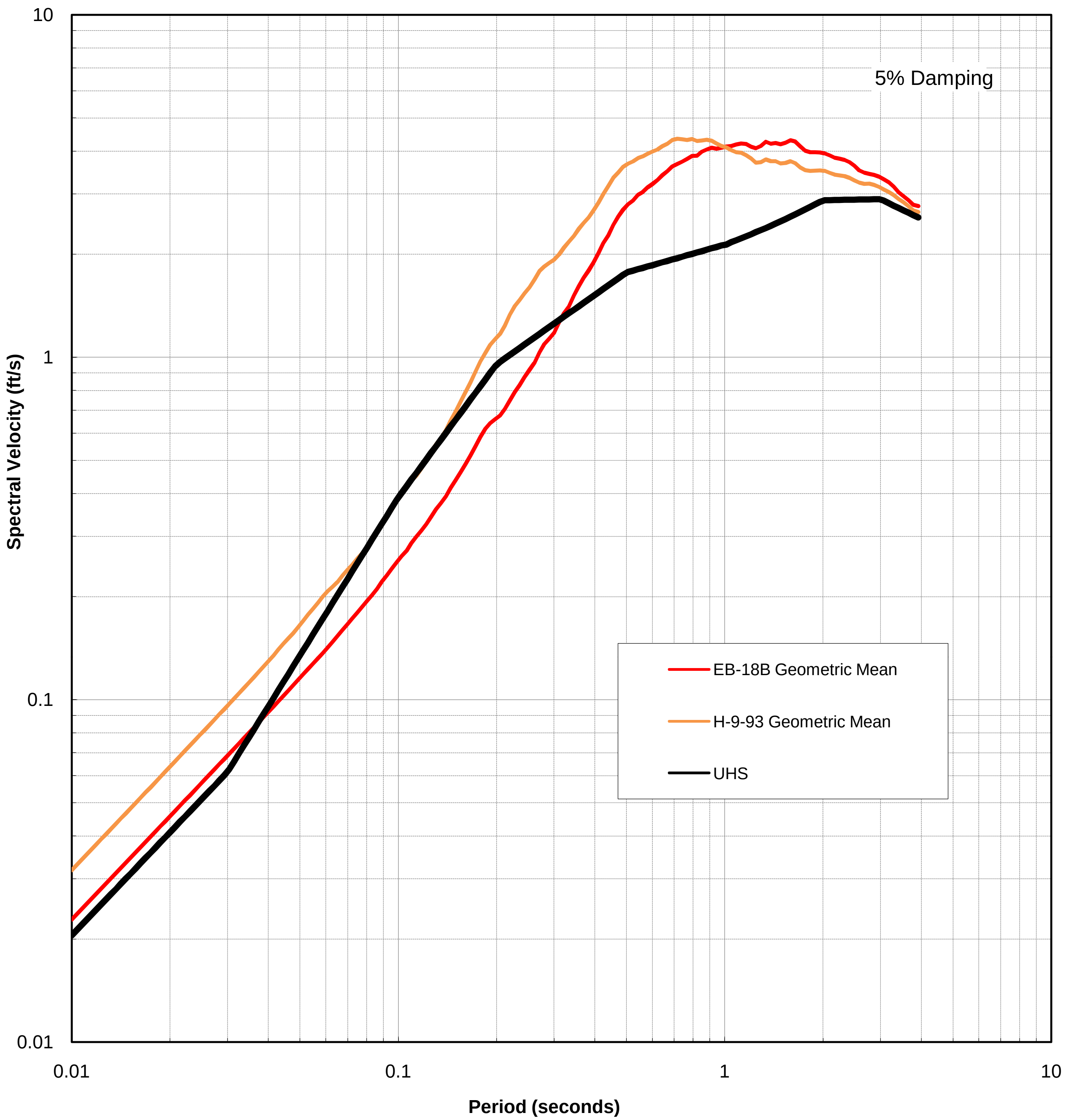
FIG. 3-2A



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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE A

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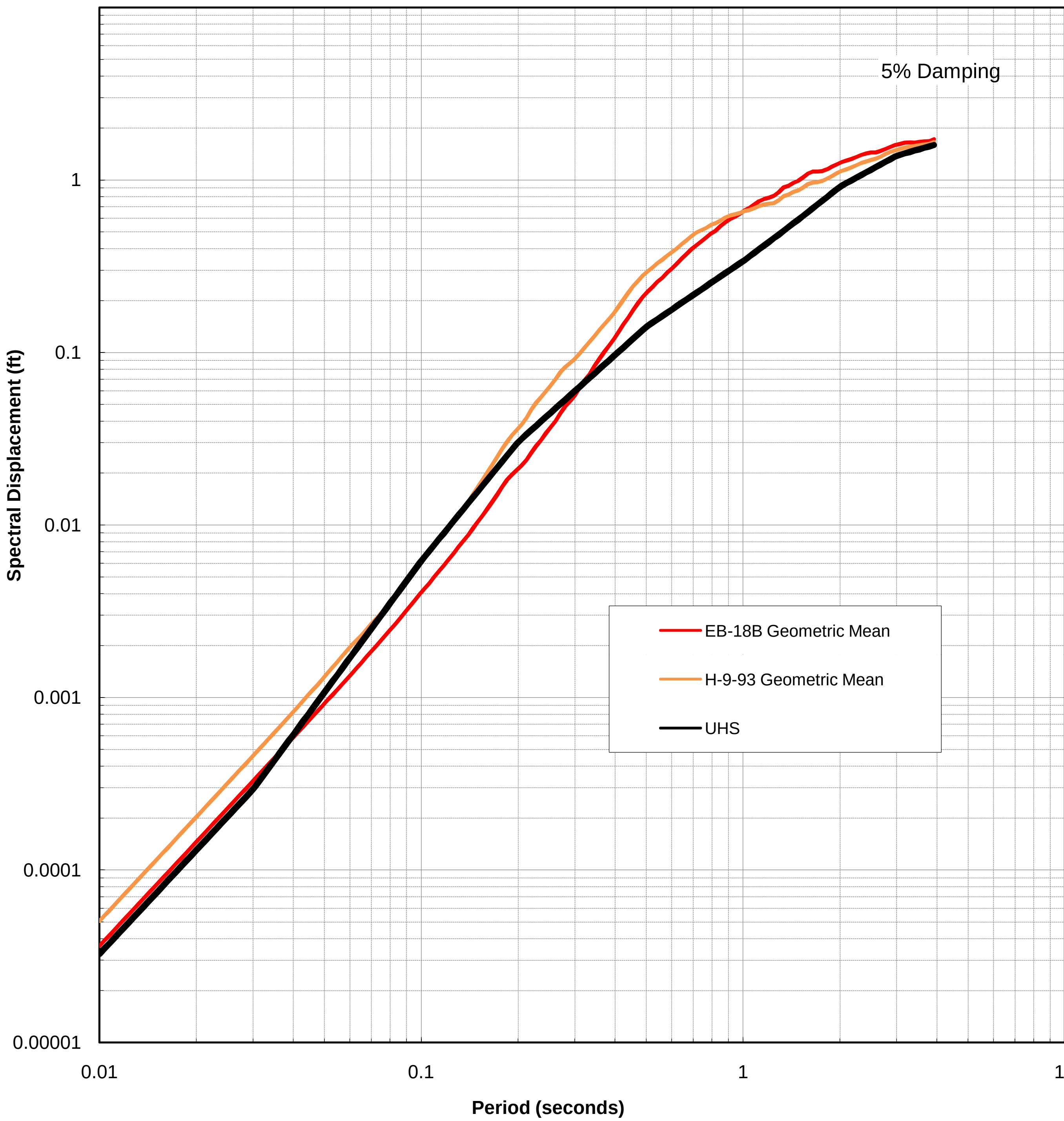
FIG. 3-2B



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Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE A

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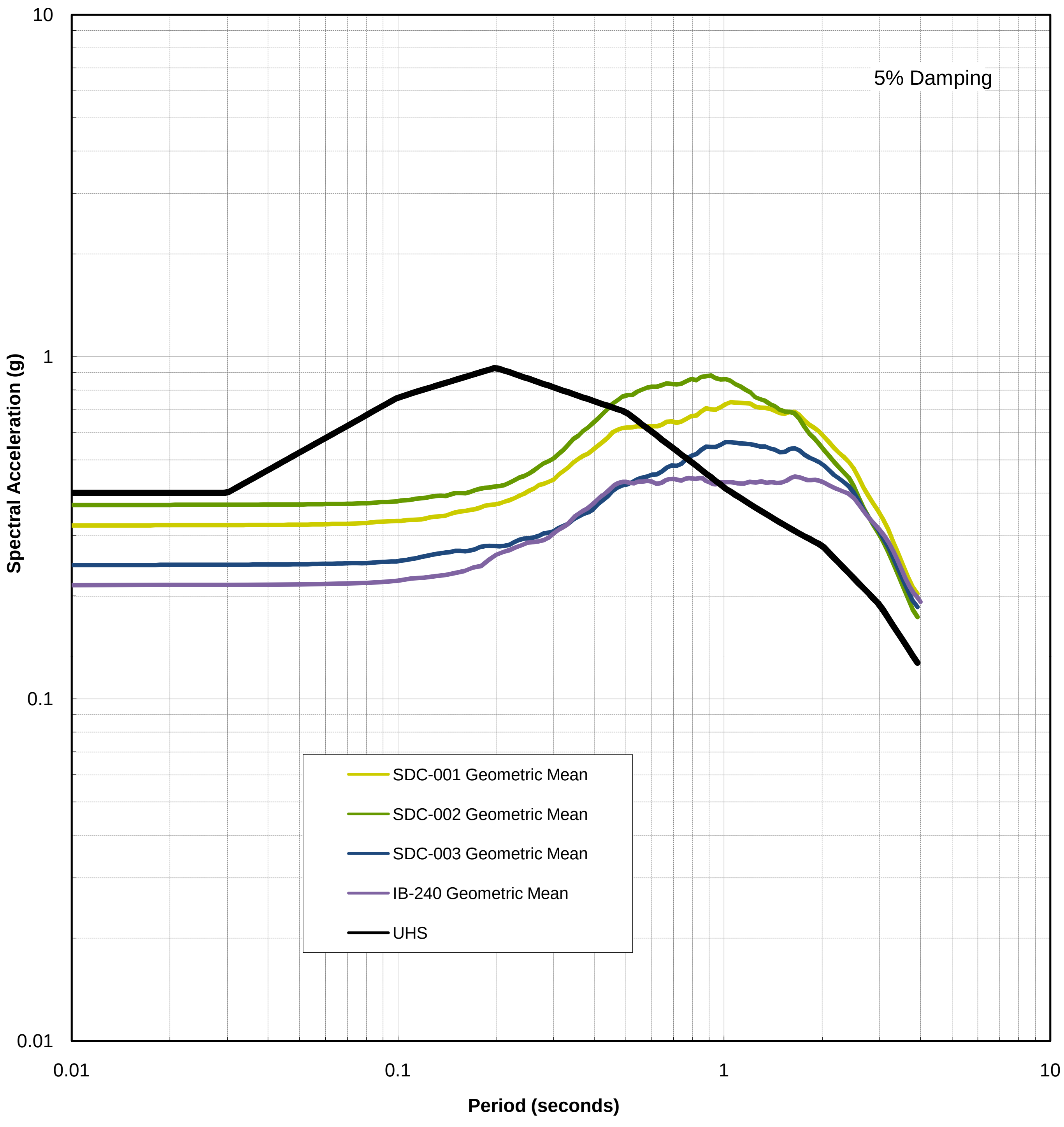
FIG. 3-2C



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Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE B

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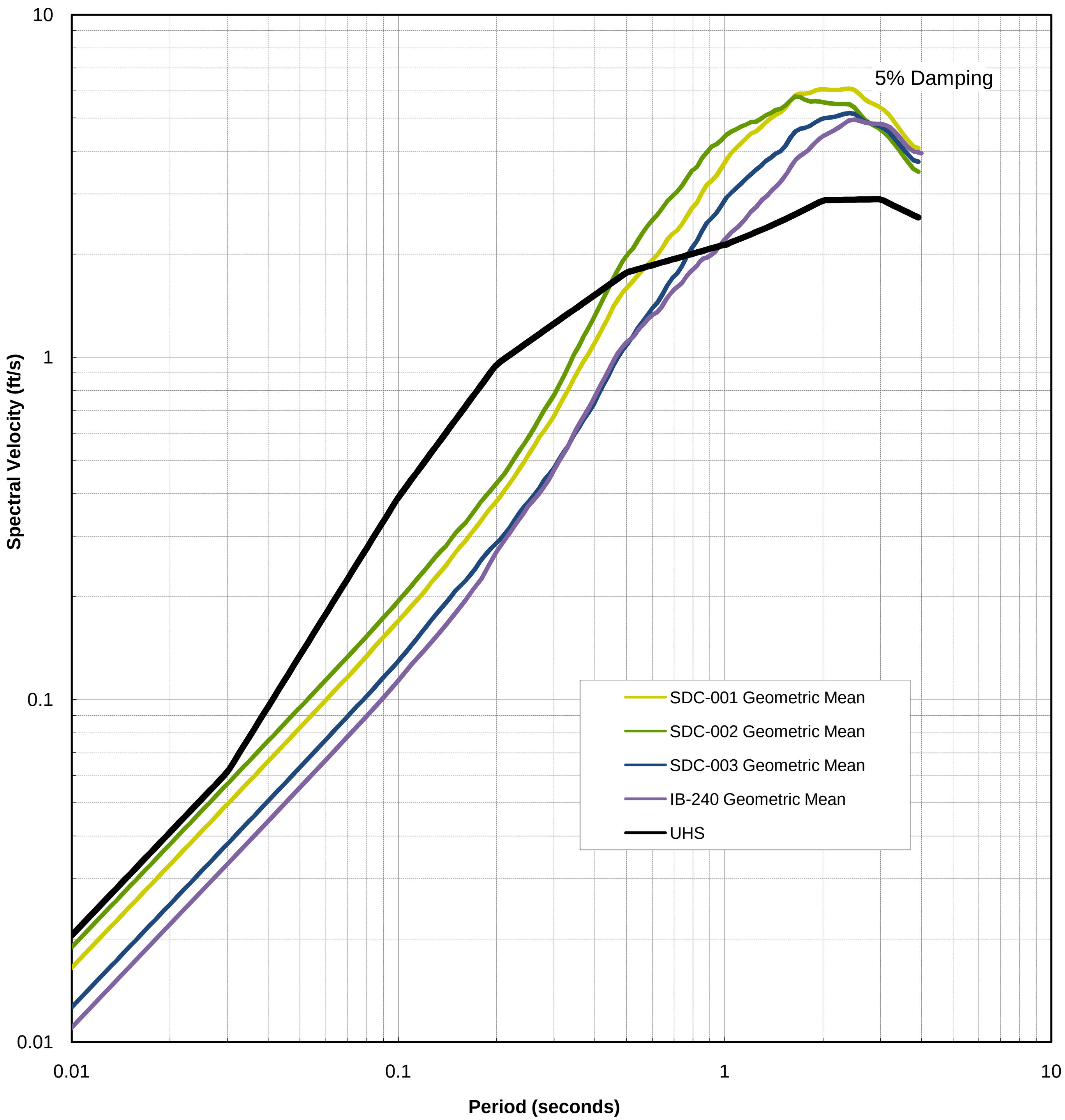
FIG. 3-3A



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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE B

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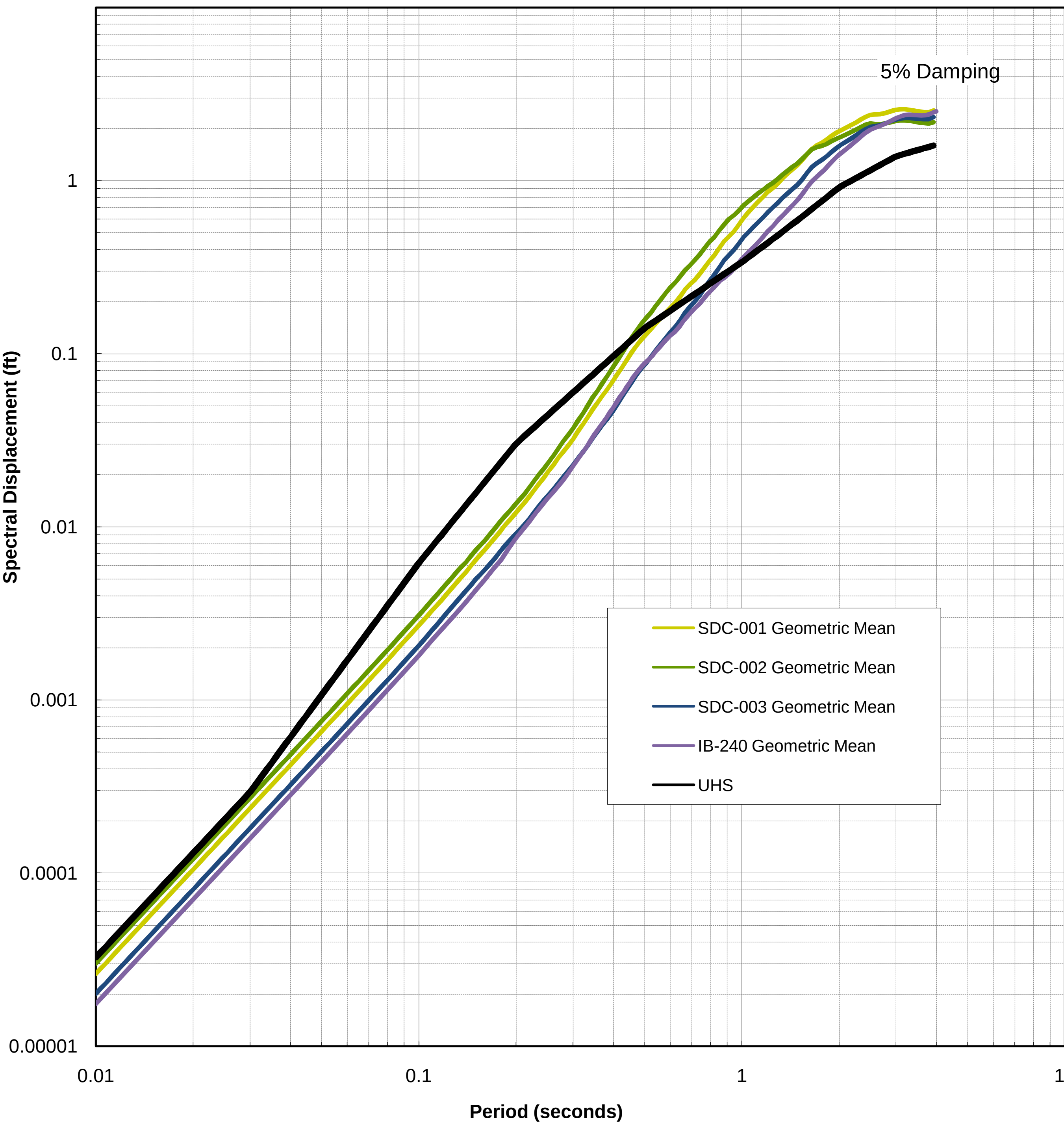
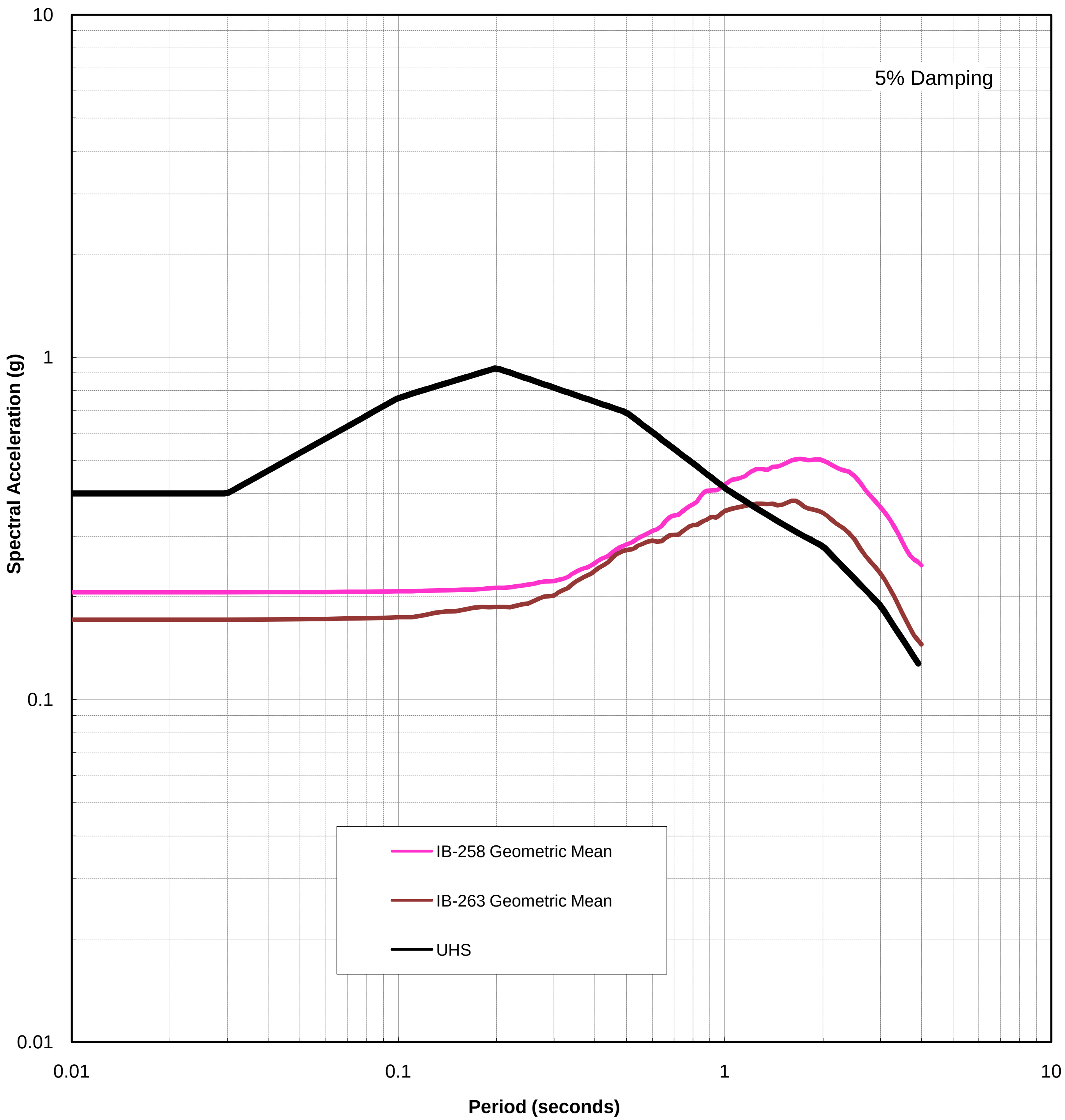
FIG. 3-3B



Alaskan Way Viaduct and Seawall Program Seismic Ground Motion Study Update Seattle, Washington	
1,000-YEAR **EQUIVALENT LINEAR SITE RESPONSE** **ZONE B** April 2009 21-1-20840-041	
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. 3-3C**



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE C

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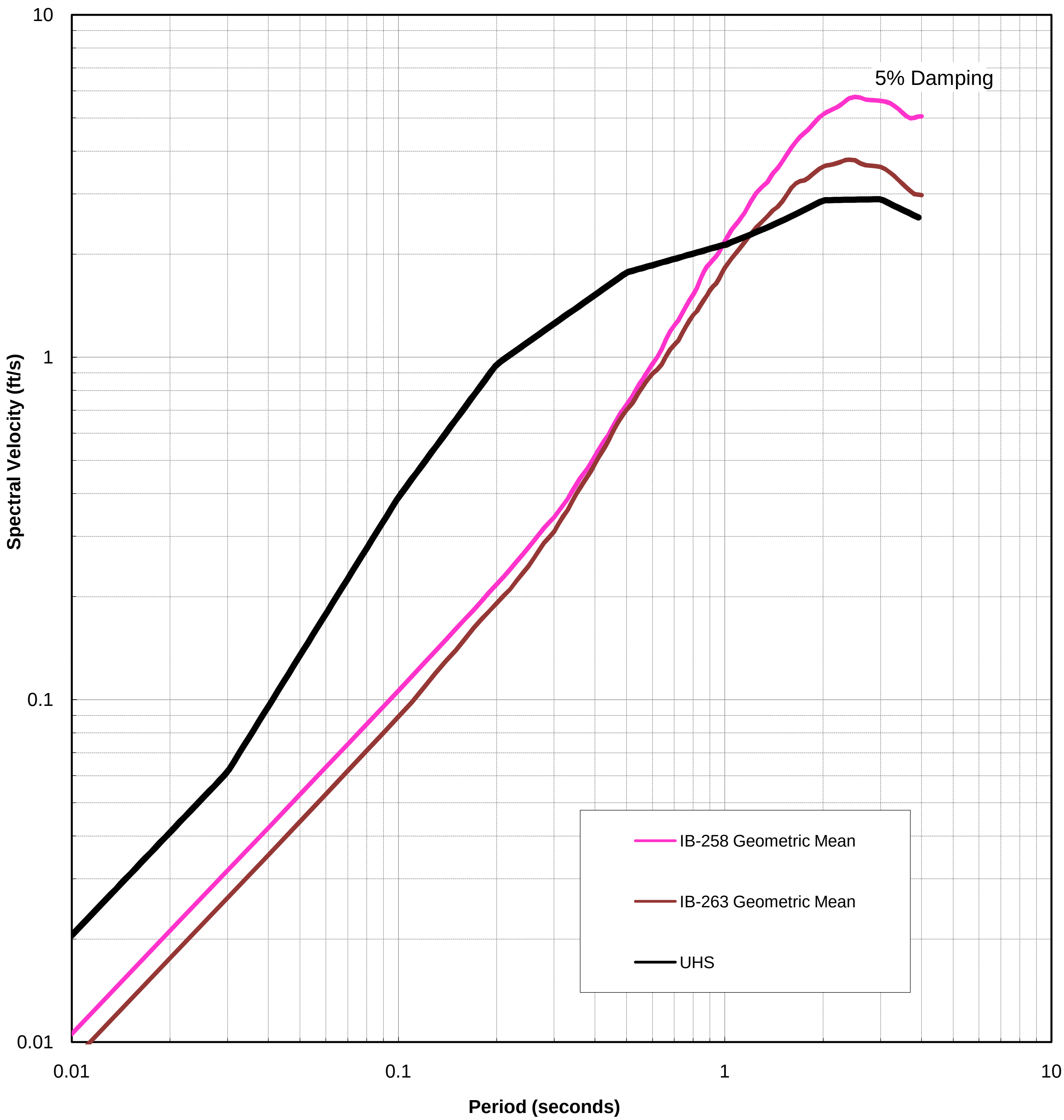
FIG. 3-4A



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Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE C

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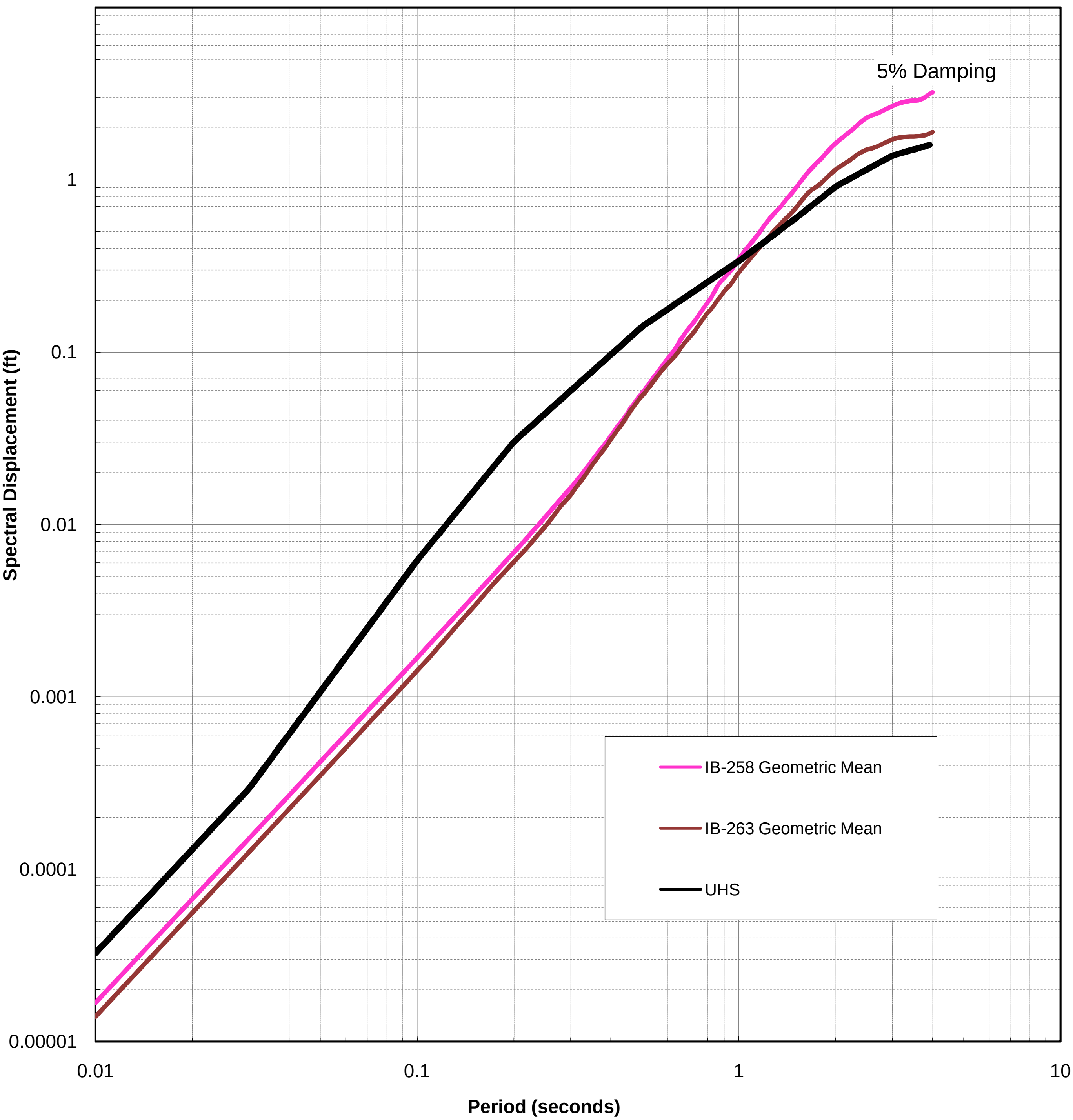
FIG. 3-4B



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE C

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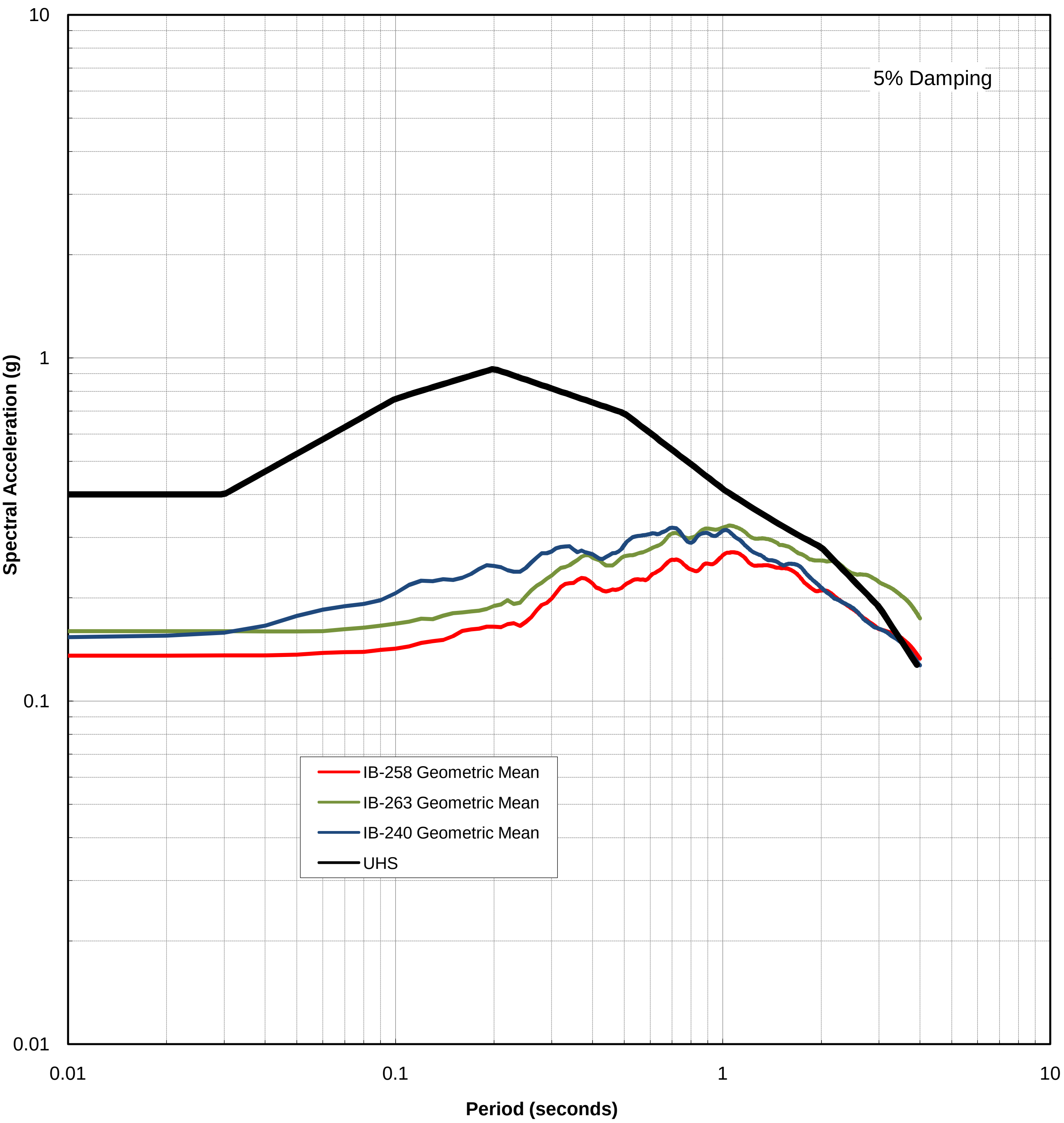
FIG. 3-4C



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR EFFECTIVE STRESS SITE RESPONSE ZONES B AND C

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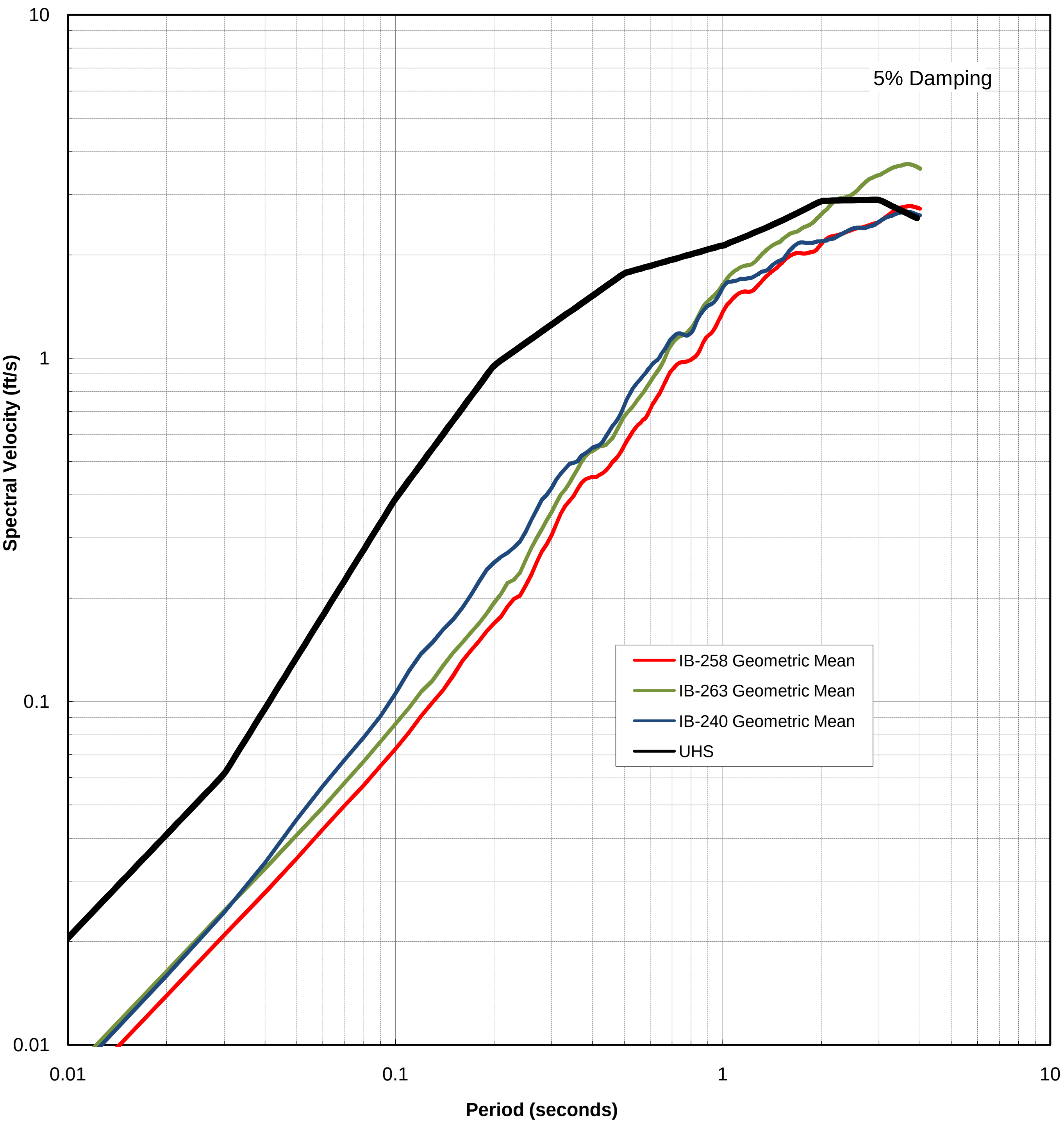
FIG. 3-5A



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Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR EFFECTIVE STRESS SITE RESPONSE ZONES B AND C

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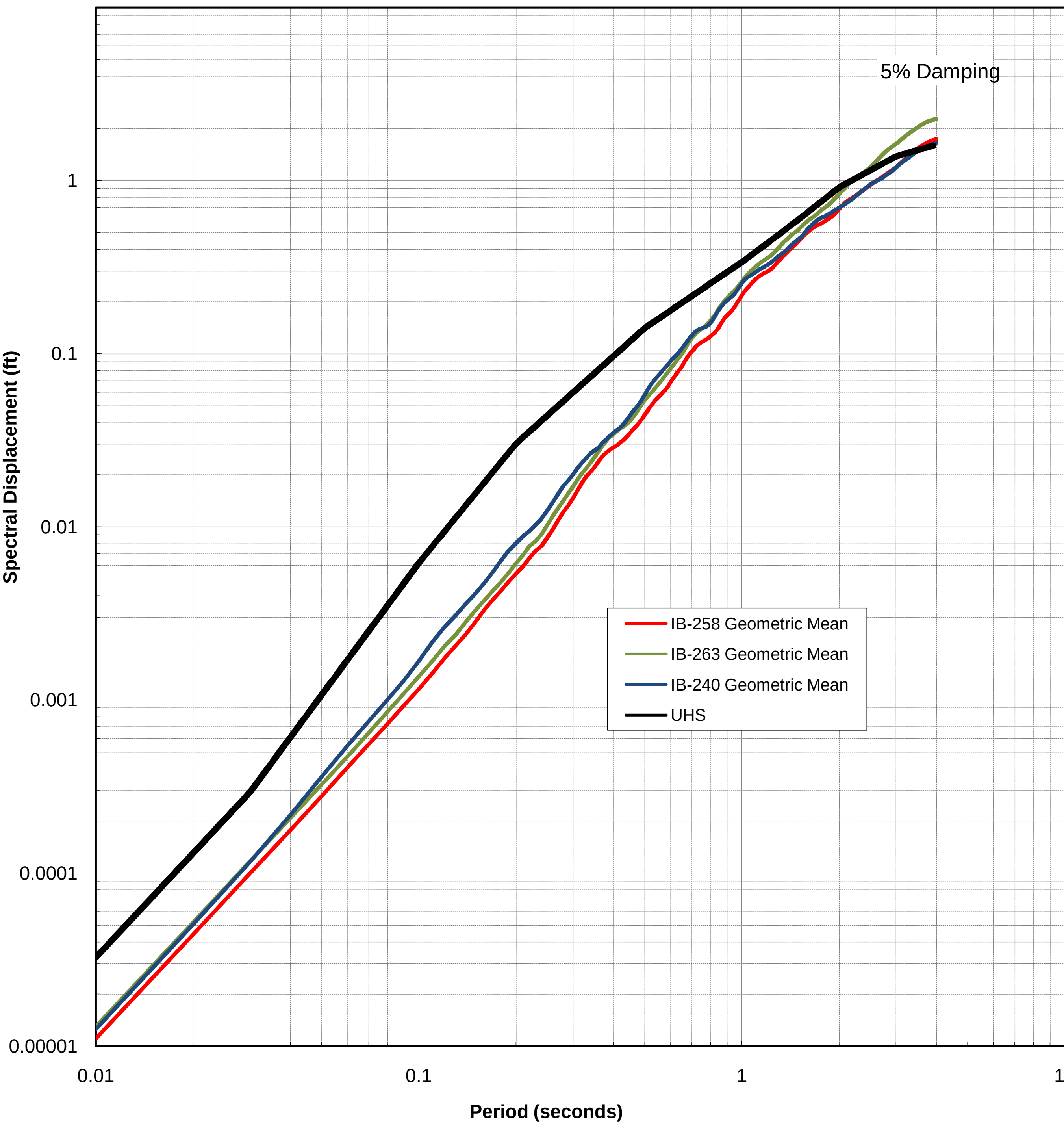
FIG. 3-5B



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR EFFECTIVE STRESS SITE RESPONSE ZONES B AND C

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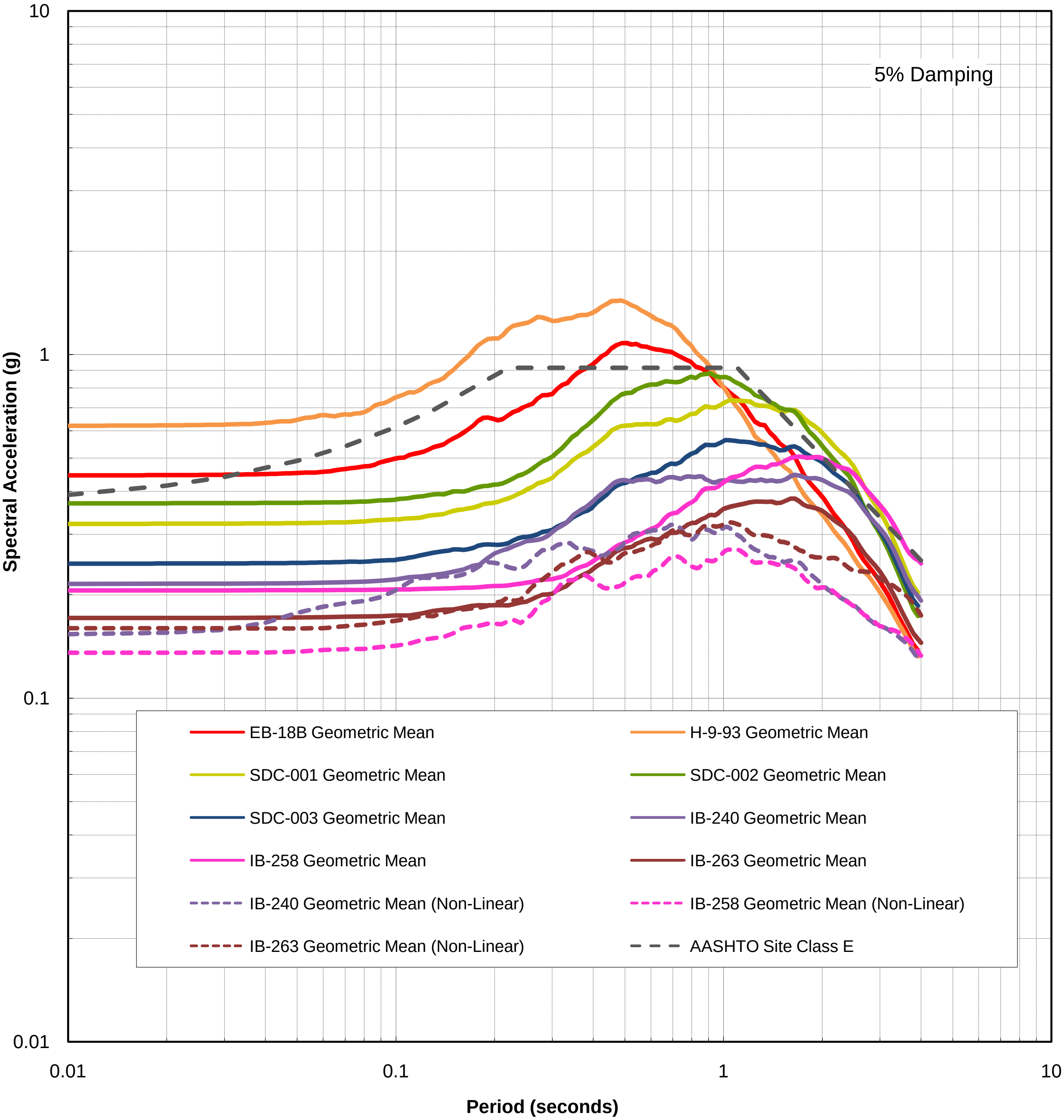
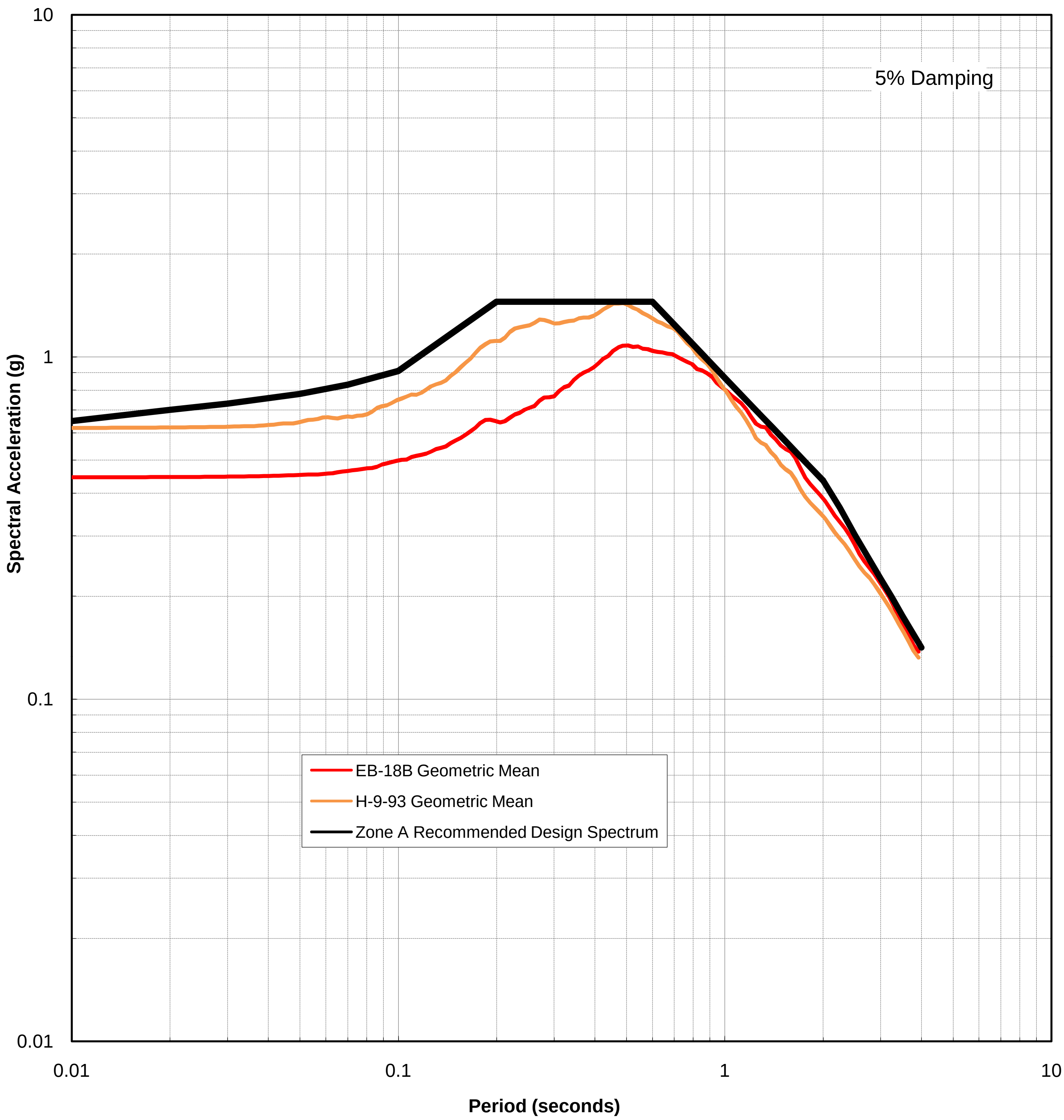
FIG. 3-5C



NOTES:

AASHTO Site Class E corresponds to the AASHTO T3 Ground Motion spectrum based on seismic parameters from 2007 AASHTO Bridge Design Guidelines.

Alaskan Way Viaduct and Seawall Program Seismic Ground Motion Study Update Seattle, Washington	
1,000-YEAR CALCULATED SITE RESPONSE AND AASHTO SPECTRA	
April 2009	21-1-20840-041
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. 4-1**



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR ZONE A
EQUIVALENT LINEAR SITE RESPONSE
AND DESIGN SPECTRA

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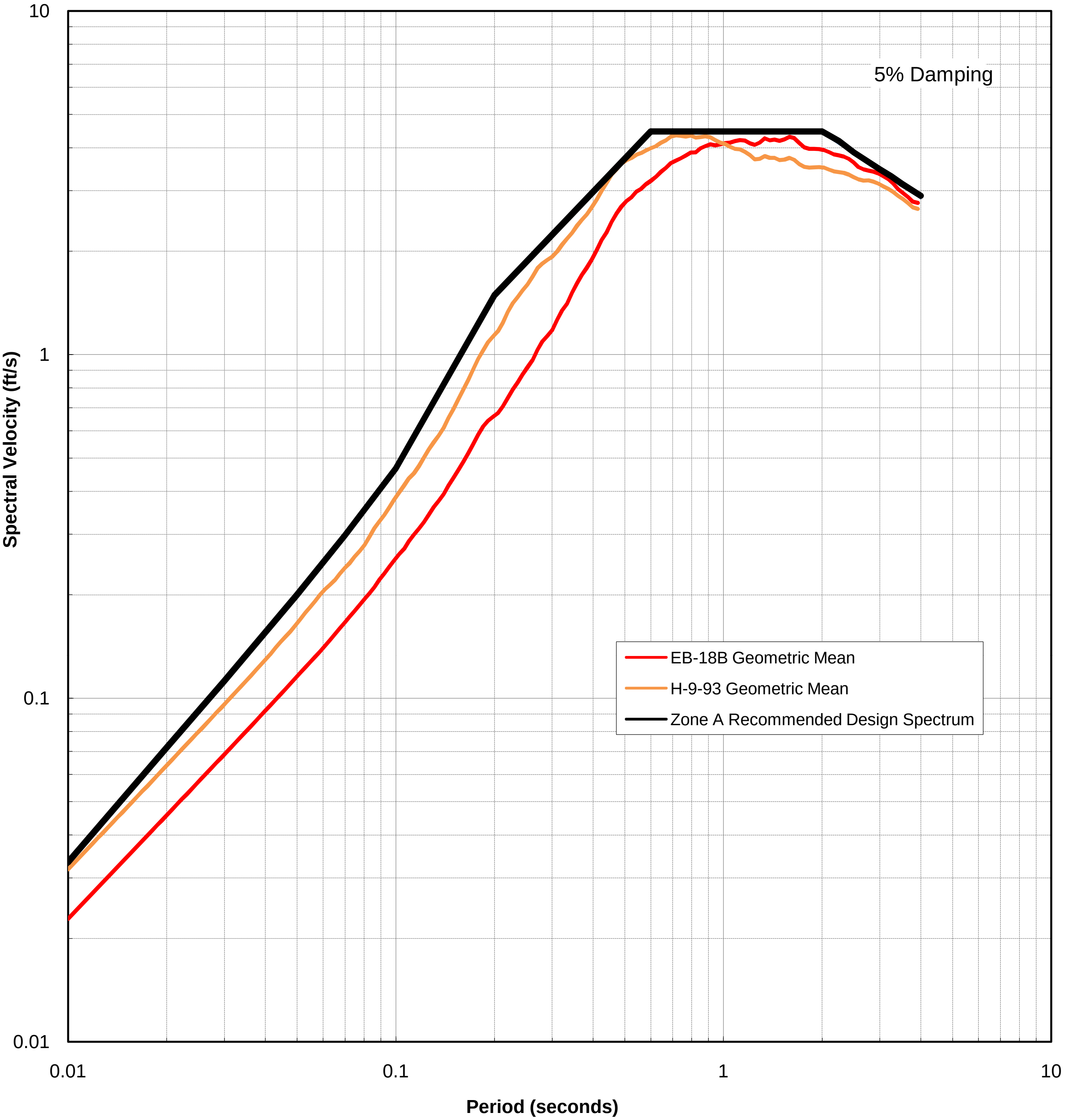
FIG. 4-2A



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE A

April 2009 | 21-1-20840-041

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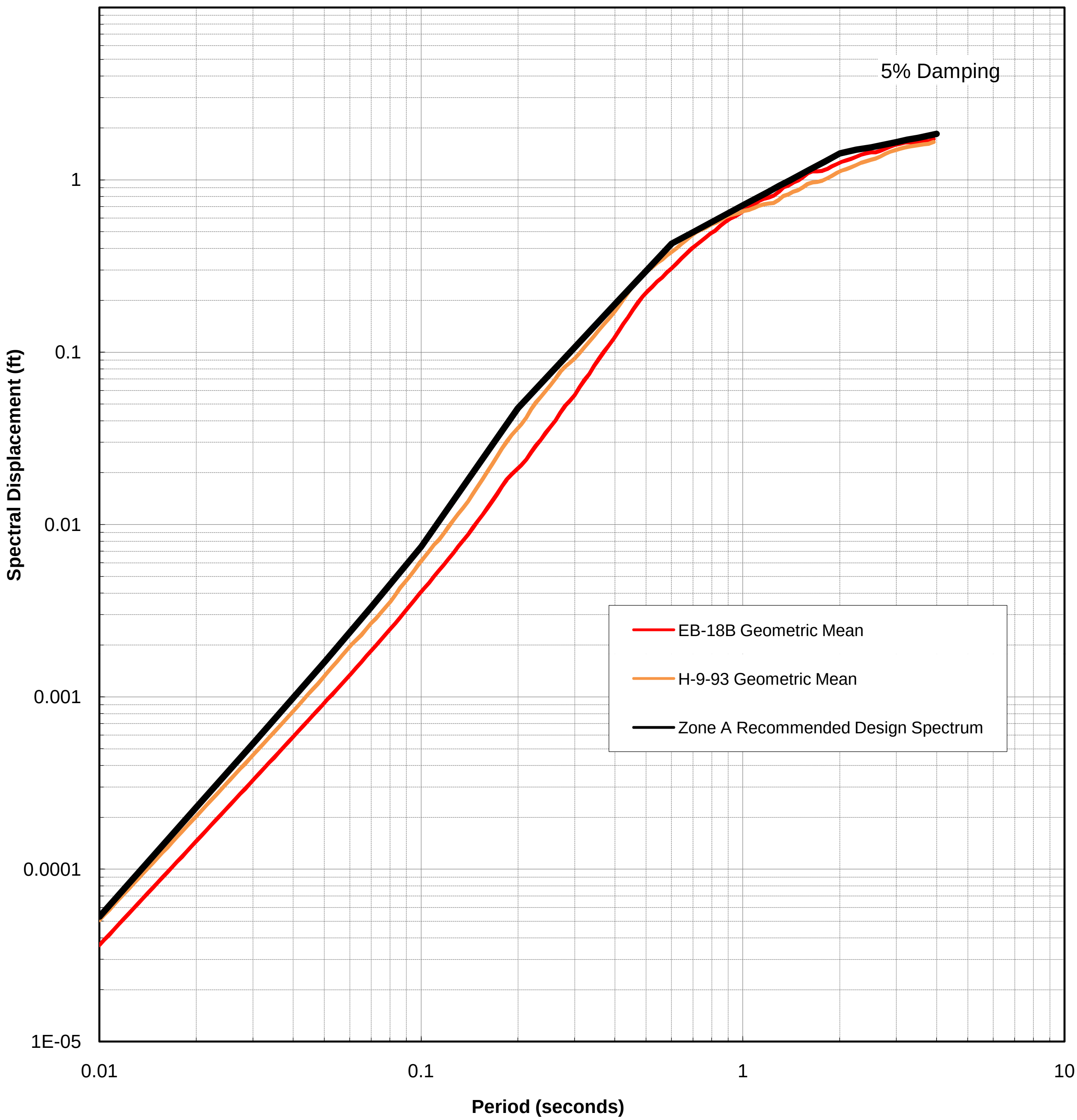
FIG. 4-2B



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE A

April 2009 | 21-1-20840-041

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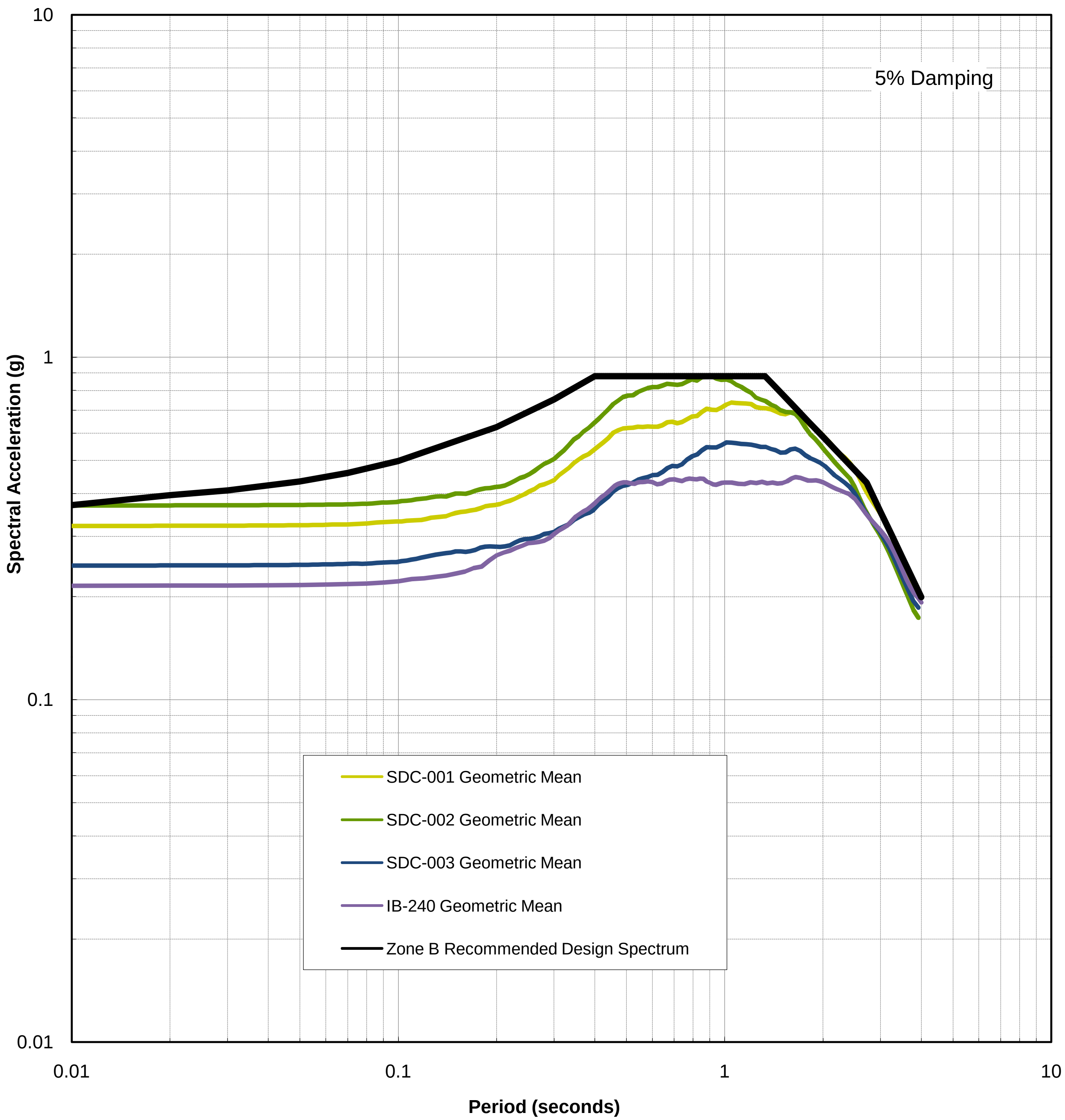
FIG. 4-2C



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR ZONE B
EQUIVALENT LINEAR SITE RESPONSE AND DESIGN SPECTRA

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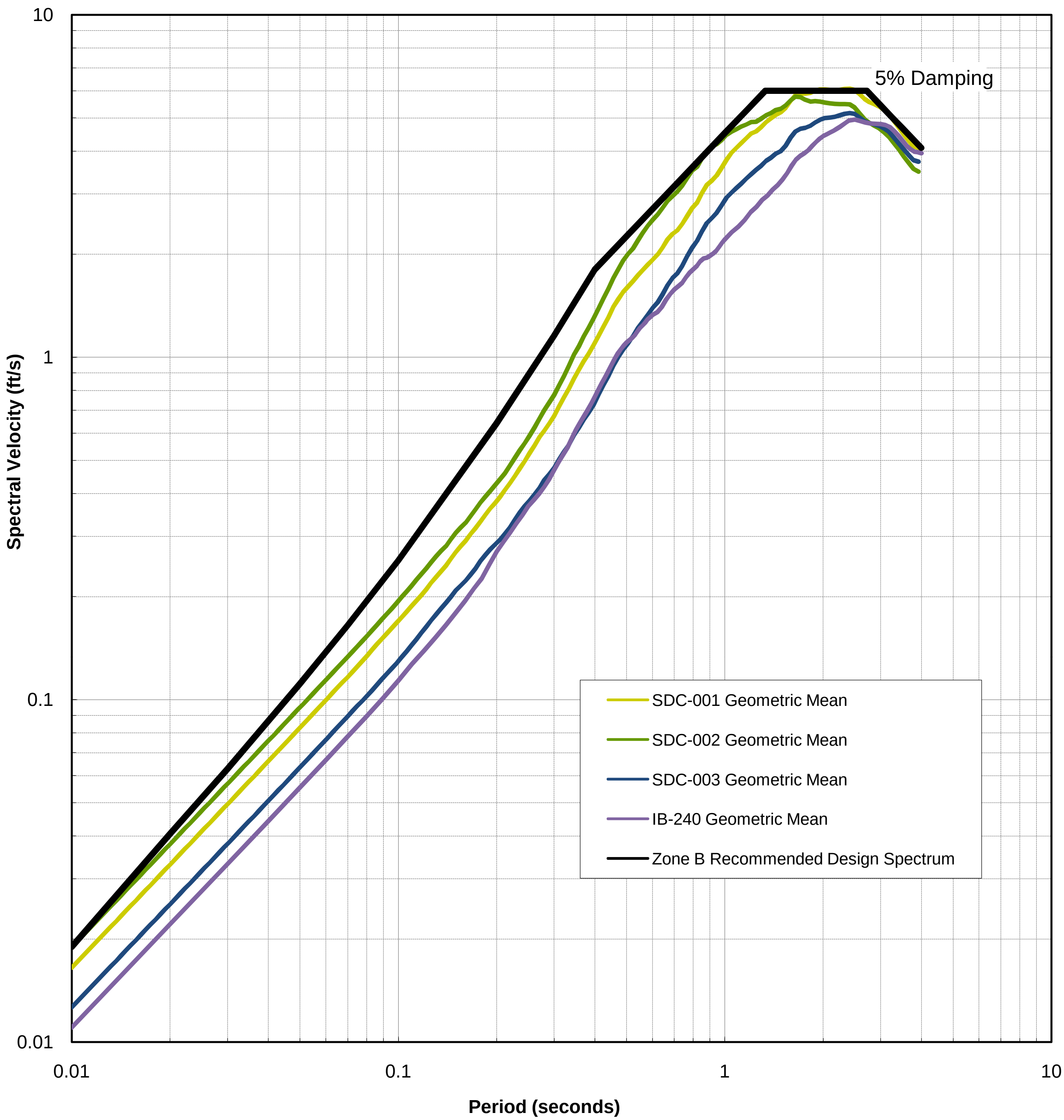
FIG. 4-3A



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE B

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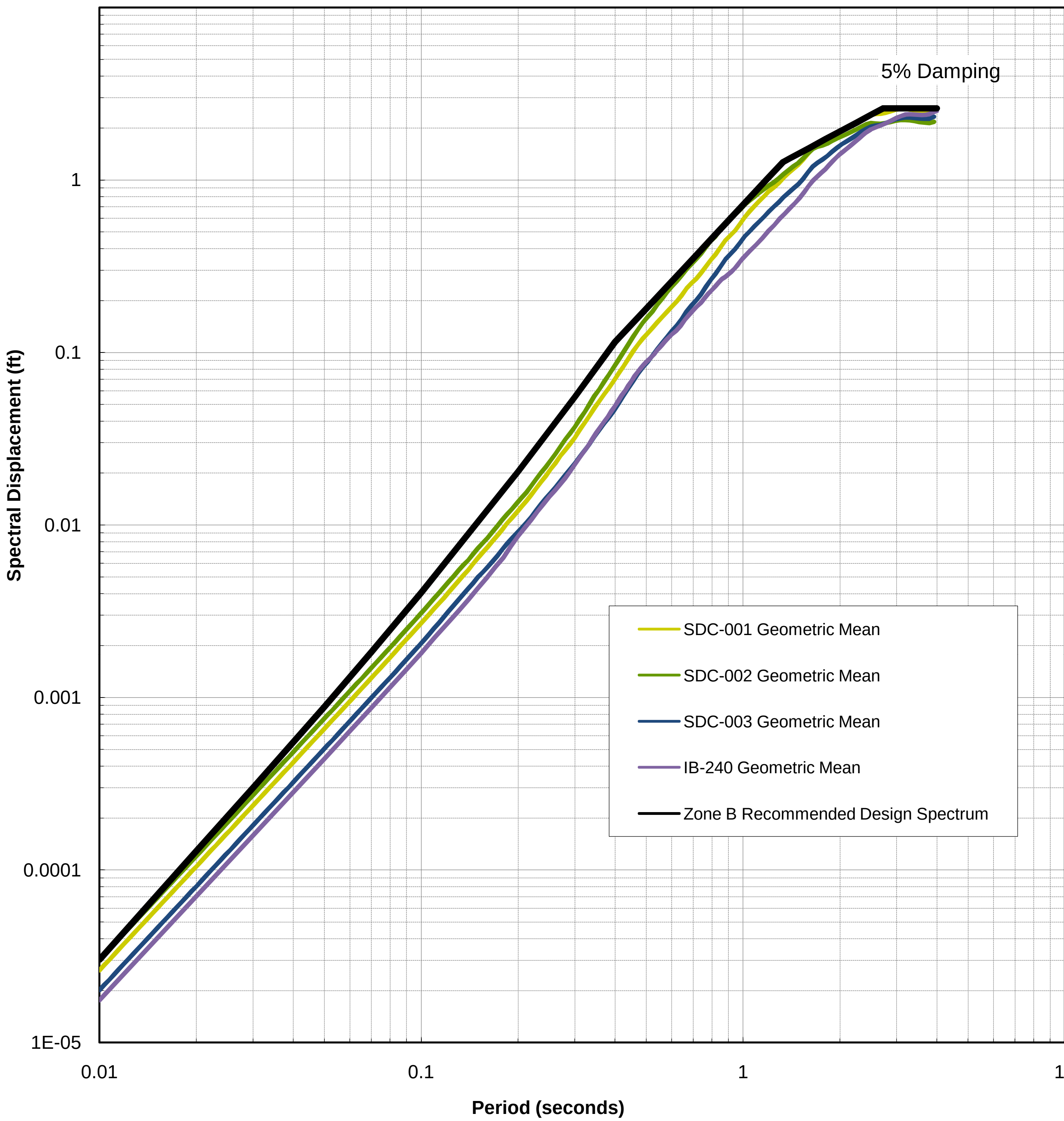
FIG. 4-3B



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE B

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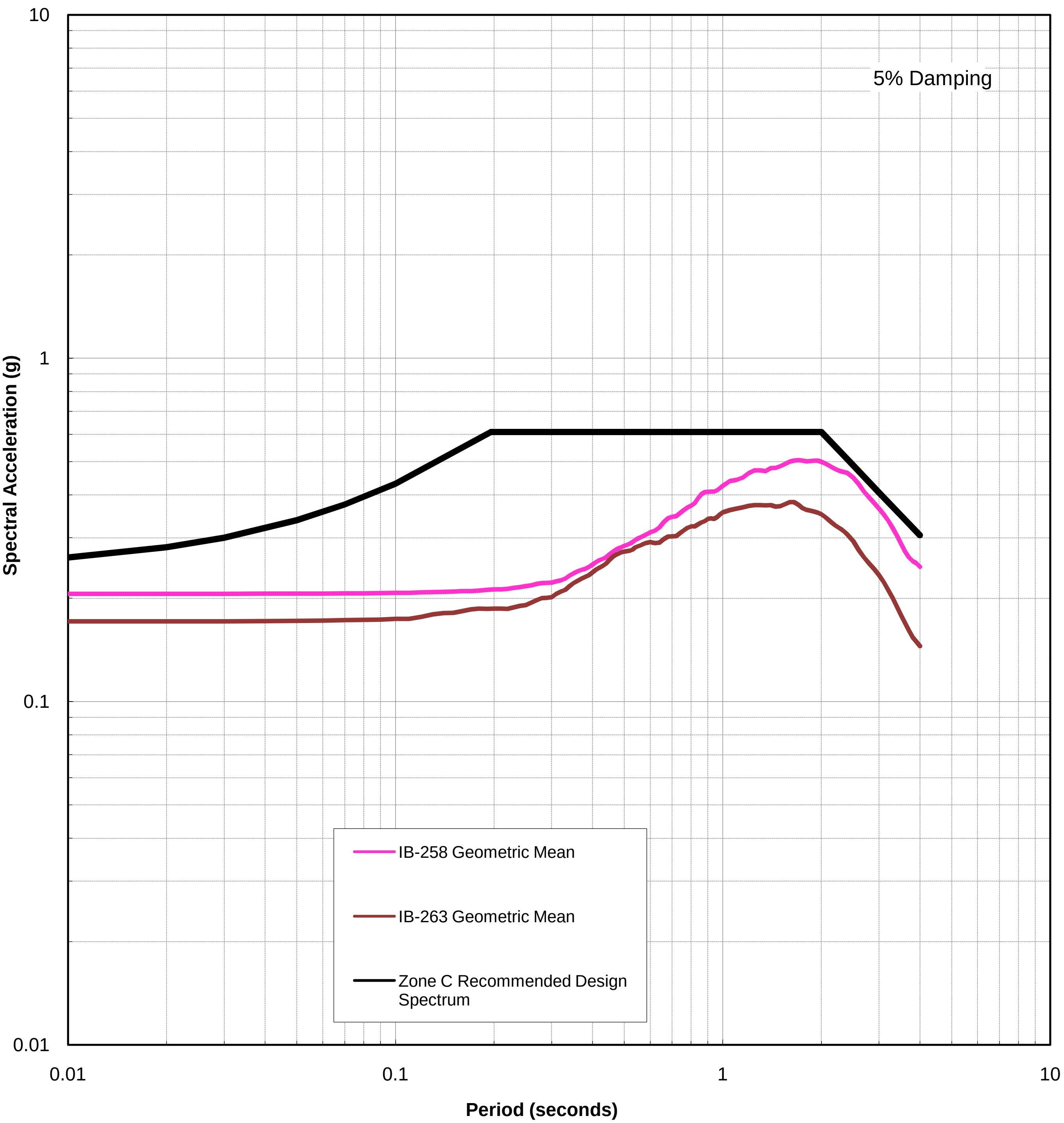
FIG. 4-3C



NOTES:

1. Recommended design spectrum includes a minimum 2/3 of AASHTO T3 Ground Motion for Site Class E.

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1,000-YEAR ZONE C EQUIVALENT LINEAR SITE RESPONSE AND DESIGN SPECTRA

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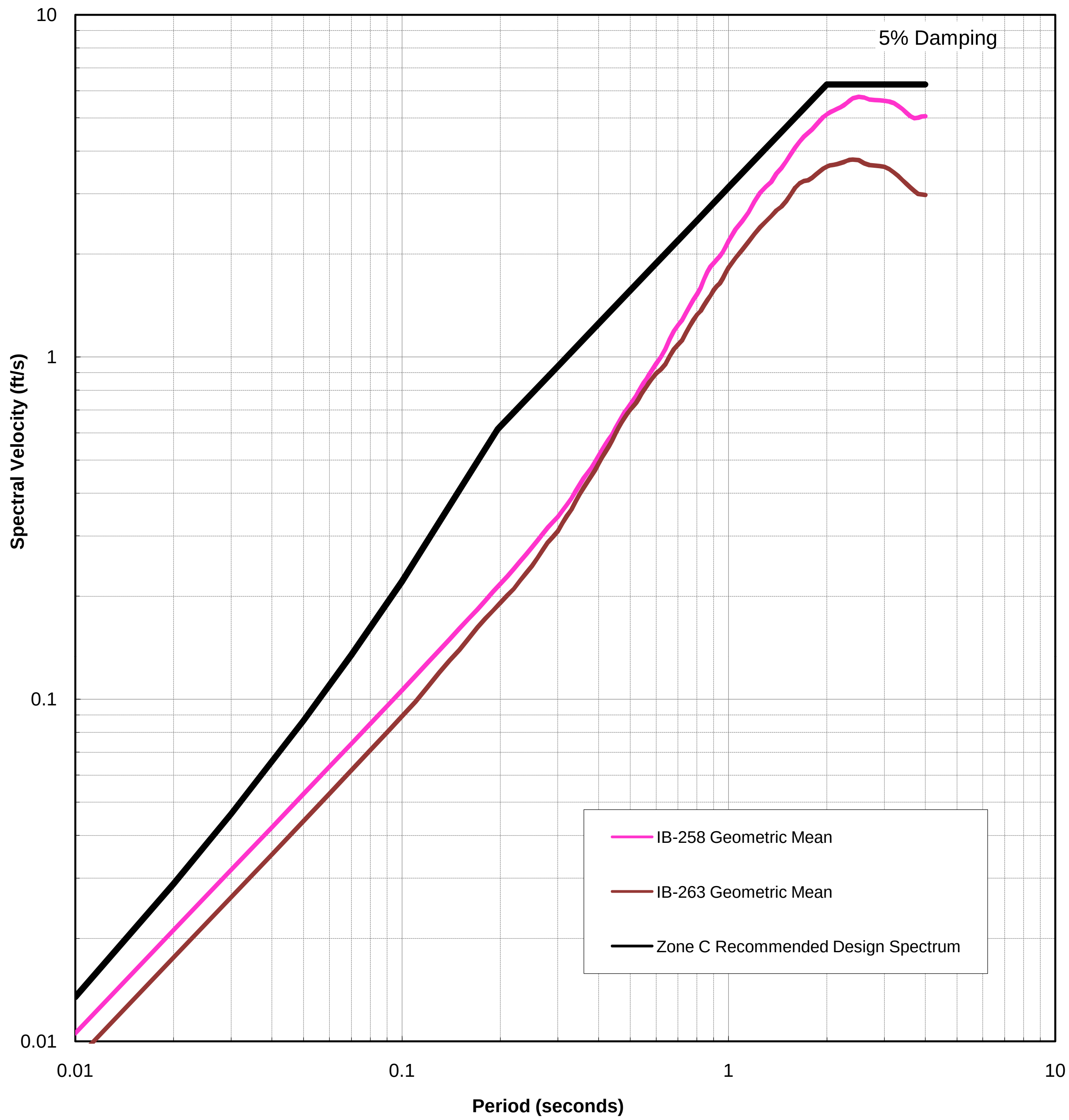
FIG. 4-4A



NOTES:

1. Recommended design spectrum includes a minimum 2/3 of AASHTO T3 Ground Motion for Site Class E.

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Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE C

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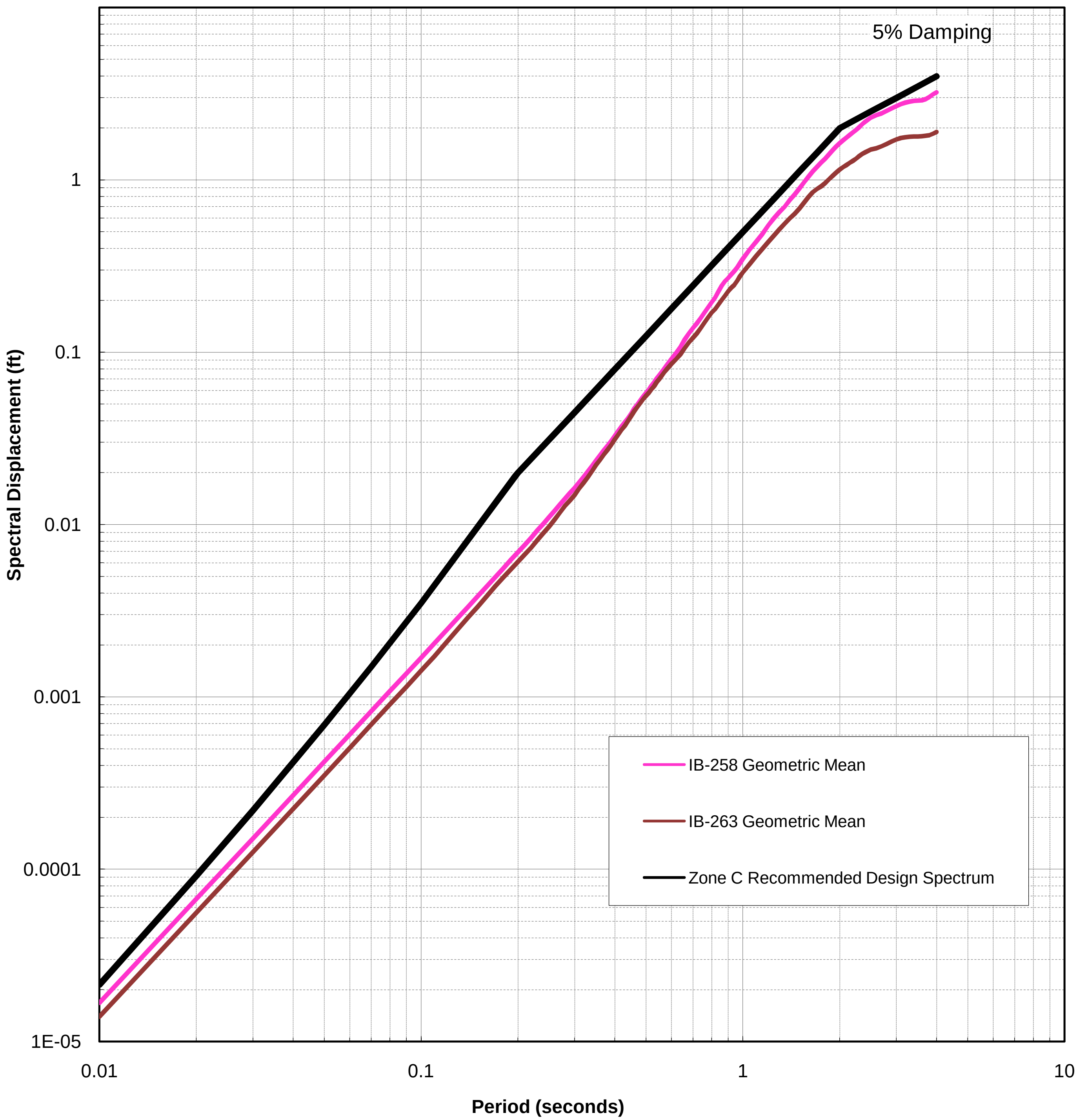
FIG. 4-4B



NOTES:

1. Recommended design spectrum includes a minimum 2/3 of AASHTO T3 Ground Motion for Site Class E.

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1,000-YEAR
EQUIVALENT LINEAR SITE RESPONSE
ZONE C

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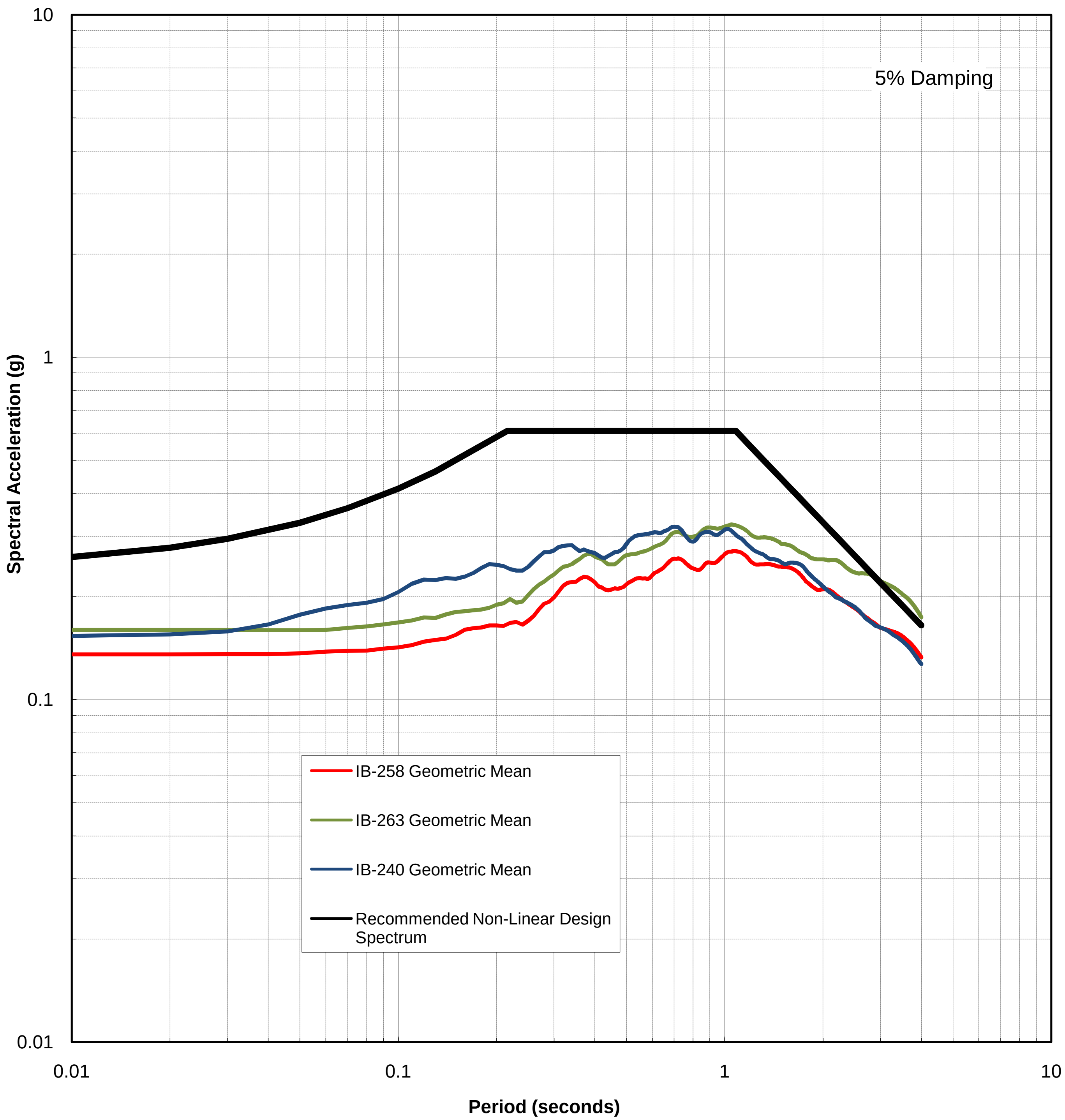
FIG. 4-4C



NOTES:

1. Recommended design spectrum includes a minimum 2/3 of AASHTO T3 Ground Motion for Site Class E.

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1,000-YEAR ZONES B AND C NON-LINEAR SITE RESPONSE AND DESIGN SPECTRA

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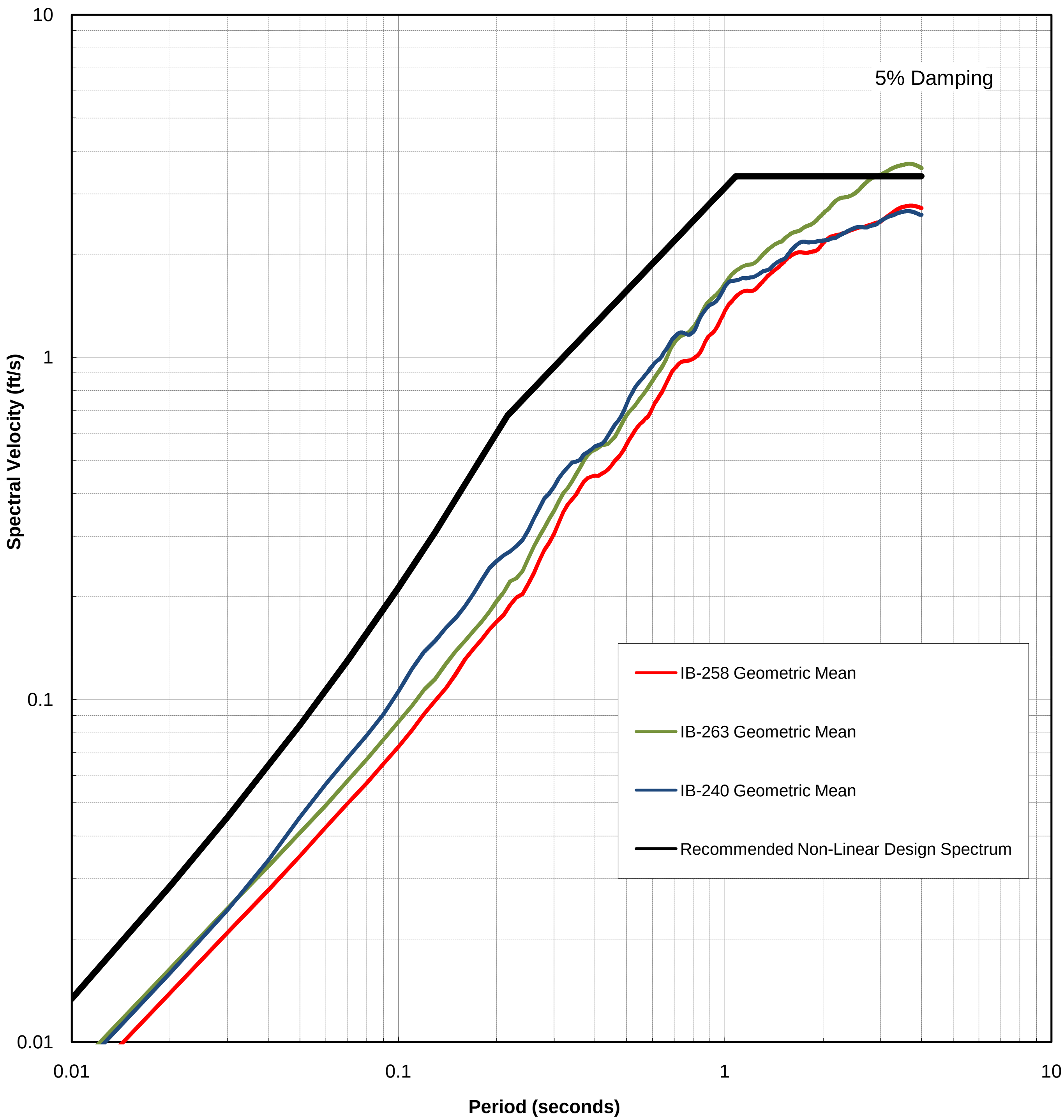
FIG. 4-5A



NOTES:

1. Recommended design spectrum includes a minimum 2/3 of AASHTO T3 Ground Motion for Site Class E.

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1,000-YEAR NON-LINEAR EFFECTIVE STRESS SITE RESPONSE ZONES B AND C

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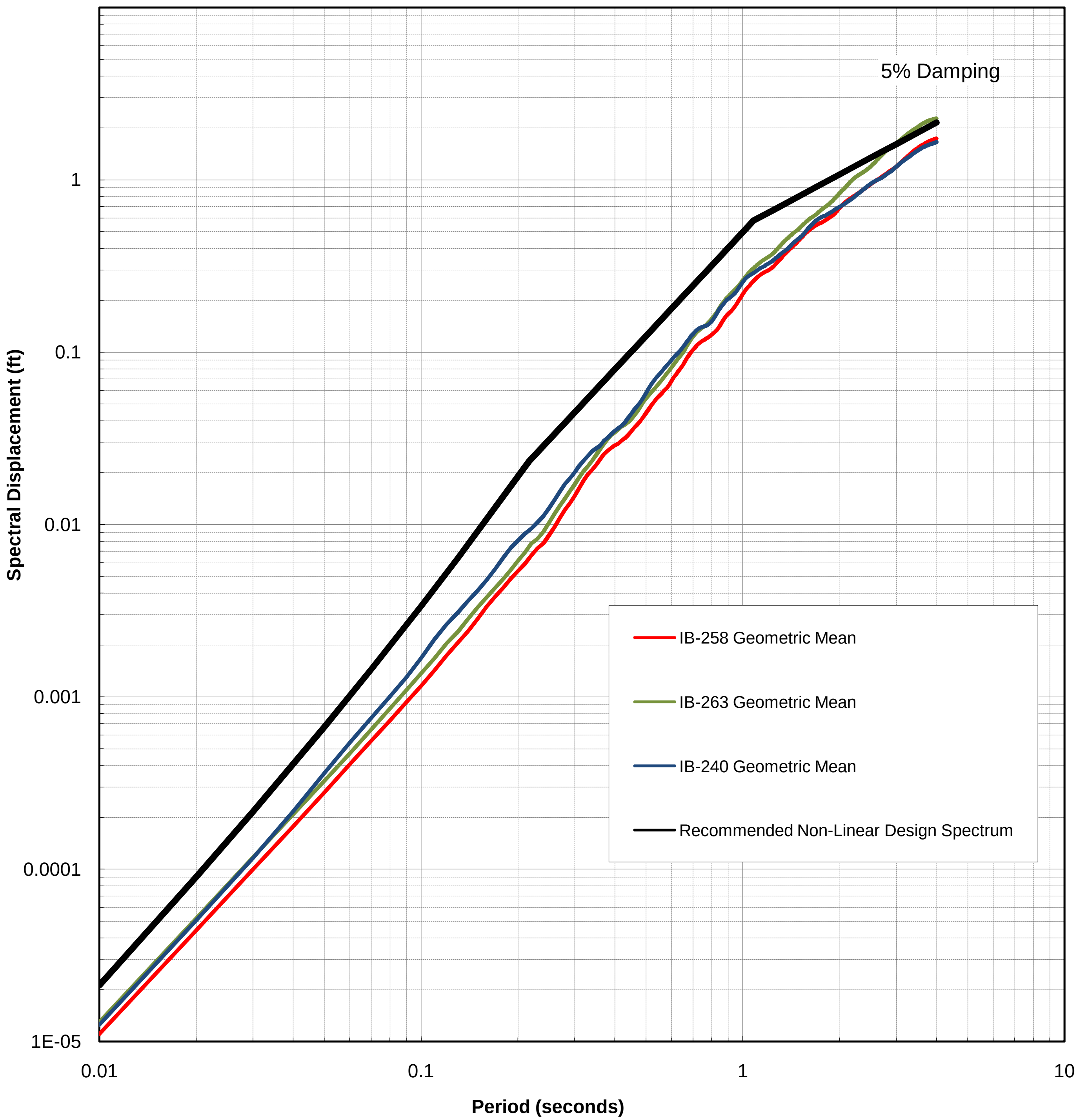
FIG. 4-5B

Non-Linear Site Response and Design Spectra.xlsm 4/29/2009: kpc



<u>NOTES</u>:

1. Recommended design spectrum includes a minimum 2/3 of AASHTO T3 Ground Motion for Site Class E.

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1,000-YEAR NON-LINEAR EFFECTIVE STRESS SITE RESPONSE ZONES B AND C

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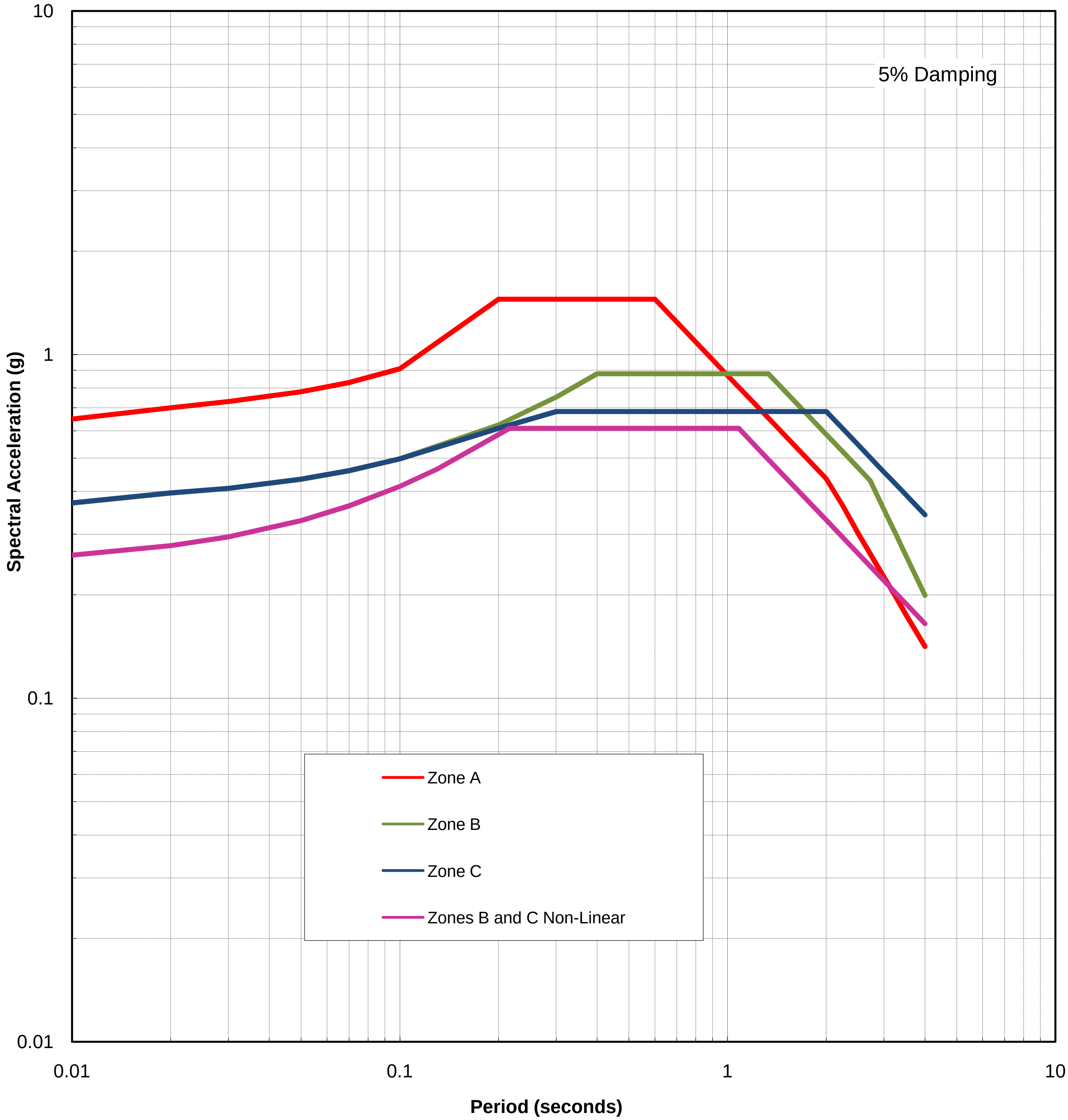
FIG. 4-5C



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RECOMMENDED HORIZONTAL RESPONSE SPECTRA

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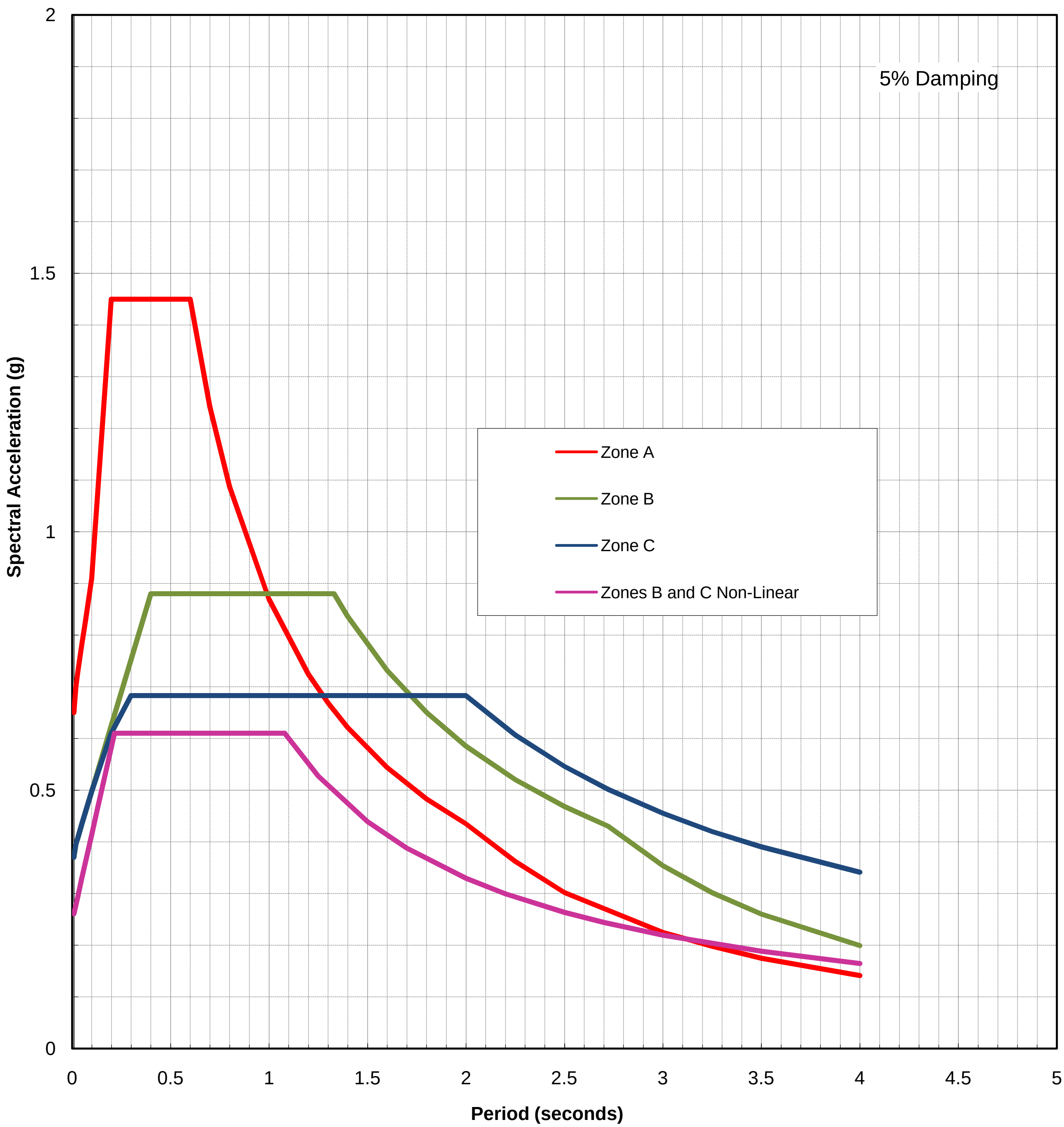
FIG. 4-6A



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RECOMMENDED HORIZONTAL RESPONSE SPECTRA

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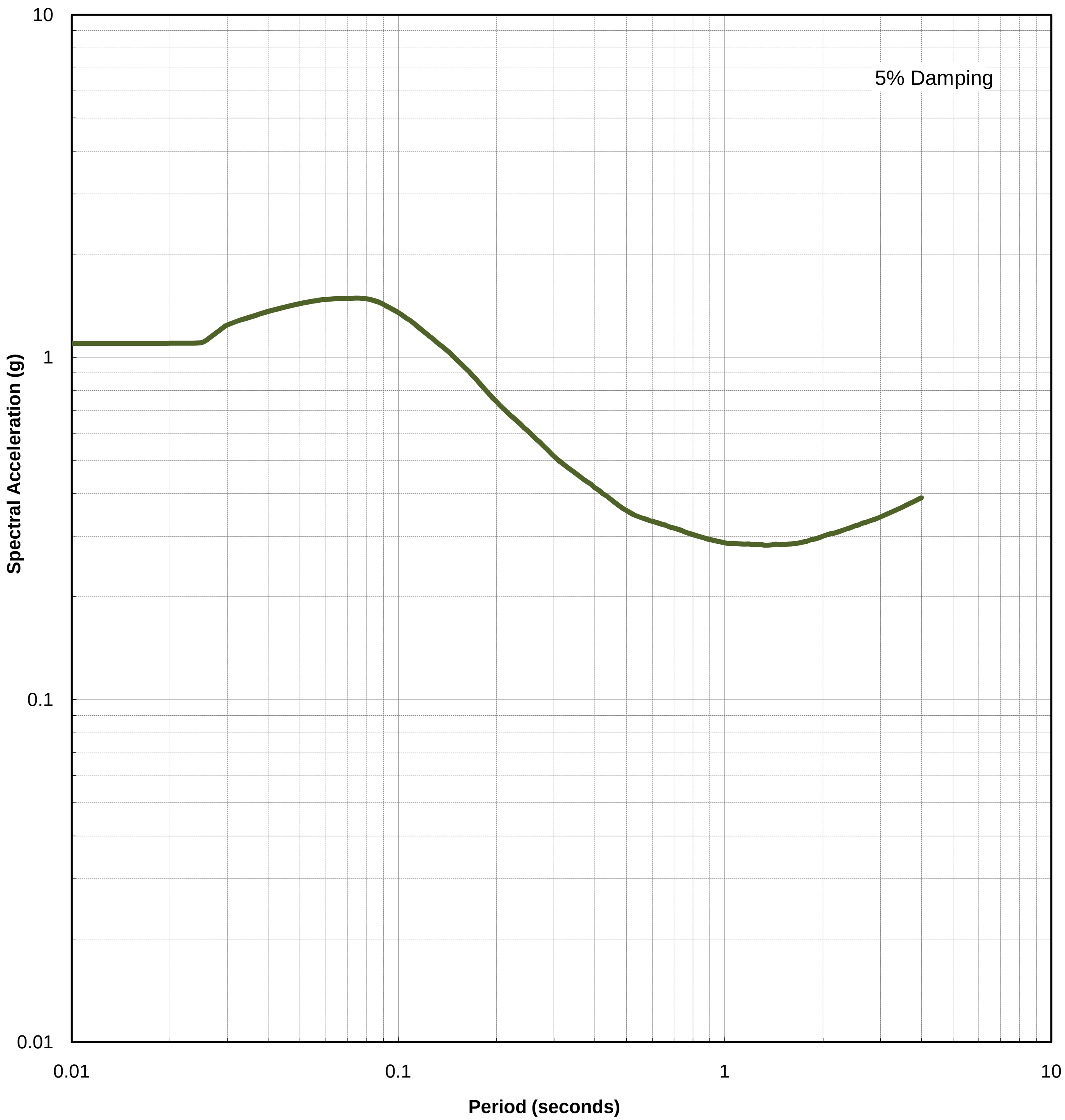
FIG. 4-6B



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V/H
SOIL SPECTRAL RATIOS

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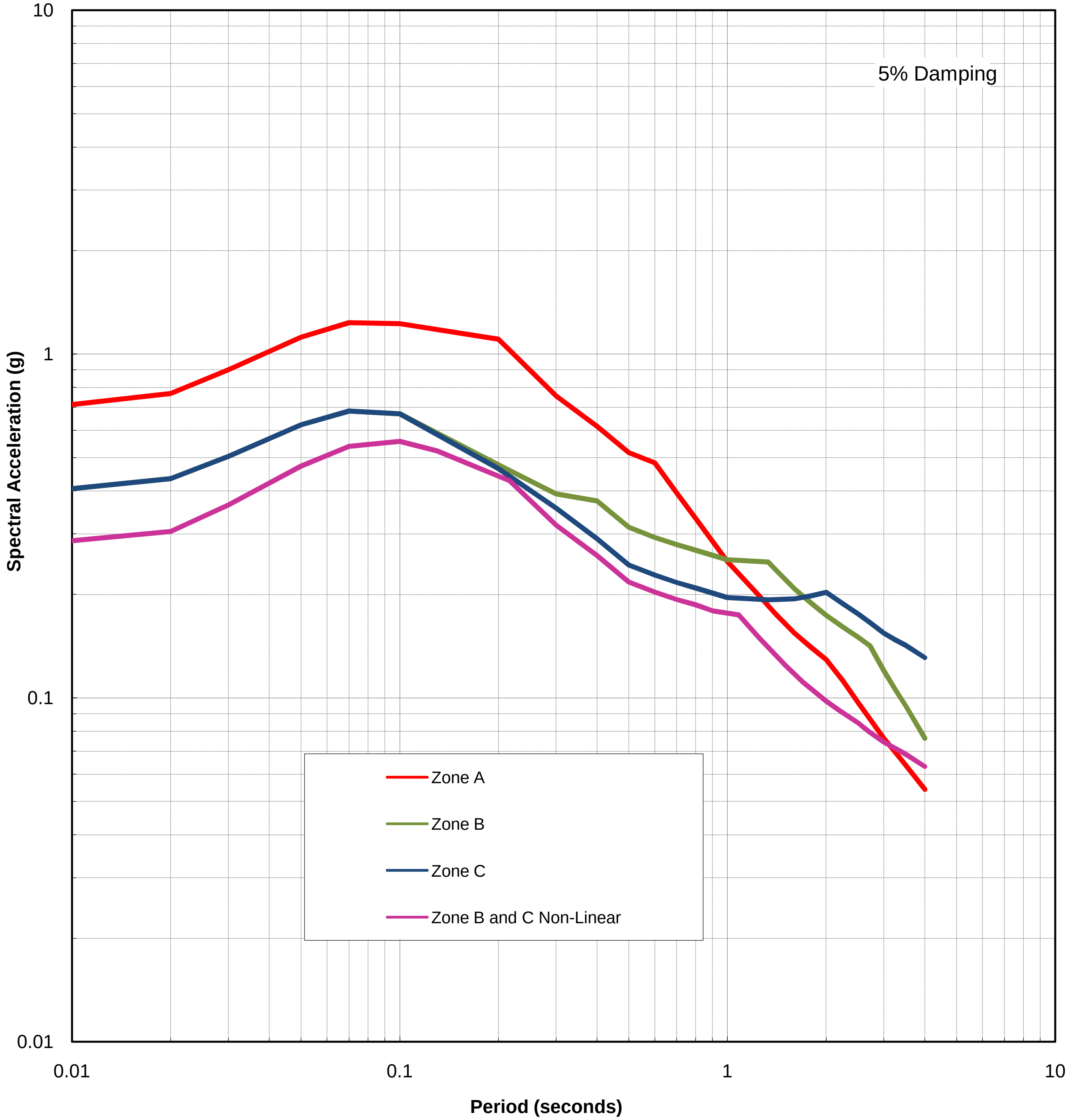
FIG. 4-7



Alaskan Way Viaduct and Seawall Program
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Seattle, Washington

RECOMMENDED VERTICAL RESPONSE SPECTRA

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FIG. 4-8

Appendix A

Reference and Spectrum Compatible Rock Time Histories

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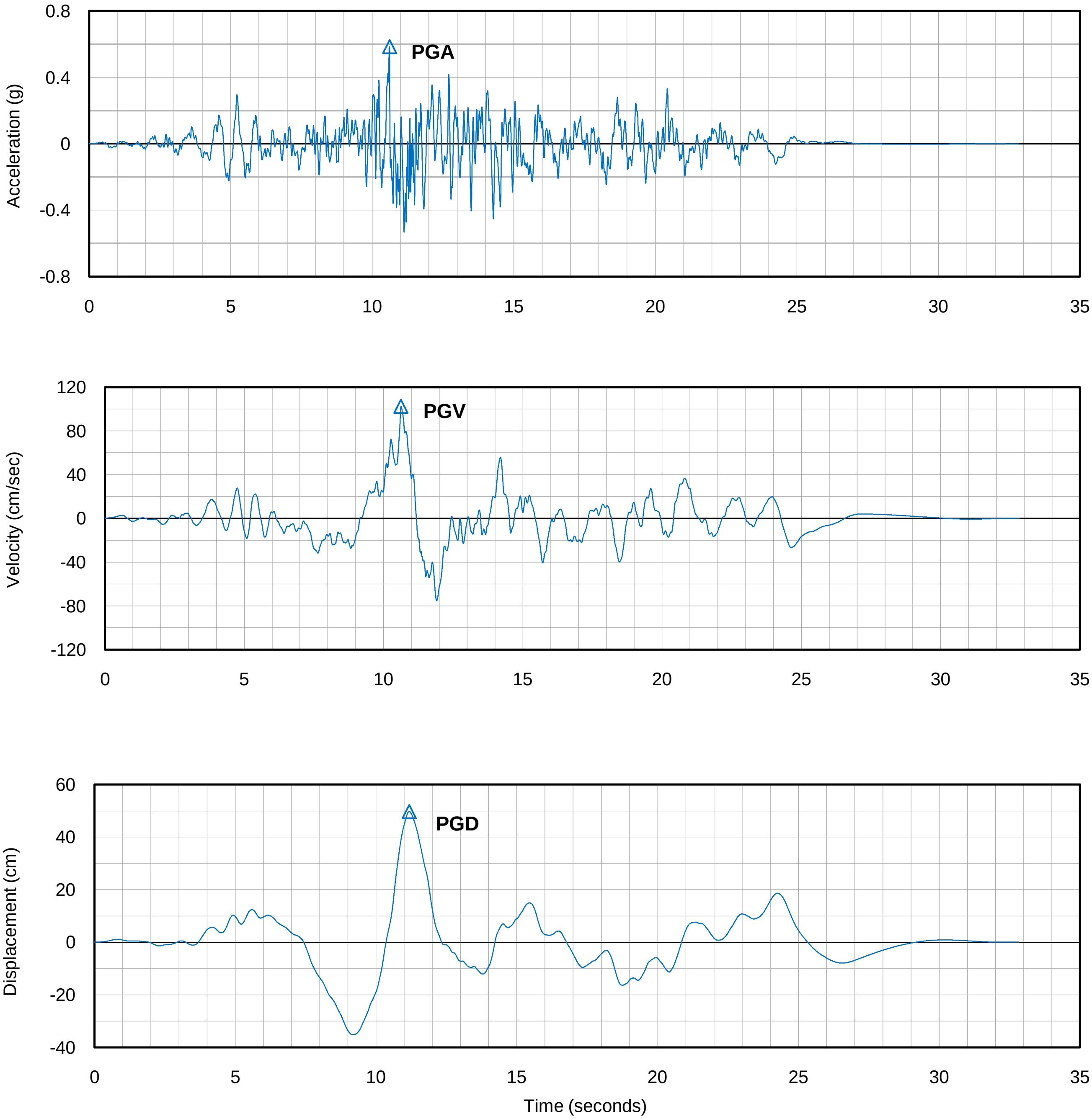
List of Figures



NOTES:

Reference Motion: Tabas, Iran;Tabas Fault Normal
File: TabFN_2c.avd

Peak Values

Acceleration	0.59 g
Velocity	102.5 cm/sec
Displacement	49.7 cm

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Seattle, Washington

1,000-YR GROUND MOTION
EQ1 FAULT NORMAL
REFERENCE TIME HISTORY

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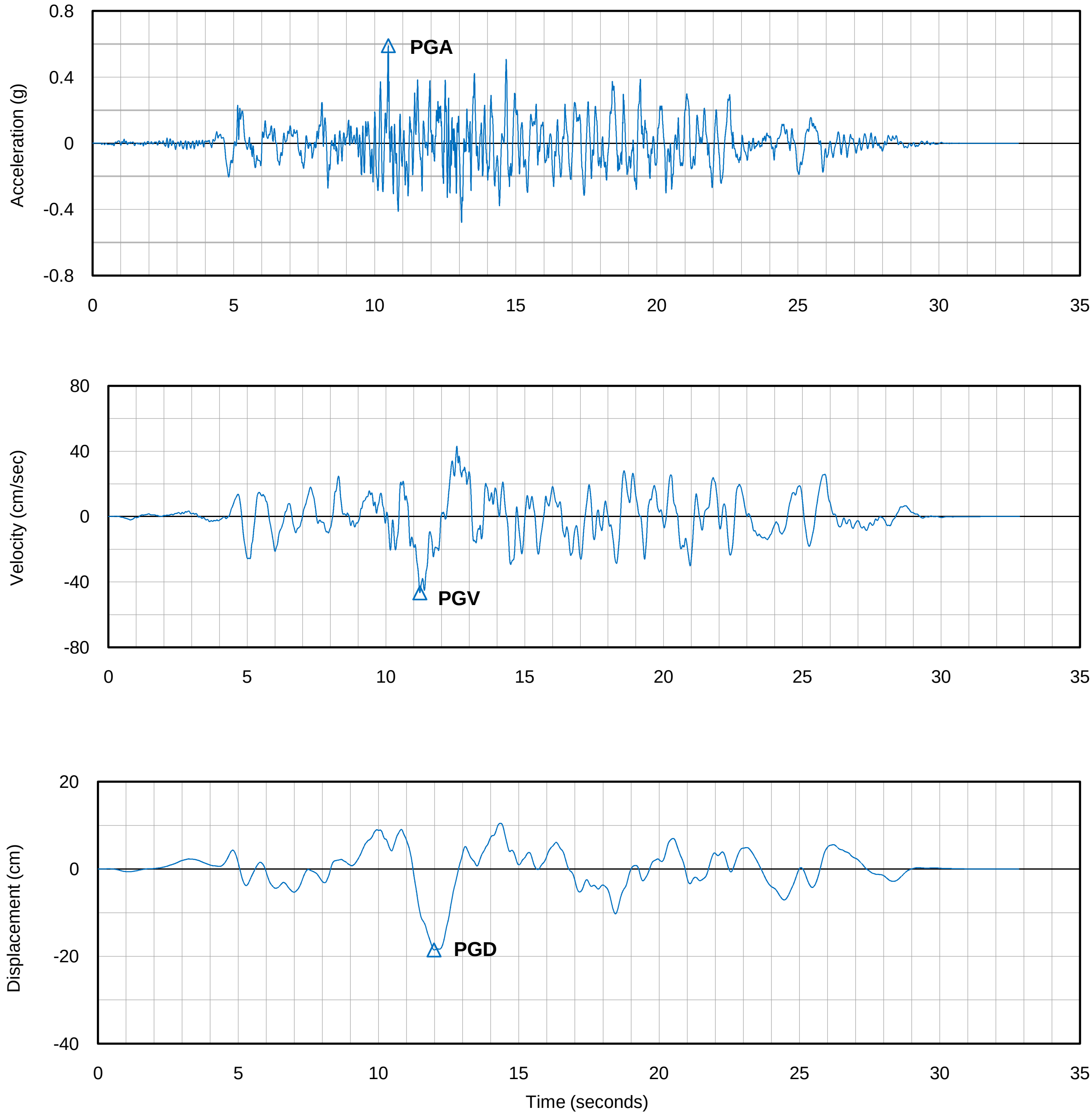
FIG. A-1



NOTES:

Reference Motion: Tabas, Iran;Tabas Fault Parallel
File: TabFP_2c.avd

Peak Values

Acceleration	0.59 g
Velocity	46.7 cm/sec
Displacement	18.6 cm

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1,000-YR GROUND MOTION
EQ1 FAULT PARALLEL
REFERENCE TIME HISTORY

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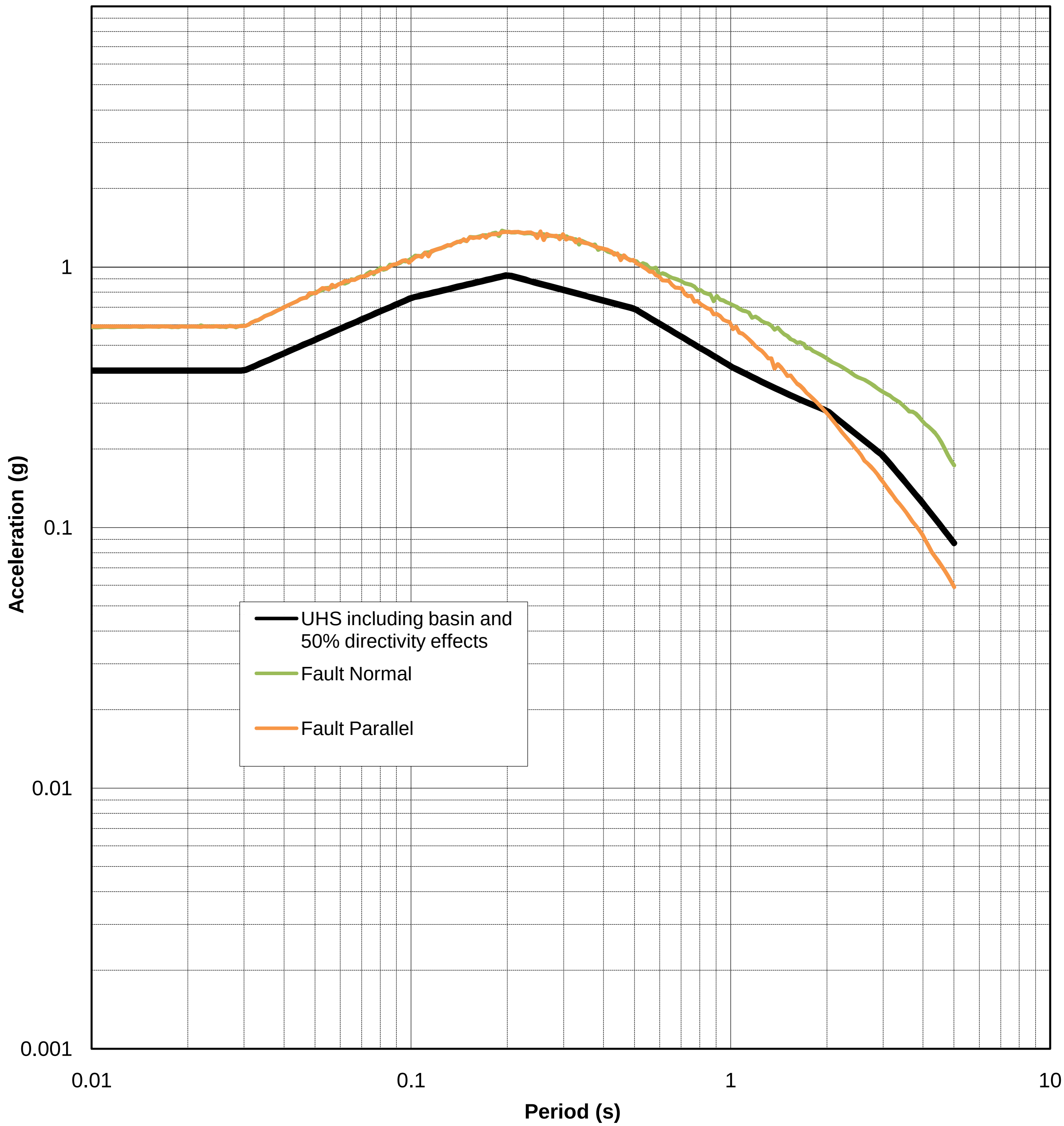
FIG. A-2



NOTES

Fault Normal File: tabfn-2c.avd
Fault Parallel File: tabfp-2c.avd

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1,000-YR GROUND MOTION
EQ1 REFERENCE TIME HISTORY
SPECTRAL ACCELERATION

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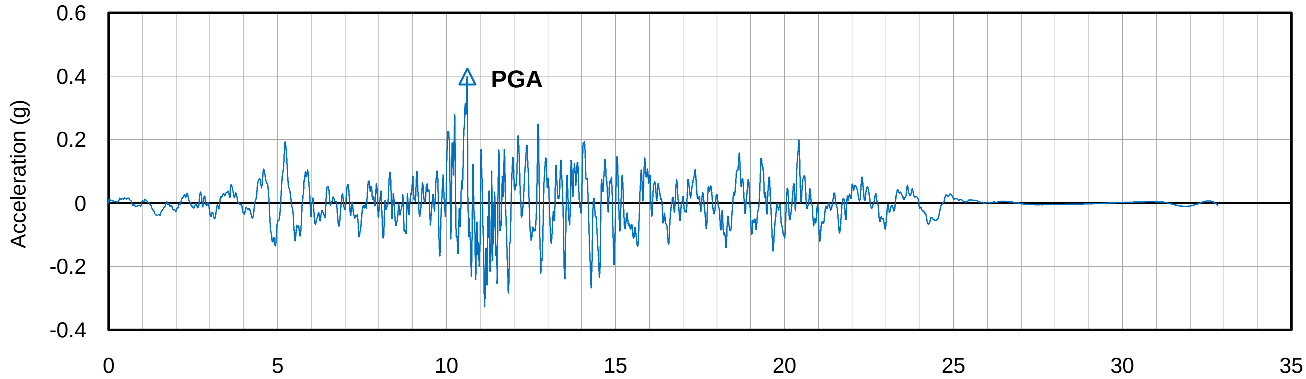
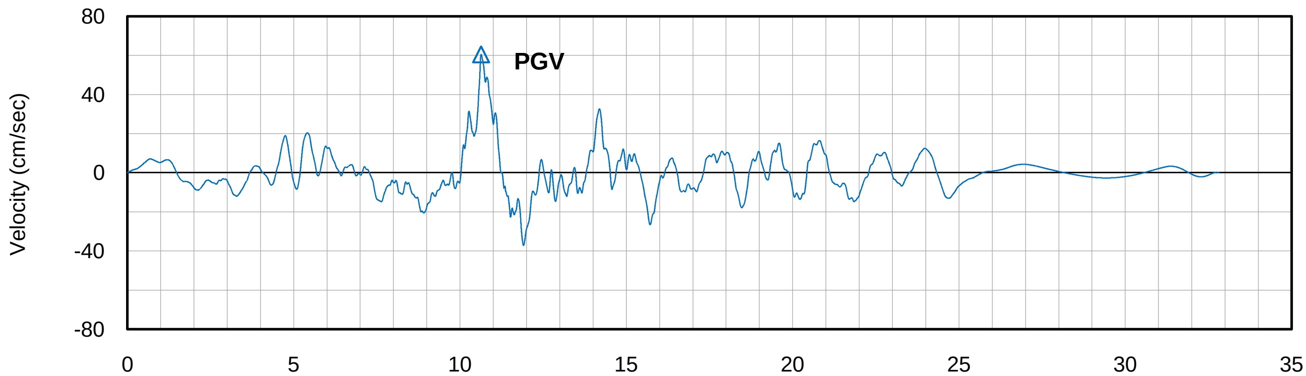
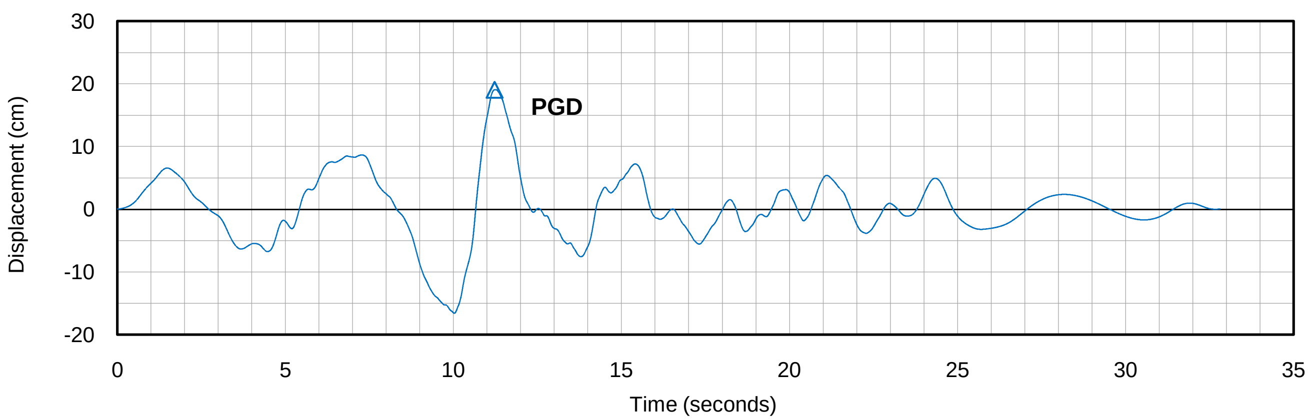
FIG. A-3







NOTES:

Reference Motion: Tabas, Iran;Tabas Fault Normal
File: tabfn-2c.avd

Peak Values

Acceleration	0.40 g
Velocity	60.5 cm/sec
Displacement	19.0 cm

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1,000-YR GROUND MOTION
EQ1 FAULT NORMAL
MATCHED TIME HISTORY

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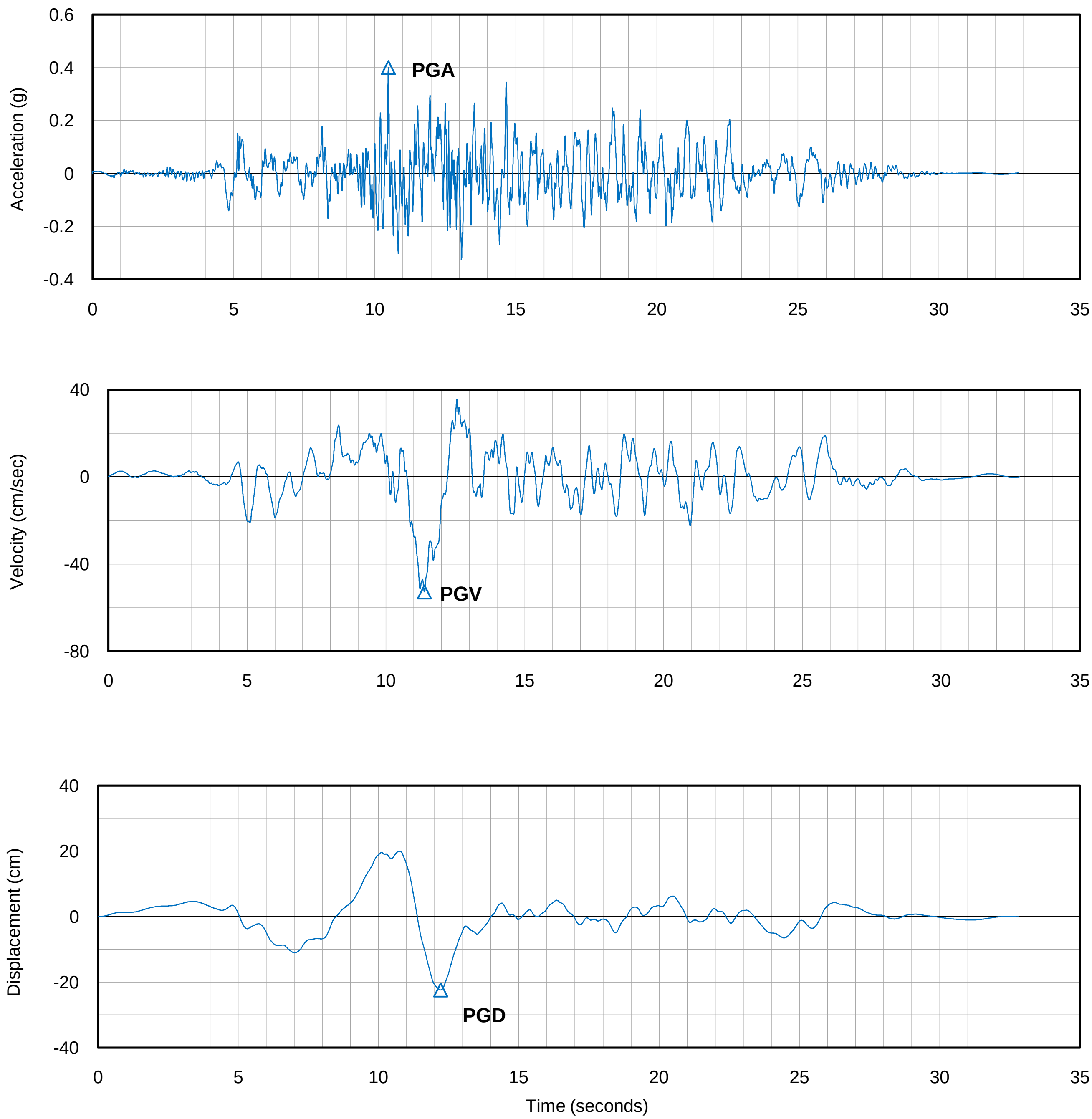
FIG. A-4



NOTES:

Reference Motion: Tabas, Iran;Tabas Fault Parallel
File: tabfp-2c.avd

Peak Values

Acceleration	0.40 g
Velocity	52.7 cm/sec
Displacement	22.4 cm

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1,000-YR GROUND MOTION
EQ1 FAULT PARALLEL
MATCHED TIME HISTORY

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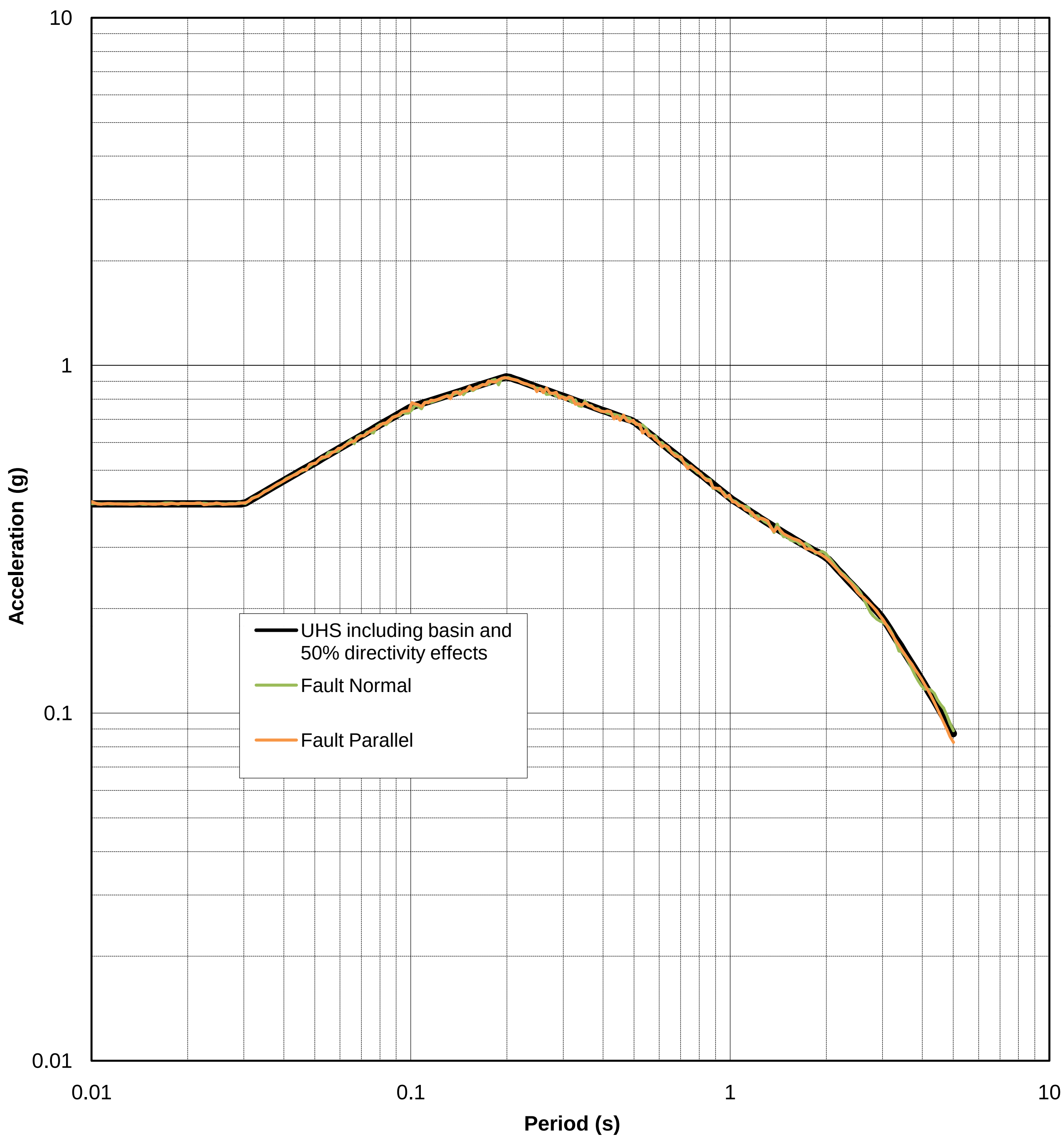
FIG. A-5



NOTES

Fault Normal File: tabfn-2c.avd
Fault Parallel File: tabfp-2c.avd

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1,000-YR GROUND MOTION EQ1 MATCHED TIME HISTORY SPECTRAL ACCELERATION

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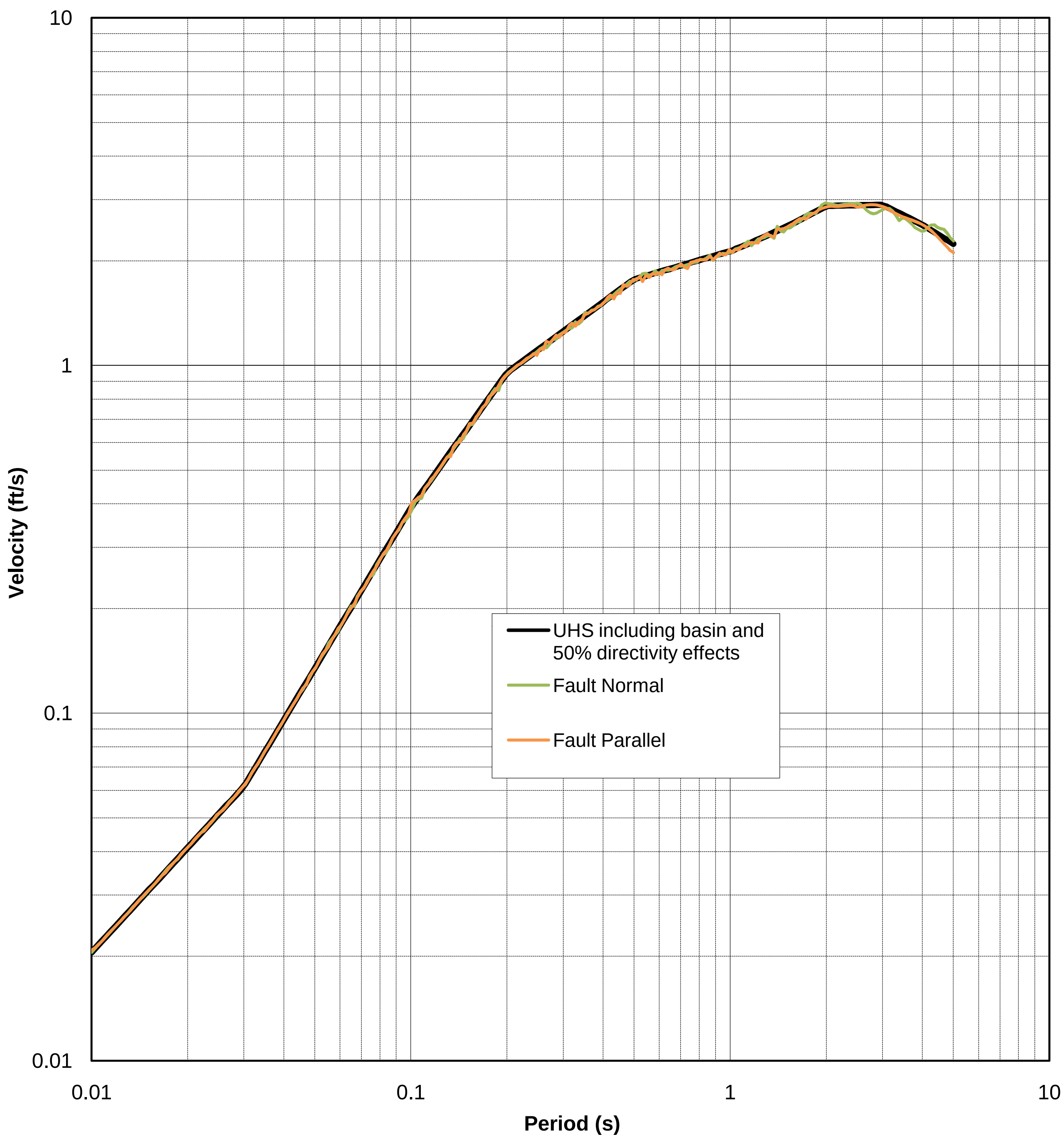
FIG. A-6



NOTES

Fault Normal File: tabfn-2c.avd
Fault Parallel File: tabfp-2c.avd

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1,000-YR GROUND MOTION
EQ1 MATCHED TIME HISTORY
SPECTRAL VELOCITY

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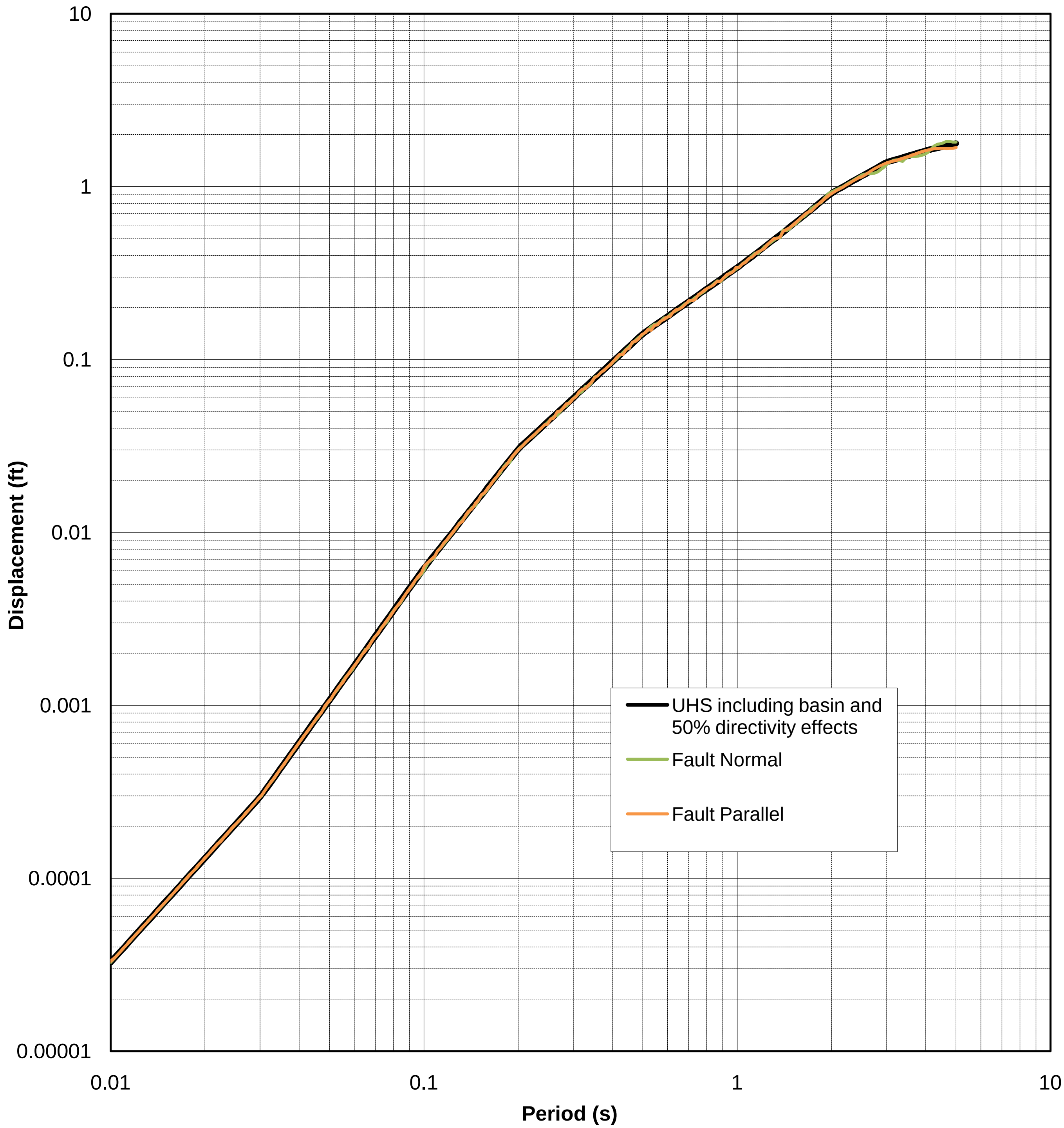
FIG. A-7



NOTES

Fault Normal File: tabfn-2c.avd
Fault Parallel File: tabfp-2c.avd

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1,000-YR GROUND MOTION
EQ1 MATCHED TIME HISTORY
SPECTRAL DISPLACEMENT

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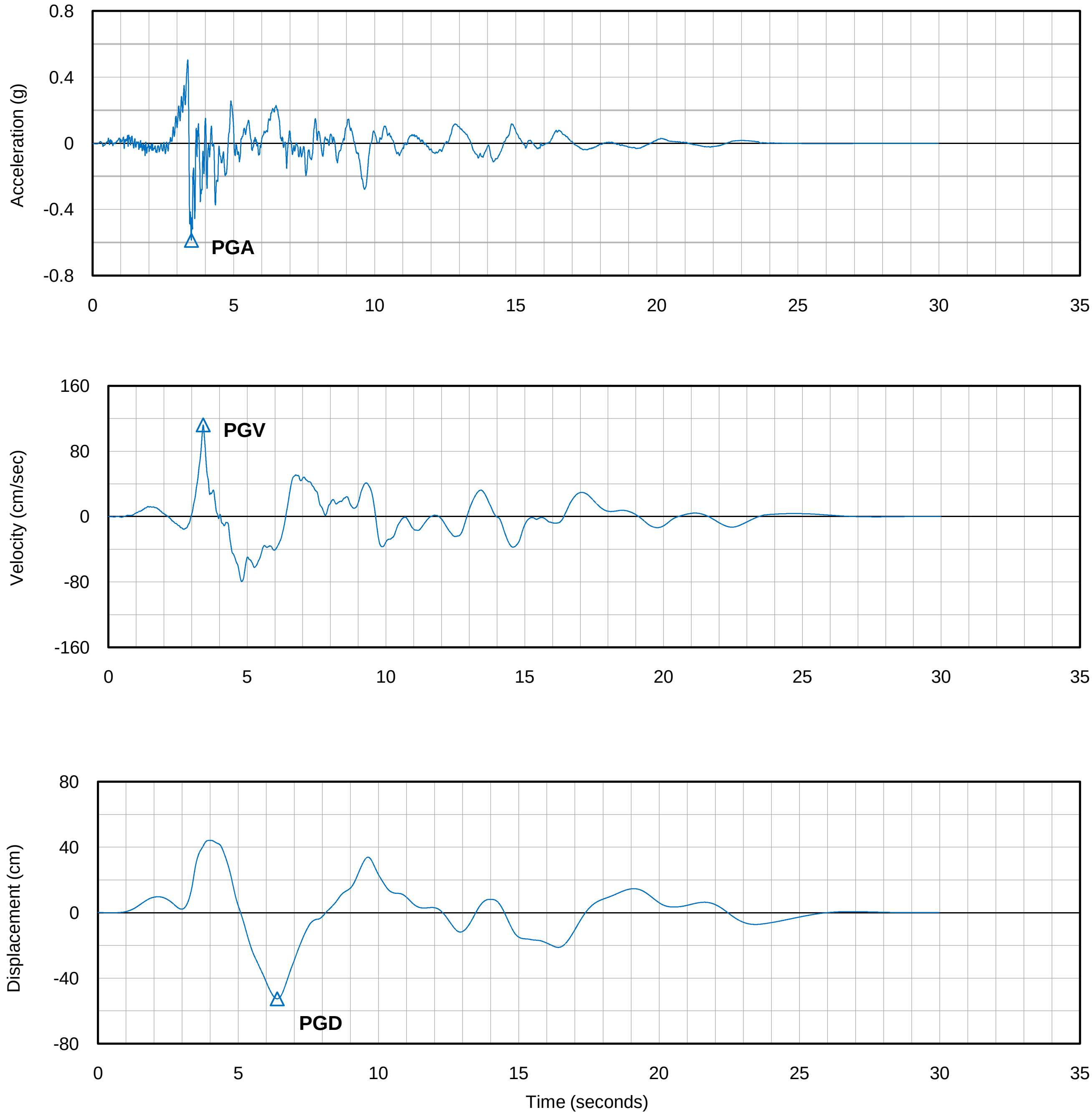
FIG. A-8



NOTES:

Reference Motion: Northridge; Pacoima Dam DS Fault Normal
File: PacFN_3cc.avd

Peak Values

Acceleration	0.59 g
Velocity	112.2 cm/sec
Displacement	52.7 cm

Alaskan Way Viaduct and Seawall Program
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Seattle, Washington

1,000-YR GROUND MOTION
EQ2 FAULT NORMAL
REFERENCE TIME HISTORY

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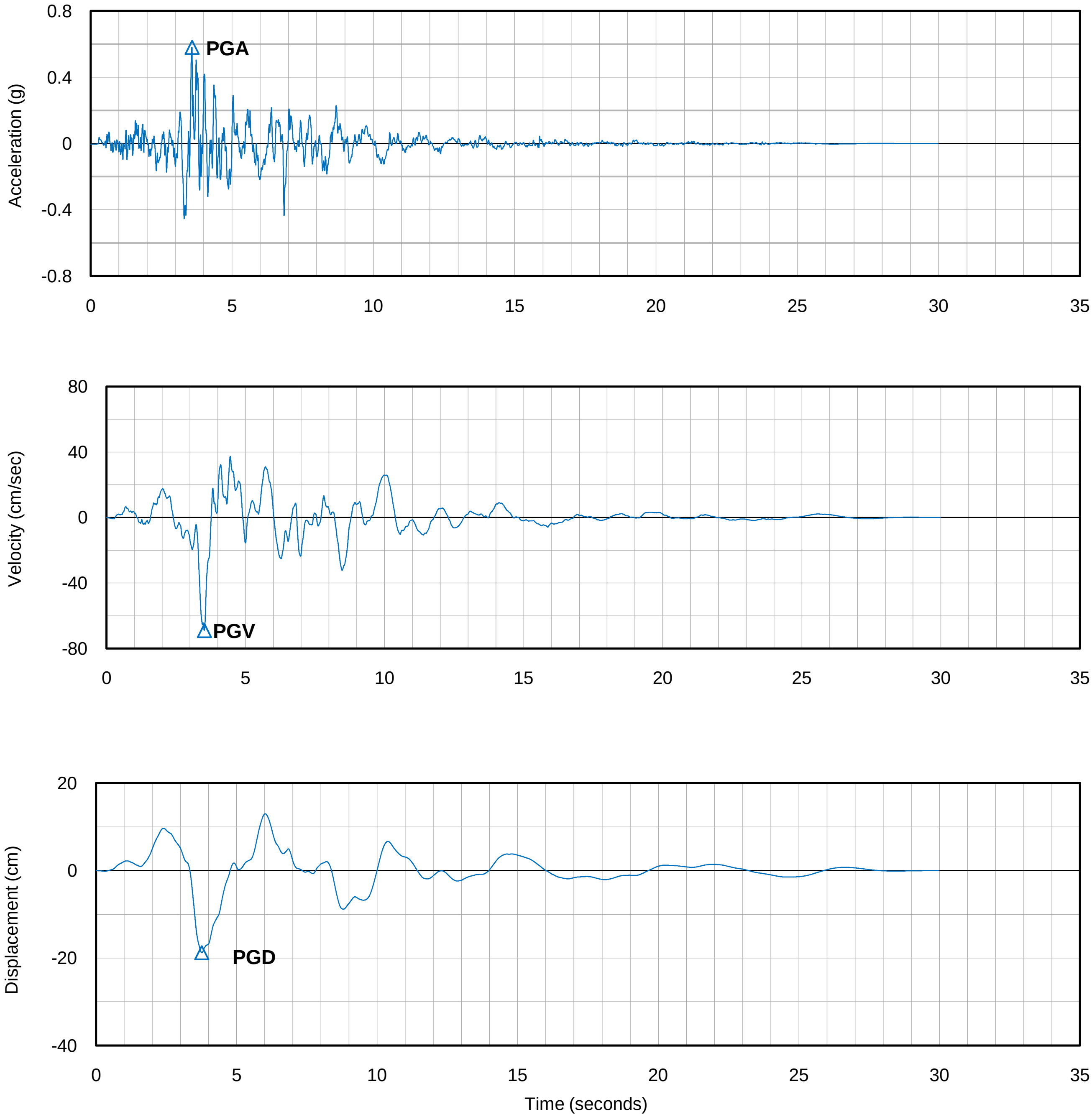
FIG. A-9



NOTES:

Reference Motion: Northridge; Pacoima Dam DS Fault Parallel
File: PacFP_3cc.avd

Peak Values

Acceleration	0.58 g
Velocity	69.1 cm/sec
Displacement	18.8 cm

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1,000-YR GROUND MOTION
EQ2 FAULT PARALLEL
REFERENCE TIME HISTORY

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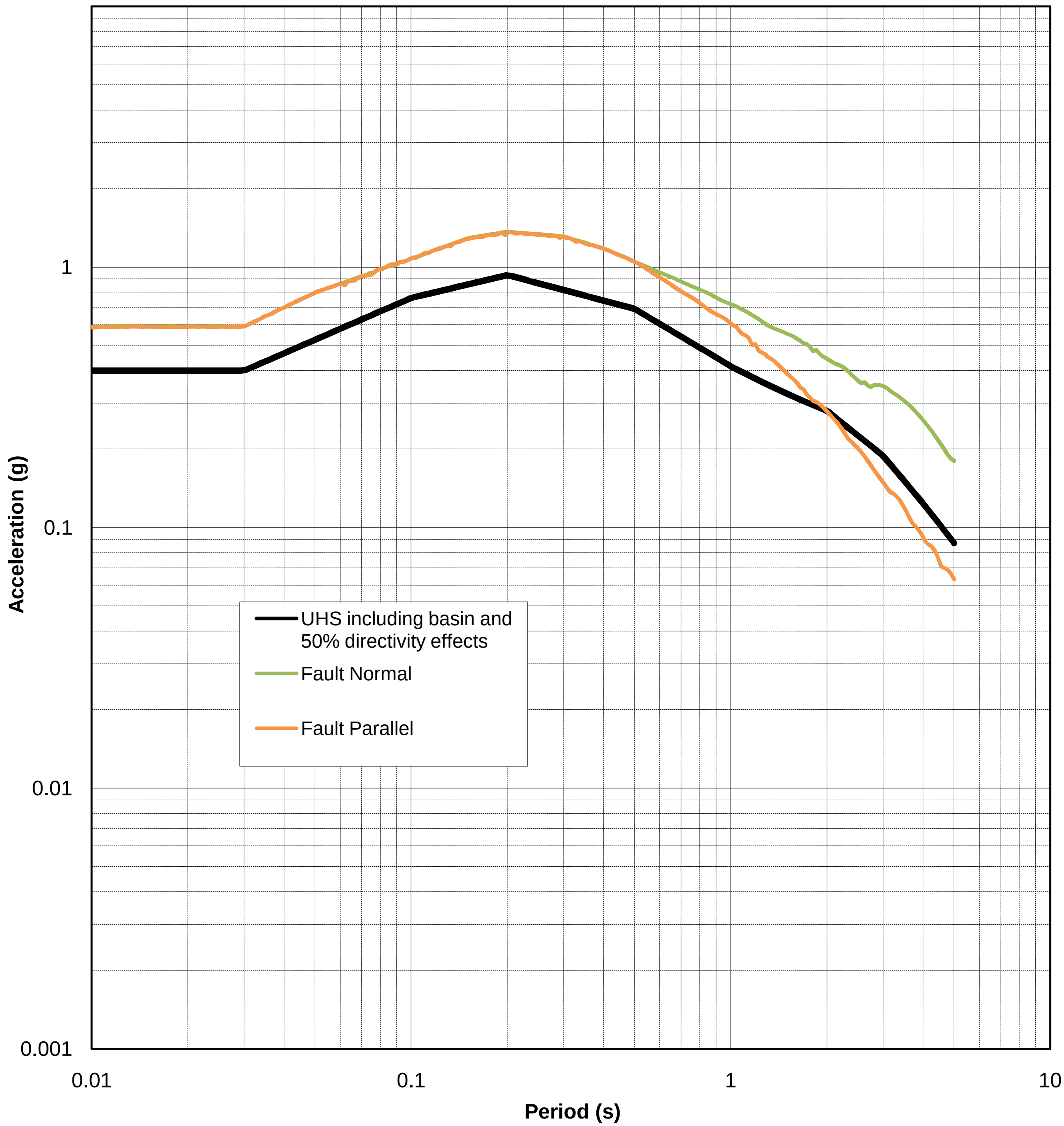
FIG. A-10



NOTES

Fault Normal File: pacfn-2c.avd
Fault Parallel File: pacfp-4c.avd

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1,000-YR GROUND MOTION EQ2 REFERENCE TIME HISTORY SPECTRAL ACCELERATION

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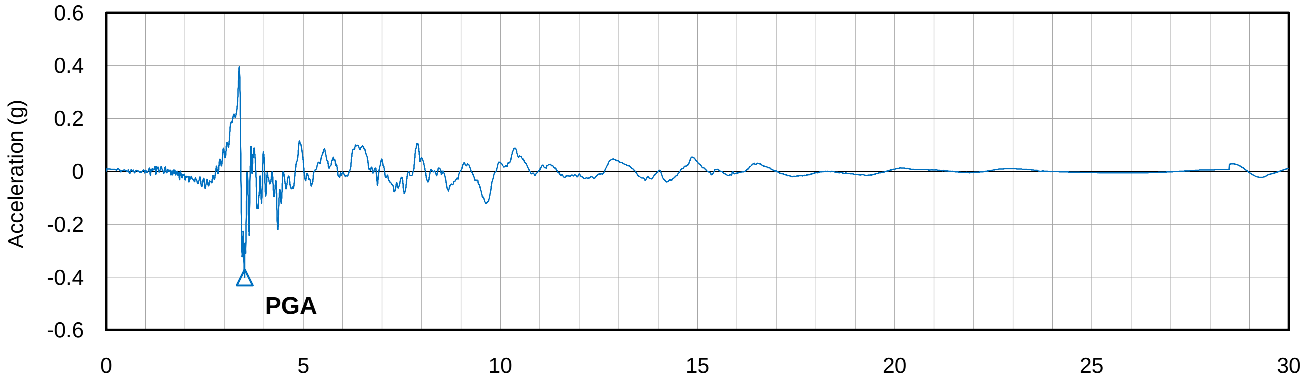
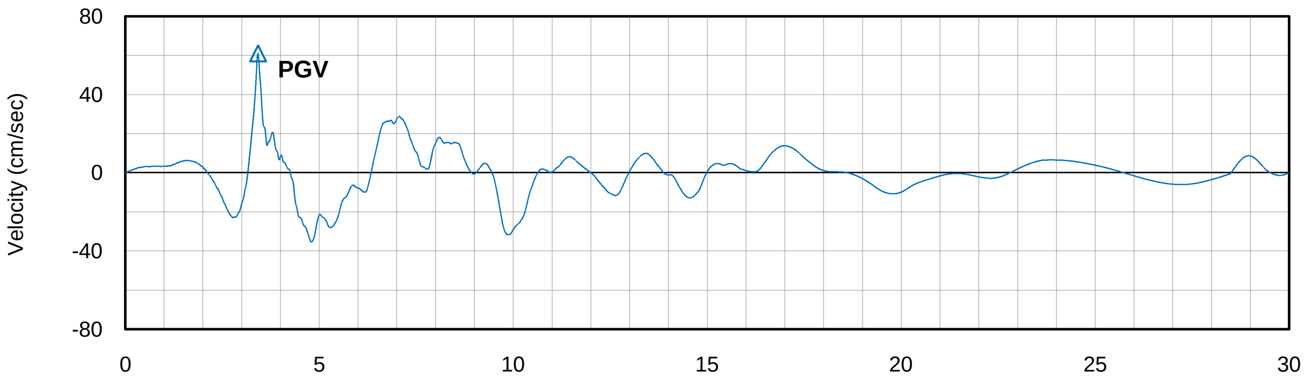
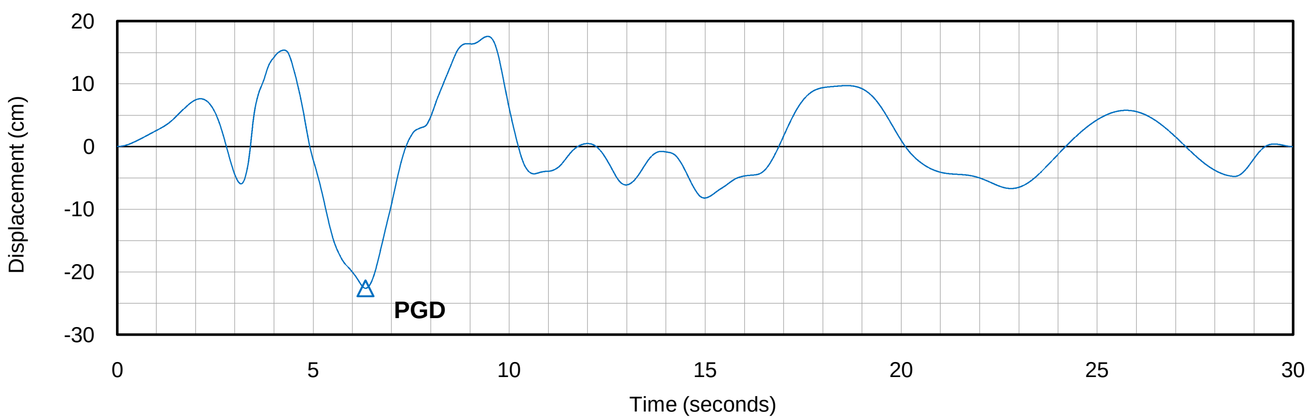
FIG. A-11







NOTES:

Reference Motion: Northridge; Pacoima Dam DS Fault Normal
File: pacfn-2c.avd

Peak Values

Acceleration	0.40 g
Velocity	61.0 cm/sec
Displacement	22.6 cm

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1,000-YR GROUND MOTION
EQ2 FAULT NORMAL
MATCHED TIME HISTORY

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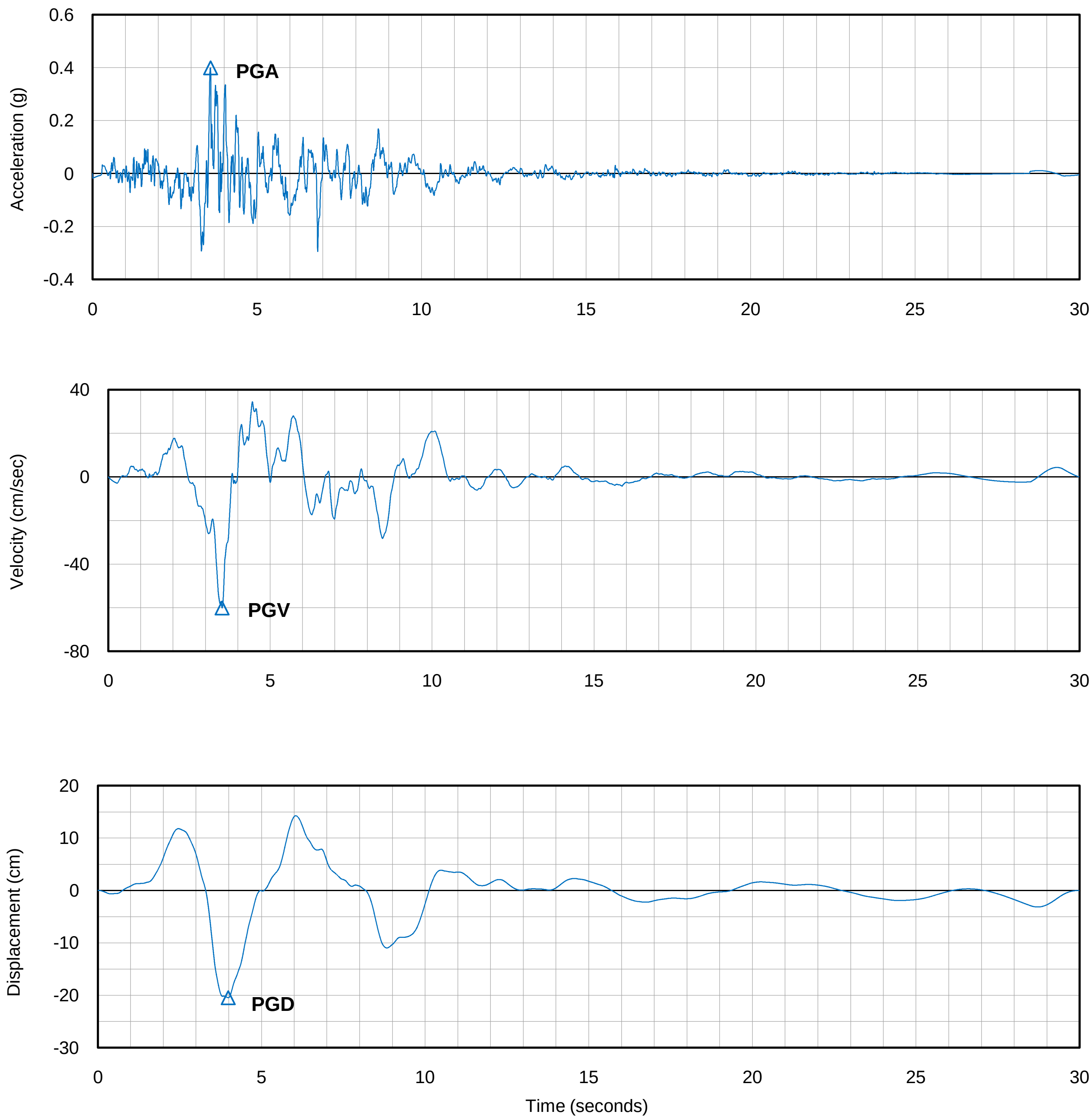
FIG. A-12



NOTES:

Reference Motion: Northridge; Pacoima Dam DS Fault Parallel
File: pacfp-4c.avd

Peak Values

Acceleration	0.40 g
Velocity	60.1 cm/sec
Displacement	20.5 cm

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1,000-YR GROUND MOTION
EQ2 FAULT PARALLEL
MATCHED TIME HISTORY

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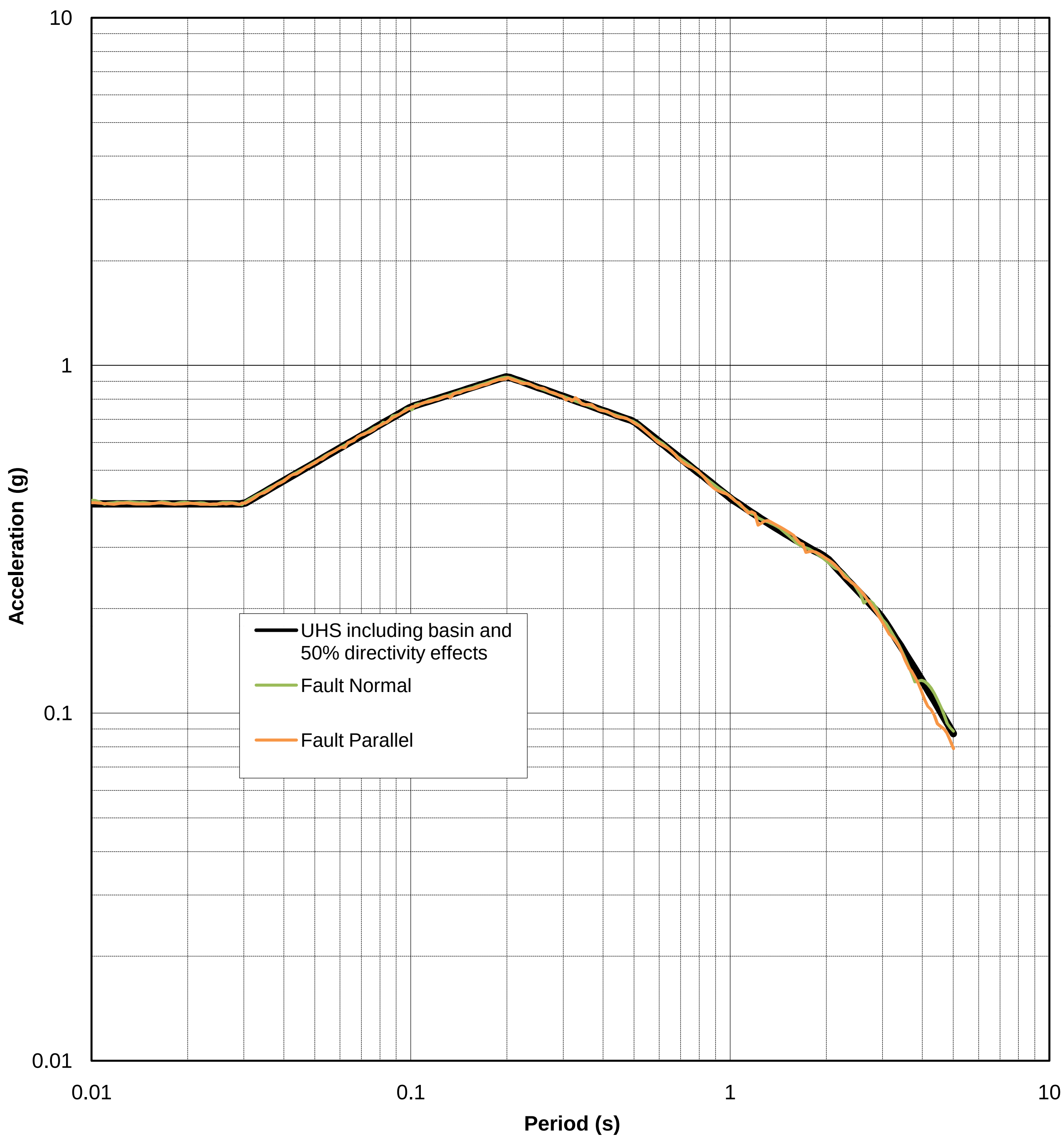
FIG. A-13



NOTES

Fault Normal File: pacfn-2c.avd
Fault Parallel File: pacfp-4c.avd

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1,000-YR GROUND MOTION EQ2 MATCHED TIME HISTORY SPECTRAL ACCELERATION

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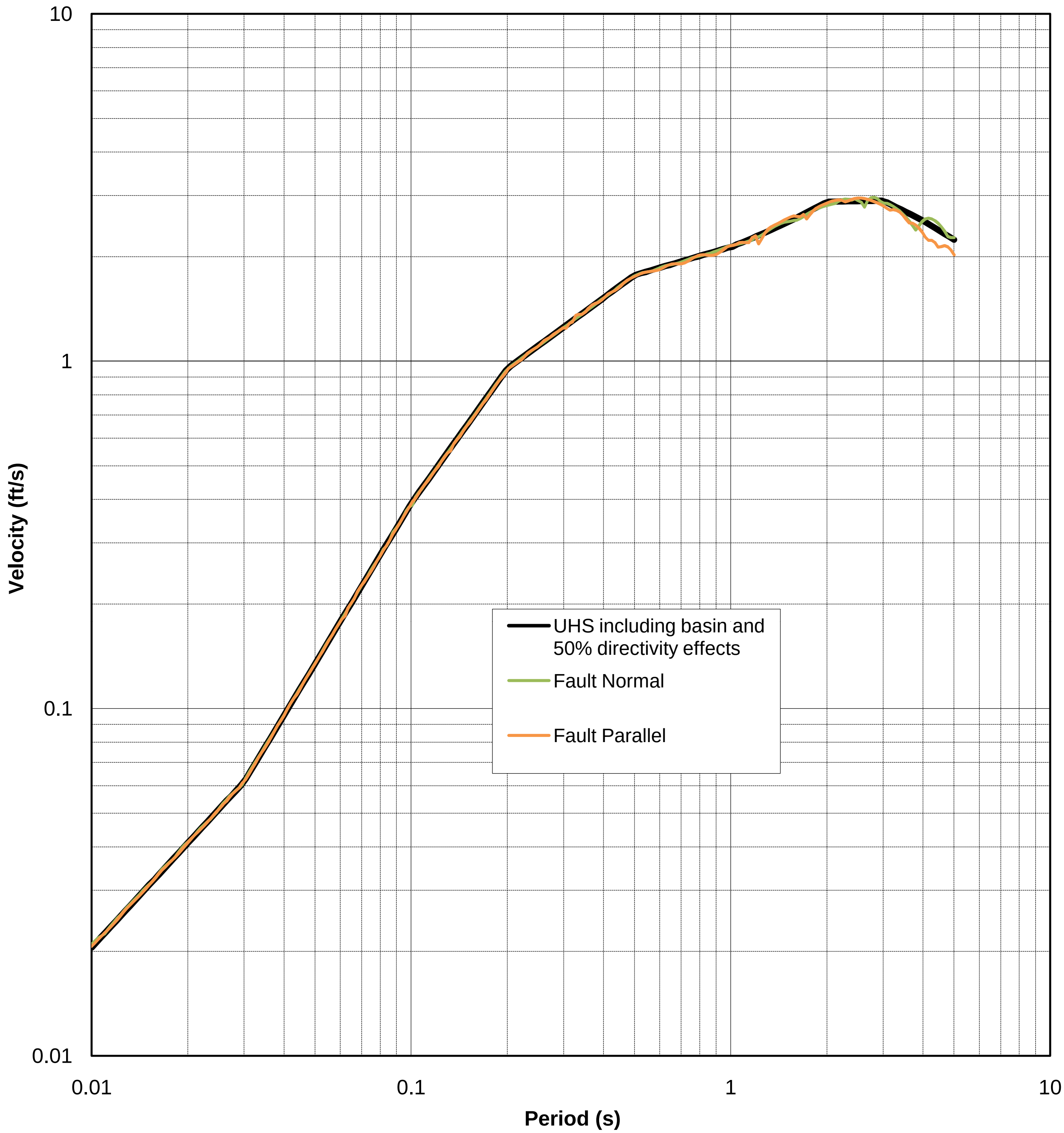
FIG. A-14



NOTES

Fault Normal File: pacfn-2c.avd
Fault Parallel File: pacfp-4c.avd

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1,000-YR GROUND MOTION EQ2 MATCHED TIME HISTORY SPECTRAL VELOCITY	
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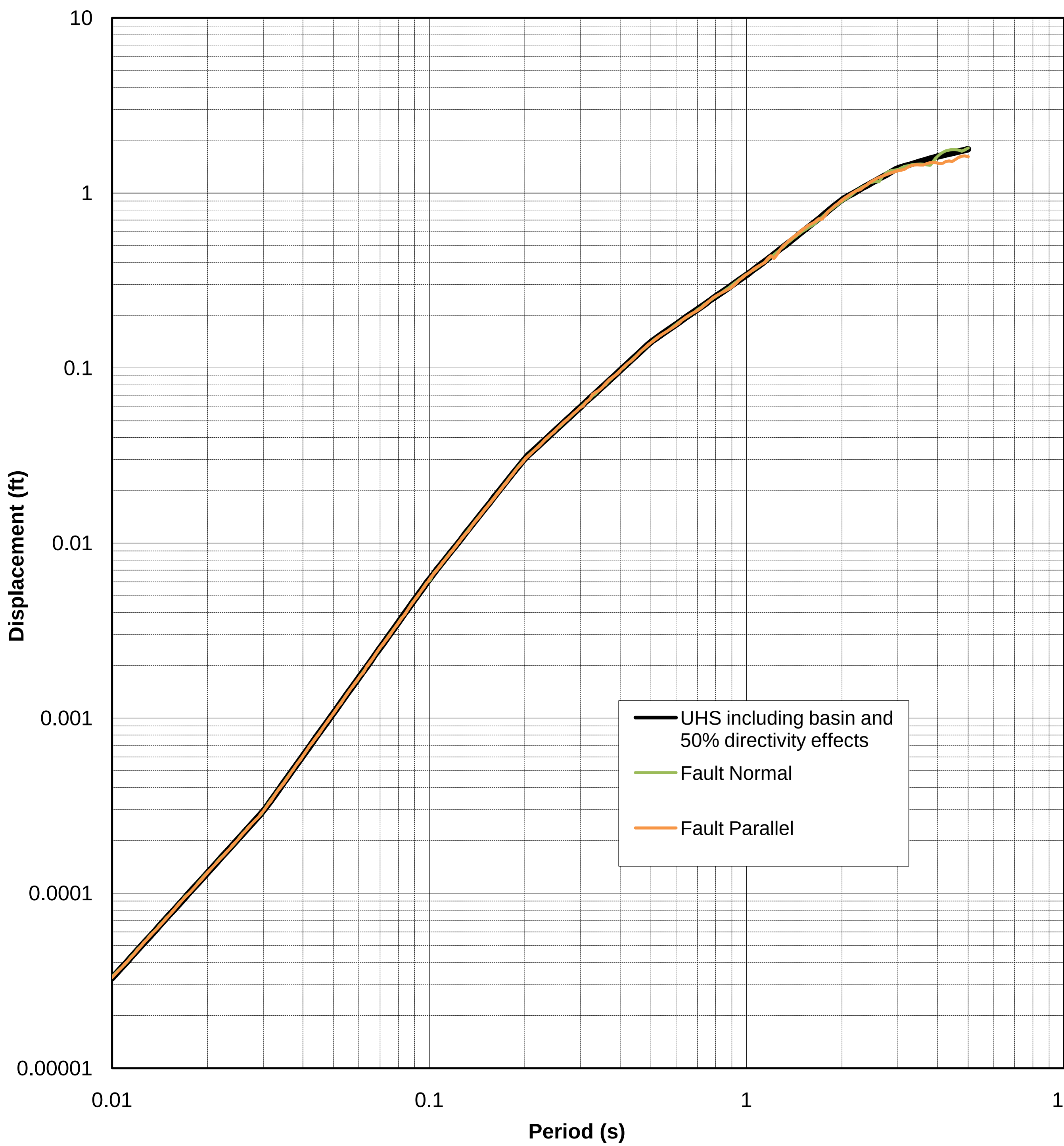
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. A-15**



NOTES

Fault Normal File: pacfn-2c.avd
Fault Parallel File: pacfp-4c.avd

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1,000-YR GROUND MOTION
EQ2 MATCHED TIME HISTORY
SPECTRAL DISPLACEMENT

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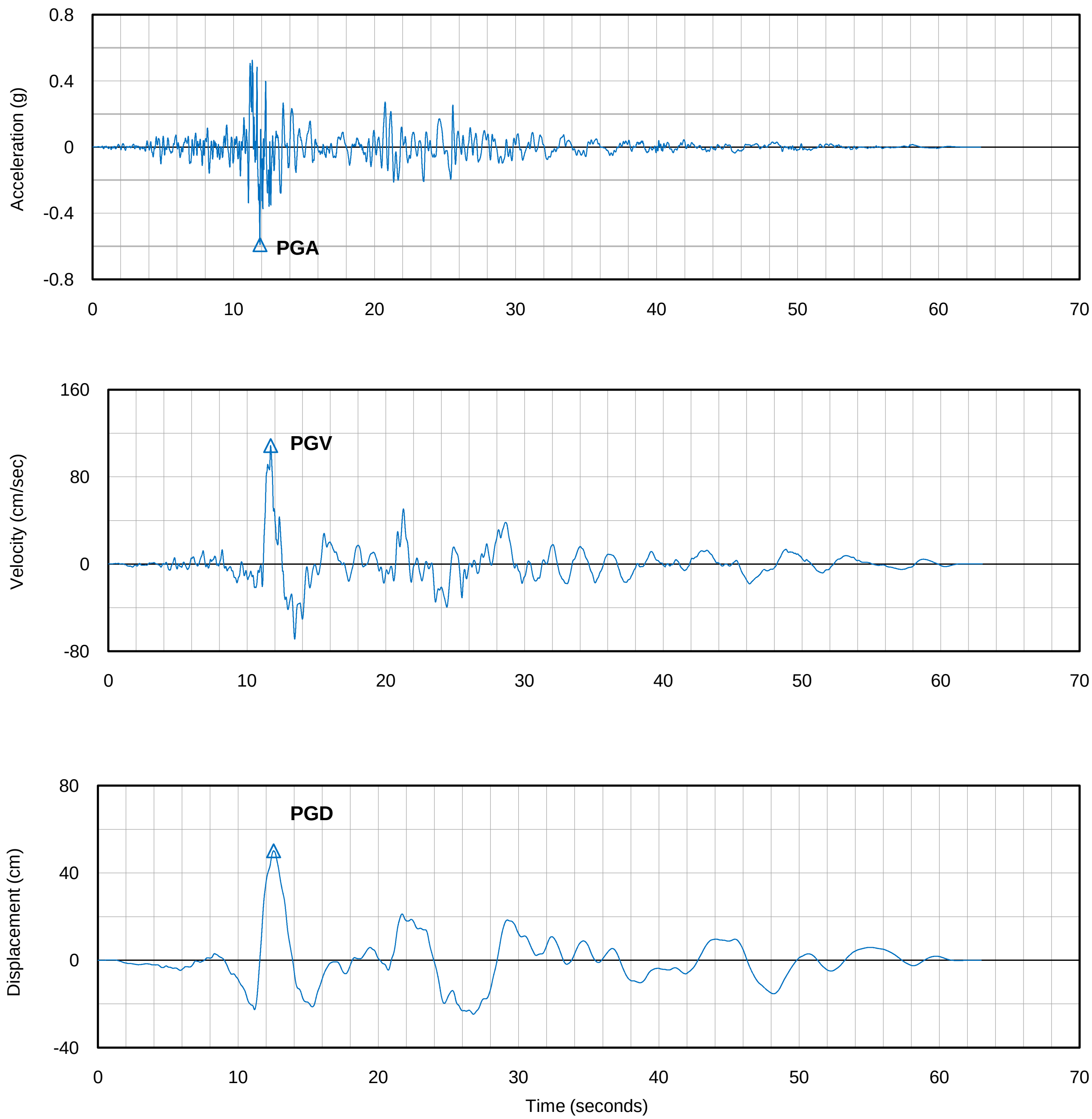
FIG. A-16



NOTES:

Reference Motion: Chi-Chi, Taiwan; TCU052 Fault Normal
File: T052Fn2dc.avd

Peak Values

Acceleration	0.59 g
Velocity	108.7 cm/sec
Displacement	50.2 cm

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Seismic Ground Motion Study Update
Seattle, Washington

1,000-YR GROUND MOTION
EQ3 FAULT NORMAL
REFERENCE TIME HISTORY

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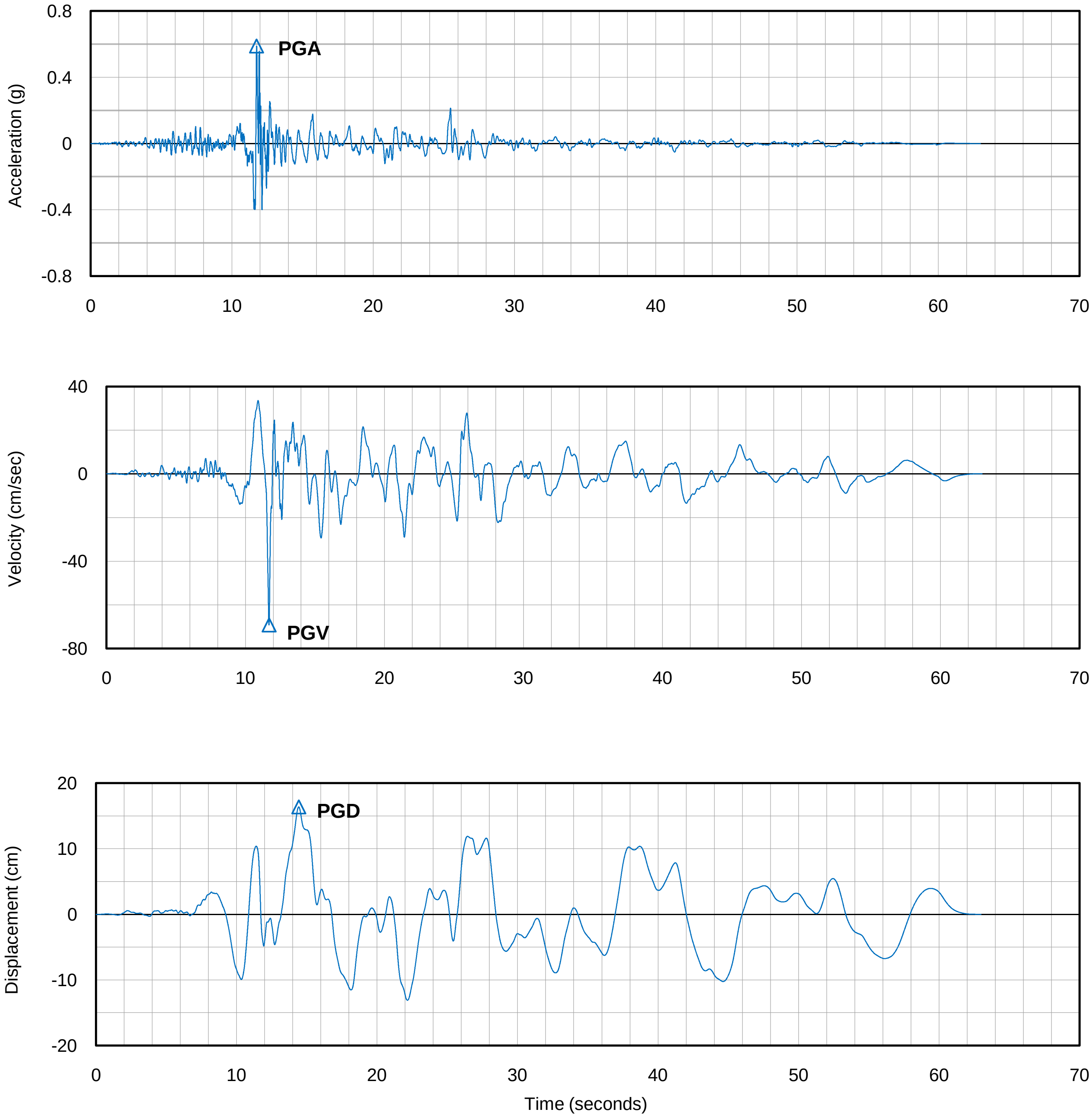
FIG. A-17



NOTES:

Reference Motion: Chi-Chi, Taiwan; TCU052 Fault Parallel
File: T052Fp2ac.avd

Peak Values

Acceleration	0.59 g
Velocity	69.3 cm/sec
Displacement	16.4 cm

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Seattle, Washington

1,000-YR GROUND MOTION
EQ3 FAULT PARALLEL
REFERENCE TIME HISTORY

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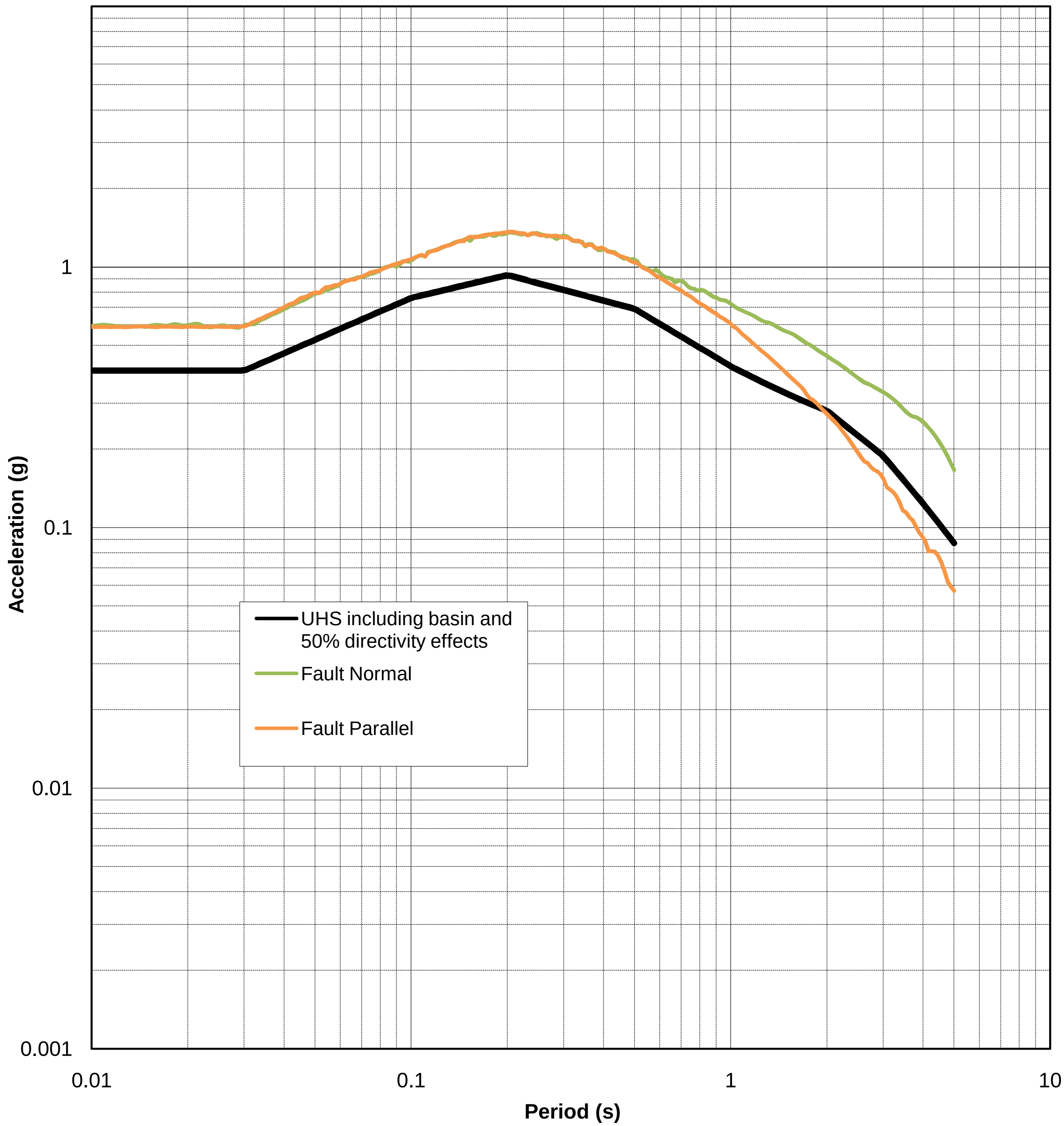
FIG. A-18



NOTES

Fault Normal File: t0fn-2c.avd
Fault Parallel File: t0fp-2c.avd

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1,000-YR GROUND MOTION
EQ3 REFERENCE TIME HISTORY
SPECTRAL ACCELERATION

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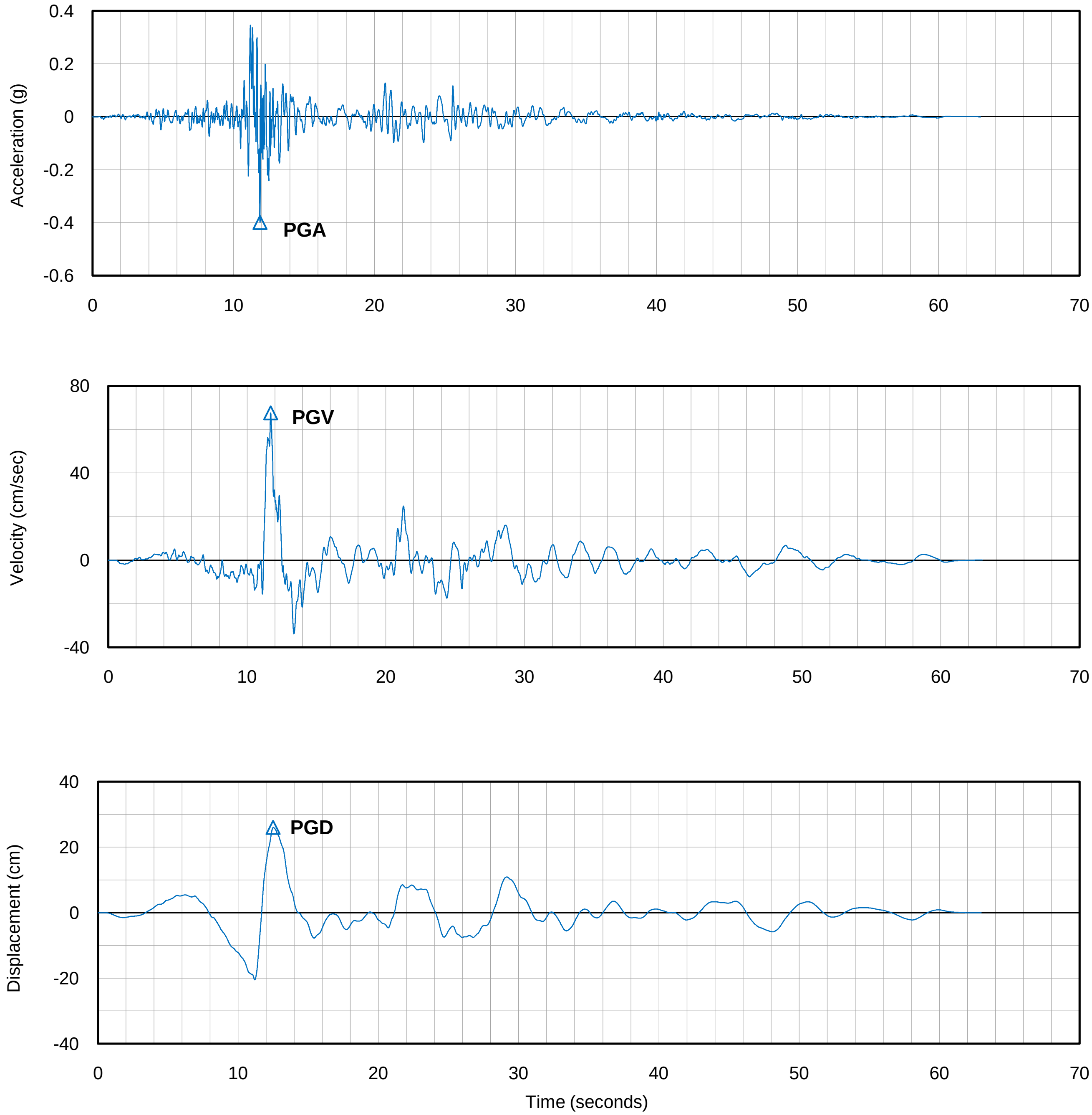
FIG. A-19



NOTES:

Reference Motion: Chi-Chi, Taiwan; TCU052 Fault Normal
File: t0fn-2c.avd

Peak Values

Acceleration	0.40 g
Velocity	67.6 cm/sec
Displacement	26.1 cm

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Seattle, Washington

1,000-YR GROUND MOTION
EQ3 FAULT NORMAL
MATCHED TIME HISTORY

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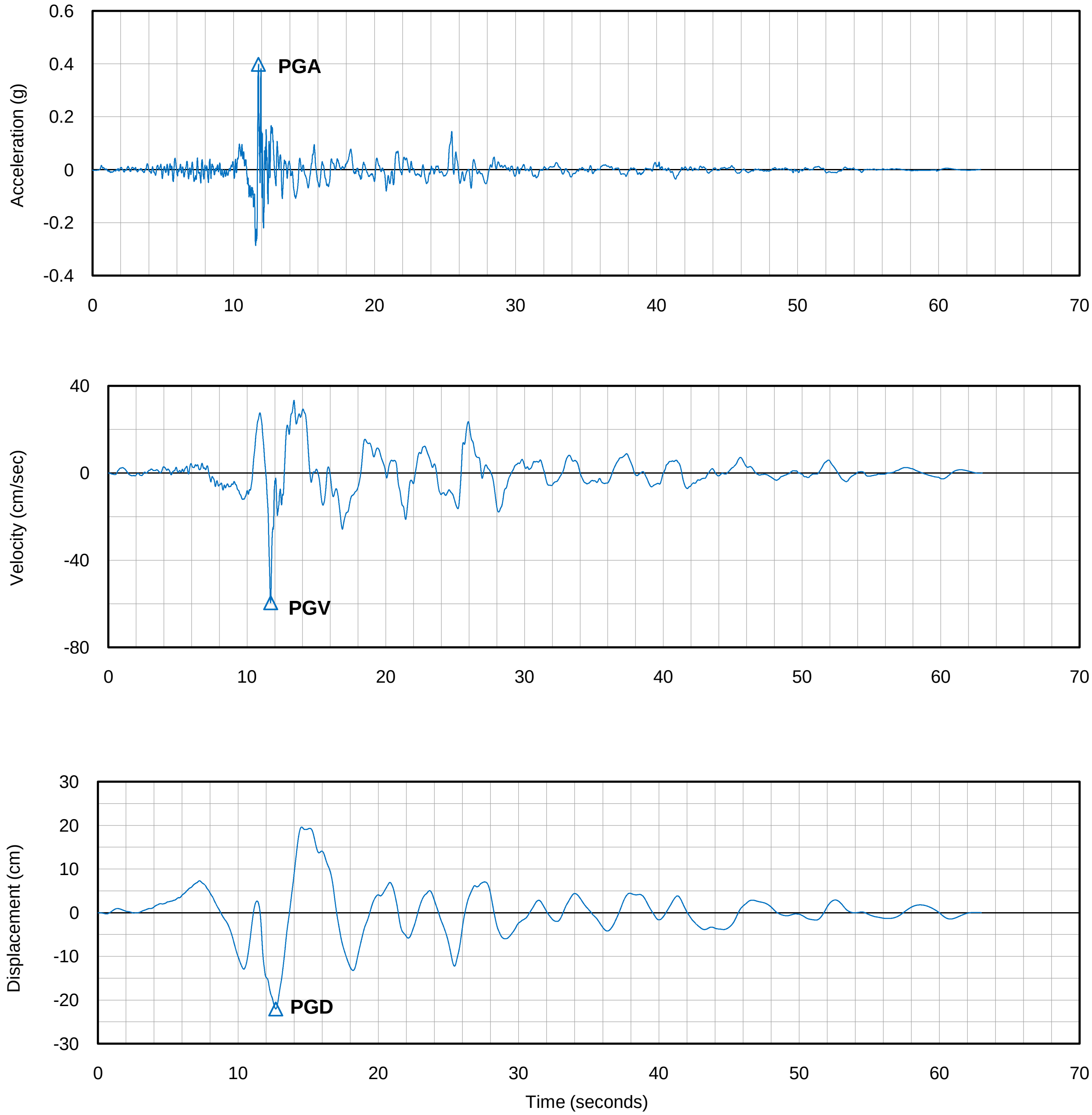
FIG. A-20



NOTES:

Reference Motion: Chi-Chi, Taiwan; TCU052 Fault Parallel
File: t0fp-2c.avd

Peak Values

Acceleration	0.40 g
Velocity	59.6 cm/sec
Displacement	22.1 cm

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1,000-YR GROUND MOTION
EQ3 FAULT PARALLEL
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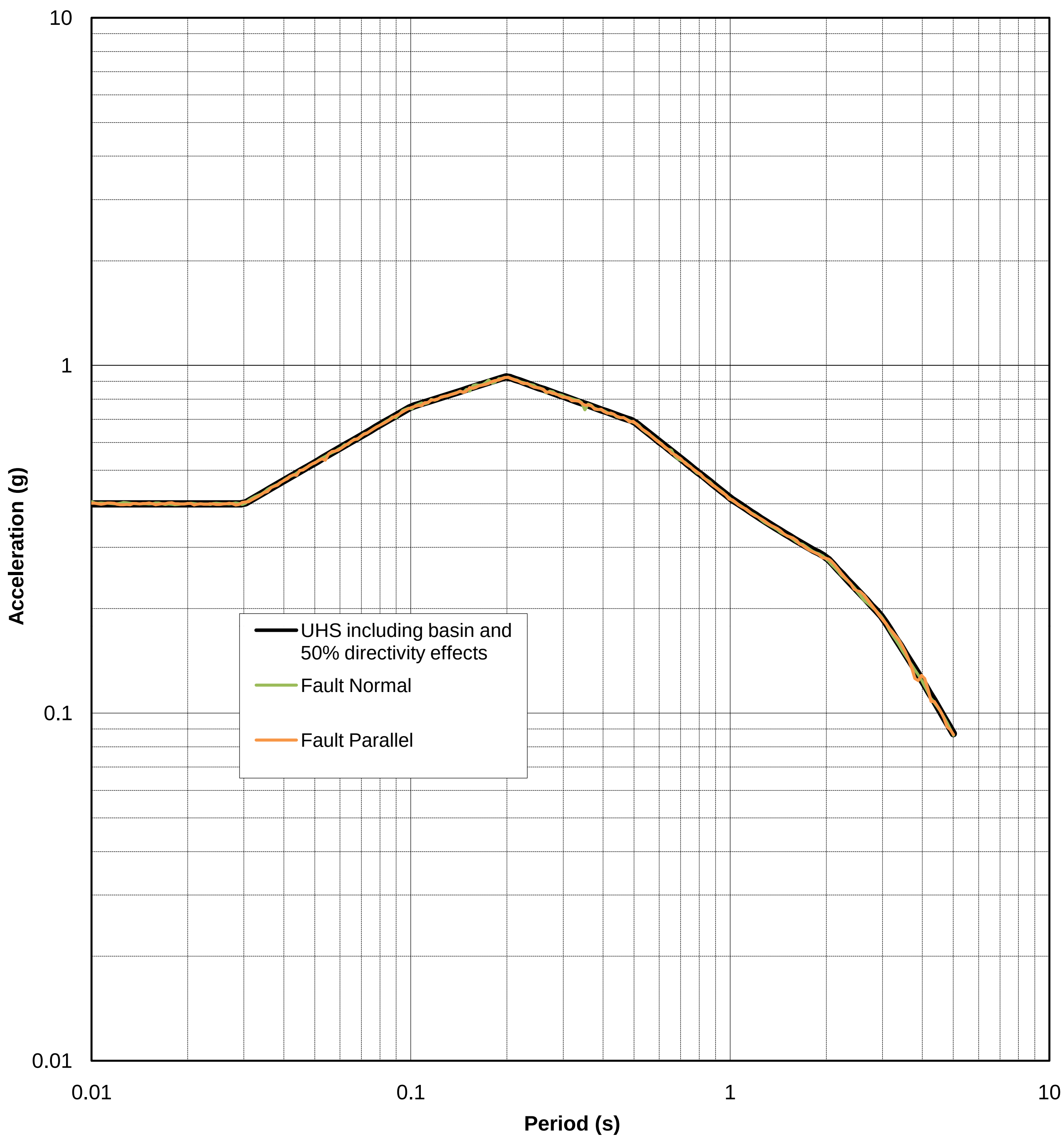
FIG. A-21



NOTES

Fault Normal File: t0fn-2c.avd
Fault Parallel File: t0fp-2c.avd

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1,000-YR GROUND MOTION
EQ3 MATCHED TIME HISTORY
SPECTRAL ACCELERATION

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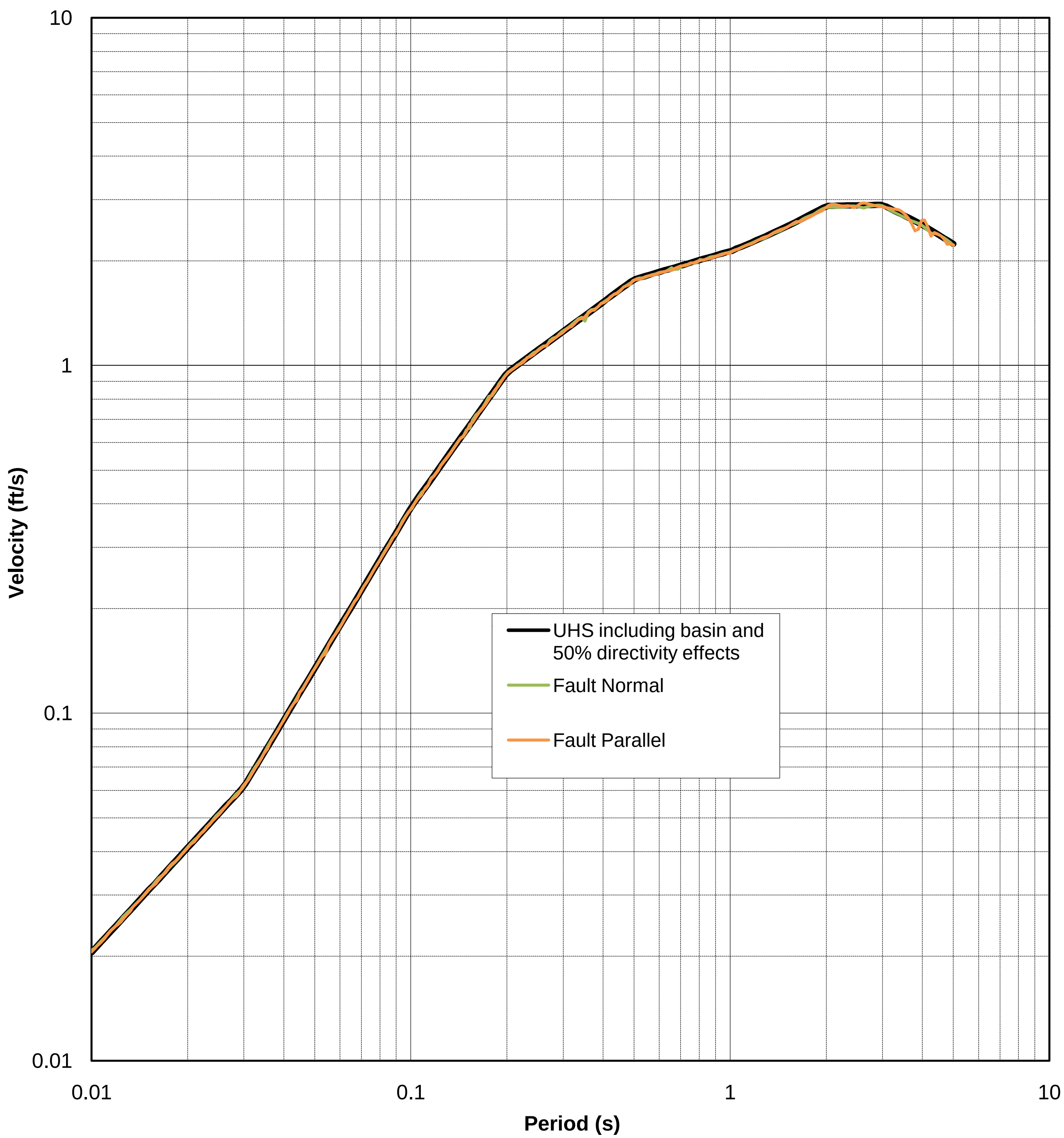
FIG. A-22



NOTES

Fault Normal File: t0fn-2c.avd
Fault Parallel File: t0fp-2c.avd

Alaska Way Viaduct and Seawall Program
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1,000-YR GROUND MOTION
EQ3 MATCHED TIME HISTORY
SPECTRAL VELOCITY

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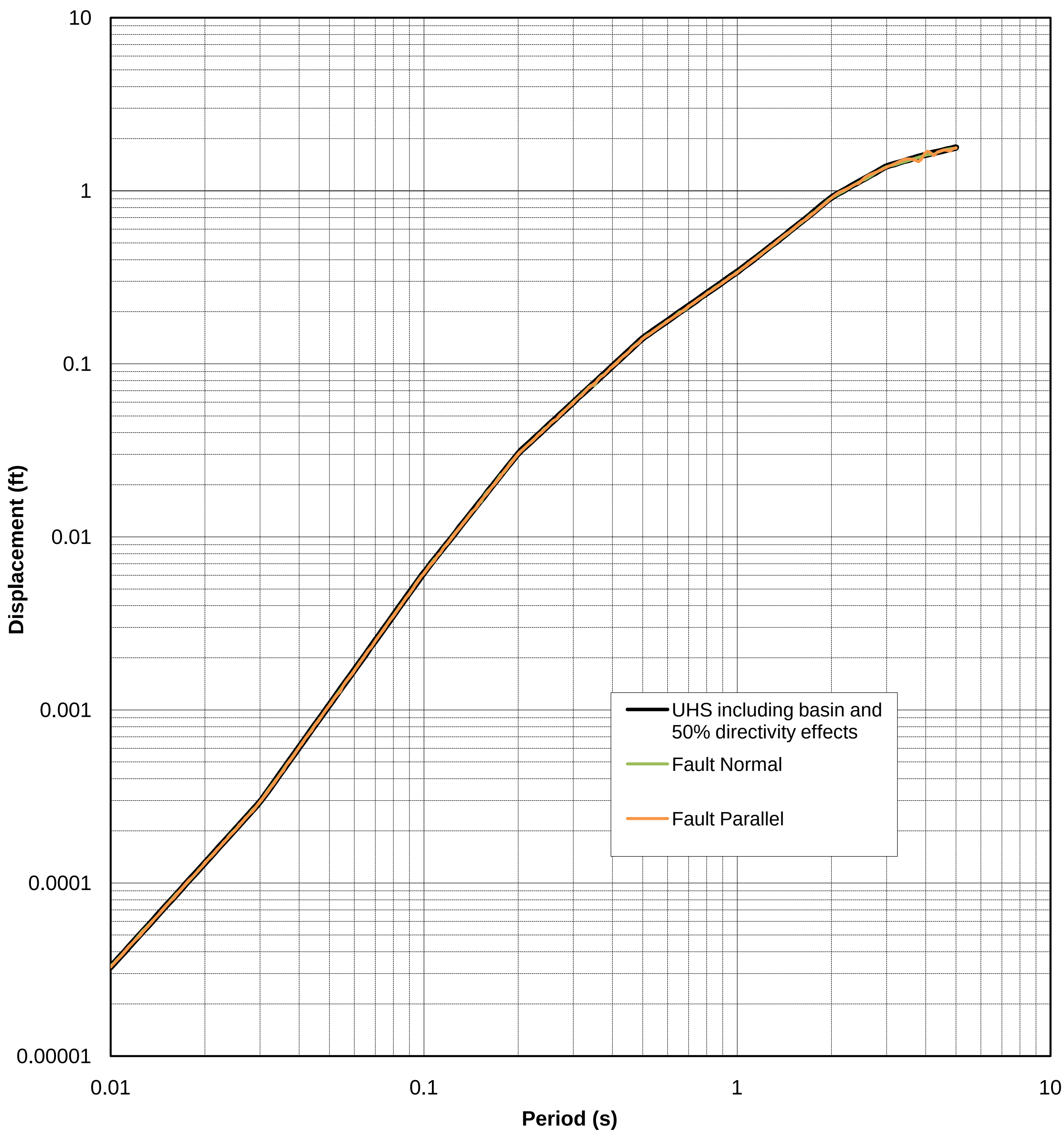
FIG. A-23



NOTES

Fault Normal File: t0fn-2c.avd
Fault Parallel File: t0fp-2c.avd

Alaska Way Viaduct and Seawall Program
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Seattle, Washington

1,000-YR GROUND MOTION EQ3 MATCHED TIME HISTORY SPECTRAL DISPLACEMENT

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FIG. A-24

Appendix B

Site-Specific Ground Response Analyses

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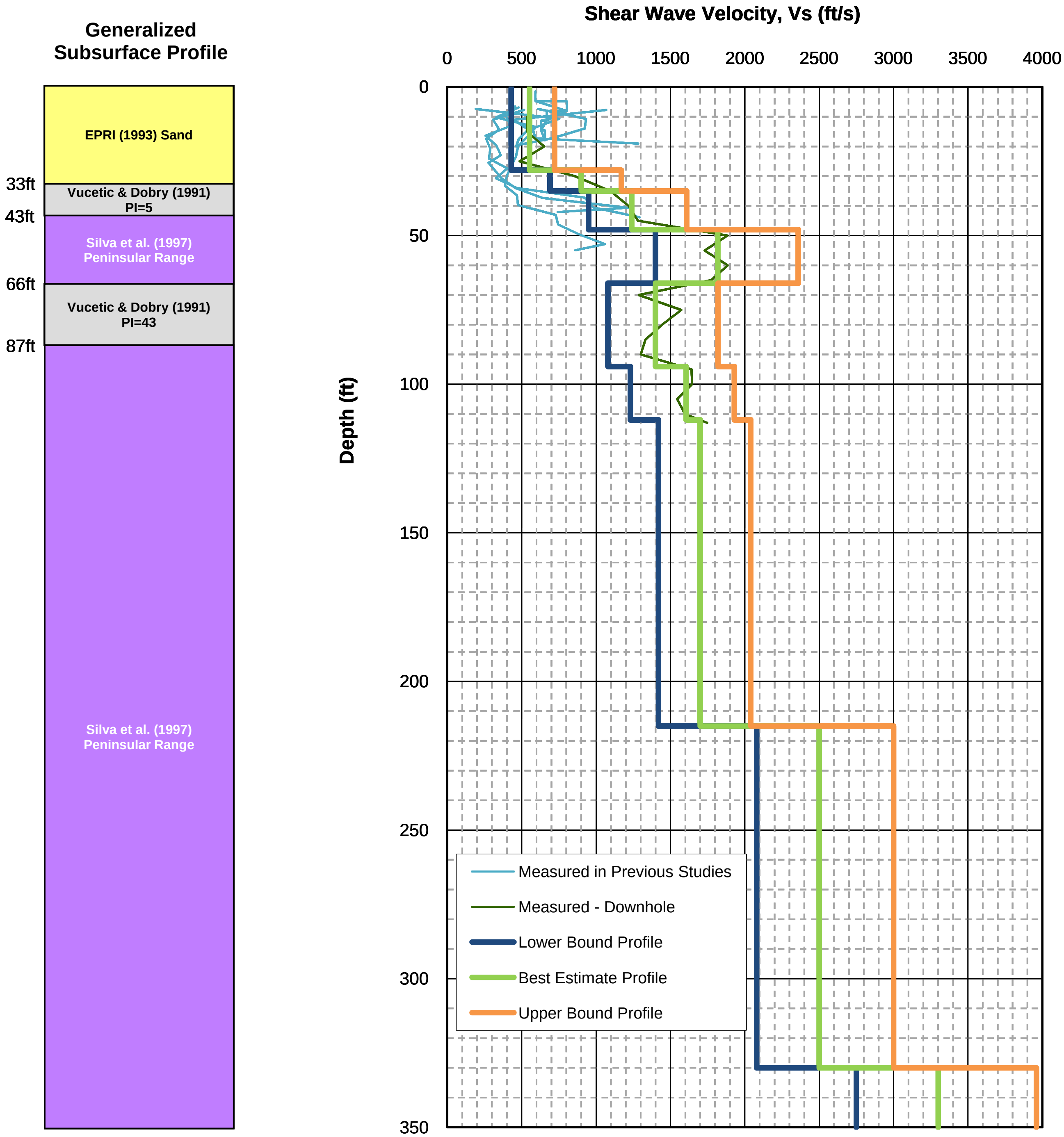

NOTES:
1. Profile contacts are approximate and are derived from boring EB-18B.

2. Velocity model is based on shear wave velocity measured at boring EB-18B and in similar geologic units in adjacent borings.

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SOIL MODEL
BORING EB-18B

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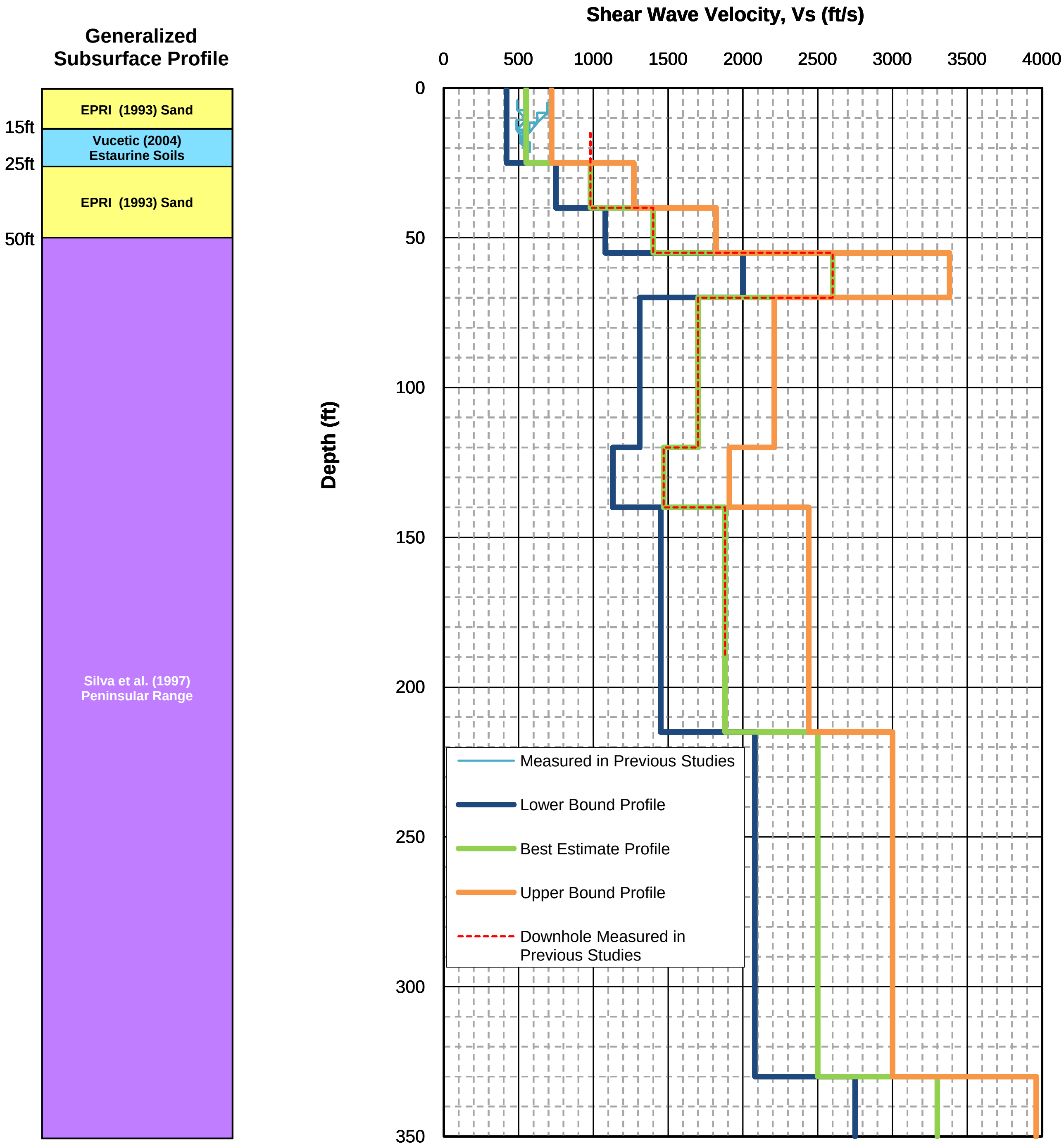
FIG. B-1

2004 Soil Models.xlsx 4/29/2009: kpc



NOTES:
1. Profile contacts are approximate and are derived from boring H-9-93.

2. Velocity model is based on shear wave velocity measured at boring H-9-93 and in similar geologic units in adjacent borings.

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SOIL MODEL
BORING H-9-93

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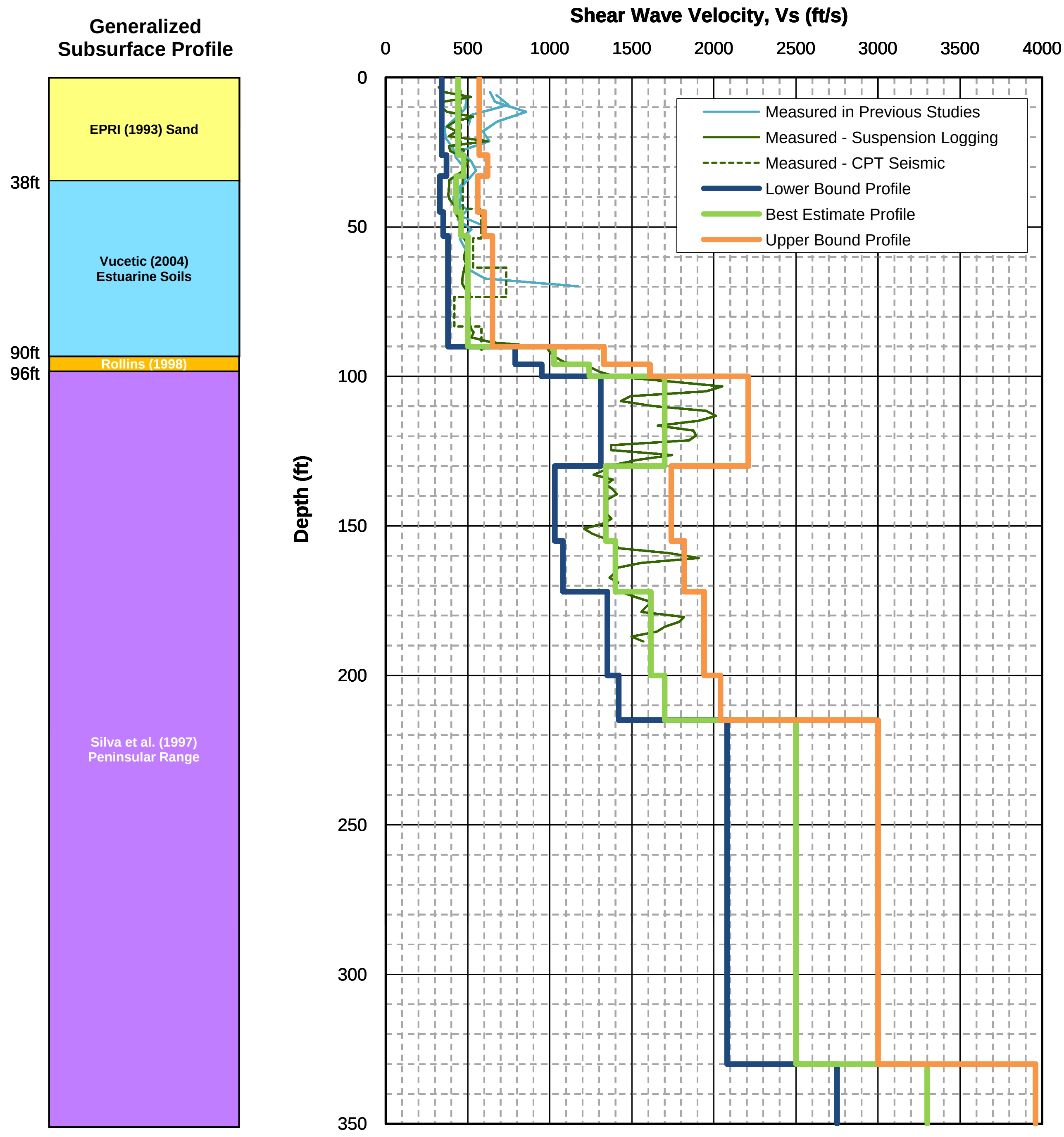
FIG. B-2



NOTES:
1. Profile contacts are approximate and are derived from boring SDC-001.

2. Velocity model is based on shear wave velocity measured at boring SDC-001 and in similar geologic units in adjacent borings.

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SOIL MODEL
BORING SDC-001

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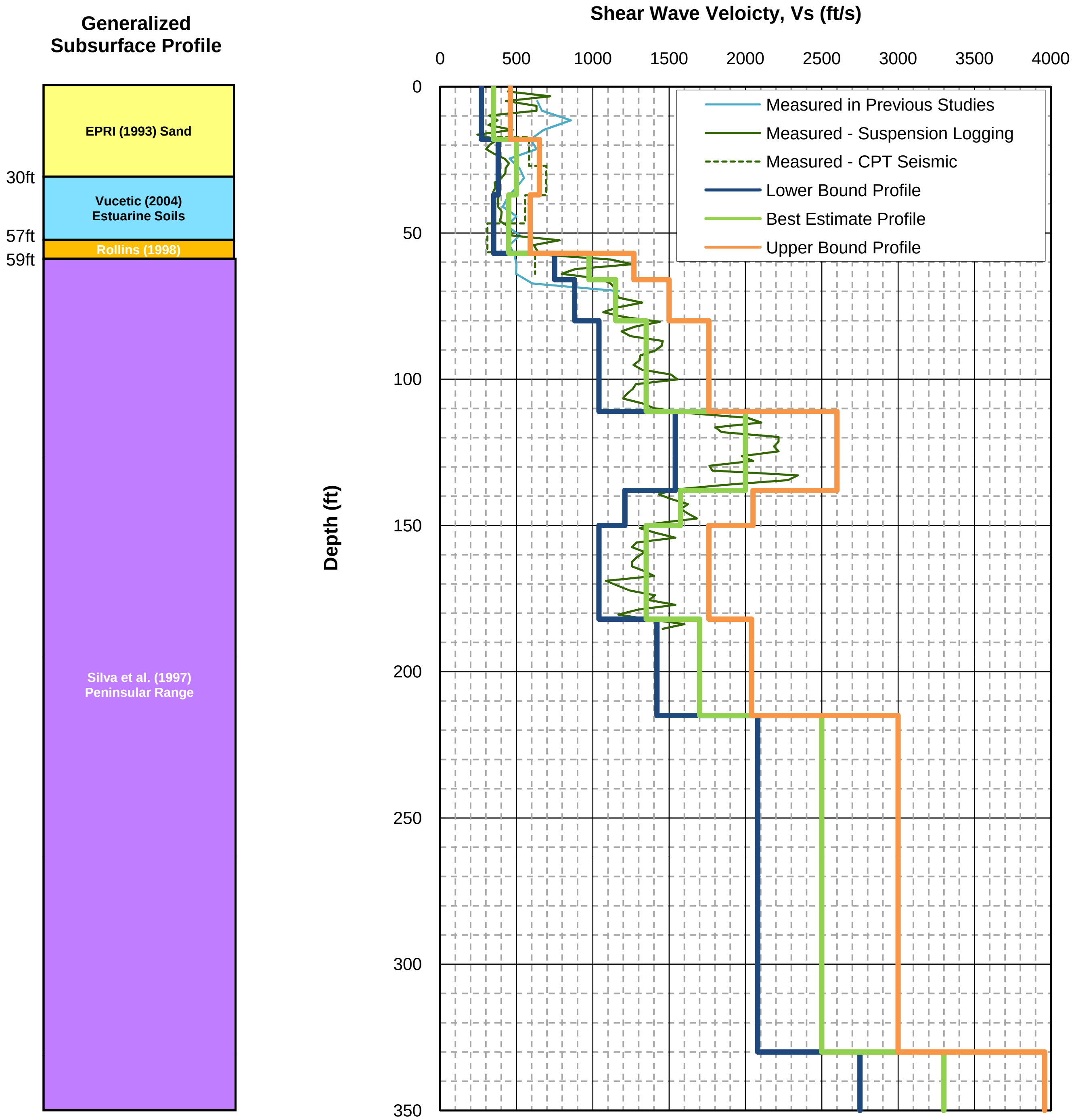
FIG. B-3



NOTES:
1. Profile contacts are approximate and are derived from boring SDC-002.

2. Velocity model is based on shear wave velocity measured at boring SDC-002 and in similar geologic units in adjacent borings.

Alaskan Way Viaduct and Seawall Program Seismic Ground Motion Study Update Seattle, Washington	
SOIL MODEL **SDC-002**	
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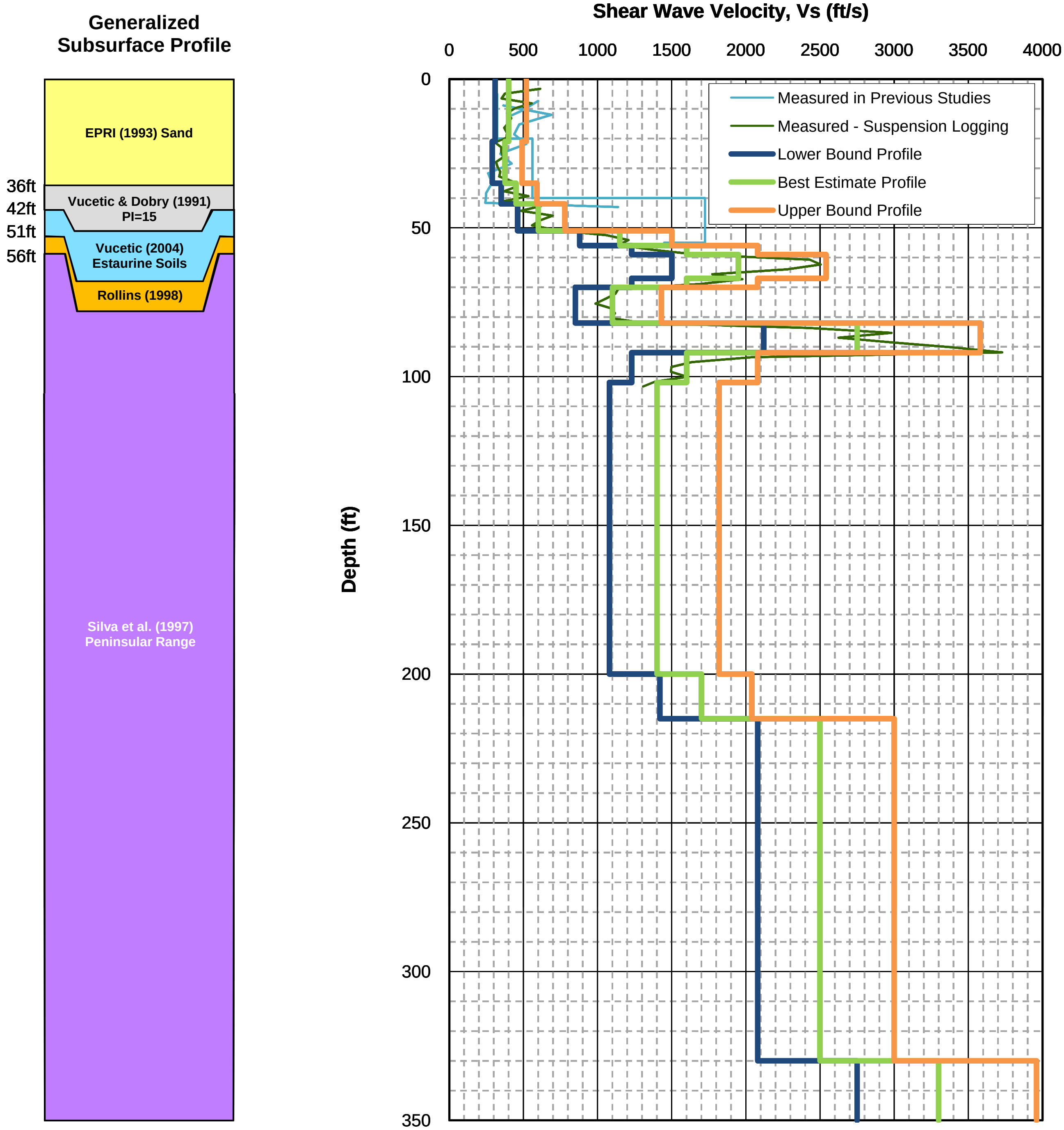
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. B-4**



NOTES:
1. Profile contacts are approximate and are derived from boring SDC-003.

2. Velocity model is based on shear wave velocity measured at boring SDC-003 and in similar geologic units in adjacent borings.

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SOIL MODEL
BORING SDC-003

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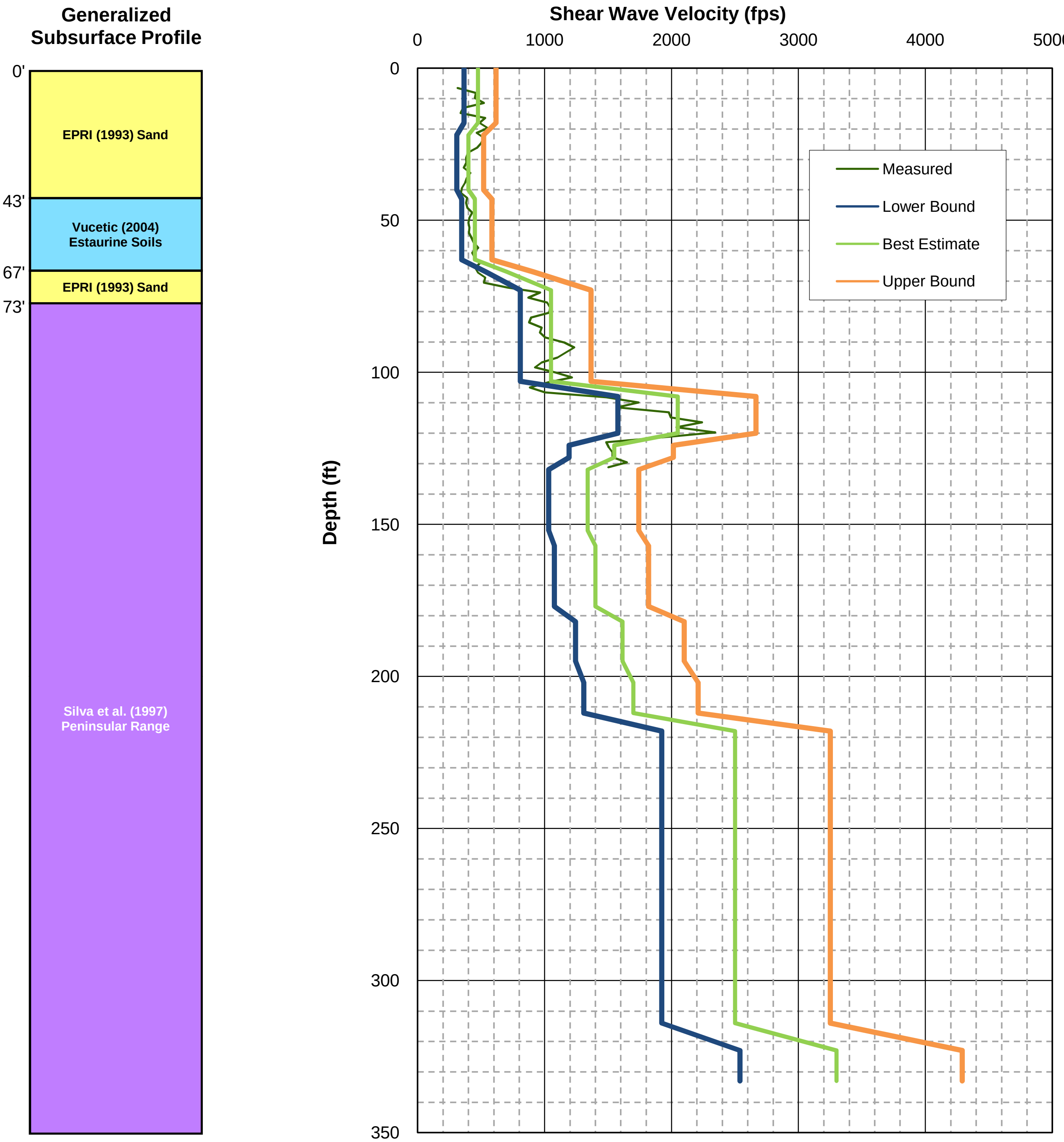
FIG. B-5

2008 Soil Models.xlsm Printed: 3/26/2009



NOTES:
1. Profile contacts are approximate and are derived from boring IB-240.

2. Velocity model is based on shear wave velocity measured at boring IB-240 and in similar geologic units in adjacent borings.

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SOIL MODEL
BORING IB-240

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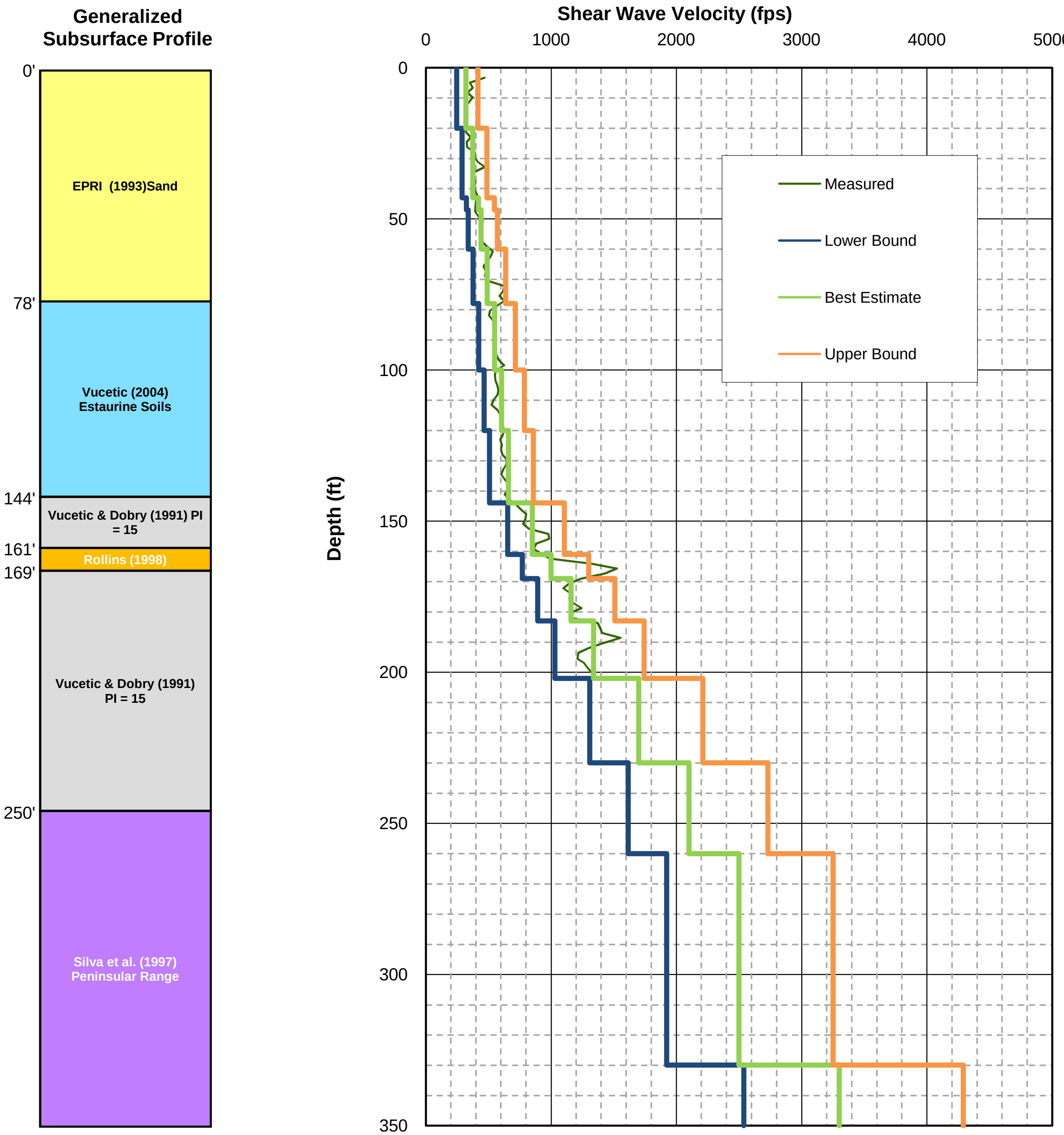
FIG. B-6



NOTES:
1. Profile contacts are approximate and are derived from boring IB-258

2. Velocity model is based on shear wave velocity measured at boring IB-258 and in similar geologic units in adjacent borings.

Alaskan Way Viaduct and Seawall Program
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SOIL MODEL
BORING IB-258

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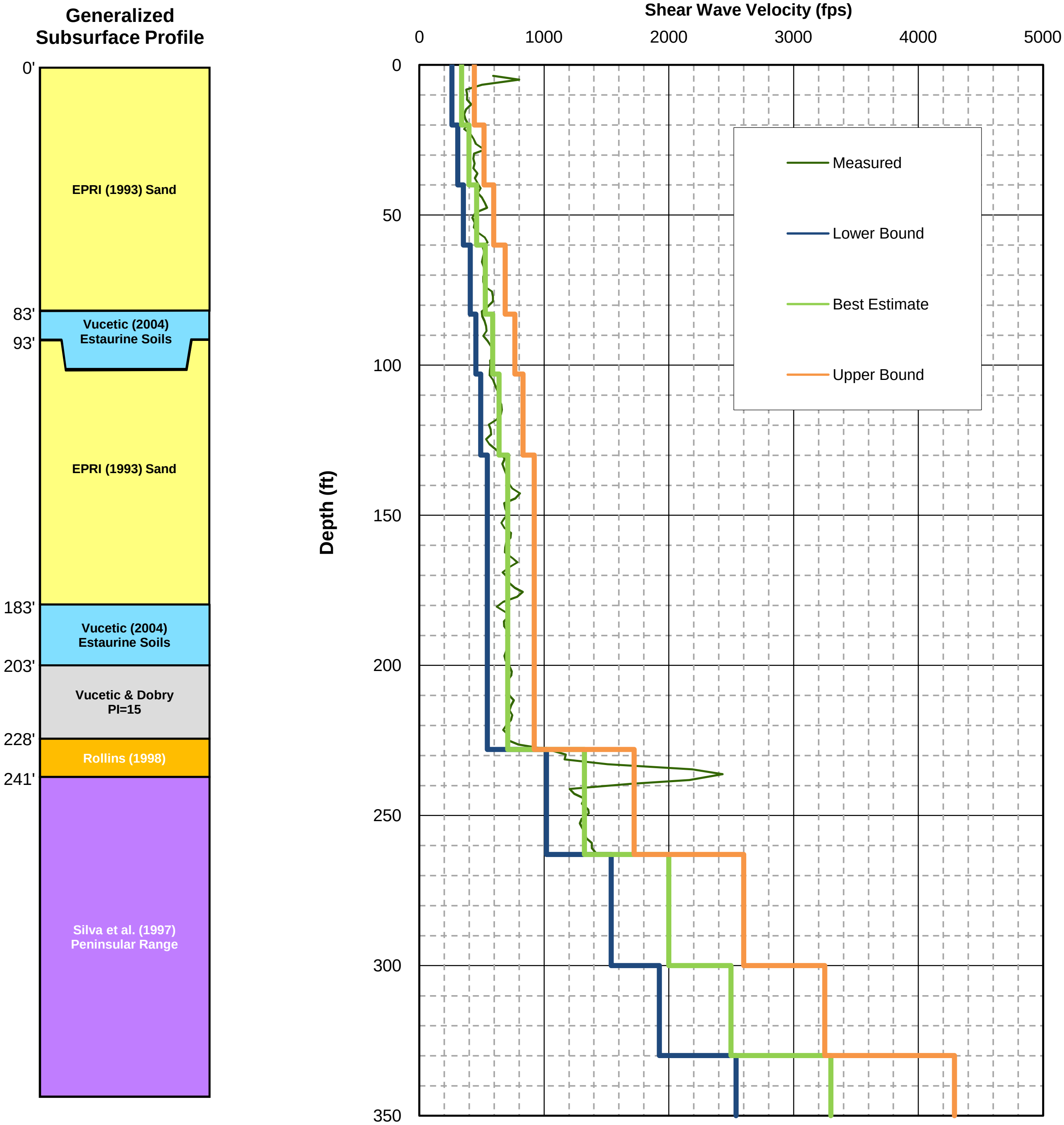
FIG. B-7



NOTES:
1. Profile contacts are approximate and are derived from boring IB-263.

2. Velocity model is based on shear wave velocity measured at boring IB-263 and in similar geologic units in adjacent borings.

Alaskan Way Viaduct and Seawall Program
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SOIL MODEL
BORING IB-263

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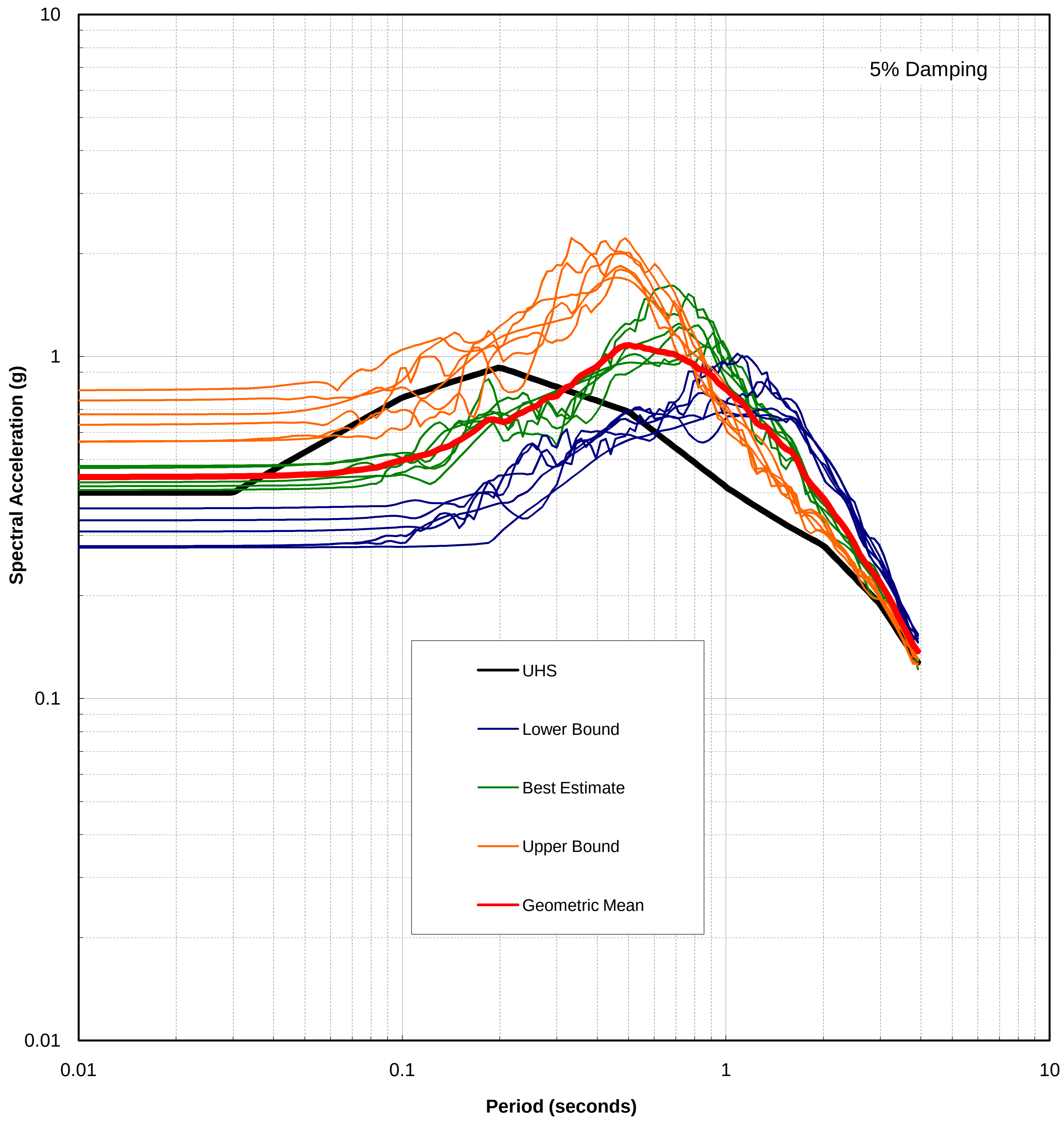
FIG. B-8



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1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA BORING EB-18B

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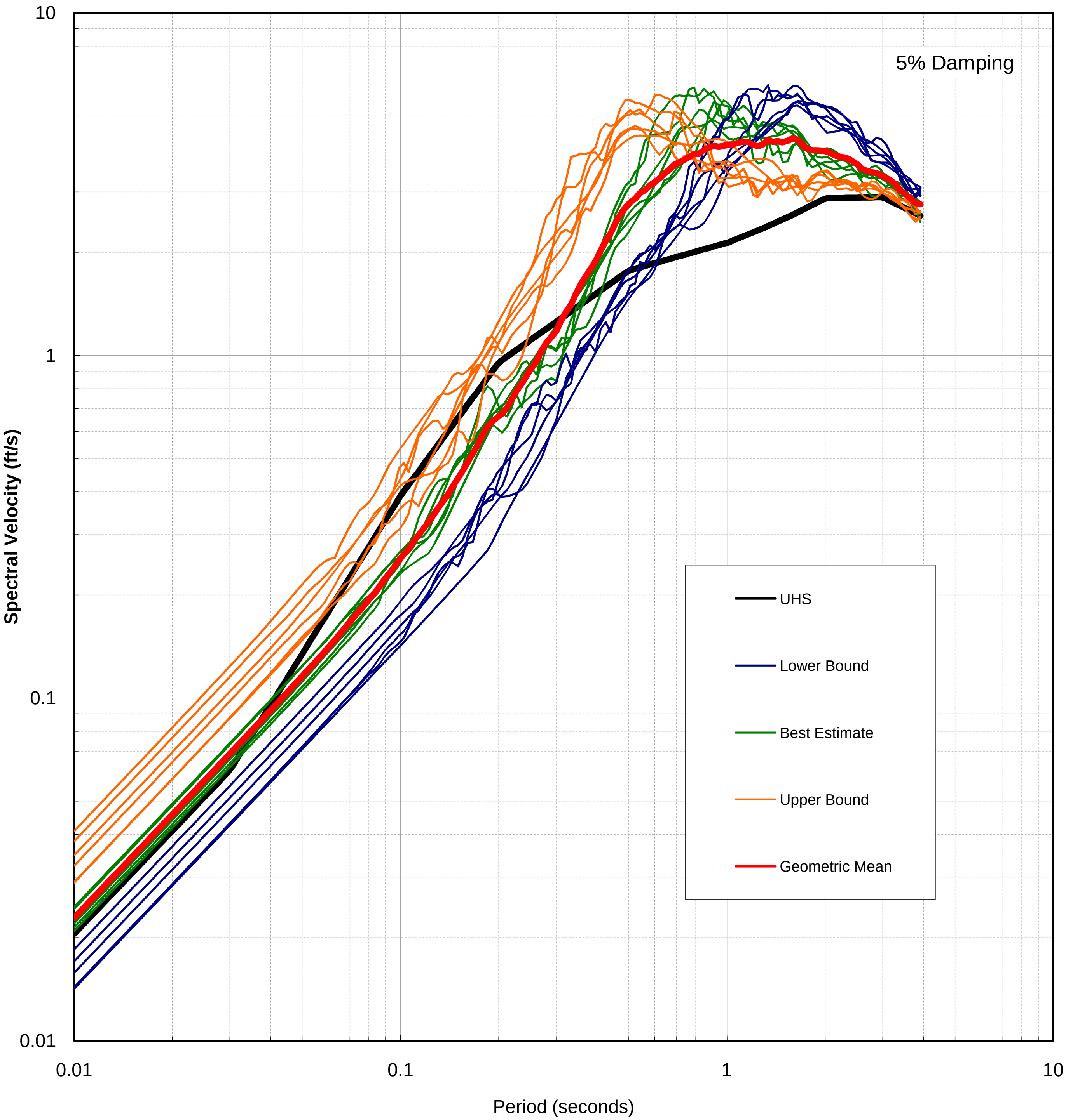
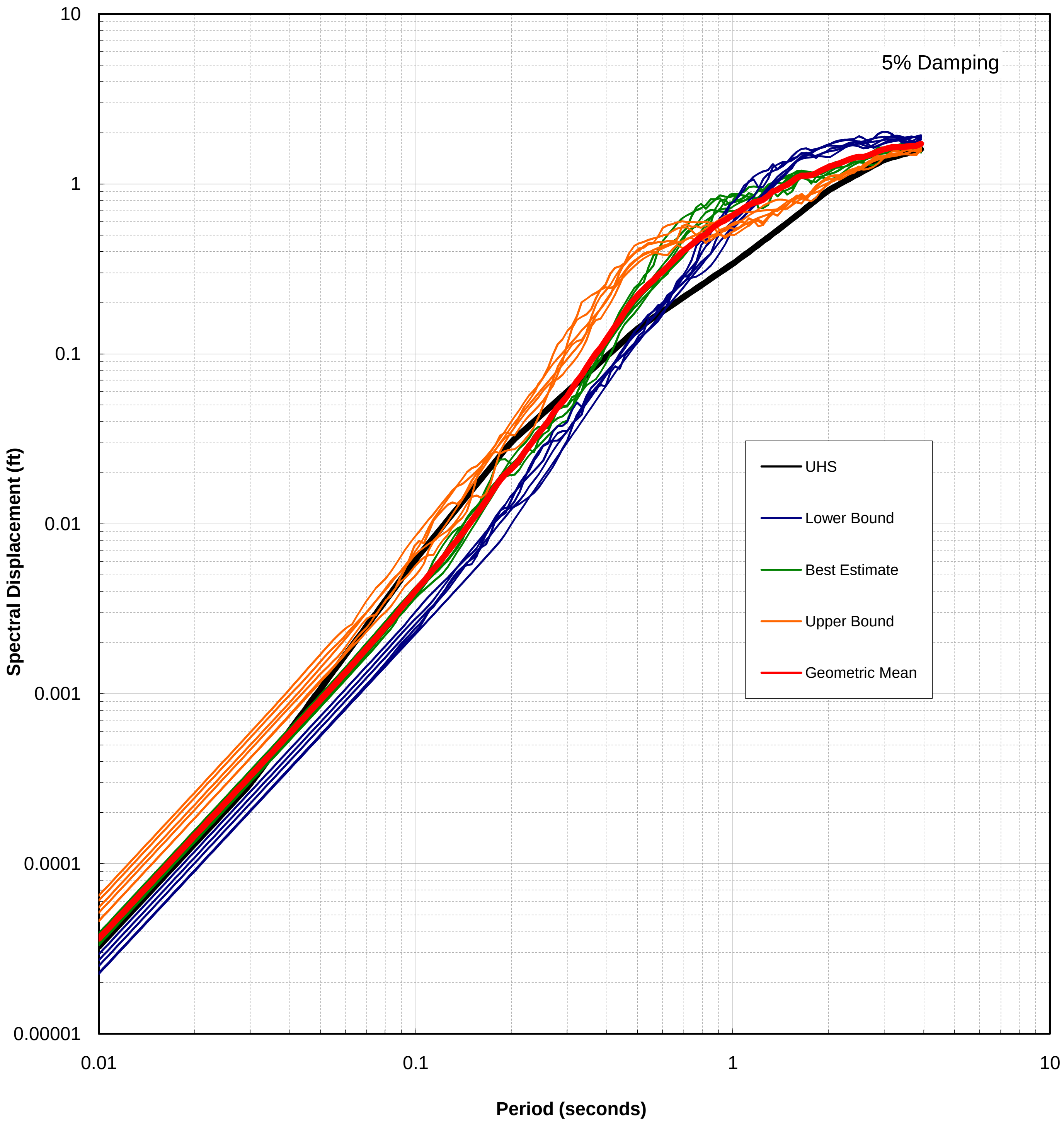
FIG. B-9

SHAKE EB-18B.xlsm 3/26/2009: kpc



Alaskan Way Viaduct and Seawall Program Seismic Ground Motion Study Update Seattle, Washington	
1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA BORING EB-18B April 2009 21-1-20840-041	
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. B-10**



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1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA BORING EB-18B

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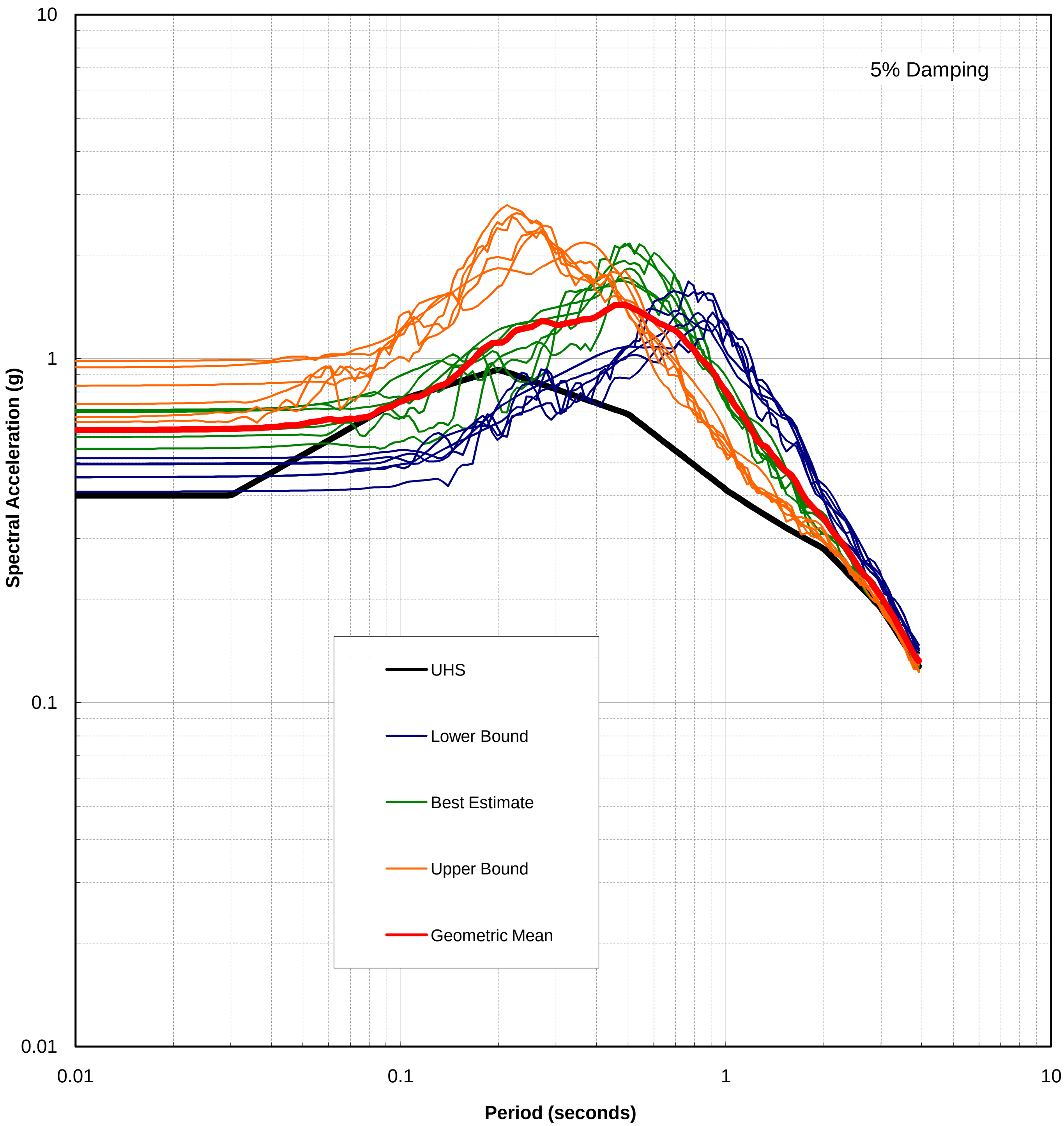
FIG. B-11



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA BORING H-9-93

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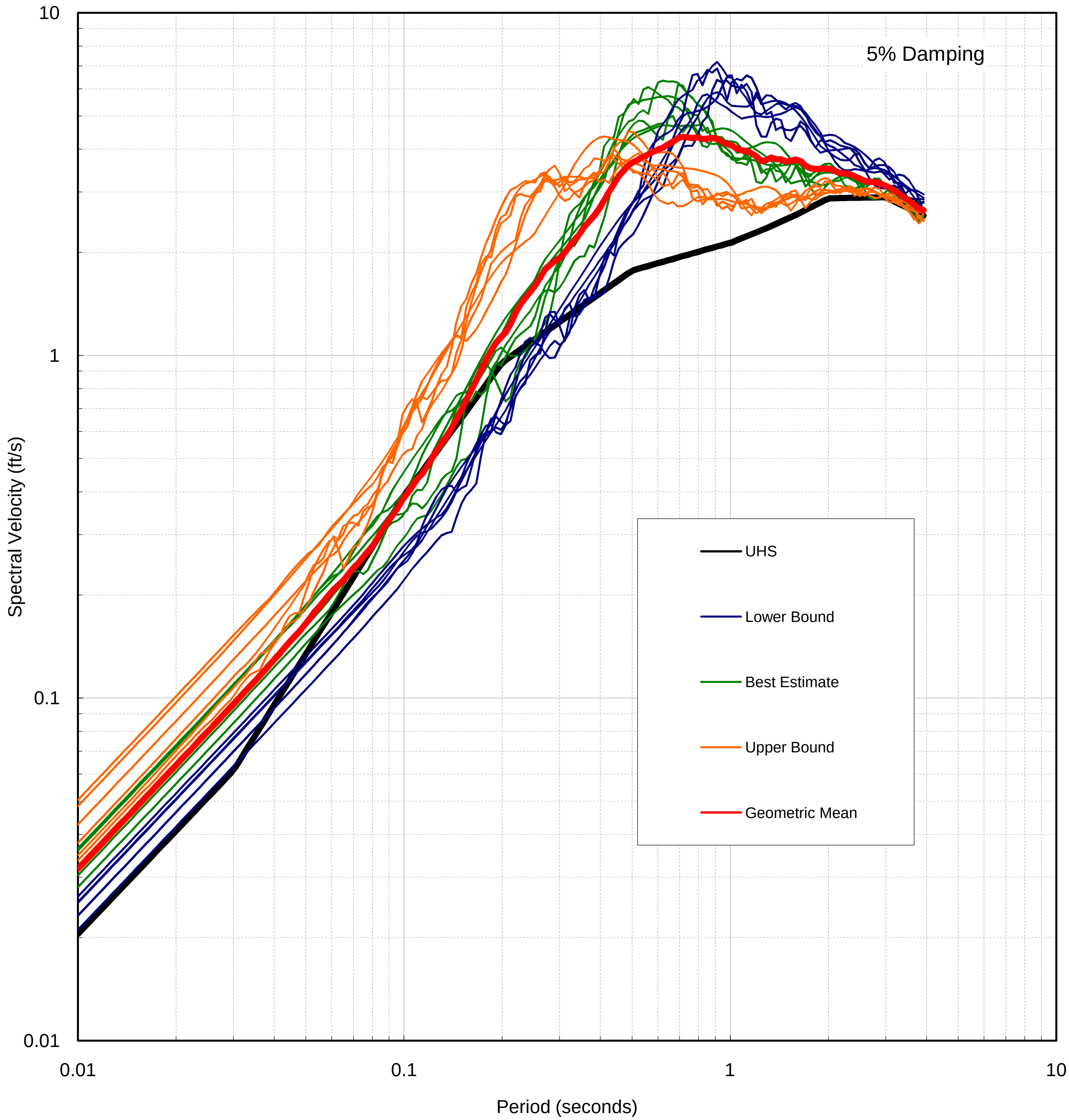
FIG. B-12

SHAKE H-9-93.xlsm 3/26/2009: kpc



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA BORING H-9-93

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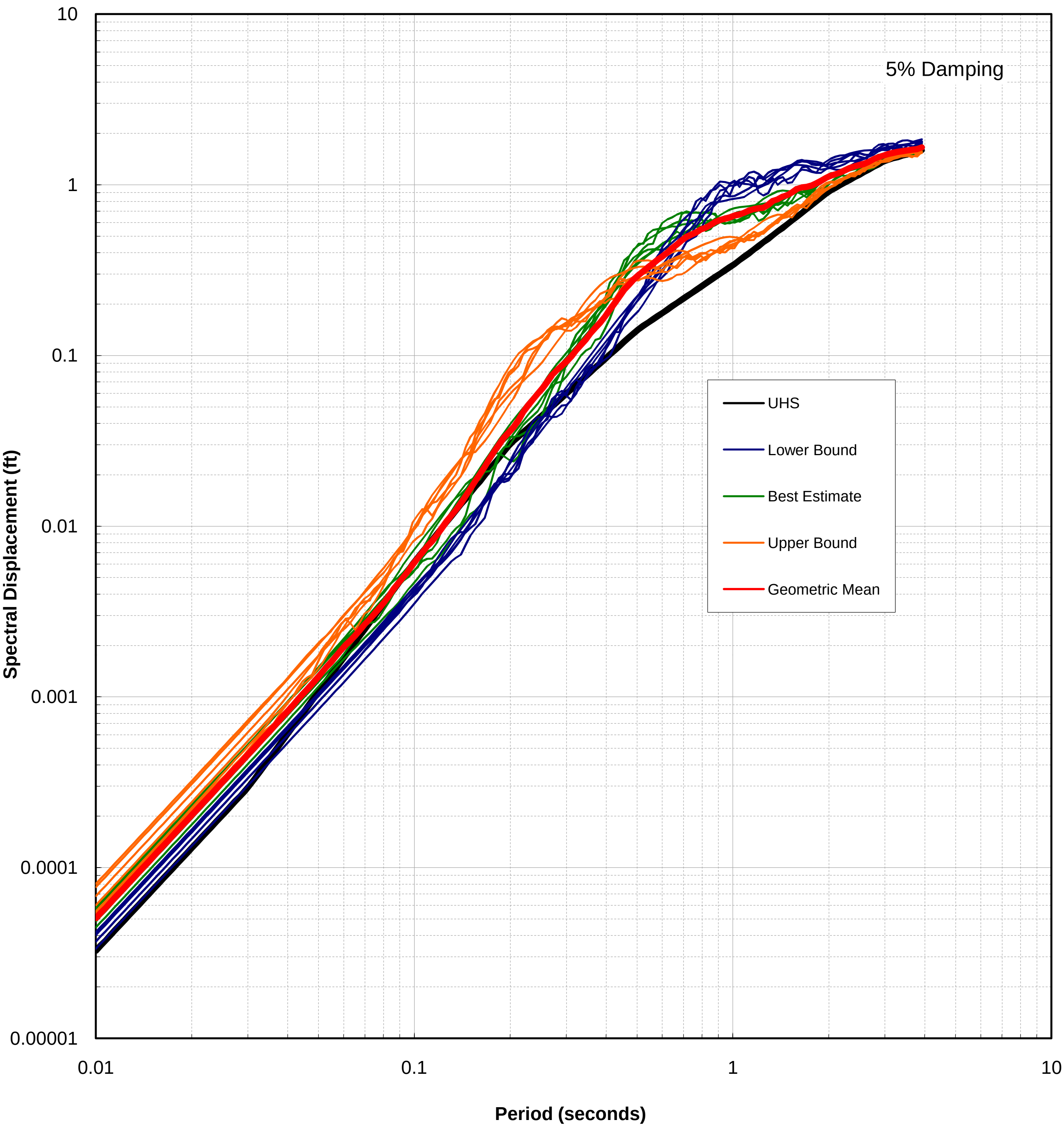
FIG. B-13



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1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA BORING H-9-93

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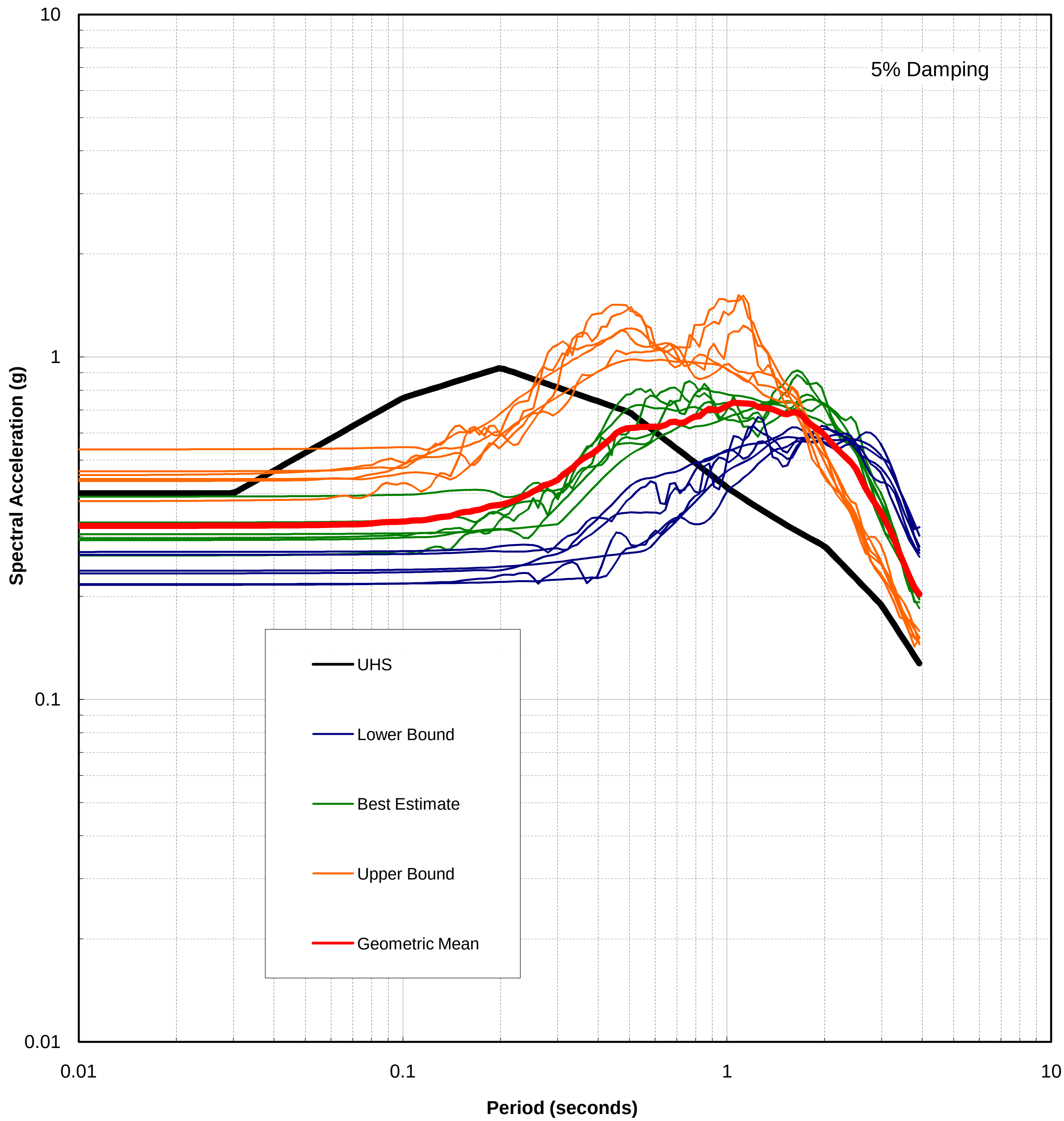
FIG. B-14



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1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA SDC-001

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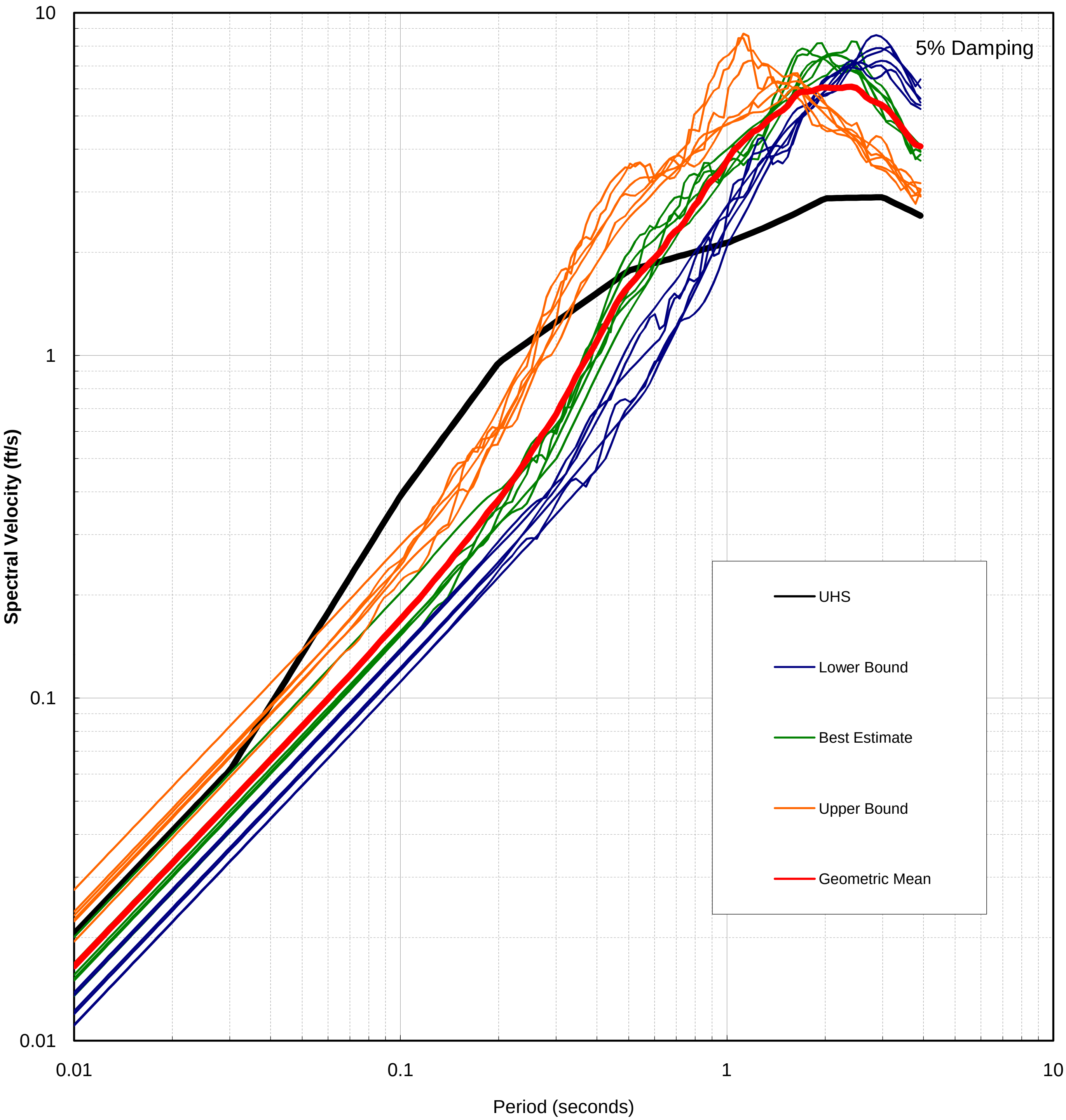
FIG. B-15



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1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA SDC-001

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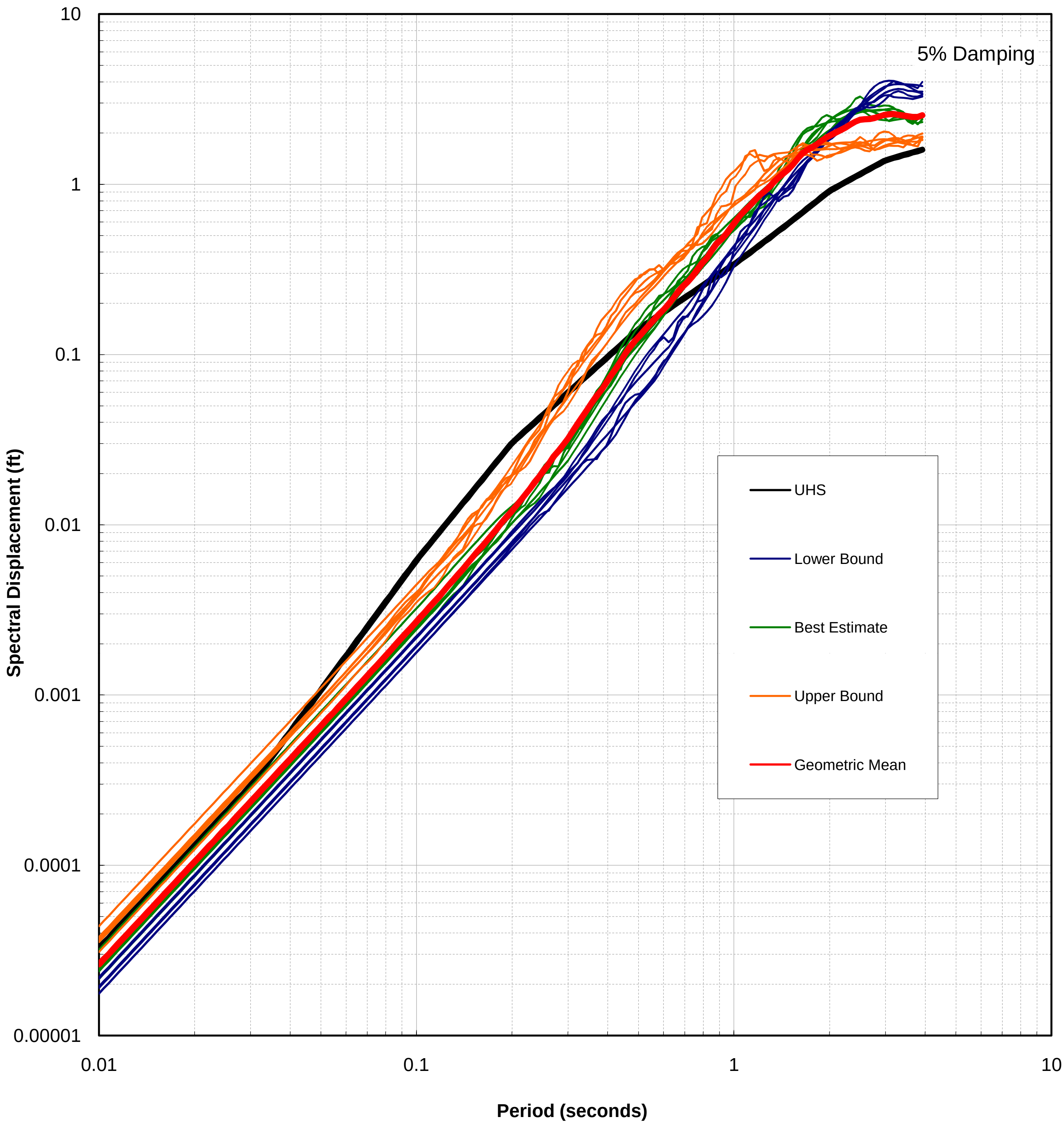
FIG. B-16

SHAKE SDC-001.xlsm 3/26/2009: kpc



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1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA SDC-001

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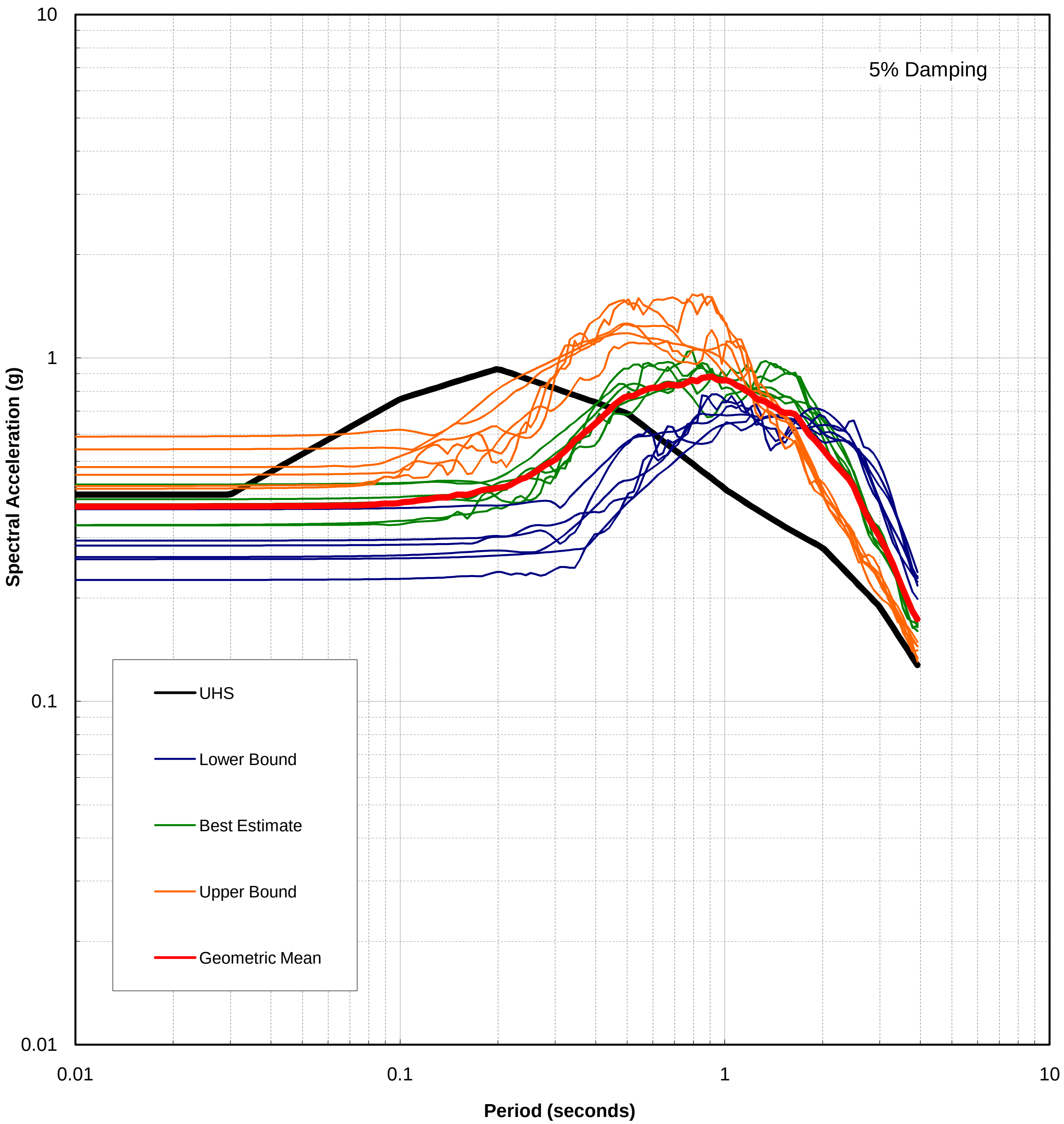
FIG. B-17



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA SDC-002

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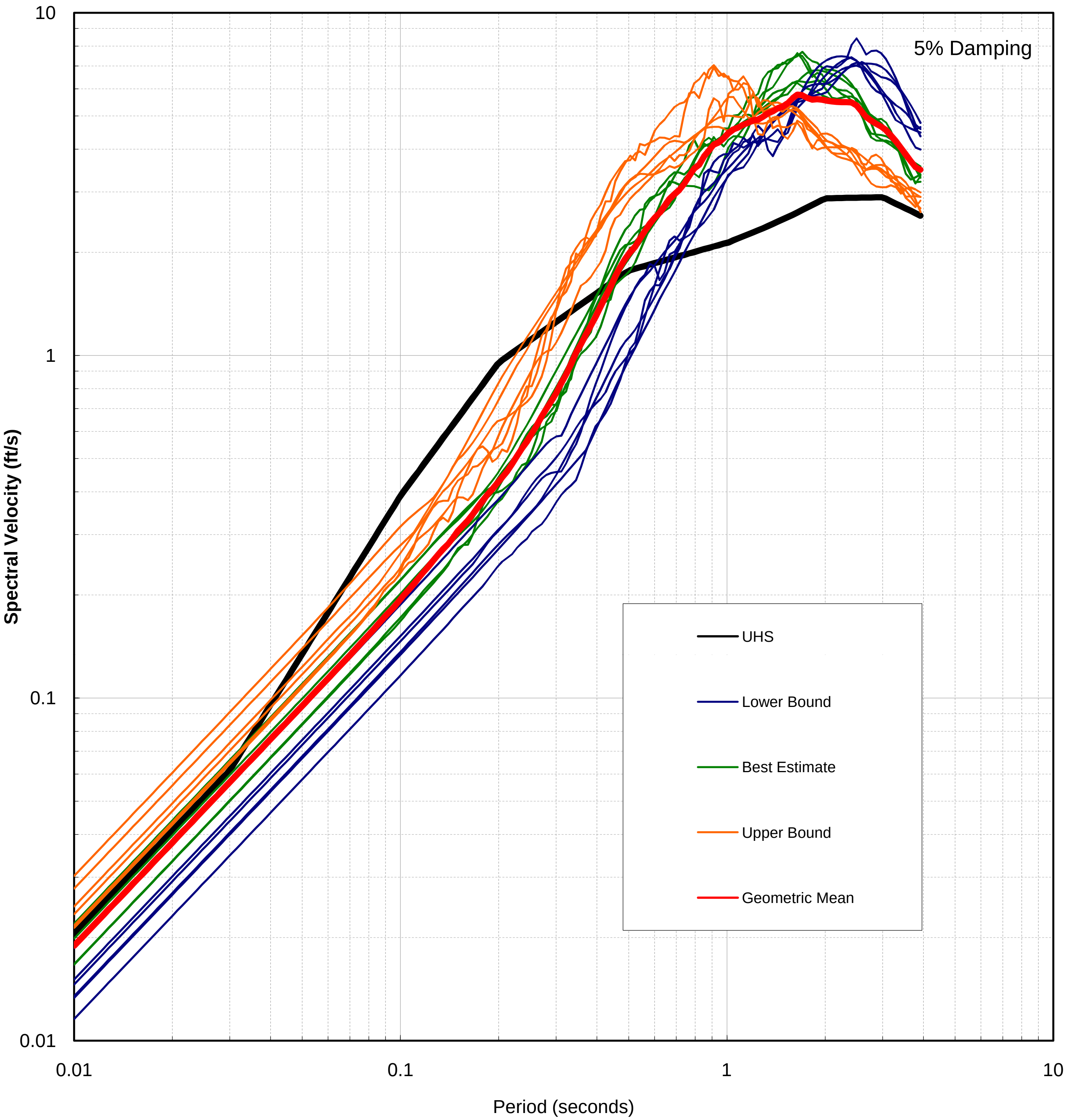
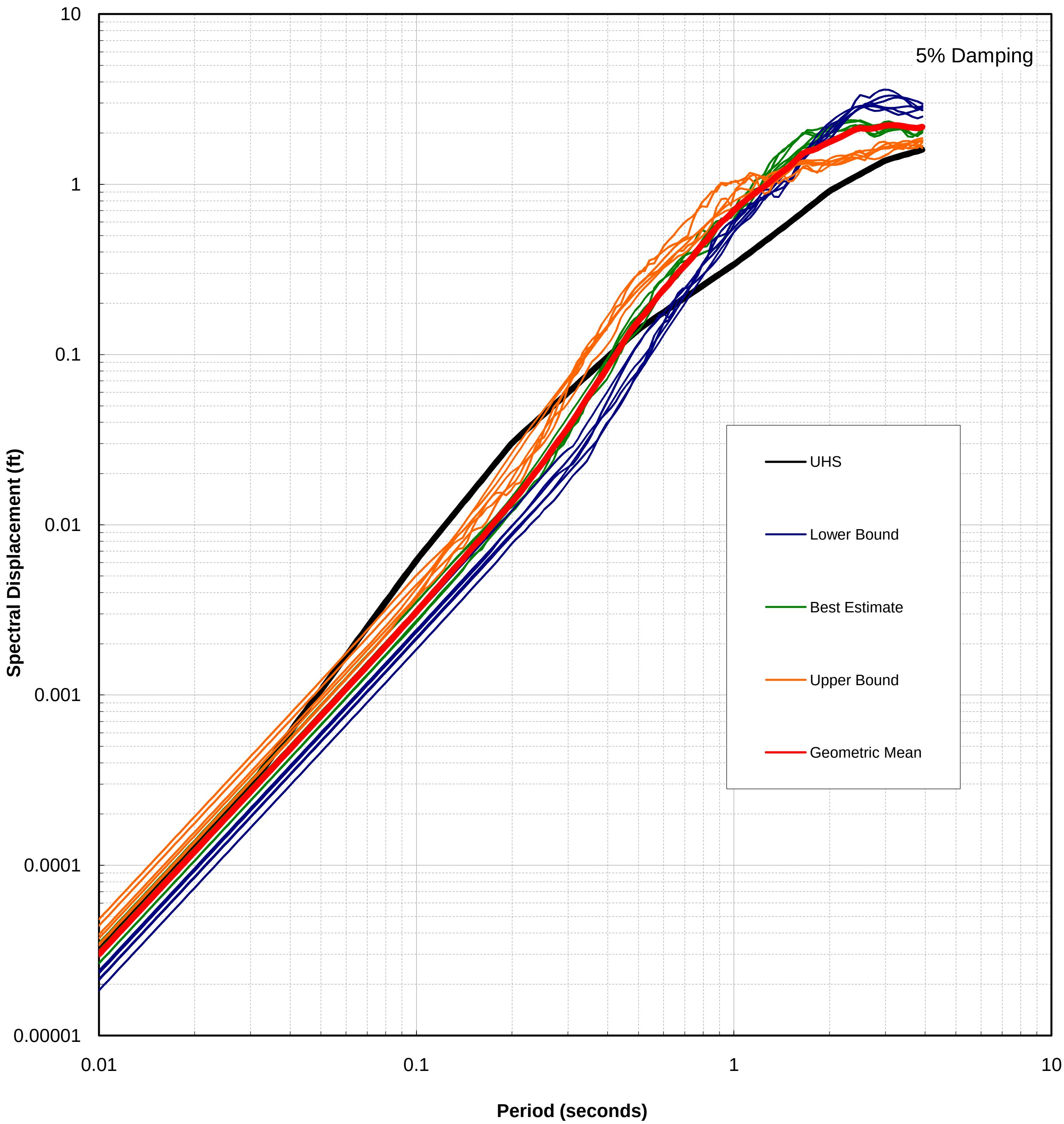
FIG. B-18

SHAKE SDC-002.xlsm 3/26/2009: kpc



Alaskan Way Viaduct and Seawall Program Seismic Ground Motion Study Update Seattle, Washington	
1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA SDC-002	
April 2009	21-1-20840-041
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants	**FIG. B-19**



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA SDC-002

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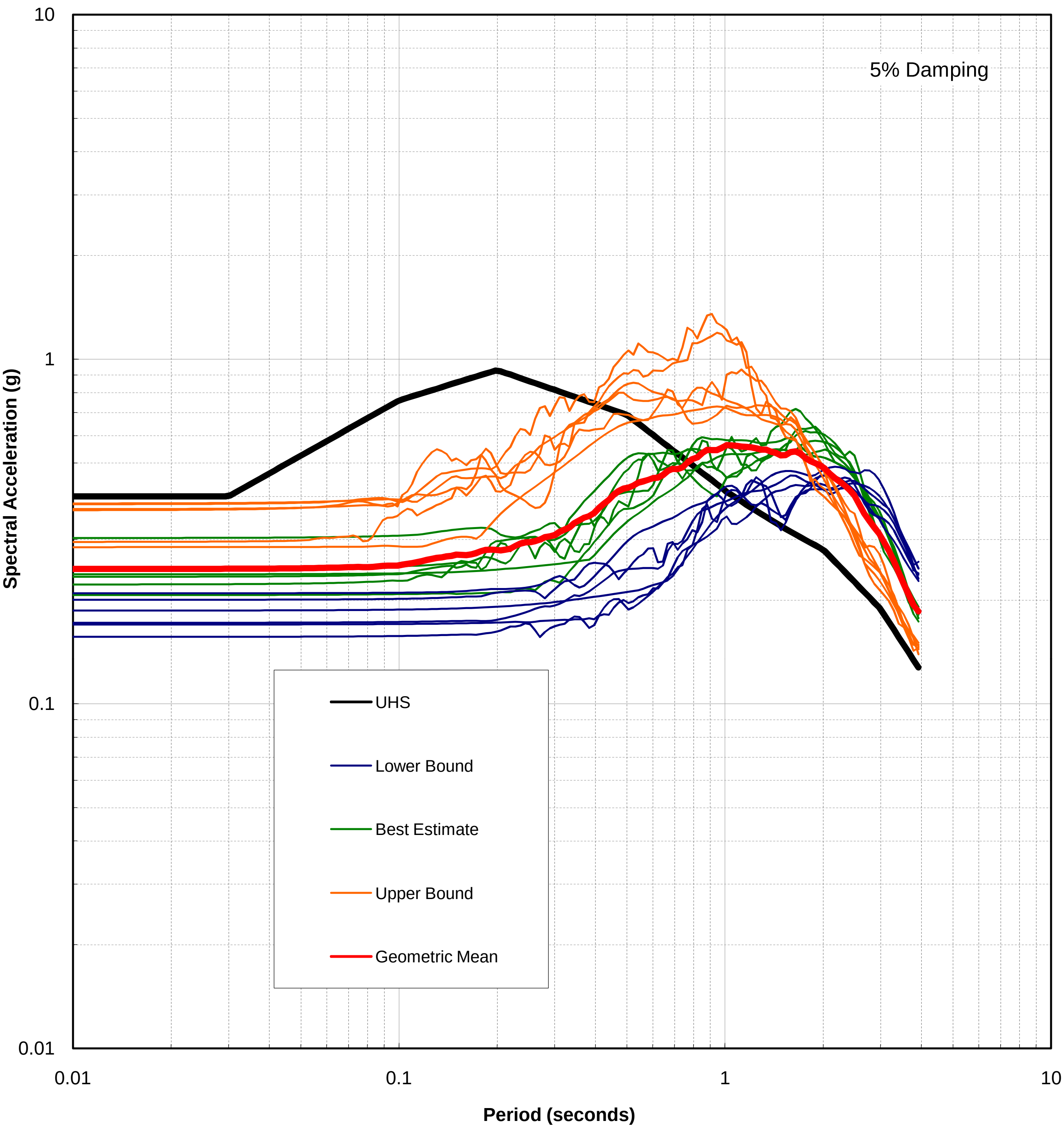
FIG. B-20



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1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA SDC-003

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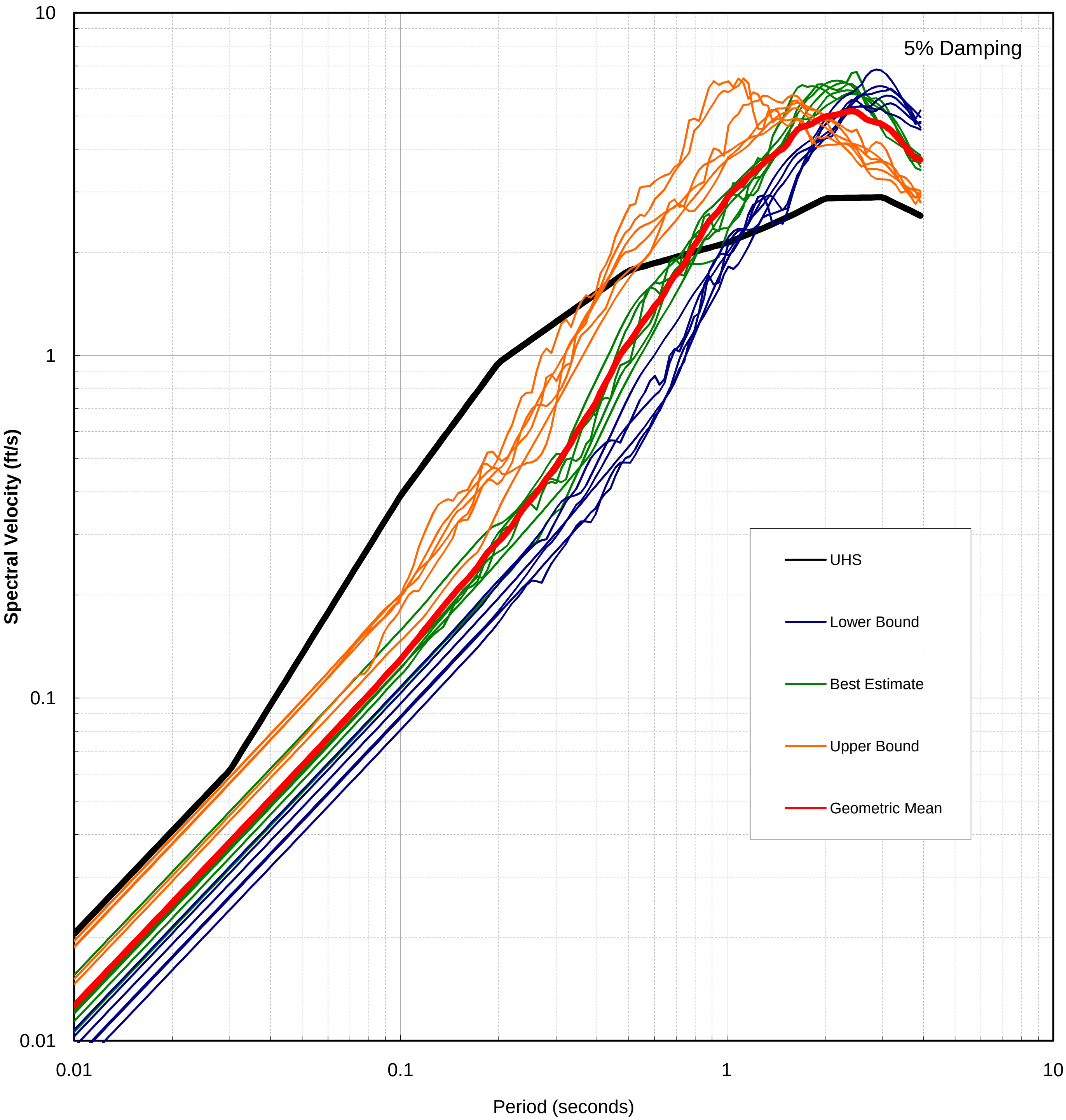
FIG. B-21



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1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA SDC-003

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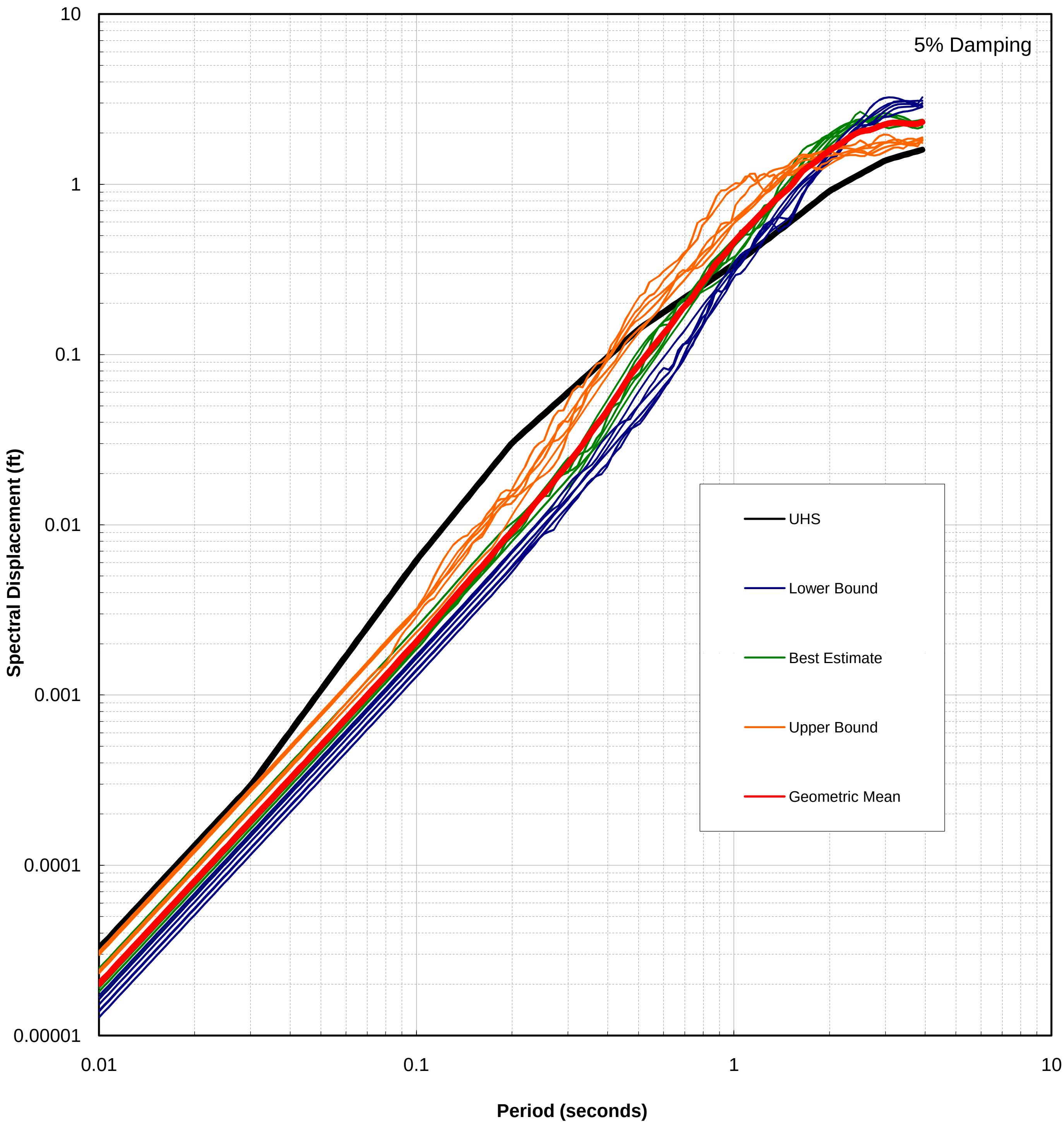
FIG. B-22



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1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA SDC-003

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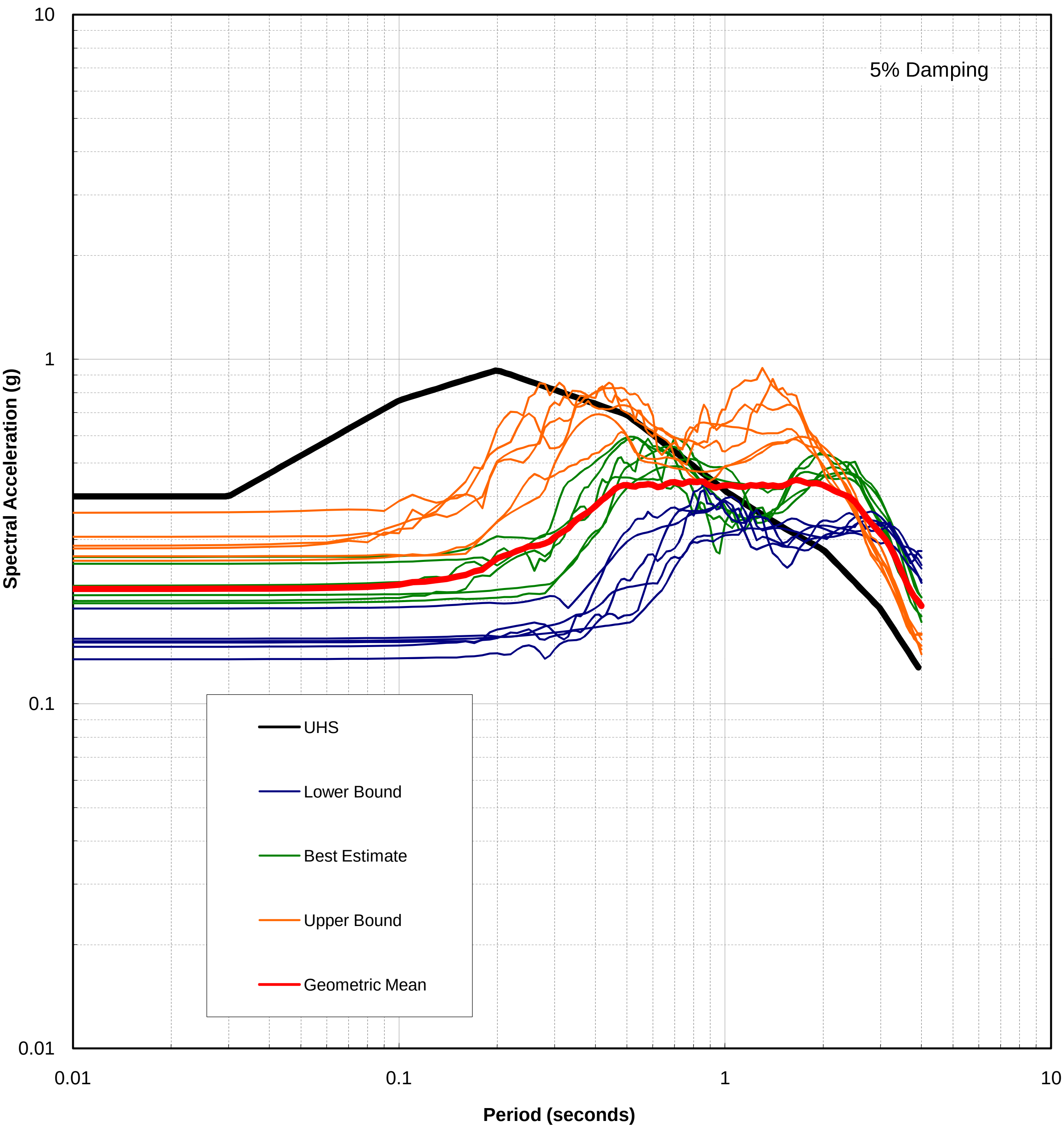
FIG. B-23



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA BORING IB-240

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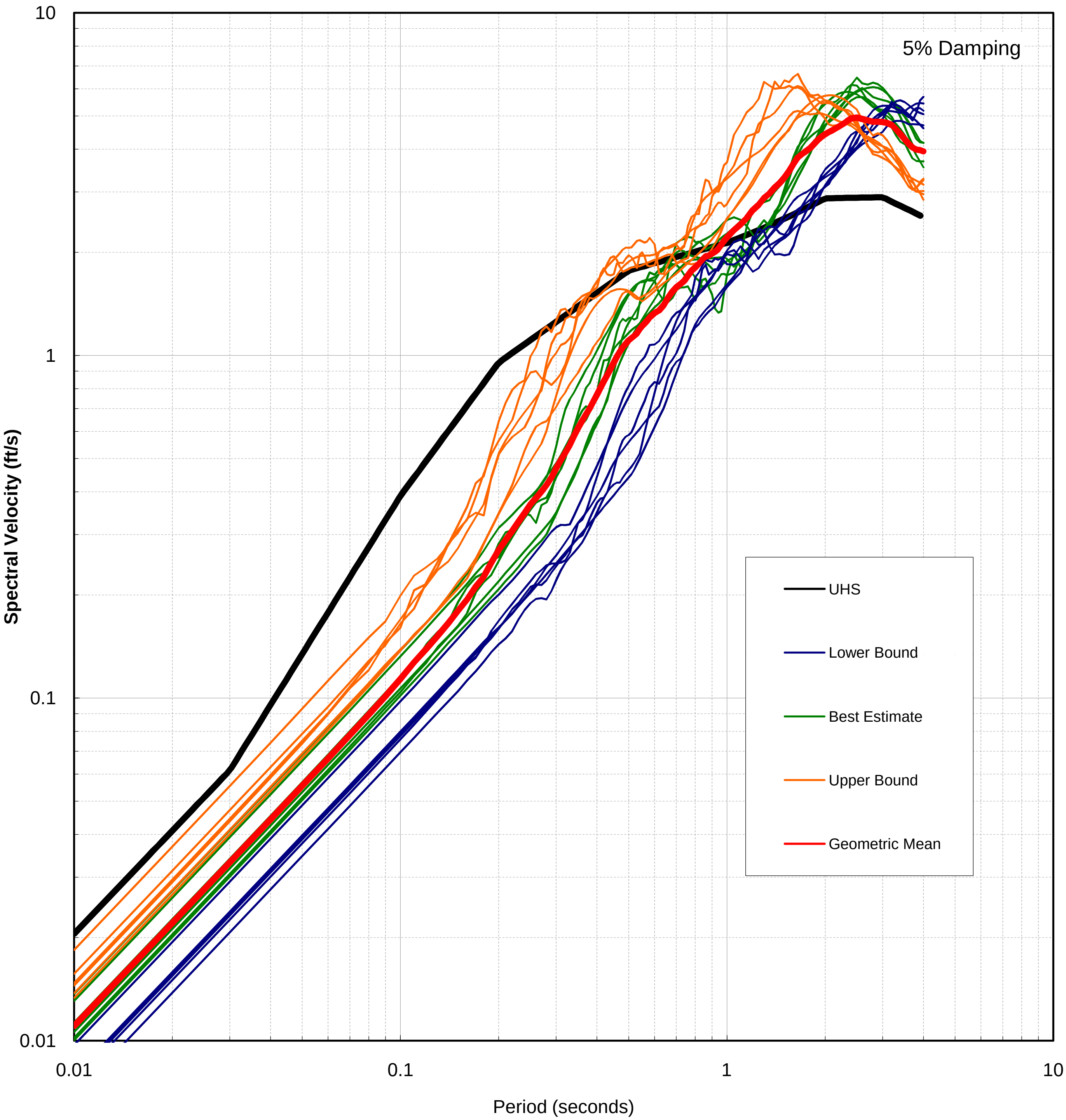
FIG. B-24



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA BORING IB-240

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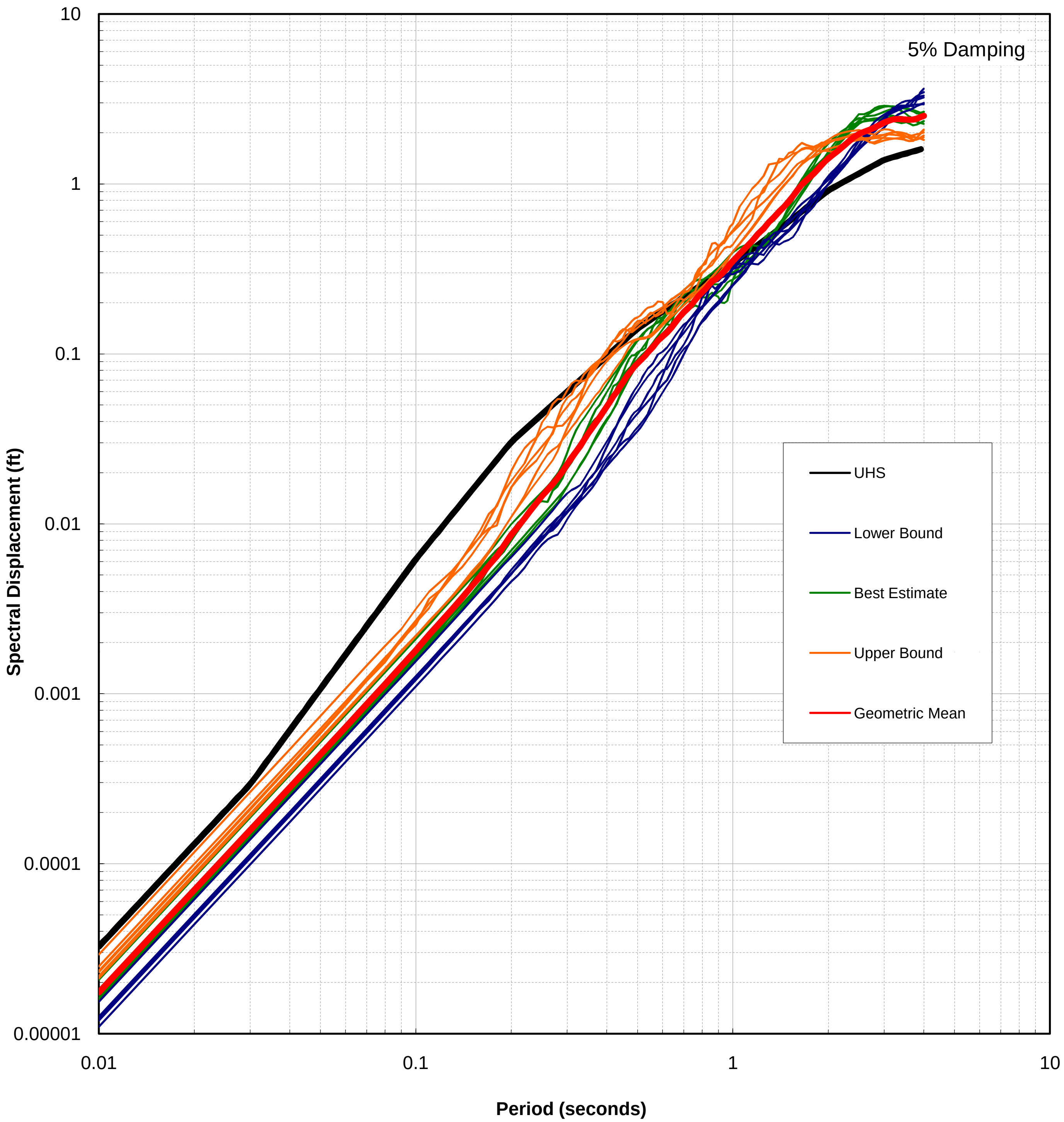
FIG. B-25



Alaskan Way Viaduct and Seawall Program
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1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA BORING IB-240

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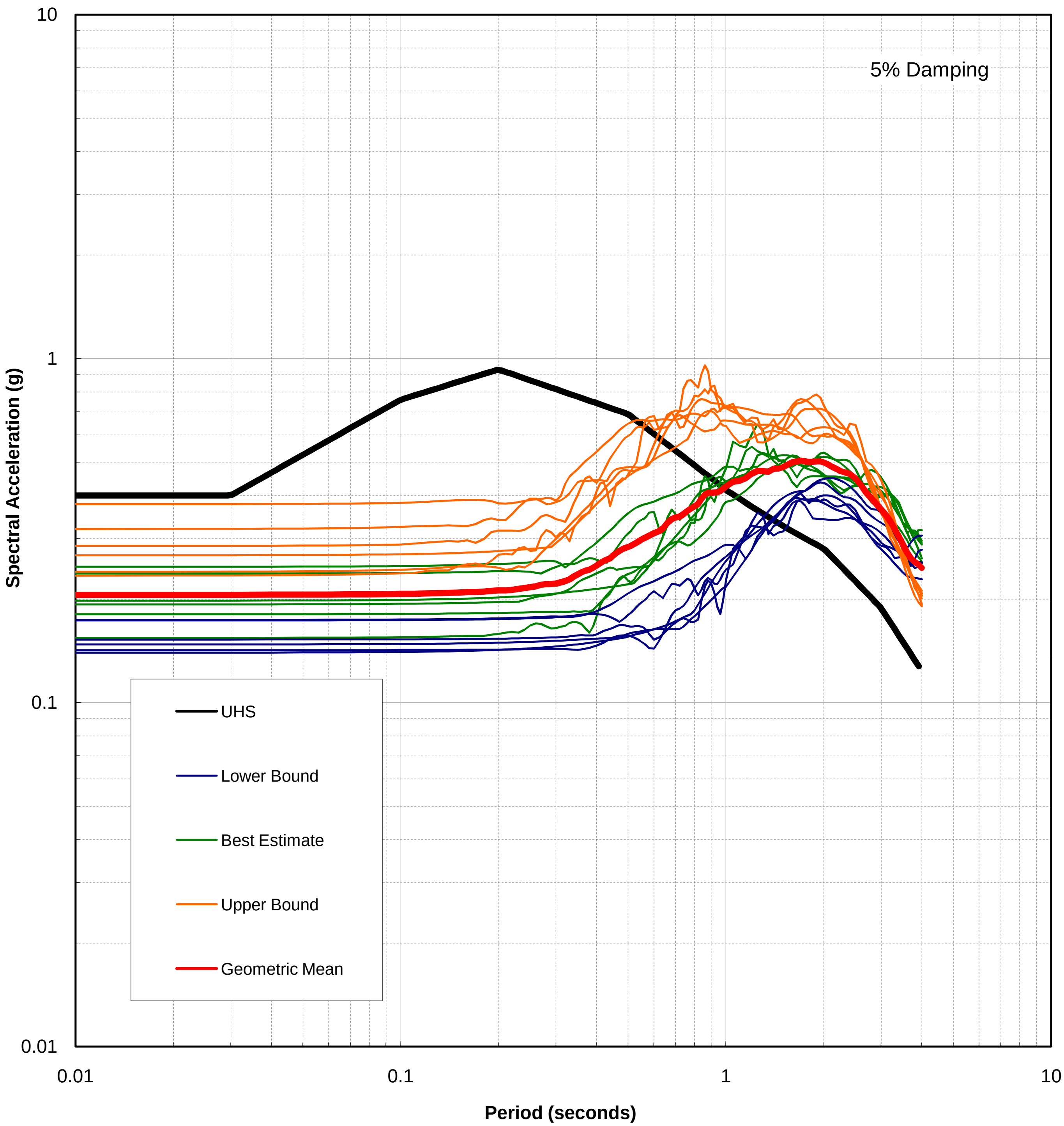
FIG. B-26



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA IB-258

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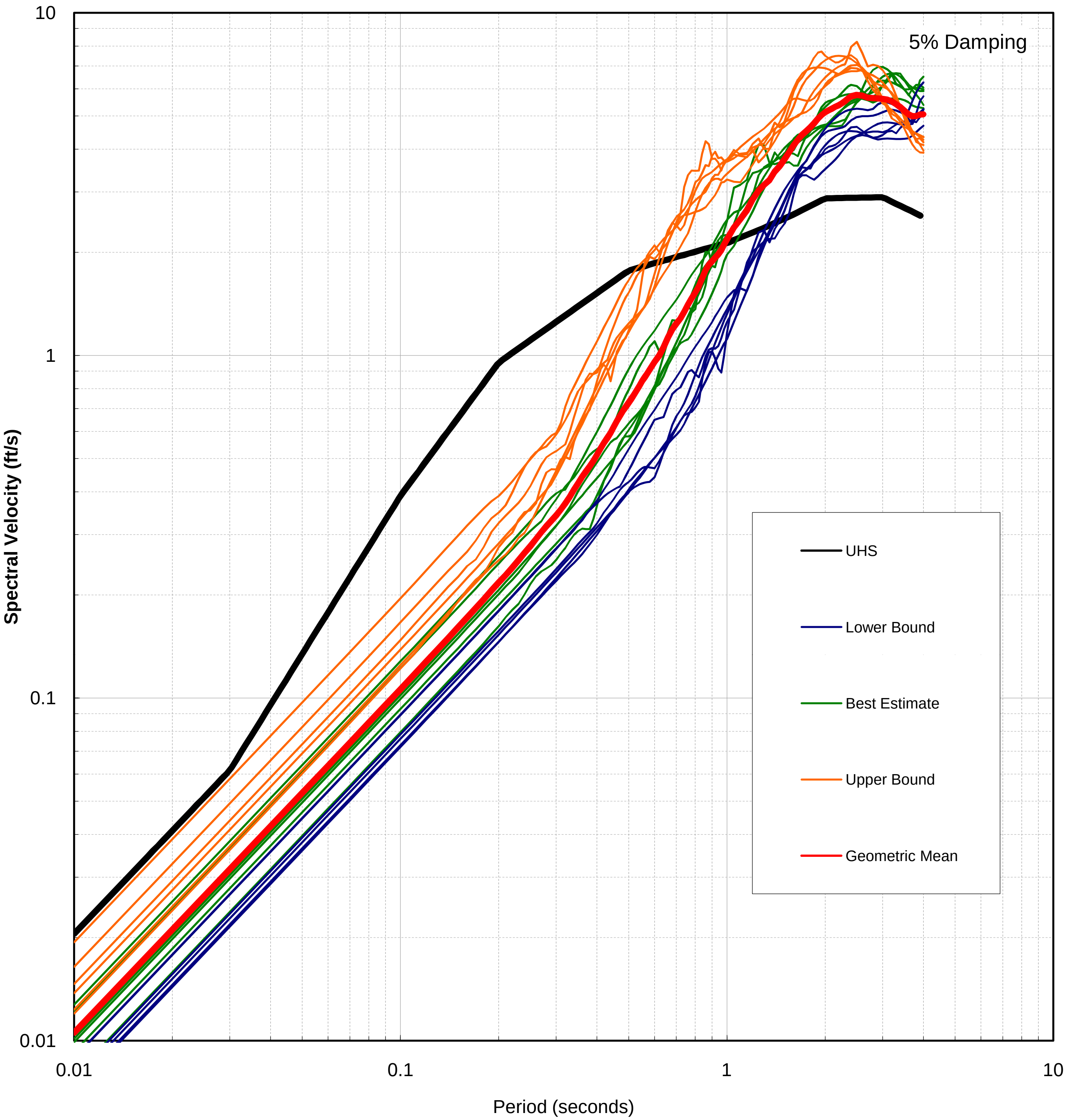
FIG. B-27



Alaskan Way Viaduct and Seawall Program
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Seattle, Washington

1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA IB-258

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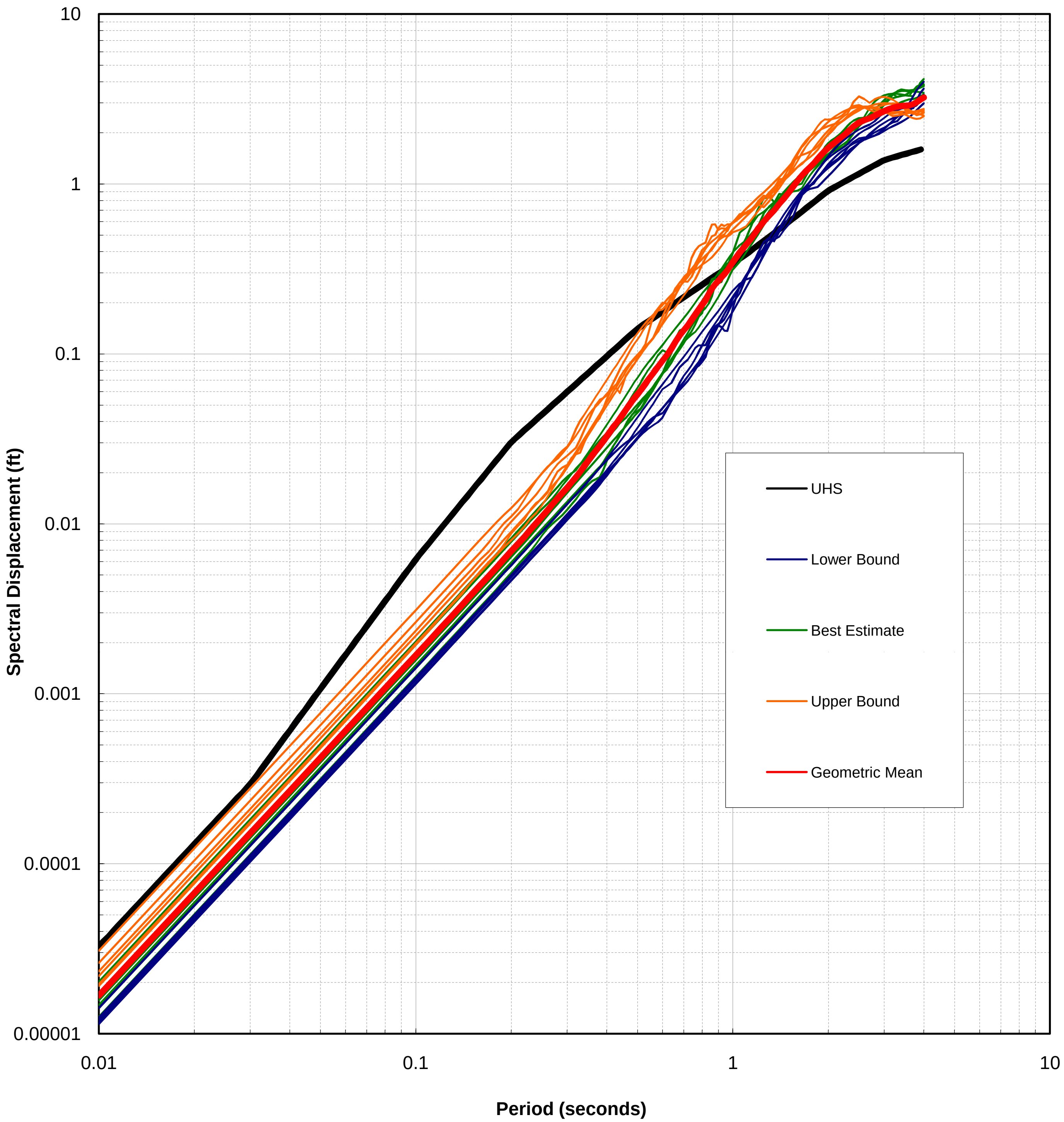
FIG. B-28



Alaskan Way Viaduct and Seawall Program
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Seattle, Washington

1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA IB-258

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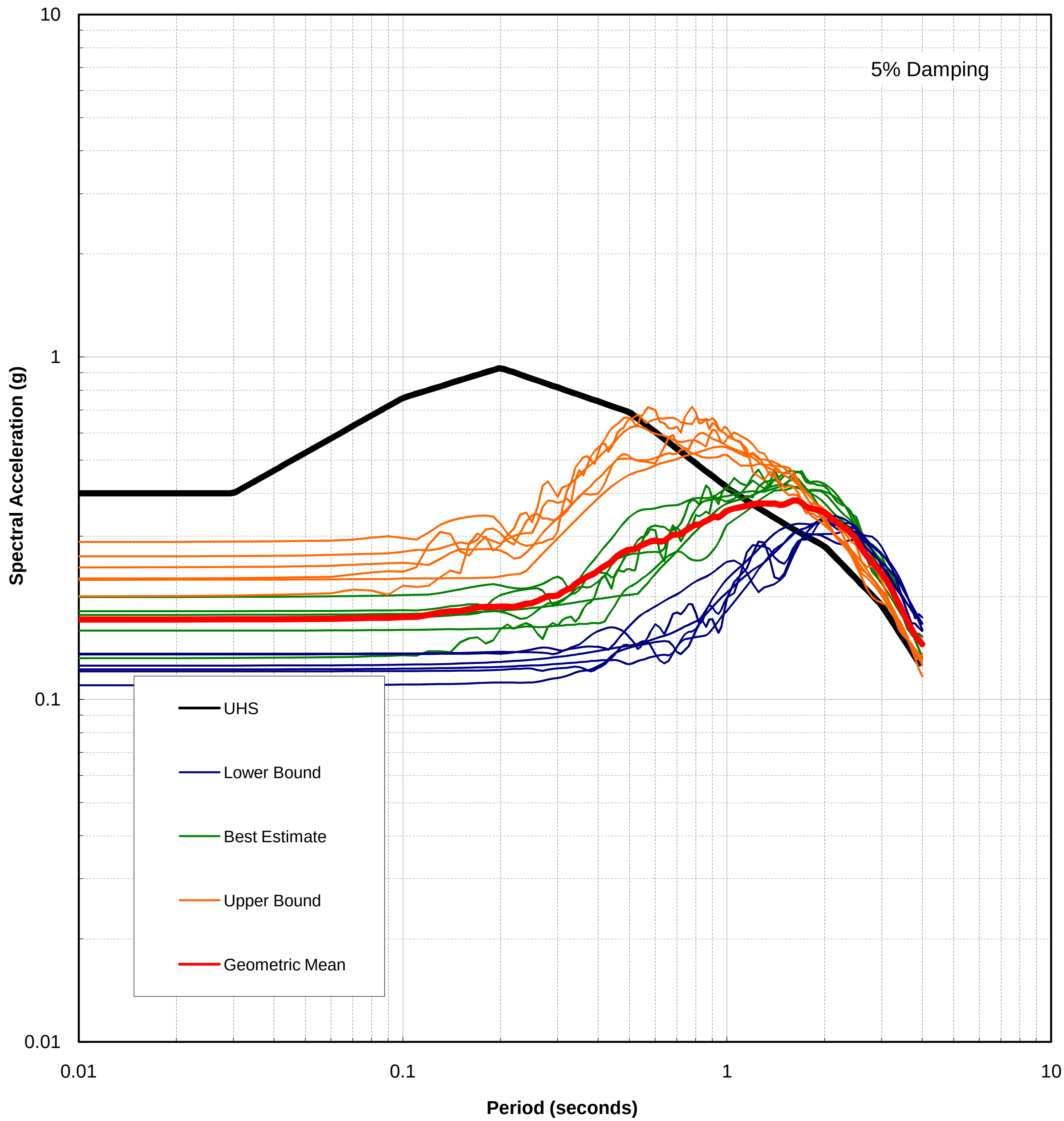
FIG. B-29



Alaskan Way Viaduct and Seawall Program
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Seattle, Washington

1,000-YEAR EQUIVALENT LINEAR ACCELERATION RESPONSE SPECTRA IB-263

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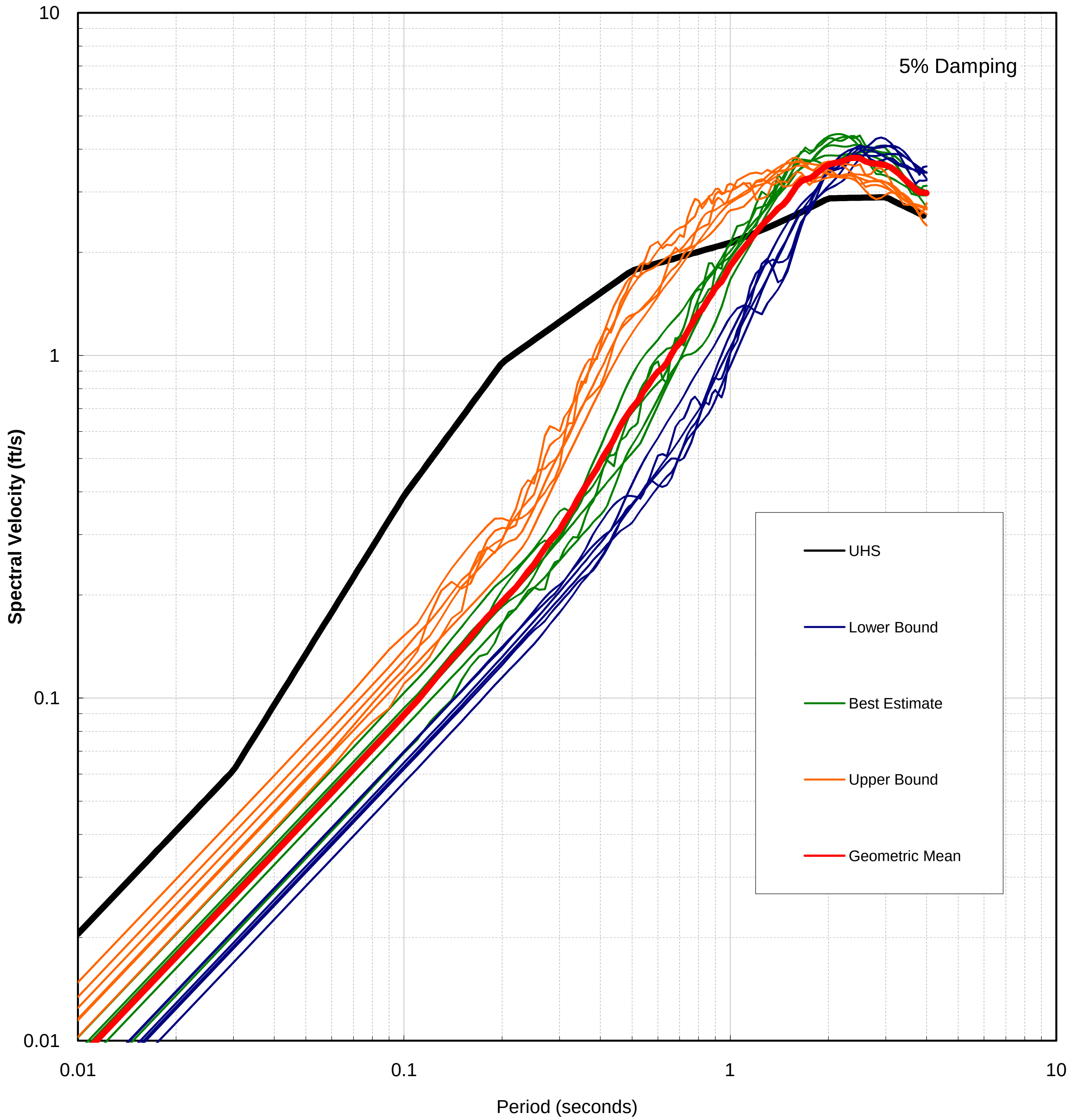
FIG. B-30

SHAKE IB-263.xlsm 3/26/2009: kpc



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR EQUIVALENT LINEAR VELOCITY RESPONSE SPECTRA IB-263

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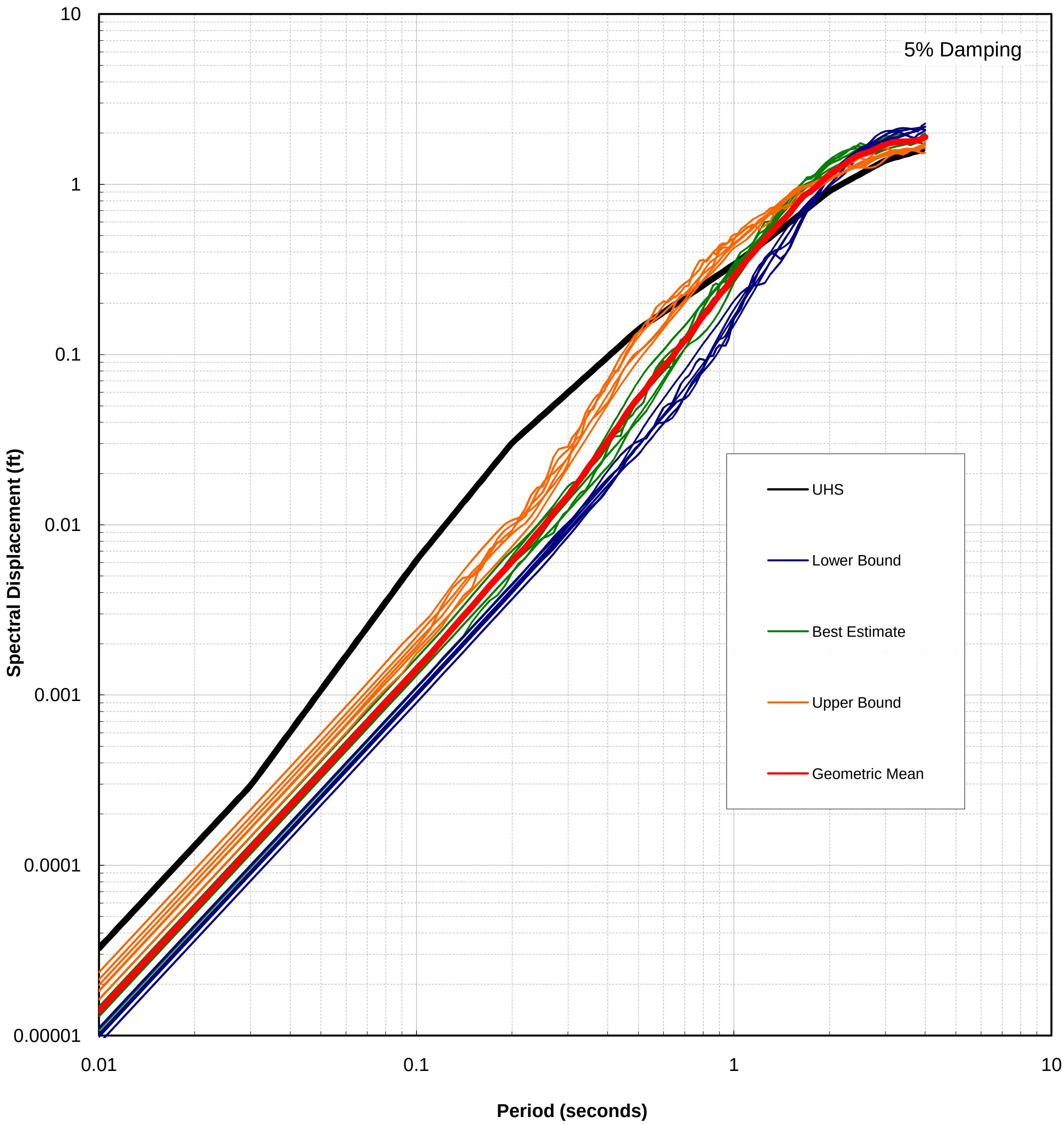
FIG. B-31



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
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1,000-YEAR EQUIVALENT LINEAR DISPLACEMENT RESPONSE SPECTRA IB-263

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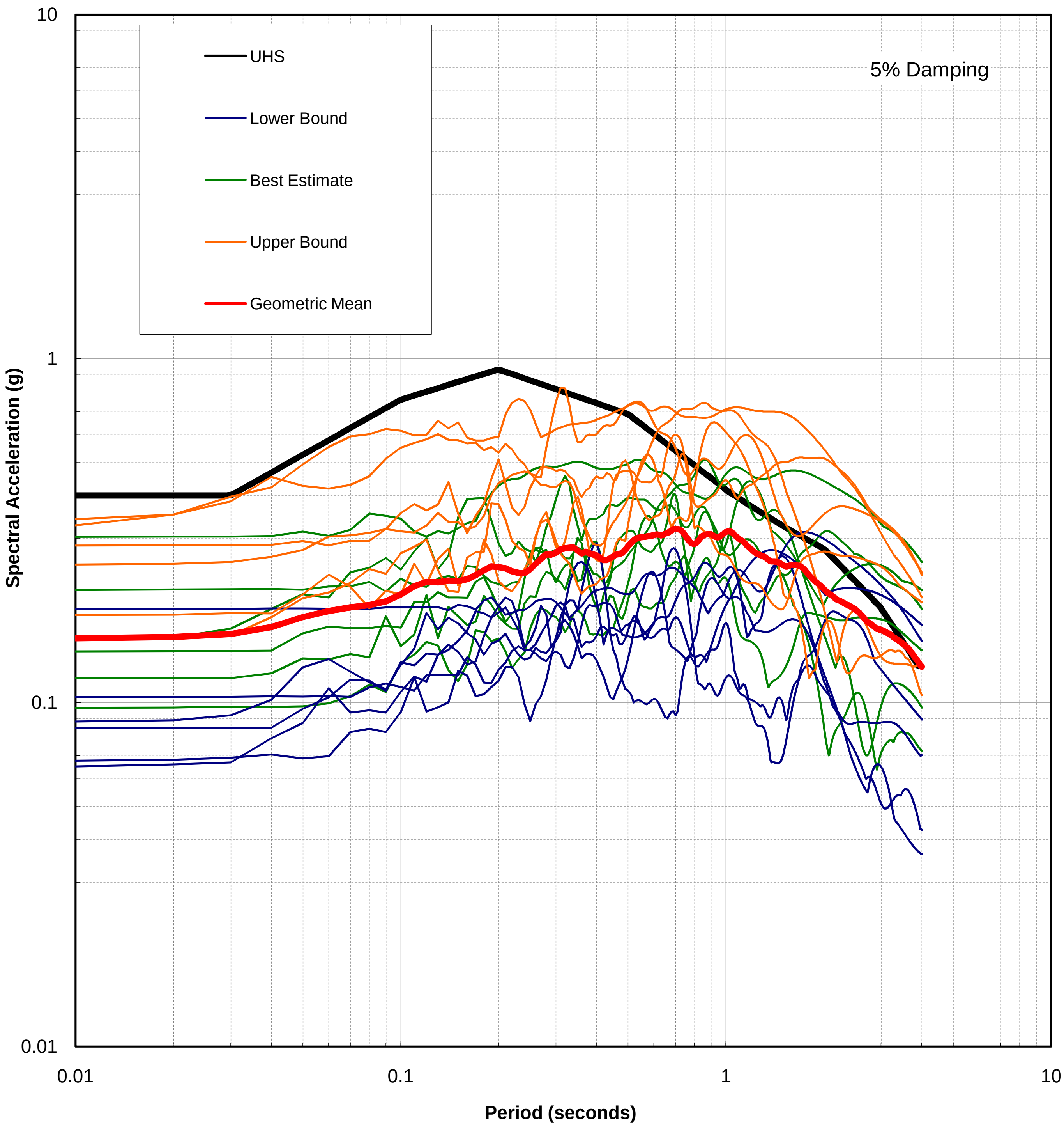
FIG. B-32

DMOD IB-240.xlsm 3/26/2009: kpc



Alaskan Way Viaduct and Seawall Program
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Seattle, Washington

1,000-YEAR NON-LINEAR ACCELERATION RESPONSE SPECTRA BORING IB-240

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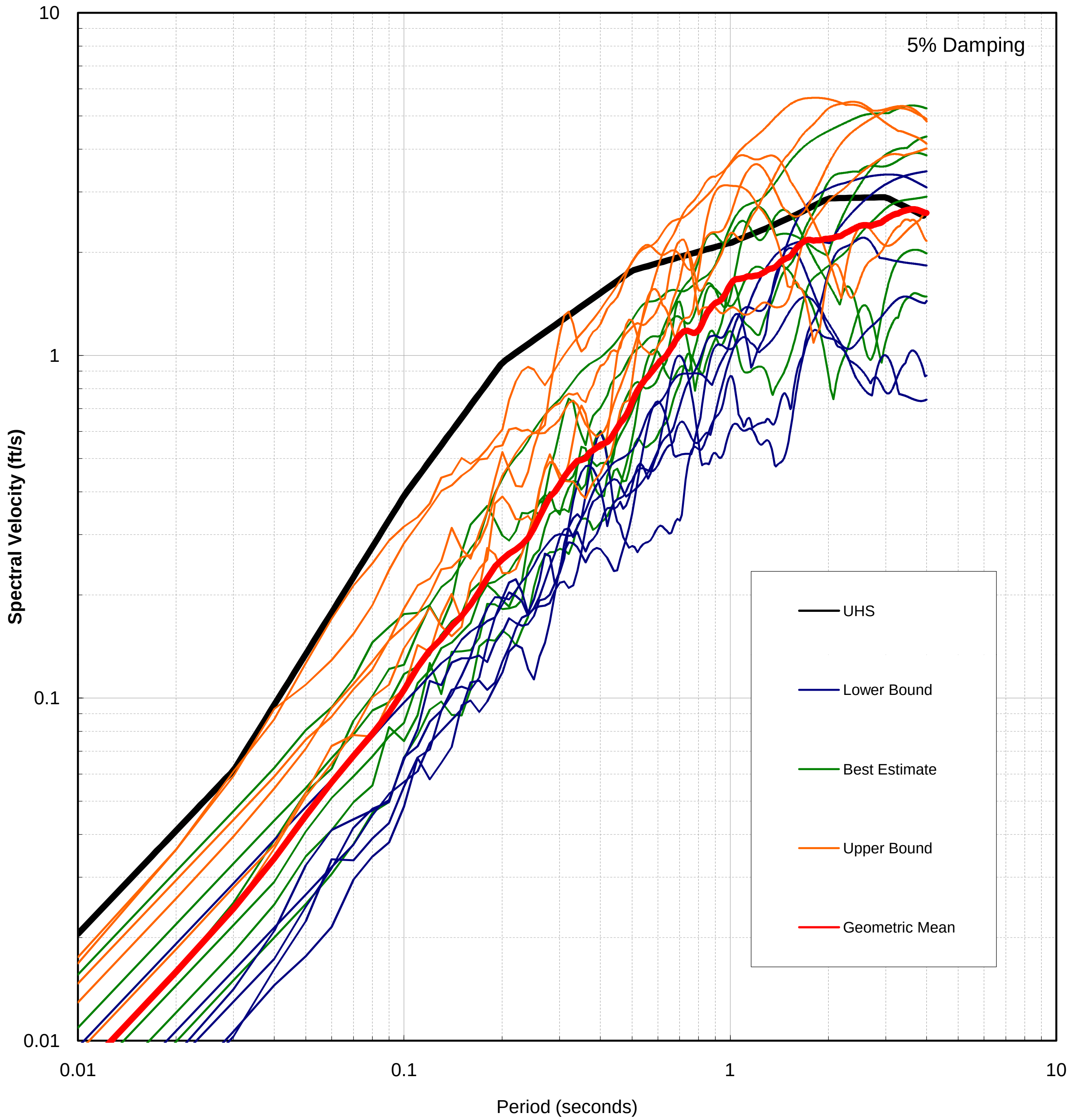
FIG. B-33



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR VELOCITY RESPONSE SPECTRA BORING IB-240

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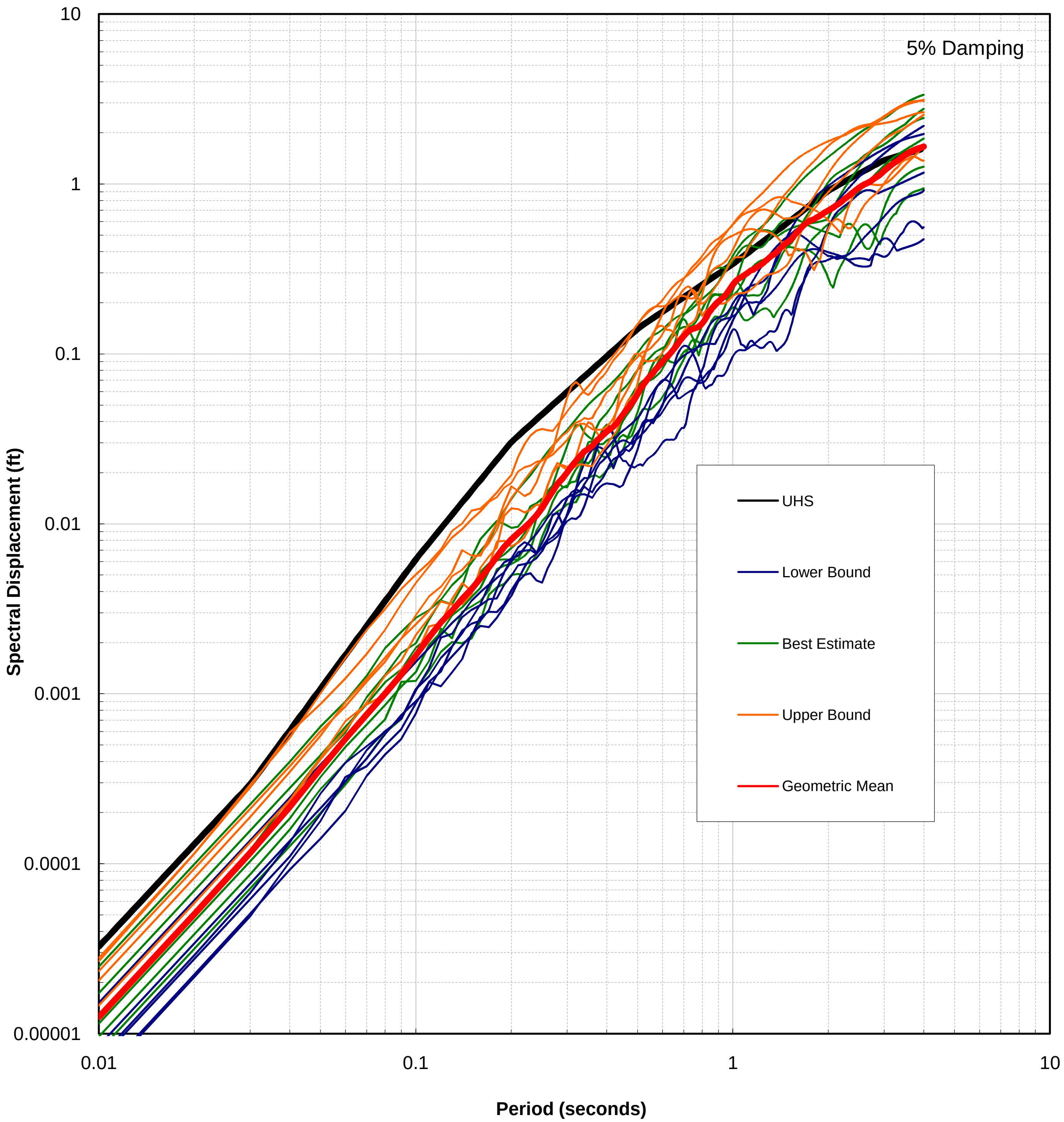
FIG. B-34

DMOD IB-240.xlsm 3/26/2009: kpc



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR DISPLACEMENT RESPONSE SPECTRA BORING IB-240

April 2009 21-1-20840-041

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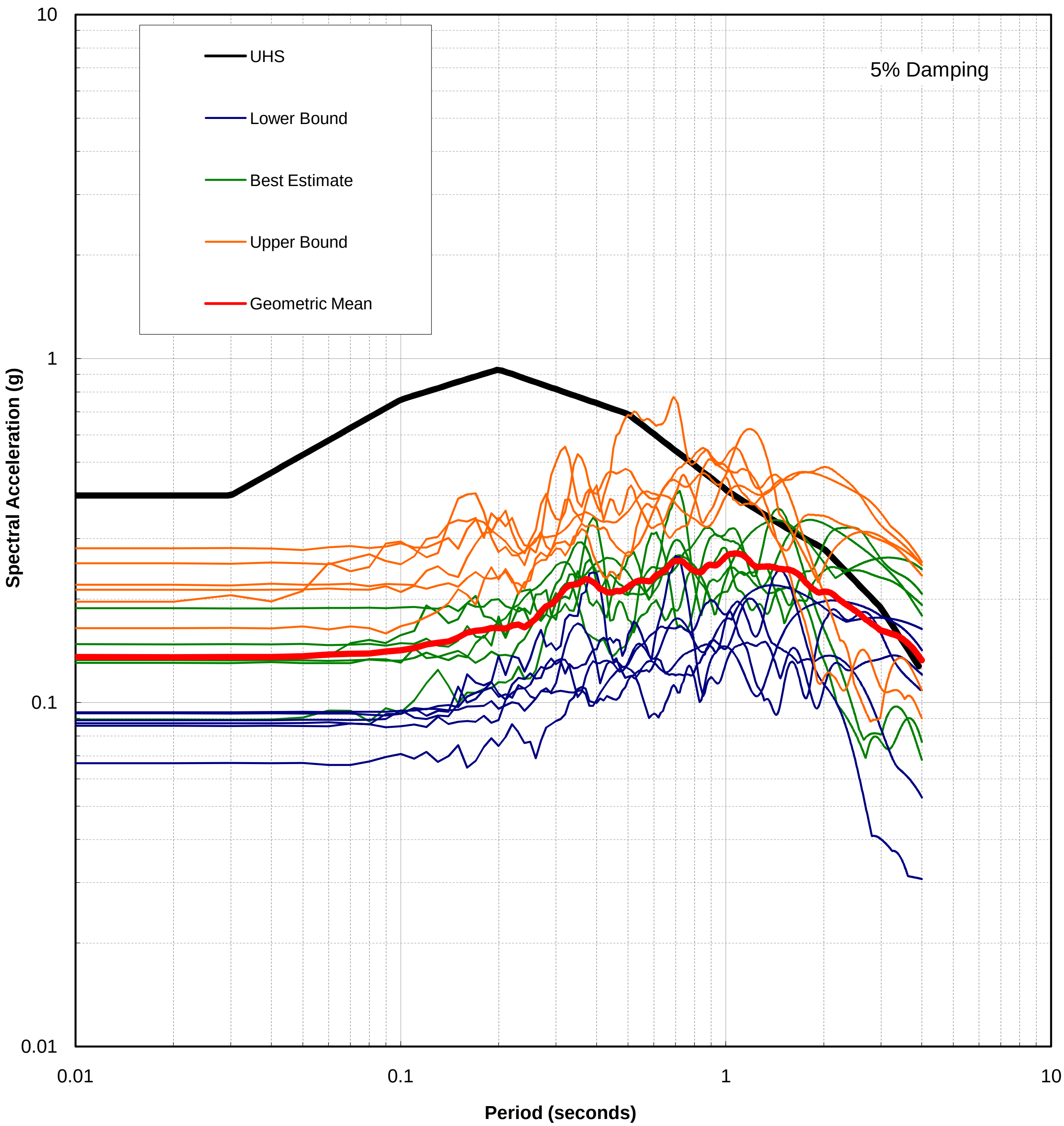
FIG. B-35



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR ACCELERATION RESPONSE SPECTRA BORING IB-258

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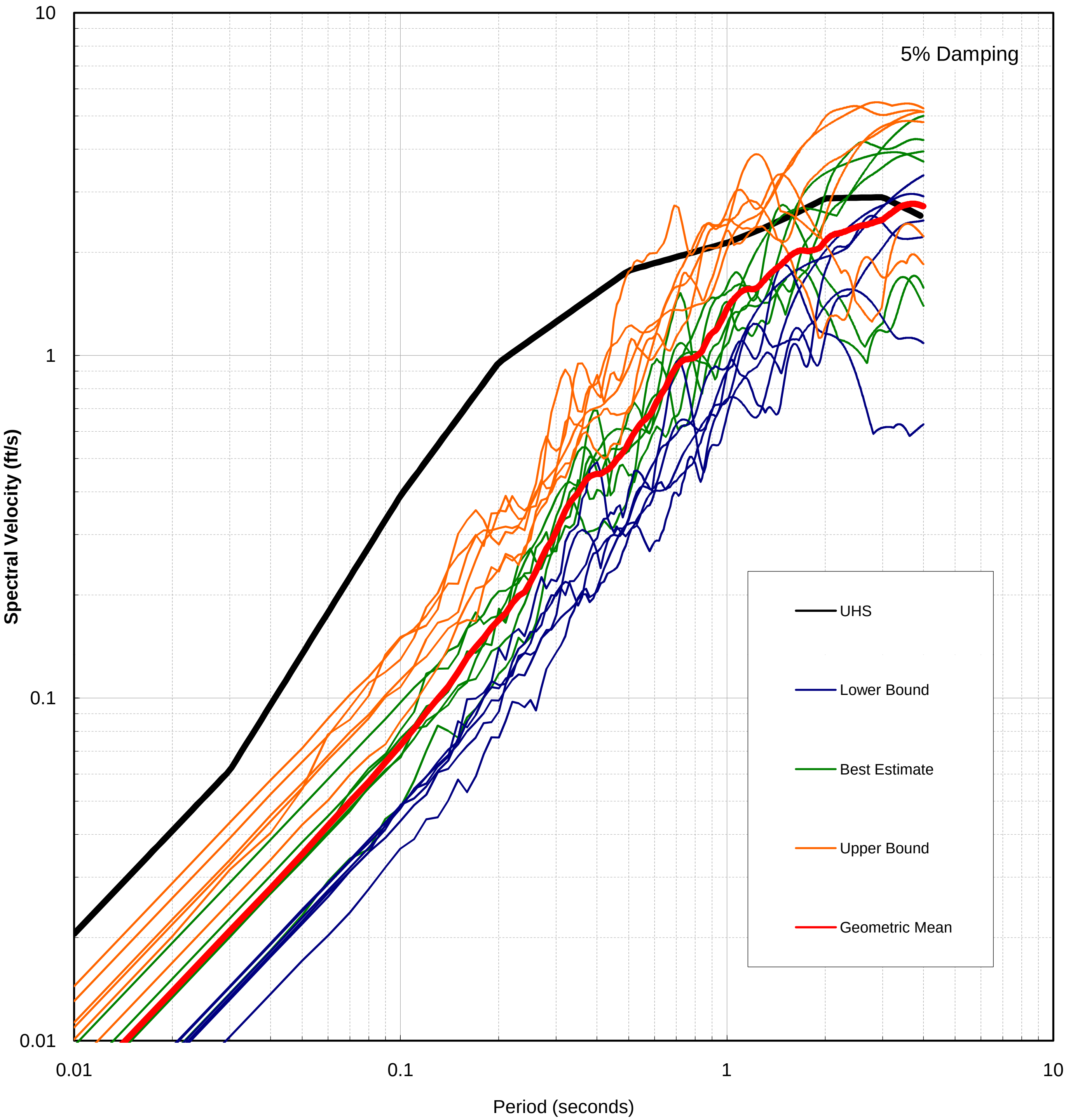
FIG. B-36



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR VELOCITY RESPONSE SPECTRA BORING IB-258

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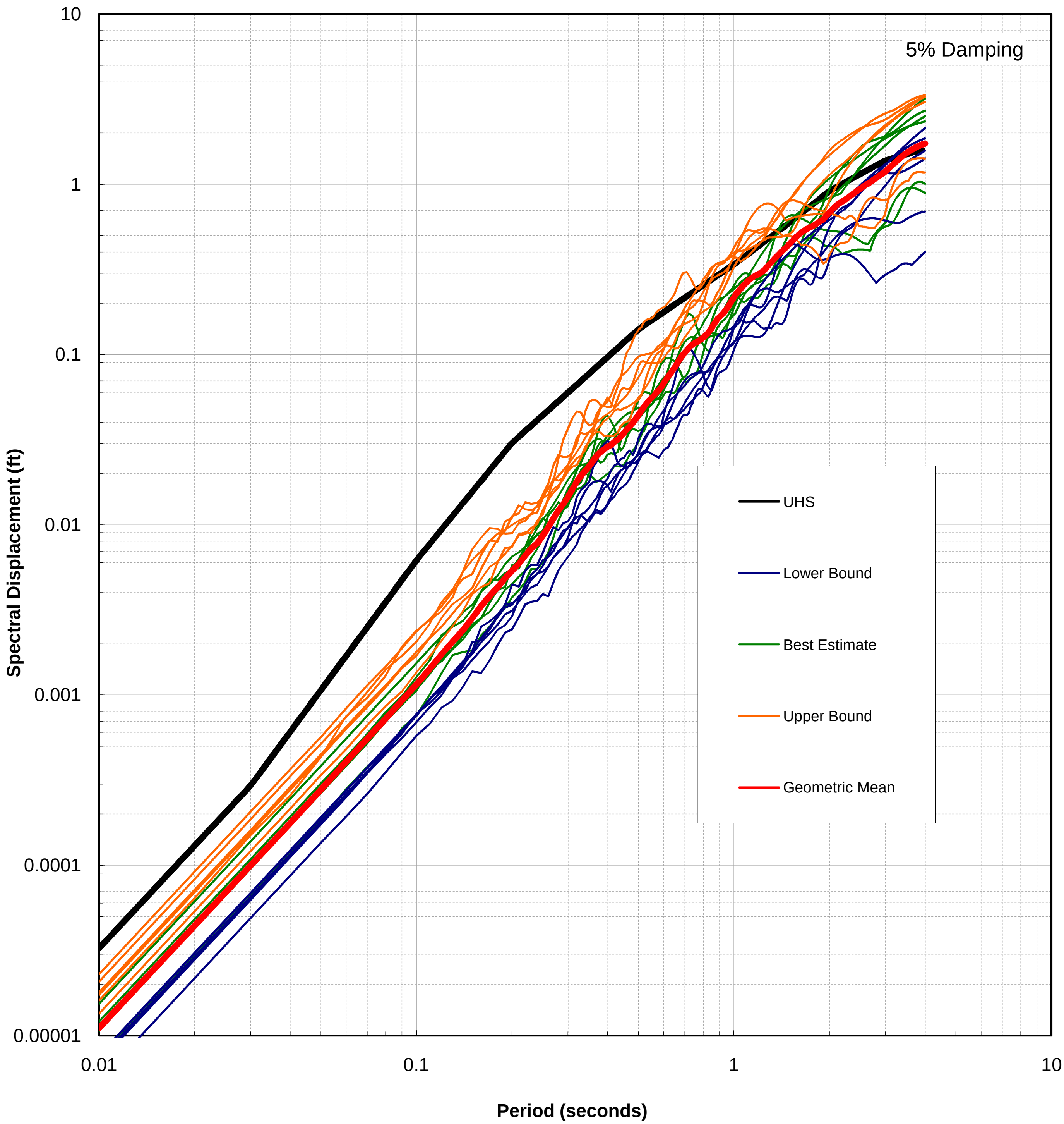
FIG. B-37



Alaskan Way Viaduct and Seawall Program
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Seattle, Washington

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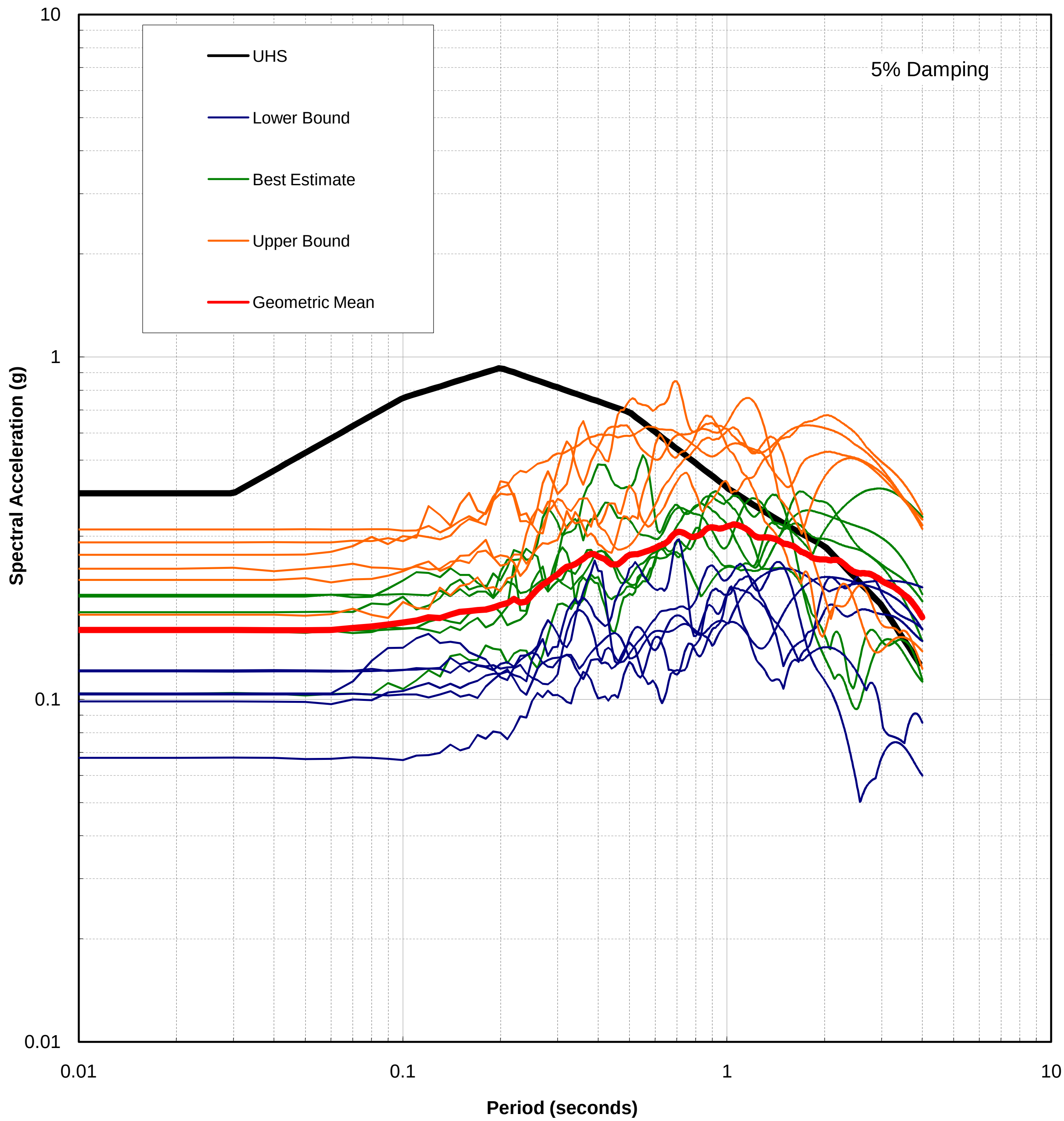
FIG. B-38



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR ACCELERATION RESPONSE SPECTRA BORING IB-263

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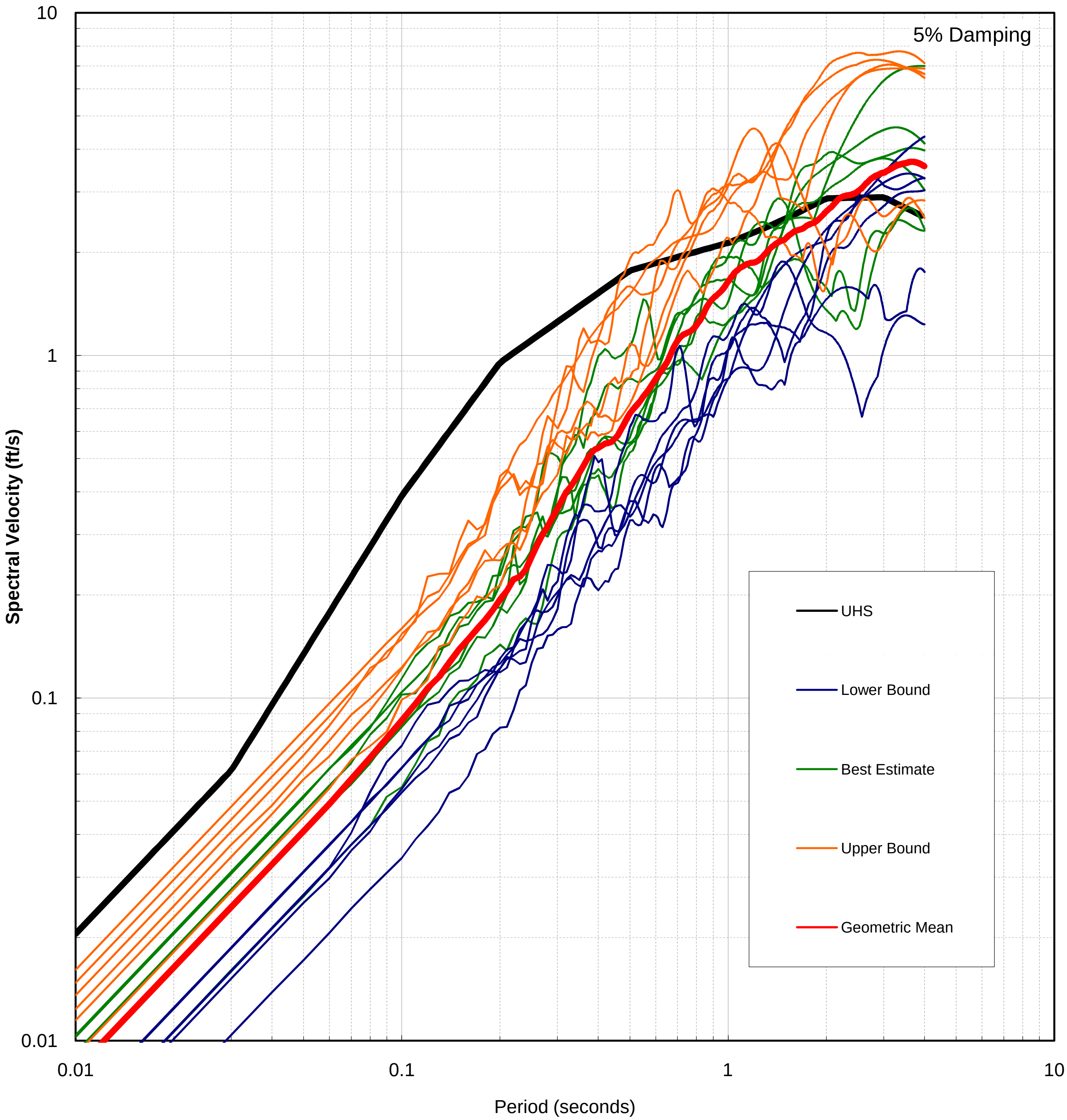
FIG. B-39



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR VELOCITY RESPONSE SPECTRA BORING IB-263

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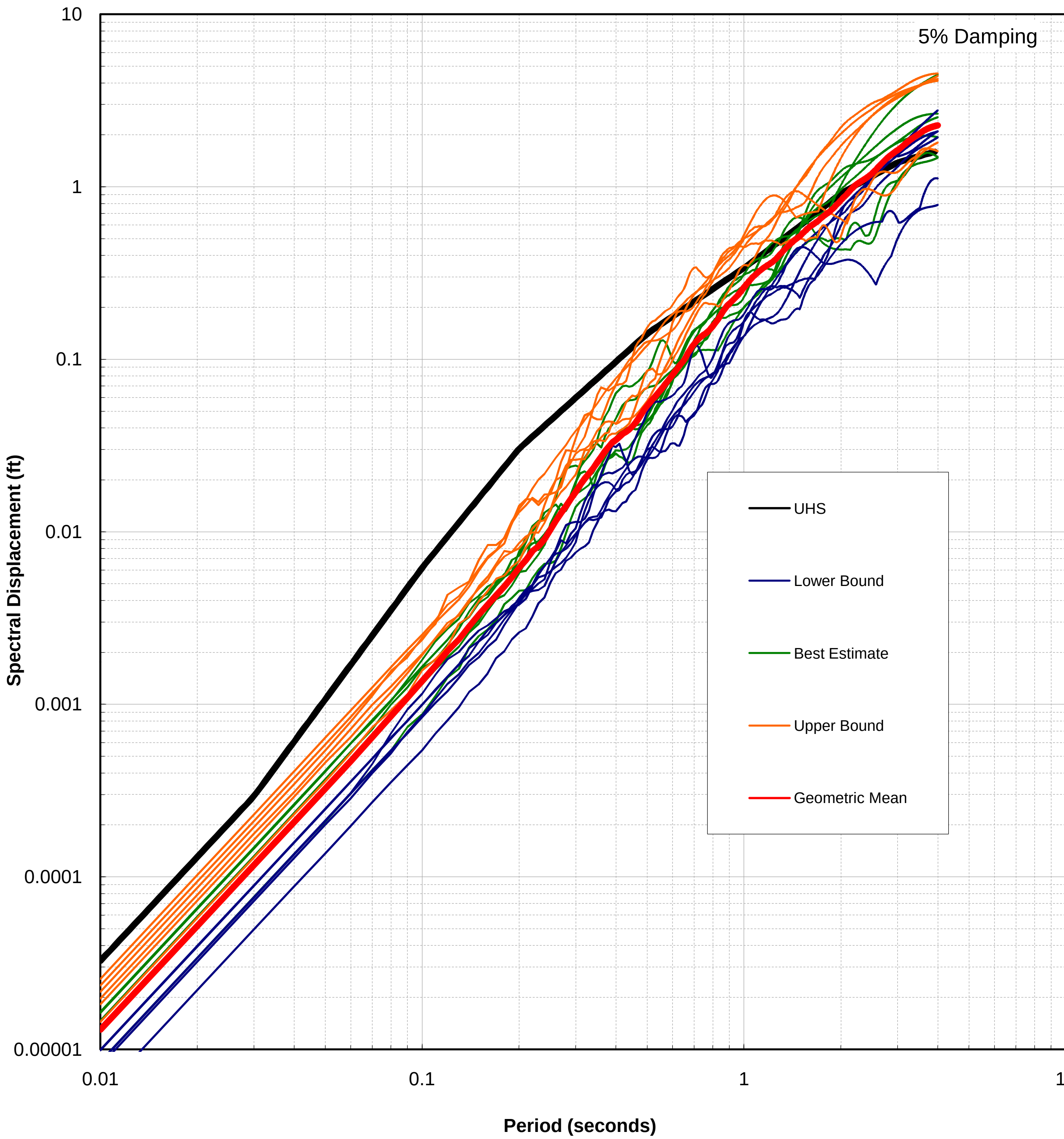
FIG. B-40



Alaskan Way Viaduct and Seawall Program
Seismic Ground Motion Study Update
Seattle, Washington

1,000-YEAR NON-LINEAR DISPLACEMENT RESPONSE SPECTRA BORING IB-263

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FIG. B-41

Appendix C

Important Information About Your Geotechnical/Environmental Report

Attachment to and part of Report 21-1-20840-044

Date: May 29, 2009
To: Mr. Mark Anderson
Washington State Department of Transportation

IMPORTANT INFORMATION ABOUT YOUR GEOTECHNICAL/ENVIRONMENTAL REPORT

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland