SEAW Earthquake Engineering Committee Structural Engineers Association of Washington	**WHITE PAPER EEC - #4 - 2022**

Title: Voluntary Use of Multi-Period Response Spectra for Determination of Seismic Hazard	**Issue Date:** November 24, 2022
Abstract: This white paper provides guidance for structural engineers in Washington State using the Multi-Period Response Spectrum (MPRS) method as allowed by Washington State Building Code Council Emergency Rule-Making Order WSR 22-11-010, and presents design examples for how the code amendment is intended to be used.	**Task Group Members:** Carson Baker, PE Michael B.W Chamberlain, PE Susan Chang, Ph.D, PE Kai Ki Mow, PE, SE Scott Neuman, PE, SE Hamilton Puangnak, PE

Committee Statement:

I. INTRODUCTION:

This white paper presents a more accessible means of calculating a design response spectrum as a voluntary alternative to the method currently mandated by the building code. Specifically, the prescriptive Multi-Period Response Spectrum (MPRS) method based on USGS mapped values provided in ASCE 7-22 is permitted to be used for seismic design within the ASCE 7-16 standard with implementation similar to the method used or a site-specific response spectrum.

Use of the MPRS method was approved in the 2018 Washington State Building Code on May 6, 2022 under Washington State Emergency Rule Making Order WSR 22-11-010. The emergency rule will remain in effect until the 2021 IBC is adopted. When the 2021 IBC is adopted by Washington State, the code amendment will be found in WAC 51-50-1613.

To validate that this process is technically acceptable, the SEAW EEC has used the process described below to develop the Washington State Building Code Council code amendment.

- Review of ASCE 7-22 for provisions that would need to be brought forward to use the MPRS
- Review of ASCE 7-16 for potential conflicts to the ASCE 7-22 provisions
- Determination of the limits to the range of applicability of the ASCE 7-22 provisions
- Comparison of the resulting seismic hazard values across the State of Washington to make sure that the use of the provisions doesn't produce unexpected or unexplainable results.
- Development of the code amendment.
- Submittal of the amendment to the State Building Code Council for approval.
- Development of this white paper.
- Review and comment by the SEAW EEC committee, and subsequent revisions to the documents.

II. RECOMMENDATIONS/GUIDELINES:

The Seismic Base Shear value of ASCE 7-16 12.8.1 may be calculated using the MPRS procedures of ASCE 7-22. The code amendment brings forward the provisions of ASCE 7-22 necessary to use the MPRS for the purposes of calculating seismic forces in ASCE 7-16, including updated Site Class definitions, seismic design parameters, and provisions for site-specific ground motion procedures. Refer to the Amendment for specific provisions and their applicability.

III. COMMENTARY:

ASCE 7-16 introduced Section 11.4.8 which requires the use of either site-specific ground motion analyses to calculate the Seismic Base Shear parameter, or a modified response spectrum which increases the Seismic Base Shear for medium-to-long period buildings. These requirements apply to structures located on Site Class E sites where S_s is greater or equal to 1.0, and for structures located on Site Class D sites where S_1 is greater or equal to 0.2. Section 11.4.8 was added in response to a recognized need for improvement to the ASCE 7-10 procedures and was intended to be a stop-gap measure until the MPRS procedure was developed for use in ASCE 7-22.

The commentary to ASCE 7-16 Section 11.4.8 states, "Multiperiod MCE_R response spectra would eliminate potential shortcomings associated with the use of seismic forces based on only two response periods by directly providing reliable values of seismic demand at all design periods of interest. Unfortunately, multiperiod hazard and associated design methods are not yet mature enough for information in seismic codes, and the site-specific requirements of Section 11.4.8 for softer sites and stronger ground motions provide a short-term solution to a problem that will ultimately be resolved by adoption of design methods based on multiperiod response spectra."

The MPRS method is a technical advancement over the Two-Period Response Spectrum approach prescribed by ASCE 7-16 and provides updated estimates of design seismic accelerations across a broad range of spectral periods for all locations in Washington State. The MPRS takes advantage of improvements in the 2018 USGS Seismic Hazard Maps that were not available when ASCE 7-16 was developed. These updated maps provide parameters that allow for MPRS to be defined for project sites without requiring ground motion hazard analysis per ASCE 7-16 Section 21.2.

Site-specific ground motion analyses are advanced approaches for developing earthquake ground motions and response spectra needed for seismic design. If performed properly, they can provide improved seismic hazard estimates at sites compared to prescriptive seismic parameters. However, they require additional geophysical testing of the soil, advanced computer modeling, and can increase the design cost and time needed to complete a project.

Allowing the use of the MPRS as an option in lieu of the site-specific analysis requirements of ASCE 7-16 will streamline the design process at locations requiring site-specific ground motion analysis, will simplify the plan review, and result in buildings on these sites that are designed more uniformly.

Because the data used to develop the MPRS is now available, it can be brought into use within ASCE 7-16 procedures to realize advantages over use of the Section 11.4.8 requirements. Use of the MPRS to calculate the design base shear for buildings allows the use of S_{DS} as calculated by the USGS Seismic Design Geodatabase per the Amendment Section 11.4.8.1.2. The S_{DS} value creates a plateau in the short period range of the MPRS spectrum where seismic forces do not need to be calculated above this value. Outside the plateau, the value of S_a at the fundamental period of the building, T, can be used to determine the design base shear as allowed in the Amendment Section 11.4.8.1.8.

For use with a modal response spectrum analysis of Section 12.9.1, the MPRS as developed by the Amendment may be used in lieu of the design response spectrum developed in Section 11.4.6. Seismic forces that result from the use of the MPRS spectrum should be scaled using ASCE 7-16 Section 12.9.1.4.1 and used for design.

ASCE 7-22 introduces additional intermediate Site Classes that are used in the calculation of MPRS. Correspondingly, the intermediate Site Classes from ASCE 7-22 must also be adopted. For the purposes of using the MPRS, the new Site Classes shall be used. For all other purposes, the Site Class as determined per ASCE 7-16 Chapter 20 shall be used. This means that to use the MPRS procedure when calculating seismic forces using ASCE 7-16 two separate Site Classes need to be determined, one for use with the MPRS, and one for use with all other code provisions.

In addition to the MPRS, provisions for scaling a site-specific spectrum produced by a geotechnical engineer to code minimum values using the provisions of ASCE 7-22 are adopted as well. These provisions limit the values of a site-specific spectrum to not less than 80% of the MPRS spectrum, which could result in higher or lower site-specific values compared to the code minimum calculated using the ASCE 7-16 provisions. The purpose of adopting the ASCE 7-22 provisions is to allow the most current understanding of seismic hazards to be used in design, and to incentivize designers to conduct more comprehensive site-specific seismic hazard evaluations.

IV. APPENDICES:

Appendix A includes a comparison of the ASCE 7-22 MPRS spectra with the ASCE 7-16 two-period spectra for Site Classes C and D for cities located across the State of Washington.

For graphs in Appendix A for Site Class C, the curves shown on the graphs are:

MPRS – The MPRS spectrum for the site computed for Site Class C.

ASCE 7-16 – The Design Response Spectrum calculated for Site Class C per ASCE 7-16 Section 11.4.6.

MPRS Sds – S_{DS} value obtained from the USGS Seismic Design Geodatabase.

For graphs in Appendix A for Site Class D, the curves shown on the graphs are:

MPRS – The MPRS spectrum for the site computed for Site Class D.

ASCE 7-16 –D by Default– The Design Response Spectrum calculated for a site where Site Class D is selected as the default site class and using ASCE 7-16 Section 11.4.6 with the Site Class D exception in Section 11.4.8.

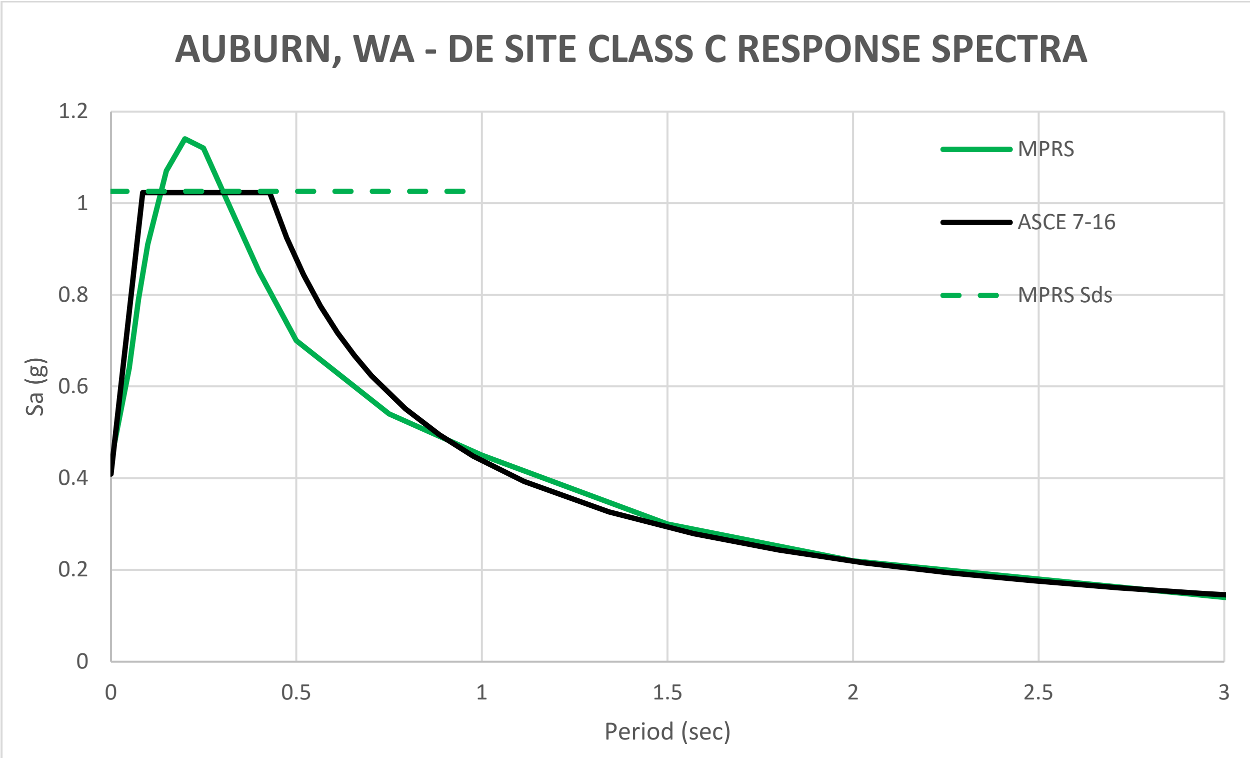
ASCE 7-16 –D - Tested with Exception – The Design Response Spectrum calculated for a site categorized as Site Class D following an investigation into the soil properties and using ASCE 7-16 Section 11.4.6 with the Site Class D exception in Section 11.4.8.

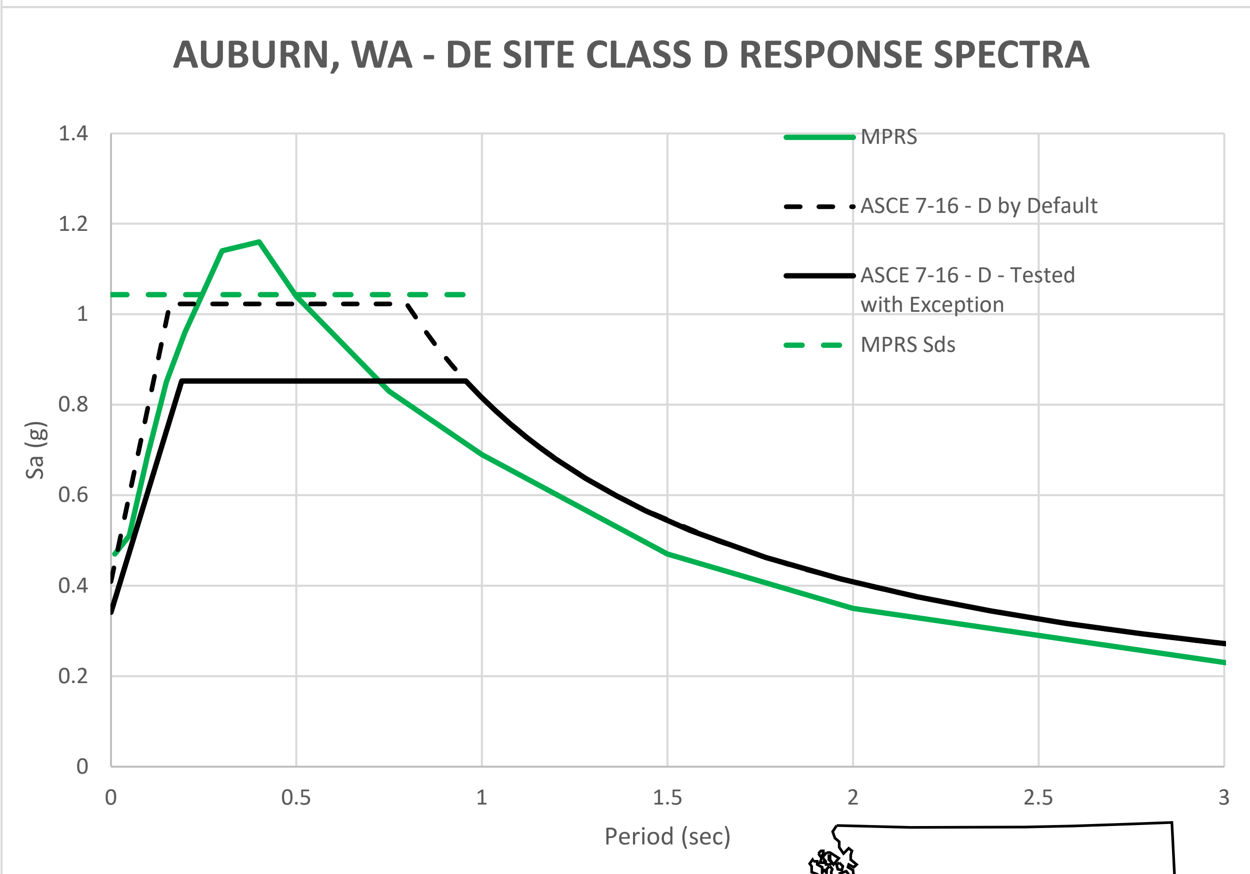
MPRS Sds – S_{DS} value obtained from the USGS Seismic Design Geodatabase.

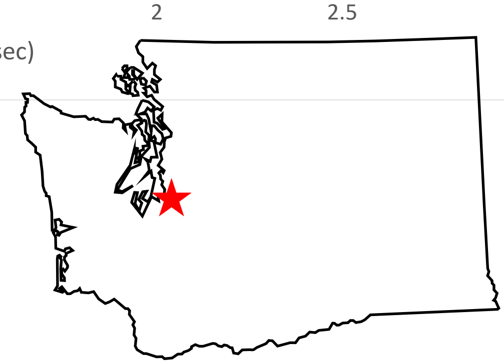
Appendix B includes examples showing the calculation of the S_{DS} and S_{D1} factors for use in ASCE 7-16 Section 12.8 equations using the MPRS.

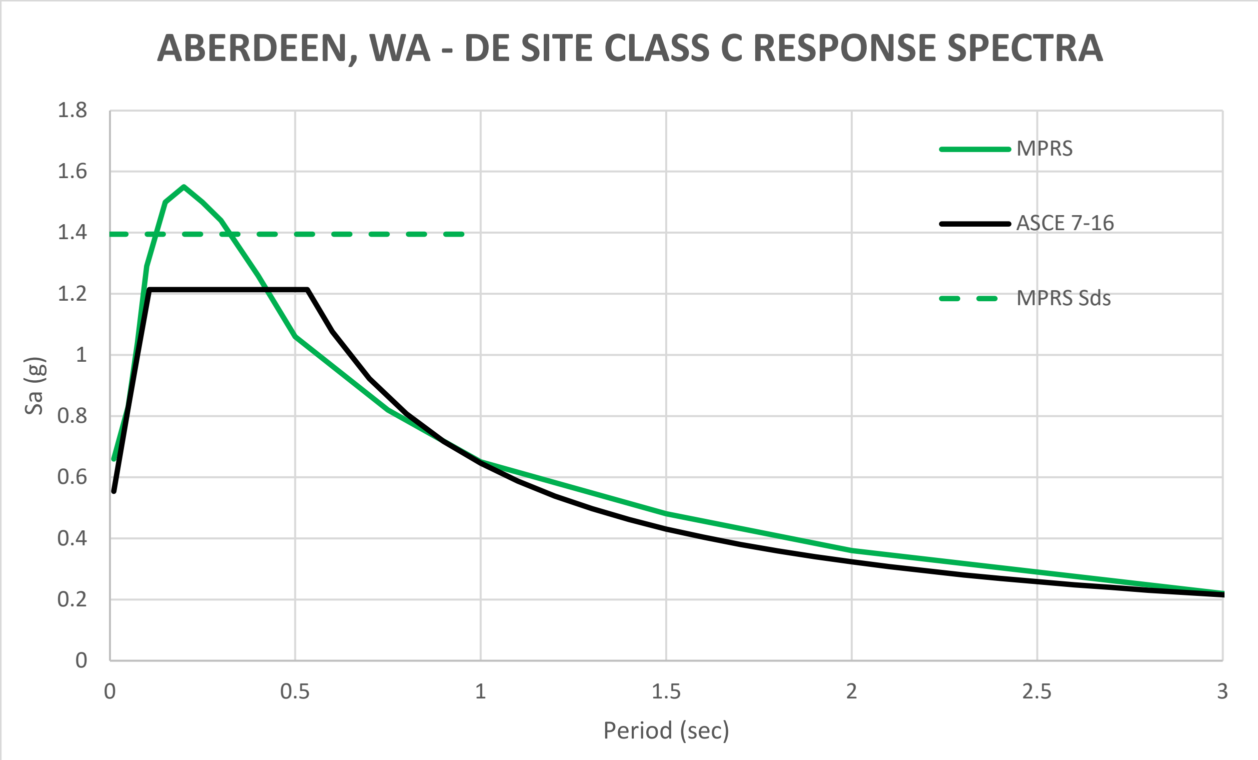
Appendix C includes WSR 22-11-010 for reference.

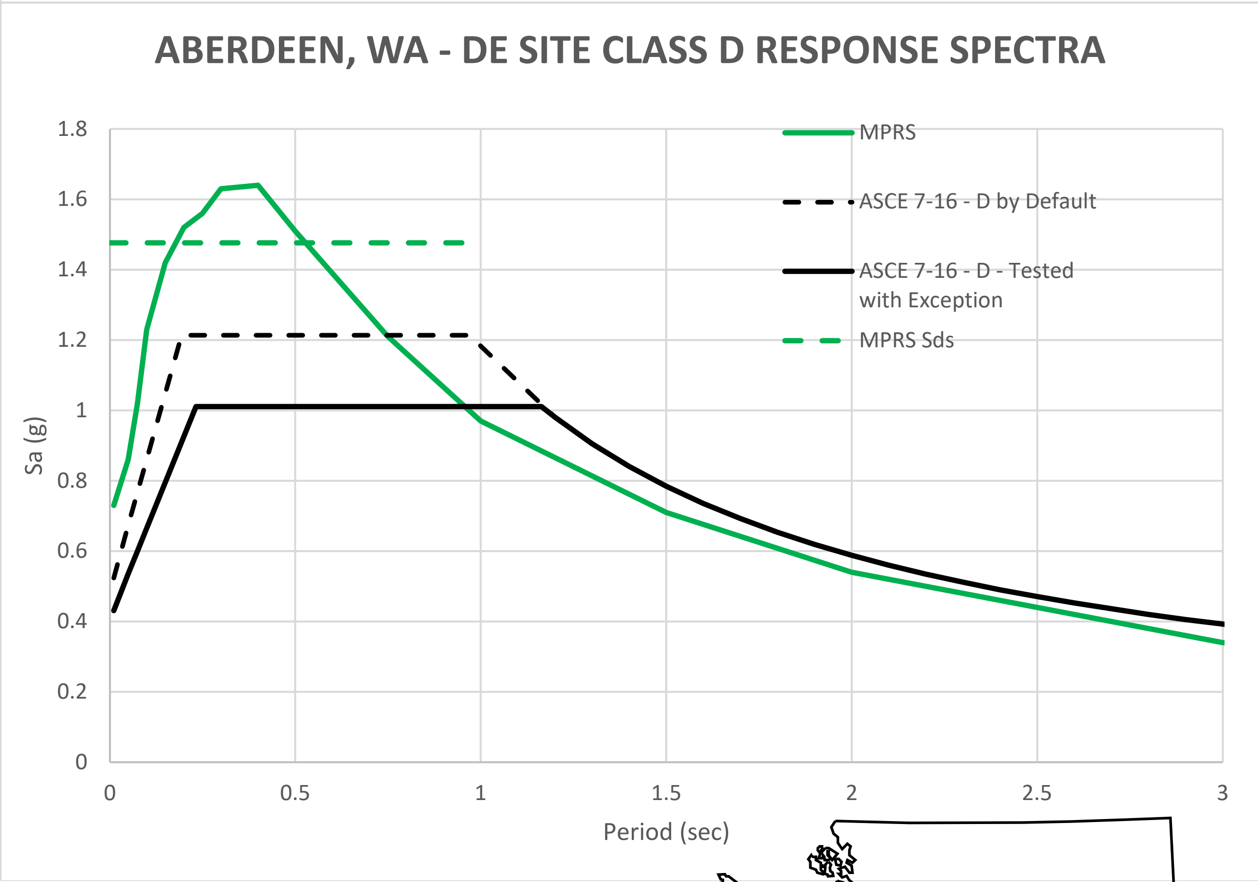
Appendix A
Comparison of MPRS and ASCE 7-16 Mapped Values

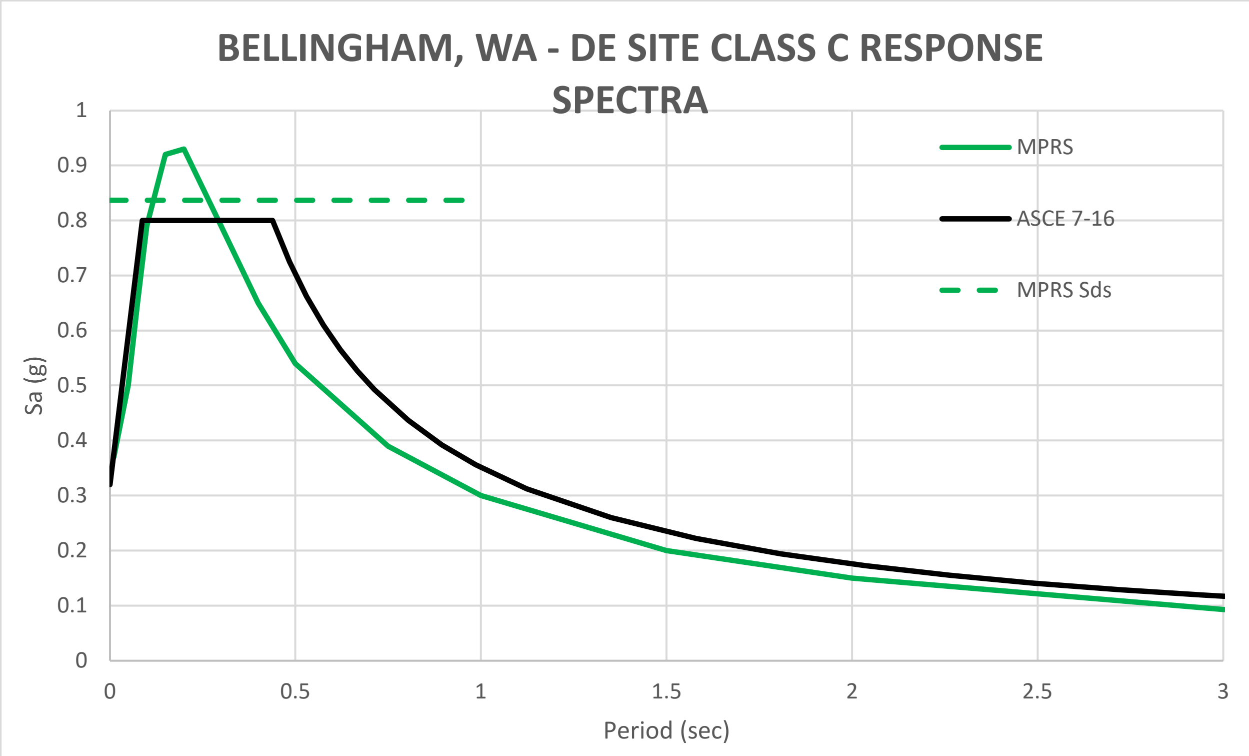

AUBURN, WA - DE SITE CLASS C RESPONSE SPECTRA
1.2
1
0.8
0.6
0.4
0.2
0
Sa (g)
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16
MPRS Sds

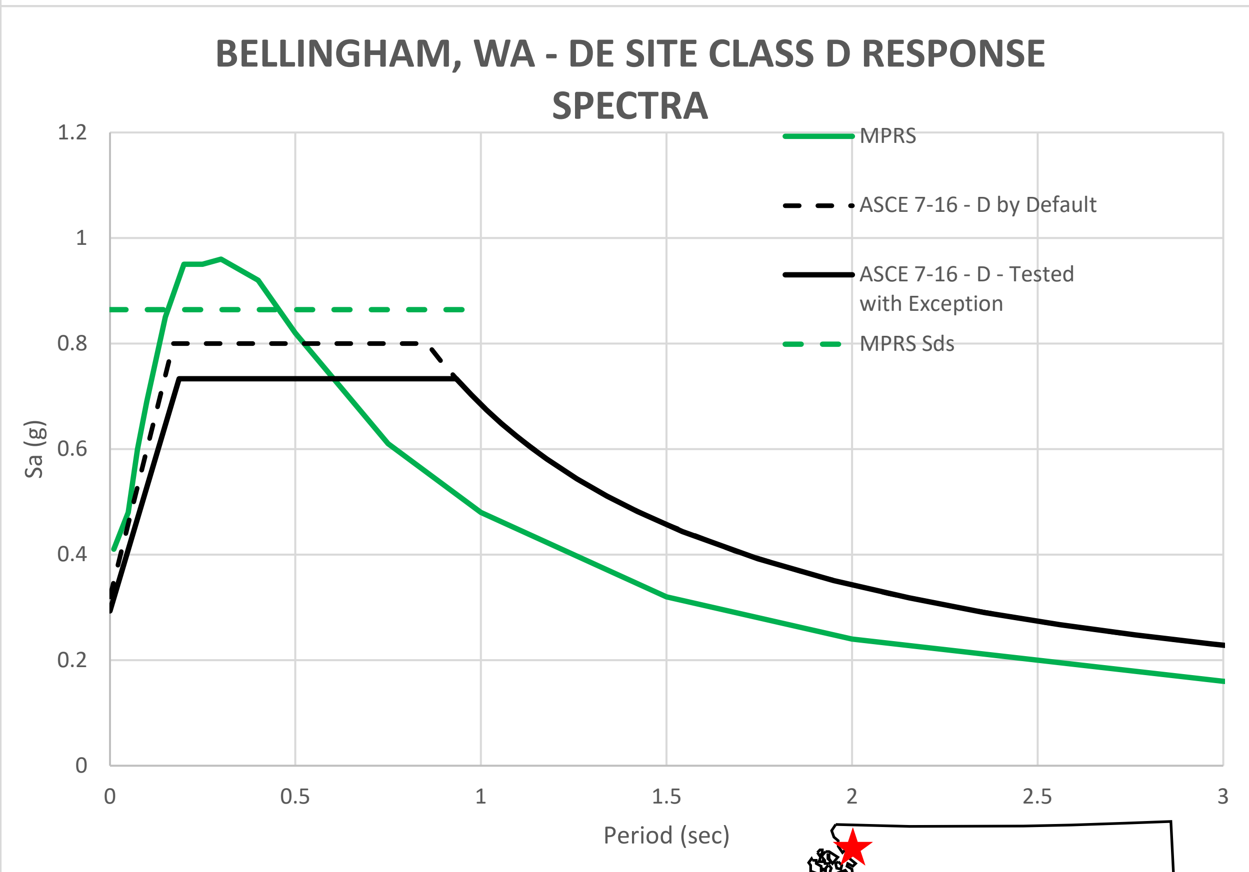

AUBURN, WA - DE SITE CLASS D RESPONSE SPECTRA
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Sa (g)
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds

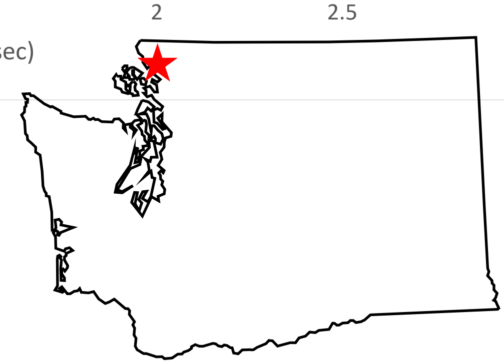


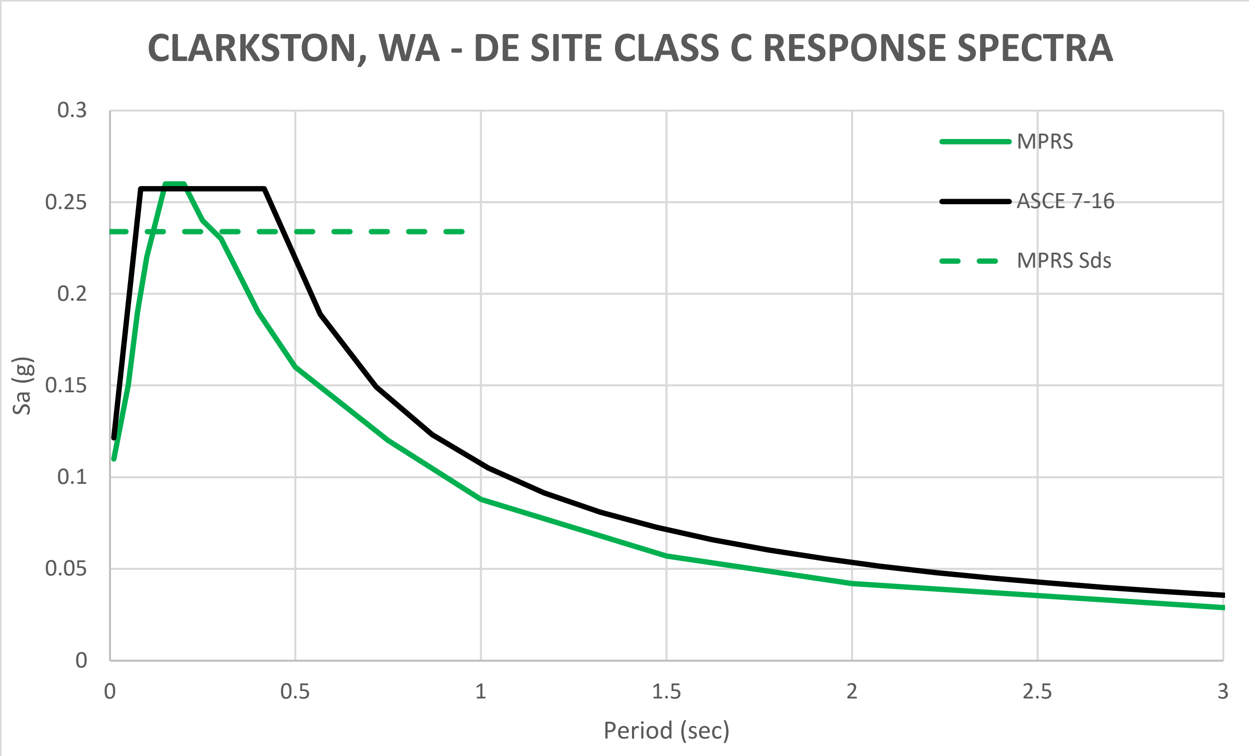

ABERDEEN, WA - DE SITE CLASS C RESPONSE SPECTRA
MPRS
ASCE 7-16
MPRS Sds
Sa (g)
Period (sec)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1.5
2
2.5
3

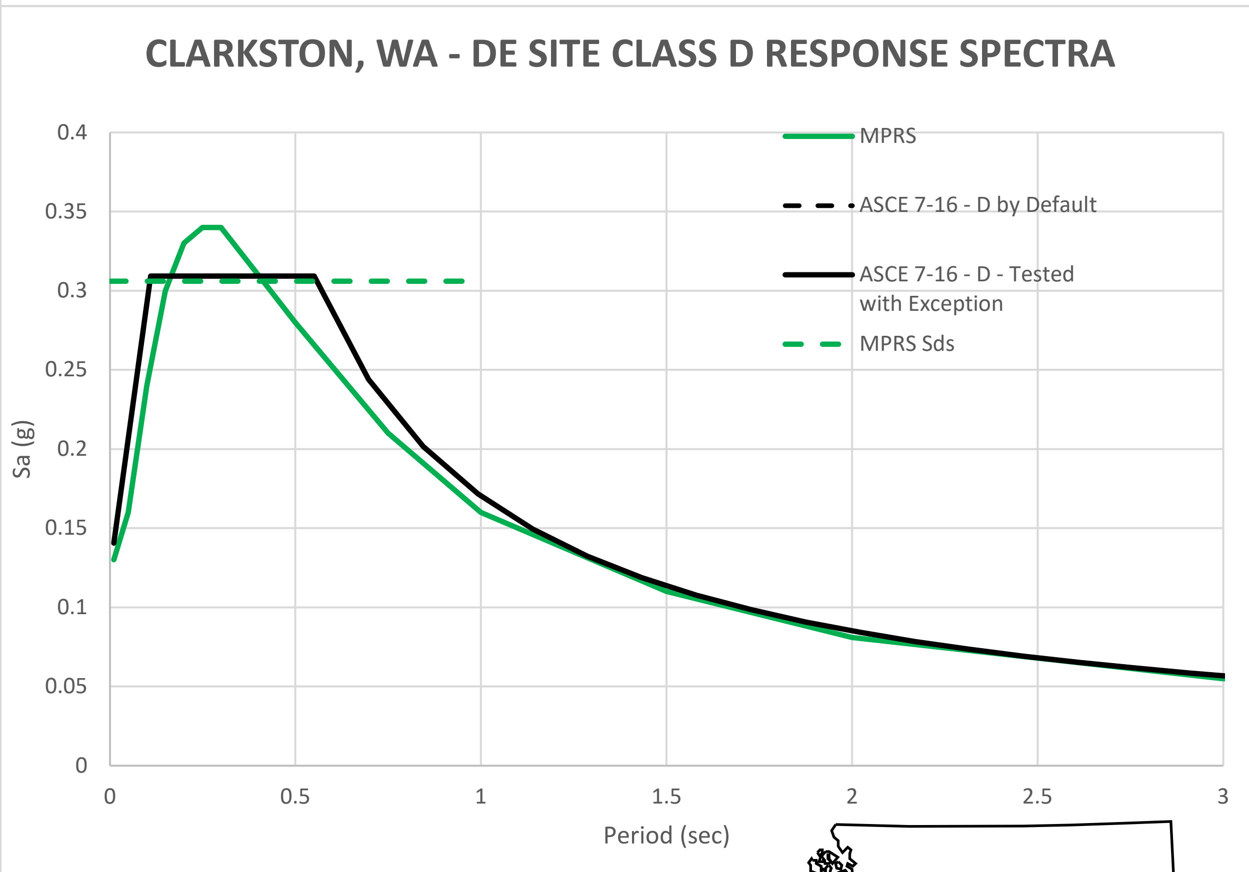

ABERDEEN, WA - DE SITE CLASS D RESPONSE SPECTRA
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds
Sa (g)
Period (sec)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1.5
2
2.5
3

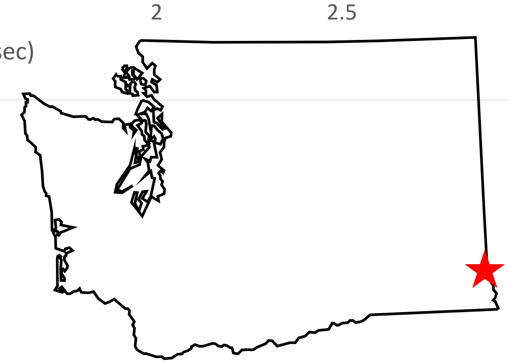

BELLINGHAM, WA - DE SITE CLASS C RESPONSE SPECTRA
MPRS
ASCE 7-16
MPRS Sds
Sa (g)
Period (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.5
1.5
2
2.5
3

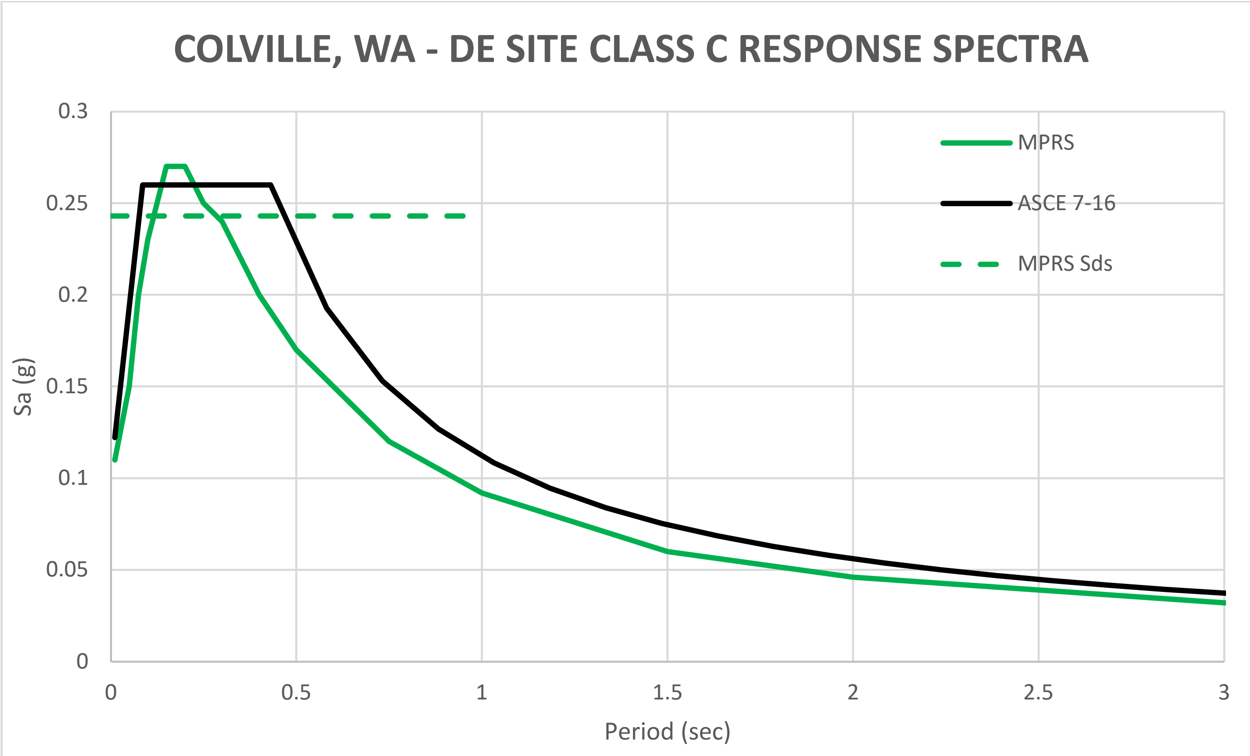

BELLINGHAM, WA - DE SITE CLASS D RESPONSE SPECTRA
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested
with Exception
MPRS Sds
Sa (g)
Period (sec)
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1.5
2
2.5
3

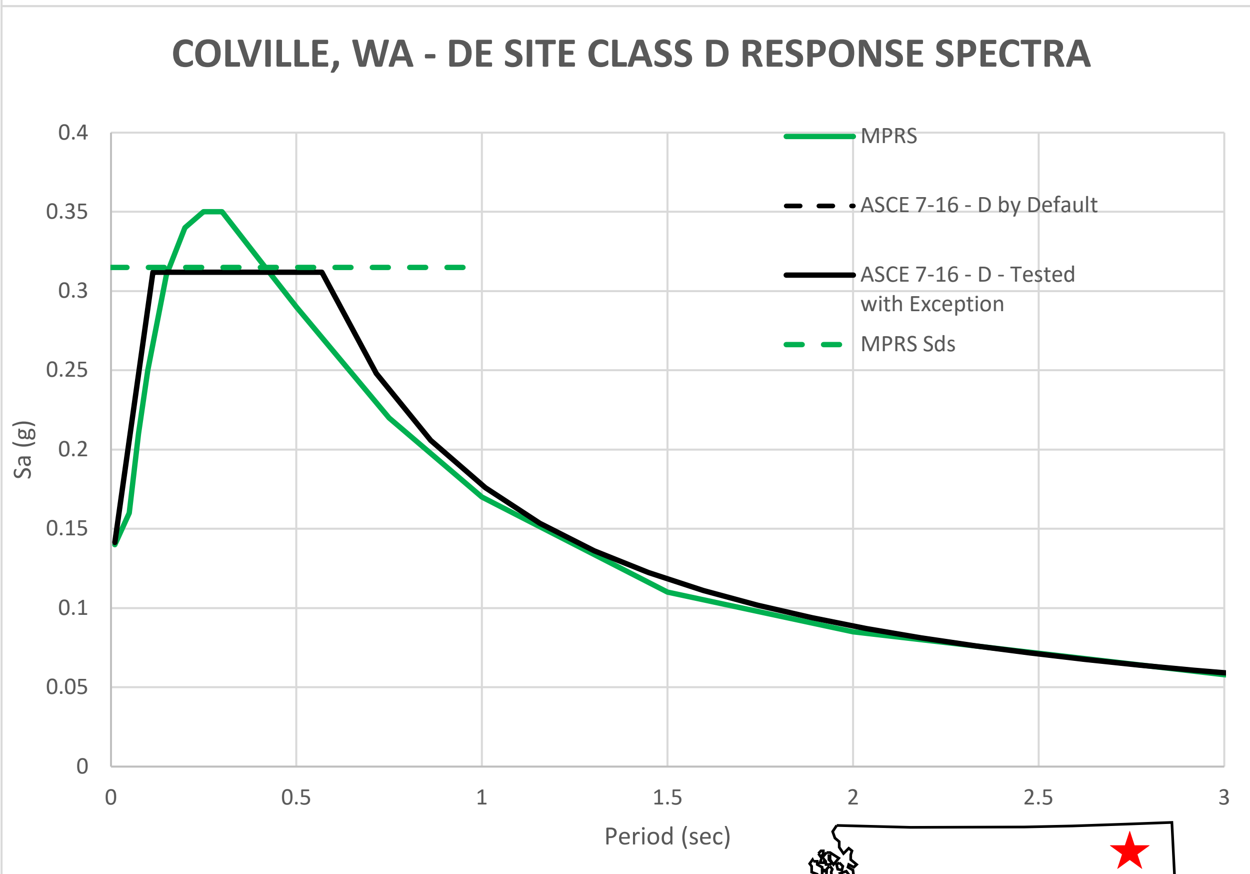


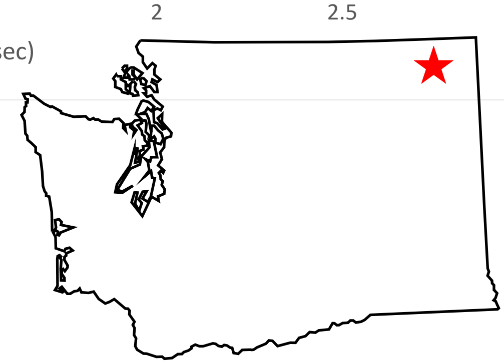

CLARKSTON, WA - DE SITE CLASS C RESPONSE SPECTRA
Sa (g)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16
MPRS Sds

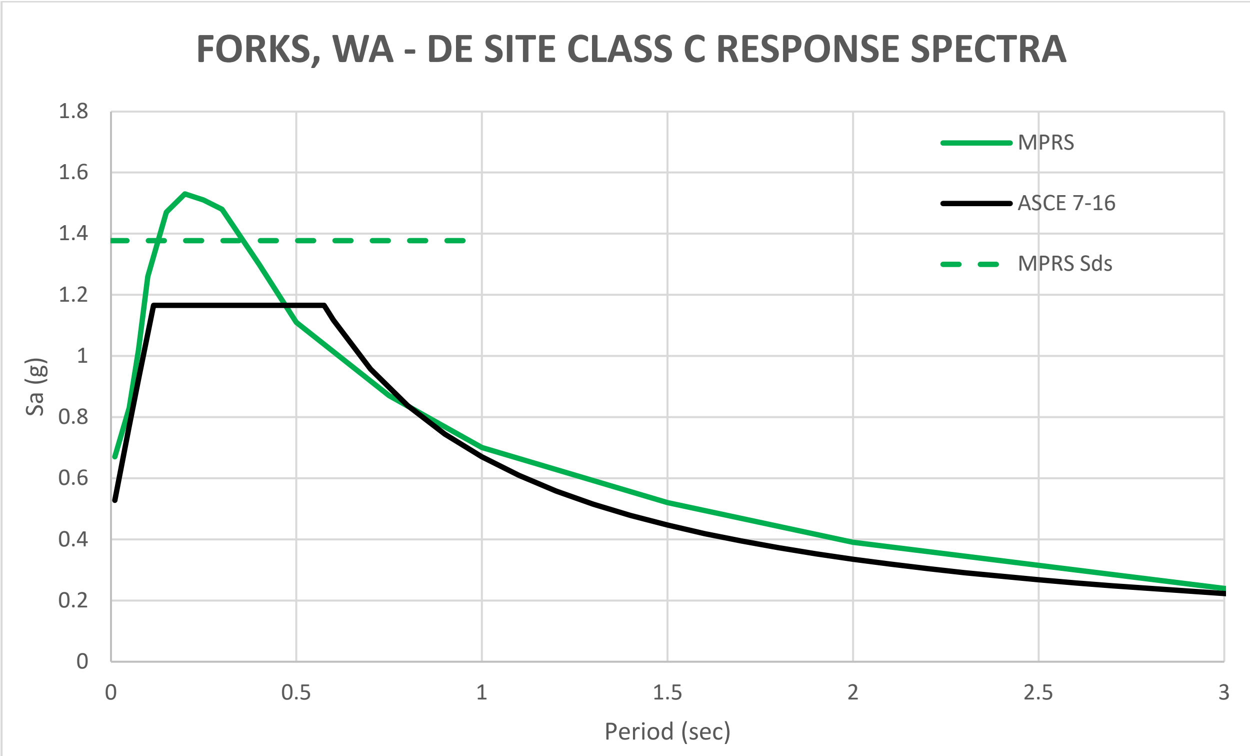

CLARKSTON, WA - DE SITE CLASS D RESPONSE SPECTRA
Sa (g)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds

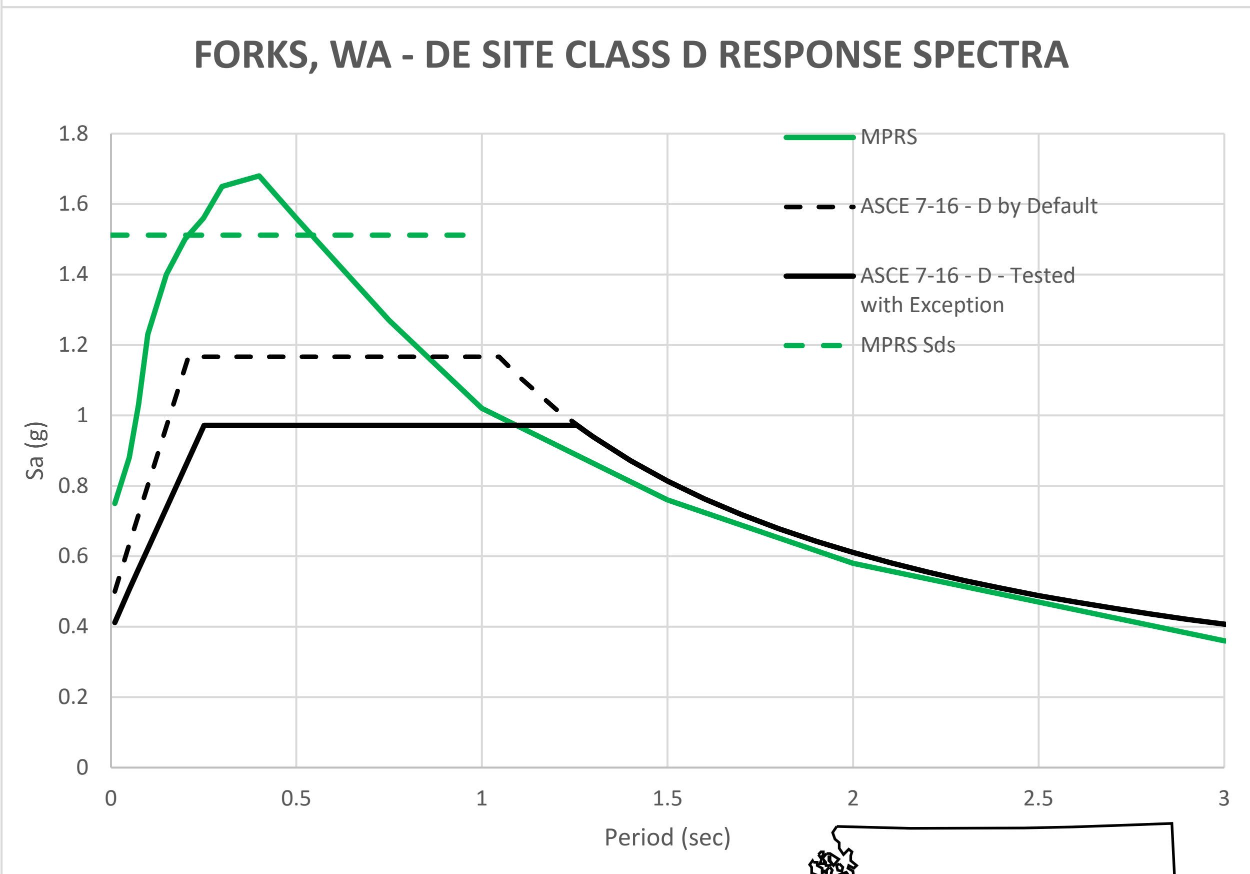


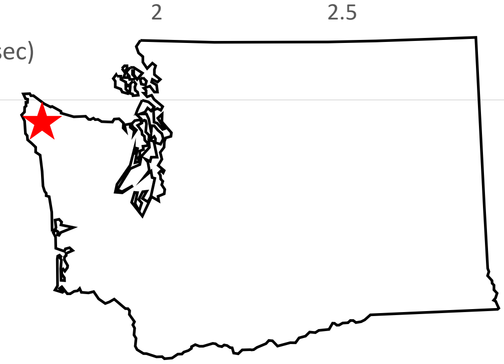

COLVILLE, WA - DE SITE CLASS C RESPONSE SPECTRA
Sa (g)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16
MPRS Sds

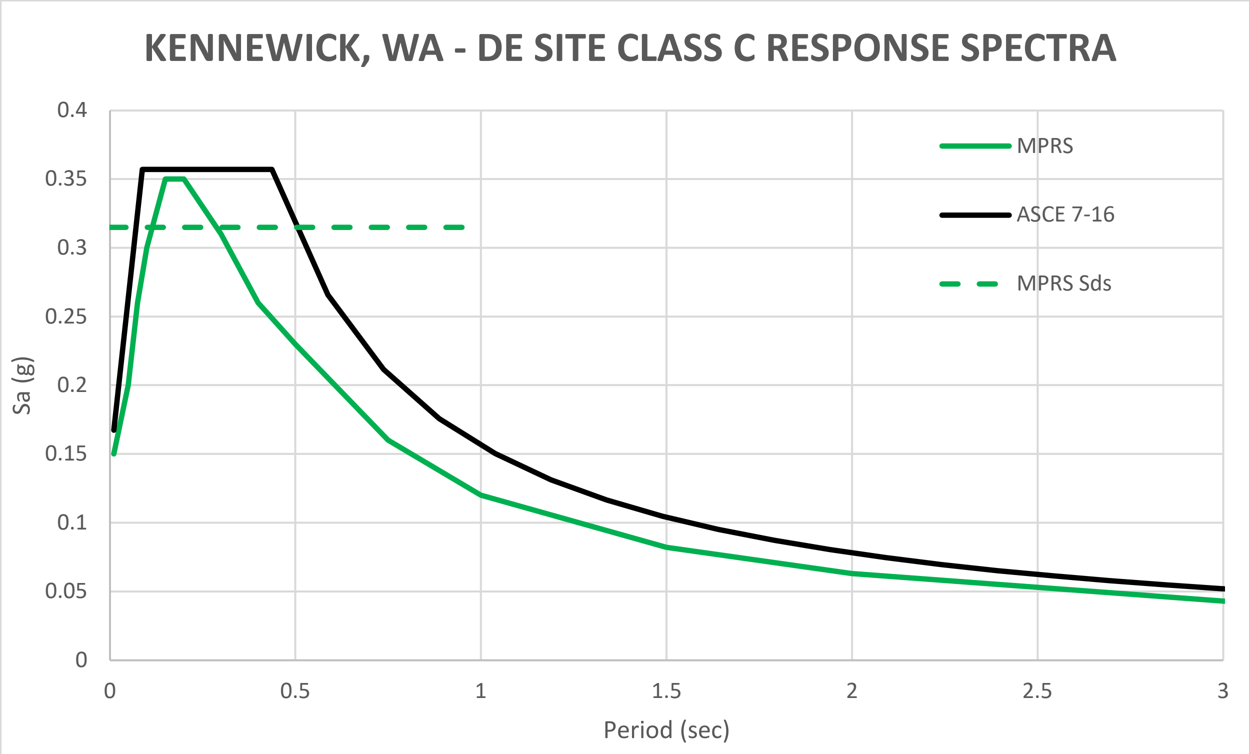

COLVILLE, WA - DE SITE CLASS D RESPONSE SPECTRA
Sa (g)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds

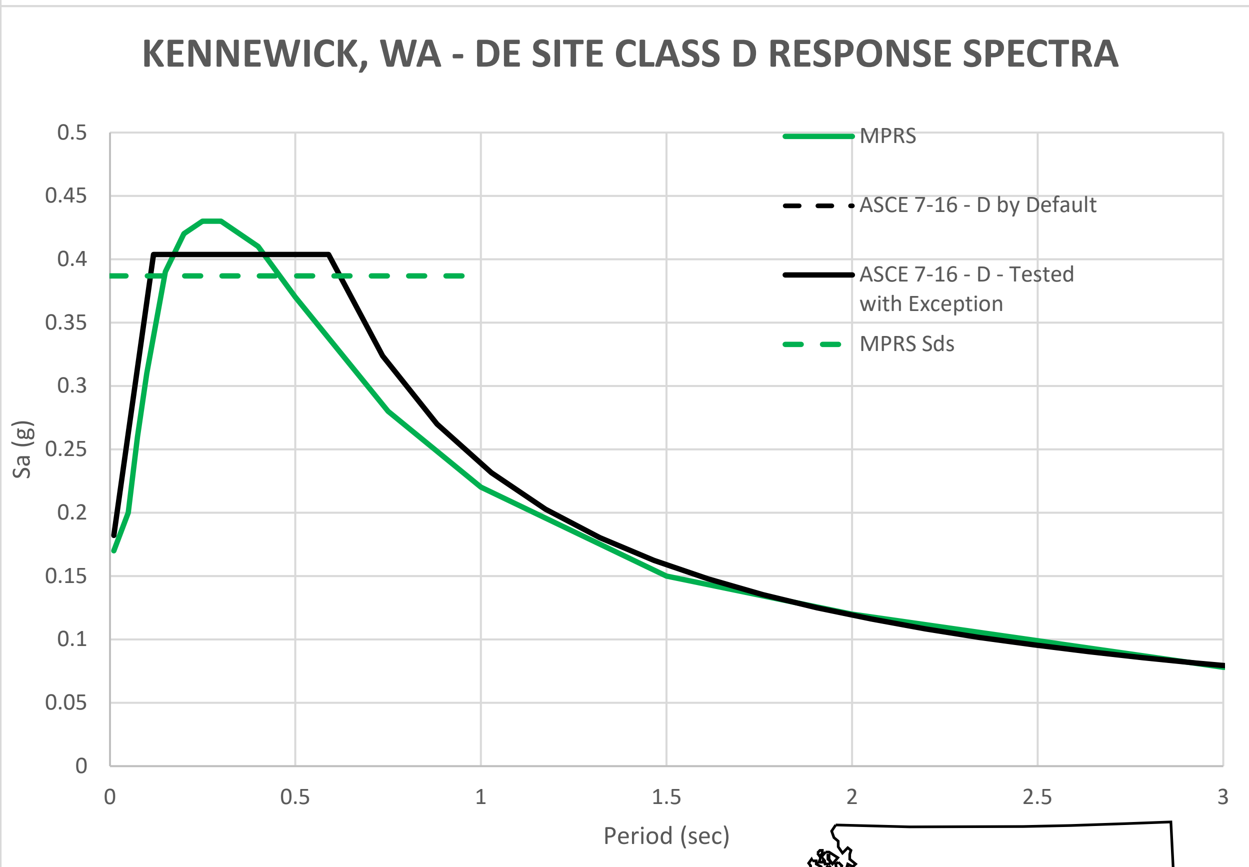


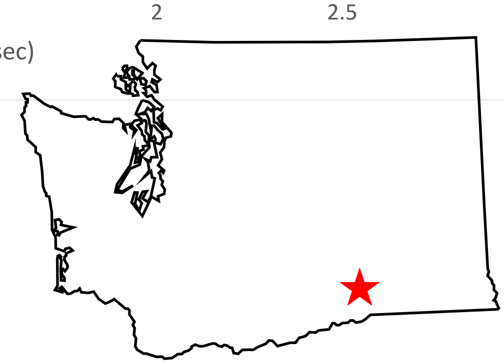

FORKS, WA - DE SITE CLASS C RESPONSE SPECTRA
MPRS
ASCE 7-16
MPRS Sds
Sa (g)
Period (sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0.5
1.5
2
2.5
3

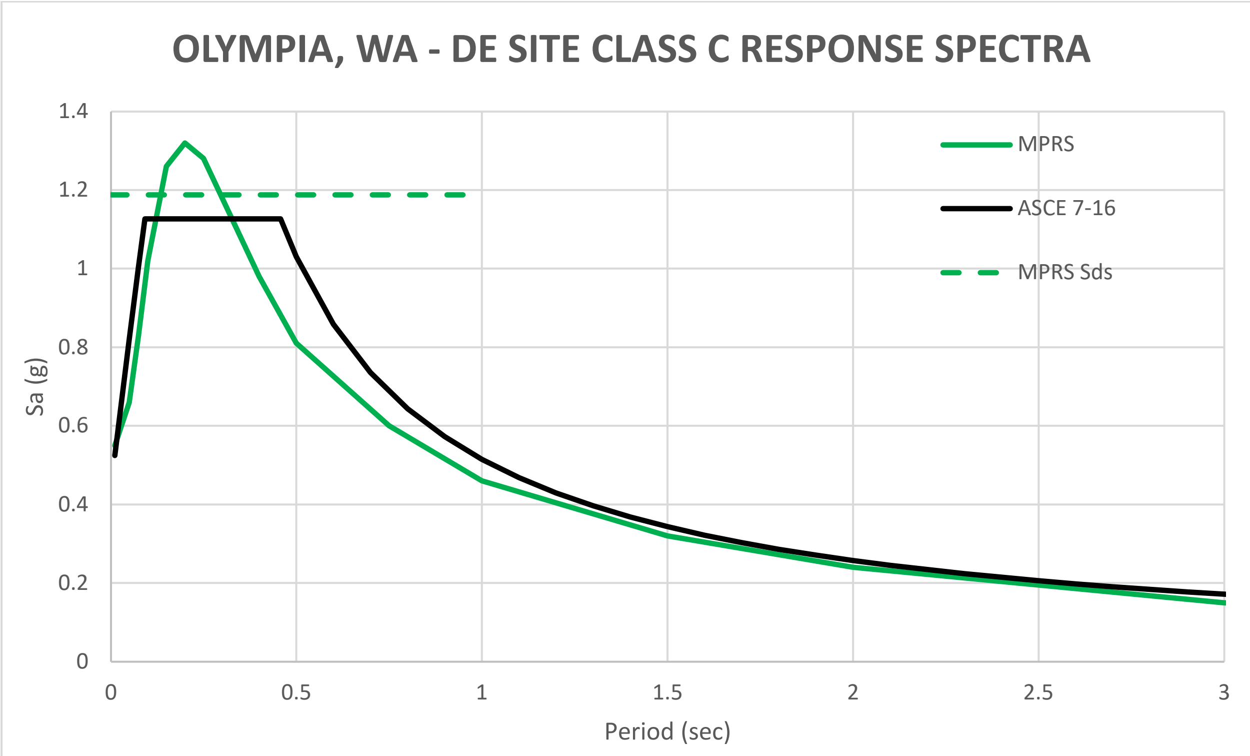

FORKS, WA - DE SITE CLASS D RESPONSE SPECTRA
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds
Sa (g)
Period (sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0.5
1.5
2
2.5
3

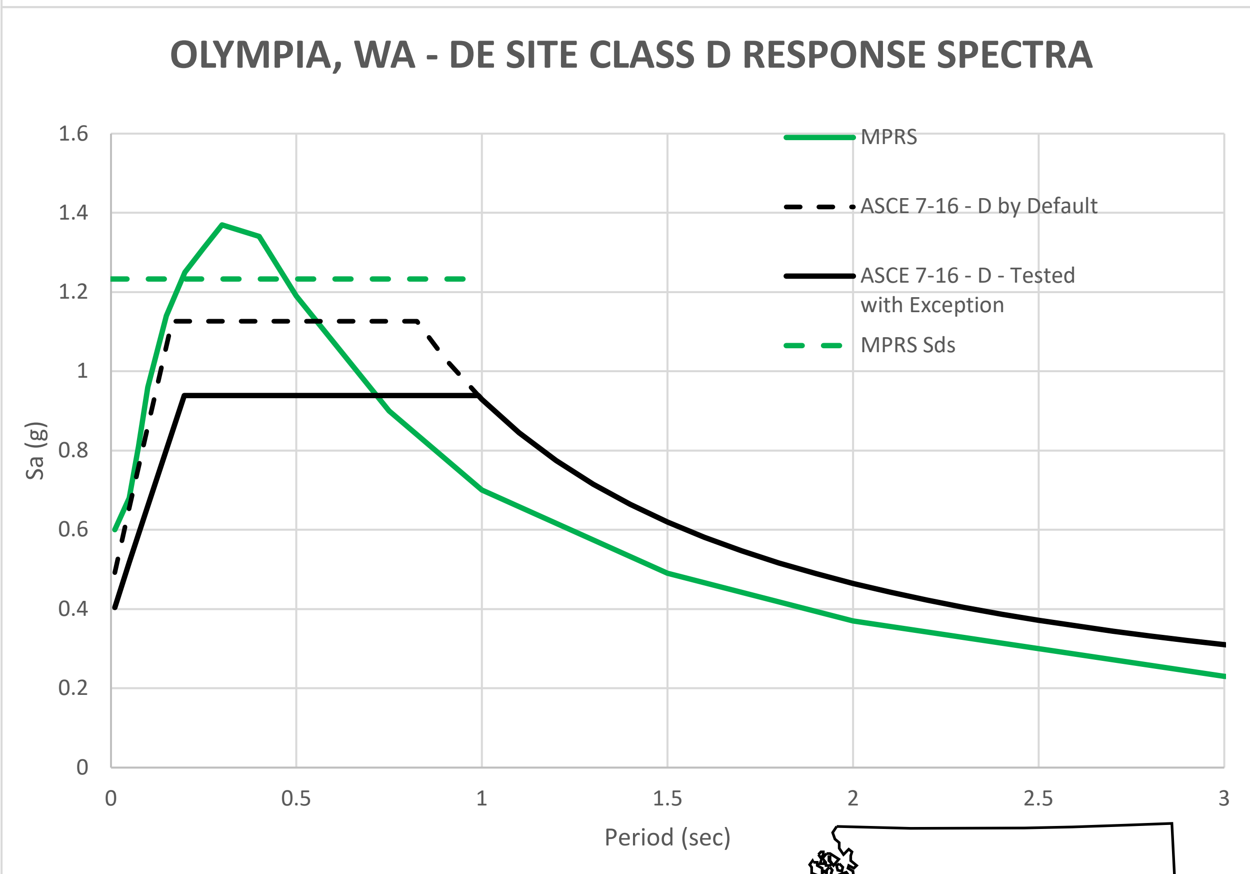


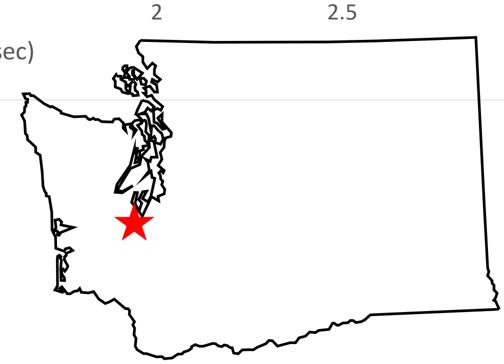

KENNEWICK, WA - DE SITE CLASS C RESPONSE SPECTRA
Sa (g)
Period (sec)
MPRS
ASCE 7-16
MPRS Sds
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.5
1
1.5
2
2.5
3

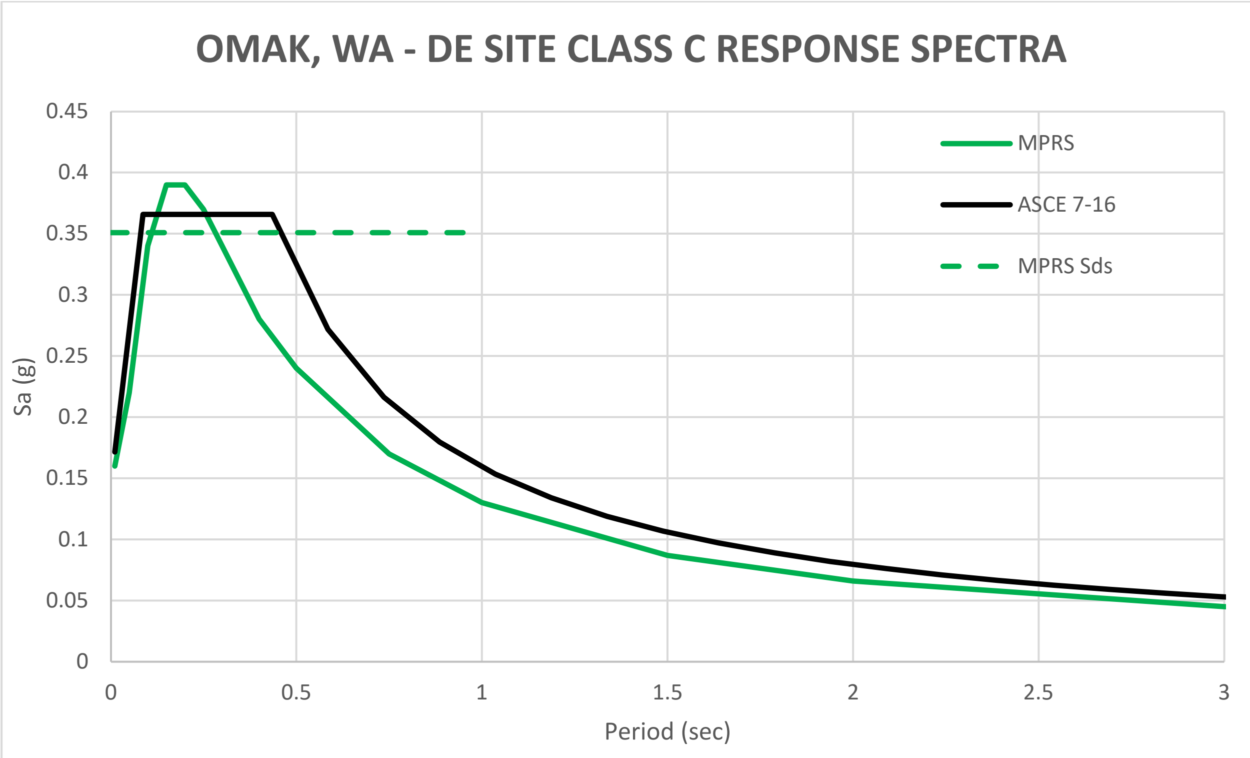

KENNEWICK, WA - DE SITE CLASS D RESPONSE SPECTRA
Sa (g)
Period (sec)
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
1
1.5
2
2.5
3

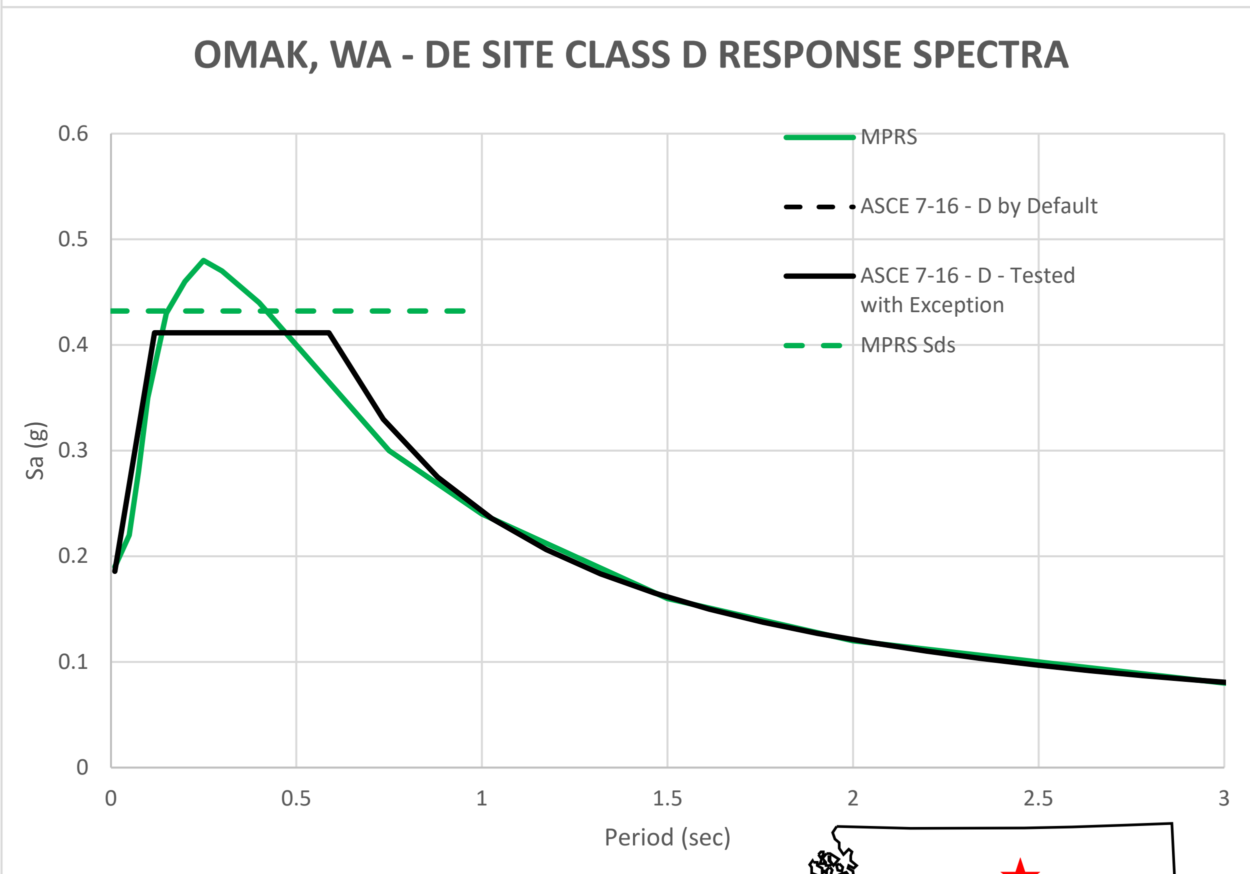


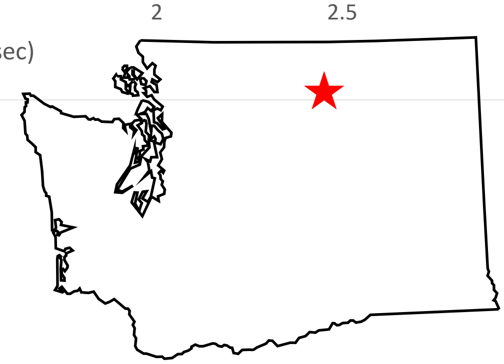

OLYMPIA, WA - DE SITE CLASS C RESPONSE SPECTRA
Sa (g)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16
MPRS Sds

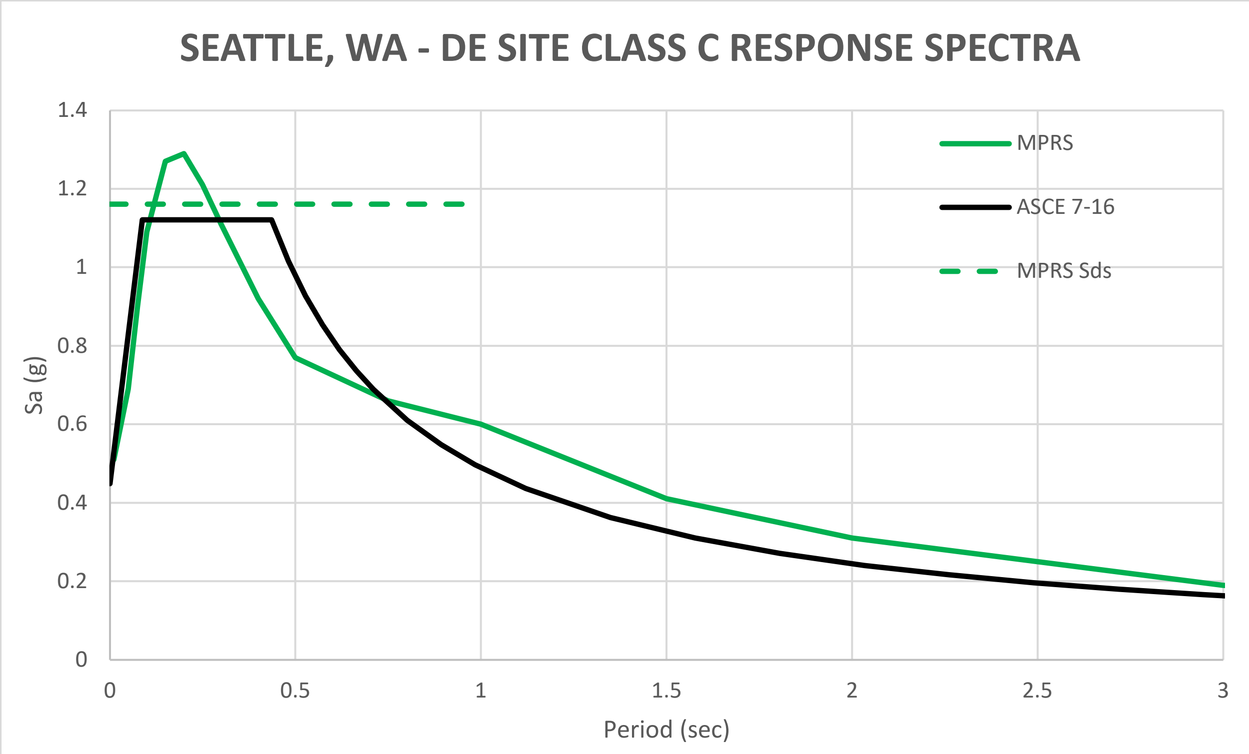

OLYMPIA, WA - DE SITE CLASS D RESPONSE SPECTRA
Sa (g)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0
0.5
1
1.5
2
2.5
3
Period (sec)
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds

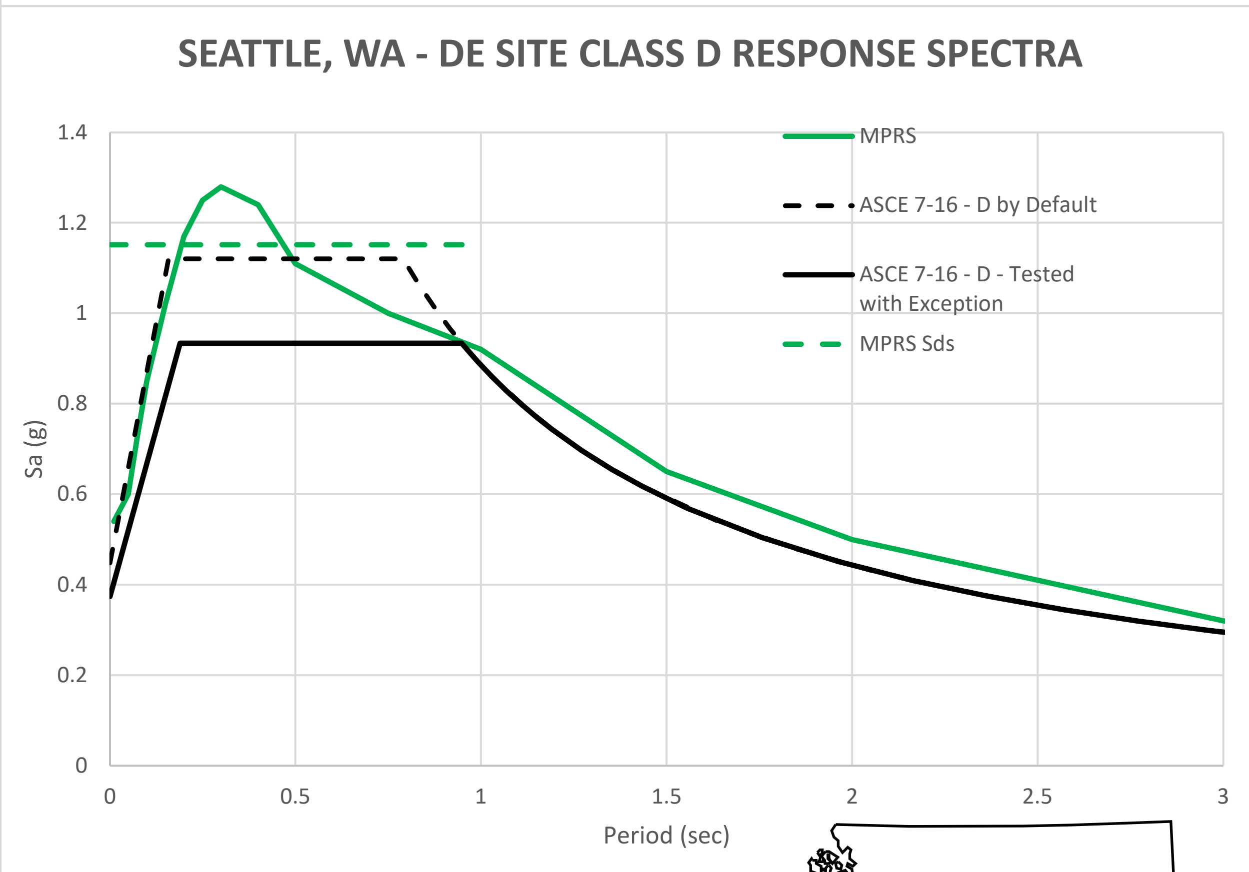


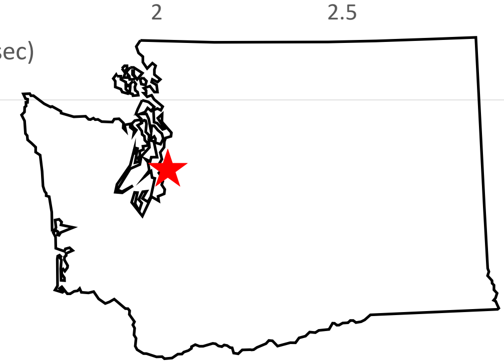

OMAK, WA - DE SITE CLASS C RESPONSE SPECTRA
MPRS
ASCE 7-16
MPRS Sds
Sa (g)
Period (sec)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0
0.5
1
1.5
2
2.5
3

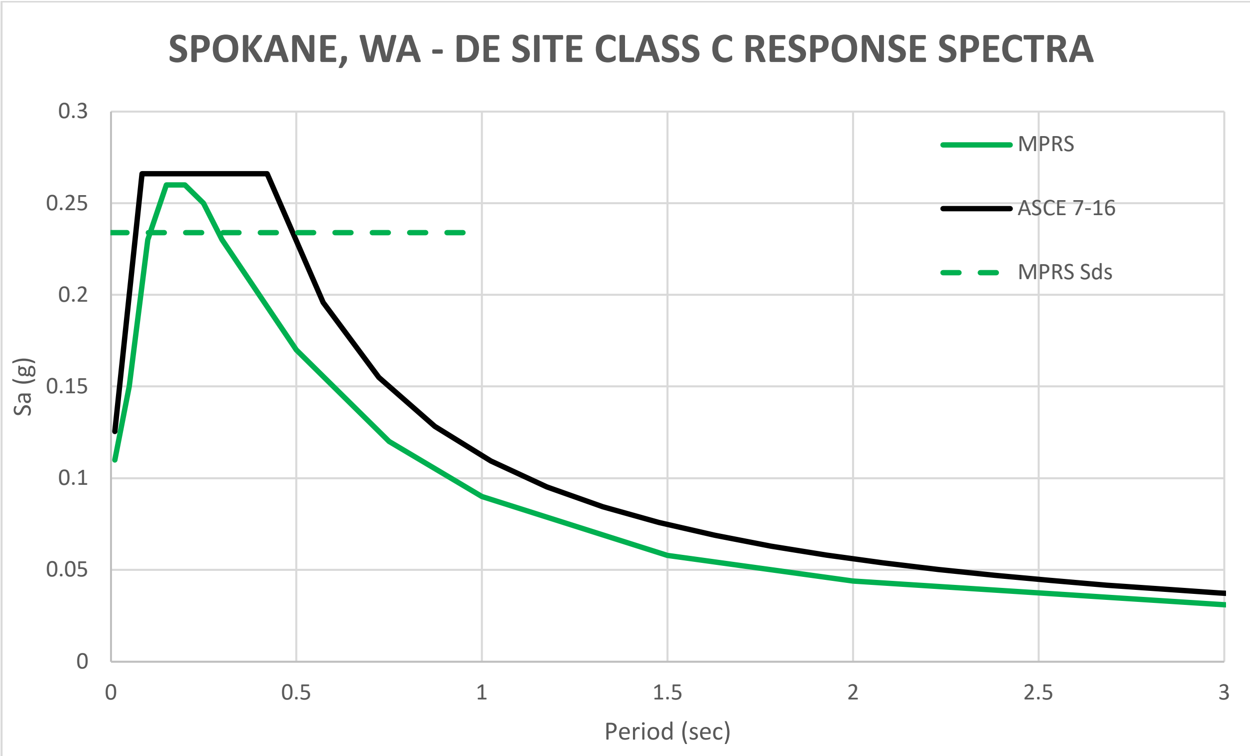

OMAK, WA - DE SITE CLASS D RESPONSE SPECTRA
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds
Sa (g)
Period (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0
0.5
1
1.5
2
2.5
3

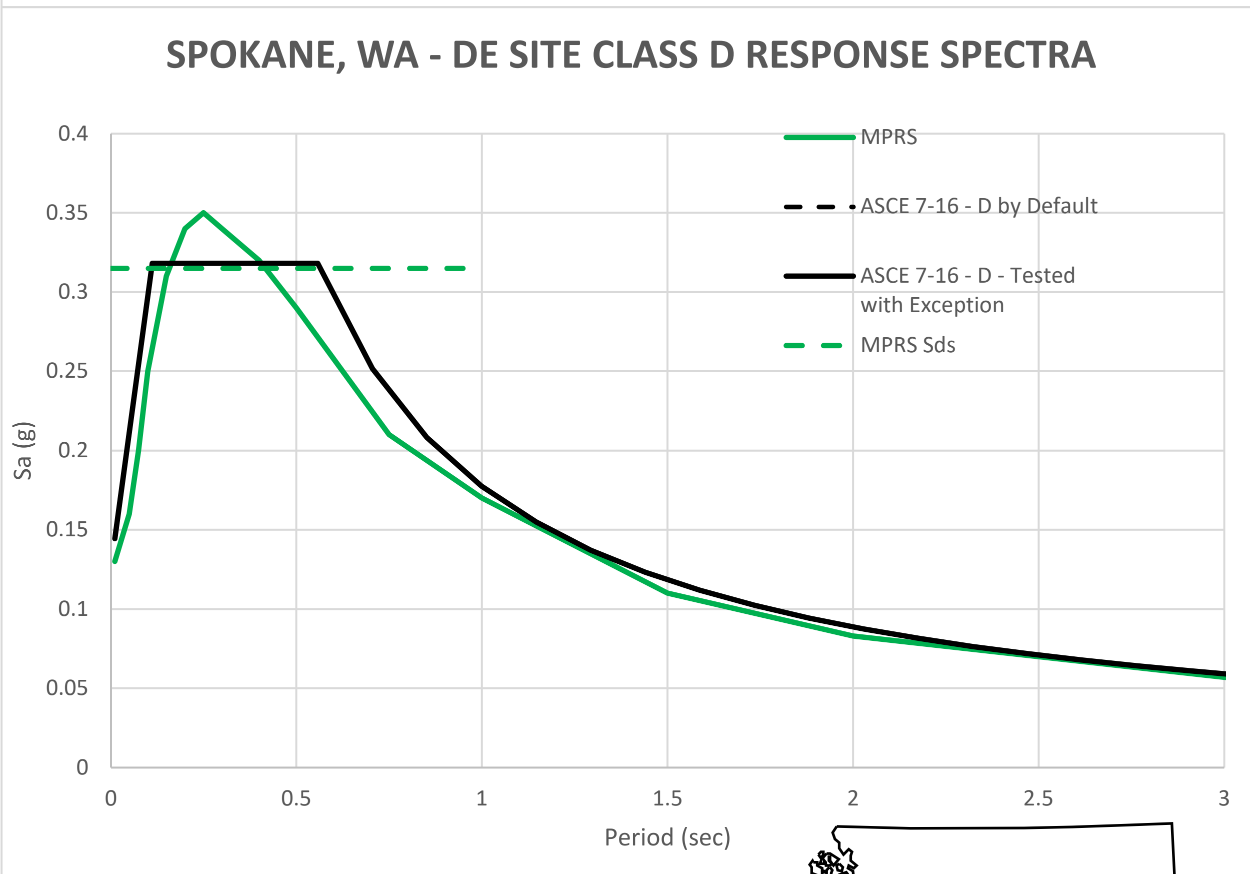


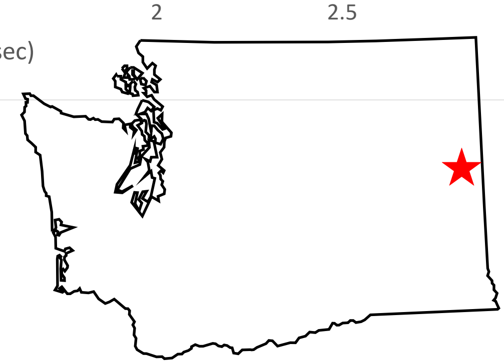

SEATTLE, WA - DE SITE CLASS C RESPONSE SPECTRA
Sa (g)
Period (sec)
MPRS
ASCE 7-16
MPRS Sds
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
0.5
1
1.5
2
2.5
3

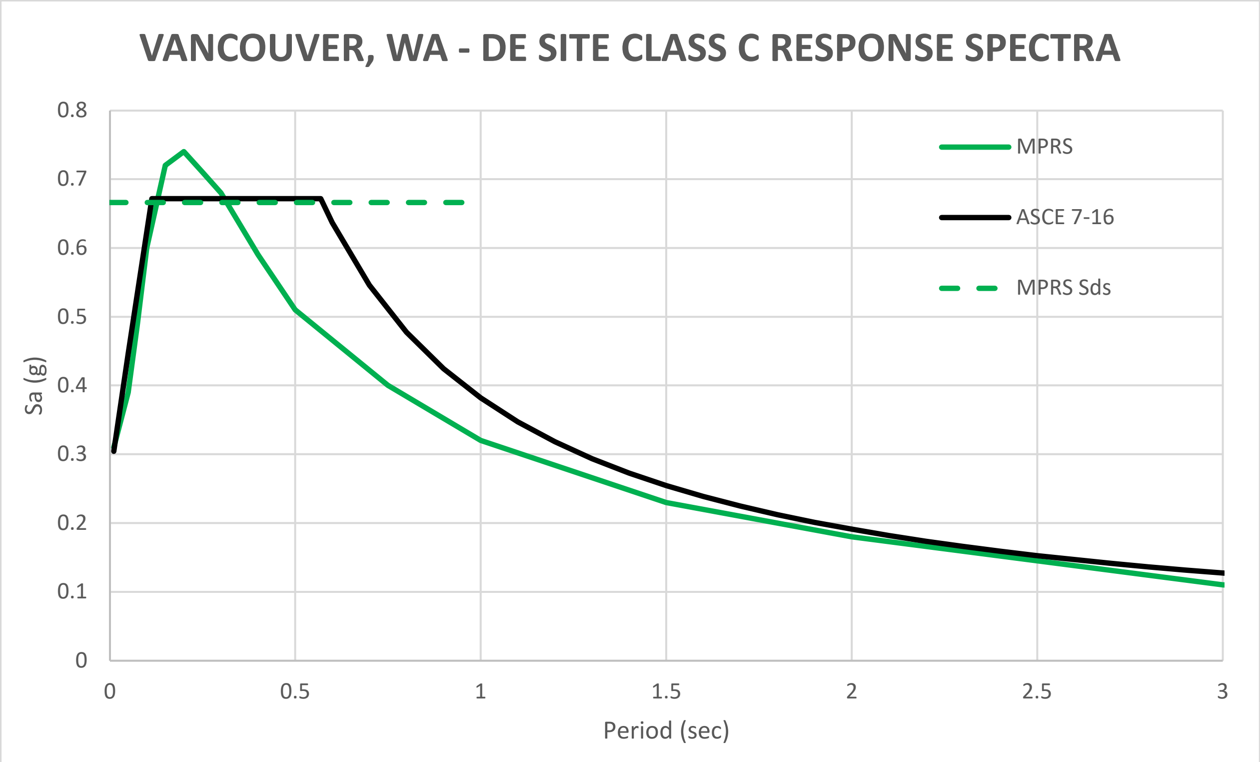

SEATTLE, WA - DE SITE CLASS D RESPONSE SPECTRA
Sa (g)
Period (sec)
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
0.5
1
1.5
2
2.5
3

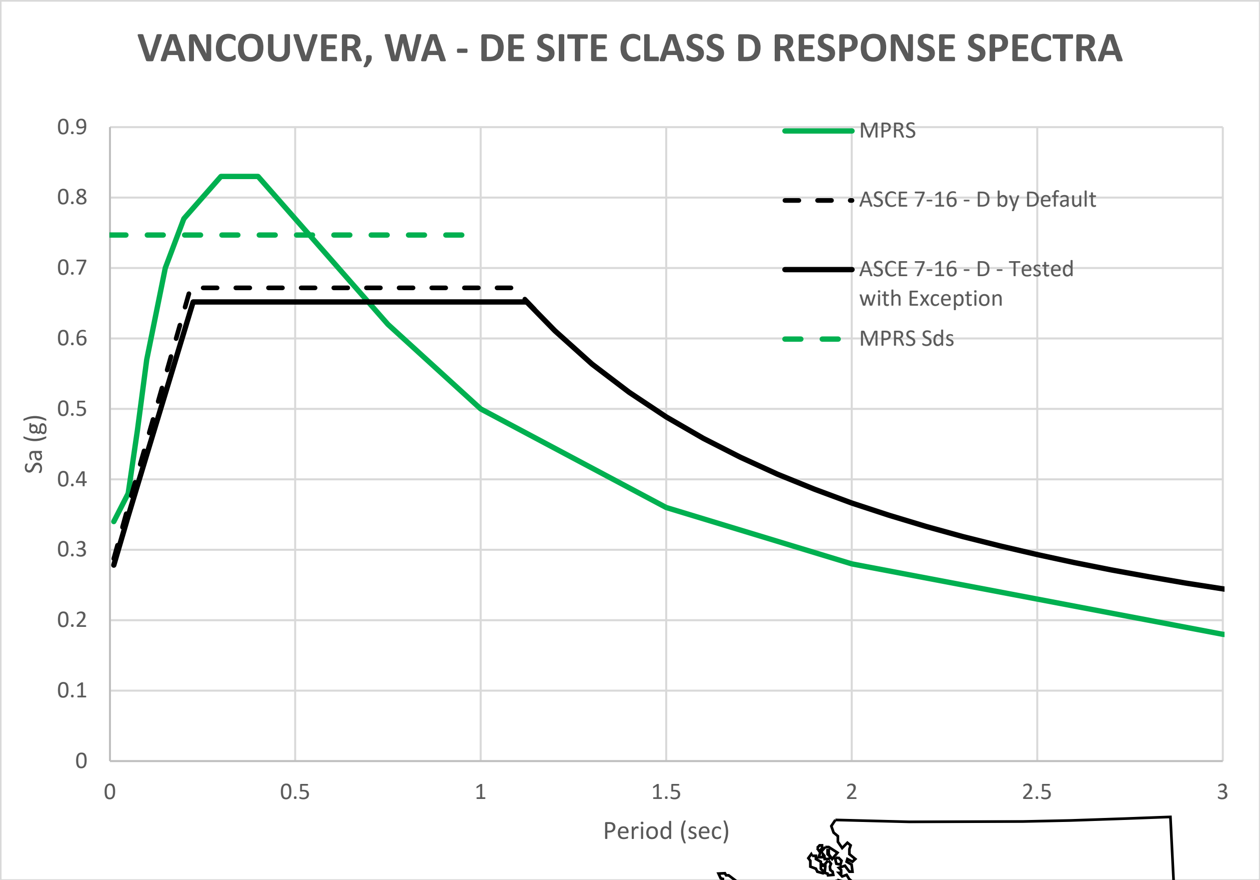


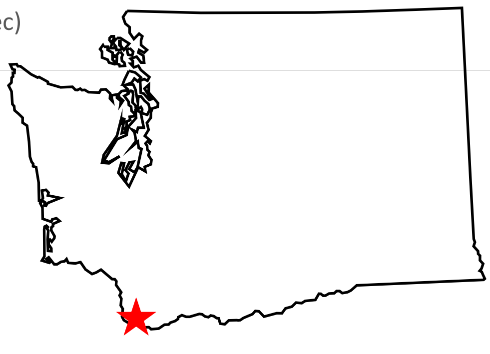

SPOKANE, WA - DE SITE CLASS C RESPONSE SPECTRA
MPRS
ASCE 7-16
MPRS Sds
Sa (g)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
0.5
1
1.5
2
2.5
3
Period (sec)


SPOKANE, WA - DE SITE CLASS D RESPONSE SPECTRA
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds
Sa (g)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
0.5
1
1.5
2
2.5
3
Period (sec)

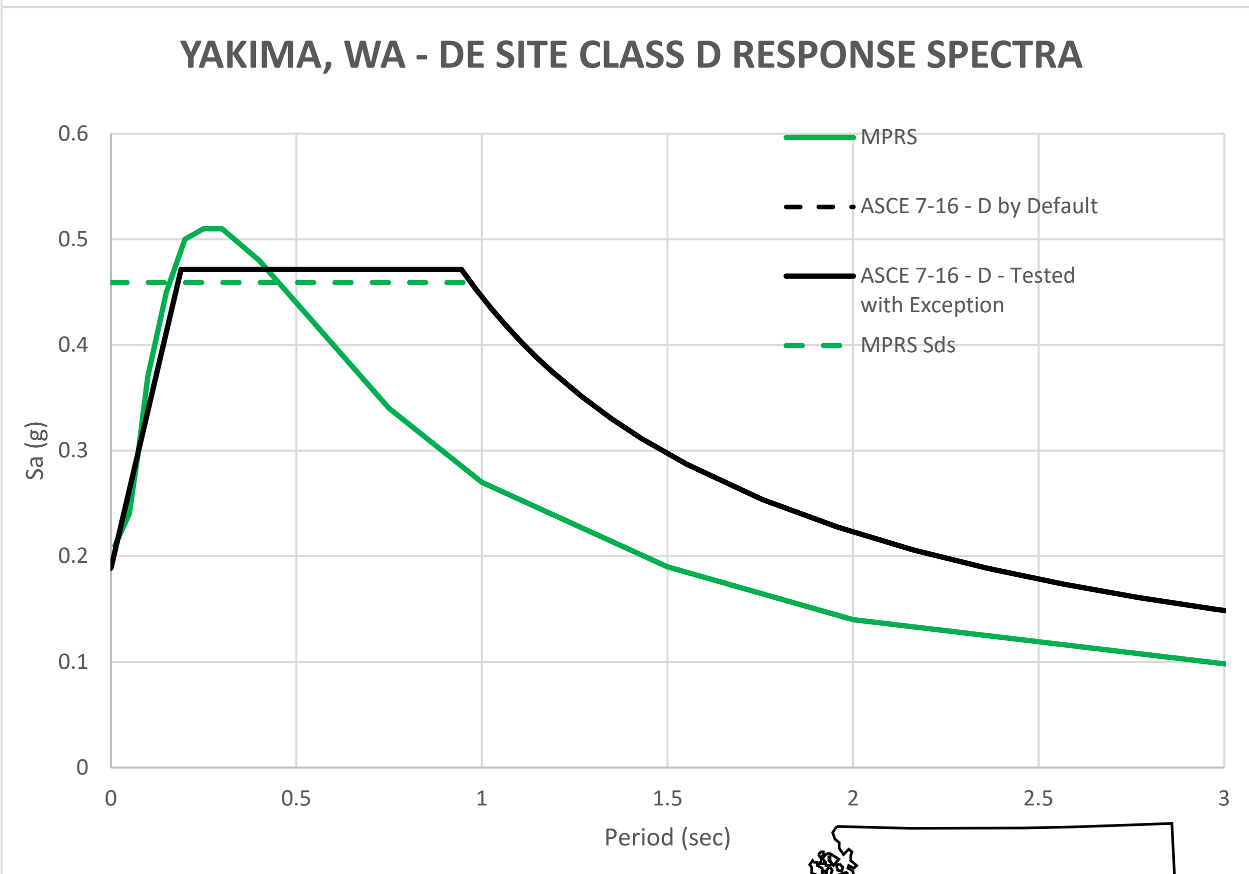


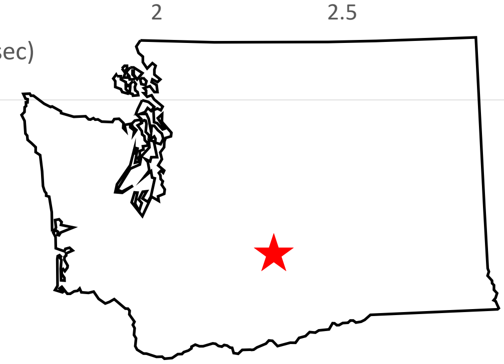

VANCOUVER, WA - DE SITE CLASS C RESPONSE SPECTRA
Sa (g)
Period (sec)
MPRS
ASCE 7-16
MPRS Sds


VANCOUVER, WA - DE SITE CLASS D RESPONSE SPECTRA
Sa (g)
Period (sec)
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds




YAKIMA, WA - DE SITE CLASS C RESPONSE SPECTRA
MPRS
ASCE 7-16
MPRS Sds
Sa (g)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
0.5
1
1.5
2
2.5
3
Period (sec)


YAKIMA, WA - DE SITE CLASS D RESPONSE SPECTRA
MPRS
ASCE 7-16 - D by Default
ASCE 7-16 - D - Tested with Exception
MPRS Sds
Sa (g)
0
0.1
0.2
0.3
0.4
0.5
0.6
0
0.5
1
1.5
2
2.5
3
Period (sec)



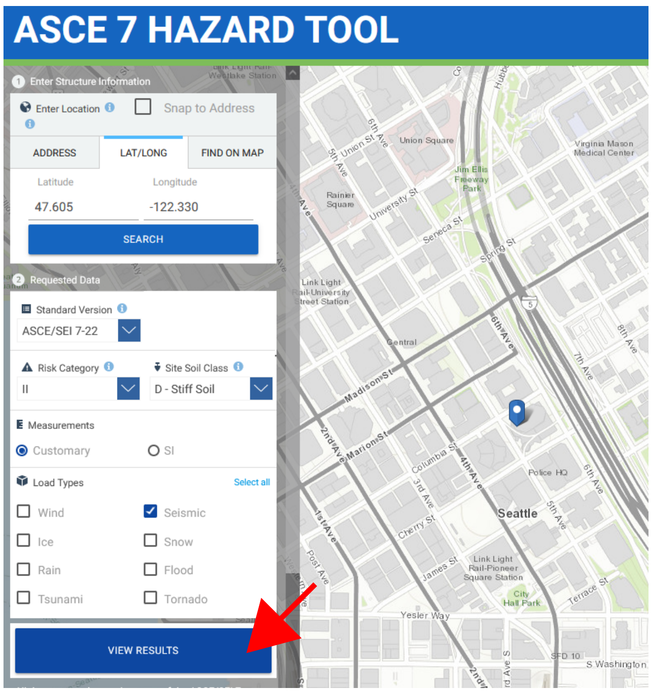
Appendix B
Example Calculations

Example 1: Short period structure located in Seattle. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

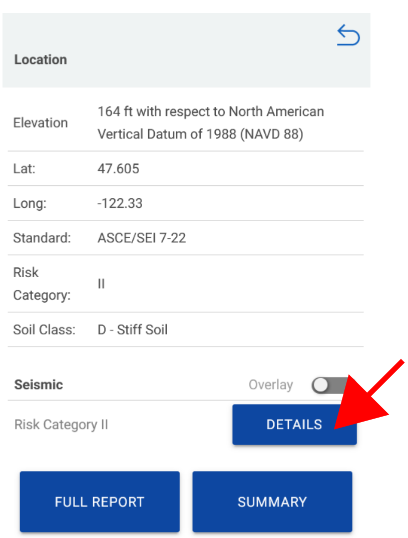
Location: Lat = 47.605 Long = -122.330
Site Class D (Determined by Geotech from shear wave velocity testing)
Risk Category II
Building Period T = 0.4 seconds

The first step to obtain the seismic parameters is to use the ASCE 7 web tool to obtain the spectrum that will be treated as a site-specific spectrum for the purposes of obtaining the seismic design parameters. Input the information above into the ASCE 7 Hazard tool as shown below.

https://asce7hazardtool.online



After clicking "View Results" click the "Details" button shown below to open an interactive panel to determine the spectral acceleration values.



Example 1: Short period structure located in Seattle. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

Seismic Details

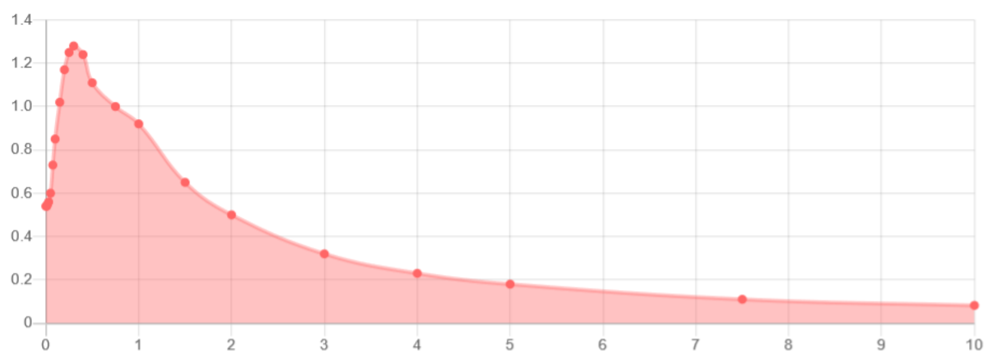
Risk Category II

S_S 1.56	S_1 0.66	S_{MS} 1.72	S_{M1} 1.38
S_{DS} 1.15	S_{D1} 0.92	T_L 6	PGA_M 0.7
V_{S30} 260			

Seismic Design Category D

Multi-Period Design Spectrum

GRAPH TABLE CSV



S_a(g) vs T(s)

Multi-Period MCE_R Spectrum

The acceleration values can be determined by mousing over the points on the graph and reading the data points, but are also presented in table format under the "Table" tab shown above. A text file of the period and acceleration values can be downloaded by clicking the "CSV" tab, and then imported into Excel.

	A	B
1	T(s)	Sa(g)
2	0	0.54
3	0.01	0.54
4	0.02	0.55
5	0.03	0.56
6	0.05	0.6
7	0.075	0.73
8	0.1	0.85
9	0.15	1.02
10	0.2	1.17
11	0.25	1.25
12	0.3	1.28
13	0.4	1.24
14	0.5	1.11
15	0.75	1
16	1	0.92
17	1.5	0.65
18	2	0.5
19	3	0.32
20	4	0.23
21	5	0.18
22	7.5	0.11
23	10	0.082

Example 1: Short period structure located in Seattle. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

S_{ds} and S_{d1} are calculated and reported using the ASCE 7 Hazard Tool. The values calculated by the tool use methods similar to ASCE 7-16 Section 21.4.

S_{ds} = 1.15 g

S_{d1} = 0.92 g

Per the Code Amendment Section 11.4.8.1.8, it is permitted to substitute the value of S_a at the building period for the value of S_{d1}/T in eq. (12.8-3). If this method is used, the value of S_{d1}/T is calculated as shown below.

$S_{d1}/T = S_a$ (at 0.4 seconds) = 1.24 g (From the data point output of the ASCE 7 web tool)

$C_s = S_{ds} / (R / I_e) = 1.15 / (R / I_e)$ (ASCE 7-16 eq. 12.8-2)

C_s max = $S_{d1} / (T \times (R / I_e)) = 0.92 / (0.4 (R / I_e))$ (ASCE 7-16 eq. 12.8-3)

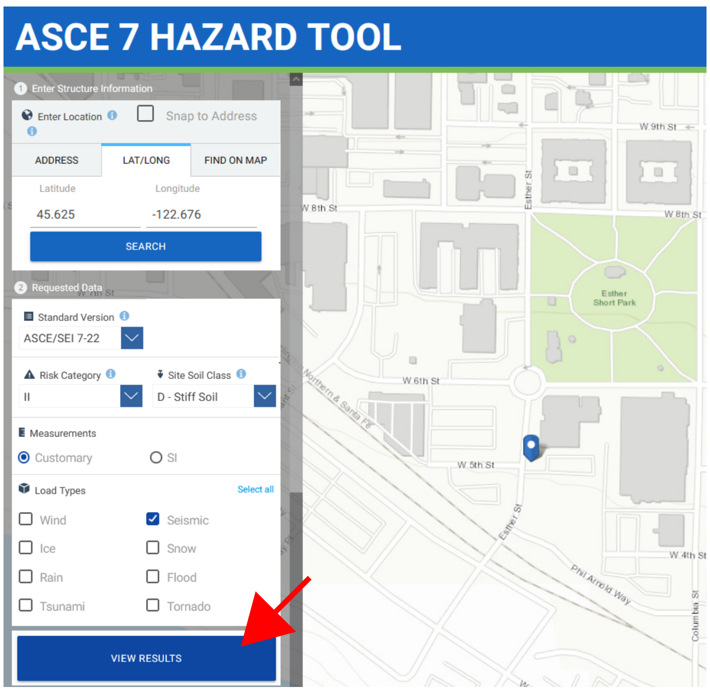
Because the C_s value will be controlled by eq. (12.8-2) due to the building period, for this example the method used to calculate S_{d1} is inconsequential.

Example 2: Medium period structure located in Vancouver. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

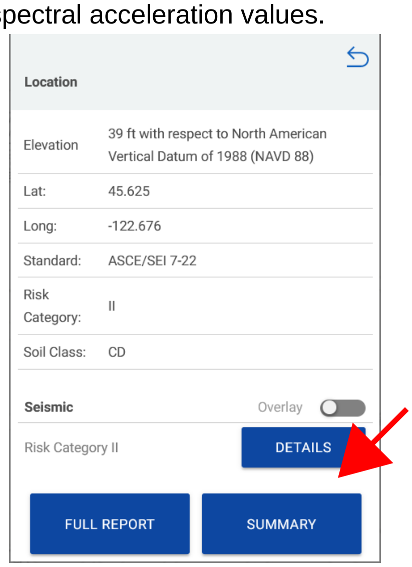
Location: Lat = 45.625 Long = -122.676
Site Class C/D (determined by geotech from shear wave velocity testing with measured $\overline{v}_s$ = 1400 ft/s)
Risk Category II
Building Period T = 0.75 seconds

The first step to obtain the seismic parameters is to use the ASCE 7 web tool to obtain the spectrum that will be treated as a site-specific spectrum for the purposes of obtaining the seismic design parameters. Input the information above into the ASCE 7 Hazard tool as shown below.

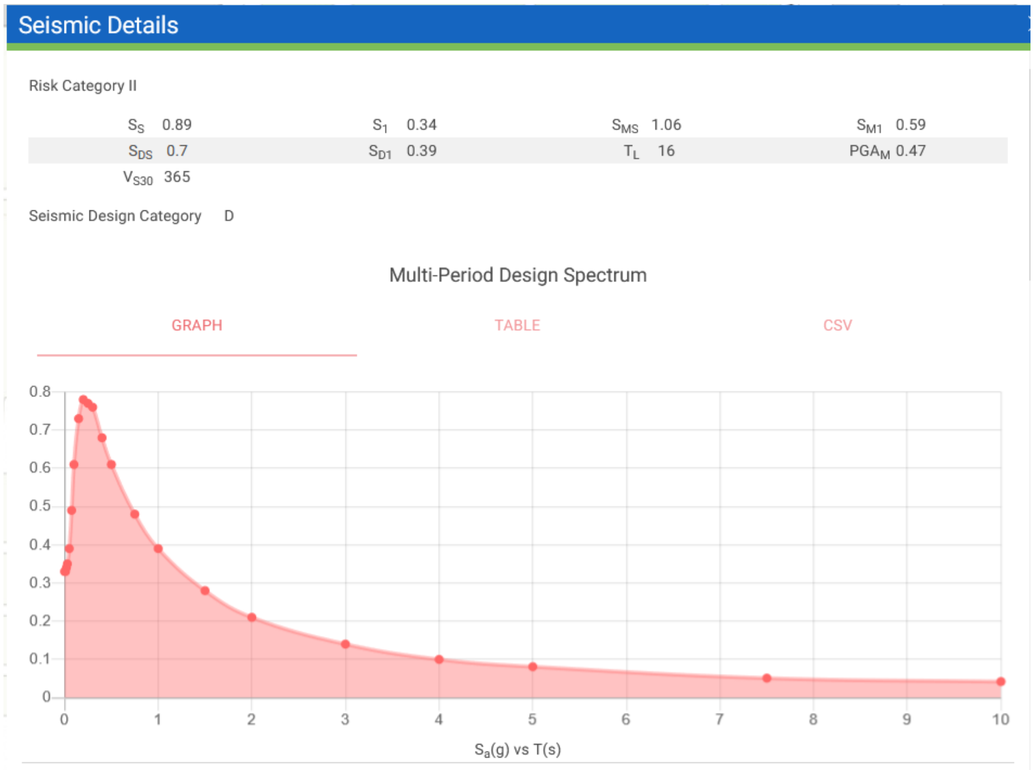
https://asce7hazardtool.online



After clicking "View Results" click the "Details" button shown below to open an interactive panel to determine the spectral acceleration values.



Example 2: Medium period structure located in Vancouver. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.



The acceleration values can be determined by mousing over the points on the graph and reading the data points, but are also presented in table format under the "Table" tab shown above. A text file of the period and acceleration values can be downloaded by clicking the "CSV" tab, and then imported into Excel.

	A	B
1	T(s)	Sa(g)
2	0	0.33
3	0.01	0.33
4	0.02	0.34
5	0.03	0.35
6	0.05	0.39
7	0.075	0.49
8	0.1	0.61
9	0.15	0.73
10	0.2	0.78
11	0.25	0.77
12	0.3	0.76
13	0.4	0.68
14	0.5	0.61
15	0.75	0.48
16	1	0.39
17	1.5	0.28
18	2	0.21
19	3	0.14
20	4	0.1
21	5	0.081
22	7.5	0.051
23	10	0.042

Example 2: Medium period structure located in Vancouver. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

S_{ds} and S_{d1} are calculated and reported using the ASCE 7 Hazard Tool. The values calculated by the tool use methods similar to ASCE 7-16 Section 21.4.

S_{ds} = 0.70 g

S_{d1} = 0.39 g

Per the Code Amendment Section 11.4.8.1.8, it is permitted to substitute the value of S_a at the building period for the value of S_{d1}/T in eq. (12.8-3). If this method is used, the value of S_{d1}/T is calculated as shown below.

$S_{d1}/T = S_a$ (at 0.75 seconds) = 0.48 g (From the data point output of the ASCE 7 web tool)

$C_s = S_{ds} / (R / I_e) = 0.70 / (R / I_e)$ (ASCE 7-16 eq. 12.8-2)

C_s max $= S_{d1} / (T \times (R / I_e)) = 0.48 / (R / I_e)$ (ASCE 7-16 eq. 12.8-3)

For this example, use of the S_a = 0.48 in eq. 12.8-3 is permissible and results in a smaller design shear because S_{d1}/T = 0.42 / 0.75 = 0.56 which is larger than the value of S_a at the fundamental period of the building.

Example 3: Short period structure located in Yakima. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

Location: Lat = 46.605 Long = -120.505
Site Class C determined by standard penetration test (SPT) blow count
estimated $\overline{v}_s$ of 1775 ft/s
Risk Category II
Building Period T = 0.5 seconds

Because the Site Class was determined using an estimation of the shear wave velocity profile, the provisions of the Amendment Section 1613.4.5 modifications to ASCE 7-16 Section 20.6.3 apply. To bound the possible soil conditions for the site, $\overline{v}_s$ should be both divided by 1.3 and multiplied by 1.3 and other possible Site Classes determined from Table 20.6.2-1. The seismic design parameters will be the largest of the resulting values.

$\overline{v}_s$ lower = $\overline{v}_s$ estimated / 1.3 = 1775 ft/s / 1.3 = 1365 ft/s (Correlates to Site Class CD)

$\overline{v}_s$ estimated = 1775 ft/s (Correlates to Site Class C)

$\overline{v}_s$ upper = $\overline{v}_s$ estimated x 1.3 = 1775 ft/s x 1.3 = 2307 ft/s (Correlates to Site Class BC)

Inputting the information above into the ASCE 7 web tool results in the period and acceleration tables shown below.

https://asce7hazardtool.online

Site Class BC multi-period		Site Class C multi-period		Site Class CD multi-period	
0	0.15	0	0.17	0	0.19
0.01	0.15	0.01	0.18	0.01	0.2
0.02	0.15	0.02	0.18	0.02	0.2
0.03	0.17	0.03	0.19	0.03	0.2
0.05	0.22	0.05	0.23	0.05	0.24
0.075	0.28	0.075	0.3	0.075	0.31
0.1	0.33	0.1	0.36	0.1	0.37
0.15	0.36	0.15	0.41	0.15	0.44
0.2	0.34	0.2	0.42	0.2	0.47
0.25	0.3	0.25	0.4	0.25	0.46
0.3	0.28	0.3	0.37	0.3	0.45
0.4	0.23	0.4	0.31	0.4	0.4
0.5	0.19	0.5	0.27	0.5	0.35
0.75	0.14	0.75	0.2	0.75	0.26
1	0.11	1	0.16	1	0.21
1.5	0.076	1.5	0.11	1.5	0.14
2	0.06	2	0.083	2	0.11
3	0.041	3	0.056	3	0.073
4	0.032	4	0.043	4	0.056
5	0.026	5	0.034	5	0.045
7.5	0.019	7.5	0.024	7.5	0.031
10	0.016	10	0.02	10	0.026

To develop the design spectrum, the most critical value for each of the three Site Classes must be used at each period. For this site, the acceleration parameters associated with Site Class CD control over the accelerations from Site Classes BC and C at all periods, so the values from Site Class CD will be used in the design shear calculations.

Example 3: Short period structure located in Yakima. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

S_{ds} and S_{d1} are calculated and reported using the ASCE 7 Hazard Tool. The values calculated by the tool use methods similar to ASCE 7-16 Section 21.4. Like the spectra shown on the previous page, S_{ds} and S_{d1} should be the maximum values from Site Classes BC, C, and CD.

S_{ds} = 0.42 g

S_{d1} = 0.21 g

Per the Code Amendment Section 11.4.8.1.8, it is permitted to substitute the value of S_a at the building period for the value of S_{d1}/T in eq. (12.8-3). If this method is used, the value of S_{d1}/T is calculated as shown below.

$S_{d1}/T = S_a$ (at 0.5 seconds) = 0.35 g (From the data point output of the ASCE 7 web tool)

$C_s = S_{ds} / (R / I_e) = 0.42 / (R / I_e)$ (ASCE 7-16 eq. 12.8-2)

C_s max = $S_{d1} / (T \times (R / I_e)) = 0.35 / (R / I_e)$ (ASCE 7-16 eq. 12.8-3)

For this example, use of the S_a = 0.35 in eq. 12.8-3 is permissible and results in a smaller design shear because S_{d1}/T = 0.21 / 0.5 = 0.42 which is larger than the value of S_a at the fundamental period of the building.

Example 4: Short period structure located in Spokane. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

Location: Lat = 47.660 Long = -117.424
No Site Class determined
Risk Category II
Building Period T = 0.4 seconds

Because the site class has not been determined by a geotechnical engineer, site class D is assumed per ASCE 7-16 Section 11.4.3. While the mapped spectral values in Spokane are not large enough to require a site-specific response spectrum per ASCE 7-16 Section 11.4.8, it is still permissible to use the MPRS method to determine the seismic design forces for structures in this region. An engineer may find that use of the MPRS provides benefits during the design of the structure.

Because no Site Class has been determined, the most critical spectral acceleration values for site classes C, C/D, and D need to be determined per the code amendment Section 1613.4.5 modifications to ASCE 7-16 Section 20.6.1.

Inputting the information above into the ASCE 7 web tool results in the tables shown below.

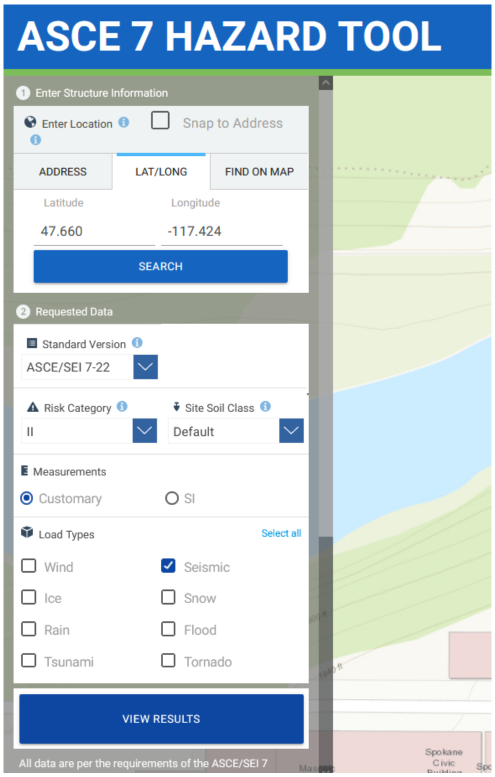
https://asce7hazardtool.online

Site Class C multi-period		Site Class C/D multi-period		Site Class D multi-period	
0.01	0.11	0.01	0.13	0.01	0.13
0.05	0.15	0.05	0.16	0.05	0.16
0.075	0.19	0.075	0.20	0.075	0.20
0.1	0.23	0.1	0.24	0.1	0.25
0.15	0.26	0.15	0.29	0.15	0.31
0.2	0.26	0.2	0.31	0.2	0.34
0.25	0.25	0.25	0.30	0.25	0.35
0.3	0.23	0.3	0.29	0.3	0.34
0.4	0.20	0.4	0.26	0.4	0.32
0.5	0.17	0.5	0.23	0.5	0.29
0.75	0.12	0.75	0.17	0.75	0.21
1	0.090	1	0.13	1	0.17
1.5	0.058	1.5	0.082	1.5	0.11
2	0.044	2	0.061	2	0.083
3	0.031	3	0.042	3	0.057
4	0.024	4	0.032	4	0.044
5	0.020	5	0.027	5	0.036
7.5	0.016	7.5	0.021	7.5	0.027
10	0.014	10	0.017	10	0.022

For this site, the acceleration parameters associated with Site Class D control over the accelerations from Site Classes C and CD at all periods, so the values from Site Class D will be used in the design shear calculations.

Example 4: Short period structure located in Spokane. Determine the seismic design parameters S_{ds} and S_{d1} to use in ASCE 7-16 Equations (12.8-2) and (12.8-3) using the MPRS.

Alternately, the "Default" site class can be selected in the ASCE 7 Hazard tool as shown below and the output that is reported for the S_{ds} and S_{d1} parameters, as well as the response spectrum table is the envelope of the values for Site Classes C, CD, and D.



S_{ds} and S_{d1} are calculated and reported using the ASCE 7 Hazard Tool. The values calculated by the tool use methods similar to ASCE 7-16 Section 21.4. Like the spectra shown on the previous page, S_{ds} and S_{d1} should be the maximum values from Site Classes C, CD, and D.

S_{ds} = 0.31 g

S_{d1} = 0.17 g

Per the Code Amendment Section 11.4.8.1.8, it is permitted to substitute the value of S_a at the building period for the value of S_{d1}/T in eq. (12.8-3). If this method is used, the value of S_{d1}/T is calculated as shown below.

$S_{d1}/T = S_a$ (at 0.4 seconds) = 0.32 g (From the data point output of the ASCE 7 web tool)

$C_s = S_{ds} / (R / I_e) = 0.31 / (R / I_e)$ (ASCE 7-16 eq. 12.8-2)

C_s max $= S_{d1} / (T \times (R / I_e)) = 0.32 / (R / I_e)$ (ASCE 7-16 eq. 12.8-3)

Because the C_s value will be controlled by eq. (12.8-2) due to the building period, for this example the method used to calculate S_{d1} is inconsequential.

Thanks to all of the SEAW members who participated in the development of the code change proposal and of the white paper. Members who were involved in this process include:

Subtask Group A: Compare ASCE 7-16 and ASCE 7-22 to confirm no conflicts arising from early use of MPRS
Scott Neuman (KPFF, SEAW EEC Chair), Juliette Peyroux (MKA), Beatriz Arostegui (MKA), Carson Baker (CPL), Doug Lindquist (Haley & Aldrich)

Subtask Group B: Compare ASCE 7-16 code spectra with exceptions to ASCE 7-22 MPRS for site classes B/C/D/E for 10 Washington cities
Scott Neuman, Hamilton Puangnak (GeoEngineers), Michael Chamberlain (Haley & Aldrich)

Subtask Group C: Draft proposed code language
Carson Baker, Scott Neuman, Susan Chang (SDCI, SEAW TG Chair), Kai Ki Mow (SDCI)

White Paper
Scott Neuman, Carson Baker, Michael Chamberlain, Susan Chang, Kai Ki Mow, Hamilton Puangnak

Other contributors:
Douglas Beck (City of Bellevue), Nathalie Boeholt (SDCI), Jeremy Butkovich (Shannon and Wilson), C.B. Crouse (AECOM), Marc Eberhard (University of Washington), Benjamin Enfield (SDCI), John Hooper (MKA, ASCE 7 Seismic Subcommittee Chair), Pao Huang (SDCI), Alex Legé (PCS), Patrick Lindblom (DCI), Terry Lundeen (CPL, ASCE 41 Subcommittee), Ali Shahbazian (Shannon and Wilson), Jon Siu (Jon Siu Consulting), Andy Taylor (KPFF, ACI 318 Chair), Melanie Walling (GeoEngineers), Minna Yan (Sound Transit), Zia Zafir (Kleinfelder)

Appendix C

WSR 22-11-010

RULE-MAKING ORDER
EMERGENCY RULE ONLY

CR-103E (December 2017)
(Implements RCW 34.05.350 and 34.05.360)

CODE REVISER USE ONLY

OFFICE OF THE CODE REVISER
STATE OF WASHINGTON
FILED

DATE: May 06, 2022
TIME: 4:14 PM

WSR 22-11-010

Agency: State Building Code Council

Effective date of rule:

Emergency Rules

☒ Immediately upon filing.

☐ Later (specify) _____

Any other findings required by other provisions of law as precondition to adoption or effectiveness of rule?

☐ Yes ☒ No If Yes, explain:

Purpose: Amend WAC 51-50 of the International Building Code, Chapter 35 Reference Standards and Section 1613, specifically addressing amendments to ASCE 7.

This emergency rule is aligning with WSR 22-05-096, an emergency rule related to elevator pit fire sprinklers.

(See Summary of Proposed Changes)

Citation of rules affected by this order:

New:
Repealed:
Amended: 2
Suspended:

Statutory authority for adoption: RCW 19.27.031

Other authority: RCW 19.27.074

EMERGENCY RULE

Under RCW 34.05.350 the agency for good cause finds:

☒ That immediate adoption, amendment, or repeal of a rule is necessary for the preservation of the public health, safety, or general welfare, and that observing the time requirements of notice and opportunity to comment upon adoption of a permanent rule would be contrary to the public interest.

☐ That state or federal law or federal rule or a federal deadline for state receipt of federal funds requires immediate adoption of a rule.

Reasons for this finding: The amendment in Section 1613 provides a simplified method to develop seismic design parameters for seismic design of buildings. The current method in ASCE 7-16 for developing seismic design response spectra is very complex, and it requires additional ground motion hazard analyses for many more building sites than required in previous versions of the code.

The purpose of the amendment in Chapter 35 is to adopt the Supplements to 2016 edition of ASCE 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 7-16), developed by the ASCE 7 Standard Committee to address important issues in between cycles of development. Some of the noted deficiencies in the ASCE 7-16 standard affect high seismic hazard locations such as Washington state and could potentially result in unconservative structural design.

Summary of Proposed Changes

Section 1613

This amendment provides a simplified method to develop seismic design parameters for seismic design of buildings. The current method in ASCE 7-16 for developing seismic design response spectra is very complex, and it requires additional ground motion hazard analyses for many more building sites than required in previous versions of the code.
Ground motion hazard analyses are an advanced approach to develop the earthquake ground motions and response spectra needed for seismic design. They require additional geophysical testing of the soil and advanced computer modeling. The

process of obtaining a ground motion hazard analysis requires geotechnical engineer with significant seismic expertise, and greatly increases the cost and time needed to complete a project.

The requirement for ground motion hazard analyses for more types of sites in Washington State also makes the job of municipal review agencies more difficult. Most jurisdictions do not have the expertise to review these analyses. Thus, they will need to contract with third-party reviewers or accept the analyses with little to no review. The first option is costly and time-consuming; the second option is dangerous and a critical life/safety issue because ground motion hazard analyses require a geotechnical engineer with significant seismic expertise to perform them correctly.

This proposal provides an alternative to the ground motion hazard analysis requirements in ASCE 7-16 by permitting an optional multi-period response spectra (MPRS) approach as described in ASCE 7-22. The primary inputs to this simplified method are the latitude/longitude of the site and the average shear wave velocity of the site, which can be obtained through standard geotechnical testing. The engineer would then obtain the equivalent of ground motion hazard analysis results from a U.S. Geological Survey website developed as part of the National Seismic Hazard Mapping project and adopted in ASCE 7-22. This simplified approach reduces the complexities, and it will result in more consistent, understandable estimation of ground motions for building design. This simplified process also results in ground motion parameters for seismic design that achieve the same level of risk and earthquake return periods that are assumed in ASCE 7-16.

This alternative would be allowed for all Soil Site Classes except Site Class F (e.g. liquefiable sites), meaning it could be used for most sites in the State of Washington. In addition, the MPRS may also be used to develop the code minimum spectrum when ground motion hazard analysis is required. The resulting MPRS would continue to be used within the framework of the current code, ASCE 7-16.

The use of the ASCE 7-22 MPRS as an option in lieu of the ground motion hazard analysis requirements of ASCE 7-16 will simplify the estimation of seismic forces for building design and streamline the design and review process of buildings throughout Washington.

Chapter 35:

The purpose of this amendment is to adopt the Supplements to 2016 edition of ASCE 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 7-16), developed by the ASCE 7 Standard Committee to address important issues in between cycles of development. Some of the noted deficiencies in the ASCE 7-16 standard affect high seismic hazard locations such as Washington state and could potentially result in unconservative structural design.

The ASCE 7-16 standard now has three published supplements- Supplement No.1 was published on December 11, 2018, Supplement No.2 was published on October 19, 2021, and Supplement No. 3 was published on November 3, 2021. Supplement No.1 was adopted into the 2021 International Building Code, but Supplement No.2 and Supplement No.3 were not included as they have just been recently published. Please refer to the attached copies of the documents for specific and detailed information of the changes, including the commentaries from ASCE 7 Standard Committee that explain the technical background of the problems addressed by the document. In general, these documents are developed to correct errors and deficiencies, and clarify the intent in the originally published 2016 standard.

Note: If any category is left blank, it will be calculated as zero. No descriptive text.

Count by whole WAC sections only, from the WAC number through the history note. A section may be counted in more than one category.

The number of sections adopted in order to comply with:

Federal statute:	New	____	Amended	____	Repealed	____
Federal rules or standards:	New	____	Amended	____	Repealed	____
Recently enacted state statutes:	New		Amended		Repealed	____

The number of sections adopted at the request of a nongovernmental entity:

New		Amended	2	Repealed	____

The number of sections adopted on the agency's own initiative:

New	____	Amended	____	Repealed	____

The number of sections adopted in order to clarify, streamline, or reform agency procedures:

	New		Amended		Repealed	
	New	____	Amended	____	Repealed	____

The number of sections adopted using:

Negotiated rule making:	New	____	Amended	____	Repealed	____
Pilot rule making:	New	____	Amended	____	Repealed	____
Other alternative rule making:	New	____	Amended	____	Repealed	____

Date Adopted: April 22, 2022	**Signature:**
Name: Tony Doan	
Title: Acting Chair, State Building Code Council	

AMENDATORY SECTION (Amending WSR 20-21-021, filed 10/9/20, effective 11/9/20)

WAC 51-50-1613 Section 1613—Earthquake loads.

1613.4 Amendments to ASCE 7. The provisions of Section 1613.4 shall be permitted as an amendment to the relevant provisions of ASCE 7. The text of ASCE 7 shall be amended as indicated in Sections 1613.4.1 through ((~~1613.4.2~~)) 1613.4.6.

1613.4.1 ASCE 7 Section 12.2.5.4. Amend ASCE 7 Section 12.2.5.4 as follows:

12.2.5.4 Increased structural height limit for steel eccentrically braced frames, steel special concentrically braced frames, steel buckling-restrained braced frames, steel special plate shear walls, and special reinforced concrete shear walls. The limits on height, h_n, in Table 12.2-1 are permitted to be increased from 160 ft (50 m) to 240 ft (75 m) for structures assigned to Seismic Design Categories D or E and from 100 ft (30 m) to 160 ft (50 m) for structures assigned to Seismic Design Category F, provided that the seismic force-resisting systems are limited to steel eccentrically braced frames, steel special concentrically braced frames, steel buckling-restrained braced frames, steel special plate shear walls, or special reinforced concrete cast-in-place shear walls and all of the following requirements are met:

1. The structure shall not have an extreme torsional irregularity as defined in Table 12.3-1 (horizontal structural irregularity Type 1b).

2. The steel eccentrically braced frames, steel special concentrically braced frames, steel buckling-restrained braced frames, steel special plate shear walls or special reinforced concrete shear walls in any one plane shall resist no more than 60 percent of the total seismic forces in each direction, neglecting accidental torsional effects.

3. Where floor and roof diaphragms transfer forces from the vertical seismic force-resisting elements above the diaphragm to other vertical force-resisting elements below the diaphragm, these in-plane transfer forces shall be amplified by the overstrength factor, Ω_o for the design of the diaphragm flexure, shear, and collectors.

4. The earthquake force demands in foundation mat slabs, grade beams, and pile caps supporting braced frames and/or walls arranged to form a shear-resisting core shall be amplified by 2 for shear and 1.5 for flexure. The redundancy factor, ρ, applies and shall be the same as that used for the structure in accordance with Section 12.3.4.

5. The earthquake shear force demands in special reinforced concrete shear walls shall be amplified by the over-strength factor, Ω_o.

1613.4.2 ASCE 7 Section 12.6. Amend ASCE 7 Section 12.6 and Table 12.6-1 to read as follows:

12.6 ANALYSIS PROCEDURE SELECTION

12.6.1 Analysis procedure. The structural analysis required by Chapter 12 shall consist of one of the types permitted in Table 12.6-1, based on the structure's seismic design category, structural system, dynamic properties, and regularity, or with the approval of the authority having jurisdiction, an alternative generally accepted procedure is permitted to be used. The analysis procedure selected shall be completed in accordance with the requirements of the corresponding section referenced in Table 12.6-1.

Table 12.6-1

Permitted Analytical Procedures

Seismic Design Category	Structural Characteristics	Equivalent Lateral Force Procedure, Section 12.8[a]	Modal Response Spectrum Analysis, Section 12.9.1, or Linear Response History Analysis, Section 12.9.2	Nonlinear Response History Procedures, Chapter 16[a]
B, C	All structures	P	P	P
D, E, F	Risk Category I or II buildings not exceeding two stories above the base	P	P	P
	Structures of light frame construction	P	P	P
	Structures with no structural irregularities and not exceeding 160 ft in structural height	P	P	P
	Structures exceeding 160 ft in structural height with no structural irregularities and with $T < 3.5 T_s$	P	P	P
	Structures not exceeding 160 ft in structural height and having only horizontal irregularities of Type 2, 3, 4, or 5 in Table 12.3-1 or vertical irregularities of Type 4, 5a, or 5b in Table 12.3-2	P	P	P
	All other structures ≤ 240 ft in height	NP	P	P
	All structures > 240 ft in height	NP	NP	P[c]

[a] P: Permitted; NP: Not Permitted; $T_s = S_{D1}/S_{DS}$.

1613.4.3 ASCE 7 Section 11.2. Amend ASCE 7 Section 11.2 to include the following definition:

USGS SEISMIC DESIGN GEODATABASE: A U.S. Geological Survey (USGS) database of geocoded values of seismic design parameters and geocoded sets of multiperiod 5%-damped risk-targeted maximum considered earthquake (MCER) response spectra. The parameters obtained from this database may only be used where referenced by Section 11.4.8.1.

User Note: The USGS Seismic Design Geodatabase is intended to be accessed through a USGS Seismic Design web service that allows the user to specify the site location, by latitude and longitude, and the site class to obtain the seismic design data. The USGS web service spatially interpolates between the gridded data of the USGS geodatabase. Both the USGS geodatabase and the USGS web service can be accessed at https://doi.org/10.5066/F7NK3C76. The USGS Seismic Design Geodatabase is available at the ASCE 7 Hazard Tool https://asce7hazardtool.online/ or an approved equivalent.

1613.4.4 ASCE 7 Section 11.4.8. Amend ASCE 7 Section 11.4.8 to include the following section:

11.4.8.1 Multiperiod design response spectrum. As an alternative to the ground motion hazard analysis requirements of Section 11.4.8, and suitable for all structures other than those designated Site Class F (unless exempted in accordance with Section 20.3.1), a multiperiod design response spectrum may be developed as follows:

1. For exclusive use with the USGS Seismic Design Geodatabase in accordance with this section, the site class shall be determined per Section 20.6.

2. Where a multiperiod design response spectrum is developed in accordance with this section, the parameters S_M, S_{M1}, S_D, S_{D1}, and T_L as obtained by the USGS Seismic Design Geodatabase shall be used for all applications of these parameters in this standard.

3. The S_S and S_1 parameters obtained by the USGS Seismic Design Geodatabase are only permitted to be used in development of the multiperiod design response spectrum and are not permitted to be used in other applications in this standard. The mapped parameters S_S and S_1 as determined by Section 11.4.2 and peak ground acceleration parameter PGA_M as determined by Section 11.8.3 shall be used for all other applications in this standard.

4. At discrete values of period, T, equal to 0.0s, 0.01s, 0.02s, 0.03s, 0.05s, 0.075s, 0.1s, 0.15s, 0.2s, 0.25s, 0.3s, 0.4s, 0.5s, 0.75s, 1.0s, 1.5s, 2.0s, 3.0s, 4.0s, 5.0s, 7.5s, and 10.0s, the 5%-damped design spectral response acceleration parameter, S_a, shall be taken as 2/3 of the multiperiod 5%-damped MCER response spectrum from the USGS Seismic Design Geodatabase for the applicable site class.

5. At each response period, T, less than 10.0s and not equal to one of the discrete values of period, T, listed in Item 4 above, S_a, shall be determined by linear interpolation between values of S_a, of Item 4 above.

6. At each response period, T, greater than 10.0s, S_a shall be taken as the value of S_a at the period of 10.0s, factored by $10/T$, where the value of T is less than or equal to that of the long-period transition period, T_L, and shall be taken as the value of S_a at the period of 10.0s factored by $10T_L/T^2$, where the value of T is greater than that of the long-period transition period, T_L.

7. Where an MCER response spectrum is required, it shall be determined by multiplying the multiperiod design response spectrum by 1.5.

8. For use with the equivalent lateral force procedure, the spectral acceleration S_a at T shall be permitted to replace S_{D1}/T in Equation (12.8-3) and $S_{D1}\ T_L/T^2$ in Equation (12.8-4).

1613.4.5 ASCE 7 Section 20.6. Amend ASCE 7 Chapter 20 to include the following section:

Section 20.6 Site classification procedure for use with Section 11.4.8.1. For exclusive use in determining the multiperiod design response spectrum and associated spectral parameters in accordance with Section 11.4.8.1, the site class shall be determined in accordance with this section. For all other applications in this standard the site class shall be determined per Section 20.1.

20.6.1 Site classification. The site soil shall be classified in accordance with Table 20.6-1 and Section 20.6.2 based on the average shear wave velocity parameter, $\bar{v}_s$, which is derived from the measured shear wave velocity profile from the ground surface to a depth of 100 ft (30 m). Where shear wave velocity is not measured, appropriate generalized correlations between shear wave velocity and standard penetration test (SPT) blow counts, cone penetration test (CPT) tip resistance, shear strength, or other geotechnical parameters shall be used to obtain an estimated shear wave velocity profile, as described in Section 20.6.3. Where site-specific data (measured shear wave velocities or other geotechnical data that can be used to estimate shear wave velocity) are available only to a maximum depth less than 100 ft (30 m), $\bar{v}_s$ shall be estimated as described in Section 20.6.3.

Where the soil properties are not known in sufficient detail to determine the site class, the most critical site conditions of Site Class C, Site Class CD and Site Class D, as defined in Section 20.6.2, shall be used unless the authority having jurisdiction or geotechnical data determine that Site Class DE, E or F soils are present at the site. Site Classes A and B shall not be assigned to a site if there is more than 10 ft (3.1 m) of soil between the rock surface and the bottom of the spread footing or mat foundation.

20.6.2 Site class definitions. Site class types shall be assigned in accordance with the definitions provided in Table 20.6.2-1 and this section.

20.6.2.1 Soft clay Site Class E. Where a site does not qualify under the criteria for Site Class F per Section 20.3.1 and there is a total thickness of soft clay greater than 10 ft (3 m), where a soft clay layer is defined by s_u<500psf (s_u<25 kPa), $w \geq 40\%$, and $PI > 20$, it shall be classified as Site Class E. This classification is made regardless of $\bar{v}_s$, as computed in Section 20.4.

20.6.2.2 Site Classes C, CD, D, DE and E. The assignment of Site Class C, CD, D, DE and E soils shall be made based on the average shear wave velocity, which is derived from the site shear wave velocity profile from the ground surface to a depth of 100 ft (30 m), as described in Section 20.4.

20.6.2.3 Site Classes B and BC (medium hard and soft rock). Site Class B can only be assigned to a site on the basis of shear wave velocity measured on site. If shear wave velocity data are not available and the site condition is estimated by a geotechnical engineer, engineering geologist, or seismologist as Site Class B or BC on the basis of site geology, consisting of competent rock with moderate fracturing and weathering, the site shall be classified as Site Class BC. Softer and more highly fractured and weathered rock shall either be measured on site for shear wave velocity or classified as Site Class C.

20.6.2.4 Site Class A (hard rock). The hard rock, Site Class A, category shall be supported by shear wave velocity measurement, either on site or on profiles of the same rock type in the same formation with an equal or greater degree of weathering and fracturing. Where hard rock conditions are known to be continuous to a depth of 100 ft (30 m), surficial shear wave velocity measurements to maximum depths less than 100 ft are permitted to be extrapolated to assess $\bar{v}_s$.

Table 20.6.2-1 Site Classification

Site Class	$\bar{v}_s$ Calculated Using Measured or Estimated Shear Wave Velocity Profile (ft/s)
A. Hard Rock	> 5,000
B. Medium Hard Rock	> 3,000 to 5,000
BC. Soft Rock	> 2,100 to 3,000
C. Very Dense Sand or Hard Clay	> 1,450 to 2,100
CD. Dense Sand or Very Stiff Clay	> 1,000 to 1,450
D. Medium Dense Sand or Stiff Clay	> 700 to 1,000
DE. Loose Sand or Medium Stiff Clay	> 500 to 700
E. Very Loose Sand or Soft Clay	≤ 500

20.6.3 Estimation of shear wave velocity profiles. Where measured shear wave velocity data are not available, shear wave velocity shall be estimated as a function of depth using correlations with suitable geotechnical parameters, including standard penetration test (SPT) blow counts, shear strength, overburden pressure, void ratio, or cone penetration test (CPT) tip resistance, measured at the site.

Site class based on estimated values of $\bar{v}_s$ shall be derived using $\bar{v}_s$, $\bar{v}_s/1.3$, and $1.3\bar{v}_s$ when correlation models are used to derive shear wave velocities. Where correlations derived for specific local regions can be demonstrated to have greater accuracy, factors less than 1.3 can be used if approved by the authority having jurisdiction. If the different average velocities result in different site classes per Table 20.6.2-1, the most critical of the site classes for ground motion analysis at each period shall be used.

Where the available data used to establish the shear wave velocity profile extends to depths less than 100 ft (30 m) but more than 50 ft (15 m), and the site geology is such that soft layers are unlikely to be encountered between 50 and 100 ft, the shear wave velocity of the last layer in the profile shall be extended to 100 ft for the calculation of $\bar{v}_s$ in Equation (20.4-1). Where the data does not extend to depths of 50 ft (15 m), default site classes, as described in Section 20.6.1, shall be used unless another site class can be justified on the basis of the site geology.

1613.4.6 ASCE 7 Section 21.3.1. Amend ASCE 7 Section 21.3 to include the following section:

Section 21.3.1 Alternate minimum design spectral response accelerations. As an alternate approach to Section 21.3, the lower limit of S_a is permitted to be determined according to this section. The design spectral response acceleration at any period shall not be taken less than 80% of the multiperiod design response spectrum as determined by Section 11.4.8.1.

For sites classified as Site Class F requiring site-specific analysis in accordance with Section 11.4.8, the design spectral response acceleration at any period shall not be less than 80% of S_a determined for Site Class E.

EXCEPTION: Where a different site class can be justified using the site-specific classification procedures in accordance with Section 20.6.2.2, a lower limit of 80% of S_a for the justified site class shall be permitted to be used.

AMENDATORY SECTION (Amending WSR 20-21-021, filed 10/9/20, effective 11/9/20)

WAC 51-50-3500 Chapter 35—Referenced standards. Add the reference standards as follows:

Standard reference number	Title	Referenced in code section number
ANSI/APA PRG-320-18	Standard for Performance-Rated Cross-Laminated Timber (revised 2018)	602.4, 2303.1.4
ASCE/SEI 7-16	Minimum Design Loads and Associated Criteria for Buildings and Other Structures with Supplement No.1, Supplement No. 2, and Supplement No.3	
NFPA 130-17	Standard for Fixed Guideway Transit and Passenger Rail Systems	3101.1, 3114
NFPA 13-16	Standard for the Installation of Sprinkler Systems **(except 8.15.5.3(5))**	403.3.3, 712.1.3.1, 903.3.1.1, 903.2, 903.3.8.2, 903.8.5, 904.13, 905.3.4, 907.6.4, 1019.3