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Salem Keizer Public Schools – Construction Services
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Attention: Mr. Joel Smallwood
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Subject: Site Specific Seismic Hazard Analysis
Salem Heights Elementary School
3495 Liberty Road South
Salem, Oregon 97302
PSI Project Number: 07041401

Professional Service Industries (PSI) an Intertek company has completed this Site-Specific Seismic Hazard Analysis for the modular classroom relocation at 3495 Liberty Road South in Salem, Oregon.

The site-specific seismic hazard analysis (SHA) has been completed to satisfy the requirements of the 2019 Oregon Structural Specialty Code (OSSC). The State of Oregon considers education facilities "special occupancy structures," which require site-specific seismic hazard analysis to be performed. PSI performed this ground motion hazard analysis according to the updated provisions provided in ASCE 7 (2016), which are incorporated into the 2018 International Building Code (IBC) and 2019 OSSC.

Purpose and Scope of Work

The purpose of the SHA was to evaluate the potential seismic hazards associated with regional and local seismicity, and to estimate the effect those hazards might have on the site. PSI's work was based on the potential for regional and local seismic activity as described in existing scientific literature, and on the subsurface conditions at the site, as determined by the geotechnical explorations at the project site. Specifically, PSI's Scope-of-Services for this site-specific SHA study included the following tasks:

1) A review of the literature, including published papers, maps, open-file reports, seismic histories and catalogs, works' in progress, and other sources of information regarding the tectonic setting, regional and local geology, and historical seismic activity that might have a significant effect on the site.
2) Compilation, examination, and evaluation of existing subsurface data gathered at and in the vicinity of the site, including analyses of boring log data. This information was used to prepare a generalized subsurface profile for the site.
3) Identification of the potential seismic events appropriate for the site and characterization of those events in terms of a series of generalized design events.
4) Office studies, based on the generalized subsurface profile and the generalized design earthquakes, resulting in conclusions and recommendations concerning:
    a. Specific seismic events that might have a significant effect on the site;
    b. Potential for seismic energy amplification at the site; and,
    c. Recommended site-specific acceleration response spectrum for the site.
5) The U.S. Geological Survey (USGS) database was examined for recorded earthquakes within 1000 km of the site and at least a moment magnitude (M_W) of 4, or that caused ground shaking at the site more intense than the Modified Mercalli III intensity.

6) The 2014 USGS probabilistic seismic hazard deaggregation was performed for the project site location for a 2,475-year return period (2% probability of exceedance in 50 years). USGS 2014 provides result for the B/C interface (V_{s30} = 760 m/sec), which are modified using site modification factors.
7) Probabilistic seismic hazard analysis (PSHA) was performed using EZ-Frisk™ Version 8.07 by Fugro Consultants, Inc. The PSHA was based on identified seismic sources, appropriate attenuation relationships for the site using a site-specific shear wave velocity (V_{s30}), and the geometric mean horizontal component of ground motion. The PSHA was used to develop site specific bedrock, and site modified response spectra based on the shear wave velocities for the 2,475-year recurrence interval earthquakes.
8) Recommended response spectra are provided based on our site-specific analysis in accordance with ASCE 7-16 using the 2014 USGS National Seismic Hazard Maps.
9) Other seismic hazards, including earthquake-induced landslides, regional subsidence, and fault displacement were considered.

Project Description

Based on the project information provided by Day CPM/OTAK, PSI understands that Salem Keizer Public Schools (SKPS) is planning to construct a modular classroom building on the northwest side of the main elementary school building. The modular building will be wood-framed and consist of an elevated wood-framed floor, with loads of less than 150 psf, supported on concrete footings. PSI anticipates that wall loads will be less than 1 kip per lineal foot, and column loads will be less than 30 kips.

A more detailed description of the site development can be found in our Geotechnical Report dated August 27, 2021.

Geology

On a regional scale, the site is located in the center of the Willamette Valley Provence, which is bordered by the Cascade Mountains to the east and the Oregon Coast Range to the west. The valley lies approximately 200 km inland from the surface expression of the Cascadia Subduction Zone, an active plate boundary along which remnants of the Farallon Plate (the Gorda, Juan de Fuca, and Explorer plates) are being subducted beneath the western edge of the North American continent. The configuration of these plates and the location, extent, and geometry of the surface expression of the subduction zone are shown schematically in Figure 1, the "Tectonic Map of the Pacific Northwest." The subduction zone is a broad, eastward-dipping zone of contact between the upper portion of the subducting slabs of the Gorda, Juan de Fuca, and Explorer plates and the over-riding North America Plate. Although seismic activity is clearly associated with converging plate margins in other parts of the world, there is little direct evidence of significant seismic activity attributable to the Cascadia Subduction Zone.

Locally in the central Willamette Valley, Marine sedimentary rocks of the Coast range and volcanic continental rocks of the Cascade Range converge beneath the sediments that infill the valley. These bedrock units are overlain by younger basalt of the Columbia River Basalt Group Lavas. Near Salem, the Columbia River basalt forms a syncline caused by the uplift of the Coast Range and the Cascade Range. The Eola Hills to the west, and the Waldo Hills to the East of Salem represents the limbs of the syncline as the Columbia River Basalt outcrops at the ground surface. The Columbia river basalt is locally overlain by basin fill sediments that vary in composition and grain size, and generally become progressively coarser towards the south end of the Central Willamette valley. In the vicinity of Salem, the basin fill is predominately gravel near the surface (Gannett, et al., 1998). The upper portion of the basin fill sediments are composed of coarse and fine-grained facies of catastrophic Missoula flood deposits of the Pleistocene epoch, and younger alluvial deposits near rivers.

The distribution of nearby faults relative to the site is depicted on Figure 1 titled, "Tectonic Map of the Pacific Northwest"; Figure 2 titled, "USGS Fault Map"; and Figure 3 titled, "Geologic Map". The relationship between specific earthquakes and individual faults in this area is not well understood, since few of the faults in the area are expressed clearly at the ground surface, and the foci of local earthquakes have not been located with precision.

Precise, quantitative information regarding historic seismic activity in the Pacific Northwest is sparse. Events that may have occurred in the region prior to settlement of the Oregon Territory in the mid-nineteenth century are speculative and have not been clearly identified in terms of location, magnitude, or frequency. From the mid-nineteenth century to the time of the installation of the first dependable seismometers in the area (about 1940), reliable information regarding location and magnitude is not available, although rough estimates of these parameters have been based on records of eyewitness accounts. Since about 1940, seismographic records of increasing sophistication and accuracy are available for local events larger than about 3.5 Richter (local) magnitude (M_L). For this project, we examined a catalog (Open File Report 0-94-04) obtained from the Oregon Department of Geology and Mineral Industries (DOGAMI) containing a list of those earthquakes known to have occurred in Oregon during the period of 1883 to 1993. Recent events that may have generated measurable accelerations in the vicinity of the project site are the 1962 Vancouver Earthquake and the 1993 Scotts Mills Earthquake. The larger of these events, the M_L 5.0 Vancouver Earthquake of 1962, produced peak horizontal accelerations of approximately 0.14 g at Portland State University, approximately 45 miles northeast of the site (Dehlinger, et al., 1963).

Site Geology

The site is underlain by the "Columbia River Basalt Group" (T_{CR}) of the Miocene epoch (see Figure B3) (O'Connor, et al., 2001). This unit is described as layered flows of dark gray to black locally porphyritic basalt. The unit locally includes tuffaceous sedimentary interbeds, is commonly jointed and locally deeply weathered. At this site, the upper approximately 10 to 20 feet of basalt is severely weathered with only the relict rock structure intact in a residual silt, clay and sand matrix.

The average shear wave velocity of the upper 100 feet (V_{s100}) measured in ReMi Array 1 was 2,323 fps, and the V_{s100} in ReMi Array 2 was 2,400 fps. In both Remi arrays, the one-dimensional shear wave velocity is approximately 1,300 fps from the surface to a depth of 18 to 20 feet. We anticipate that this represents weathered basalt. In the ReMi profiles, the shear wave velocity increases stepwise from approximately 2,400 fps to 3,100 from a depth of 20 feet to 100 feet, which likely represents a decrease in the degree of weathering, and intact basalt being present below a depth of 20 feet.

PSI has used an average of the two ReMi arrays for V_{s100} value of 2,362 fps (720 m/s) to perform our site-specific seismic hazard assessment and model site amplifications to the response spectra.

SEISMIC AND TECTONIC SETTTING

Due to the limited history of earthquakes in Oregon, the geologic and seismologic information available for identifying the nature of the seismicity at the site is incomplete, and large uncertainties are associated with estimates of the probable magnitude, location, and frequency of occurrence of earthquakes that might affect the site. For this reason, several methods were used to model the seismic sources during evaluation of seismic hazard at this site. This study has relied on existing information, primarily from published articles and the USGS Quaternary fault database, to develop the input parameters for the PSHA. The PSHA input parameters generally consist of: maximum earthquake magnitude, slip rate (rate of strain accumulation), and recurrence interval (Personius, 2002).

The information that is available indicates that the seismic hazards at the site can be grouped into three independent categories: subduction zone events related to sudden slip between the upper surface of the Juan de Fuca plate and the lower surface of the North American plate, subcrustal events related to deformation and volume changes within the subducted mass of the Juan de Fuca plate, and local crustal events associated with movement on shallow, local faults within and adjacent to the Willamette Valley. The tectonic setting is depicted on Figure 1 titled, "Tectonic Map of the Pacific Northwest." Based on our review of currently available information, we have developed generalized design earthquakes for each of these categories. The design earthquakes are characterized by three important properties: size, location relative to the subject site, and the peak horizontal bedrock accelerations produced by the event. In this study, size is expressed in Richter (local) magnitude (M_L), surface wave magnitude (M_S), Japanese Meteorological Association magnitude (M_{JMA}), or moment magnitude (M_w); location is expressed as epicentral or focal distance, measured radially from the subject site in kilometers; and peak horizontal bedrock accelerations are expressed in gravities (1 g = 980.6 cm/sec/sec).

Cascadia Subduction Zone (CSZ)

The CSZ is a megathrust structure that forms the convergent plate boundary between the subducting Explorer, Juan de Fuca, and Gorda Plates and the overriding North America Plate, and extends from offshore northern California to southern British Columbia. Subduction is driven by eastward movement of the Explorer, Juan de Fuca, and Gorda Plates due to sea-floor spreading at the Gorda-Juan de Fuca-Explorer Mid-Ocean Ridge System. The subduction plates are the remnants of the Farallon Plate, which once underlay most of the eastern Pacific and has been converging with the North America Plate since at least the Jurassic period (Atwater, 1970; Duncan and Kulm, 1989). Tectonic elements associated with the subduction zone include: 1) an accretionary wedge of sediment and sedimentary rocks deformed by a broad fold and thrust belt and east-striking strike-slip fault; 2) a forearc basin of sedimentary and igneous rocks that accumulated during plate collision, broken in places by minor Quaternary faults and folds; and 3) a volcanic arc (Cascade Range) consisting of Eocene through Quaternary volcanic rocks, active andesitic volcanoes, and numerous, mostly extensional, Quaternary faults. The historic seismicity on the CSZ is limited. There are numerous records of intraplate events on the Gorda block and in the Puget Sound area; however, there are few or no records of these in Central CSZ. Geological studies show that great megathrust earthquakes have occurred repeatedly in the past 7,000 years (e.g., Atwater and others, 1995; Clague, 1997; Goldfinger, 2003; and Kelsey, 2005), and geodetic studies (e.g., Hyndman and Wang, 1995; Savage, et al., 2000) indicate rate of strain accumulation consistent with the notion that the CSZ is locked beneath offshore northern California, Oregon, Washington, and southern British Columbia (Fluck and others, 1997; Wang, et al., 2001). Numerous geological and geophysical studies suggest the CSZ may be segmented (Hughes and Carr, 1980; Weaver and Michaelson, 1985; Guffanti and Weaver, 1988; Goldfinger, 1994; Kelsey, et al., 1994; Mitchell, et al., 1994; Personius, 1995; Nelson and Personius, 1996; Witter, 1999), but the most recent studies suggest that for the last great earthquake in 1700, most of the subduction zone ruptured in a single Mw 9 earthquake (Satake, et al., 1996; Atwater and Hemphill-Haley; Clague, et al., 2000).

The surface trace of the subduction zone megathrust is located offshore in deep water, so paleoseismic studies have focused on "off fault" evidence of subduction zone earthquakes, such as coseismic uplift and subsidence, earthquake-induced turbidite and tsunami records, and liquefaction features caused by seismic shaking. However, it is difficult to discern whether some of these paleoseismic features are related to displacements on crustal faults, which may or may not deform concurrent with subduction zone earthquakes (McNeill, et al., 1998; Yeats, et al., 2001; Kelsey, et al., 2002; Witter, et al., 2003).

Studies indicate coastal subsidence, tsunamis, liquefaction, and turbidite triggering consistent with a massive earthquake on the CSZ about 300 years ago. Tree rings in cedars rooted in the youngest buried soil beneath wetlands in southwestern Washington date tree death from submergence to between August

AD 1699 and May AD 1700 (Atwater, et al., 1991; Atwater and Yamaguchi, 1991; Yamaguchi, et al., 1997; Jacoby, et al., 1997; Benson, et al., 2001). Historical documents from Japanese harbors inundated by a tsunami and trans-Pacific tsunami modeling show that the tsunami from a Cascadia megathrust earthquake was generated by a M_w =9 earthquake on the subduction zone on January 26, 1700 (Satake, et al., 1996; 2003).

Numerous detailed studies of coastal subsidence, tsunamis, and turbidites yield a wide range of recurrence intervals, but the most complete records (>4,000 years) indicate average intervals of 350 to 600 years between great earthquakes on the CSZ (Adams, 1990; Atwater and Hemphill-Haley, 1997; Witter, 1999; Clague, et al., 2000; Goldfinger, et al., 2002; Kelsey, et al., 2002; Kelsey, et al., 2005; Witter, et al., 2003). Magnetic anomaly studies on the Juan de Fuca plate and geodetic studies indicate a rate of oblique convergence of about 35 to 45 mm/yr in a northeast direction across the subduction zone. The total structure length is approximately 754 km. Fault rupture is expected to produce estimated an M_w of 8.3 to 9.0 earthquakes.

Subcrustal Event

Estimates of the probable size, location, and frequency of subcrustal events in the Pacific Northwest are generally based on comparisons of the Cascadia Subduction Zone with active convergent plate margins in other parts of the world and on the historical seismic record for the region surrounding Puget Sound, where significant events known to have occurred within the subducting Juan de Fuca plate have been recorded. Published estimates of the probable maximum size of these events range from moment magnitude (M_w) of 7.0 to 7.5. Published information regarding the location and geometry of the subduction zone indicates that minimum focal distances of 40 to 60 km (measured from Portland) are probable (Weaver and Shedlock, 1989). Estimates of recurrence intervals applicable to the Portland area are not available.

Local Crustal Event

The history of local seismic activity is commonly used as a basis for determining the size and frequency to be expected of local crustal events. Although the historical record of local earthquakes is relatively short (the earliest reported seismic event in the area occurred in 1841), it can serve as a guide for estimating the potential for seismic activity in the area. A significant earthquake could occur on a local fault near the site within the design life of the proposed structure. Such an event would cause ground shaking at the site that could be more intense than the CSZ event, though the duration would be shorter. The precise relationship between specific earthquakes and individual faults is not well understood, since few of the faults in the area are expressed at the ground surface, and the foci of the observed earthquakes have not been located with precision.

A table of the mapped faults within approximately 25 miles to the site is provided in Table 1.

Table 1 - Summary of Published, Nearby Faults

Fault Name	*Type of Fault*	*Slip Rate (mm/yr)*	*Direction*	*Distance Miles*	*Distance km*	*Fault ID Number*
Waldo Hills fault	Normal	< 0.2	East	4.7	7.6	872
Salem-Eola Hills homocline	Homocline	< 0.2	West	3.4	5.5	719
Turner and Mill Creek faults	Unspecified	< 0.2	Southeast	7.0	11.3	871
Mount Angel fault	Reverse	< 0.2	Northeast	16.5	26.6	873

These mapped faults are located on Figure 2 titled, “USGS Fault Map.”

HISTORIC SEISMICITY

There is a limited database of historic earthquakes for Oregon due to a relatively short period of written records (approximately 170 years) and a regional rate of seismicity that is lower than that in the neighboring states of California and Washington. Table 2 lists the largest historical earthquakes felt in Oregon. Figure 4, Historical Seismicity, depicts historical seismicity in Western Oregon on the central and southern CSZ (Burns, 2008). As shown on the figure, the northwestern Oregon area is located in a zone of higher historic seismicity. Over 500 km to the south, the subducting Gorda Plate has been subject to considerably more historic earthquakes, primarily offshore of northern California and associated with the subduction trench axis. The historic record of moderate-sized earthquakes (M 5.0 to 7.0) in both the Puget Sound and Gorda Plate areas is generally associated with intraslab earthquakes. In the Puget Sound area, these moderate to large earthquakes are deep (40 to 60 km) and over 200 km from the deformation front of the subduction zone. At the Gorda Block, the earthquakes are shallower (up to 40 km) and located along the deformation front. Wong (2005) hypothesizes that due to subduction zone geometry, geophysical conditions and local geology, Oregon may not be subject to intra-slab earthquakes.

Table 2 - Largest Historical Earthquakes Felt in Oregon

Date	*Latitude*	*Longitude*	*Magnitude*	*Modified Mercalli Intensity*	*Location*
11/23/1873	-	-	6.8	-	Near Brookings, OR
10/12/1877	45.5	122.5	5.3	VII	Portland, OR
7/15/1936	-	-	6.4	-	Milton-Freewater, OR
4/13/1949	47.1	122.7	7	VIII	Olympia, WA
11/5/1962	45.6	122.6	5.3	-	Portland, OR
4/29/1965	47.4	122.4	6.8	VIII	Puget Sound, WA
1968	42.3	119.8	5.1	-	Adel, OR
4/12/1976	-	-	4.8	-	Maupin, OR
4/25/1992	-	-	7	-	Cape Mendocino, CA
3/25/1993	45.04	122.6	5.6	-	Scotts Mills, OR
9/21/1993	42.4	122.09	6	-	Klamath Falls, OR
2/28/2001	47.2	122.7	6.8	-	Nisqually, WA
6/14/2005	41.33	125.86	7	IV	near Crescent City, CA
8/22/2018	43.65	127.60	6.2	-	Pacific Ocean, Off Coast of OR

Notes:

1) Data from Advanced National Seismic System (ANSS), US Geological Survey (USGS), and Johnson A. and Madin, I, 1994, Earthquake Database for Oregon, 1983 through October 25, 1993: Oregon Department of Geology and Mineral Industries Open File Report 0-94-4, and the USGS online Earthquake database.
2) Magnitudes are M_S, M_L, mb or based on felt area of Modified Mercalli Intensity. Maximum reported magnitudes are listed on the table.

GROUND MOTION HAZARD ANALYSIS

PSI has conducted a Probabilistic Seismic Hazard Analysis (PSHA) and a Deterministic Seismic Hazard Analysis (DSHA) to develop seismic design response spectrum and design acceleration parameters for comparison to the general procedure spectrum and design parameters. The ASCE 7-16 code values are graphically represented in Figure 5. PSI's seismic hazard analysis was performed for the site located at a coordinate of 44.9055° North and 123.0516° West.

PROBABILISTIC SEISMIC HAZARD ANALYSIS

The input for a Probabilistic Seismic Hazard Analysis (PSHA) consists of three significant components:

1) Identification of earthquake sources, locations, and physical characteristics (e.g., dip angle, rupture width, length, etc.);
2) Characterization of the seismicity rate for each seismic source using an appropriate model (e.g., exponential or normal distribution); and,
3) Selection of empirical attenuation relationships that describe how the characteristics of the strong ground motions change as the waves propagate from the seismic source to a given site location.

To identify nearby earthquake sources and contribution to the overall seismic hazard, PSI performed a probabilistic deaggregation using the USGS Unified Hazard Tool, based on the 2014 National Seismic Hazard Maps (NSHM). A summary of published USGS deaggregation data for the proposed improvements is provided in Table 3 below with respect to the seismic source, distance from site, and percent contribution to the seismic hazard based on the USGS probabilistic model and seismic hazard curve:

Table 3 - USGS 2014 Deaggregation

Principal sources (faults, subduction, random seismicity having > 10% contribution)

Source Category	*Percent Contribution*	*Distance (km)*	*Magnitude (Richter)*	*Epsilon0 (mean values)*
Cascadia Megathrust (bottom rupture)	36.82	61.05	9.10	0.53
Cascadia Megathrust (midpoint rupture)	16.16	106.51	8.92	1.25

Based on the deaggregation of the USGS PSHA, it concludes that the Cascadia Subduction Zone Megathrust (i.e., the rupture of the entire CSZ) is the primary contributor of the probabilistic seismic hazard.

Figure 6 shows the modeled activity rate of the seismic sources, expressed as the annual rate of exceedance over a range of moment magnitudes. Figure 7 shows the contribution to the total hazard of the seismic sources over different Peak Ground Accelerations based on the annual rate of exceedance (return period).

These components include uncertainties associated with our limited knowledge and understanding of the fault sources and their predicted behavior. Aleatory uncertainty describes the probabilistic randomness associated with estimating fault behavior and earthquakes. Epistemic uncertainty is associated with our incomplete knowledge or understanding of the seismic model or parameters. The PSHA method combines and incorporates these uncertainties to obtain a probabilistic ground motion, which is defined by the likelihood of an earthquake of a specific magnitude occurring within a specific length of time.

A logic tree is used to evaluate uncertainties in the attenuation relationships used in the analysis. The logic tree assigns each ground motion model parameter a “tree branch” and a relative weight (some fraction of 1.0), based on the level of confidence in that quantified parameter. Multiple levels of tree branches can be assigned corresponding to levels of confidence associated with factors such as fault location, appropriate recurrence model, or probability of activity. The seismic hazard is then calculated by summing up the weighted hazards, each calculated independently from the branches of the logic tree.

For this analysis, the logic tree for Ground Motion Model (GMM) equation weighting was selected in general accordance with the USGS 2014 National Seismic Hazard Maps (NSHM).

Table 4 below represents the GMM equations and the applied weighting factors used in this analysis:

Table 4: Ground Motion Models and Weighting Factors

Seismic Source Type	*Ground Motion Models (GMM)*	*Weighting Factor*
Deep Gridded	Atkinson and Boore (2003) Global Model	0.1667
	Atkinson and Boore (2003) Cascadia Model	0.1667
	Zhao and Others (2006)	0.33
	BC Hydro (Addo and Others, 2012)	0.33
CSZ Interface	Atkinson and Boore (2003) Global Model	0.10
	Zhao and Others (2006)	0.30
	Atkinson and Macias (2009)	0.30
	BC Hydro (Addo and Others, 2012)	0.30
Local Faults	Abrahamson and Others (2013, 2014)	0.22
	Boore and Others (2013, 2014)	0.22
	Campbell and Bozorgnia (2013, 2014)	0.22
	Chiou and Youngs (2013, 2014)	0.22
	Idriss (2013, 2014)	0.12

Probabilistic seismic hazard analyses are typically completed in one of two ways to generate ground surface earthquake characteristics:

1) A PSHA is completed using empirical attenuation relationships for estimating ground motion parameters (e.g., peak acceleration, acceleration response spectra) on bedrock. A dynamic soil response model is then used to simulate the propagation of representative earthquake motions from a defined bedrock layer through a soil column, with pertinent soil properties identified through a geotechnical investigation at the site. This modeling provides the characteristics of the design earthquake motions at specified depths of interest, usually at the ground surface or at depths representative of the proposed foundations.

2) The PSHA is completed using attenuation relationships derived from historical earthquake recording stations at soil sites. The individual attenuation relationships provide ground surface characteristics as a function of the site conditions at the recording station. In this procedure, the ground surface motions (i.e., PGA, PGV, response spectra) are obtained directly from the PSHA results.

In this analysis, site parameters based on the Vs_{100} were applied directly to the GMMs, and the response spectra was developed directly from the attenuation equation, at the B/C interface and the ground surface. Site parameters that were input directly into EZ-frisk include the Vs_{100} parameter defined as average shear wave velocity in the upper 100 feet of the ground surface. The first analysis was performed with the Vs_{100} set to 2,500 fps and the Z1 parameter as defined in the appropriate attenuation equations to develop a response spectrum at the B/C interface. The second analysis was performed to assess the ground motions at the surface based a Vs_{100} of 2,362 fps. A tectonic setting of forearc was applied to the BCHydro (2012) GMPE, based on the Willamette Valley Forearc setting in relation to the CSZ. The ratio of the spectral acceleration of the PSHA at the ground surface based on input Vs_{100} values to the spectral accelerations at the B/C interface (Vs_{100} = 2,500 fps) represents Site Amplification Ratio (SAR).

PROBABILISTIC MCE_R

The probability of occurrence of an earthquake of a specific magnitude at a given location is commonly expressed by its return period, i.e., the average length of time between successive occurrences of an earthquake of that size or larger at that location. The GMMs return the spectral acceleration values for the geometric mean direction of a specified return period. For this project, a design life of 50 years and an acceptable probability of exceedance of 2% with 5% damping have been considered, in accordance with the requirements of the 2019 OSSC. The relationship between the return period, the design life, and the exceedance probability is such that the choice of a 50-year design life and a 2% probability of exceedance result in a return period of approximately 2,475 years.

Figure 8 shows the probabilistic response spectrum and corresponding attenuation equations for the Geometric Mean Maximum Considered Earthquake (MCE_G) at the B/C boundary.

The MCE_G was adjusted to represent the maximum response in the horizontal plane using the scale factors outlined in Section 21.2 of ASCE 7-16. This response spectrum represents the Uniform Hazard Response Spectrum. The Site Amplification Ratio is represented as the uniform hazard spectra for the site-specific uniform-hazard spectra divided by the uniform-hazard spectra at the B/C interface at the different periods. Figure 9 shows the Uniform Hazard Spectra for the B/C interface and the Site-Modified Uniform Hazard at the ground surface (VS_{100} = 2,362 fps), and Figure 10 shows the corresponding SAR.

The Uniform Hazard Response Spectrum is further modified by risk coefficients to develop the Risk Targeted Maximum Considered Earthquake (MCE_R), which represents the response spectrum that is expected to achieve a 1% probability of collapse within a 50-year period. For our analysis the Probabilistic MCE_R Spectrum was developed using the risk coefficients (C_{RS} and C_{R1}) found in figures 22-18 and 22-19 of ASCE 7-16, and adjusted for different spectral periods in accordance with Method 1 as outlined in section 21.2.1.1 of ASCE 7-16. Figure 11 shows the Risk-Targeted Maximum Considered Earthquake (MCE_R) developed from the Uniform Hazard Response Spectrum, and Table 5 shows the Uniform Hazard Spectra and corresponding SAR values for selected periods.

Table 5 – Uniform Hazard and SAR

Period	*V_{s100} 2,500 fps Uniform Hazard Spectrum*	*V_{s100} 2,362 fps Uniform Hazard Spectrum*	*Site Amplification Ratio*
0.2	0.984	0.998	1.014
1.0	0.485	0.499	1.028

DETERMINISTIC MCE_R

PSI performed a screening for the Deterministic Seismic Hazard Analysis (DSHA) to estimate the ground motions at the site, and to help define the risk-targeted maximum considered earthquake (MCE_R) in accordance with Section 21.2.2 of ASCE 7 (2016). A DSHA is completed by estimating ground motions for characteristic magnitude earthquakes at the location of active seismic sources in the region. Typically, the characteristic earthquakes are analyzed using an average of the same attenuation relationships used for the PSHA for consistency.

The deterministic spectral response acceleration at each period is defined as the largest 84th percentile, 5% damped spectral response acceleration in the direction of maximum horizontal direction for characteristic earthquakes on all known active faults within the region. The ordinates of the deterministic ground motions response spectrum should not be taken as lower than the corresponding ordinates of the response spectrum (i.e., the "Deterministic Lower Limit") determined in accordance with Figure 21.2-1, where F_a and F_v are determined using Tables 11.4-1 and 11.4-2, respectively. Figure 12 shows the Deterministic $MCE_{R,}$ the Deterministic Lower Limit, and the Probabilistic MCE_R.

SITE-SPECIFIC MCE_R

Section 21.2.3 of ASCE 7-16 defines the site-specific MCE_R spectral response acceleration as the lesser of the probabilistic and deterministic ground motion at any period. As seen in Figure 12 the Probabilistic MCE_R is less than the Deterministic MCE_R over all the evaluated periods, and thus represents the Site-Specific MCE_R spectrum.

SITE-SPECIFIC DESIGN RESPONSE SPECTRUM AND DESIGN ACCELERATION PARAMETERS

The design spectral response spectrum is taken as 2/3 of the Site-Specific MCE_R. As indicated in ASCE 7-16 the parameter S_{DS} shall be taken as 90% of the maximum spectral acceleration (S_a) obtained from the site-specific MCE_R spectrum at any period within the range from 0.2s to 5s. The parameter S_{D1} shall be taken as the as the maximum value of the product, T x Sa, for periods from 1 to 2s for sites with Vs_{100} > 1,200 ft/s, and periods from 1s to 5s for sites with Vs_{100} < 1,200. The parameters S_{MS} and S_{M1} shall be taken as 1.5 times S_{DS} and S_{D1}, respectively. The value obtained as described above shall not be less than 80 percent of the values determined in accordance with ASCE 7-16 Section 11.4.3 for S_{MS} and S_{M1} and Section 11.4.4 for S_{DS} and S_{D1}.

The recommended design response spectrum determined as outlined above is shown in Figure 13. A comparison of the recommended Site-Specific MCE_R and Site-Specific Design Response spectra, and the ASCE 7-16 Site Class C Code-Based spectra is shown in Figure 14.

Based on the procedure described above, PSI recommends an S_{DS} value of **0.530 g** and an S_{D1} values of **0.337 g.**

SUMMARY

Table 6 shows the ASCE 7-16 Site Class C code-based seismic parameters, and our recommended site-specific seismic parameters.

Table 6 – Recommended Site-Specific Design Response Spectrum

Parameter	*ASCE 7-16 (Site Class C)*	*Site Specific Spectrum*
S_{SUH}	0.944	-
S_{1UH}	0.484	-
C_{rs}	0.878	0.878
C_{r1}	0.864	0.864
S_s	0.829	-
S_1	0.418	-
F_a	1.2	-
F_v	1.5	-
S_{MS}	0.995	0.796
S_{M1}	0.627	0.506
S_{DS}	0.663	**0.530**
S_{D1}	0.418	**0.337**
PGA	0.386	**-**
F_{PGA}	1.2	**-**
PGA_M	0.463	**-**

*Risk Coefficient based on ASCE 7-16 for continuity with applied GMM from 2014 NSHM

GEOTECHNICAL RISK AND REPORT LIMITATIONS

The concept of risk is an important aspect of the geotechnical evaluation. The primary reason for this is that the analytical methods used to develop geotechnical recommendations do not comprise an exact science. The analytical tools which geotechnical engineers use are generally empirical and must be used in conjunction with engineering judgment and experience. Therefore, the solutions and recommendations presented in the geotechnical evaluation should not be considered risk-free and, more importantly, are not a guarantee that the interaction between the soils and the proposed structure will perform as planned. The engineering recommendations presented in the preceding sections constitute PSI's professional estimate of those measures that are necessary for the proposed structure to perform according to the proposed design based on the information generated and referenced during this evaluation, and PSI's experience in working with these conditions.

The recommendations submitted are based on the available subsurface information obtained by PSI, and information provided by Mr. Smallwood. If there are any revisions to the plans for this project or if deviations from the subsurface conditions noted in this report are encountered during construction, PSI should be notified immediately to determine if changes in the foundation and/or other recommendations are required. If PSI is not retained to perform these functions, PSI cannot be responsible for the impact of those conditions on the performance of the project.

The Geotechnical Engineer should be retained and provided the opportunity to review the final design plans and specifications to check that our engineering recommendations have been properly incorporated into the design documents. At that time, it may be necessary to submit supplementary recommendations. This report has been prepared for the exclusive use of Mr. Smallwood and his design consultants for the specific application to the proposed Salem Heights Elementary school improvements located at 3495 Liberty Road South in Salem, Oregon.

This letter is an addendum to PSI Report Number 07041356. All information, terms, conditions, findings, and recommendations remain in effect except as expressly addressed herein. Should you have any questions after reviewing this letter, please feel free to contact us at your convenience.

Respectfully Submitted,

PROFESSIONAL SERVICE INDUSTRIES, INC.

RENEWS: 06/30/2023

Brian R. Jackson, EI
Staff Engineer

Britton W. Gentry, PE, GE
Chief Engineer

FIGURES:	FIGURE 1 -	TECTONIC MAP OF THE PACIFIC NORTHWEST, DOGAMI 2010
	FIGURE 2 -	FAULT MAP, USGS FAULT AND FOLD DATABASE
	FIGURE 3 -	GEOLOGIC MAP
	FIGURE 4 -	HISTORICAL SIESMICITY
	FIGURE 5 -	ASCE 7-16 CODE SPECTRA
	FIGURE 6 -	ACTIVITY RATE BY SEISMIC SOURCE
	FIGURE 7 -	HAZARD CONTRIBUTION BY SEISMIC SOURCE
	FIGURE 8 -	SITE-SPECIFIC PROBABILISTIC GEOMTERIC MEAN MCE
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	FIGURE 13 -	RECOMENDDED SITE-SPECIUFIC DESIGN RESPONSE SPECTRUM
	FIGURE 14 -	SITE-SPECIFIC AND ASCE 7-16 SPECTRA

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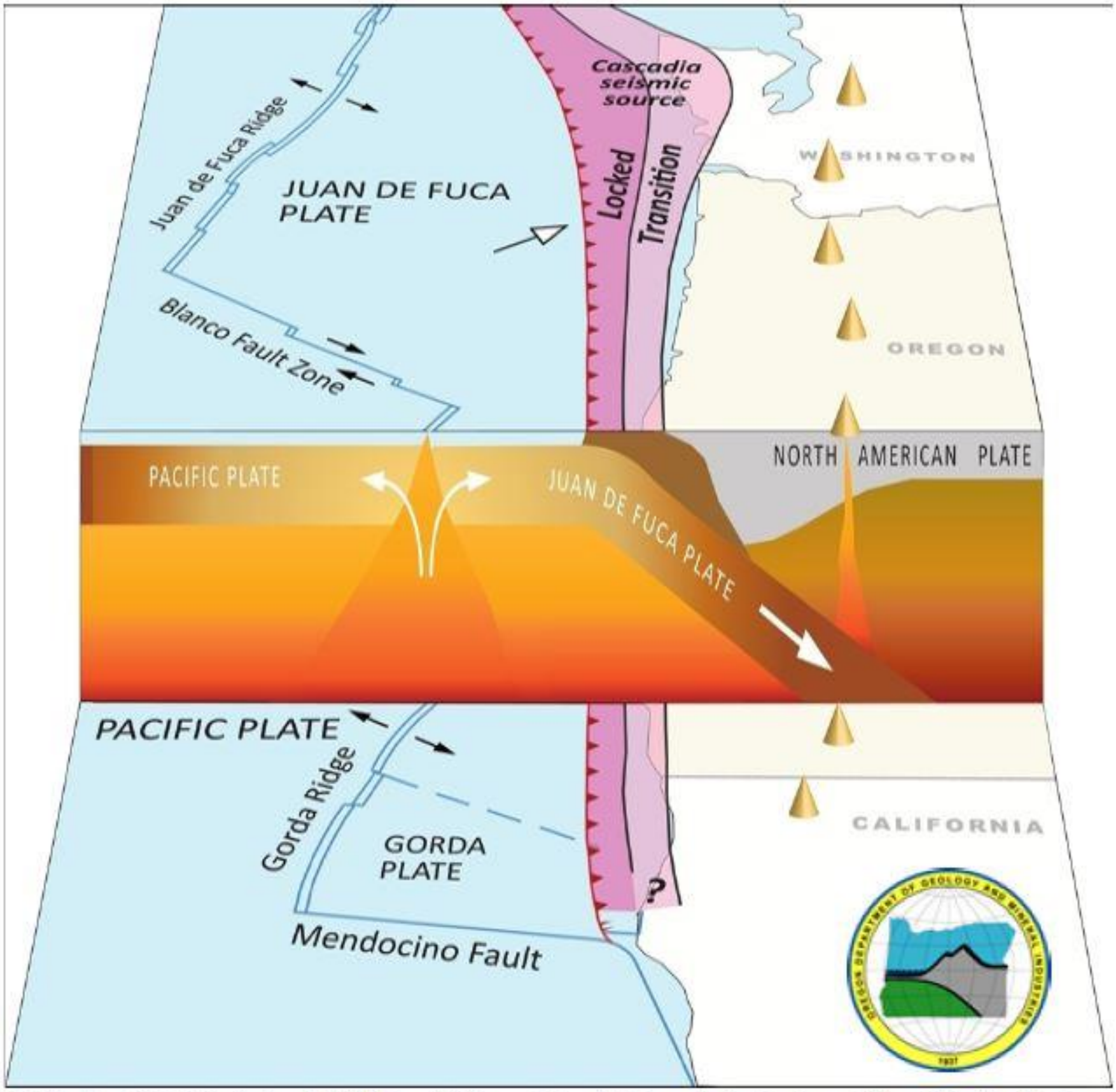
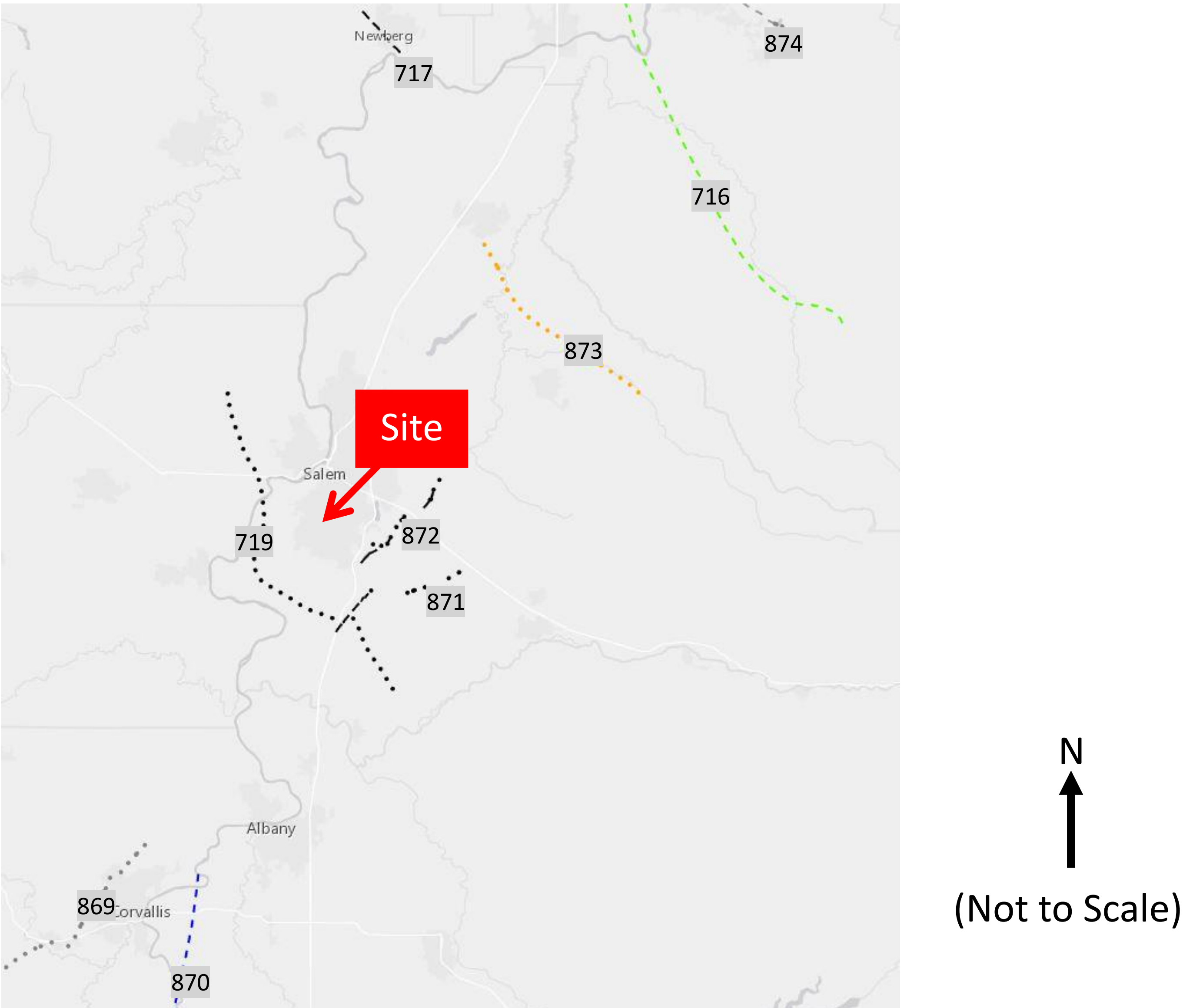


Tectonic Map of the Pacific Northwest. Modified from 2010 issue of Cascadia, Oregon Dept. of Geology and Mineral Industries. Map shows schematic locations of the 3 principal types of earthquakes, interplate at the Cascadia subduction zone, intraplate in the downgoing (subducted) oceanic plate, and crustal from active faults in the North American Plate. Map also illustrates divergence of oceanic plates at the mid-ocean ridges where oceanic plates are created. Oceanic plates are pulled away from the ridges when they sink into the earth's mantle. The oceanic plates move laterally past one another at the Blanco Fault Zone and the Mendocino Fault; these types of faults are commonly called oceanic fracture zones or transform faults. The Mendocino Fault may be considered the offshore extension of the San Andreas Fault in California. The Cascadia subduction zone, marked by the red line with triangles, is where the oceanic plates converge with and dive (subduct) under the North American Plate. The Cascadia subduction zone ends at the Mendocino fault. Note that where the subduction zone meets the Pacific Plate and Gorda Plate, you have three plates in contact; this is called a "triple junction."

intertek psi	DATE AUGUST 2021	SALEM HEIGHTS ELEMENTARY SCHOOL 3495 LIBERTY ROAD SOUTH SALEM, OREGON 97302	PSI PROJECT #: 07041401
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**TECTONIC MAP OF THE PACIFIC NORTHWEST, DOGAMI 2010**	**FIGURE 1**



Number	*Fault Name*
719	Salem-Eola Hills Homocline
872	Waldo Hills Fault
871	Mill Creek Fault
873	Mount Angel Fault
870	Owl Creek Fault
716	Canby-Molalla Fault
869	Corvallis Fault Zone
717	Newberg Fault
874	Bolton Fault

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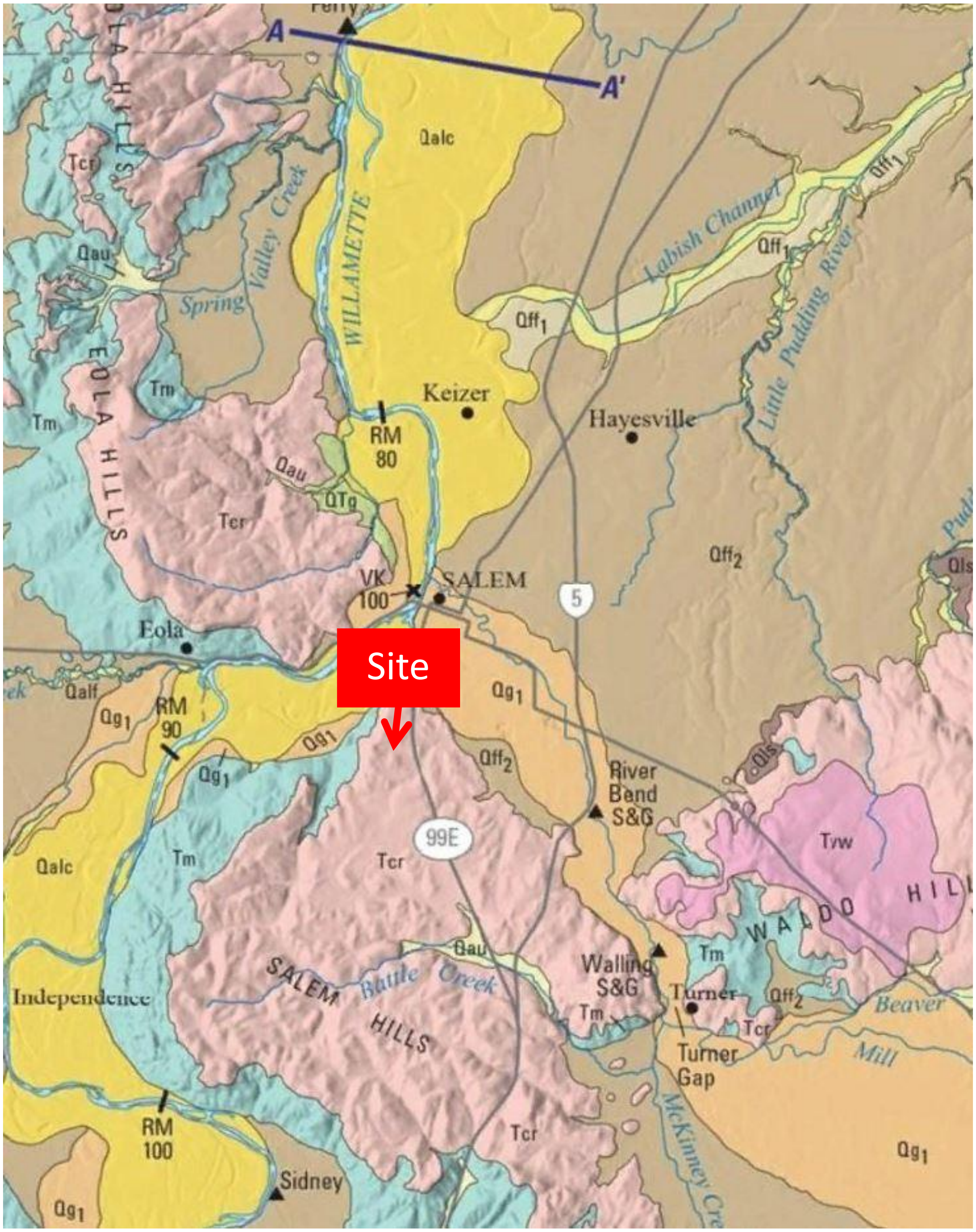
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**FAULT MAP, USGS FAULT AND FOLD DATABASE**	**FIGURE 2**



N

(Not to Scale)

T_{cr} = Columbia River Basalt Group

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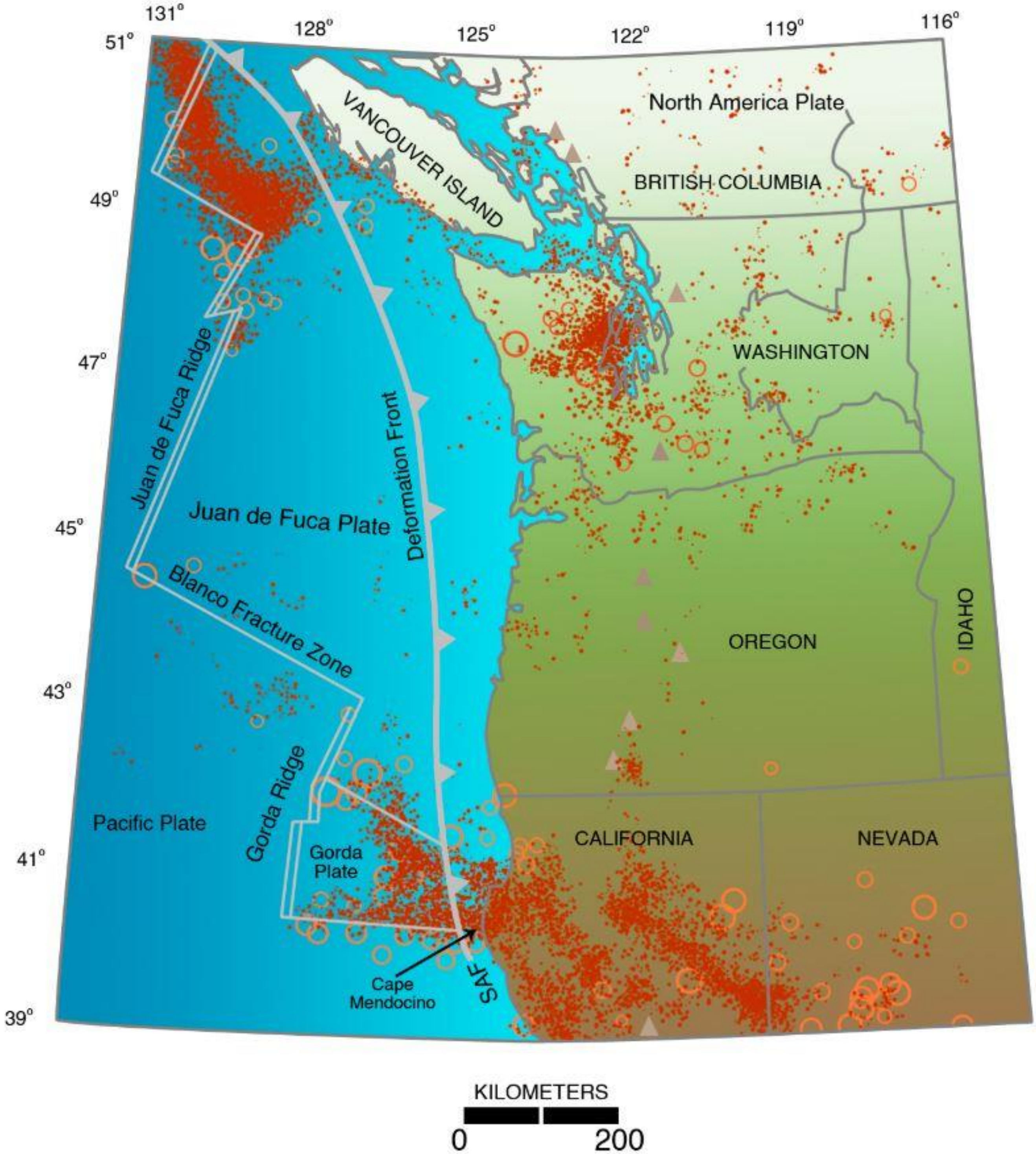

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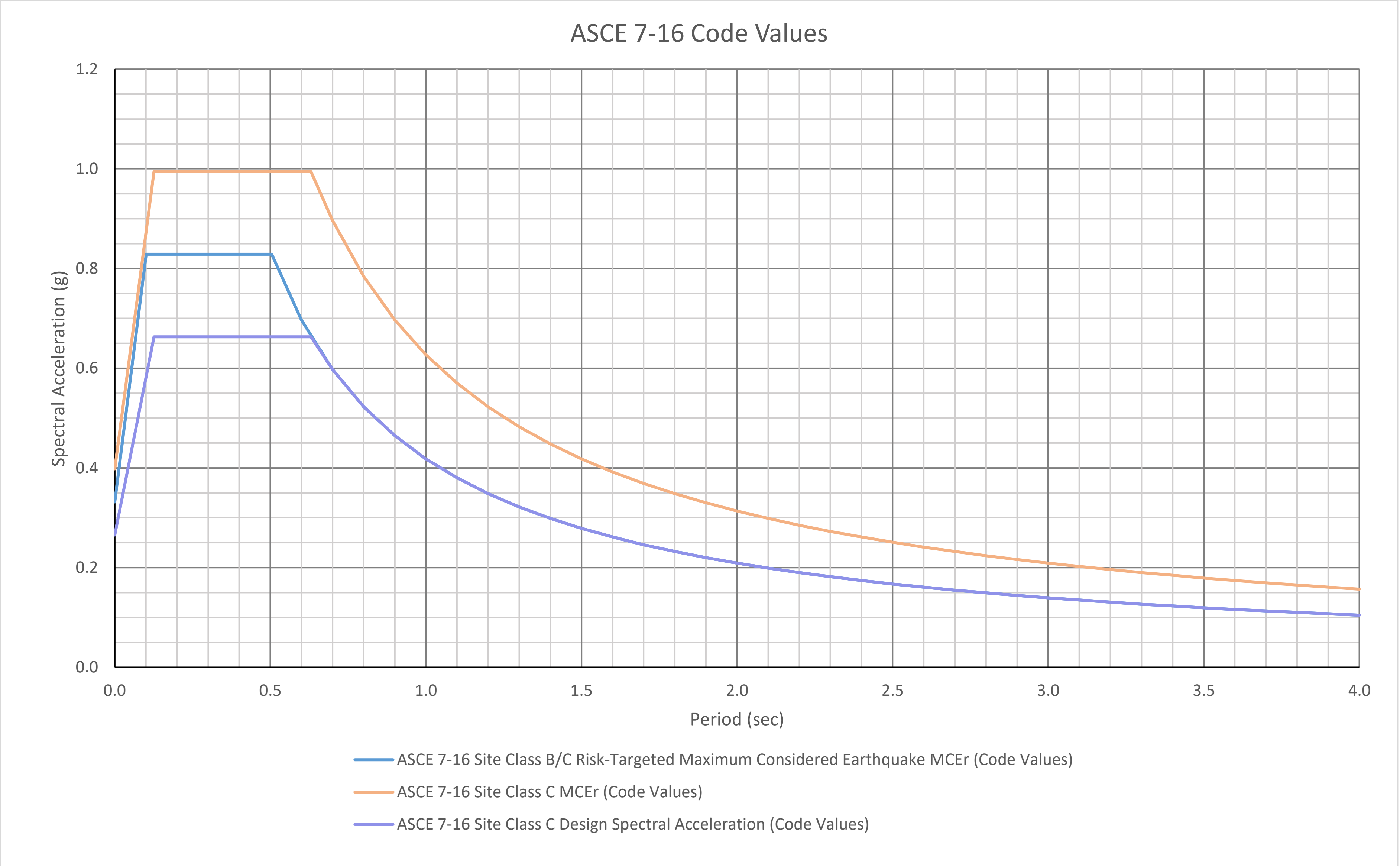
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**HISTORICAL SIESMICITY, USGS**	**FIGURE 4**



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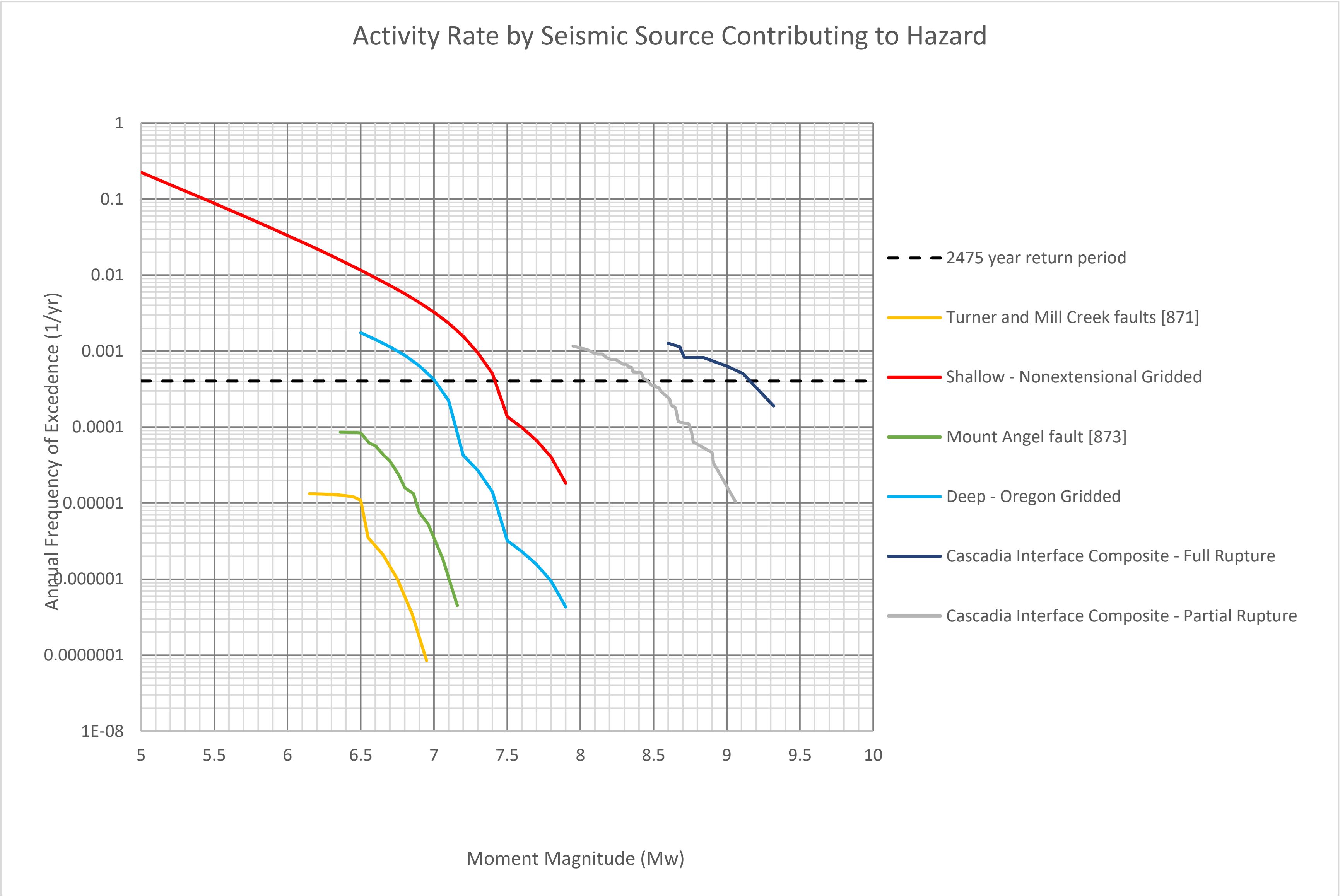
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**ASCE 7-16 CODE SPECTRA**	**FIGURE 5**



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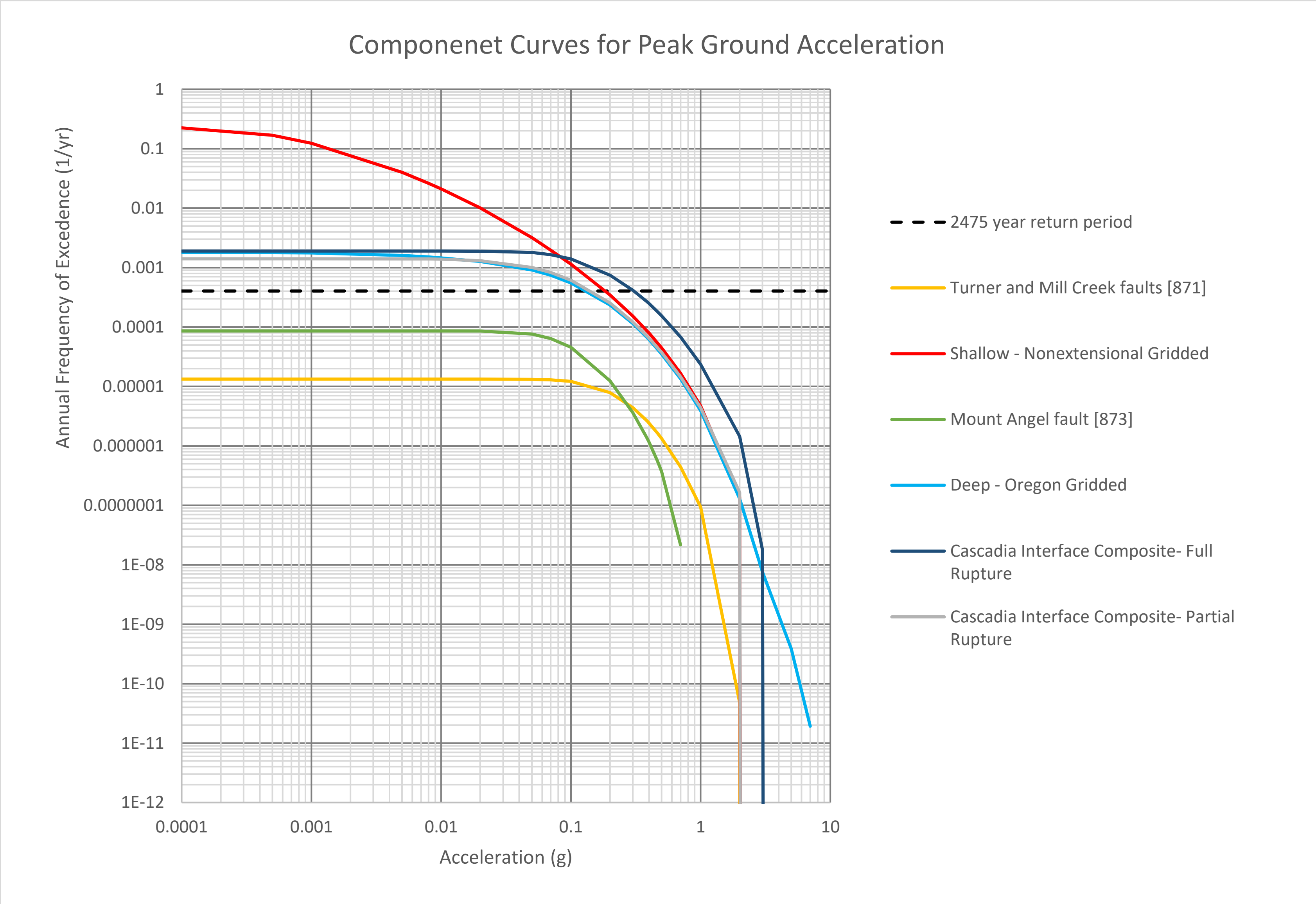
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**ACTIVITY RATE BY SEISMIC SOURCE**	**FIGURE 6**



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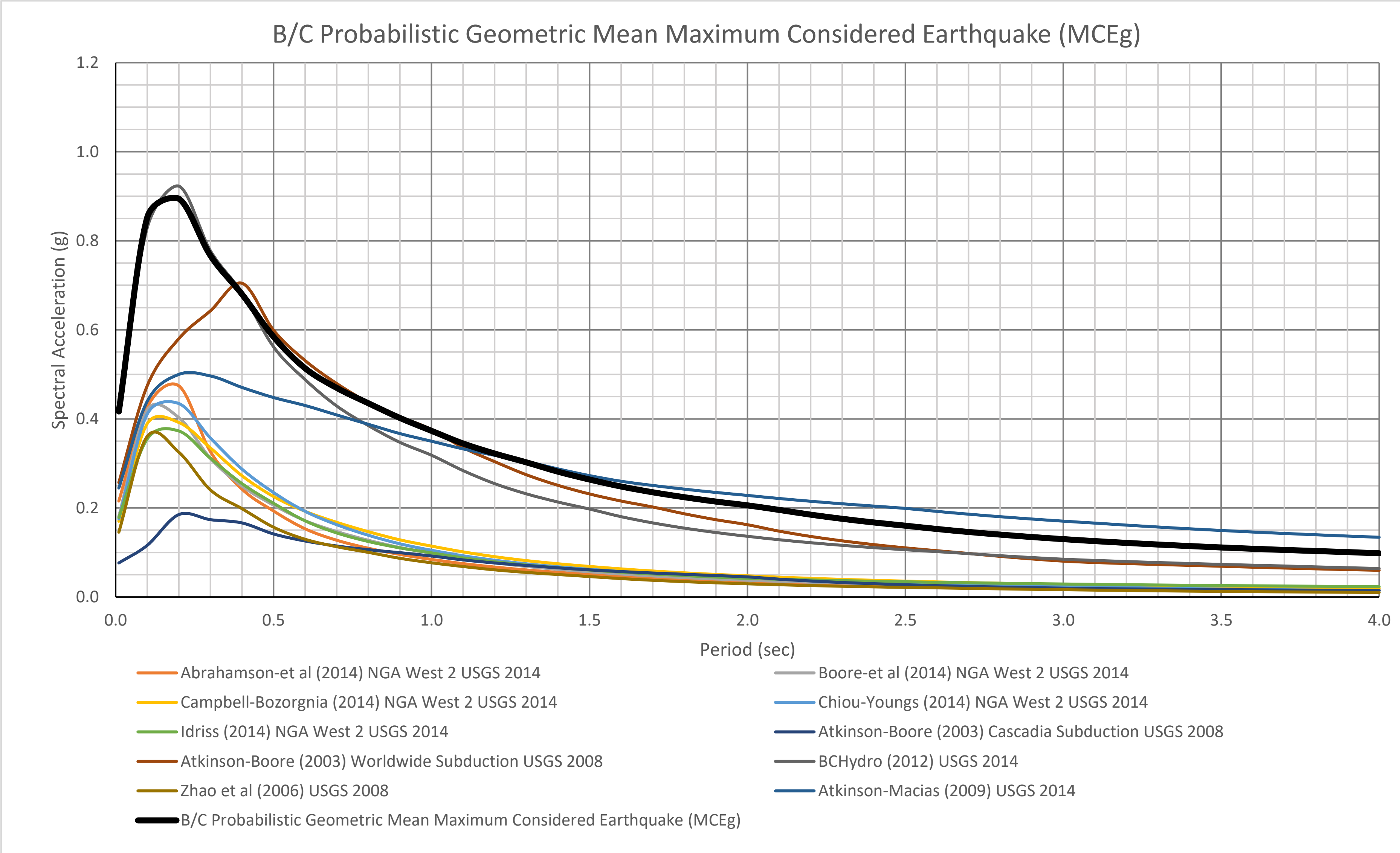
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**HAZARD CONTRIBUTION BY SEISMIC SOURCE AT PGA**	**FIGURE 7**



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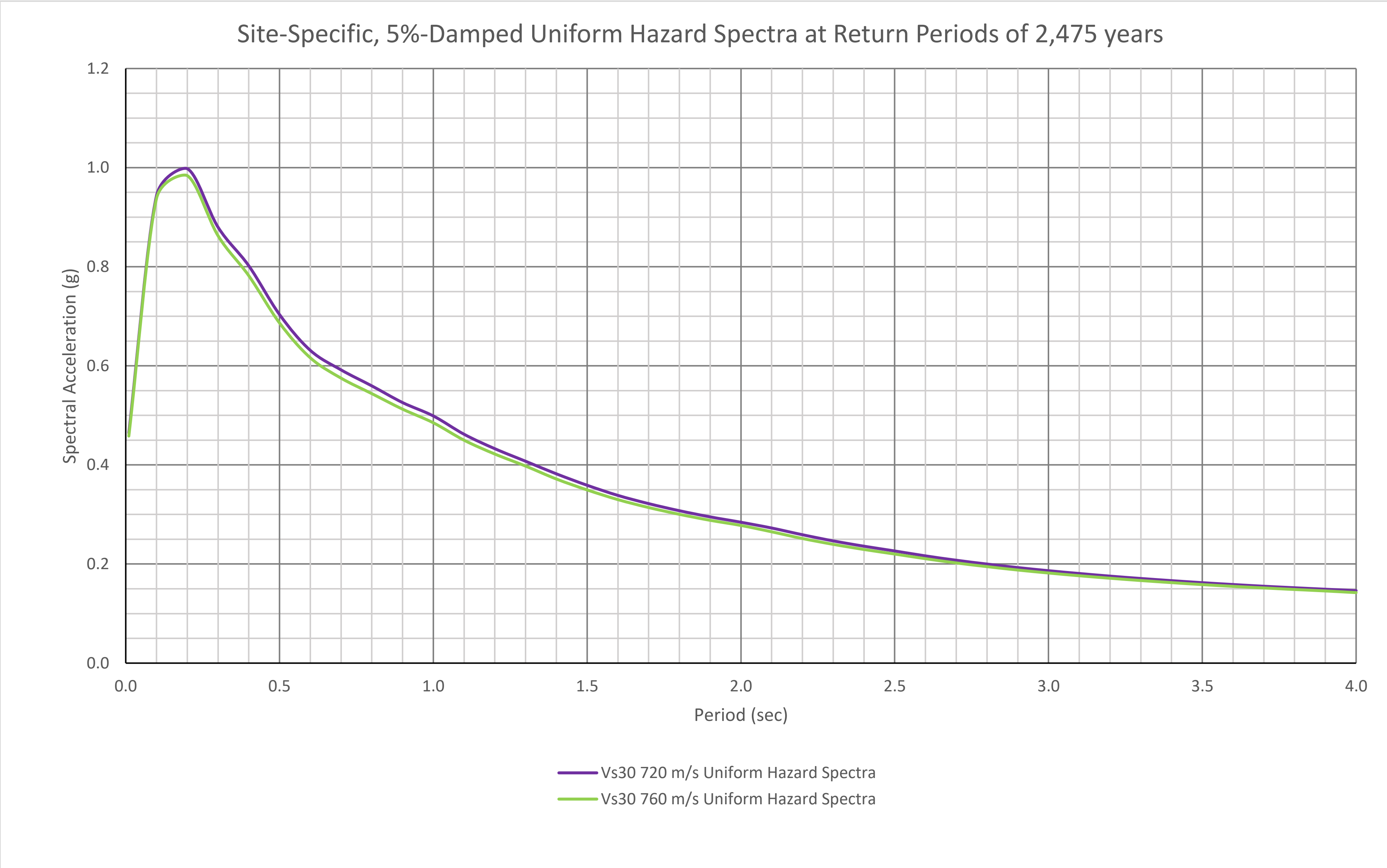
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**SITE-SPECIFIC B/C PROBABILISTIC GEOMETRIC MEAN MAXIMUM CONSIDERED EARTHQUAKE**	**FIGURE 8**



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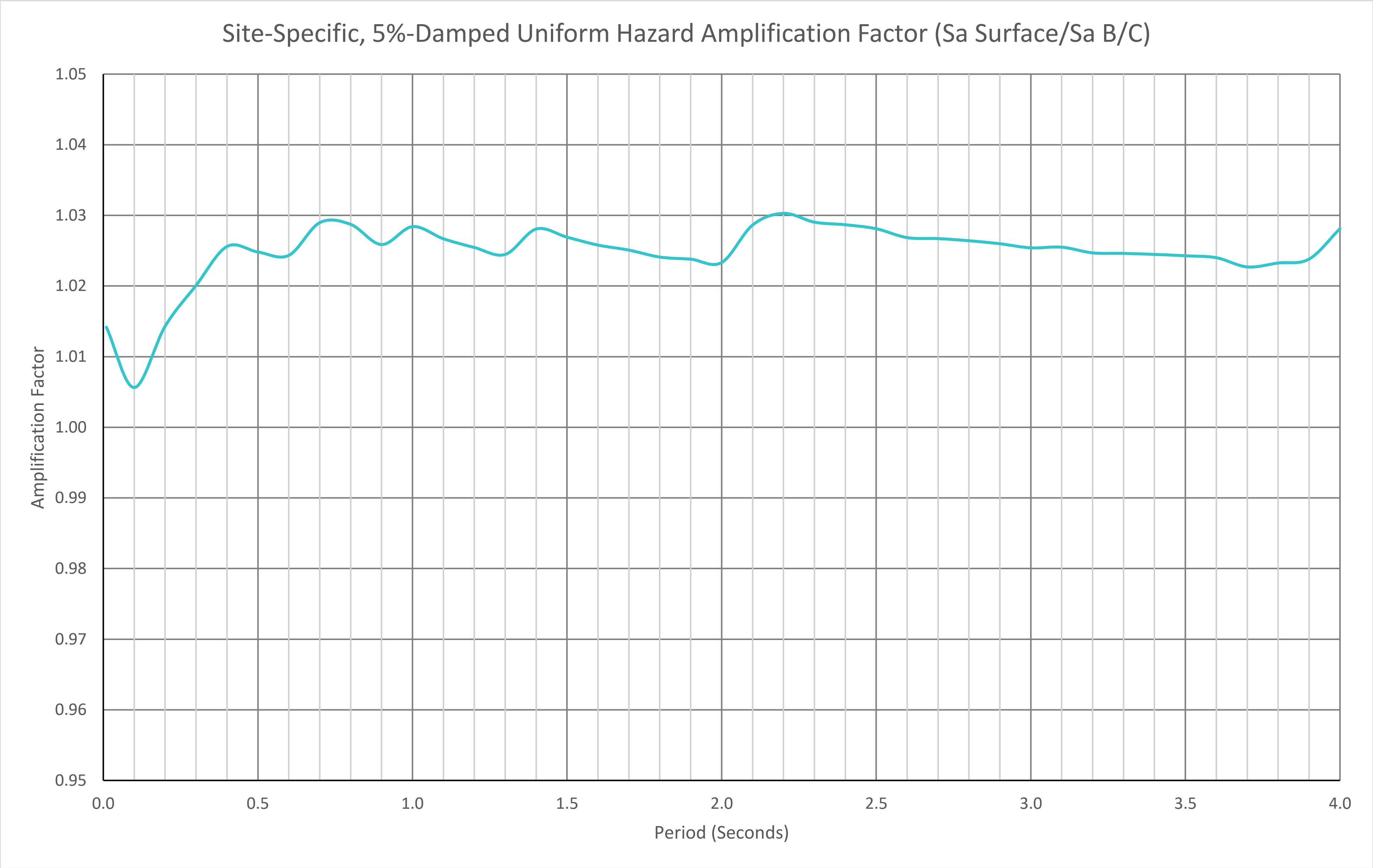
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**SITE-SPECIFIC, 5%-DAMPED UNIFORM HAZARD SPECTRA AT RETURN PERIOD OF 2,475 YEARS**	**FIGURE 9**



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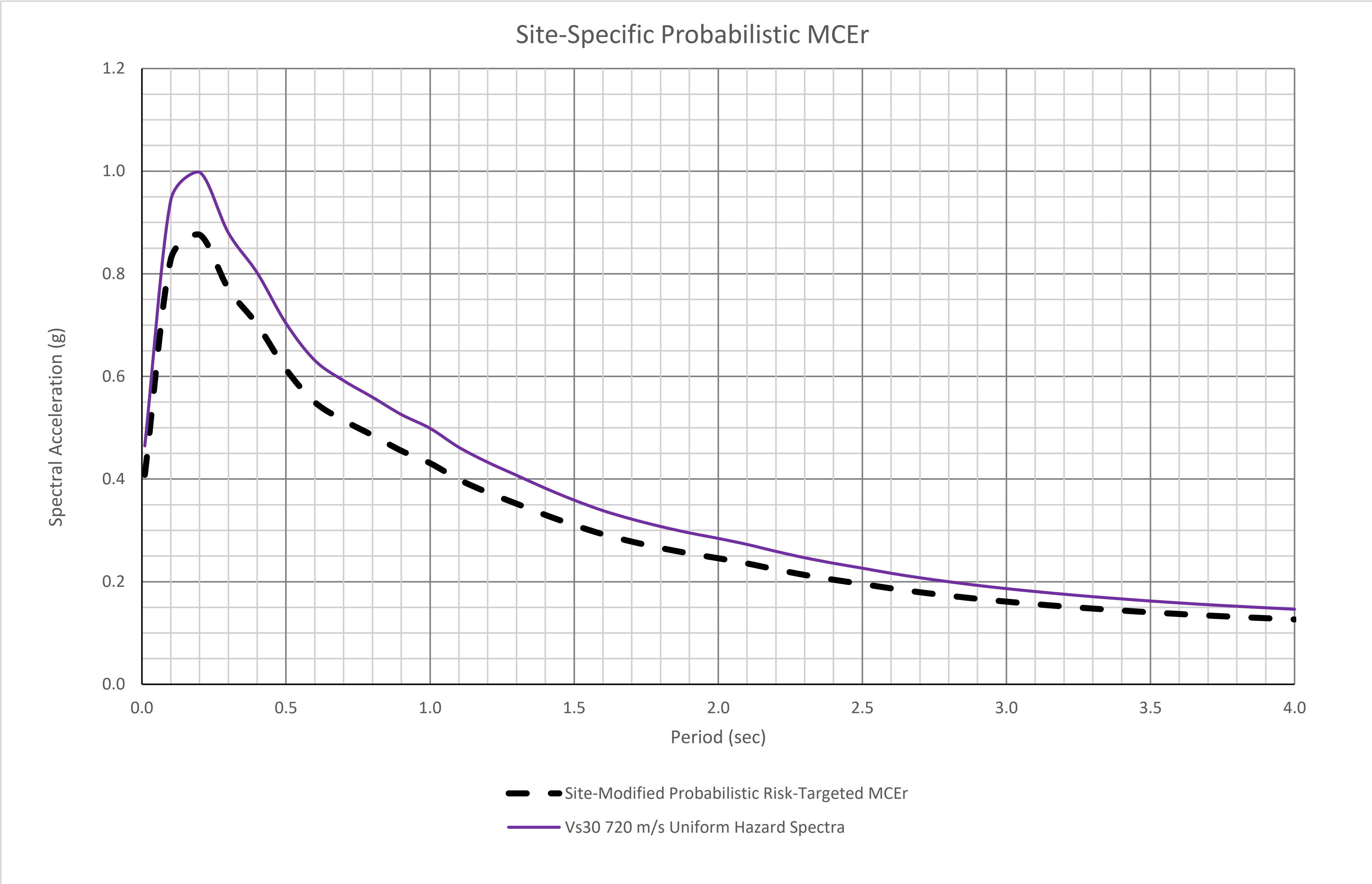
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**SITE-SPECIFIC, 5% DAMPED UNIFORM HAZARD AMPLIFICATION FACTOR**	**FIGURE 10**



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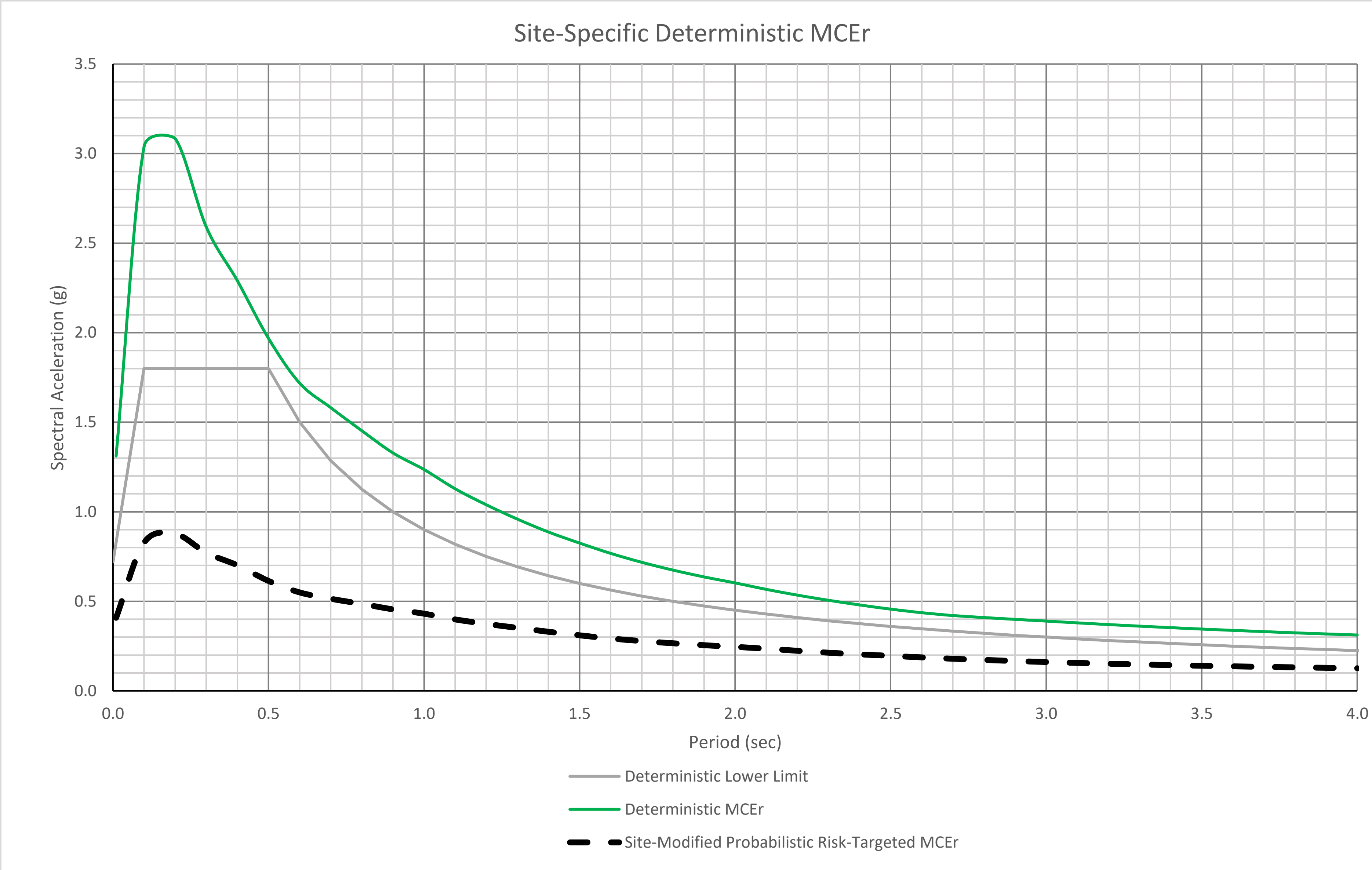
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**SITE SPECIFIC MCE$_R$**	**FIGURE 11**



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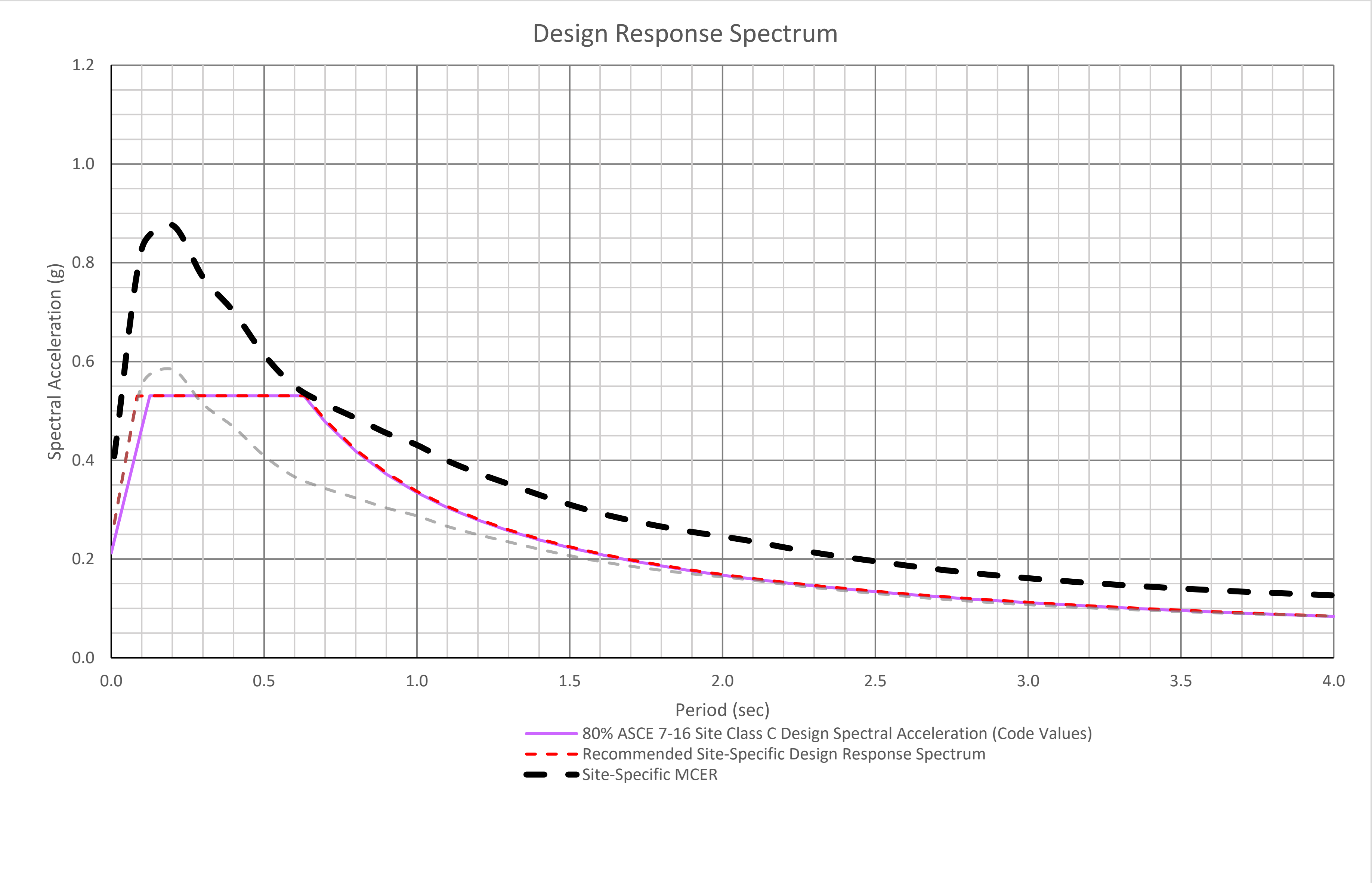
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**SITE-SPECIFIC DETERMINISTIC MCE$_R$**	**FIGURE 12**



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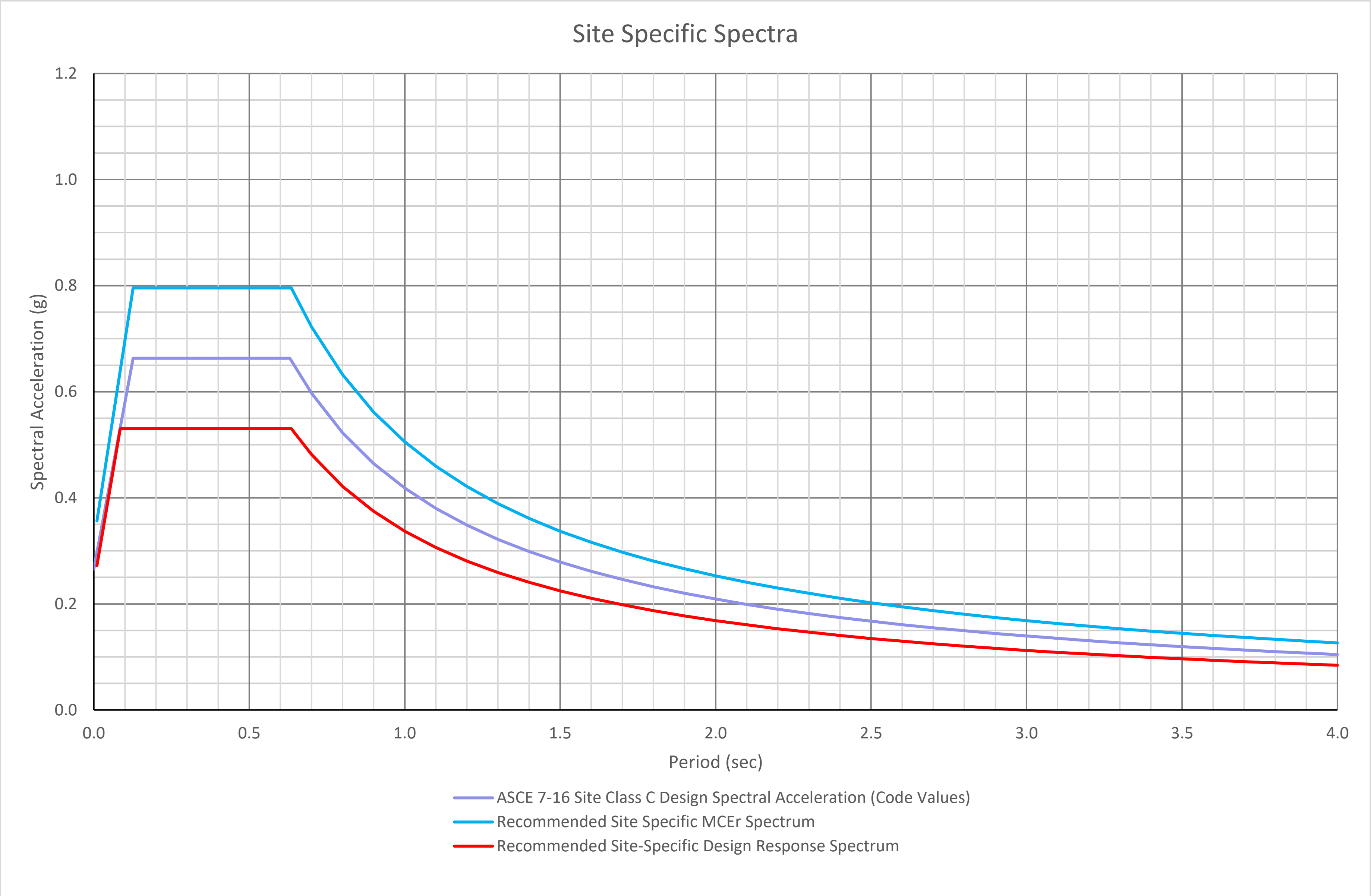
PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**RECOMMENDED SITE-SPECIFIC DESIGN RESPONSE SPECTRUM**	**FIGURE 13**



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PSI, INC. 6032 N. CUTTER CIRLCE, SUITE 480 PORTLAND, OREGON 97217 (503) 289-1778	DRAWN BY: BRJ	**SITE-SPECIFIC AND ASCE 7-16 SPECTRA**	**FIGURE 14**