SHALLOW SEISMIC SITE CHARACTERIZATIONS AT 23 STRONG-MOTION STATION SITES IN AND NEAR WASHINGTON STATE

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ABSTRACT

In this NEHRP –funded study, we conducted shallow active and passive seismic surveys to estimate near-surface P- and S-wave velocities (Vp and Vs) with respect to depth at 23 strongmotion sites, 22 in western Washington and 1 in Portland. In addition, we recorded ambient (noise) vibrations to estimate thickness (>30 or >100 meters) and average velocity of sediment cover for selected sites. Our survey methods include Multichannel Analysis of Surface Waves (MASW), Microtremor Array Measurements (MAM), P- and S-wave refractions, and Horizontal-to-Vertical Spectral Ratio (HVRS) using single-station ambient noise measurements. We subsequently calculated Vs30m (average Vs in the top 30m), as well as Vp/Vs and Poisson's ratio profiles, from the estimated Vp and Vs profiles. We determined fundamental frequencies from HVRS analyses using ambient noise measurements, and estimated depths and average velocities based on these frequencies. For each site we provide these quantities in tabular and graphical form along with interpreted geology, NEHRP site classifications using Vs30 estimates, and fundamental frequencies with estimated maximum depth and average velocity of sediment covers.

INTRODUCTION

The Washington State Department of Natural Resources (DNR), Division of Geology and Earth Resources (DGER), conducted shallow seismic surveys, including Multichannel Analysis of Surface Waves (MASW), Microtremor Array Measurements (MAM), P- and S-wave refraction methods to estimate near-surface P- and S-wave velocity (Vp and Vs) profiles, and ambient noise measurements to estimate maximum depths and average velocities of sediment covers at 23 National Strong-Motion Project (NSMP) refrence sites in Washington and Portland. Work was funded through the U.S. Geological Survey/National Earthquake Hazard Reduction Program external grant program (USGS/NEHRP Award Number G10AP00027).

Puget Sound, Washington, and coastal areas from along the Oregon-Washington to British Columbia of Canada are historically the most seismically active regions in the Pacific Northwest (Wong et al, 2003; Pratt et al., 2003; Atwater, 1996). Damaging interslab 1949 Olympia (M=7.1), 1965 Seattle-Tacoma (M=6.5) and 2001 Nisqually (M=6.8) earthquakes that occurred in the past are prime examples of the region's hazardous seismic activity, in addition to an expected Cascadia subduction megatrust earthquake (M=9) (Atwater, 1996). The 11 March 2011 (Mw=9.0) Tohoku earthquake is the most recent example showing the level of likely damages when the similar Cascadia megatrust earthquake strikes.

When a large earthquake strikes, near-surface soil or sediment amplifications or deamplifications are expected at sites as have been observed in various areas around the world including the Puget Sound area; for example, Aki (1993), Pratt et al. (2003), Frankel et al. (2002) and (1999) and Hartzell et al (2002) are a few studies besides many others, documenting such site effects. A clear understanding of the non-linear amplification effects at soil sites is one of the most important parts of the site-specific seismic hazard mapping (Aki, 1993), particularly in and around the metropolitan areas such as Seattle (Washington) and Portland (Oregon) (Cakir and Walsh, 2010; Frankel et al., 2007).

To accurately quantify the near-surface seismic properties (Vs=shear-wave velocity, Vp=P-wave velocity, and Poisson's ratio) with respect to depth, we conducted noninvasive active and passive surveys at 23 station sites in Washington and Oregon (Fig. 1). We used the same methodology as Cakir and Walsh (2010) for active and passive seismic surveys and processing methods to quantify soil seismic properties up to 30 meter and greater depths. We also ran surveys with (if site condition permitted) longer spreads (spread length =100-140m) to estimate Vs and Vp at deeper (30m<target depth<140m) layers. In addition, we measured ambient noise at selected sites (Fig. 2) to roughly estimate maximum depth and average velocity of thicker (>30m) sediment cover at each site. The ambient noise measurements were conducted using Guralp CMG-6TD and Tromino (www.tromino.it) instruments. Latter was used for early measurements to test the HVSR methodology at various sites in Puget Lowland (Albarello et al, 2011a).

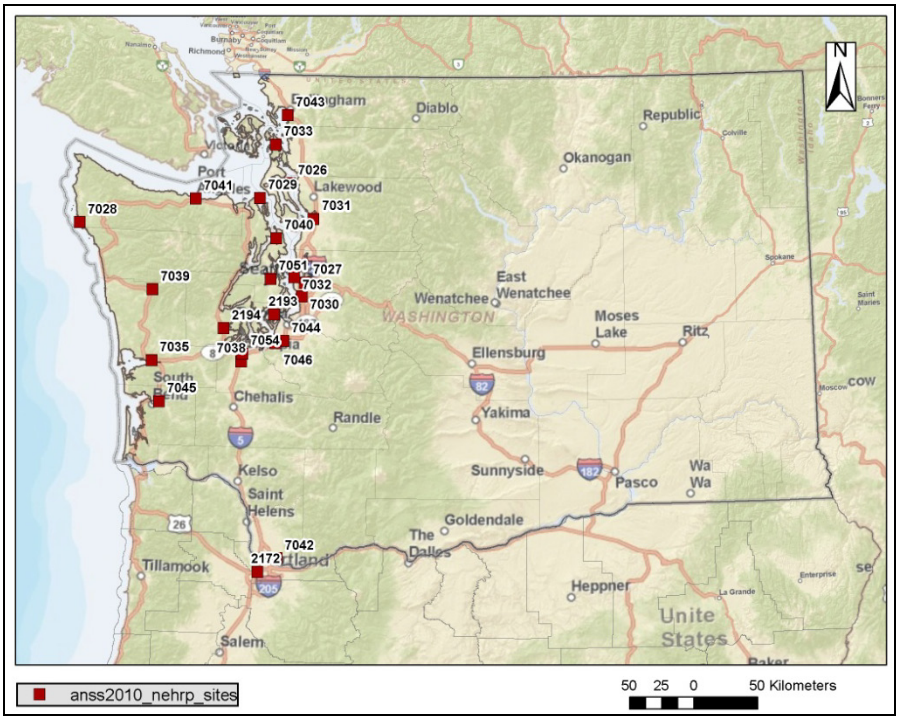

Figure 1. Shallow seismic survey locations.

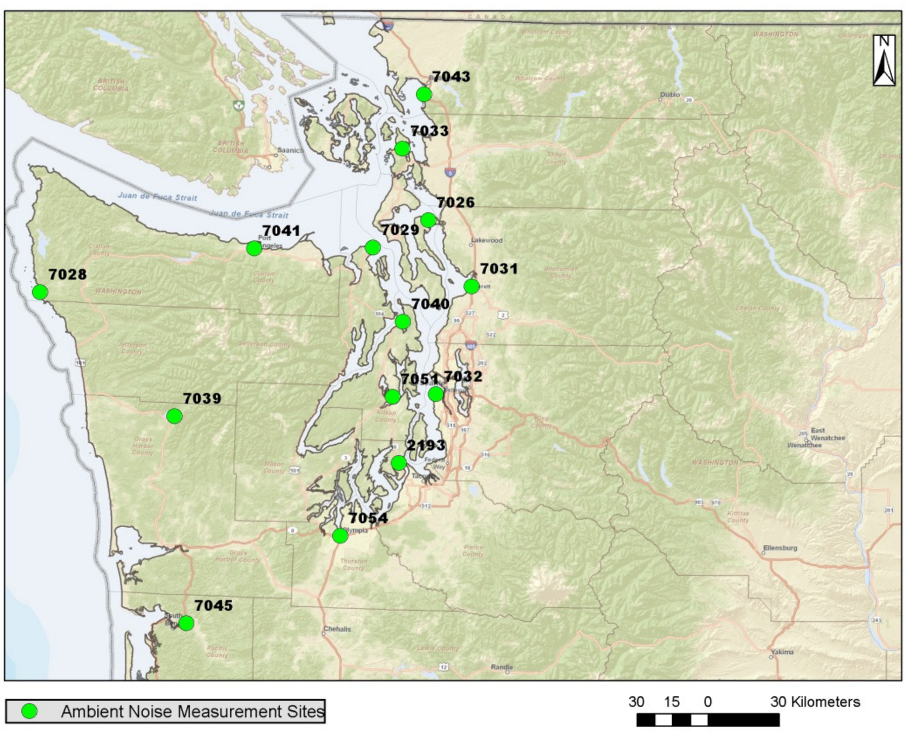

Figure 2. Ambient noise measurement locations at selected sites.

Results and along with a relevant study was also presented at the 2011 Annual Seismological Society of America (SSA) meeting, in Memphis, Tennessee (Cakir and Walsh, 2011; Albarello et al, 2011b).

GEOLOGIC SETTING

Geology information for each site is compiled and summarized in this section. Geologic interpretations are based on available geologic maps and nearby borehole information available through the Washington State Department of Ecology (DOE) and Washington Division of Geology and Earth Resources (DGER).

ST 2172 PORTLAND; PORTLAND STATE UNIVERSITY

This site is underlain by the fine-grained facies of the catastrophic flood deposits of the Missoula floods(Beeson and others, 1991), which consists of silt-to coarse sand. A geotechnical borehole about 150m to the northwest penetrated 50 ft of silty sand. Another less well-located water well in the vicinity penetrated 87 ft of brown sand and sand, silt, and gravel to a depth of 113 ft. Below that, it penetrated gravel to a depth of 232 ft, where it reached basalt bedrock.

ST 2193 GIG HARBOR; FIRE STATION

This site is underlain by Vashon Till. In nearby water wells, the till is about 25 ft thick and is underlain by sand. The top of the advance outwash sand in a gully about ¼ mi east of this location is persistently about 30 ft lower than at the fire station (Troost and others, in review(b)).

ST 2194 SHELTON; FIRE STATION

This site is underlain by sand and gravel of Vashon recessional outwash over Vashon till (Schasse and others, 2003). Map relations suggest that the Vashon is here underlain by outwash of an Olympic alpine glaciation. The nearest water well suggests a sequence of about 30 feet of Vashon outwash overlying about 10 ft of till, in turn overlying at least 30 ft of an older, presumably Olympic, outwash.

ST 7026 STANWOOD; CAMANO ISLAND FIRE STATION NO. 1

This site is underlain by Everson Glaciomarine Drift, a clayey to silty diamicton with variable content of gravel; it is mostly loose and soft, but locally hard and compact (Scasse and others, 2009). Deposits are typically between 20 and 100 ft thick (Dragovich and others, 2002). The only nearby water well is difficult to interpret but suggest that this unit is about 38 ft thick, overlying about 5 ft of till, which in turn overlies a thick sequence of outwash sand and gravel.

ST 7027 SEATTLE; FIRE STATION NO.28

This site is underlain by a thin fill overlying the Blakeley Formation of Weaver, 1916, as redefined by Fulmer, 1975. Geotechnical borings about 100m to the north of this site encountered about 10 ft of silty fill on topof hard silstone. The rocks to the northwest and southeast of here strike nw and dip steeply ~60) to the northeast (Troost and others, 2005).

ST 7028 FORKS; LA PUSH COAST GUARD STATION

This site is underlain by alluvium of the Quillayute River (Gerstel and Lingley, 2000), which upstream of La Push is generally silt loam (Halloin, 1987). Channel alluvium in the vicinity is sand and gravely as coarse as cobble gravel. Thickness is unknown.

ST 7029 PORT TOWNSEND; FORT WORDEN STATE PARK

This site is extensively regraded (Schasse and Slaughter, 2005) but generally is a Vashon till plain (Grimstad and Carson, 1981; Washington Department of Ecology, 1978). The bluff a short distance to the north exposes about 20 ft of Vashon till overlying about 25 ft of Vashon outwash sand and gravel, which in turn overlies about 40 ft of interbedded sand and silt (Washington Department of Ecology, 1978)

ST 7030 SEATTLE; SEATAC AIRPORT FIRE STATION

This site is on extensively graded and compacted soil of SeaTac Airport (Booth and Waldron, 2004). Prior to grading, this site was a gently undulating till plain (Willis and Smith, 1899). Boreholes at the airport generally penetrate 10-15 ft of fill over either till or sand and gravel, although in some places fill was placed on peat.

ST 7031 EVERETT; FIRE STATION NO.2

This site is on a Vashon till plain (Minard, 1985). In a nearby geotechnical boring, the till is at least 25 ft thick and is underlain by a clean sand with some gravel, which is as much as 200 ft thick in this area (Minard, 1985).

ST 7032 WEST SEATTLE; FIRE STATION NO. 29

This site is underlain by Vashon sandy advance outwash, here known as the Esperance Sand (Troost and others, 2005). A geotechnical borehole at this site penetrated 3.5 ft of sandy fill over 12.5 ft of dense to very dense sand. Four blocks west of this site, a geotechnical borehole penetrated 40 ft of Esperance Sand. A geotechnical borehole 6 blocks north-northeast of this site penetrated 53 ft of sand overlying 62 ft of silt and clay, here known as the Lawton Clay.

ST 7033 ANACORTES; FIRE STATION

This site is on a thin fill overlying Everson glaciomarine drift (Lapen, 2000), which is mostly silty, sandy, clayey diamicton (Dragovich and others, 2000), moderately to poorly indurated, with lenses and discontinuous beds of moderately to well-sorted gravel, sand, silt, and clay. The thickness of this unit is highly variable. Logs of nearby wells are difficult to interpret; a well log from about two blocks north of this site reports sandstone at a depth of 12 ft but well logs from two blocks east report silt and clay to a depth of 340 ft.

ST 7035 ABERDEEN; FIRE STATION

This site is on Chehalis River alluvium (Logan, 1987). It consists of silt, clayey silt, sandy silt, and silty sand. It is at least 100 ft thick in nearby geotechnical boreholes and blow counts about 2 blocks to the south southeast it is medium dense at 100 ft depth.

ST 7038 TUMWATER; FIRE STATION HDQTRS

This site is on Vashon recessional outwash sand informally called the Tumwater Sand (Walsh and others, 2003; Logan and others, 2009). A water well at this site has 39 ft of sand overlying about 100 ft of sand and gravel with some silty interbeds.

St 7039 QUINAULT LAKE; RANGER STATION

This site is on latest Wisconsinan alpine drift of the Olympic Mountains (Logan, 2003). Monitoring wells at the site encountered at least 50 ft of sand and gravel with some silty layers. Total thickness is unknown.

ST 7040 PORT GAMBLE; MUSEUM

This site is underlain by Vashon till. The nearest water well, about 1,000 ft to the south southeast, encountered 36 ft of till overlying a ~100 ft thick, sandy clay?

ST 7041 PORT ANGELES; FIRE STATION

This site is underlain by sandy recessional outwash of latest Wisconsinan age (Schasse and other, 2004). Marine mudstone (Pysht Formation) is exposed about ¾ mile southeast of here. Well logs are difficult to interpret but show that unconsolidated sediments are at least 50 ft thick midway between this site and the bedrock exposures, and a well 3 blocks west of this site penetrated unconsolidated sediments to a depth of

155 ft, suggesting that the thickness of sediments here is >100 ft.

ST 7042 VANCOUVER; USGS, CASCADES VOLCANO OBSERVATORY

This site is underlain by a bar and channel complex of the gravel facies of the cataclysmic food deposits of the Missoula floods (Evarts and O'Connor, 2008). These are bouldery- to cobbly gravel and sand deposits, with angular basaltic andesite boulders as much as 7m across in a matrix of rounded cobbles and pebbles (Evarts and O'Connor, 2008). Nearby water wells show this unit to be more than 150 ft thick.

ST 7043 BELLINGHAM; FIRE STATION NO. 2

This site is underlain by thin glacial drift underlain by Eocene sandstone, siltstone, and coal of the Chuckanut Formation (Lapen, 2000). A water well 6 blocks west of this site penetrated 25 ft of silt and sand and gravel. The thickness of the drift at this site is unknown.

ST 7044 MCCHORD AFB; FIRE STATION

This site is underlain by sand and gravel of the Clover Creek channel of Steilacoom Gravel (Troost, in review). The gravel is 110 ft thick in a borehole about 650 ft northwest of here, and overlies a thick section of sand.

ST 7045 RAYMOND; FIRE STATION

This site is underlain by Willapa River alluvium. Nearby water wells are too shallow to constrain the thickness of the alluvium. An oil well (Raymond Oil Co. Willapa #1) was drilled about ¾ mile southeast of her and encountered shale bedrock of the Astoria Formation at a depth of 34 ft (Wagner, 1967). The valley is narrow here and is bounded by Astoria Formation bedrock at distances of ~1/2-~3/4 mile from here, so the alluvium is not expected to be significantly deeper than 34 ft.

ST 7046 CAMP MURRAY

This site is underlain by sand and gravel of the Clover Creek channel of Steilacoom Gravel (Troost and others, in review(a)). The gravel is at least 40 ft thick in a borehole near here and is probably considerably thicker, by comparison with Site 7044.

ST 7051 BREMERTON; NEW FIRE STATION NO. 1

This site is underlain by Vashon recessional outwash sand and gravel. Nearby Department of Transportation boreholes penetrate 115 ft of sand and gravel.

ST 7054 OLYMPIA, CENTENNIAL PARK

This site is underlain by the Tumwater sand of Walsh and others, 2003). It is latest glacial sand and silt deposited by streams flowing into Glacial Lake Russell and into lower stands of water in the Puget Sound basin. A borehole drilled at this site penetrated 101.5 ft of silty sand, sandy silt, and clayey silt (unpublished DNR boring log).

ACTIVE AND PASSIVE SEISMIC SURVEY AND DATA PROCESSING METHODS

Multichannel Analysis of Surface Waves (MASW)

The MASW active source method better overcomes noise problem and resolves Rayleigh wave dispersion (phase velocity as a function of frequency) by employing multichannel recordings. The method has been extensively studied and tested for various shallow earth problems by the Kansas Geological Survey (KGS) (Miller and others, 1999; Park and others, 1999; Xia and others, 1999, 2000, 2003, 2004). More applications and references can be found at the KGS website (http://www.kgs.ku.edu/Geophysics/pubs.html). An 8.2 kg sledgehammer source and 4.5-Hz vertical geophones with (generally) 3 m spacing were used to generate and receive surface (Rayleigh) waves on a 24-channel seismograph (GEODE). Sampling time, record length, and shot interval for MASW data acquisition and geometry were generally selected as 0.125 millisecond, 1-1.5 second, and 3 meters, respectively. We also used a 48-channel spread when site conditions are appropriate for a longer spread (>69 meters) (see Table 2 for spread lengths used at each stations site). Dispersion curves (phase velocity vs. frequency) and their inverted shear-wave velocity profiles were obtained by using a procedure described in the SeisImager/SW software manual (Geometrics, 2009a). Figure 3 shows the general processing steps of the 1D/2D MASW analyses.

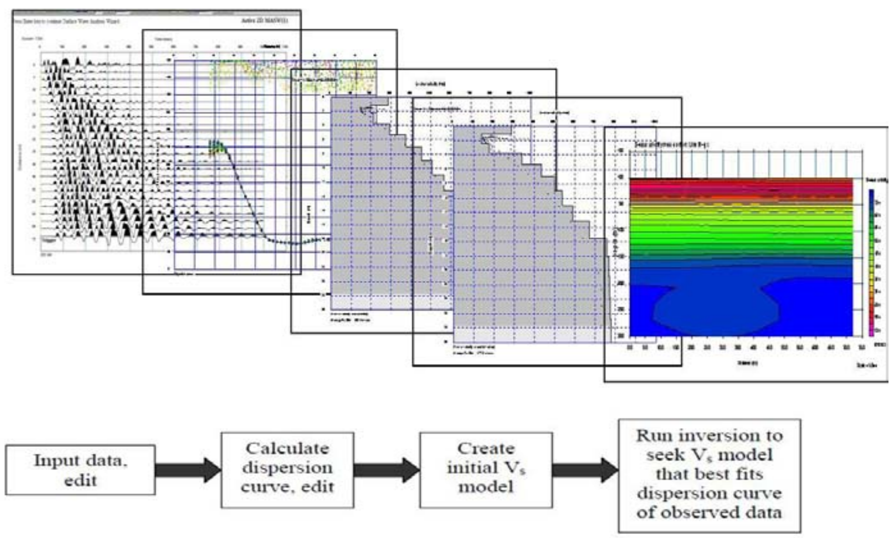

Figure 3. Processing steps for the Multichannel Analysis of Surface Waves (MASW) (Cakir and Walsh, 2010; Geometrics, 2009a).

A flow chart of two-dimensional MASW processing steps is shown in Figure 4. Input data (usually 32 shot gathers) were first checked if they had a correct geometry, then calculated common mid points (CMP) cross-correlations (CMPCC) gathers (Hayashi and Suzuki, 2004) increasing the lateral resolution of 2-D Vs (x=distance, z=depth) image. Dispersion curves (12 for 24-channel shot gathers) were then calculated from these CMPCC gathers and edited (if needed). Initial velocity models were generated from the CMPCC dispersion curves, and inverted until finding best model parameters (depth and velocity) that fit observed dispersion curves. Resulting final fundamental-mode dispersion curves were checked to make sure they are not mixed with or crossed higher mode curves (Figures 3 and 4).

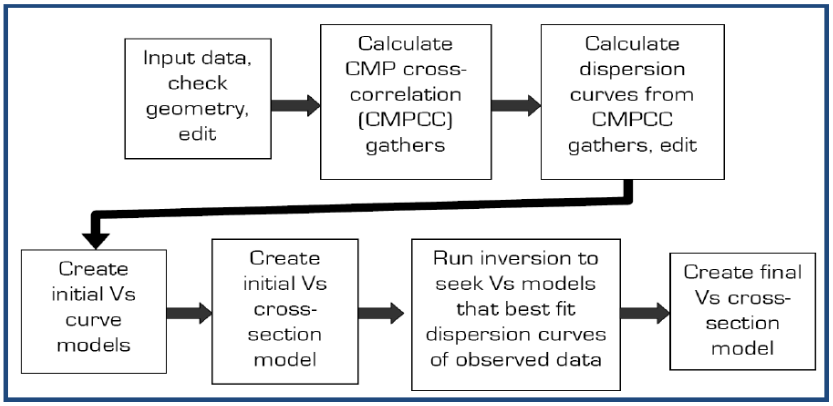

Figure 4. Processing steps for a two-dimensional imaging of the MASW data (Underwood, 2007).

Microtremor Array Measurements (MAM)

Following the same methodology used in Cakir and Walsh (2010), we recorded passive-source vibrations generated by cultural noise, traffic, wind, etc (Fig. 5). We considered steady vibrations, examples given in Geometrics (2009a), higher amplitude and consistent signals observed in frequency range of less than 30Hz, as the best quality data (Fig 6). The MAM field data acquisition parameters of 2-millisecond sampling time, 32-second record length, and linear (a line) were commonly used. To determine a full stretched dispersion curve (for example, 4–50Hz); dispersion curves of active (MASW) and passive (MAM) surface-wave methods were combined to better estimate deeper (>15 or 30 m) and shallow (<15 or 30 m) shear-wave velocities. Depending on the site accessibility, we generally choose maximum geophone spread lengths (indication for the maximum target depth) of 69 or 115 m for the linear array. Specifically in downtown areas we had more limitations to setup a longer spread length (> 48 or 69 meters).

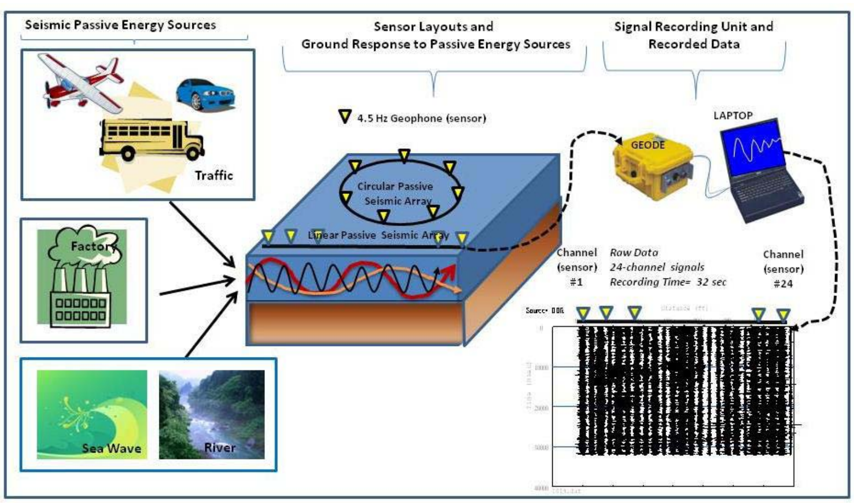

Figure 5. A schematic view for Microtremor Array Measurement (MAM) passive seismic survey and its data (duration=32 seconds) on a 24-channel seismograph (Geode seismograph, Geometrics Inc.); passive seismic signals consisting of cultural and natural noise propagating at various wavelengths (sampling different layered materials) interact with near-surface geology under linear or other (circular, triangular, L-shaped etc.) sensor arrays. The seismograph (data logger, GEODE) receives signals from the sensor array and transfers them to the laptop as a digital signal. An example record of a 32-second 24-channel passive survey (MAM) data set is shown (bottom-right corner).

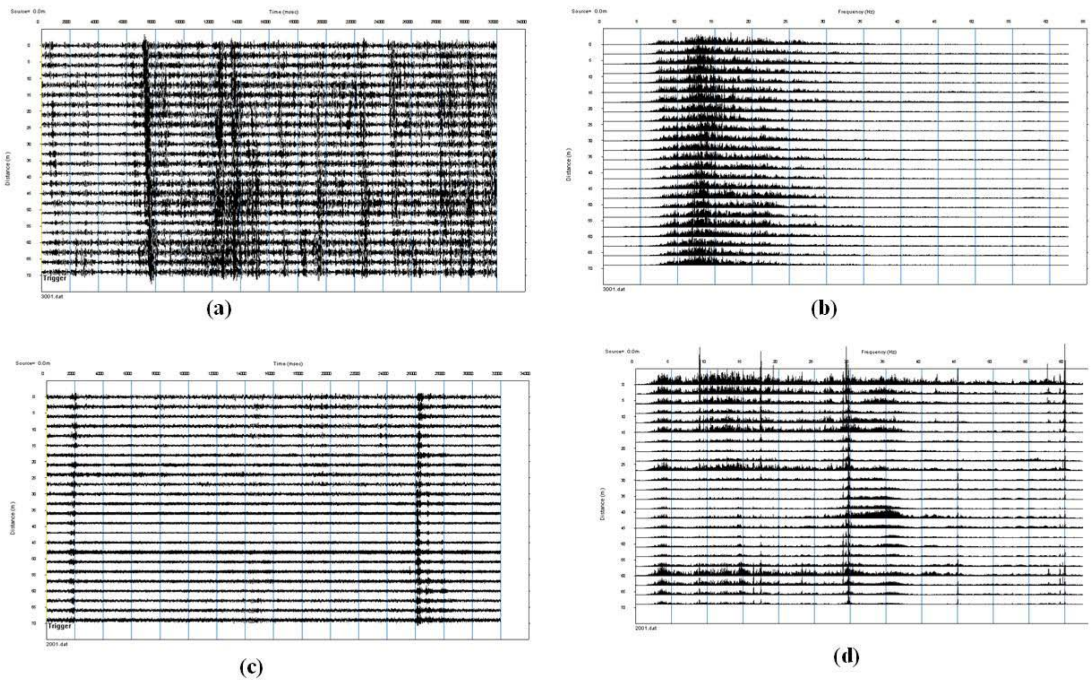

Figure 6. Signal quality for multichannel microtremor array measurements (MAM): **(a)-(c)** and **(b)-(d)** show the time histories and corresponding Fourier amplitude spectrums, respectively, and time histories in **(a)** and its corresponding Fourier amplitude spectrums **(b)** are considered as good quality, compared to ones shown in **(c)** and **(d).**

However, soil Vs profiles of the top 30 m were generally well determined using combined passive and active dispersion curves. The passive method estimates the Vs better for deeper parts of the subsurface layers, whereas the active method better resolves the shallower parts. General processing steps of the MAM are given in Figure 7. Middle section of the array is generally considered as a representation for the 1-D Vs profile.

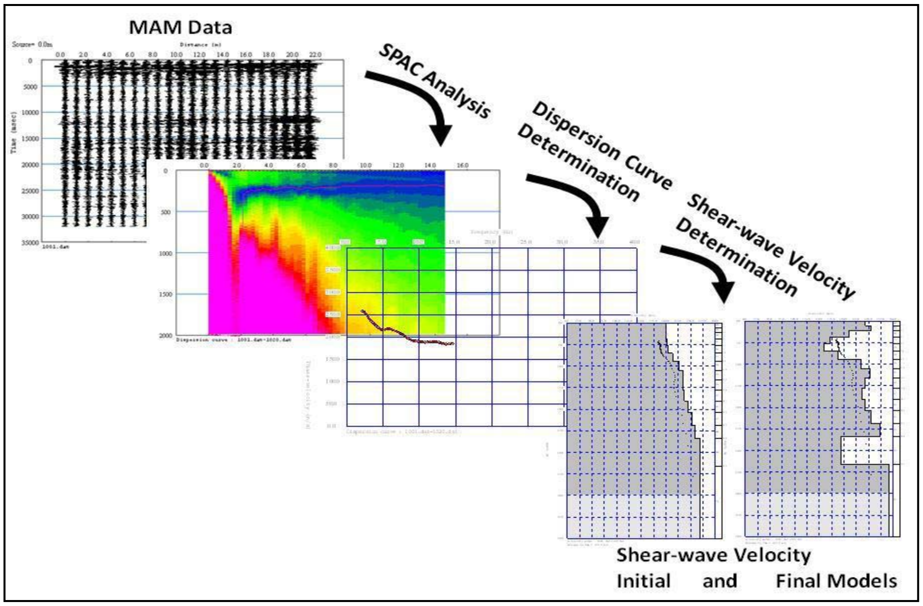

Figure 6. Microtremor Array Measurement (MAM) processing steps: The MAM data having a total of 10 minutes of approximately 20 32-second passive seismic records with a 24-channel seismograph (GEODE) are used as input for Spatial Autocorrelation (SPAC) analysis (originally proposed by Aki, 1957), resulted as a dispersion (frequency vs. velocity) image, which is edited (if needed) for the construction of the fundamental mode dispersion curve. Then a 1-D shear wave velocity (Vs) profile as an initial model is calculated from this dispersion curve. A final Vs profile is generated after an inversion process. The Vs velocity profile is considered as representing the middle part of the array (for example, middle section of the linear array). (Cakir and Walsh, 2010; Geometrics, 2009a)

S- and P-wave Refraction

We recorded active-source (sledgehammer) shear-wave data using 24 14-Hz horizontal-component geophones, generally with 3m geophone interval. Forward and/or reverse shots (minimum two) were performed, where space permitted. We generally used 0.125-millisecond time intervals. Record length was determined after test shots, that were performed at the most distant shot location, to record SH-wave doublets along with Love waves trains on 24 and/or 48 channels (Fig 8). A 9-ft-long 6 x 10 in. wood beam with 1.5-in.-thick protective steel end caps was coupled to the ground by parking the front two wheels of the field vehicle on top of the beam (Cakir and Walsh, 2010; Bilderback et al, 2008). We generated horizontally polarized, out-of-plane shear waves (SH) by striking each end of the wood beam with an 8.2-kg sledgehammer. These shear wave energy were then received by 24 8-Hz horizontal geophones and recorded on a 24-channel seismograph (GEODE), manufactured by Geometrics Inc. Figure 8 shows an example of the SH-wave data. We used the same MASW survey lines for the SH-wave recordings. The MASW survey lines and signals are directly used for picking the P-wave first breaks.

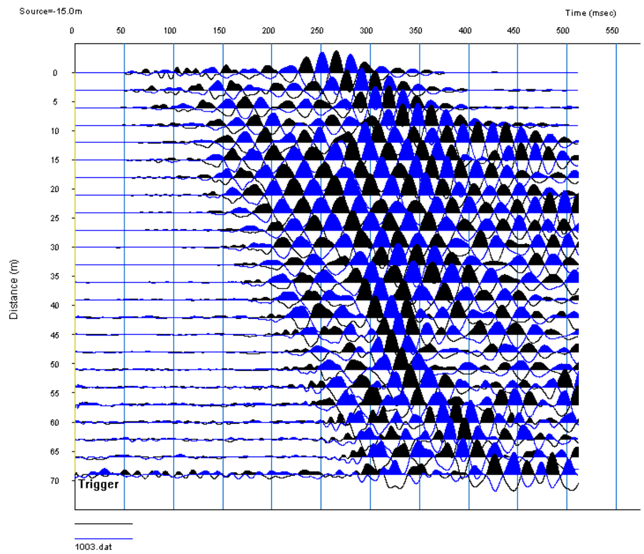

Figure 7. A shot gather with 180°-polarized shear-wave onsets, generated by striking both ends of the wood beam coupled to the ground by parking the front two wheels of the field vehicle on the beam. First onset of the doublets show the arrival times picked for refraction analysis (Cakir and Walsh, 2010).

We also generated P-wave data by vertically striking an aluminum plate with an 8.2-kg sledgehammer and received them on 4.5-Hz vertical component geophones at about 3-m spacing. We generally used the same S-wave and MASW linear array geometry and recording parameters (geophone spacing, record length, spread length, sampling time) for the P-wave refraction surveys. Figure 9 shows examples of forward, center and reverse shot gathers and p-wave first-break picks (red lines).

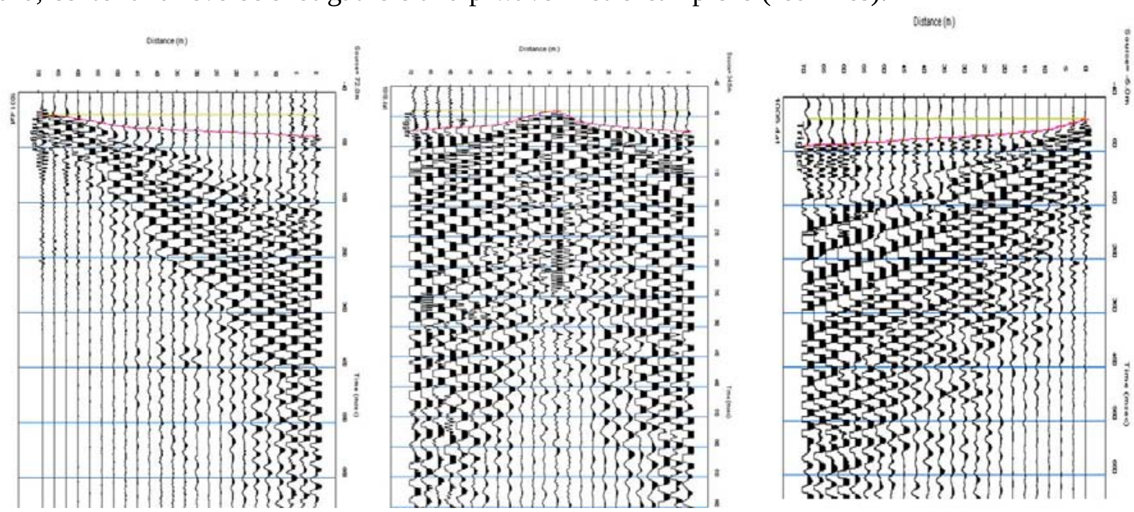

Figure 8. Examples of forward, center and reverse shot gathers. Red lines shows the p-wave first break picks used for the p-wave refraction analysis to estimate subsurface (shallow) Vp profiles by using two-layer or three-layer time term inversion analysis to generate initial Vp model that can be used in tomography process (see text below).

We then used a "time-term inversion" calculation method for a simple two or three-layer refraction model (Geometrics, 2009). After calculation of the velocity model from the travel time curves, a ray tracing was run and initial model generated, then this initial model was used in tomography (Fig 10). Inversion process (tomography) was then performed until finding the best fit (RMS<3) between observed and calculated travel times, resulting in a final layered model. The processing steps are shown in Figure 10. The same procedure (Fig 10) was also used to estimate Vs profiles from the SH data first break picks. However, we used SH-wave refraction analysis to roughly verify our Vs values estimated from the surface analyses (MASW and/or MAM). Also, the SH-wave data can be later used in multichannel Love-wave analyses, as shown by Xia et al. (2010, 2009).

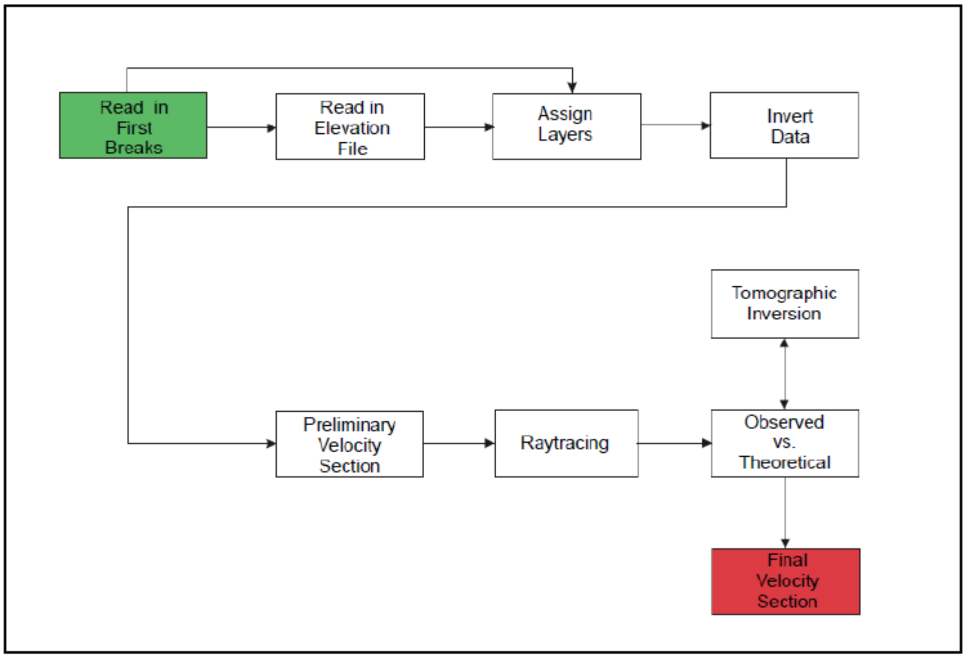

Figure 9. The general flow of the time-term inversion technique (Geometrics, 2009b). To estimate Vp and Vs profiles; a) first-arrival times were picked from the shot gathers and travel-time curves generated from these picks, b) preliminary velocity section were obtained after inverting the travel times curves whose layers visually assigned, c) initial travel time curves were later modified based on running the raytracing, finally d) nonlinear travel time tomography was iteratively run to find the final model until travel time data fits the perturbed initial model (Zhang and Toksöz, 1998).

AMBIENT NOISE MEASUREMENTS AND HORIZONTAL-TO-VERTICAL SPECTRAL RATIO (HVSR) METHOD

Recently, Horizontal to Vertical Spectral Ratio (HVSR) method based on ambient vibrations measurements (Nakamura 1989; Bard 1999) has been popularly used as a tool for the seismic characterization of the subsoil in terms of seismic microzoning (e.g., D'Amico *et al.* 2004, 2008) while array measurements are widely considered for subsoil seismic characterization exploration up to crustal depths (e.g., Larose *et al.* 2006). The simple goal of single-station ambient vibration measurements is to detect seismic impedance contrasts, thus seismic resonance (e.g., Kramer, 1996), in the subsoil. In particular, the determination of the fundamental resonance frequency of the soft sedimentary cover is of major concern (SESAME, 2004). To this purpose, average *HVSR* ratios of horizontal (*H*) to vertical (*V*) spectral components of ambient vibrations are measured at 14 station sites (Fig 2).

In Summer 2010, DGER, in collaboration with University Siena (Italy), tested the HVSR method at various sites in western Washington by running ambient measurement surveys using Tromino (www.tromino.it) , a mini portable seismograph recently developed and manufactured in Italy (Albarello et al. 2011a, in preparation). In order to carry on the ambient noise measurement surveys, we, in consulting with the Pacific Northwest Seismic Network (Bodin, 2010) and USGS-external grant office, later purchased Guralp CMG-6TD a 3-component, broadband seismometer in December 2010. We then revisited the sites, as many as we could, we characterized in Summer 2010 by using shallow active and passive seismic surveys (Fig 2). The Guralp CMG-6TD velocity seismometer has a flat instrument response (0.03-50 Hz), operates with a 12-volt marine battery (Fig 11) is mostly used. To measure the ambient noise we installed the seismometer in the following order; the seismometer was levelled and oriented north, placed in a plastic bag for protection, then buried in a ~50-60 cm hole (whose bottom is compacted by using a tampering tool) to reduce the noise and to (perhaps) stabilize the temperature changes and possible instrument tilting (Fig 12). After positioning the seismometer, it was allowed to settle about 10 minutes, then the ambient noise recording continued about 20-30 minutes. A data-recording software, SCREAM (distributed by Guralp Inc.), was used to record and store the data on a laptop computer and a GPS unit (located about 10-15 meters distance from the sensor) was connected to the system to record time and duration. The ambient noise signals were recorded with 100Hz sampling rate at each site, recording took about 40-50 minutes at each site. Later these signals inspected using the SESAME (2004) and uncontaminated signals were used for the HVSR analysis (Fig 13).

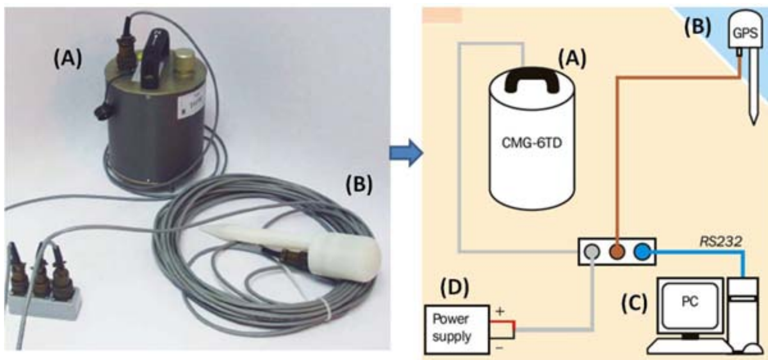

Figure 10. Components of the data acquisition system: (A) Guralp CMG-6TD seismometer, (B) GPS unit, (C) data recording and storage (SCREAM; data acquisition system software running on a Laptop computer), (D) battery. [http://www.guralp.com/products/6TD/]

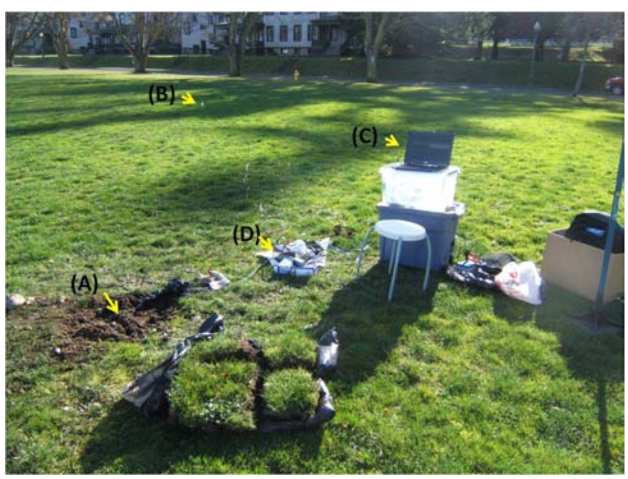

Figure 11. A typical ambient noise field setup used at station 7029. Bold letters are described in Figure 10.

We carried out ambient noise measurements at 14 station sites and recorded the all 3 component (East-West and North-South, and Vertical) signals and stored them in SAC format. Each SAC file (digital signals) were read in MATLAB (http://www.mathworks.com) environment using the Geophysical Institute Seismology Matlab Objects (GISMO) (http://www.giseis.alaska.edu/Seis/EQ/tools/GISMO/) tools and visually inspected for editing (Fig 12). Then the each (EW, NS and Z) SAC file was converted to ASCII file and processed using the SESAME procedure (SESAME, 2004). We also generated a Matlab script to roughly compare the results obtained from SESAME procedure. Quality of HVSR curves were evaluated using SESAME (2004) (Albarello et al., 2011a, 2011b):

1) Curve reliability (i.e., sufficient number of windows and significant cycles for a given f_0, acceptable low scattering among all windows over a given frequency range around f_0) was verified
2) Then, reliability of HVSR peaks (i.e., fulfilment of amplitude and stability criteria) was checked. Particular attention was devoted to identify eventual peaks induced by low-frequency disturbances (wind blowing, in case of nearby tall buildings, poor soil-sensor coupling, etc.) and to better resolve broad or multiple peaks (i.e., by varying the smoothing parameters). Possible “fake” HVSR peaks induced by electromagnetic noise of industrial origin or due to impulsive or strongly localized anthropogenic sources were evaluated by following SESAME (2004) criteria. To this purpose, directionality and time stability of HVSR estimates were evaluated (Fig.2.0). Strongest transients have been eliminated before the HVSR estimate was performed.
3) Furthermore, in order to evaluate the actual repeatability of the HVSR measurement, measurements at each site have been repeated at least two times by displacing the instrument by a few tens of meters.

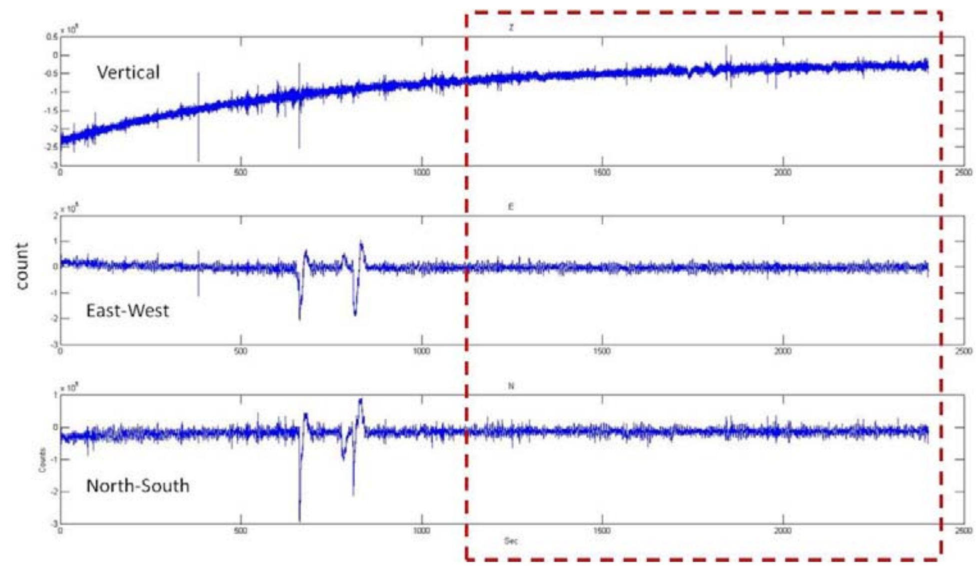

Figure 12. Three-component (E-W, N-S and Vertical) ambient noise recording. Dashed red box shows examples of signals used for the HVSR analysis.

The HVSR data processing was completed based on Albarello et al. (2011a) and generally following the SESAME (2004) guidelines. The basic assumptions of the HVSR method are 1) Rayleigh waves in the fundamental mode dominate ambient vibration wave field, and 2) these waves propagate within a nearly homogeneous soft layer (characterized by V_s values smoothly increasing with depth) overlying a rigid bedrock. Also, it can be assumed that Vs as function depth (z) is $Vs(z) = V_{0S}(1+z)^X$ (where V_{0S}=S-wave velocity at 1 m below the surface, and x=constant determined experimentally. The fundamental mode resonant frequency approach relating the fundamental frequency to thickness (h) and average shear-wave velocity <Vs> of a soil layer over a rigid bedrock (Kramer, 1996) is

$$f_0 \cong \frac{\langle V_s \rangle}{4h} \qquad \textbf{(1)}$$

Ibs Von Seht and Wohlemberg (1999) proposed a simple approximate relationship between the resonance frequency f_r and the thickness of the soft sedimentary layer h (Albarello, 2011a):

$$h \cong \left[\frac{V_0(1-x)}{4f_r}+1\right]^{\frac{1}{1-x}} -1 \qquad \textbf{(2)}$$

Since f_r=f_0, the average Vs can be evaluated via equation:

$$\langle V_S \rangle \cong 4f_0 h \cong 4f_0 \left\{\left[\frac{V_0(1+x)}{4f_0}+1\right]^{\frac{1}{1-x}} -1\right\} \qquad \textbf{(3)}$$

This method requires predefined V_0 and x (from borehole or preliminary geologic surveys), and experimental studies in soil layers show that a significant negative correlation exists between the values of V_0 and x: the stronger the lithostatic load effect (i.e. as x is higher), the lower the expected value of V_S at surface (Albarello et al, 2011a). For fast and rough estimations of the sediment cover thickness (h) (Eq. 2) and average velocity *(<Vs>)* (Eq. 3). Albarello et al also reported three indicative couples of V_0 and x values (Table 1). We used V_0 and x values of 170 m/sec and 0,25, respectively, to estimate the *<Vs>* and *h* at each site (Table 3).

Table 1 Three indicative couples of V_0 and x values.

V_0	*x*	**Soil Material Type**
210	0.20	Compact soil
170	0.25	Sand(s)
110	0.40	Reworked or very recent soil (such as landslide)

ACTIVE AND PASSIVE SEISMIC SURVEY RESULTS

We characterized the 23 strong-motion sites based on NEHRP categories using the Vs30 estimates obtained from the active and passive seismic results. Our active and passive (or combined) MASW and refraction surveys, using a 24-channel seismograph with 4.5-Hz (vertical) and 14-Hz (horizontal) geophones, penetrated depths generally equal or greater than 30 meters and less than about 70 meters, with an exception of penetration depth >100 m at 7029. This penetration depth (>30 m) allowed us to efficiently classify sites based on NEHRP categories (Tables 2 and 4) using the averaged shear-wave velocity to top 30 meters (Vs30m) of the soil layers (Table 4). We compared our results at a couple sites (7046, 7030, 7051, 7032, 7028 and 7030) with Wong et al (2011) and found that our MASW results strongly agrees with theirs, except for the station 7027. In addition, we compiled the borehole and geology information, and provided geologic interpretation for each site. Summary of our results are given in Appendix A. Our overall active and passive seismic data quality is good (except for station 7030, that may be counted as a fair quality). We generally used maximum shot offset as ~15meters and used the multiple stacking for the P- and S-wave refraction analysis. This lower SNR (signal-to-noise ratio) P-wave refraction data were also used for the 1-D MASW analyses, where 2D-MASW data are in poor quality or gave a poor quality of a dispersion curve constructed.

We used a linear array (spread length range= 69 to 140 meters, generally =69 meters) for the multichannel passive and active seismic measurements (e.g., MAM, MASW, P- and SH-wave refraction) for each site. P- and SH-wave refraction surveys conducted on the same spread used for the MASW. The SH-wave refraction data were analyzed to verify the range of the Vs values obtained from the surface-wave analysis (MASW and MAM dispersion curves). Table 2 summarizes the results obtained from active and passive MASW surface wave analyses and the NEHRP site classifications, based on the calculated Vs30 values, for each site. Finally, we provide Vs, Vp, Vp/Vs and Poisson's ratio profiles, along with site geology and Vs30 values associated with the NEHRP classifications, for each site (Appendix A).

Ambient noise data acquired using the single station (with 3-component broad-band seismometers) at 14 sites (Fig 2). A thickness map of unconsolidated deposits for Puget Sound lowland area (Jones, 1996) covering the most of the measured sites was used as a reference information to interpret the sediment thickness and average velocity estimated from the HVSR fundamental frequencies. Estimated shear-wave velocity (<Vs>) and thickness (h) values of the sediment cover from the observed fundamental frequency (maximum primary and/ or secondary dominant peaks on the HVSR) were checked if they are consistent with the sediment thickness map (Jones, 1996). Table 3 shows the all observable sharp or dominant peaks detected on the HVSR and corresponding the average Vs and thickness (h) estimates, using the approach given in Albarello et al (2011a). Our interpreted results for the HVSR estimates for selected 14 sites are also summarized in Appendix A. These estimates should be considered as secondary data, compared to the MASW (primary data). HVSR processing results and evaluation criteria (SESAME, 2005) for each station site are shown in Appendix B and given in Albarello et al (2011a).

Table 2. Shallow-seismic survey (strongmotion-station site) locations, conducted survey types, Vs30m which is the calculated average Vs to 30-m depth (International Code Council, 2006) and derived NEHRP site classifications from this study. We considered MASW, MAM and P-wave refraction as primary data acquisition methods for measurements of the Vs and Vp profiles (velocity versus depth).

StNum	State	StName	Latitude	Longitude	Conducted Seismic Surveys (*)	Maximum Geophone Spread Length	Vs30m	NEHRP Site Class. (This study)
2172	OR	Portland; Portland State University	45.513	-122.685	1,2,3	69	326	D
2193	WA	Gig Harbor; Fire Station	47.320	-122.586	1,2,3,5	69	416	C
2194	WA	Shelton; Fire Station	47.214	-123.101	1,2,3,4	48	312	D
7026	WA	Stanwood; Camano Island Fire Station No. 1	48.243	-122.455	1,2,3,4,5	69	367	D-C
7027	WA	Seattle; Fire Station No. 28	47.548	-122.277	1,2,3	69	304	D
7028	WA	Forks; La Push Coast Guard Station	47.914	-124.634	1,2,3,4,5	69	271	D
7029	WA	Port Townsend; Fort Worden State Park	48.134	-122.765	1,2,3,4,5	141	386	D-C
7030	WA	Seattle; SeaTac Airport Fire Station	47.451	-122.302	1,2,3	69	244	D
7031	WA	Everett; Fire Station No. 2	47.997	-122.199	1,2,3,4,5	69	538	C
7032	WA	West Seattle; Fire Station No. 29	47.584	-122.389	1,2,3,4,5	69	333	D
7033	WA	Anacortes; Fire Station	48.512	-122.613	1,2,3,4,5	69	204	C
7035	WA	Aberdeen; Fire Station	46.972	-123.826	1,2,3,4	69	154	E
7038	WA	Tumwater; Fire Station Hdqtrs	46.985	-122.910	1,2,3	69	312	D
7039	WA	Quinault Lake; Ranger Station	47.468	-123.847	1,2,3,4,5	48	359	D-C
7040	WA	Port Gamble; Museum	47.856	-122.583	1,2,3,4,5	69	285	D
7041	WA	Port Angeles; Fire Station	48.115	-123.437	1,2,3,4,5	69	339	D
7042	WA	Vancouver; USGS, Cascades Volcano Observatory	45.611	-122.496	1,2,3,4	69	455	C
7043	WA	Bellingham; Fire Station No. 2	48.720	-122.498	1,2,3,4,5	69	317	D
7044	WA	McChord AFB;	47.136	-122.482	1,2,3,4	115	404	C

		Fire Station						
7045	WA	Raymond; Fire Station	46.685	-123.734	1,2,3,4,5	69	171	E
7046	WA	Camp Murray	47.120	-122.565	1,2,3,4	69	513	C
7051	WA	Bremerton; New Fire Station No. 1	47.570	-122.631	1,2,3,5	69	466	C
7054	WA	Olympia, Centennial Park	47.039	-122.899	1,2,3,5,6	69	193	D or D-E
(*) **1**=MASW, **2**=MAM, **3**=P-wave refraction, **4**=S-wave refraction, **5**=Ambient noise measurement, **6=**Downhole seismic								

Table 3. Observed HVSR fundamental frequencies and corresponding shear-wave velocity (m/sec) and depth (m) estimates for selected sites (Fig 2). STM stands for Sediment Thickness Map (Jones, 1996). Bold black and red numbers linking the consistent and meaningful values of velocity and depth estimates based on geology, geophysics and/or the STM. The MASW and geology information are used for the interpretations, where the STM is not available. Bold black and red numbers represent the link between the HVSR estimates and reported depths from other studies and methods.

StNum	First Maximum fundamental frequency (f0) (Hz) peak on H/V spectrum	Secondary Maximum fundamental frequency peak (f1) on (Hz) H/V spectrum	Calculated Depth (m) and Average Vs (m/sec) (using fundamental f0)	(Calculated Depth (m), <Vs> (m/sec)) using secondary f0 (=f1)	Depth-dependent Parameters (V_0 , x) (Table 1.)	Sediment Cover (m) from Geology /Geophysics/ Sediment Thickness Map (STM) (or MASW (m)	Vs30m (Active and/or passive seismic surveys)
2193	0.32	7	(**467**, 598)	(16, 452)	(170, 0.25)	**488** (STM)	416
7026	0.23-3	5-**5.5**	(**723**, 665) – (509, 610)	(13, 267) – (**12**, **261**)	(170, 0.25)	**732** (STM); Stiffer soil at **11m** (MASW)	367=(Vs30m); **234=(Vs12m)**
7028	**3.1 - 4.1**	NA	**(24**, 301**)** **(17, 280)**	NA	(170, 0.25)	Stiffer soil at **24** and **16m** (MASW)	**271**
7029	0.23	9	(**723**, 665)	(7, 235)	(170,0.25)	**732** (STM)	386
7031	0.25	NA	(**585**, 631)	NA	(170,0.25)	**457** (STM)	538
7032	0.26	1.1	(615, 639)	(**92**,405)	(170,0.25)	**91** (STM)	333
7033	0.59	**2.2**	(208, 492)	(**38**, 331)	(170,0.25)	**30** (STM)	204
7039	2.83	NA	**(27, 309)**	NA	(170,0.25)	Change to stiffer soil at **27**m (MASW)	**359**
7040	0.52	NA	(**246**, 512)	NA	(170,0.25)	**244** (STM)	285
7041	2.69	NA	**(29, 313)**	NA	(170,0.25)	183m (STM); Stiffer soil at **29**m (MASW)	**339**
7043	7.27	0.6	(**8**,246)	(204,489)	(170,0.25)	~30m (STM); Stiffer soil at **8**m	317
7045	1.6	NA	**(57,363)**	NA	(170,0.25)	**Very sharp peak on H/V**	171
7051	0.45	NA	(**298**,536)	NA	(170,0.25)	**274**	466
7054	0.4-0.8	**~20**	(348,556) **-** (**140**,447)	**(2,138)**	(170, 0.25) **(110, 0.4)**	**122** (STM)	193 =(Vs30m) ; **122=(Vs2m)**

Table 4. NEHRP site classification and Vs30 (m/sec) calculation (International Code Council, 2006)

<table>
<tr><td>NEHRP Site Class</td><td>Vs100 (ft/sec)</td><td>Vs30 (m/sec)</td><td rowspan="7">Average Vs, for top 30m:
$$V_s30 = \frac{\sum_{i=1}^{n} d_i}{\sum\left(\frac{d_i}{V_{si}}\right)}$$
where
v_{si}= shear-wave velocity in m/sec for each layer
d_i= thickness of layers between 0 to 30.480m (100ft), and
$$\sum_{i=1}^{n} d_i = 30m$$</td></tr>
<tr><td>A</td><td>>5000</td><td>>1524</td></tr>
<tr><td>B</td><td>2500 to 5000</td><td>762 to 1524</td></tr>
<tr><td>C</td><td>1200 to 2500</td><td>366 to 762</td></tr>
<tr><td>D</td><td>600 to 1200</td><td>183 to 366</td></tr>
<tr><td>E</td><td><600</td><td>< 183</td></tr>
</table>

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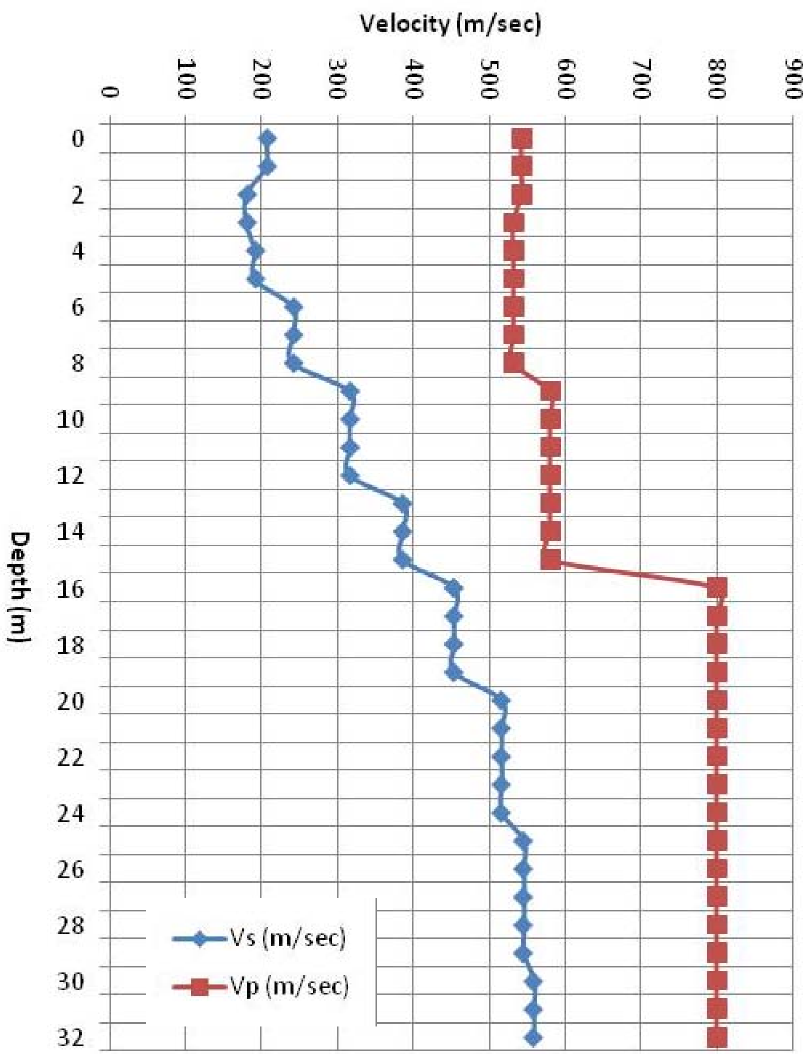
APPENDICIES

APPENDIX A

Summary plots and tables of Vs, Vp, Vp/Vs, Poisson's ratios (PRs), predicted Vp from plus and minus standard deviations and average measured PRs at 23 sites, and interpreted sediment cover depths and velocities from HVSR fundamental frequencies at 14 station sites.



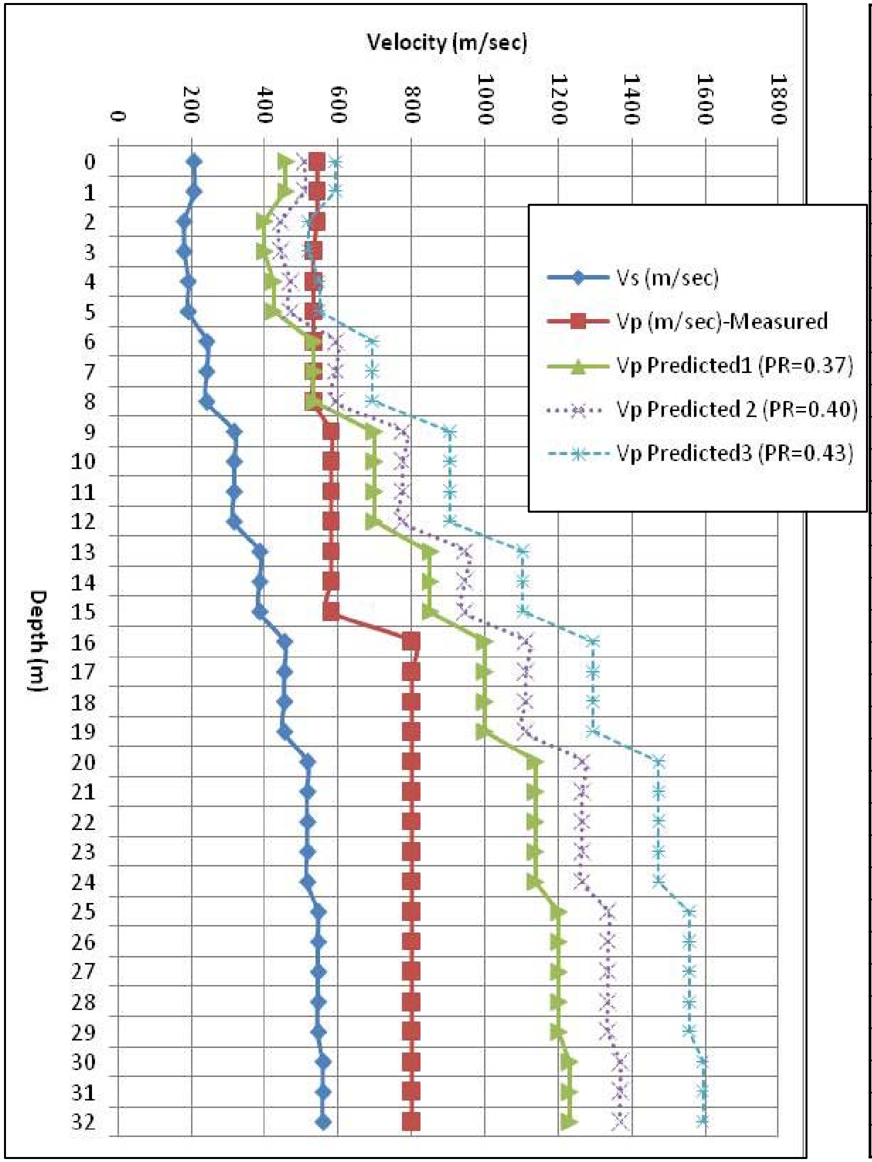
From	To	Vs (m/Sec)
0	2	208
2	4	181
4	6	193
6	9	243
9	13	317
13	16	387
16	20	454
20	25	517
25	30	546
30		559

From	To	Vp (m/sec)
0	3	543
3	9	533
9	16	581
16	22	800
22	37	800
37	52	800
52	67	800
67	82	800
82	97	800
97	?	2000

Site Geology: This site is underlain by the fine-grained facies of the catastrophic flood deposits of the Missoula floods(Beeson and others, 1991), which consists of silt-to coarse sand. A geotechnical borehole about 150m to the northwest penetrated 50 ft of silty sand. Another less well-located water well in the vicinity penetrated 87 ft of brown sand and sand, silt, and gravel to a depth of 113 ft. Below that, it penetrated gravel to a depth of 232 ft, where it reached basalt bedrock.

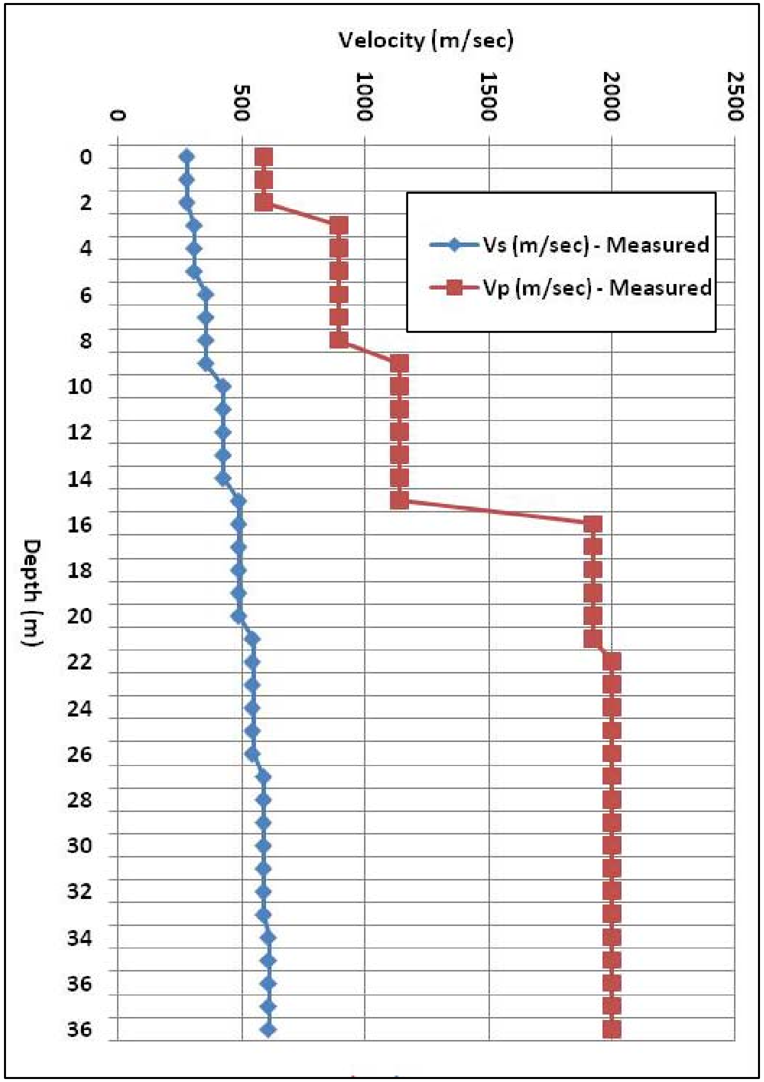
Vs30m = 326 m/sec (max depth resolved =27m)
NEHRP Site Classification = D

Figure A1. S-wave and P-wave velocity profiles and site geology at station 2172, Portland State University, Portland, Oregon.



Depth (m)	Vp/Vs	PR Measured	PR1	PR2	PR 3	Vp1 (PR1=0.37)	Vp2 (PR2=0.40)	Vp3 (PR3=0.43)
0	2.6	0.41	0.37	0.40	0.43	457	509	593
1	2.6	0.41	0.37	0.40	0.43	457	509	593
2	3.0	0.44	0.37	0.40	0.43	399	444	518
3	2.9	0.43	0.37	0.40	0.43	399	444	518
4	2.8	0.42	0.37	0.40	0.43	424	472	549
5	2.8	0.42	0.37	0.40	0.43	424	472	549
6	2.2	0.37	0.37	0.40	0.43	534	594	693
7	2.2	0.37	0.37	0.40	0.43	534	594	693
8	2.2	0.37	0.37	0.40	0.43	534	594	693
9	1.8	0.29	0.37	0.40	0.43	698	777	905
10	1.8	0.29	0.37	0.40	0.43	698	777	905
11	1.8	0.29	0.37	0.40	0.43	698	777	905
12	1.8	0.29	0.37	0.40	0.43	698	777	905
13	1.5	0.10	0.37	0.40	0.43	851	947	1103
14	1.5	0.10	0.37	0.40	0.43	851	947	1103
15	1.5	0.10	0.37	0.40	0.43	851	947	1103
16	1.8	0.26	0.37	0.40	0.43	999	1112	1295
17	1.8	0.26	0.37	0.40	0.43	999	1112	1295
18	1.8	0.26	0.37	0.40	0.43	999	1112	1295
19	1.8	0.26	0.37	0.40	0.43	999	1112	1295
20	1.5	0.14	0.37	0.40	0.43	1137	1265	1474
21	1.5	0.14	0.37	0.40	0.43	1137	1265	1474
22	1.5	0.14	0.37	0.40	0.43	1137	1265	1474
23	1.5	0.14	0.37	0.40	0.43	1137	1265	1474
24	1.5	0.14	0.37	0.40	0.43	1137	1265	1474
25	1.5	0.07	0.37	0.40	0.43	1201	1336	1557
26	1.5	0.07	0.37	0.40	0.43	1201	1336	1557
27	1.5	0.07	0.37	0.40	0.43	1201	1336	1557
28	1.5	0.07	0.37	0.40	0.43	1201	1336	1557
29	1.5	0.07	0.37	0.40	0.43	1201	1336	1557
30	1.4	0.02	0.37	0.40	0.43	1230	1369	1595
31	1.4	0.02	0.37	0.40	0.43	1230	1369	1595
32	1.4	0.02	0.37	0.40	0.43	1230	1369	1595

Figure A2 - Predicted P-wave velocities from possible Poisson’s ratios (0.37-.43) at station 2172, Portland State University, Portland, Oregon.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	2.8	277.97		0.0	3.1	591.17
2.8	6.3	307.58		3.1	9.4	894.22
6.3	10.4	355.78		9.4	15.6	1139.88
10.4	15.3	426.02		15.6	21.9	1925.05
15.3	20.8	489.82		21.9	36.9	2000.00
20.8	27.1	545.65				
27.1	30.0	591.11				
30.0	34.0	591.11				
34.0	41.7	610.68				
41.7		610.46				

Site Geology

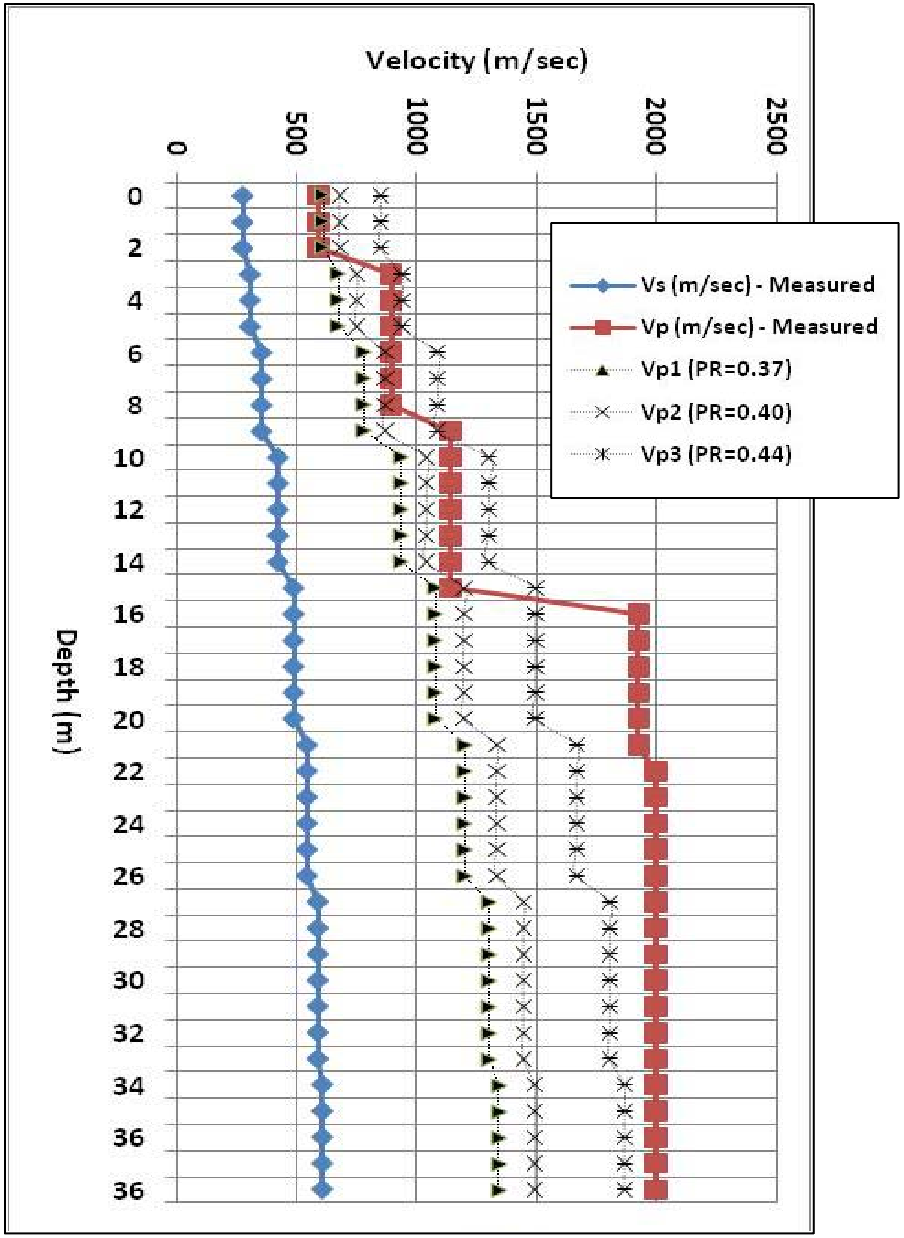
This site is underlain by Vashon Till. In nearby water wells, the till is about 25 ft thick and is underlain by sand. The top of the advance outwash sand in a gully about ¼ mi east of this location is persistently about 30 ft lower than at the fire station (Troost and others, in review(b)).

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
0.32	598	467

(*)See Table 3 for details

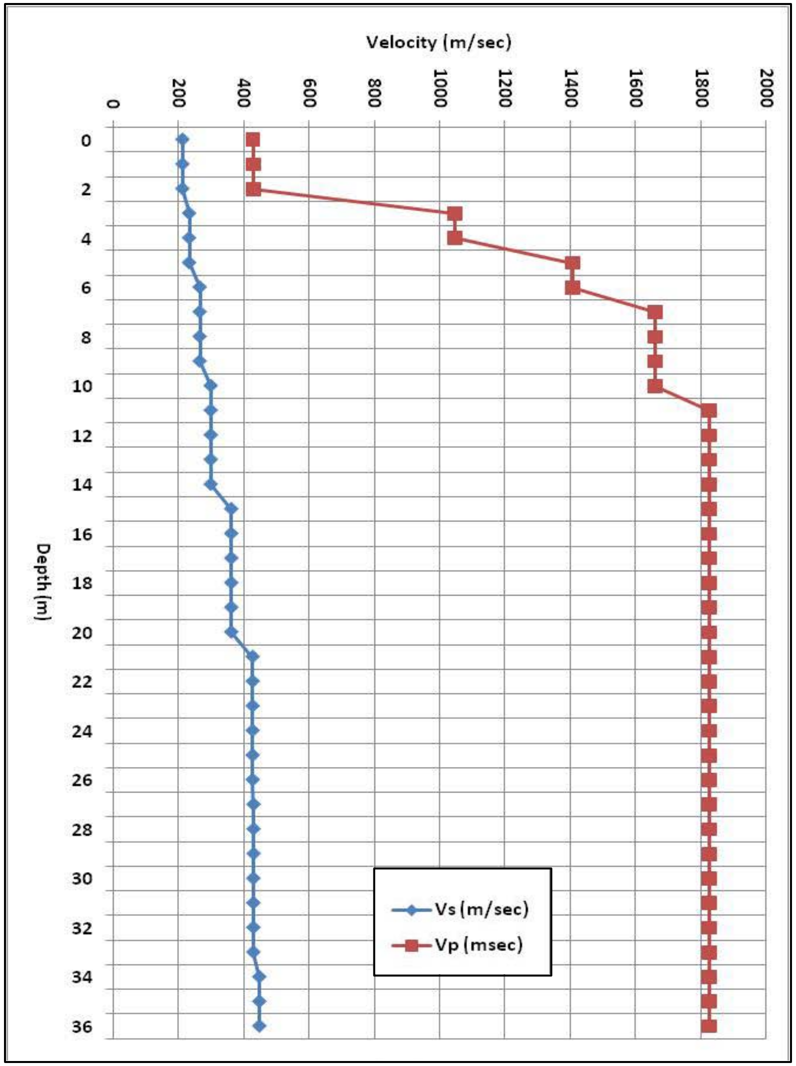
Vs30m = 416 m/sec (max depth resolved =27m)
NEHRP Site Classification = C

Figure A3. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 2193, Gig Harbor, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.37)	Vp2 (PR=0.40)	Vp3 (PR=0.44)
0	2.13	0.36	612	681	849
1	2.13	0.36	612	681	849
2	2.13	0.36	612	681	849
3	2.91	0.43	677	753	940
4	2.91	0.43	677	753	940
5	2.91	0.43	677	753	940
6	2.51	0.41	783	871	1087
7	2.51	0.41	783	871	1087
8	2.51	0.41	783	871	1087
9	3.20	0.45	783	871	1087
10	2.68	0.42	938	1044	1302
11	2.68	0.42	938	1044	1302
12	2.68	0.42	938	1044	1302
13	2.68	0.42	938	1044	1302
14	2.68	0.42	938	1044	1302
15	2.33	0.39	1078	1200	1496
16	3.93	0.47	1078	1200	1496
17	3.93	0.47	1078	1200	1496
18	3.93	0.47	1078	1200	1496
19	3.93	0.47	1078	1200	1496
20	3.93	0.47	1078	1200	1496
21	3.53	0.46	1201	1337	1667
22	3.67	0.46	1201	1337	1667
23	3.67	0.46	1201	1337	1667
24	3.67	0.46	1201	1337	1667
25	3.67	0.46	1201	1337	1667
26	3.67	0.46	1201	1337	1667
27	3.38	0.45	1301	1448	1806
28	3.38	0.45	1301	1448	1806
29	3.38	0.45	1301	1448	1806
30	3.38	0.45	1301	1448	1806
31	3.38	0.45	1301	1448	1806
32	3.38	0.45	1301	1448	1806
33	3.38	0.45	1301	1448	1806
34	3.28	0.45	1344	1496	1866
35	3.28	0.45	1344	1496	1866
36	3.28	0.45	1344	1496	1866
35	3.28	0.45	1344	1496	1866
36	3.28	0.45	1344	1496	1866

Figure A4 - Predicted P-wave velocities from possible Poisson's ratios (0.37, 0.40 and 0.44) at station 2193. PR=0.44 (average measured) well predicts the Vp profile at 2193.

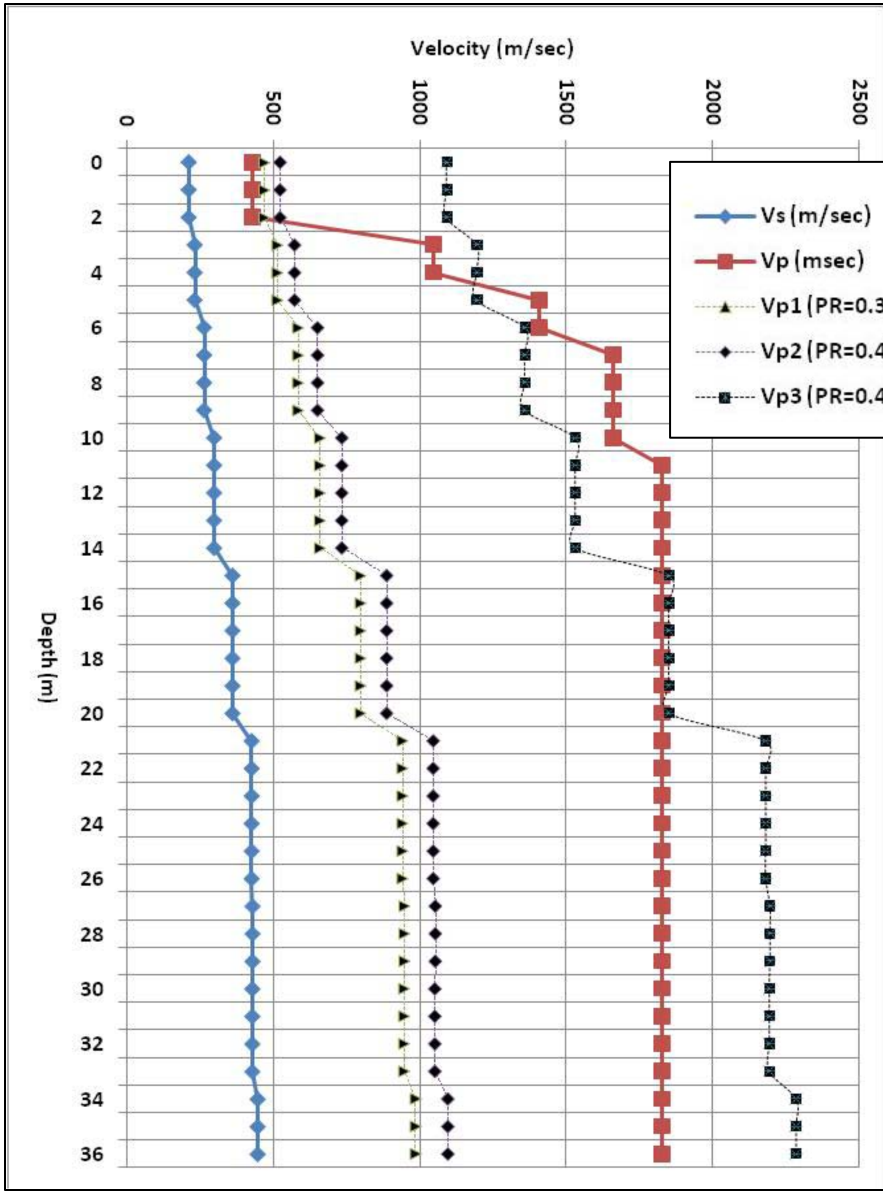


Depth (m) From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	2.8	214.39		0.0	0.94	429.11
2.8	6.3	234.63		0.9	2.81	429.55
6.3	10.4	266.62		2.8	4.69	1046.03
10.4	15.3	300.45		4.7	6.56	1406.28
15.3	20.8	362.83		6.6	11.06	1659.18
20.8	27.1	427.66		11.1	15.56	1826.02
27.1	30.0	430.53		15.6	20.06	1826.02
30.0	34.0	430.00		20.1	24.56	1826.02
34.0	41.7	447.96		24.6	29.06	1826.02
41.7	50.0	447.89		29.1	30.00	1826.02
50.0		447.96		30.0		

Vs30m = 312 m/sec (max depth resolved =37m)
NEHRP Site Classification = D

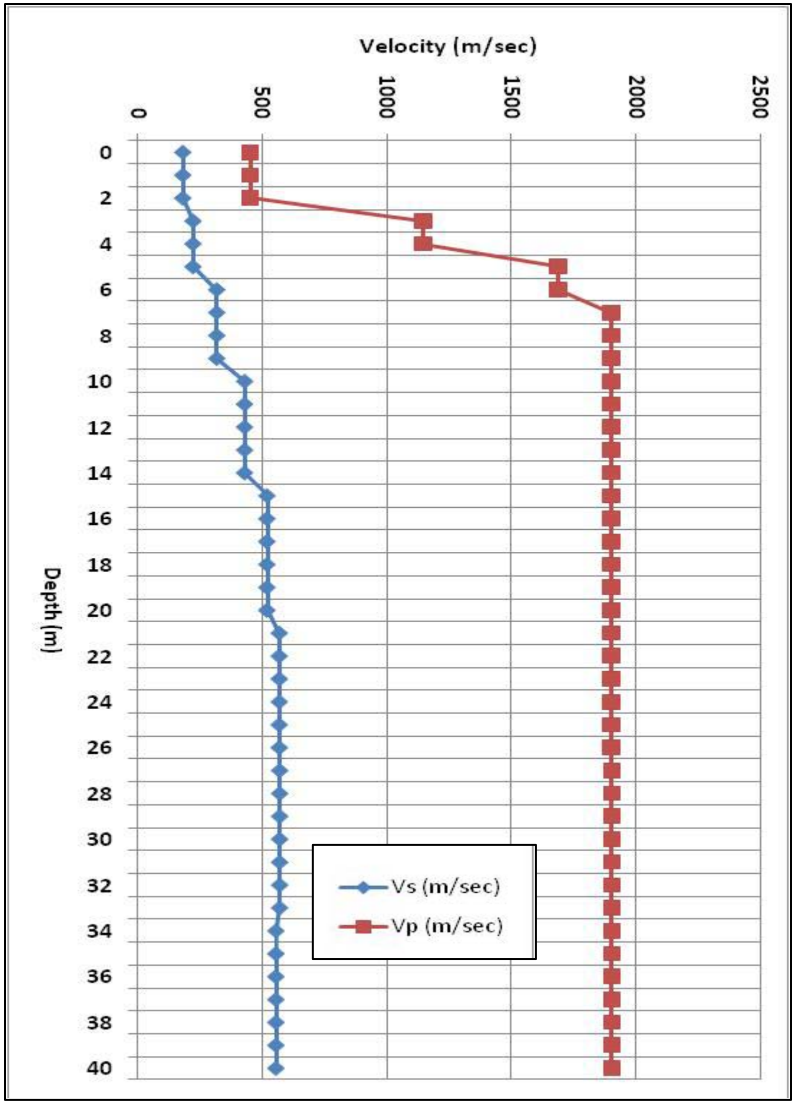
Site Geology
This site is underlain by sand and gravel of Vashon recessional outwash over Vashon till (Schasse and others, 2003). Map relations suggest that the Vashon is here underlain by outwash of an Olympic alpine glaciation. The nearest water well suggests a sequence of about 30 feet of Vashon outwash overlying about 10 ft of till, in turn overlying at least 30 ft of an older, presumably Olympic, outwash.

Figure A5. S-wave and P-wave velocity profiles and site geology at 2194, Shelton, Washington.



Depth (m)	PR (Measured)	Vp1 (PR=0.37)	Vp2 (PR=0.4)	Vp3 (PR=0.48)
0	0.334	472	525	1093
1	0.334	472	525	1093
2	0.334	472	525	1093
3	0.474	517	575	1196
4	0.474	517	575	1196
5	0.486	517	575	1196
6	0.481	587	653	1360
7	0.487	587	653	1360
8	0.487	587	653	1360
9	0.487	587	653	1360
10	0.483	661	736	1532
11	0.486	661	736	1532
12	0.486	661	736	1532
13	0.486	661	736	1532
14	0.486	661	736	1532
15	0.479	799	889	1850
16	0.479	799	889	1850
17	0.479	799	889	1850
18	0.479	799	889	1850
19	0.479	799	889	1850
20	0.479	799	889	1850
21	0.471	941	1048	2181
22	0.471	941	1048	2181
23	0.471	941	1048	2181
24	0.471	941	1048	2181
25	0.471	941	1048	2181
26	0.471	941	1048	2181
27	0.471	948	1055	2195
28	0.471	948	1055	2195
29	0.471	948	1055	2195
30	0.471	947	1053	2193
31	0.471	947	1053	2193
32	0.471	947	1053	2193
33	0.471	947	1053	2193
34	0.468	986	1097	2284
35	0.468	986	1097	2284
36	0.468	986	1097	2284

Figure A6 - Predicted P-wave velocities from possible Poisson's ratios (0.37, 0.40 and 0.48) at station 2194. PR=0.448 (average measured) well predicts the Vp profile (Vp3). Maximum reliable depth for measure P-waves is about 12meters. Vp values at depth greater than 12 m can be adjusted by using predicted Vp3 profile.



Vs30m = 367 m/sec (max depth resolved =37m)
NEHRP Site Classification = D-C

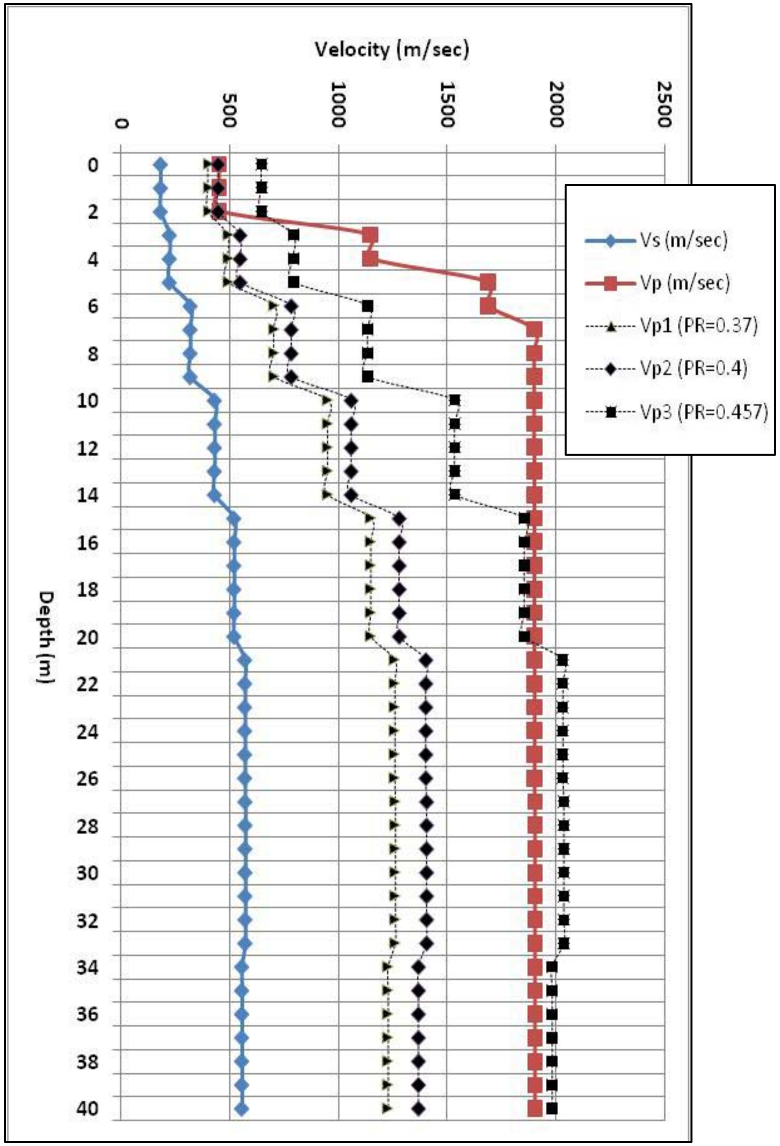
From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	2.8	182.62		0.0	1.0	452.49
2.8	6.3	223.74		1.0	3.1	452.49
6.3	10.4	319.62		3.1	5.2	1146.85
10.4	15.3	432.02		5.2	7.2	1688.85
15.3	20.8	522.06		7.2	12.2	1900.83
20.8	27.1	572.00		12.2	17.1	1901.83
27.1	30.0	573.38		17.1	22.1	1902.83
30.0	34.0	573.38		22.1	27.0	1903.83
34.0	41.7	558.17		27.0	32.0	1904.83
41.7	50.0	538.97		32.0		1905.83
50.0		573.38				

Site Geology:
This site is underlain by Everson Glaciomarine Drift, a clayey to silty diamicton with variable content of gravel; it is mostly loose and soft, but locally hard and compact (Scasse and others, 2009). Deposits are typically between 20 and 100 ft thick (Dragovich and others, 2002). The only nearby water well is difficult to interpret but suggest that this unit is about 38 ft thick, overlying about 5 ft of till, which in turn overlies a thick sequence of outwash sand and gravel.

Measured Fundamental Frequency (Hz) on H/V (Albarello et al, 2011a) (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
5.5	261	12

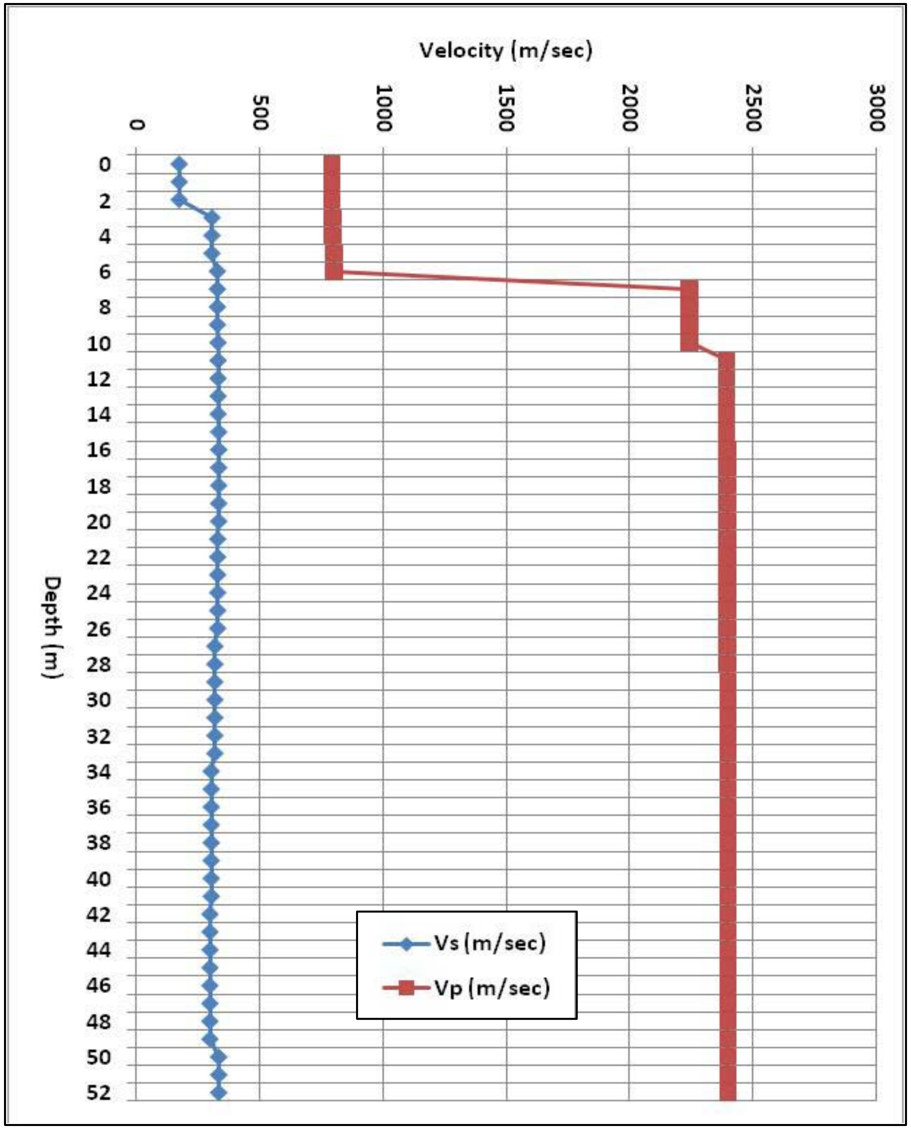
(*)See Table 3 for details

Figure A7. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7026, Camano, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.37)	Vp2 (PR=0.4)	Vp3 (PR=0.457)
0.0	2.5	0.40	402	447	649
1.0	2.5	0.40	402	447	649
2.0	2.5	0.40	402	447	649
3.0	5.1	0.48	493	548	795
4.0	5.1	0.48	493	548	795
5.0	7.5	0.49	493	548	795
6.0	5.3	0.48	704	783	1136
7.0	5.9	0.49	704	783	1136
8.0	5.9	0.49	704	783	1136
9.0	5.9	0.49	704	783	1136
10.0	4.4	0.47	951	1058	1535
11.0	4.4	0.47	951	1058	1535
12.0	4.4	0.47	951	1058	1535
13.0	4.4	0.47	951	1058	1535
14.0	4.4	0.47	951	1058	1535
15.0	3.6	0.46	1149	1279	1855
16.0	3.6	0.46	1149	1279	1855
17.0	3.6	0.46	1149	1279	1855
18.0	3.6	0.46	1149	1279	1855
19.0	3.6	0.46	1149	1279	1855
20.0	3.6	0.46	1149	1279	1855
21.0	3.3	0.45	1259	1401	2033
22.0	3.3	0.45	1259	1401	2033
23.0	3.3	0.45	1259	1401	2033
24.0	3.3	0.45	1259	1401	2033
25.0	3.3	0.45	1259	1401	2033
26.0	3.3	0.45	1259	1401	2033
27.0	3.3	0.45	1262	1404	2038
28.0	3.3	0.45	1262	1404	2038
29.0	3.3	0.45	1262	1404	2038
30.0	3.3	0.45	1262	1404	2038
31.0	3.3	0.45	1262	1404	2038
32.0	3.3	0.45	1262	1404	2038
33.0	3.3	0.45	1262	1404	2038
34.0	3.4	0.45	1229	1367	1983
35.0	3.4	0.45	1229	1367	1983

Figure A8 - Predicted P-wave velocities from possible Poisson's ratios (0.37, 0.40 and 0.46) at station 7026. PR=0.46(average measured) well predicts the Vp profile (Vp3). Maximum reliable depth for measure P-waves is about 10 meters. Vp values at depth greater than 10m can be adjusted by using predicted Vp3 profile.



Depth(m)	Vs (m/s)		Depth (m)	Vp (m/sec)
0.00	176.69		0.00	792.43
2.78	308.08		0.94	794.73
6.25	330.05		2.81	795.48
10.42	332.68		4.69	800.92
15.28	335.21		6.56	2241.86
20.83	331.16		11.06	2394.43
27.08	319.77		15.56	2395.43
30.00	319.77		20.06	2396.43
34.03	305.40		24.56	2397.43
41.67	300.08		29.06	2398.43
50.00	335.21			

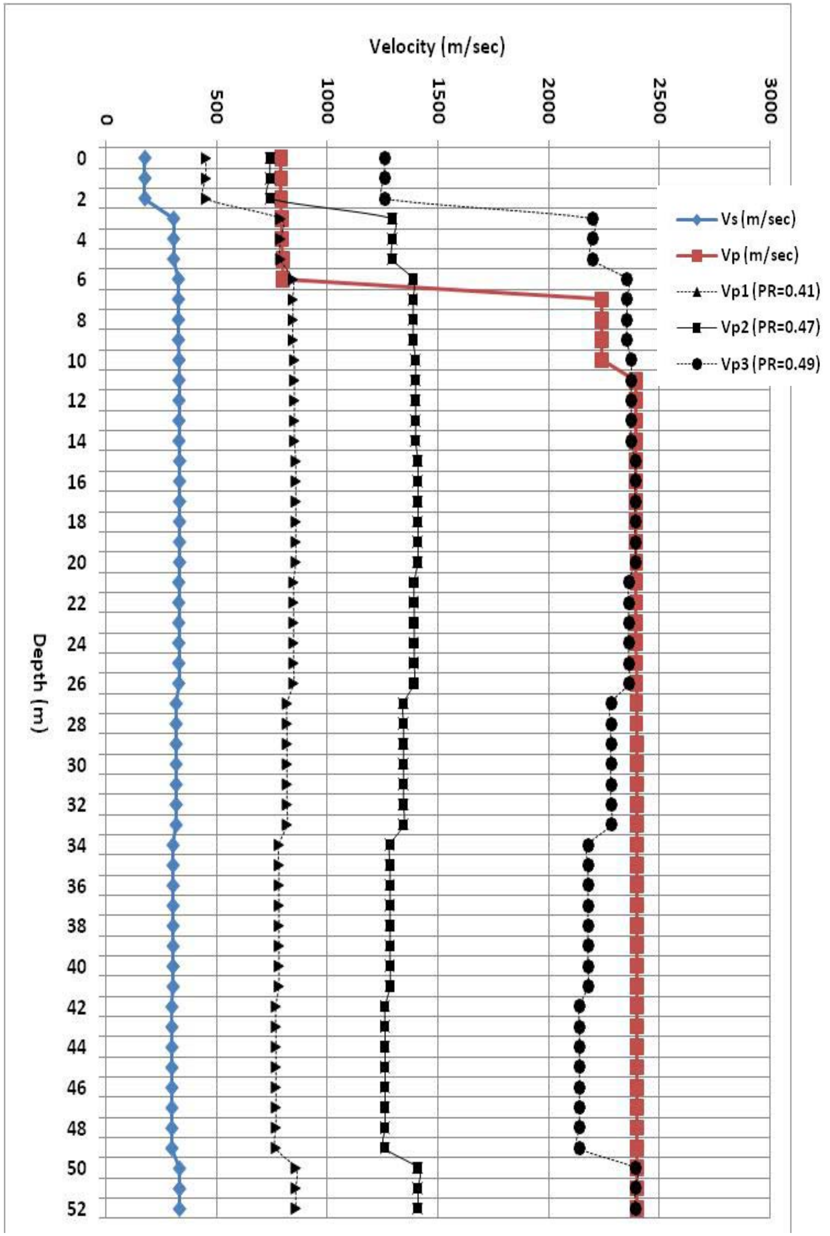
Site Geology

This site is underlain by a thin fill overlying the Blakeley Formation of Weaver, 1916, as redefined by Fulmer, 1975. Geotechnical borings about 100m to the north of this site encountered about 10 ft of silty fill on top of hard silstone. The rocks to the northwest and southeast of here strike nw and dip steeply ~60) to the northeast (Troost and others, 2005).

Vs30m = 304 m/sec (max depth resolved =38m)

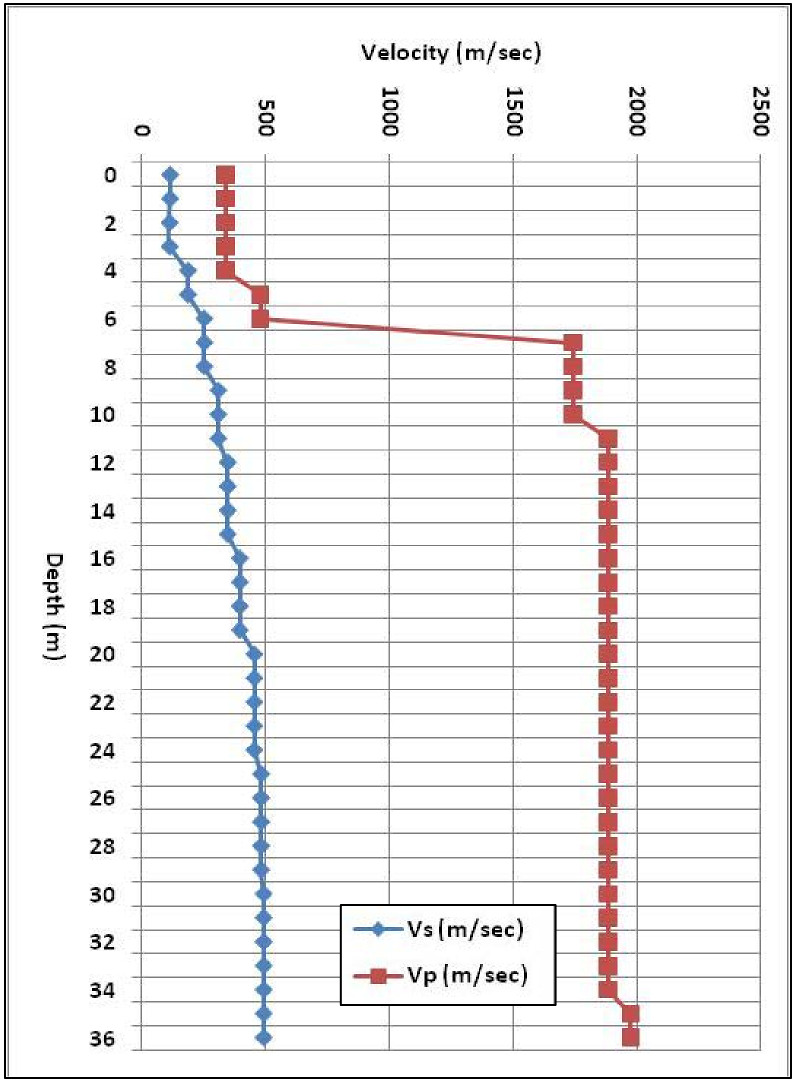
NEHRP Site Classification = D

Figure A9. S-wave and P-wave velocity profiles and site geology at 7027, South Seattle, Washington. Wong et al (2011) also reports a Vs30= 690 m/sec, with NEHRP site class of C for this site. Discrepancy between two results may come from the selection of location of the seismic surveys in relation with complex geology (showing the steeply dipping rocks).



Depth (m)	Vp/Vs	PR (Measured)	**Vp1 (PR=0.41)**	**Vp2 (PR=0.47)**	**Vp3 (PR=0.49)**
0	4.48	0.47	452	743	1262
1	4.48	0.47	452	743	1262
2	4.48	0.47	452	743	1262
3	2.58	0.41	789	1295	2200
4	2.58	0.41	789	1295	2200
5	2.60	0.41	789	1295	2200
6	2.43	0.40	845	1387	2357
7	6.79	0.49	845	1387	2357
8	6.79	0.49	845	1387	2357
9	6.79	0.49	845	1387	2357
10	6.74	0.49	852	1398	2376
11	7.20	0.49	852	1398	2376
12	7.20	0.49	852	1398	2376
13	7.20	0.49	852	1398	2376
14	7.20	0.49	852	1398	2376
15	7.14	0.49	858	1409	2394
16	7.15	0.49	858	1409	2394
17	7.15	0.49	858	1409	2394
18	7.15	0.49	858	1409	2394
19	7.15	0.49	858	1409	2394
20	7.15	0.49	858	1409	2394
21	7.24	0.49	848	1392	2365
22	7.24	0.49	848	1392	2365
23	7.24	0.49	848	1392	2365
24	7.24	0.49	848	1392	2365
25	7.24	0.49	848	1392	2365
26	7.24	0.49	848	1392	2365
27	7.50	0.49	819	1344	2284
28	7.50	0.49	819	1344	2284
29	7.50	0.49	819	1344	2284
30	7.50	0.49	819	1344	2284
31	7.50	0.49	819	1344	2284
32	7.50	0.49	819	1344	2284
33	7.50	0.49	819	1344	2284
34	7.85	0.49	782	1284	2181
35	7.85	0.49	782	1284	2181
36	7.85	0.49	782	1284	2181
37	7.85	0.49	782	1284	2181
38	7.85	0.49	782	1284	2181
39	7.85	0.49	782	1284	2181
40	7.85	0.49	782	1284	2181
41	7.85	0.49	782	1284	2181
42	7.99	0.49	768	1261	2143
43	7.99	0.49	768	1261	2143
44	7.99	0.49	768	1261	2143
45	7.99	0.49	768	1261	2143

Figure A10 - Predicted P-wave velocities from possible Poisson's ratios (0.37, 0.40 and 0.46) at station 7027. PR=0.49(average measured) predicts the Vp profile (Vp3). Maximum reliable depth for measured Vp is about 10 meters. Vp values at depth greater than 10m can be adjusted by using assumed Poisson's Ratios (PRs) greater than 0.4.



From	To	Vs (m/sec)
0.0	1.7	114.07
1.7	3.8	112.14
3.8	6.3	186.79
6.3	9.2	252.60
9.2	12.5	309.70
12.5	16.2	348.52
16.2	20.4	397.24
20.4	25.0	456.15
25.0	30.0	483.61
30.0		494.49

From	To	Vp (m/sec)
0.0	2.8	339.12
2.8	4.7	340.11
4.7	6.6	478.73
6.6	11.1	1742.48
11.1	35.1	1882.28
35.1		1974.63

Site Geology

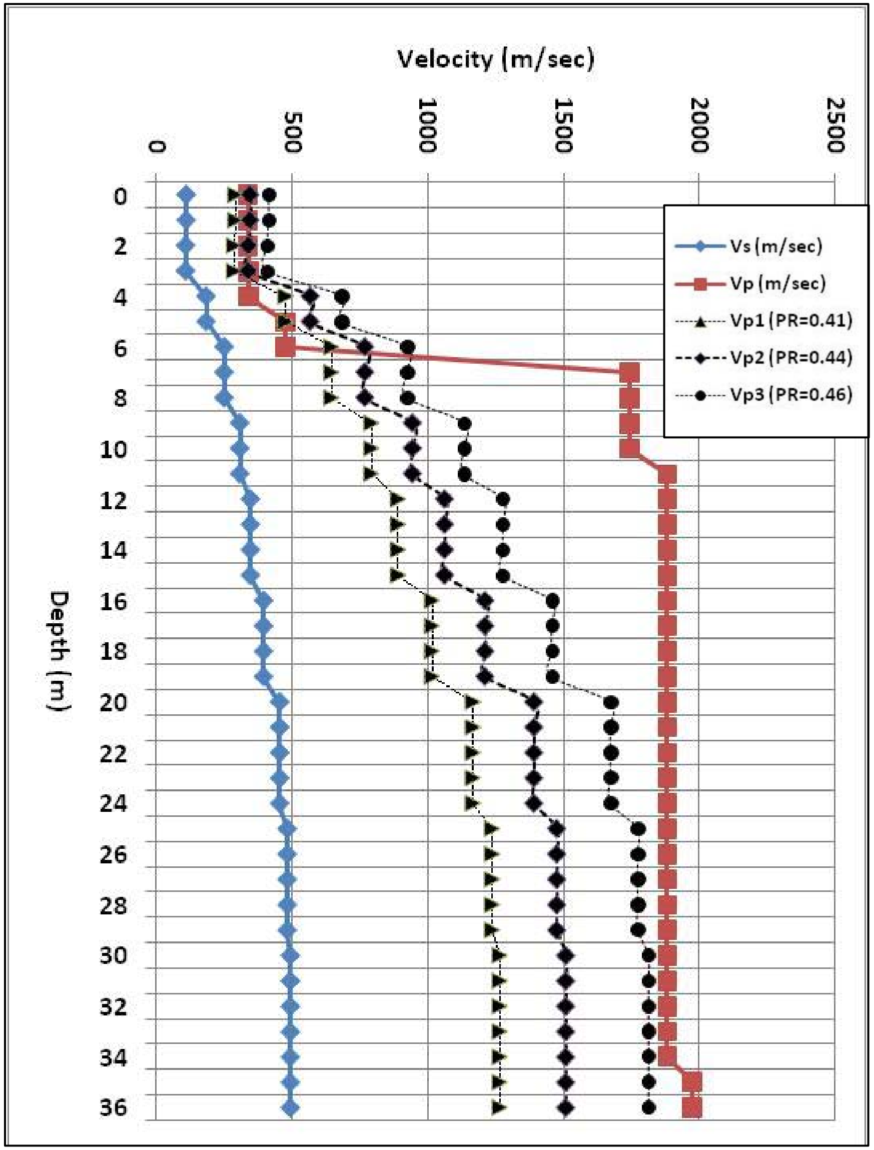
This site is underlain by alluvium of the Quillayute River (Gerstel and Lingley, 2000), which upstream of La Push is generally silt loam (Halloin, 1987). Channel alluvium in the vicinity is sand and gravely as coarse as cobble gravel. Thickness is unknown.

Measured Fundamental Frequency (Hz) on H/V (Albarello et al, 2011a) (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
3.1	301	24

(*)See Table 3 for details

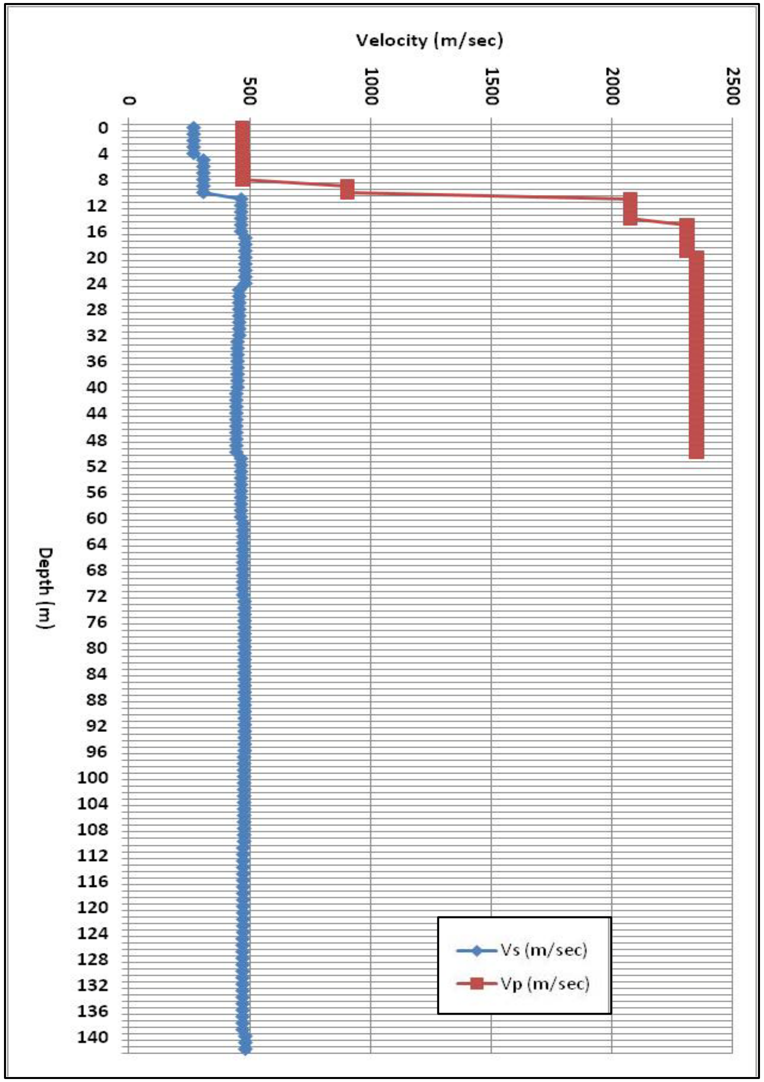
Vs30m = 271 m/sec (max depth resolved =28m)
NEHRP Site Classification = D

Figure A11. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7028, LaPush (Forks), Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.41)	Vp2 (PR=0.44)	Vp3 (PR=0.46)
0	2.97	0.44	292	348	419
1	2.97	0.44	292	348	419
2	3.02	0.44	287	343	412
3	3.03	0.44	287	343	412
4	1.82	0.28	478	571	686
5	2.56	0.41	478	571	686
6	1.90	0.31	647	772	928
7	6.90	0.49	647	772	928
8	6.90	0.49	647	772	928
9	5.63	0.48	793	946	1138
10	5.63	0.48	793	946	1138
11	6.08	0.49	793	946	1138
12	5.40	0.48	892	1065	1281
13	5.40	0.48	892	1065	1281
14	5.40	0.48	892	1065	1281
15	5.40	0.48	892	1065	1281
16	4.74	0.48	1017	1214	1460
17	4.74	0.48	1017	1214	1460
18	4.74	0.48	1017	1214	1460
19	4.74	0.48	1017	1214	1460
20	4.13	0.47	1168	1394	1676
21	4.13	0.47	1168	1394	1676
22	4.13	0.47	1168	1394	1676
23	4.13	0.47	1168	1394	1676
24	4.13	0.47	1168	1394	1676
25	3.89	0.46	1238	1477	1777
26	3.89	0.46	1238	1477	1777
27	3.89	0.46	1238	1477	1777
28	3.89	0.46	1238	1477	1777
29	3.89	0.46	1238	1477	1777
30	3.81	0.46	1266	1511	1817
31	3.81	0.46	1266	1511	1817
32	3.81	0.46	1266	1511	1817
33	3.81	0.46	1266	1511	1817
34	3.81	0.46	1266	1511	1817
35	3.99	0.47	1266	1511	1817
36	3.99	0.47	1266	1511	1817

Figure A12 - Predicted P-wave velocities from possible Poisson's ratios (0.41, 0.44 and 0.46) at station 7028. Vp values for depths greater than 6m can be adjusted by using assumed Poisson's Ratios (PRs) greater than 0.4.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	5.0	271.09		0.0	1.0	469.20
5.0	10.8	311.47		1.0	2.9	469.20
10.8	17.3	467.19		2.9	4.9	469.20
17.3	24.6	484.03		4.9	6.9	474.02
24.6	30.0	459.23		6.9	8.8	474.02
30.0	32.7	459.23		8.8	10.8	905.19
32.7	41.5	452.06		10.8	15.2	2076.13
41.5	51.2	447.31		15.2	19.6	2308.55
51.2	61.5	466.69		19.6	24.0	2348.95
61.5	72.7	475.63		24.0	28.4	2349.11
72.7	84.6	480.88		28.4	32.8	2349.27
84.6	97.3	481.55		32.8	37.2	2349.43
97.3	100.0	479.02		37.2	41.6	2349.59
100.0	125.0	475.51		41.6	46.0	2349.74
125.0	140.0	473.27		46.0		2350.72
140.0		484.03				

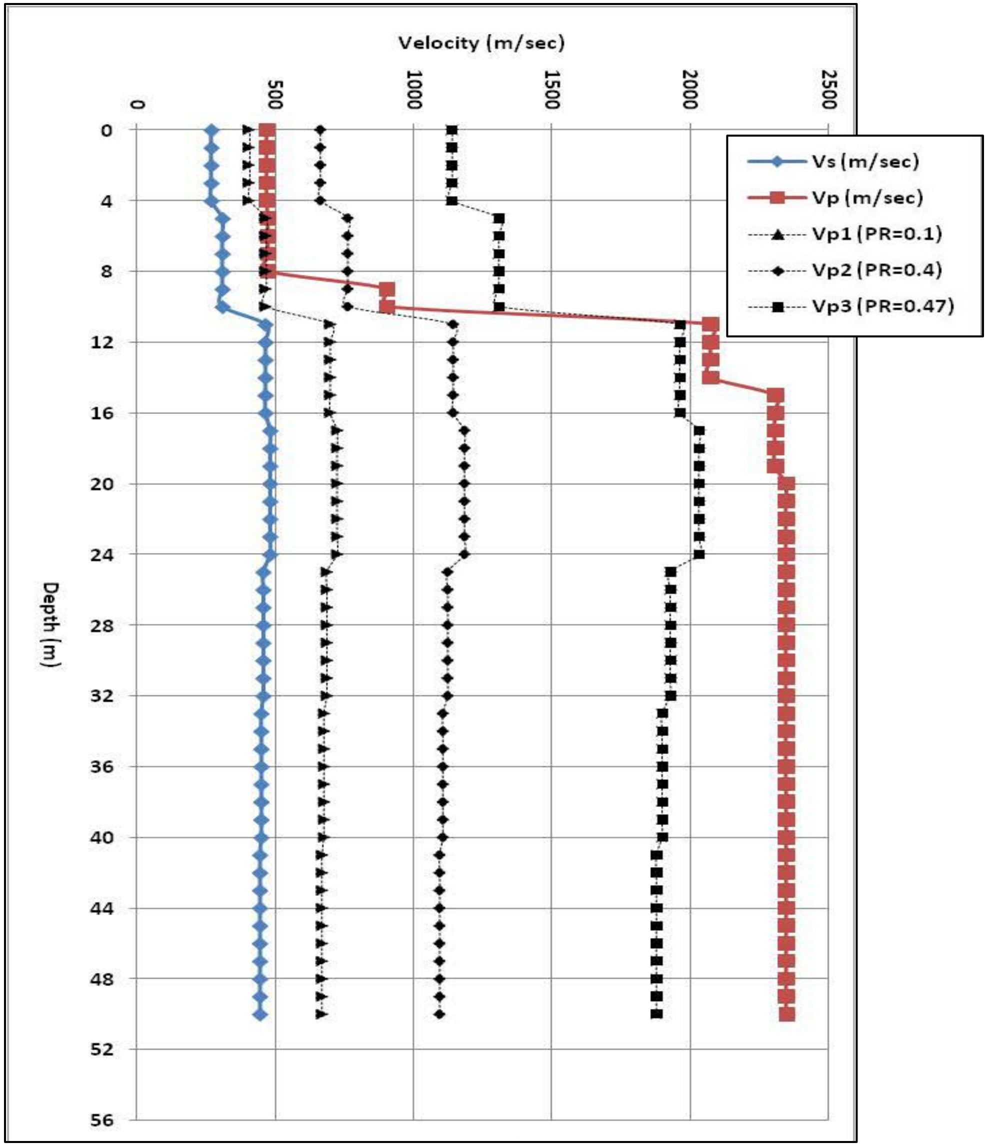
This site is extensively regraded (Schasse and Slaughter, 2005) but generally is a Vashon till plain (Grimstad and Carson, 1981; Washington Department of Ecology, 1978). The bluff a short distance to the north exposes about 20 ft of Vashon till overlying about 25 ft of Vashon outwash sand and gravel, which in turn overlies about 40 ft of interbedded sand and silt (Washington Department of Ecology, 1978)

Vs30m = 386 m/sec (max depth resolved =140m)
Vs100m= 440 m/sec
NEHRP Site Classification = C-D or C

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
0.23	665	723

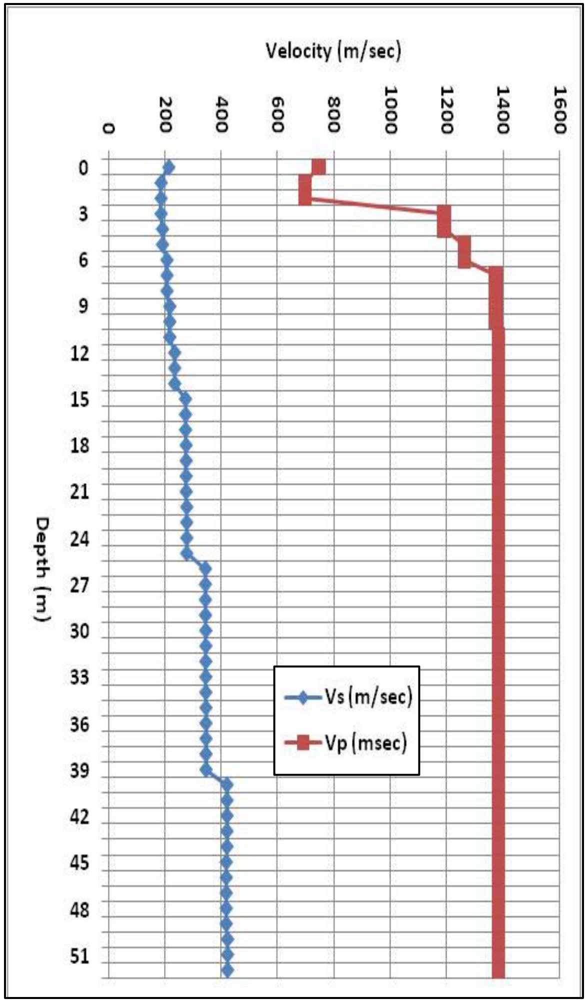
(*)See Table 3 for details

Figure A13. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7029 (Fort Worden) Port Townsend, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.1)	Vp2 (PR=0.4)	Vp3 (PR=0.47)
0	1.73	0.25	407	664	1139
1	1.73	0.25	407	664	1139
2	1.73	0.25	407	664	1139
3	1.73	0.25	407	664	1139
4	1.73	0.25	407	664	1139
5	1.52	0.12	467	763	1309
6	1.52	0.12	467	763	1309
7	1.52	0.12	467	763	1309
8	1.52	0.12	467	763	1309
9	2.91	0.43	467	763	1309
10	2.91	0.43	467	763	1309
11	4.44	0.47	701	1144	1964
12	4.44	0.47	701	1144	1964
13	4.44	0.47	701	1144	1964
14	4.44	0.47	701	1144	1964
15	4.94	0.48	701	1144	1964
16	4.94	0.48	701	1144	1964
17	4.77	0.48	726	1186	2034
18	4.77	0.48	726	1186	2034
19	4.77	0.48	726	1186	2034
20	4.85	0.48	726	1186	2034
21	4.85	0.48	726	1186	2034
22	4.85	0.48	726	1186	2034
23	4.85	0.48	726	1186	2034
24	4.85	0.48	726	1186	2034
25	5.12	0.48	689	1125	1930
26	5.12	0.48	689	1125	1930
27	5.12	0.48	689	1125	1930
28	5.12	0.48	689	1125	1930
29	5.12	0.48	689	1125	1930
30	5.12	0.48	689	1125	1930
31	5.12	0.48	689	1125	1930
32	5.12	0.48	689	1125	1930
33	5.20	0.48	678	1107	1900
34	5.20	0.48	678	1107	1900
35	5.20	0.48	678	1107	1900

Figure A14 - Predicted P-wave velocities from possible Poisson's ratios (0.1, 0.4 and 0.47) at station 7029. Distinct PRs indicate the well graded subsurface soil material, also described in the site geology.



Depth (m) From	Depth (m) To	Vs (m/sec)
0.0	1.8	214.04
1.8	3.8	186.37
3.8	6.2	191.51
6.2	8.8	207.61
8.8	11.7	217.72
11.7	14.8	235.09
14.8	18.3	273.81
18.3	22.0	276.02
22.0	26.0	278.09
26.0	30.0	345.18
30.0	30.2	345.18
30.2	34.8	346.47
34.8	39.6	346.94
39.6	44.6	422.00
44.6	50.0	419.59
50.0		

Depth (m) From	Depth (m) To	Vp (m/sec)
0.0	0.9	745.95
0.9	2.8	697.71
2.8	4.7	1190.05
4.7	6.6	1262.63
6.6	11.1	1373.27
11.1	15.6	1383.78
15.6	20.1	1383.78
20.1	24.6	1383.78
24.6	29.1	1383.78
29.1		1383.78

Vs30m = 244 m/sec (max depth resolved = 40m)
NEHRP Site Classification = D

Site Geology
This site is on extensively graded and compacted soil of SeaTac Airport (Booth and Waldron, 2004). Prior to grading, this site was a gently undulating till plain (Willis and Smith, 1899). Boreholes at the airport generally penetrate 10-15 ft of fill over either till or sand and gravel, although in some places fill was placed on peat.

Depth (m)	Vs (ft/sec) Wong et al. (2011)	Vs (m/sec)
0.0	350	106.68
0.5	650	198.12
2.0	1000	304.8
5.0	1200	365.76
15.7	1300	396.24
52.3	2800	853.44

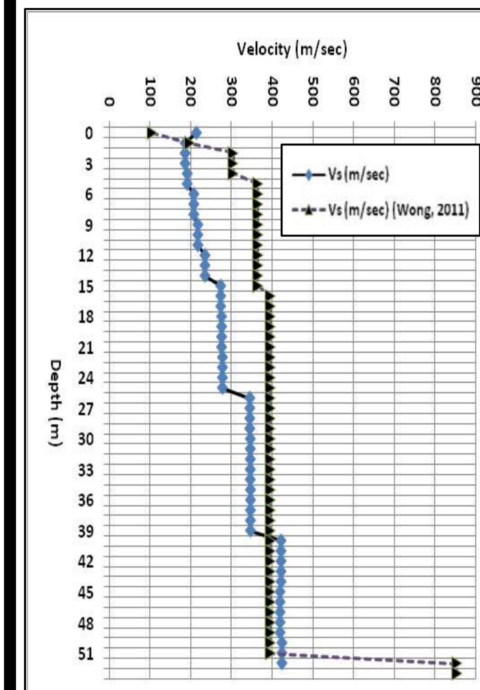
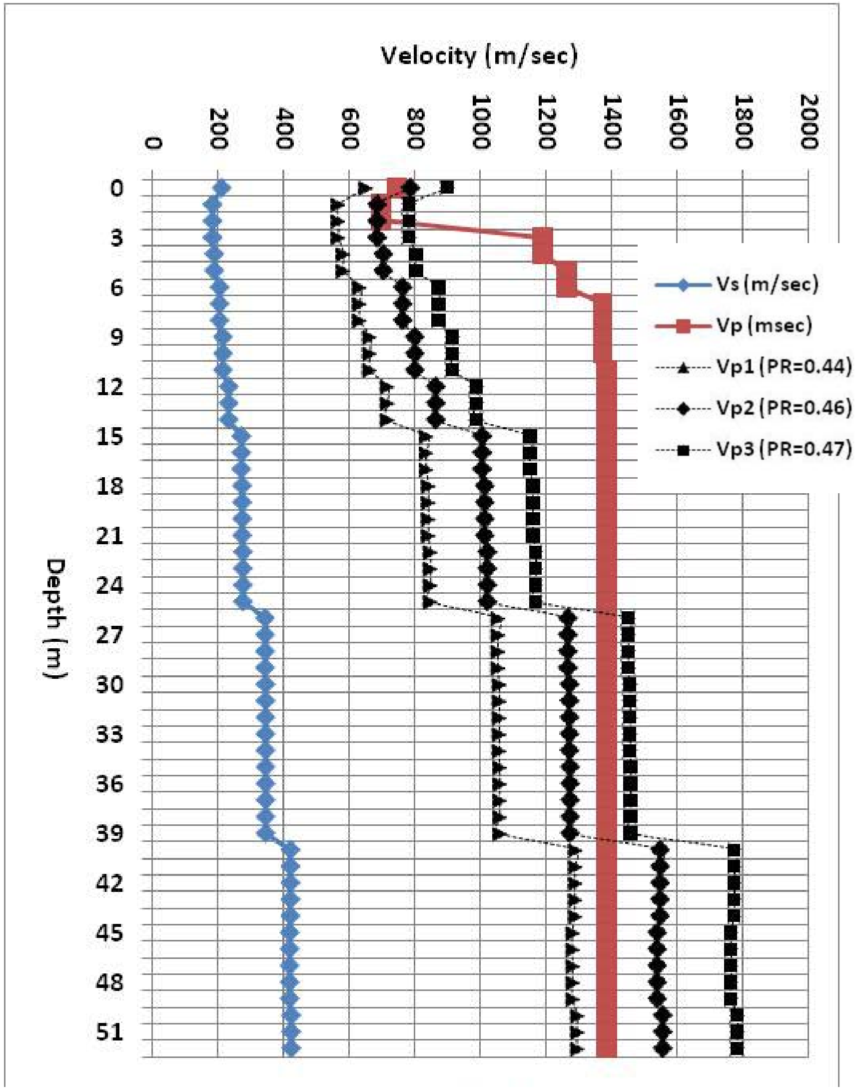
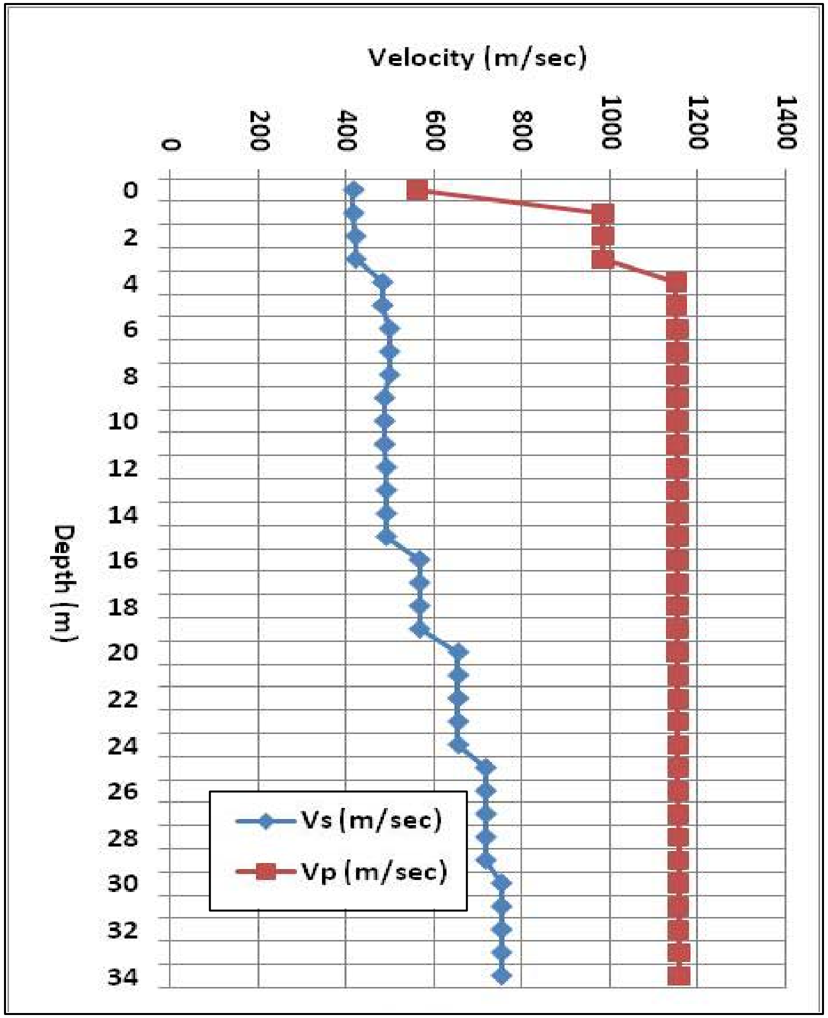


Figure A15. S-wave and P-wave velocity profiles and site geology at 7030, SeaTac Airport Fire Station, Washington. Right side of the soli d black line shows the comparison between SASW (Wong et al. 2011) and MASW (this study). Both studies classifies the site as that the NEHRP site class is D.



Depth (m/sec)	Vp/Vs		PR (Measured)	Vp/Vs (Wong2011)	PR (Wong2011)	Vp1 (PR=0.44)	Vp2 (PR=0.46)	Vp3 (PR=0.47)
0	3.49		0.46	6.99	0.49	654	786	900
1	3.74		0.46	3.52	0.46	569	685	783
2	3.74		0.46	2.29	0.38	569	685	783
3	6.39		0.49	3.90	0.46	569	685	783
4	6.21		0.49	3.90	0.46	585	704	805
5	6.59		0.49	3.45	0.45	585	704	805
6	6.08		0.49	3.45	0.45	634	763	873
7	6.61		0.49	3.75	0.46	634	763	873
8	6.61		0.49	3.75	0.46	634	763	873
9	6.31		0.49	3.75	0.46	665	800	915
10	6.31		0.49	3.75	0.46	665	800	915
11	6.36		0.49	3.78	0.46	665	800	915
12	5.89		0.49	3.78	0.46	718	864	988
13	5.89		0.49	3.78	0.46	718	864	988
14	5.89		0.49	3.78	0.46	718	864	988
15	5.05		0.48	3.78	0.46	837	1006	1151
16	5.05		0.48	3.49	0.46	837	1006	1151
17	5.05		0.48	3.49	0.46	837	1006	1151
18	5.01		0.48	3.49	0.46	843	1014	1160
19	5.01		0.48	3.49	0.46	843	1014	1160
20	5.01		0.48	3.49	0.46	843	1014	1160
21	5.01		0.48	3.49	0.46	843	1014	1160
22	4.98		0.48	3.49	0.46	850	1022	1169
23	4.98		0.48	3.49	0.46	850	1022	1169
24	4.98		0.48	3.49	0.46	850	1022	1169
25	4.98		0.48	3.49	0.46	850	1022	1169
26	4.01		0.47	3.49	0.46	1055	1268	1451
27	4.01		0.47	3.49	0.46	1055	1268	1451
28	4.01		0.47	3.49	0.46	1055	1268	1451
29	4.01		0.47	3.49	0.46	1055	1268	1451
30	3.99		0.47	3.49	0.46	1058	1273	1456
31	3.99		0.47	3.49	0.46	1058	1273	1456
32	3.99		0.47	3.49	0.46	1058	1273	1456
33	3.99		0.47	3.49	0.46	1058	1273	1456
34	3.99		0.47	3.49	0.46	1058	1273	1456
35	3.99		0.47	3.49	0.46	1060	1275	1458
36	3.99		0.47	3.49	0.46	1060	1275	1458
37	3.99		0.47	3.49	0.46	1060	1275	1458
38	3.99		0.47	3.49	0.46	1060	1275	1458
39	3.99		0.47	3.49	0.46	1060	1275	1458
40	3.28		0.45	3.49	0.46	1289	1551	1774

Figure A16 - Predicted P-wave velocities from possible Poisson's ratios (0.44, 0.46 and 0.47) at station 7030.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	1.7	416.56		0	1.25	561.73
1.7	3.8	421.29		1.25	3.75	983.87
3.8	6.3	482.58		3.75	6.25	1151.61
6.3	9.2	498.04		6.25	8.75	1152.61
9.2	12.5	486.94		8.75	14.75	1153.53
12.5	16.3	490.88		14.75	20.75	1154.43
16.3	20.4	566.53		20.75	26.75	1155.32
20.4	25.0	654.46		26.75	32.75	1156.22
25.0	30.0	717.02		32.75	38.75	1157.11
30.0		752.75		38.75		1158.01

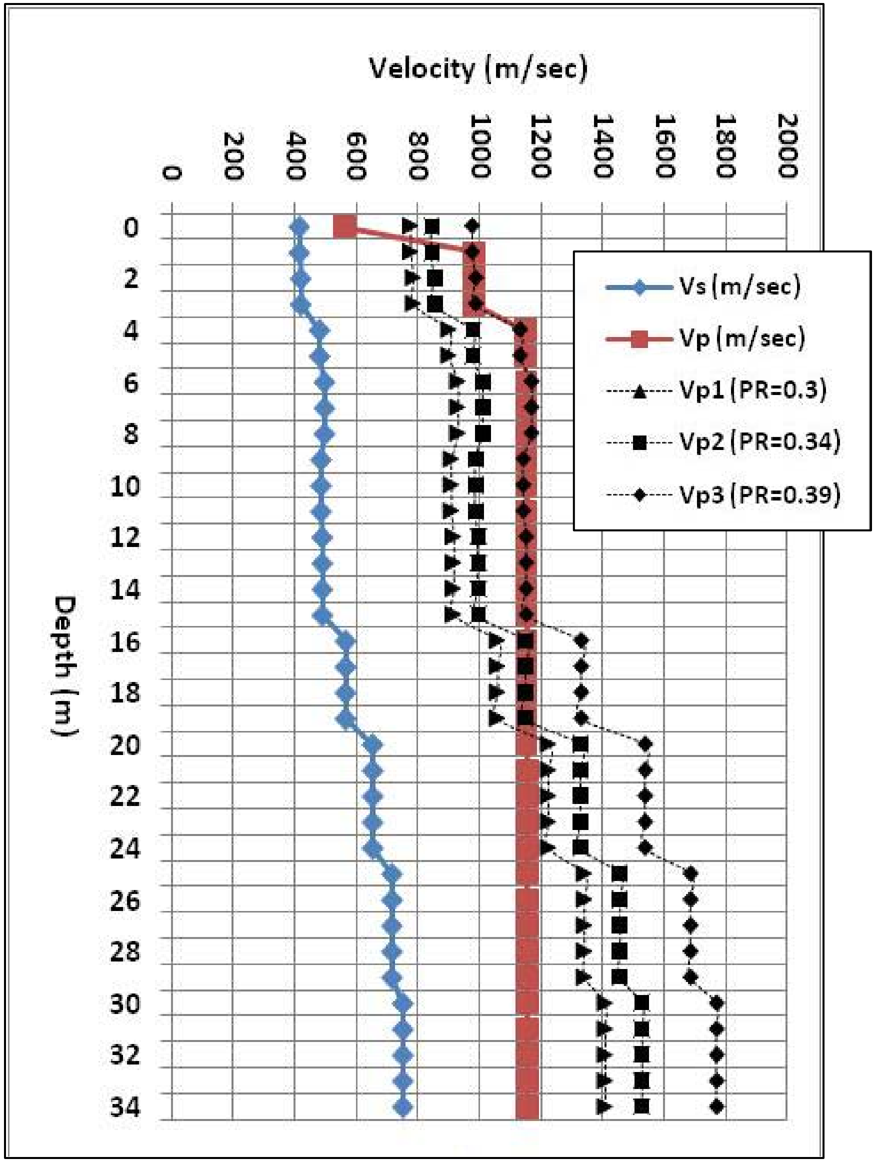
Site Geology
This site is on a Vashon till plain (Minard, 1985). In a nearby geotechnical boring, the till is at least 25 ft thick and is underlain by a clean sand with some gravel, which is as much as 200 ft thick in this area (Minard, 1985).

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
0.25	631	585

(*)See Table 3 for details

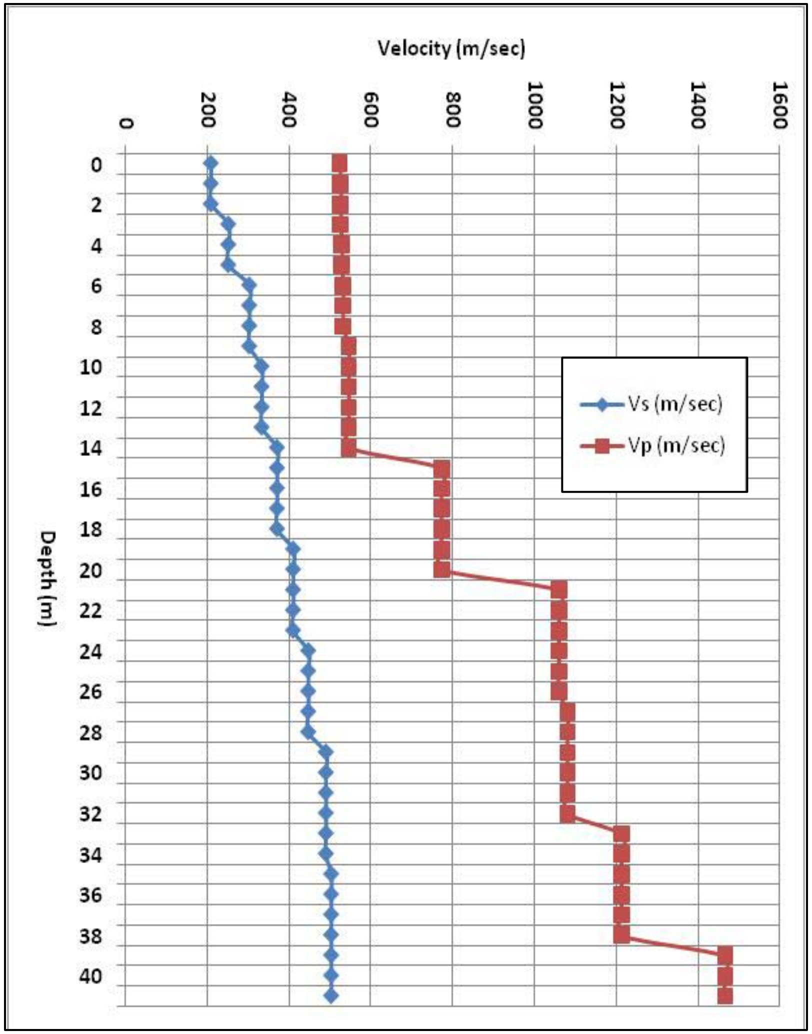
Vs30m = 538 m/sec (max depth resolved =40m)
NEHRP Site Classification = C

Figure A17. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7031, Everett, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.3)	Vp2 (PR=0.34)	Vp3 (PR=0.39)
0	1.35	-0.11	779	846	981
1	2.36	0.39	779	846	981
2	2.34	0.39	788	856	992
3	2.34	0.39	788	856	992
4	2.39	0.39	903	980	1136
5	2.39	0.39	903	980	1136
6	2.31	0.39	932	1012	1173
7	2.31	0.39	932	1012	1173
8	2.31	0.39	932	1012	1173
9	2.37	0.39	911	989	1147
10	2.37	0.39	911	989	1147
11	2.37	0.39	911	989	1147
12	2.35	0.39	918	997	1156
13	2.35	0.39	918	997	1156
14	2.35	0.39	918	997	1156
15	2.35	0.39	918	997	1156
16	2.04	0.34	1060	1151	1334
17	2.04	0.34	1060	1151	1334
18	2.04	0.34	1060	1151	1334
19	2.04	0.34	1060	1151	1334
20	1.76	0.26	1224	1329	1541
21	1.77	0.26	1224	1329	1541
22	1.77	0.26	1224	1329	1541
23	1.77	0.26	1224	1329	1541
24	1.77	0.26	1224	1329	1541
25	1.61	0.19	1341	1456	1689
26	1.61	0.19	1341	1456	1689
27	1.61	0.19	1341	1456	1689
28	1.61	0.19	1341	1456	1689
29	1.61	0.19	1341	1456	1689
30	1.54	0.13	1408	1529	1773
31	1.54	0.13	1408	1529	1773
32	1.54	0.13	1408	1529	1773
33	1.54	0.13	1408	1529	1773
34	1.54	0.13	1408	1529	1773

Figure A18 - Predicted P-wave velocities from possible Poisson's ratios (0.30, 0.34 and 0.39) at station 7031. Poisson ratio (PR) -0.11 suggests a Vp correction to from 562 to 981 m/sec .



Vs30m = 333 m/sec (max depth resolved =40m)
NEHRP Site Classification = D

From	To	Vs (m/sec)
0.0	2.9	209.65
2.9	6.2	252.38
6.2	9.9	303.42
9.9	14.1	333.67
14.1	18.7	371.22
18.7	23.7	410.74
23.7	29.2	447.53
29.2	35.2	490.59
35.2	41.5	503.49
41.5	48.4	506.28
48.4	55.6	504.30
55.6	63.3	500.05
63.3	71.4	498.65
71.4	80.0	506.88
80.0		532.16

From	To	Vp (m/sec)
0.0	1.3	523.84
1.3	3.8	526.38
3.8	6.3	529.56
6.3	8.8	532.14
8.8	14.8	546.18
14.8	20.8	772.83
20.8	26.8	1060.35
26.8	32.8	1081.54
32.8	38.8	1213.96
38.8		1466.08

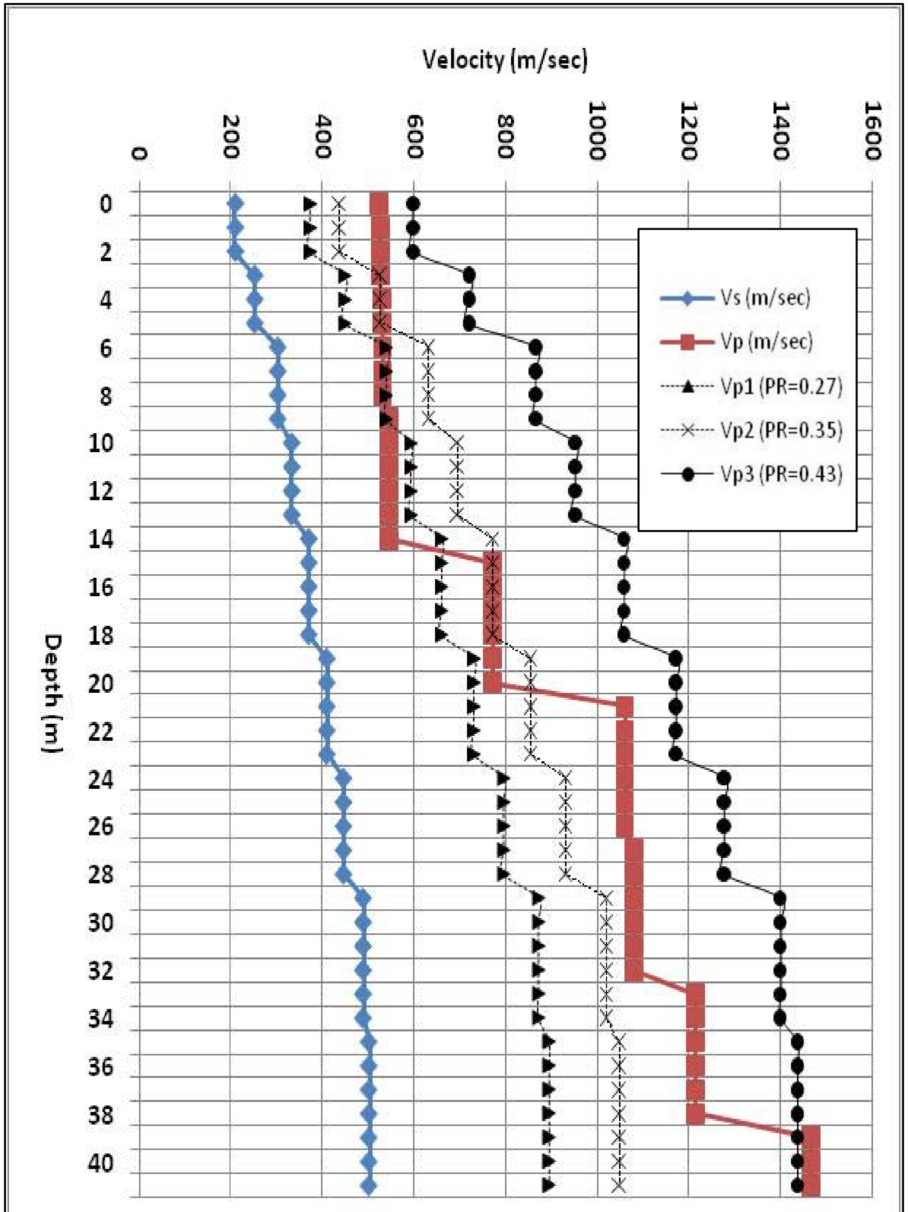
Site Geology

This site is underlain by Vashon sandy advance outwash, here known as the Esperance Sand (Troost and others, 2005). A geotechnical borehole at this site penetrated 3.5 ft of sandy fill over 12.5 ft of dense to very dense sand. Four blocks west of this site, a geotechnical borehole penetrated 40 ft of Esperance Sand. A geotechnical borehole 6 blocks north-northeast of this site penetrated 53 ft of sand overlying 62 ft of silt and clay, here known as the Lawton Clay.

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
1.1	405	92

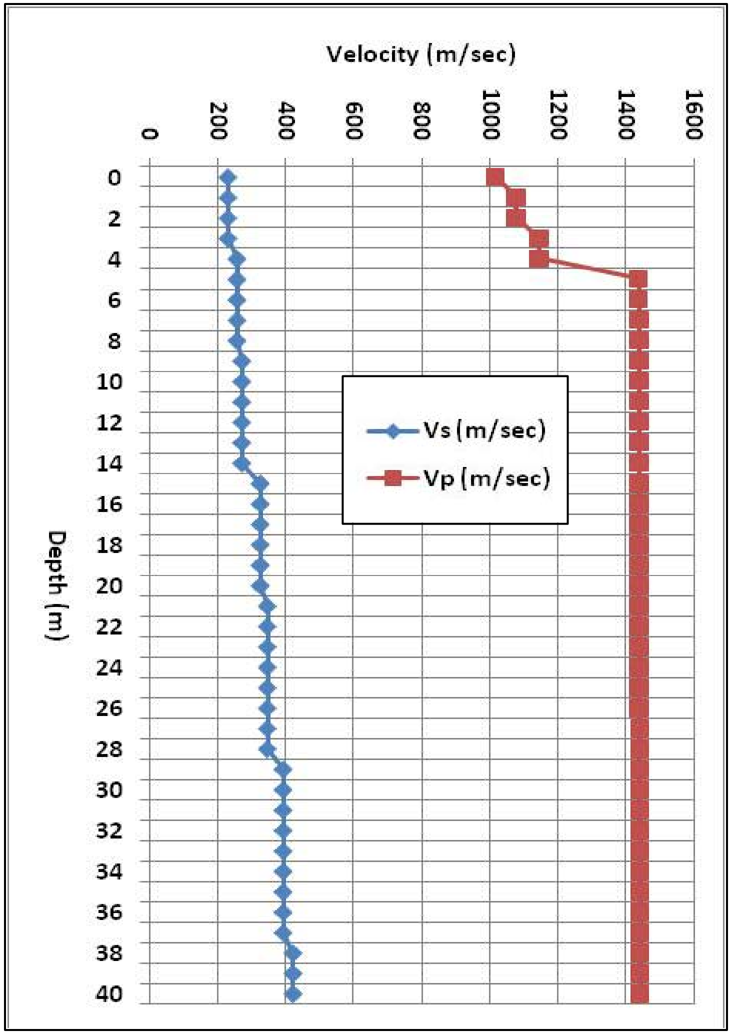
(*)See Table 3 for details

Figure A19. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7032, West Seattle. Wong et al. (2011) similarly reported Vs30 (=328m/sec) and NHRP site classification (=D) at 7032.



Depth (m)	Vp/Vs	PR	Vp1 (PR=0.27)	Vp2 (PR=0.35)	Vp3 (PR=0.43)
0	2.50	0.40	374	436	598
1	2.51	0.41	374	436	598
2	2.51	0.41	374	436	598
3	2.09	0.35	450	525	720
4	2.10	0.35	450	525	720
5	2.10	0.35	450	525	720
6	1.75	0.26	541	632	866
7	1.75	0.26	541	632	866
8	1.75	0.26	541	632	866
9	1.80	0.28	541	632	866
10	1.64	0.20	594	695	952
11	1.64	0.20	594	695	952
12	1.64	0.20	594	695	952
13	1.64	0.20	594	695	952
14	1.47	0.07	661	773	1059
15	2.08	0.35	661	773	1059
16	2.08	0.35	661	773	1059
17	2.08	0.35	661	773	1059
18	2.08	0.35	661	773	1059
19	1.88	0.30	732	855	1172
20	1.88	0.30	732	855	1172
21	2.58	0.41	732	855	1172
22	2.58	0.41	732	855	1172
23	2.58	0.41	732	855	1172
24	2.37	0.39	797	932	1277
25	2.37	0.39	797	932	1277
26	2.37	0.39	797	932	1277
27	2.42	0.40	797	932	1277
28	2.42	0.40	797	932	1277
29	2.20	0.37	874	1021	1400
30	2.20	0.37	874	1021	1400
31	2.20	0.37	874	1021	1400
32	2.20	0.37	874	1021	1400
33	2.47	0.40	874	1021	1400
34	2.47	0.40	874	1021	1400
35	2.41	0.40	897	1048	1437

Figure A20 - Predicted P-wave velocities from possible Poisson's ratios (0.27, 0.35 and 0.43) at station 7032.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	3.9	232.14		0.0	1.0	1016.73
3.9	8.8	258.96		1.0	3.1	1078.56
8.8	14.6	273.22		3.1	5.2	1145.83
14.6	21.4	327.39		5.2	7.2	1436.79
21.4	29.2	347.60		7.2	12.2	1437.54
29.2	30.0	394.49		12.2	17.1	1438.29
30.0	37.9	394.49		17.1	22.1	1439.04
37.9	47.6	423.04		22.1	27.0	1439.79
47.6	58.3	423.55		27.0	32.0	1440.54
58.3	70.0	404.44		32.0		1441.29
70.0		423.55				

Site Geology

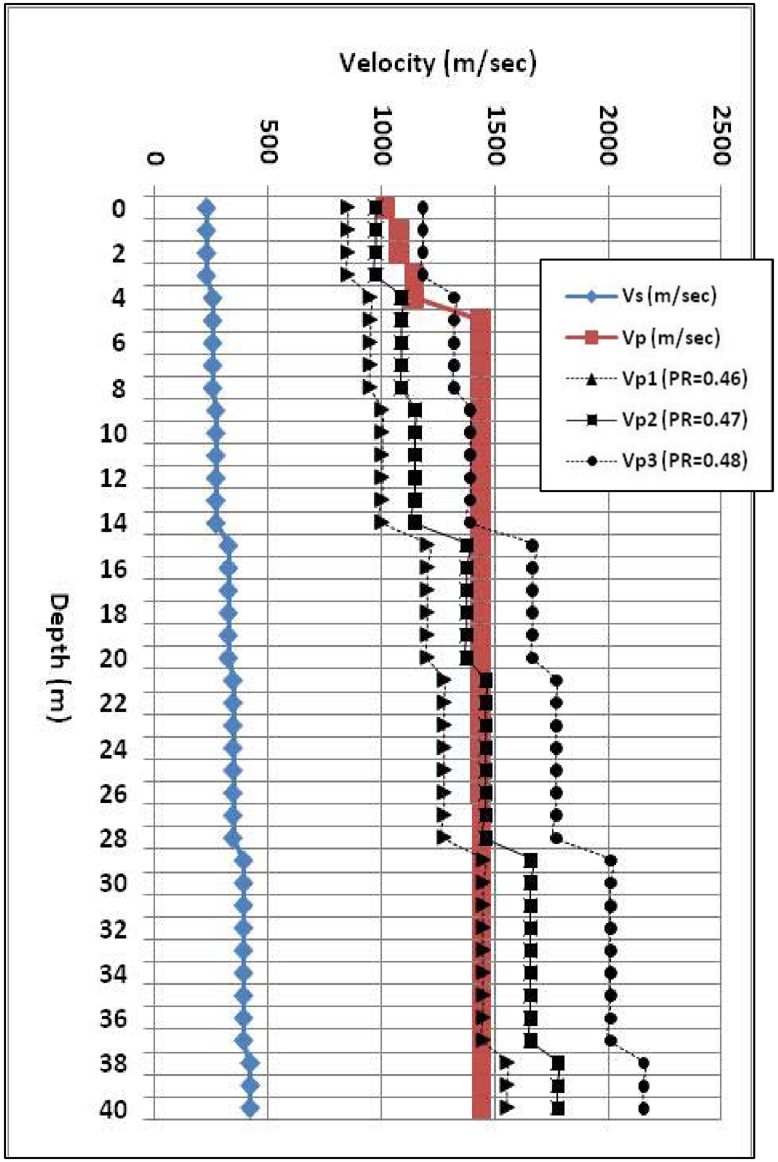
This site is on a thin fill overlying Everson glaciomarine drift (Lapen, 2000), which is mostly silty, sandy, clayey diamicton (Dragovich and others, 2000), moderately to poorly indurated, with lenses and discontinuous beds of moderately to well-sorted gravel, sand, silt, and clay.The thickness of this unit is highly variable. Logs of nearby wells are difficult to interpret; a well log from about two blocks north of this site reports sandstone at a depth of 12 ft but well logs from two blocks east report silt and clay to a depth of 340 ft.

Vs30m = 204 m/sec (max depth resolved =67m)
NEHRP Site Classification = D

Measured Fundamental Frequency (Hz) on H/V (Albarello et al, 2011a) (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
2.2	331	38

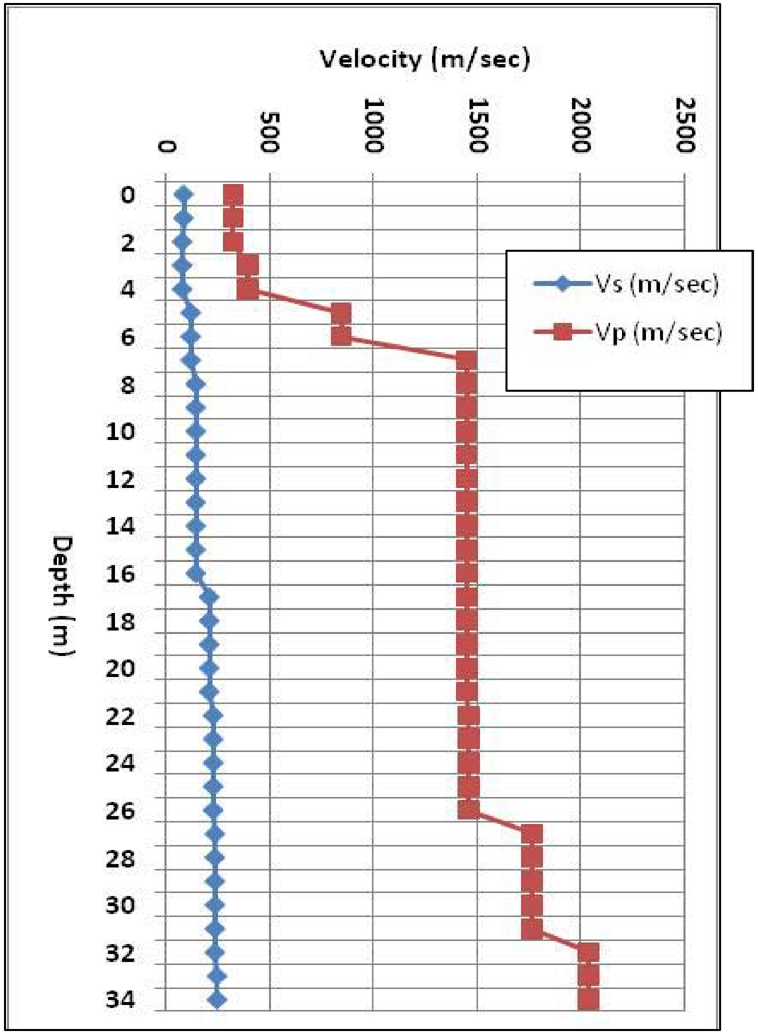
(*)See Table 3 for details

Figure A21. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7033, Anacortes, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.46)	Vp2 (PR=0.47)	Vp3 (PR=0.48)
0	4.38	0.47	853	976	1184
1	4.65	0.48	853	976	1184
2	4.65	0.48	853	976	1184
3	4.94	0.48	853	976	1184
4	4.42	0.47	951	1088	1320
5	5.55	0.48	951	1088	1320
6	5.55	0.48	951	1088	1320
7	5.55	0.48	951	1088	1320
8	5.55	0.48	951	1088	1320
9	5.26	0.48	1004	1148	1393
10	5.26	0.48	1004	1148	1393
11	5.26	0.48	1004	1148	1393
12	5.26	0.48	1004	1148	1393
13	5.26	0.48	1004	1148	1393
14	5.26	0.48	1004	1148	1393
15	4.39	0.47	1203	1376	1669
16	4.39	0.47	1203	1376	1669
17	4.40	0.47	1203	1376	1669
18	4.40	0.47	1203	1376	1669
19	4.40	0.47	1203	1376	1669
20	4.40	0.47	1203	1376	1669
21	4.14	0.47	1277	1461	1772
22	4.14	0.47	1277	1461	1772
23	4.14	0.47	1277	1461	1772
24	4.14	0.47	1277	1461	1772
25	4.14	0.47	1277	1461	1772
26	4.14	0.47	1277	1461	1772
27	4.14	0.47	1277	1461	1772
28	4.14	0.47	1277	1461	1772
29	3.65	0.46	1449	1658	2012
30	3.65	0.46	1449	1658	2012
31	3.65	0.46	1449	1658	2012
32	3.65	0.46	1449	1658	2012
33	3.65	0.46	1449	1658	2012
34	3.65	0.46	1449	1658	2012
35	3.65	0.46	1449	1658	2012
36	3.65	0.46	1449	1658	2012
37	3.65	0.46	1449	1658	2012
38	3.41	0.45	1554	1778	2157
39	3.41	0.45	1554	1778	2157
40	3.41	0.45	1554	1778	2157

Figure A22 - Predicted P-wave velocities from possible Poisson's ratios (0.47, 0.48 and 0.49) at station 7033. standard deviation for measured Poisson ratios (PRs) is 0.01.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	2.2	88.68		0.0	1.0	324.39
2.2	5.0	82.43		1.0	3.1	324.64
5.0	8.3	124.05		3.1	5.2	397.41
8.3	12.2	147.96		5.2	7.2	846.69
12.2	16.7	183.08		7.2	12.2	1448.59
16.7	21.7	212.74		12.2	17.1	1453.33
21.7	27.2	232.87		17.1	22.1	1453.33
27.2	30.0	240.85		22.1	27.0	1457.92
30.0	33.3	240.85		27.0	32.0	1764.31
33.3	53.3	250.95		32.0		2040.31
53.3		250.95				

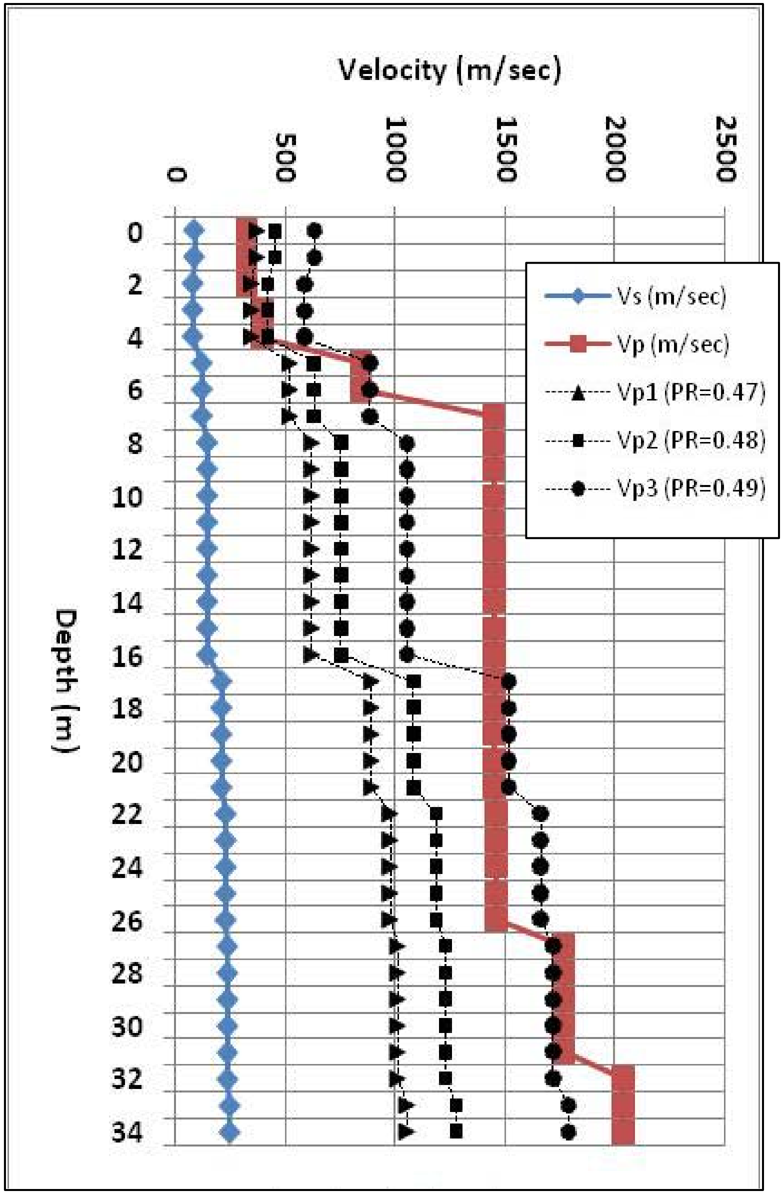
Site Geology

This site is on Chehalis River alluvium (Logan, 1987). It consists of silt, clayey silt, sandy silt, and silty sand. It is at least 100 ft thick in nearby geotechnical boreholes and blow counts about 2 blocks to the south southeast it is medium dense at 100 ft depth.

Vs30m = 154 m/sec (max depth resolved =30m)

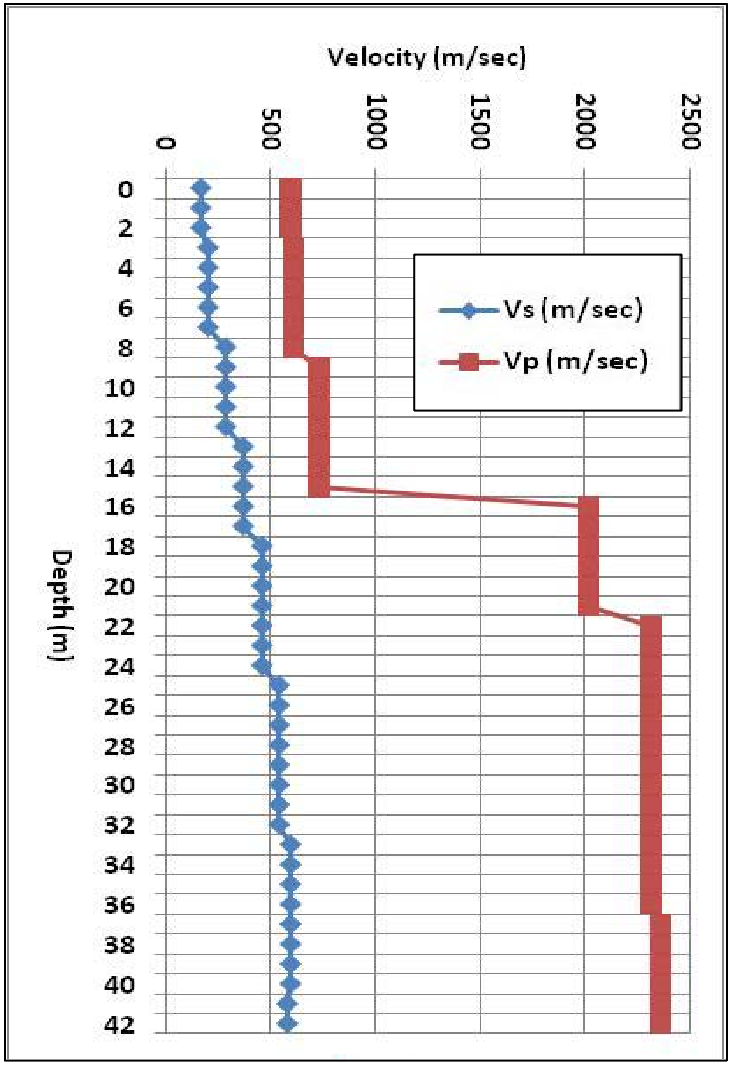
NEHRP Site Classification = E

Figure A23. S-wave and P-wave velocity profiles and site geology at 7035, Aberdeen, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.47)	Vp2 (PR=0.48)	Vp3 (PR=0.49)
0	3.66	0.46	373	452	633
1	3.66	0.46	373	452	633
2	3.94	0.47	346	420	589
3	4.82	0.48	346	420	589
4	4.82	0.48	346	420	589
5	6.83	0.49	521	633	886
6	6.83	0.49	521	633	886
7	11.68	0.50	521	633	886
8	9.79	0.49	622	754	1057
9	9.79	0.49	622	754	1057
10	9.79	0.49	622	754	1057
11	9.79	0.49	622	754	1057
12	9.82	0.49	622	754	1057
13	9.82	0.49	622	754	1057
14	9.82	0.49	622	754	1057
15	9.82	0.49	622	754	1057
16	9.82	0.49	622	754	1057
17	6.83	0.49	894	1085	1519
18	6.83	0.49	894	1085	1519
19	6.83	0.49	894	1085	1519
20	6.83	0.49	894	1085	1519
21	6.83	0.49	894	1085	1519
22	6.26	0.49	979	1187	1663
23	6.26	0.49	979	1187	1663
24	6.26	0.49	979	1187	1663
25	6.26	0.49	979	1187	1663
26	6.26	0.49	979	1187	1663
27	7.33	0.49	1012	1228	1720
28	7.33	0.49	1012	1228	1720
29	7.33	0.49	1012	1228	1720
30	7.33	0.49	1012	1228	1720
31	7.33	0.49	1012	1228	1720
32	8.47	0.49	1012	1228	1720
33	8.13	0.49	1055	1280	1792
34	8.13	0.49	1055	1280	1792

Figure A24 - Predicted P-wave velocities from possible Poisson's ratios (0.47, 0.48 and 0.49) at station 7035. Average Poisson's ratio (PR) measured is 0.488 with standard deviation of 0.01. PR 0.50 suggests a Vp correction from 1449 to 886 m/sec (based on assumed PR=0.49).

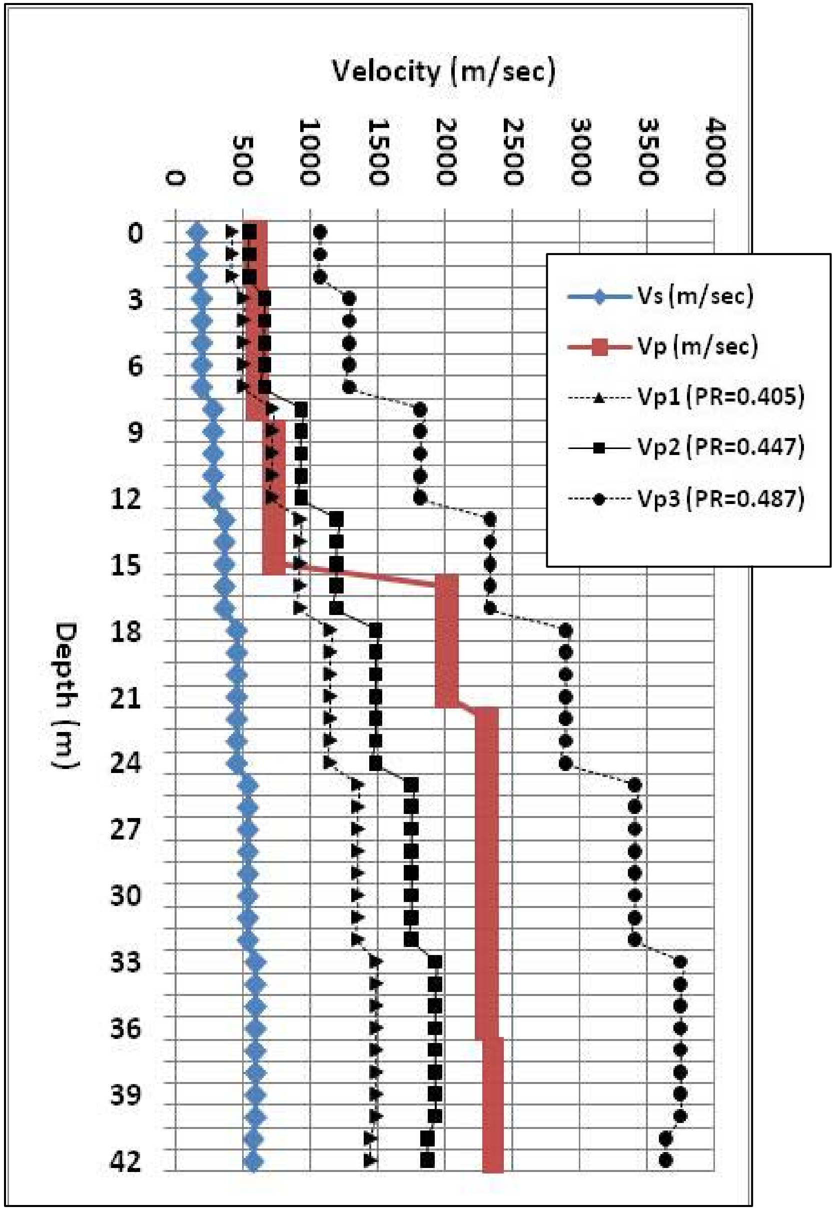


From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	3.3	171.63		0.0	3.1	596.59
3.3	7.5	205.99		3.1	9.4	610.26
7.5	12.5	290.15		9.4	15.6	733.09
12.5	18.3	372.17		15.6	21.9	2015.97
18.3	25.0	460.85		21.9	36.9	2312.71
25.0	30.0	542.55		36.9	51.9	2359.38
30.0	32.5	542.55		51.9	66.9	2376.04
32.5	40.8	596.50		66.9	81.9	2377.30
40.8	50.0	580.06		81.9	0.0	2380.43
50.0	60.0	489.78				
60.0		639.76				

Site Geology
This site is on Vashon recessional outwash sand informally called the Tumwater Sand (Walsh and others, 2003; Logan and others, 2009). A water well at this site has 39 ft of sand overlying about 100 ft of sand and gravel with some silty interbeds.

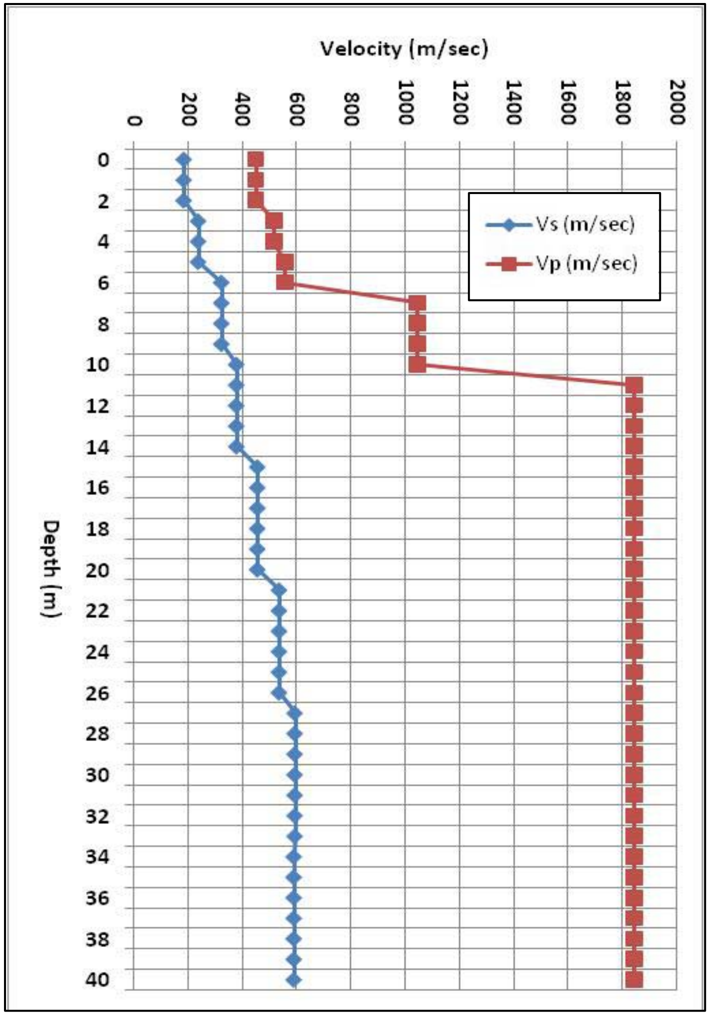
Vs30m = 312 m/sec (max depth resolved =40m)
NEHRP Site Classification = D

Figure A25. S-wave and P-wave velocity profiles and site geology at 7038, Tumwater, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.405)	Vp2 (PR=0.447)	Vp3 (PR=0.487)
0	3.48	0.45	430	554	1078
1	3.48	0.45	430	554	1078
2	3.48	0.45	430	554	1078
3	2.96	0.44	516	665	1294
4	2.96	0.44	516	665	1294
5	2.96	0.44	516	665	1294
6	2.96	0.44	516	665	1294
7	2.96	0.44	516	665	1294
8	2.10	0.35	726	937	1823
9	2.53	0.41	726	937	1823
10	2.53	0.41	726	937	1823
11	2.53	0.41	726	937	1823
12	2.53	0.41	726	937	1823
13	1.97	0.33	931	1202	2338
14	1.97	0.33	931	1202	2338
15	1.97	0.33	931	1202	2338
16	5.42	0.48	931	1202	2338
17	5.42	0.48	931	1202	2338
18	4.37	0.47	1153	1489	2895
19	4.37	0.47	1153	1489	2895
20	4.37	0.47	1153	1489	2895
21	4.37	0.47	1153	1489	2895
22	5.02	0.48	1153	1489	2895
23	5.02	0.48	1153	1489	2895
24	5.02	0.48	1153	1489	2895
25	4.26	0.47	1358	1753	3408
26	4.26	0.47	1358	1753	3408
27	4.26	0.47	1358	1753	3408
28	4.26	0.47	1358	1753	3408
29	4.26	0.47	1358	1753	3408
30	4.26	0.47	1358	1753	3408
31	4.26	0.47	1358	1753	3408
32	4.26	0.47	1358	1753	3408
33	3.88	0.46	1493	1927	3747
34	3.88	0.46	1493	1927	3747
35	3.88	0.46	1493	1927	3747
36	3.88	0.46	1493	1927	3747
37	3.96	0.47	1493	1927	3747
38	3.96	0.47	1493	1927	3747
39	3.96	0.47	1493	1927	3747
40	3.96	0.47	1493	1927	3747
41	4.07	0.47	1452	1874	3644
42	4.07	0.47	1452	1874	3644

Figure A26 - Predicted P-wave velocities from possible Poisson's ratios (0.41, 0.45 and 0.49) at station 7038. Average measured Poisson's ratio (PR) is 0.448 with standard deviation of 0.04.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	2.8	186.32		0.0	0.9	450.00
2.8	6.3	239.61		0.9	2.8	450.03
6.3	10.4	325.28		2.8	4.7	518.39
10.4	15.3	380.36		4.7	6.6	558.79
15.3	20.8	458.30		6.6	11.1	1046.72
20.8	27.1	538.10		11.1	15.6	1844.87
27.1	34.0	595.80		15.6	20.1	1845.12
34.0	41.7	592.37		20.1	24.6	1845.37
41.7	50.0	519.68		24.6	29.1	1845.62
50.0		676.57		29.1		1845.62

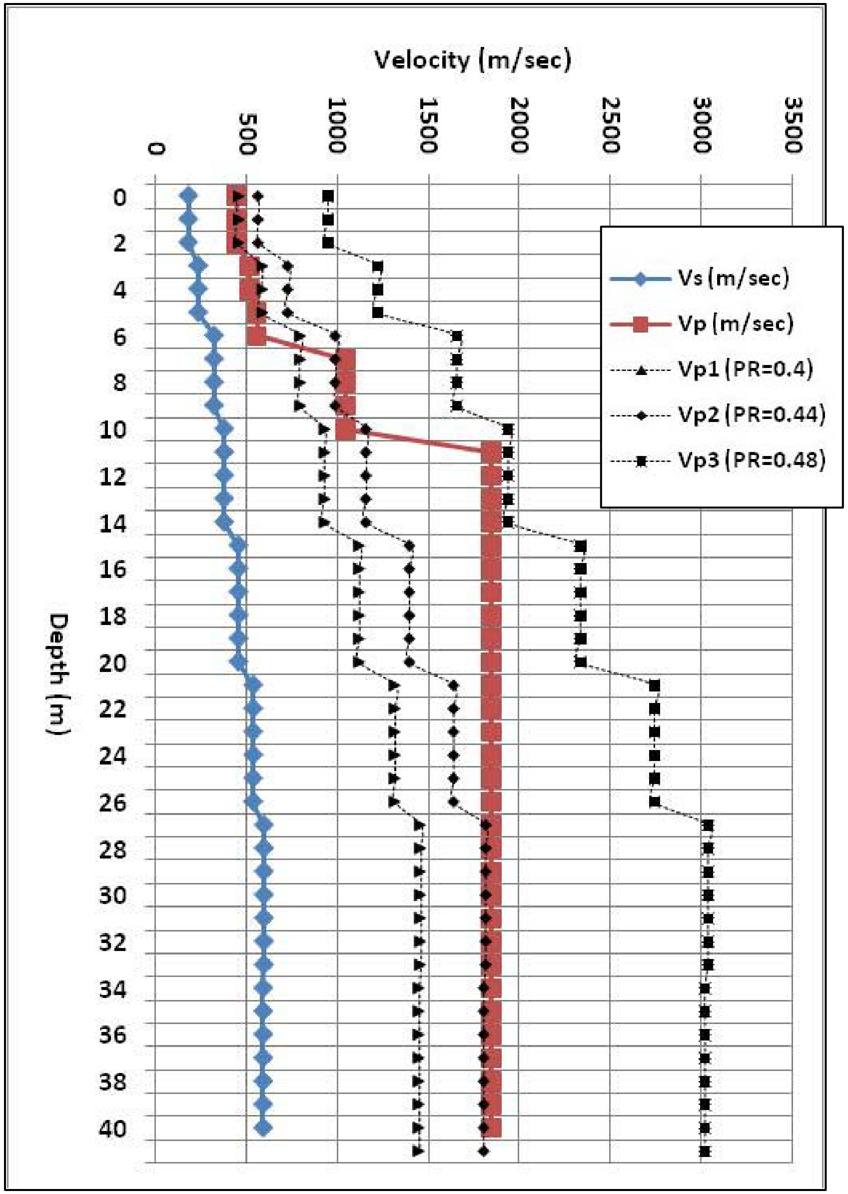
Site Geology
This site is on latest Wisconsinan alpine drift of the Olympic Mountains (Logan, 2003). Monitoring wells at the site encountered at least 50 ft of sand and gravel with some silty layers. Total thickness is unknown.

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
2.83	309	27

(*)See Table 3 for details

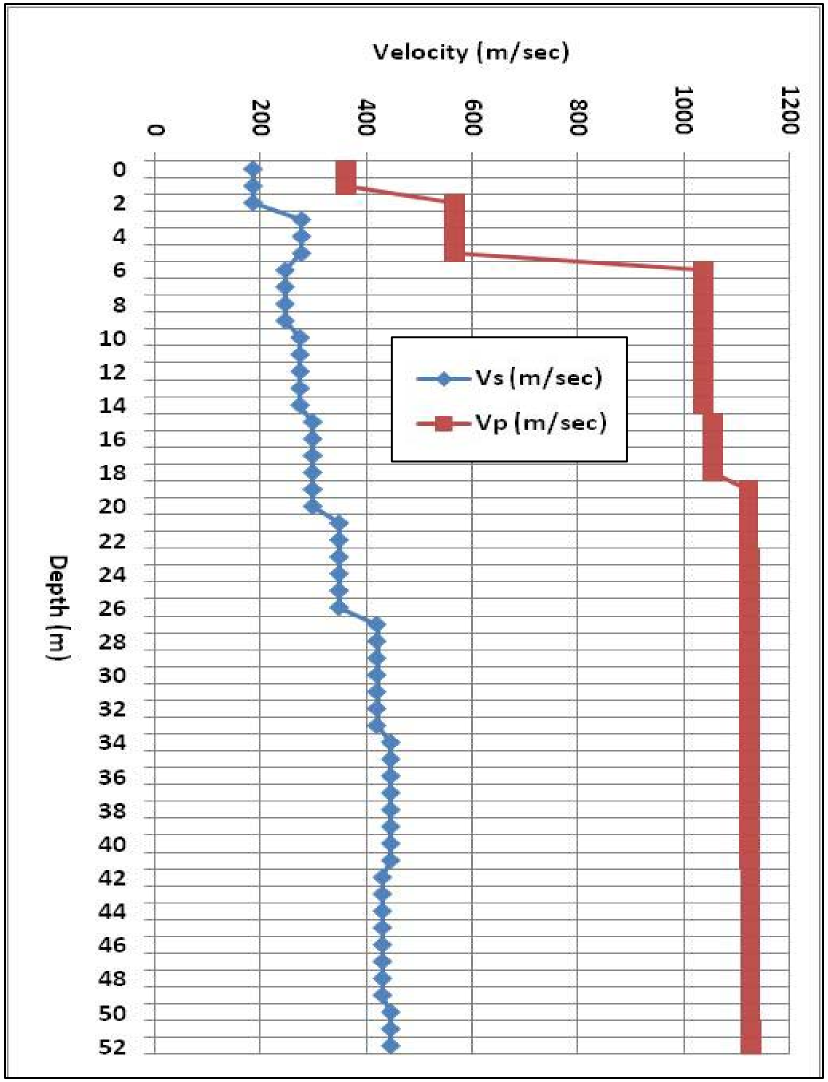
Vs30m = 359 m/sec (max depth resolved =40m)
NEHRP Site Classification = D-C

Figure A27. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7039, Lake Quinalt, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.4)	Vp2 (PR=0.44)	Vp3 (PR=0.48)
0	2.42	0.40	456	569	950
1	2.42	0.40	456	569	950
2	2.42	0.40	456	569	950
3	2.16	0.36	587	732	1222
4	2.16	0.36	587	732	1222
5	2.33	0.39	587	732	1222
6	1.72	0.24	797	994	1659
7	3.22	0.45	797	994	1659
8	3.22	0.45	797	994	1659
9	3.22	0.45	797	994	1659
10	2.75	0.42	932	1162	1939
11	4.85	0.48	932	1162	1939
12	4.85	0.48	932	1162	1939
13	4.85	0.48	932	1162	1939
14	4.85	0.48	932	1162	1939
15	4.03	0.47	1123	1400	2337
16	4.03	0.47	1123	1400	2337
17	4.03	0.47	1123	1400	2337
18	4.03	0.47	1123	1400	2337
19	4.03	0.47	1123	1400	2337
20	4.03	0.47	1123	1400	2337
21	3.43	0.45	1318	1644	2744
22	3.43	0.45	1318	1644	2744
23	3.43	0.45	1318	1644	2744
24	3.43	0.45	1318	1644	2744
25	3.43	0.45	1318	1644	2744
26	3.43	0.45	1318	1644	2744
27	3.10	0.44	1459	1820	3038
28	3.10	0.44	1459	1820	3038
29	3.10	0.44	1459	1820	3038
30	3.10	0.44	1459	1820	3038
31	3.10	0.44	1459	1820	3038
32	3.10	0.44	1459	1820	3038
33	3.10	0.44	1459	1820	3038
34	3.12	0.44	1451	1810	3021
35	3.12	0.44	1451	1810	3021
36	3.12	0.44	1451	1810	3021

Figure A28. Predicted P-wave velocities from possible Poisson's ratios (0.40, 0.44 and 0.48) at station 7039. Average measured Poisson's ratio (PR) is 0.44 with standard deviation of 0.04.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	2.8	186.34		0.0	2.1	361.33
2.8	6.3	278.51		2.1	6.3	567.28
6.3	10.4	247.31		6.3	10.4	1036.89
10.4	15.3	275.56		10.4	14.6	1037.89
15.3	20.8	299.48		14.6	18.8	1056.21
20.8	27.1	349.35		18.8	22.9	1123.00
27.1	30.0	420.58		22.9		1124.00
30.0	34.0	420.58				
34.0	41.7	447.09				
41.7	50.0	431.41				
50.0		447.09				

Site Geology

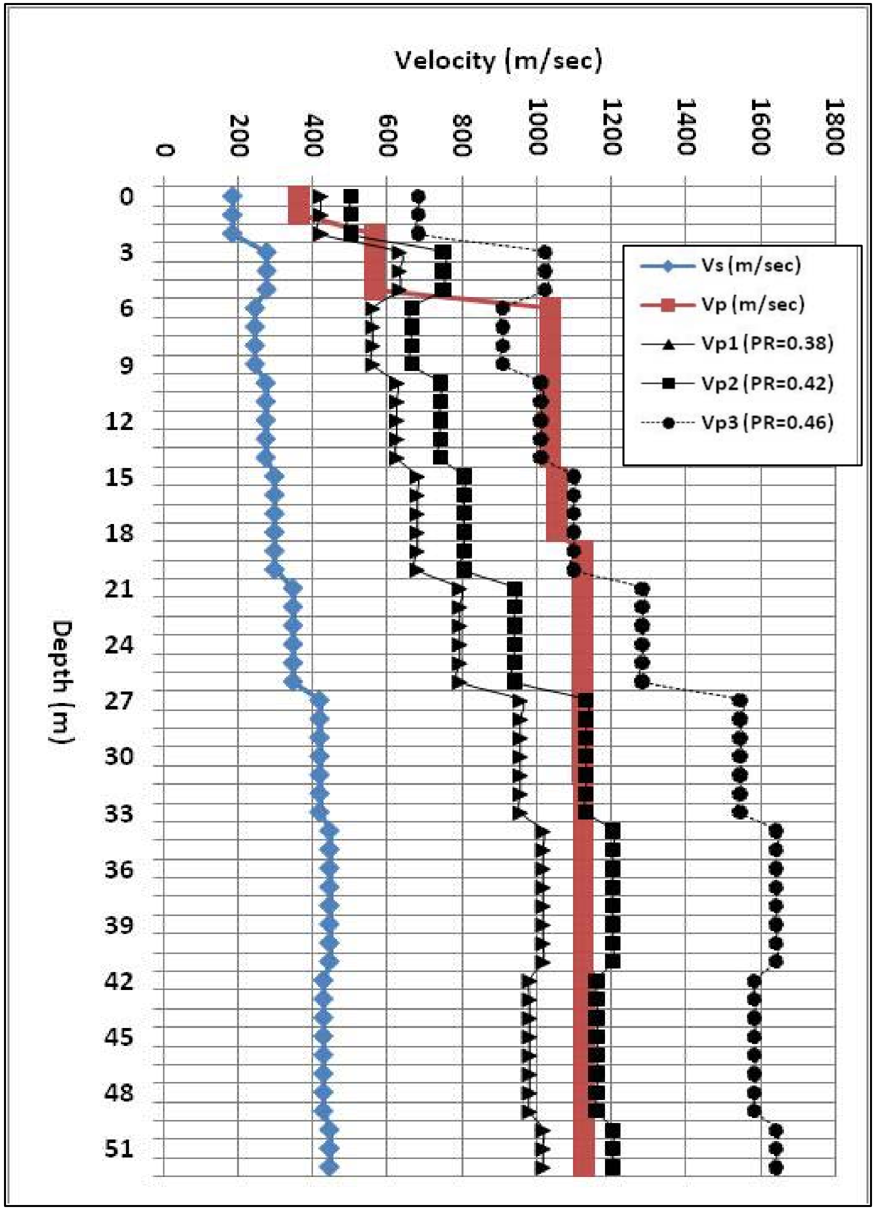
This site is underlain by Vashon till. The nearest water well, about 1,000 ft to the south southeast, encountered 36 ft of till overlying a about 100 ft thick, sandy clay?

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
0.52	512	246

(*)See Table 3 for details

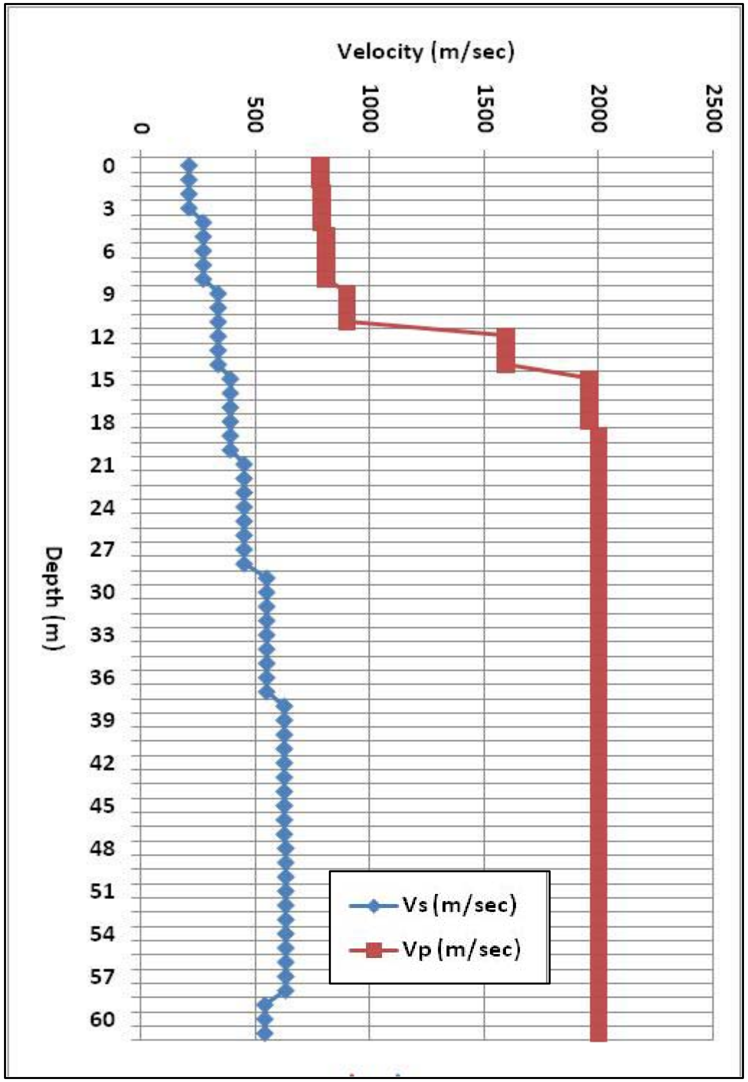
Vs30m = 285 m/sec (max depth resolved =56m)
NEHRP Site Classification = D

Figure A29. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7040, (Museum) Port Gamble, Washington.



Depth (m/sec)	Vp/Vs	PR (Measured)	Vp1 (PR=0.38)	Vp2 (PR=0.42)	Vp3 (PR=0.46)
0	1.94	0.32	424	502	685
1	1.94	0.32	424	502	685
2	3.04	0.44	424	502	685
3	2.04	0.34	633	750	1023
4	2.04	0.34	633	750	1023
5	2.04	0.34	633	750	1023
6	4.19	0.47	562	666	909
7	4.19	0.47	562	666	909
8	4.19	0.47	562	666	909
9	4.19	0.47	562	666	909
10	3.77	0.46	626	742	1012
11	3.77	0.46	626	742	1012
12	3.77	0.46	626	742	1012
13	3.77	0.46	626	742	1012
14	3.77	0.46	626	742	1012
15	3.53	0.46	681	806	1100
16	3.53	0.46	681	806	1100
17	3.53	0.46	681	806	1100
18	3.53	0.46	681	806	1100
19	3.75	0.46	681	806	1100
20	3.75	0.46	681	806	1100
21	3.21	0.45	794	941	1284
22	3.21	0.45	794	941	1284
23	3.22	0.45	794	941	1284
24	3.22	0.45	794	941	1284
25	3.22	0.45	794	941	1284
26	3.22	0.45	794	941	1284
27	2.67	0.42	956	1132	1545
28	2.67	0.42	956	1132	1545
29	2.67	0.42	956	1132	1545
30	2.67	0.42	956	1132	1545
31	2.67	0.42	956	1132	1545
32	2.67	0.42	956	1132	1545
33	2.67	0.42	956	1132	1545
34	2.52	0.41	1016	1204	1643
35	2.52	0.41	1016	1204	1643

Figure A30. Predicted P-wave velocities from possible Poisson's ratios (0.38, 0.42 and 0.46) at station 7040. Average measured Poisson's ratio (PR) is 0.42 with standard deviation of 0.04.



Vs30m = 339 m/sec (max depth resolved =53m)
NEHRP Site Classification = D

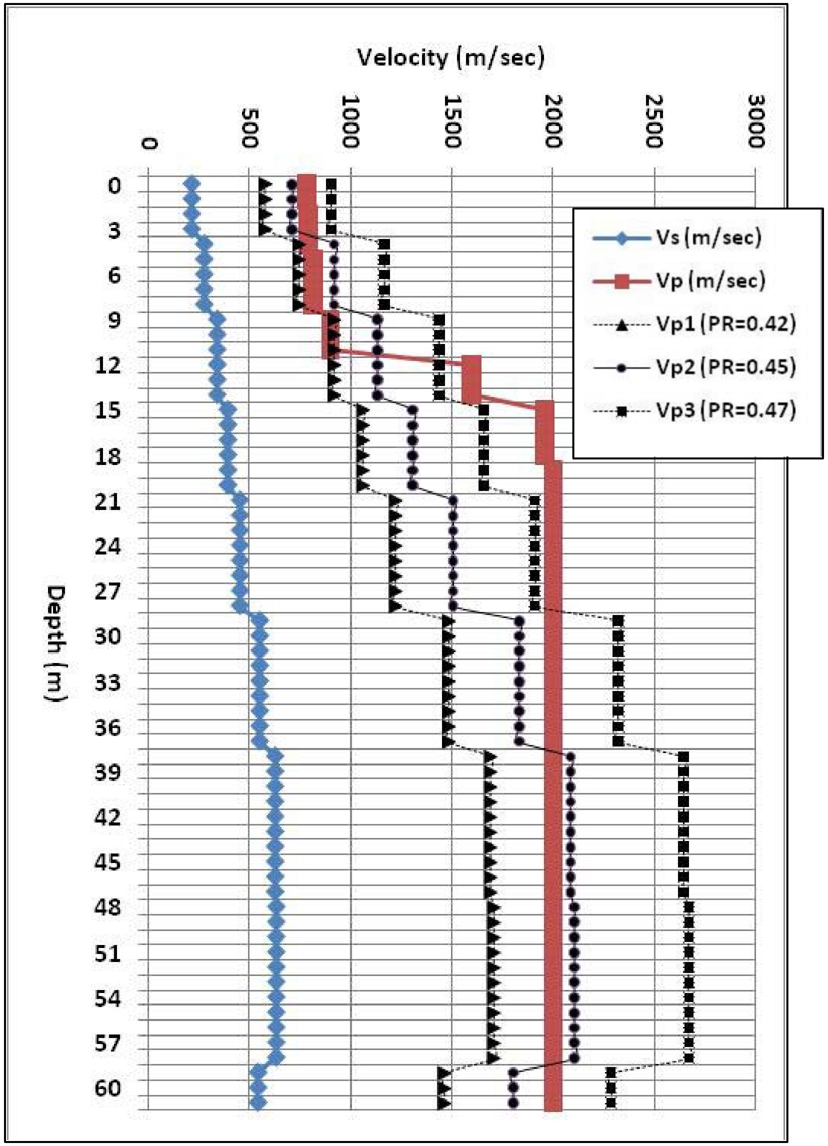
From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	3.9	215.09		0.0	0.7	783.29
3.9	8.8	277.39		0.7	2.2	784.29
8.8	14.6	342.00		2.2	3.6	789.86
14.6	21.4	394.61		3.6	5.0	789.86
21.4	29.2	454.78		5.0	8.5	811.64
29.2	30.0	552.74		8.5	11.9	901.53
30.0	37.9	552.74		11.9	15.4	1597.39
37.9	47.6	629.39		15.4	18.8	1961.33
47.6	58.3	635.50		18.8	22.3	2000.00
58.3	70.0	544.48		22.3		2000.00
70.0		727.71				

Site Geology
This site is underlain by sandy recessional outwash of latest Wisconsinan age (Schasse and other, 2004). Marine mudstone (Pysht Formation) is exposed about ¾ mile southeast of here. Well logs are difficult to interpret but show that unconsolidated sediments are at least 50 ft thick midway between this site and the bedrock exposures, and a well 3 blocks west of this site penetrated unconsolidated sediments to a depth of 155 ft,suggesting that the thickness of sediments here is >100 ft.

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
2.69	313	29

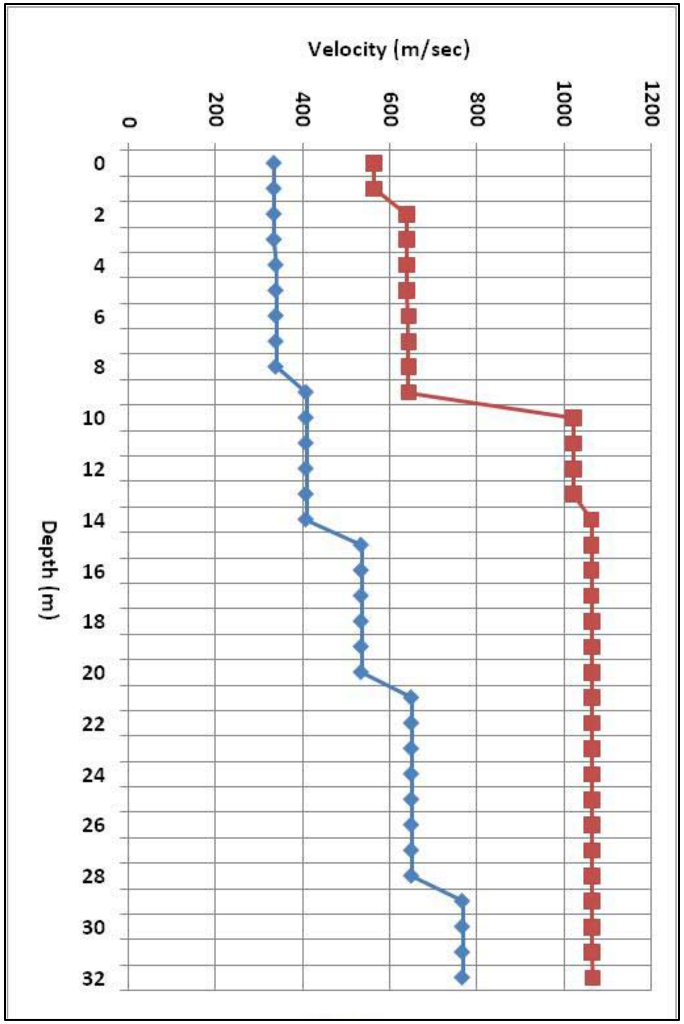
(*)See Table 3 for details.

Figure A31. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7041, Port Angeles, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.42)	Vp2 (PR=0.45)	Vp3 (PR=0.47)
0	3.64	0.46	579	713	904
1	3.65	0.46	579	713	904
2	3.67	0.46	579	713	904
3	3.67	0.46	579	713	904
4	2.85	0.43	747	920	1166
5	2.93	0.43	747	920	1166
6	2.93	0.43	747	920	1166
7	2.93	0.43	747	920	1166
8	2.93	0.43	747	920	1166
9	2.64	0.42	921	1134	1437
10	2.64	0.42	921	1134	1437
11	2.64	0.42	921	1134	1437
12	4.67	0.48	921	1134	1437
13	4.67	0.48	921	1134	1437
14	4.67	0.48	921	1134	1437
15	4.97	0.48	1063	1309	1659
16	4.97	0.48	1063	1309	1659
17	4.97	0.48	1063	1309	1659
18	4.97	0.48	1063	1309	1659
19	5.07	0.48	1063	1309	1659
20	5.07	0.48	1063	1309	1659
21	4.40	0.47	1225	1508	1912
22	4.40	0.47	1225	1508	1912
23	4.40	0.47	1225	1508	1912
24	4.40	0.47	1225	1508	1912
25	4.40	0.47	1225	1508	1912
26	4.40	0.47	1225	1508	1912
27	4.40	0.47	1225	1508	1912
28	4.40	0.47	1225	1508	1912
29	3.62	0.46	1488	1833	2323
30	3.62	0.46	1488	1833	2323
31	3.62	0.46	1488	1833	2323
32	3.62	0.46	1488	1833	2323
33	3.62	0.46	1488	1833	2323
34	3.62	0.46	1488	1833	2323
35	3.62	0.46	1488	1833	2323

Figure A32. Predicted P-wave velocities from possible Poisson's ratios (0.42, 0.45 and 0.47) at station 7041. Average measured Poisson's ratio (PR) is 0.45 with standard deviation of 0.02.



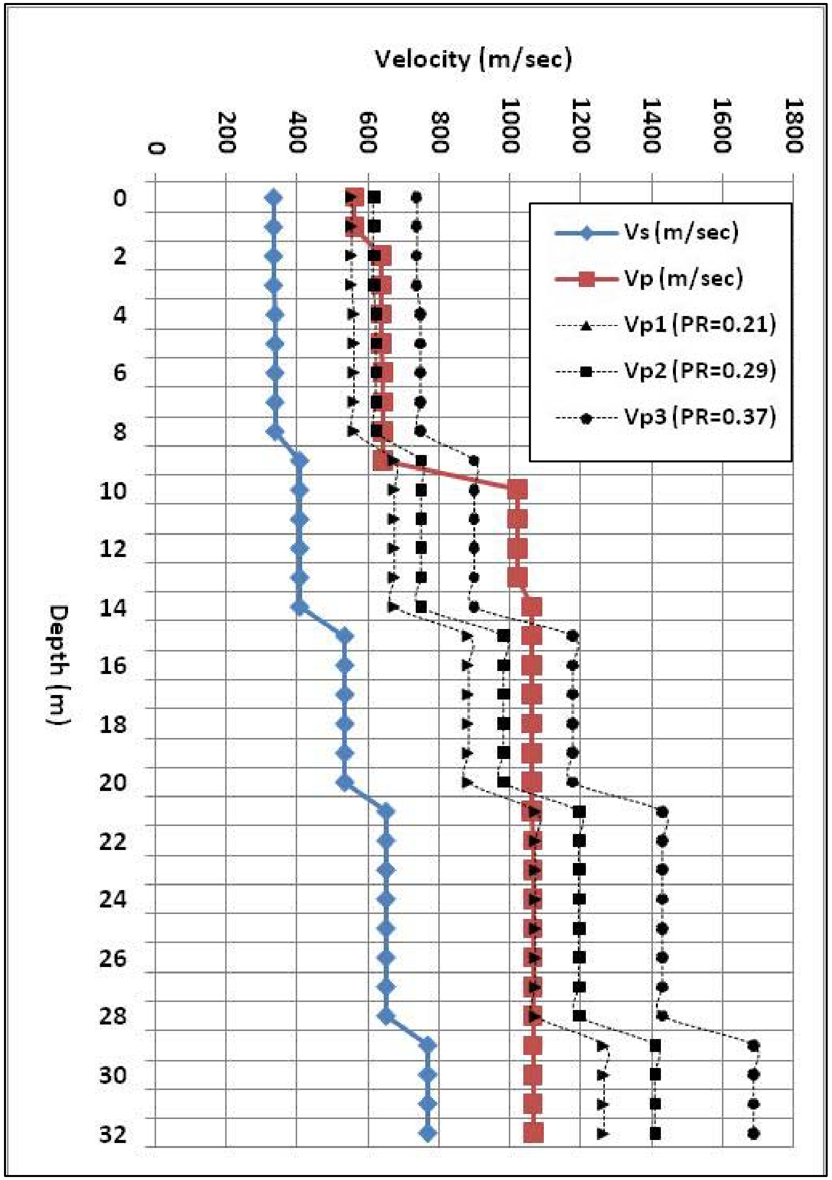
From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	3.9	335.08		0.0	2.0	562.82
3.9	8.8	339.32		2.0	6.1	638.88
8.8	14.6	408.49		6.1	10.2	643.19
14.6	21.4	535.21		10.2	14.3	1021.29
21.4	29.2	650.51		14.3	18.4	1063.05
29.2	30.0	767.54		18.4	22.4	1064.05
30.0	37.9	767.54		22.4	31.6	1065.05
37.9	47.6	789.21		31.6		1066.05
47.6	58.3	742.50				
58.3	70.0	641.27				
70.0		829.11				

Site Geology

This site is underlain by a bar and channel complex of the gravel facies of the cataclysmic food deposits of the Missoula floods (Evarts and O'Connor, 2008). These are bouldery- to cobbly gravel and sand deposits, with angular basaltic andesite boulders as much as 7m across in a matrix of rounded cobbles and pebbles (Evarts and O'Connor, 2008). Nearby water wells show this unit to be more than 150 ft thick.

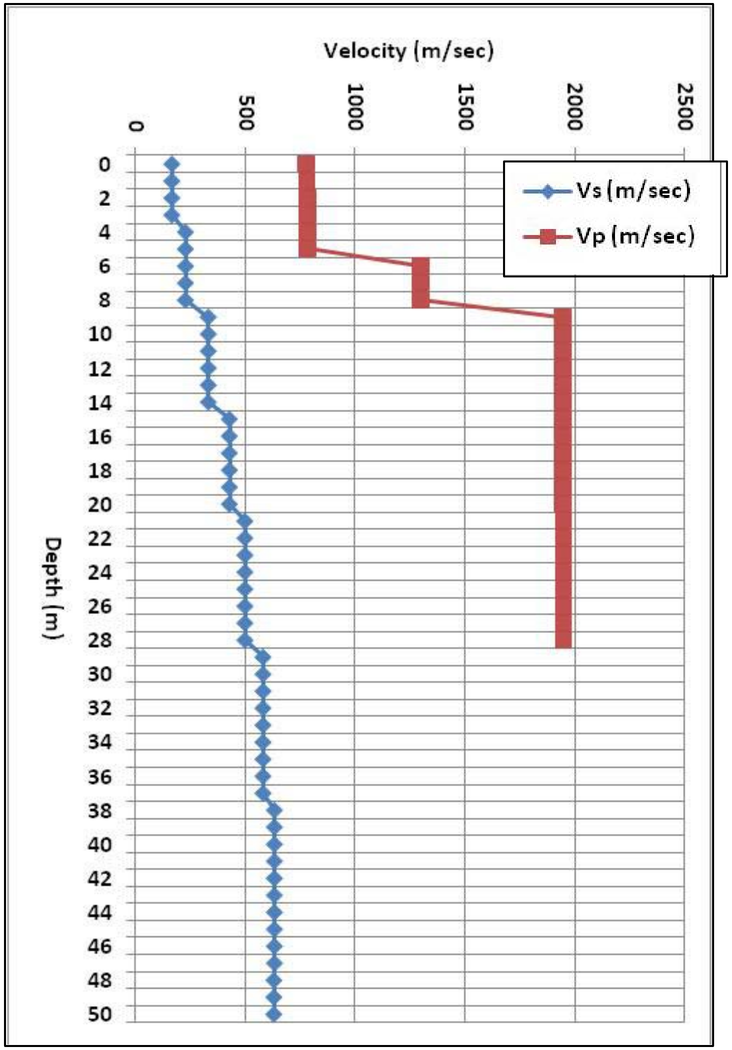
Vs30m = 455 m/sec (max depth resolved =63m)
NEHRP Site Classification = C

Figure A33. S-wave and P-wave velocity profiles and site geology at 7042, CVO, Vancouver, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.21)	Vp2 (PR=0.29)	Vp3 (PR=0.37)
0	1.68	0.23	553	616	738
1	1.68	0.23	553	616	738
2	1.91	0.31	553	616	738
3	1.91	0.31	553	616	738
4	1.88	0.30	560	624	747
5	1.88	0.30	560	624	747
6	1.90	0.31	560	624	747
7	1.90	0.31	560	624	747
8	1.90	0.31	560	624	747
9	1.57	0.16	674	751	899
10	2.50	0.40	674	751	899
11	2.50	0.40	674	751	899
12	2.50	0.40	674	751	899
13	2.50	0.40	674	751	899
14	2.60	0.41	674	751	899
15	1.99	0.33	883	984	1178
16	1.99	0.33	883	984	1178
17	1.99	0.33	883	984	1178
18	1.99	0.33	883	984	1178
19	1.99	0.33	883	984	1178
20	1.99	0.33	883	984	1178
21	1.64	0.20	1074	1196	1432
22	1.64	0.20	1074	1196	1432
23	1.64	0.20	1074	1196	1432
24	1.64	0.20	1074	1196	1432
25	1.64	0.20	1074	1196	1432
26	1.64	0.20	1074	1196	1432
27	1.64	0.20	1074	1196	1432
28	1.64	0.20	1074	1196	1432
29	1.39	-0.04	1267	1411	1690
30	1.39	-0.04	1267	1411	1690
31	1.39	-0.04	1267	1411	1690
32	1.39	-0.04	1267	1411	1690

Figure A34. Predicted P-wave velocities from possible Poisson's ratios (0.21, 0.29 and 0.37) at station 7042. Average measured Poisson's ratio (PR) is 0.29 with standard deviation of 0.08.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	3.9	167.95		0.0	0.8	778.64
3.9	8.8	229.85		0.8	2.3	781.16
8.8	14.6	333.69		2.3	3.9	781.66
14.6	21.4	429.22		3.9	5.5	782.16
21.4	29.2	499.98		5.5	9.2	1299.41
29.2	30.0	582.36		9.2	13.0	1945.48
30.0	37.9	582.36		13.0	16.7	1946.48
37.9	47.6	633.95		16.7	20.5	1947.48
47.6	58.3	631.46		20.5	24.2	1948.48
58.3	70.0	595.33		24.2		1949.48
70.0		683.46				

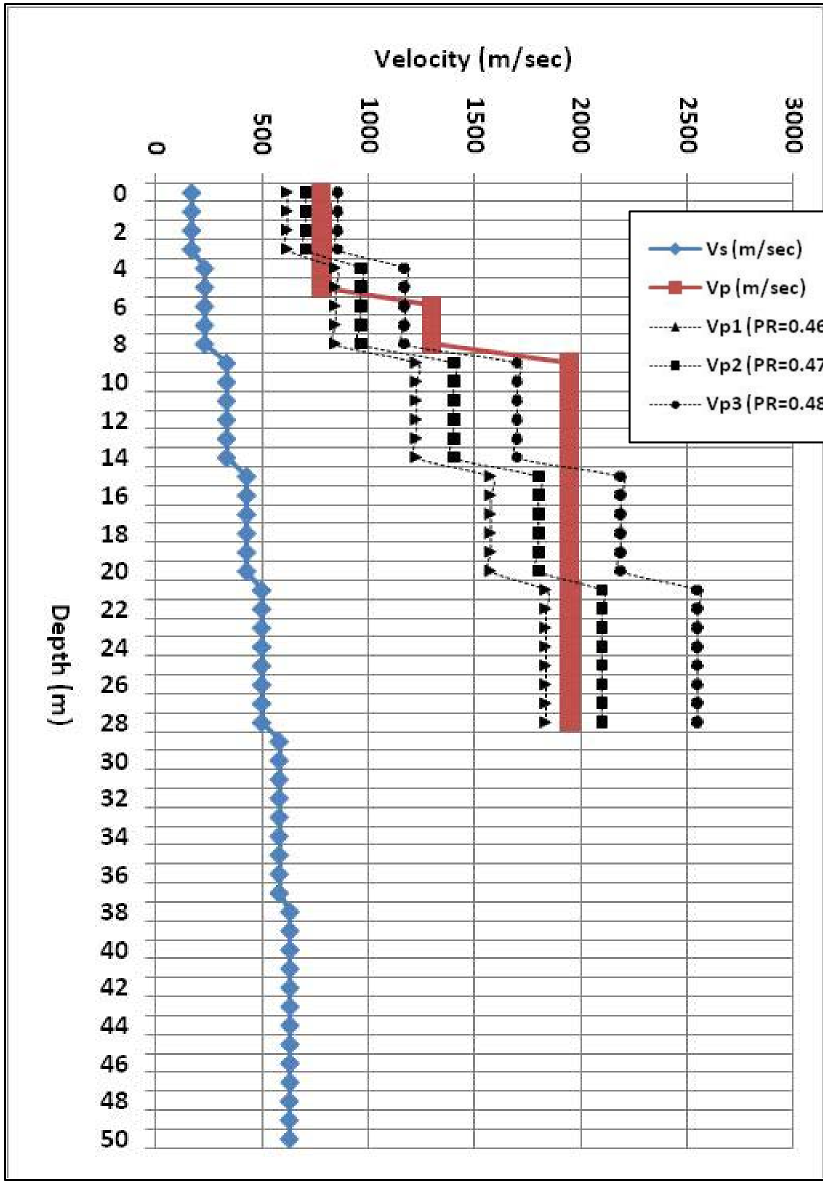
Site Geology
This site is underlain by thin glacial drift underlain by Eocene sandstone, siltstone, and coal of the Chuckanut Formation (Lapen, 2000). A water well 6 blocks west of this site penetrated 25 ft of silt and sand and gravel. The thickness of the drift at this site is unknown.

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
7.27	246	8

(*)See Table 3 for details

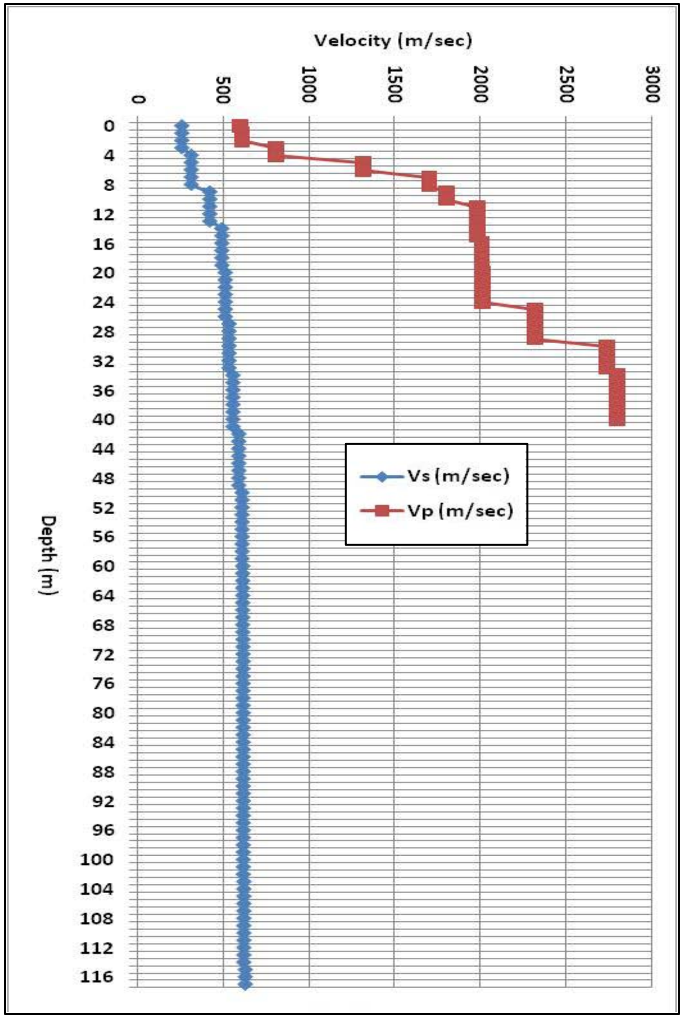
Vs30m = 317 m/sec (max depth resolved =52m)
NEHRP Site Classification = D

Figure A35. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7043, Bellingham, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.46)	Vp2 (PR=0.47)	Vp3 (PR=0.48)
0	4.64	0.48	617	706	856
1	4.65	0.48	617	706	856
2	4.65	0.48	617	706	856
3	4.65	0.48	617	706	856
4	3.40	0.45	845	966	1172
5	3.40	0.45	845	966	1172
6	5.65	0.48	845	966	1172
7	5.65	0.48	845	966	1172
8	5.65	0.48	845	966	1172
9	5.83	0.48	1226	1403	1702
10	5.83	0.48	1226	1403	1702
11	5.83	0.48	1226	1403	1702
12	5.83	0.48	1226	1403	1702
13	5.83	0.48	1226	1403	1702
14	5.83	0.48	1226	1403	1702
15	4.53	0.47	1577	1804	2189
16	4.53	0.47	1577	1804	2189
17	4.54	0.47	1577	1804	2189
18	4.54	0.47	1577	1804	2189
19	4.54	0.47	1577	1804	2189
20	4.54	0.47	1577	1804	2189
21	3.90	0.46	1837	2101	2549
22	3.90	0.46	1837	2101	2549
23	3.90	0.46	1837	2101	2549
24	3.90	0.46	1837	2101	2549
25	3.90	0.46	1837	2101	2549
26	3.90	0.46	1837	2101	2549
27	3.90	0.46	1837	2101	2549
28	3.90	0.46	1837	2101	2549

Figure A36. Predicted P-wave velocities from possible Poisson's ratios (0.46, 0.47 and 0.48) at station 7043. Average measured Poisson's ratio (PR) is 0.47 with standard deviation of 0.01.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	4.1	260.13		0.0	1.0	600.00
4.1	8.8	315.48		1.0	3.1	611.80
8.8	14.2	425.03		3.1	5.1	806.97
14.2	20.2	496.07		5.1	7.1	1316.97
20.2	26.9	516.41		7.1	9.2	1701.33
26.9	30.0	538.51		9.2	11.2	1805.29
30.0	34.1	538.51		11.2	15.8	1980.96
34.1	42.0	561.55		15.8	20.4	2008.08
42.0	50.5	595.76		20.4	25.0	2011.40
50.5	59.7	615.49		25.0	29.6	2317.24
59.7	69.5	619.19		29.6	34.2	2739.30
69.5	79.9	621.31		34.2	38.8	2800.00
79.9	91.0	621.96		38.8	43.3	2800.00
91.0	102.7	622.60		43.3	47.9	2800.00
102.7	115.0	625.72		47.9		2800.00
115.0		634.02				

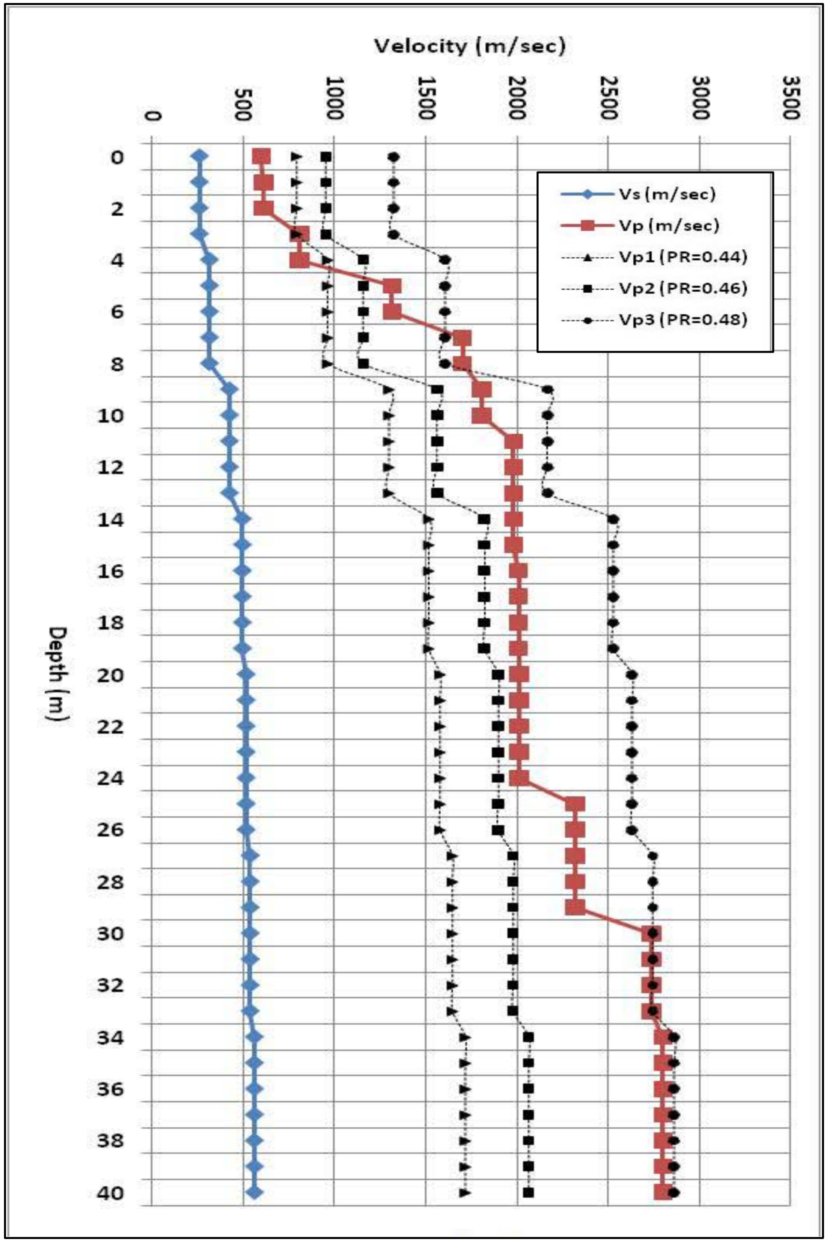
Site Geology

This site is underlain by sand and gravel of the Clover Creek channel of Steilacoom Gravel (Troost, in review). The gravel is 110 ft thick in a borehole about 650 ft northwest of here, and overlies a thick section of sand.

Vs30m = 404 m/sec (max depth resolved = 105 m)

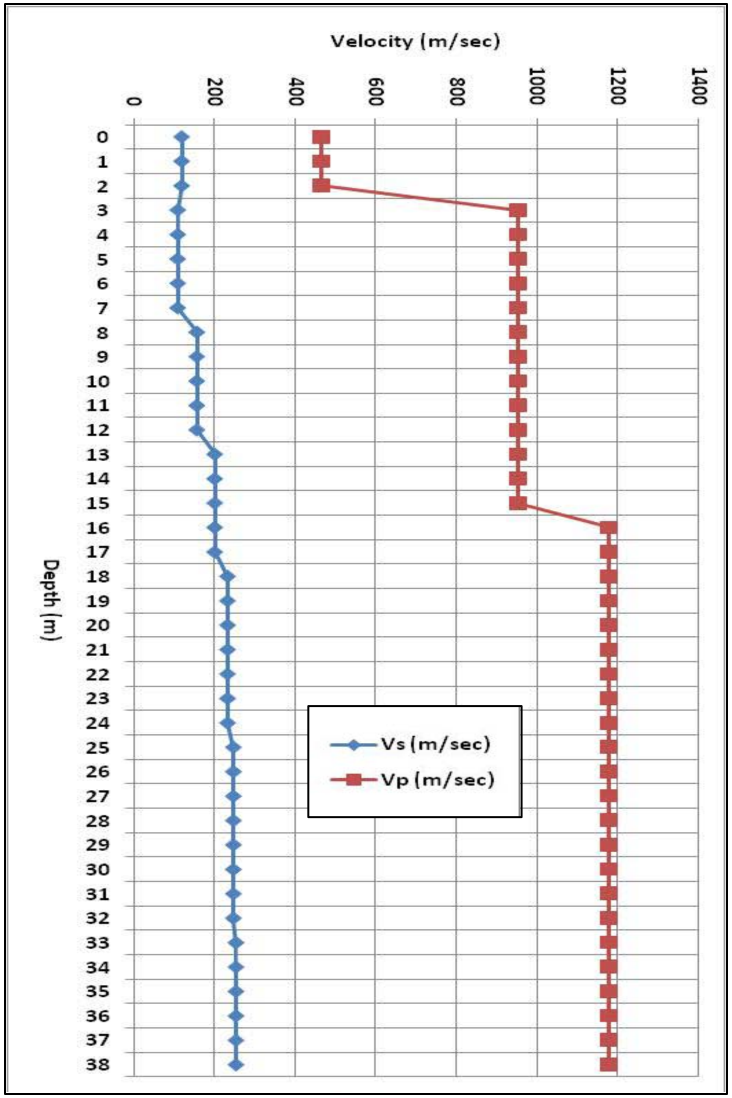
NEHRP Site Classification = C

Figure A37. S-wave and P-wave velocity profiles and site geology at 7044, McChord, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.44)	Vp2 (PR=0.46)	Vp3 (PR=0.48)
0	2.31	0.38	795	956	1326
1	2.35	0.39	795	956	1326
2	2.35	0.39	795	956	1326
3	3.10	0.44	795	956	1326
4	2.56	0.41	964	1159	1609
5	4.17	0.47	964	1159	1609
6	4.17	0.47	964	1159	1609
7	5.39	0.48	964	1159	1609
8	5.39	0.48	964	1159	1609
9	4.25	0.47	1298	1562	2167
10	4.25	0.47	1298	1562	2167
11	4.66	0.48	1298	1562	2167
12	4.66	0.48	1298	1562	2167
13	4.66	0.48	1298	1562	2167
14	3.99	0.47	1516	1823	2529
15	3.99	0.47	1516	1823	2529
16	4.05	0.47	1516	1823	2529
17	4.05	0.47	1516	1823	2529
18	4.05	0.47	1516	1823	2529
19	4.05	0.47	1516	1823	2529
20	3.89	0.46	1578	1897	2633
21	3.89	0.46	1578	1897	2633
22	3.89	0.46	1578	1897	2633
23	3.89	0.46	1578	1897	2633
24	3.89	0.46	1578	1897	2633
25	4.49	0.47	1578	1897	2633
26	4.49	0.47	1578	1897	2633
27	4.30	0.47	1645	1979	2746
28	4.30	0.47	1645	1979	2746
29	4.30	0.47	1645	1979	2746
30	5.09	0.48	1645	1979	2746
31	5.09	0.48	1645	1979	2746
32	5.09	0.48	1645	1979	2746
33	5.09	0.48	1645	1979	2746
34	4.99	0.48	1716	2063	2863
35	4.99	0.48	1716	2063	2863
36	4.99	0.48	1716	2063	2863
37	4.99	0.48	1716	2063	2863
38	4.99	0.48	1716	2063	2863
39	4.99	0.48	1716	2063	2863
40	4.99	0.48	1716	2063	2863

Figure A38. Predicted P-wave velocities from possible Poisson's ratios (0.44, 0.46 and 0.48) at station 7044. Average measured Poisson's ratio (PR) is 0.46 with standard deviation of 0.02.



Vs30m = 171 m/sec (max depth resolved = 32 m)
NEHRP Site Classification = E

From	To	Vs (m/sec)
0.0	3.3	119.38
3.3	7.5	109.67
7.5	12.5	156.98
12.5	18.3	201.46
18.3	25.0	233.35
25.0	30.0	247.96
30.0	32.5	247.96
32.5	40.8	254.44
40.8		254.44

From	To	Vp (m/sec)
0.0	3.1	466.07
3.1	9.4	953.51
9.4	15.6	954.08
15.6	21.9	1177.34
21.9	36.9	1178.34

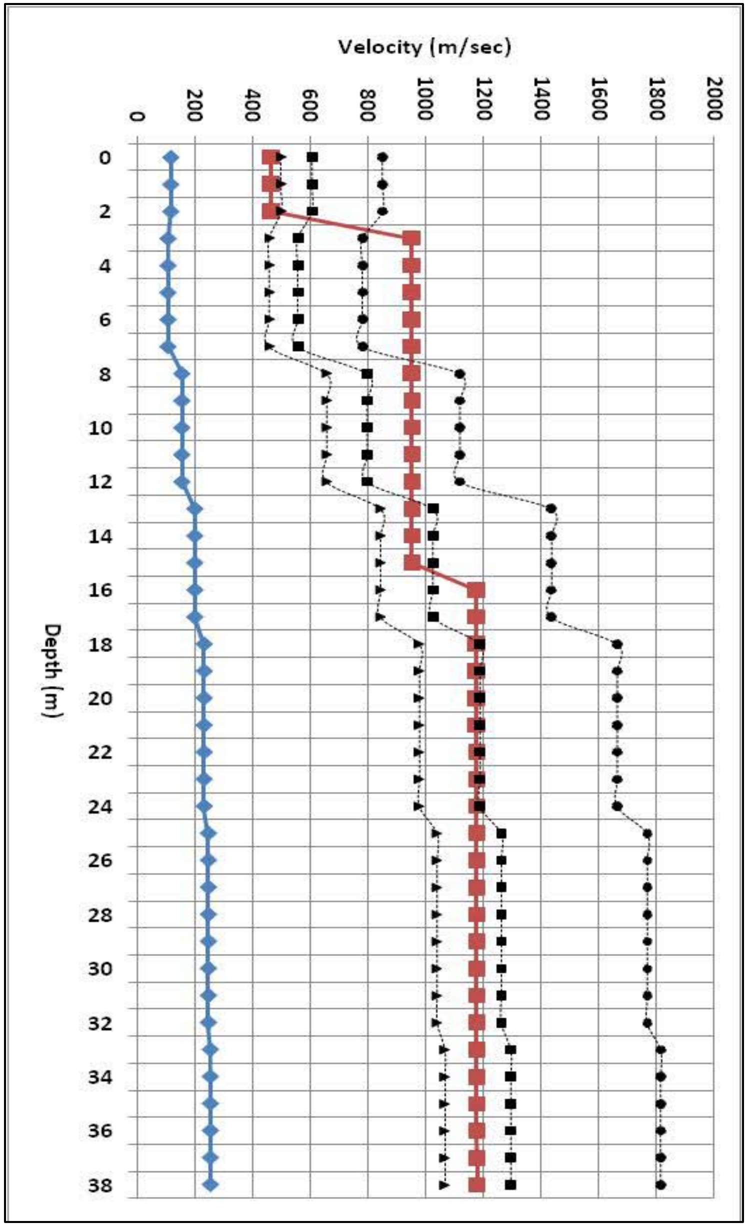
Site Geology

This site is underlain by Willapa River alluvium. Nearby water wells are too shallow to constrain the thickness of the alluvium. An oil well (Raymond Oil Co. Willapa #1) was drilled about ¾ mile southeast of her and encountered shale bedrock of the Astoria Formation at a depth of 34 ft (Wagner, 1967). The valley is narrow here and is bounded by Astoria Formation bedrock at distances of ~1/2-~3/4 mile from here, so the alluvium is not expected to be significantly deeper than 34 ft.

Measured Fundamental Frequency (Hz) on H/V (Albarello et al, 2011a) (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
1.6	363	57

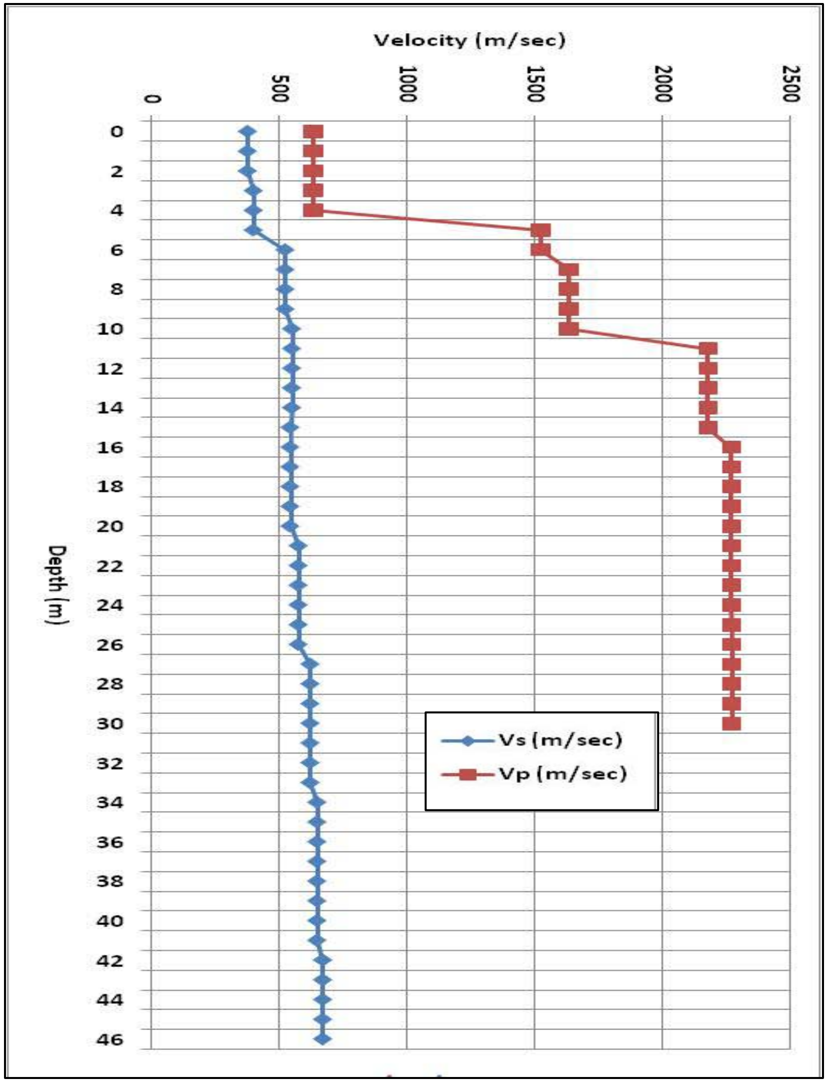
(*)See Table 3 for details

Figure A39. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7045, Raymond, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.46)	Vp2 (PR=0.47)	Vp3 (PR=0.47)
0	3.90	0.46	455	502	569
1	3.90	0.46	455	502	569
2	3.90	0.46	455	502	569
3	8.69	0.49	418	461	523
4	8.69	0.49	418	461	523
5	8.69	0.49	418	461	523
6	8.69	0.49	418	461	523
7	8.69	0.49	418	461	523
8	6.07	0.49	598	660	749
9	6.08	0.49	598	660	749
10	6.08	0.49	598	660	749
11	6.08	0.49	598	660	749
12	6.08	0.49	598	660	749
13	4.74	0.48	767	847	961
14	4.74	0.48	767	847	961
15	4.74	0.48	767	847	961
16	5.84	0.48	767	847	961
17	5.84	0.48	767	847	961
18	5.05	0.48	889	981	1113
19	5.05	0.48	889	981	1113
20	5.05	0.48	889	981	1113
21	5.05	0.48	889	981	1113
22	5.05	0.48	889	981	1113
23	5.05	0.48	889	981	1113
24	5.05	0.48	889	981	1113
25	4.75	0.48	945	1042	1182
26	4.75	0.48	945	1042	1182
27	4.75	0.48	945	1042	1182
28	4.75	0.48	945	1042	1182
29	4.75	0.48	945	1042	1182
30	4.75	0.48	945	1042	1182
31	4.75	0.48	945	1042	1182
32	4.75	0.48	945	1042	1182
33	4.63	0.48	969	1069	1213
34	4.63	0.48	969	1069	1213
35	4.63	0.48	969	1069	1213
36	4.63	0.48	969	1069	1213
37	4.64	0.48	969	1069	1213
38	4.64	0.48	969	1069	1213

Figure A40 Predicted P-wave velocities from possible Poisson's ratios (0.47, 0.48 and 0.49) at station 7045. Average measured Poisson's ratio (PR) is 0.48 with standard deviation of 0.01.

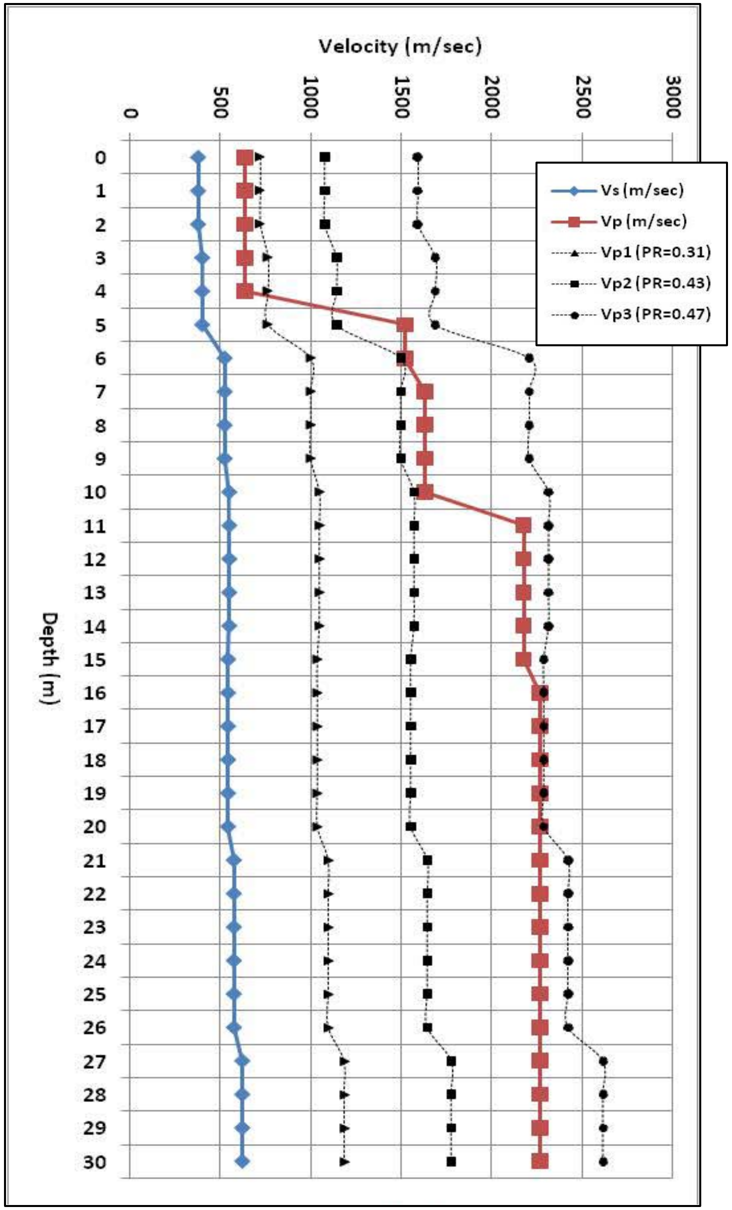


From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	2.8	379.15		0.0	0.9	481.65
2.8	6.3	401.90		0.9	2.8	534.06
6.3	10.4	525.68		2.8	4.7	635.09
10.4	15.3	551.15		4.7	6.6	1520.71
15.3	20.8	544.82		6.6	11.1	1632.84
20.8	27.1	576.73		11.1	15.6	2176.30
27.1	30.0	622.83		15.6	20.1	2268.01
30.0	34.0	622.83		20.1	24.6	2268.38
34.0	41.7	649.57		24.6	29.1	2268.75

Site Geology
This site is underlain by sand and gravel of the Clover Creek channel of Steilacoom Gravel (Troost and others, in review(a)). The gravel is at least 40 ft thick in a borehole near here and is probably considerably thicker, by comparison with Site 7044.

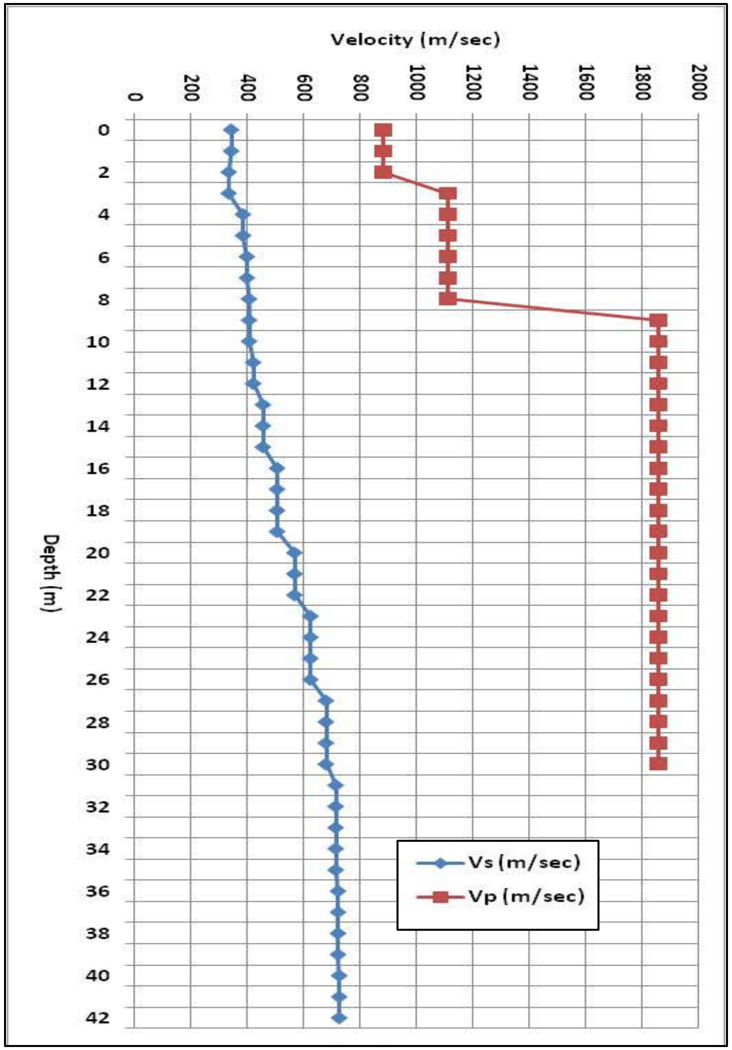
Vs30m = 513 m/sec (max depth resolved = 44 m)
NEHRP Site Classification = C

Figure A41 S-wave and P-wave velocity profiles and site geology at 7046, Camp Murray, Washington.



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.31)	Vp2 (PR=0.43)	Vp3 (PR=0.47)
0	1.68	0.22	723	1082	1594
1	1.68	0.22	723	1082	1594
2	1.68	0.22	723	1082	1594
3	1.58	0.17	766	1147	1689
4	1.58	0.17	766	1147	1689
5	3.78	0.46	766	1147	1689
6	2.89	0.43	1002	1500	2210
7	3.11	0.44	1002	1500	2210
8	3.11	0.44	1002	1500	2210
9	3.11	0.44	1002	1500	2210
10	2.96	0.44	1050	1573	2317
11	3.95	0.47	1050	1573	2317
12	3.95	0.47	1050	1573	2317
13	3.95	0.47	1050	1573	2317
14	3.95	0.47	1050	1573	2317
15	3.99	0.47	1038	1555	2290
16	4.16	0.47	1038	1555	2290
17	4.16	0.47	1038	1555	2290
18	4.16	0.47	1038	1555	2290
19	4.16	0.47	1038	1555	2290
20	4.16	0.47	1038	1555	2290
21	3.93	0.47	1099	1646	2424
22	3.93	0.47	1099	1646	2424
23	3.93	0.47	1099	1646	2424
24	3.93	0.47	1099	1646	2424
25	3.93	0.47	1099	1646	2424
26	3.93	0.47	1099	1646	2424
27	3.64	0.46	1187	1777	2618
28	3.64	0.46	1187	1777	2618
29	3.64	0.46	1187	1777	2618
30	3.64	0.46	1187	1777	2618

Figure A42. Predicted P-wave velocities from possible Poisson's ratios (0.31, 0.43 and 0.47) at station 7046. Average measured Poisson's ratio (PR) is 0.42 with standard deviation of 0.09 (highly variable). Note that Vp (635.09 m/sec) at 3m also assigned to Vp values at 0-2 m depth, because the PR values at these depths are negative.



From	To	Vs (m/sec)		From	To	Vp (m/sec)
0.0	1.6	345.08		0.0	3.0	500.00
1.6	3.5	336.50		3.0	9.1	1113.59
3.5	5.6	387.23		9.1	15.1	1857.52
5.6	7.9	401.23		15.1	21.2	1857.52
7.9	10.5	409.01		21.2	35.7	1857.52
10.5	13.4	423.33				
13.4	16.4	458.10				
16.4	19.8	508.25				
19.8	23.4	569.73				
23.4	27.2	626.38				
27.2	30.0	681.31				
30.0	31.3	681.31				
31.3	35.6	716.21				
35.6	40.2	724.53				
40.2	54.6	728.82				

Site Geology

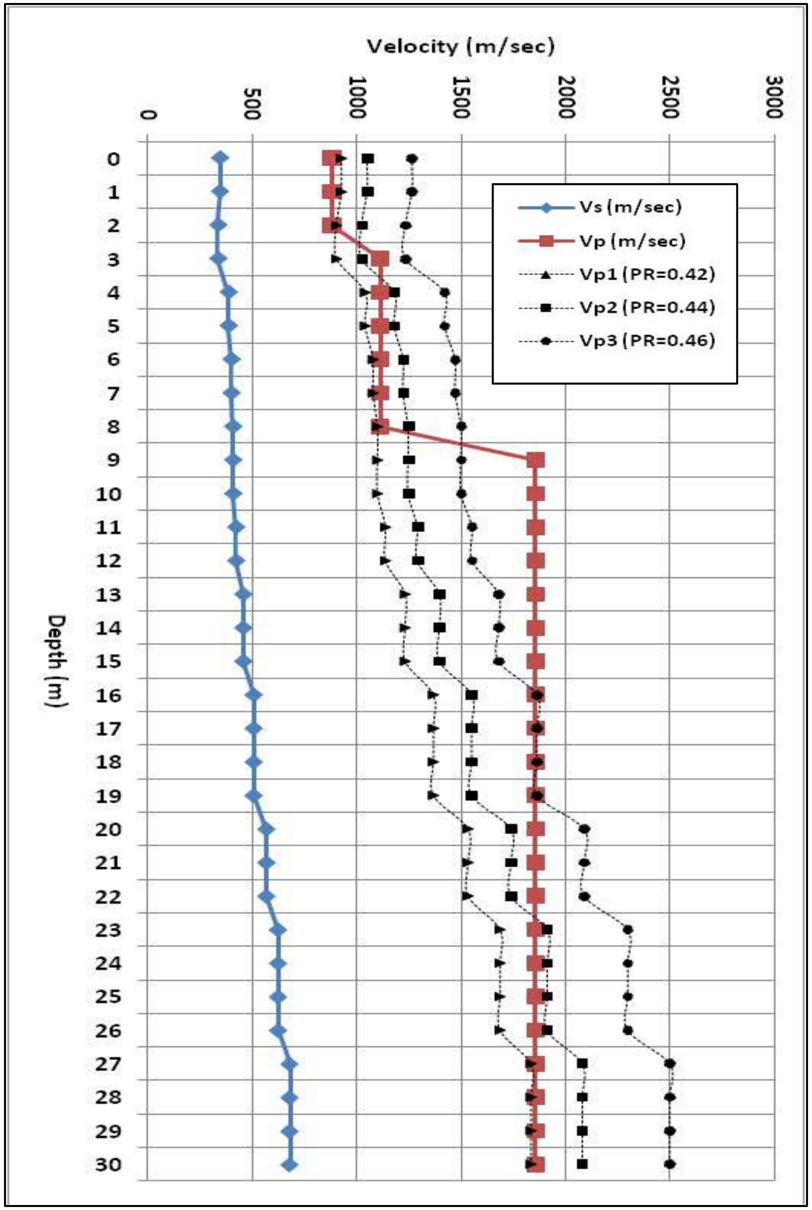
This site is underlain by Vashon recessional outwash sand and gravel. Nearby Department of Transportation boreholes penetrate 115 ft of sand and gravel.

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
0.45	536	298

(*)See Table 3 for details

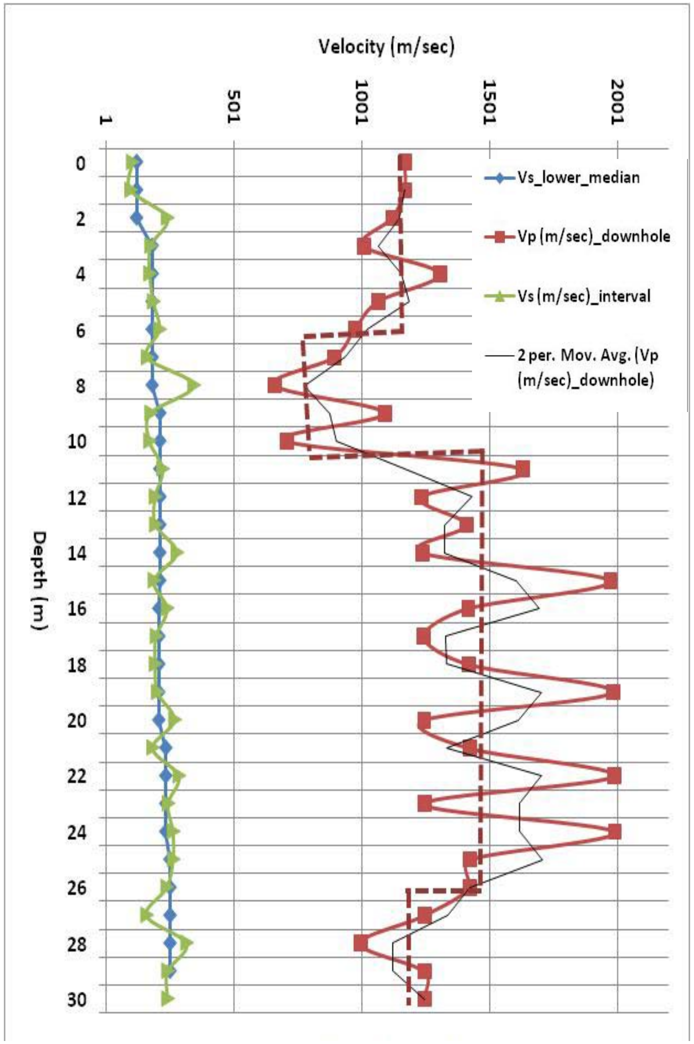
Vs30m = 466 m/sec (max depth resolved = 44 m)
NEHRP Site Classification = C

Figure A43. S-wave and P-wave velocity profiles, HVSR estimates and site geology at 7051, Bremerton, Washington. Wong et al. (2011) also reported Vs30m = 463 m/sec and NEHRP site classification of C at this site (using old station code 7034).



Depth (m)	Vp/Vs	PR (Measured)	Vp1 (PR=0.42)	Vp2 (PR=0.44)	Vp3 (PR=0.46)
0	2.56	0.41	929	1054	1268
1	2.56	0.41	929	1054	1268
2	2.63	0.42	906	1028	1236
3	3.31	0.45	906	1028	1236
4	2.88	0.43	1043	1183	1423
5	2.88	0.43	1043	1183	1423
6	2.78	0.43	1080	1226	1474
7	2.78	0.43	1080	1226	1474
8	2.72	0.42	1101	1250	1503
9	4.54	0.47	1101	1250	1503
10	4.54	0.47	1101	1250	1503
11	4.39	0.47	1140	1293	1555
12	4.39	0.47	1140	1293	1555
13	4.05	0.47	1233	1400	1683
14	4.05	0.47	1233	1400	1683
15	4.05	0.47	1233	1400	1683
16	3.65	0.46	1369	1553	1867
17	3.65	0.46	1369	1553	1867
18	3.65	0.46	1369	1553	1867
19	3.65	0.46	1369	1553	1867
20	3.26	0.45	1534	1741	2093
21	3.26	0.45	1534	1741	2093
22	3.26	0.45	1534	1741	2093
23	2.97	0.44	1687	1914	2301
24	2.97	0.44	1687	1914	2301
25	2.97	0.44	1687	1914	2301
26	2.97	0.44	1687	1914	2301
27	2.73	0.42	1834	2081	2503
28	2.73	0.42	1834	2081	2503
29	2.73	0.42	1834	2081	2503
30	2.73	0.42	1834	2081	2503

Figure A44. Predicted P-wave velocities from possible Poisson's ratios (0.42, 0.44 and 0.46) at station 7051. Average measured Poisson's ratio (PR) is 0.44 with standard deviation of 0.02. Note that Vp (500 m/sec) at 0-3 m also assigned to 929 m/sec (based on assumed PR =0.42).



Depth (m)	Vs_(m/sec) (Downhole seismic)	Vp (m/sec) (downhole seismic)
0	121.71	1171.99
1	121.71	1171.99
2	121.71	1122.97
3	121.71	1010.76
4	182.74	1307.08
5	182.74	1068.44
6	182.74	976.79
7	182.74	895.54
8	182.74	663.08
9	182.74	1093.55
10	212.61	710.71
11	212.61	1632.40
12	212.61	1236.30
13	212.61	1412.45
14	212.61	1240.35
15	212.61	1973.74
16	212.61	1418.69
17	208.56	1243.95
18	208.56	1420.96
19	208.56	1984.64
20	208.56	1245.89
21	208.56	1423.27
22	235.93	1988.98
23	235.93	1247.05
24	235.93	1990.96
25	235.93	1425.08
26	252.42	1425.37
27	252.42	1247.97
28	252.42	999.06
29	252.42	1248.22
30	252.42	1248.22

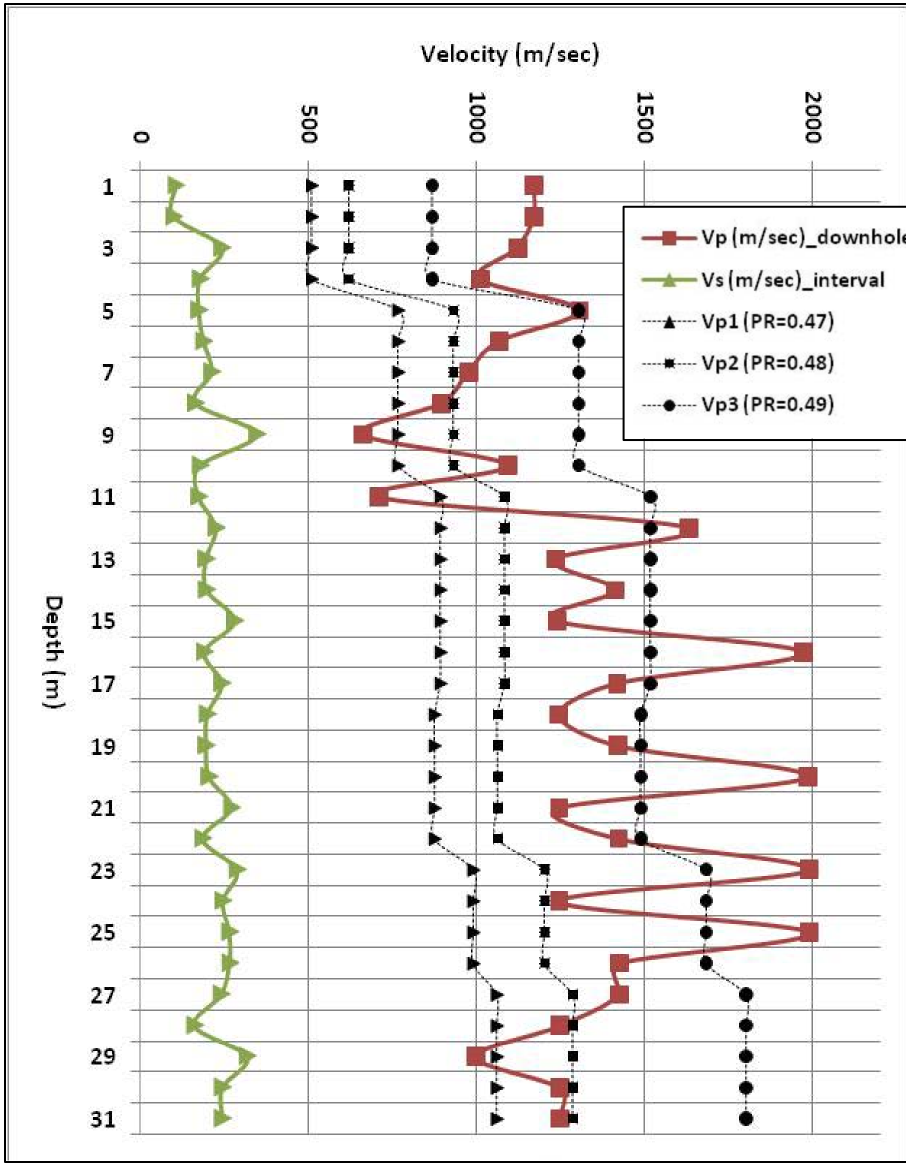
Site Geology
This site is underlain by the Tumwater sand of Walsh and others, 2003). It is latest glacial sand and silt deposited by streams flowing into Glacial Lake Russell and into lower stands of water in the Puget Sound basin. A borehole drilled at this site penetrated 101.5 ft of silty sand, sandy silt, and clayey silt (unpublished DNR boring log).

Measured Fundamental Frequency (Hz) on H/V (*)	Estimated Average Vs (m/sec) for Sediment Cover (*)	Estimated Thickness (m) for Sediment Cover (*)
0.8	447	140

(*)See Table 3 for details

Vs30m = 193 m/sec (max depth penetrated = 30 m)
NEHRP Site Classification = D (closer to D-E)

Figure A45. S-wave and P-wave velocity profiles and site geology at 7054, Centennial Park, Olympia, Washington. Cakir and Walsh (2008) downhole seismic analysis results are used for Vs30m calculation at this site.



Depth	Vp/Vs	PR (Measured)	Vp1 (PR=0.47)	Vp2 (PR=0.48)	Vp3 (PR=0.49)
0	9.63	0.49	512	621	869
1	9.63	0.49	512	621	869
2	9.23	0.49	512	621	869
3	8.30	0.49	512	621	869
4	7.15	0.49	768	932	1305
5	5.85	0.48	768	932	1305
6	5.35	0.48	768	932	1305
7	4.90	0.48	768	932	1305
8	3.63	0.46	768	932	1305
9	5.98	0.49	768	932	1305
10	3.34	0.45	894	1084	1518
11	7.68	0.49	894	1084	1518
12	5.81	0.48	894	1084	1518
13	6.64	0.49	894	1084	1518
14	5.83	0.48	894	1084	1518
15	9.28	0.49	894	1084	1518
16	6.67	0.49	894	1084	1518
17	5.96	0.49	877	1063	1489
18	6.81	0.49	877	1063	1489
19	9.52	0.49	877	1063	1489
20	5.97	0.49	877	1063	1489
21	6.82	0.49	877	1063	1489
22	8.43	0.49	992	1203	1685
23	5.29	0.48	992	1203	1685
24	8.44	0.49	992	1203	1685
25	6.04	0.49	992	1203	1685
26	5.65	0.48	1061	1287	1803
27	4.94	0.48	1061	1287	1803
28	3.96	0.47	1061	1287	1803
29	4.94	0.48	1061	1287	1803
30	4.94	0.48	1061	1287	1803

Figure A42. Predicted P-wave velocities from possible Poisson's ratios (0.47, 0.48 and 0.49) at station 7046. Average measured Poisson's ratio (PR) is 0.48 with standard deviation of 0.01. PRs indicate presence of very soft subsurface soil materials in top 30 meters. Vs and Vp profiles are generated using downhole seismic data (Cakir et al., 2008; unpublished DNR-DGER data)

APPENDIX B

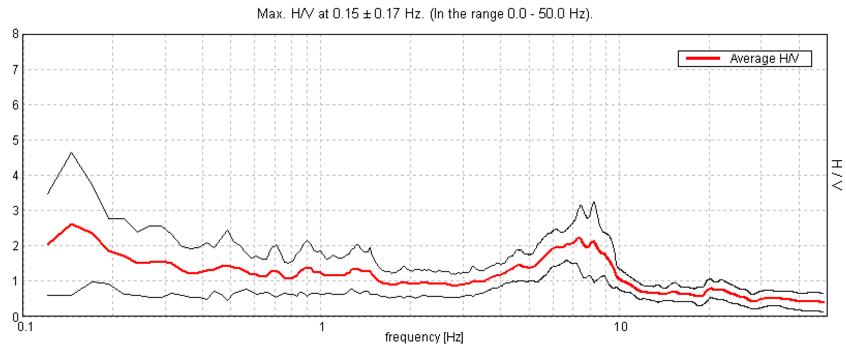
Ambient noise measurement and HVRS processing results at selected sites (Figure 2).
Processing method follows SESAME (2004) and Albarello et al. (2011a).

SITE_2193,

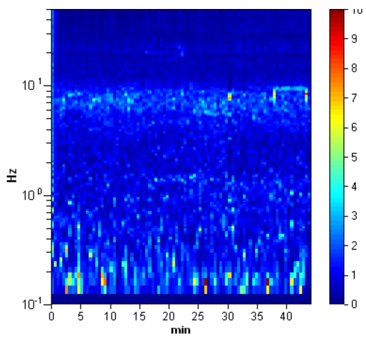
Instrument: EXT-Guralp
Start recording: 02/02/11 19:01:10 End recording: 02/02/11 19:45:29
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h44'19''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

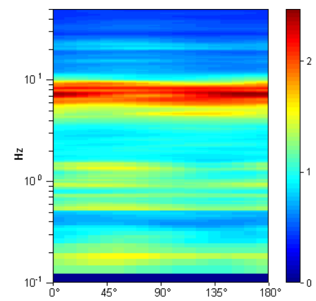
HORIZONTAL TO VERTICAL SPECTRAL RATIO



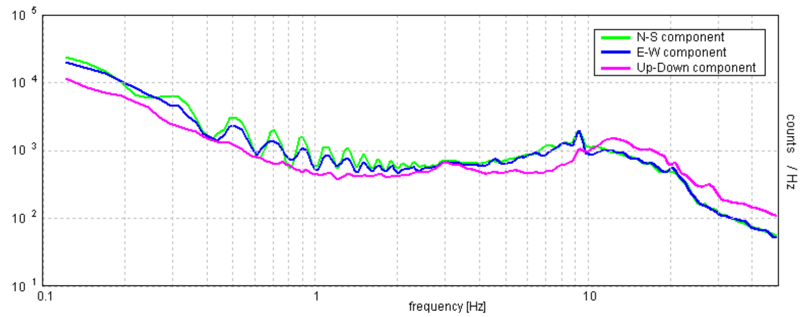
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines]

Max. H/V at 0.15 ± 0.17 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.15 > 0.33		NO
$n_c(f_0) > 200$	386.7 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 10 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.098 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.342 Hz	OK	
$A_0 > 2$	2.63 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.56494| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.08276 < 0.03662		NO
$\sigma_A(f_0) < \theta(f_0)$	1.0089 < 3.0	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

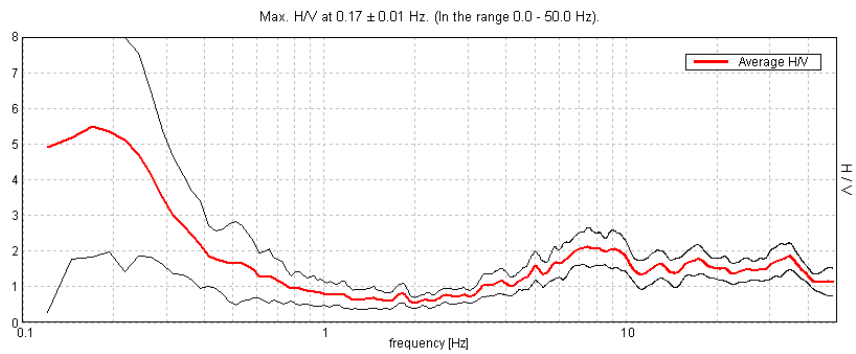
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7029,

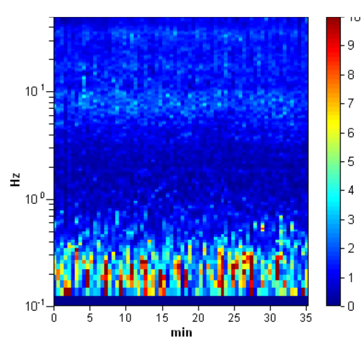
Instrument: EXT-Guralp
Start recording: 03/02/11 20:31:26 End recording: 03/02/11 21:06:47
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h35'21''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

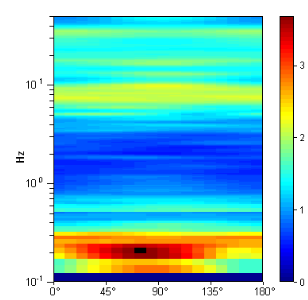
HORIZONTAL TO VERTICAL SPECTRAL RATIO



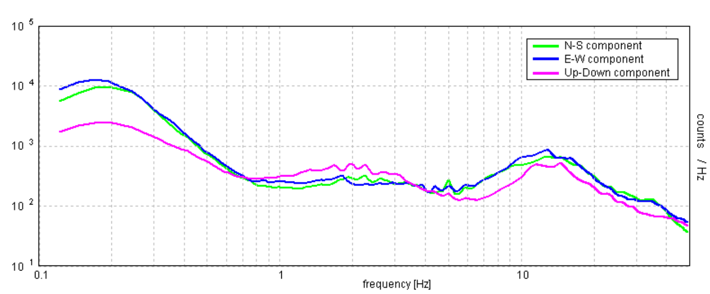
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.17 ± 0.01 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.17 > 0.33		NO
$n_c(f_0) > 200$	358.9 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$Hz**	Exceeded 5 out of 12 times		NO
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.098 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.342 Hz	OK	
$A_0 > 2$	5.49 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.015| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.00256 < 0.04272	OK	
$\sigma_A(f_0) < \theta(f_0)$	1.8219 < 3.0	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

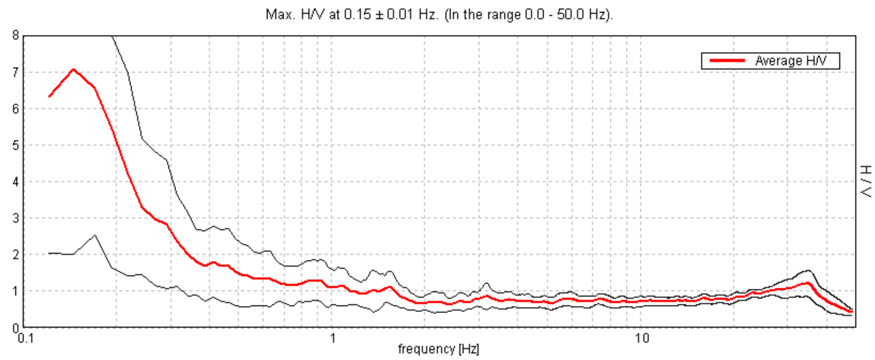
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7031,

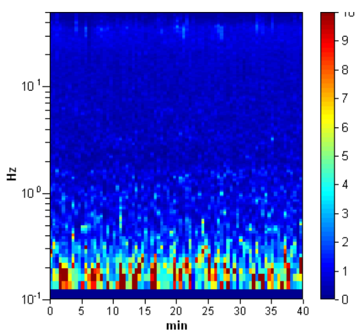
Instrument: EXT-Guralp
Start recording: 28/01/11 00:00:00 End recording: 28/01/11 00:40:01
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h40'01". Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

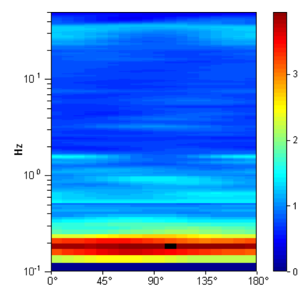
HORIZONTAL TO VERTICAL SPECTRAL RATIO



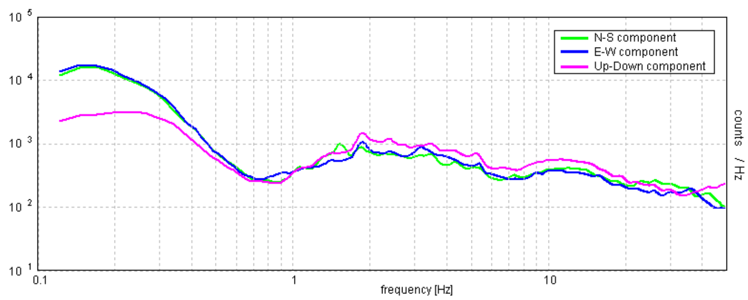
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.15 ± 0.01 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.15 > 0.33		NO
$n_c(f_0) > 200$	351.6 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 4 out of 10 times		NO
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.098 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.244 Hz	OK	
$A_0 > 2$	7.09 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.01816| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.00266 < 0.03662	OK	
$\sigma_A(f_0) < \theta(f_0)$	2.5323 < 3.0	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

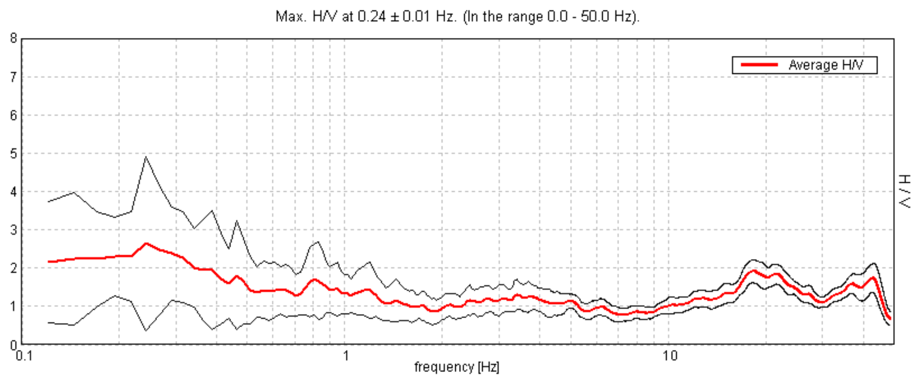
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7032,

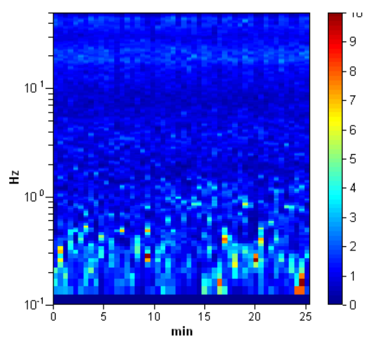
Instrument: EXT-Guralp
Start recording: 29/01/11 01:01:11 End recording: 29/01/11 01:26:40
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h25'29''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

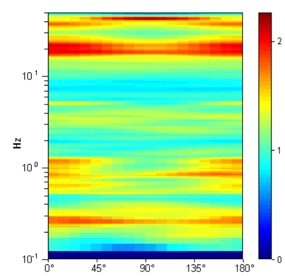
HORIZONTAL TO VERTICAL SPECTRAL RATIO



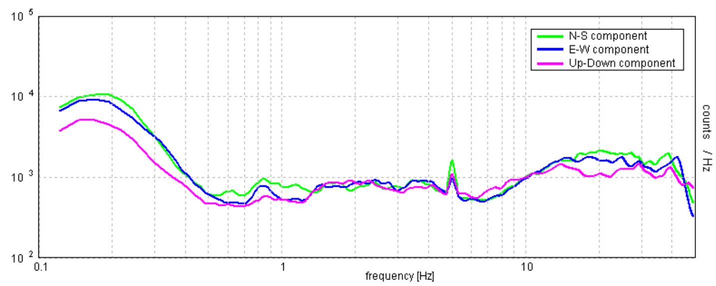
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.24 ± 0.01 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.24 > 0.33		NO
$n_c(f_0) > 200$	366.2 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 16 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.098 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.708 Hz	OK	
$A_0 > 2$	2.64 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.02577| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.00629 < 0.04883	OK	
$\sigma_A(f_0) < \theta(f_0)$	1.1172 < 2.5	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

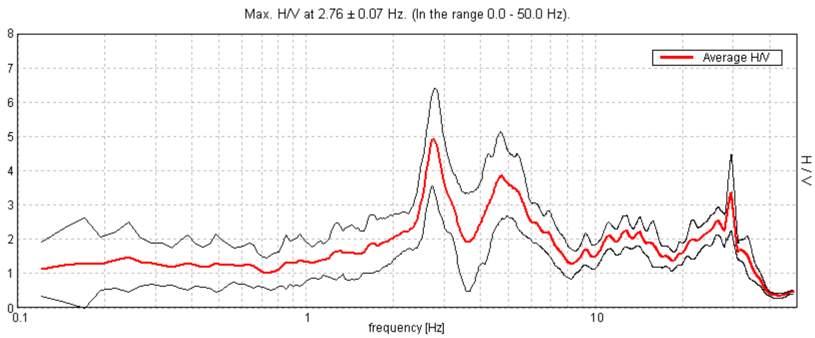
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7039,

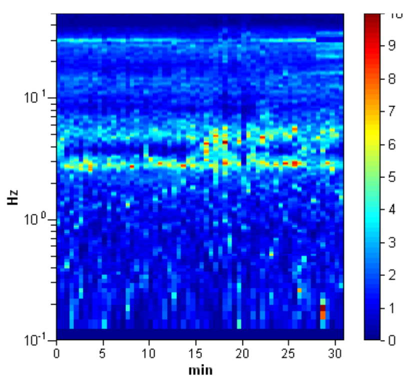
Instrument: EXT-Guralp
Start recording: 05/02/11 19:28:59 End recording: 05/02/11 20:00:00
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h31'01''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

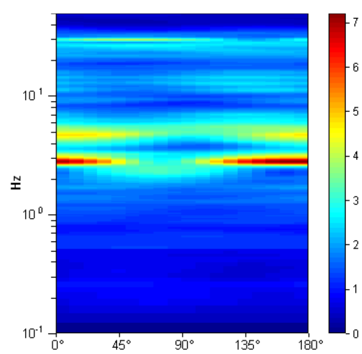
HORIZONTAL TO VERTICAL SPECTRAL RATIO



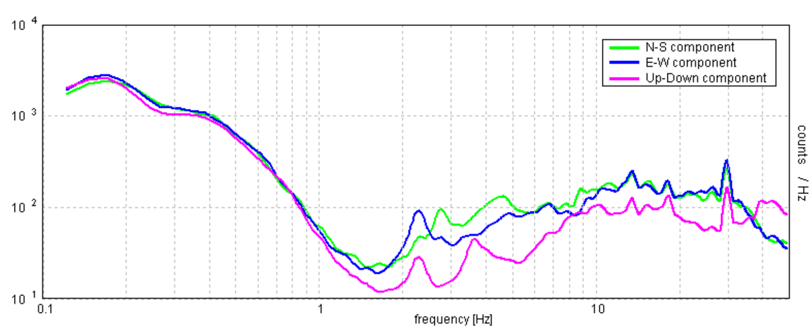
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 2.76 ± 0.07 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	2.76 > 0.33	OK	
$n_c(f_0) > 200$	5131.3 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$	Exceeded 0 out of 170 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	2.368 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	3.369 Hz	OK	
$A_0 > 2$	4.91 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.01319| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.03638 < 0.13794	OK	
$\sigma_A(f_0) < \theta(f_0)$	0.6915 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

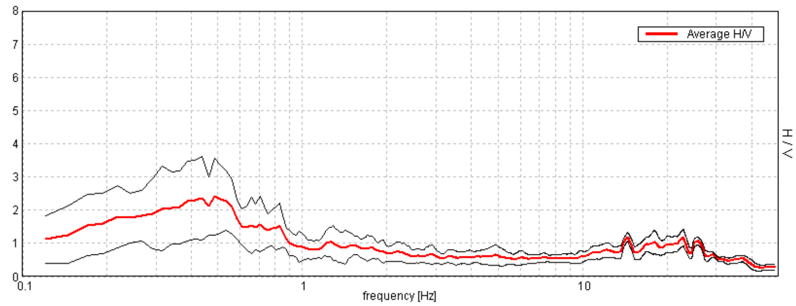
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	$0.25 f_0$	$0.2 f_0$	$0.15 f_0$	$0.10 f_0$	$0.05 f_0$
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7040,

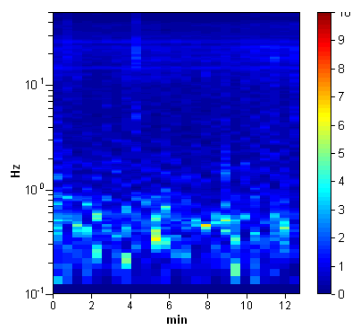
Instrument: EXT-Guralp
Start recording: 03/02/11 02:00:00 End recording: 03/02/11 02:12:47
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h12'47''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

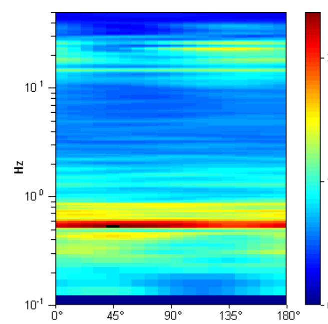
HORIZONTAL TO VERTICAL SPECTRAL RATIO



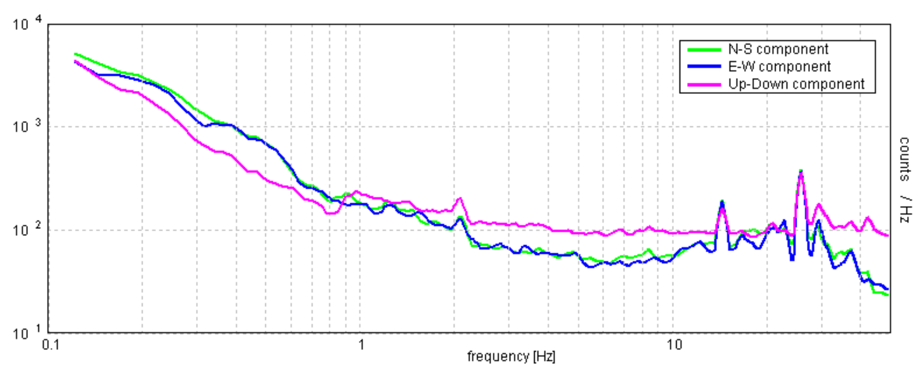
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.49 ± 0.03 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.49 > 0.33	**OK**	
$n_c(f_0) > 200$	366.2 > 200	**OK**	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 31 times	**OK**	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.122 Hz	**OK**	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.879 Hz	**OK**	
$A_0 > 2$	2.40 > 2	**OK**	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.02538| < 0.05	**OK**	
$\sigma_f < \varepsilon(f_0)$	0.01239 < 0.09766	**OK**	
$\sigma_A(f_0) < \theta(f_0)$	0.5505 < 2.5	**OK**	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

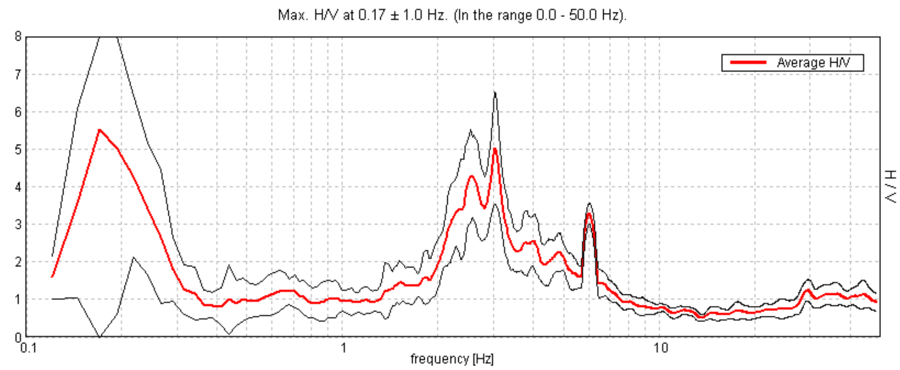
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7041_SITE1,

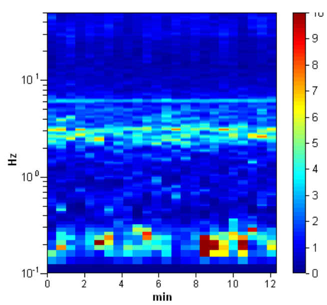
Instrument: EXT-Guralp
Start recording: 04/02/11 01:17:58 End recording: 04/02/11 01:30:20
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h12'22''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

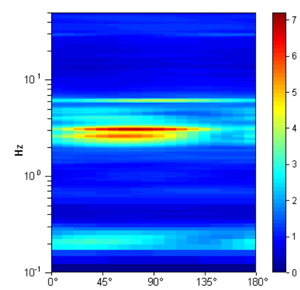
HORIZONTAL TO VERTICAL SPECTRAL RATIO



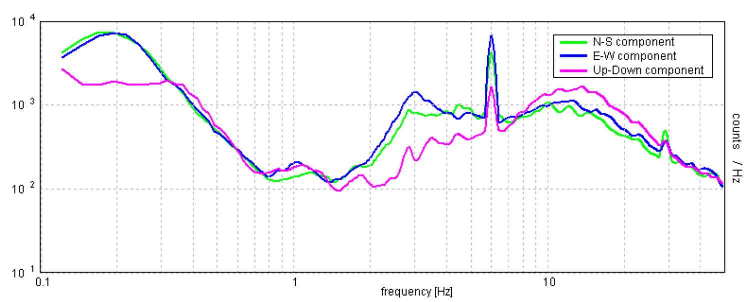
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.17 ± 1.0 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.17 > 0.33		NO
$n_c(f_0) > 200$	123.0 > 200		NO
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 2 out of 12 times		NO
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.122 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.269 Hz	OK	
$A_0 > 2$	5.53 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|2.77832| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.47481 < 0.04272		NO
$\sigma_A(f_0) < \theta(f_0)$	2.7256 < 3.0	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

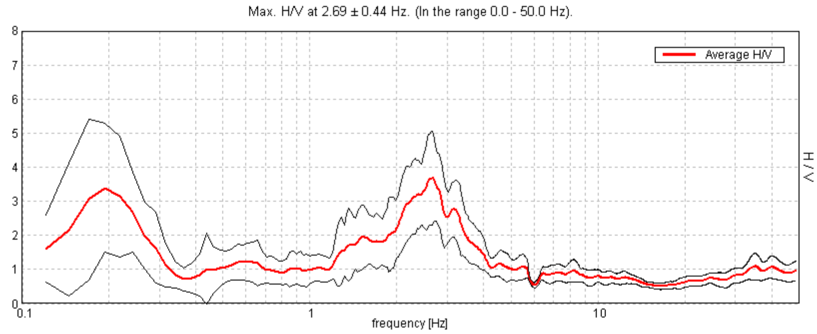
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7041_SITE2,

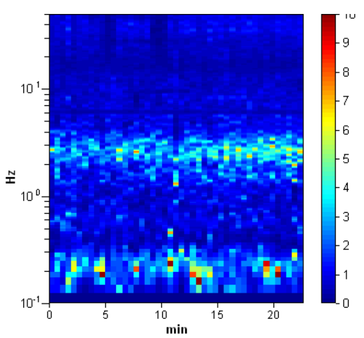
Instrument: EXT-Guralp
Start recording: 04/02/11 17:33:31 End recording: 04/02/11 17:56:11
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h22'40''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

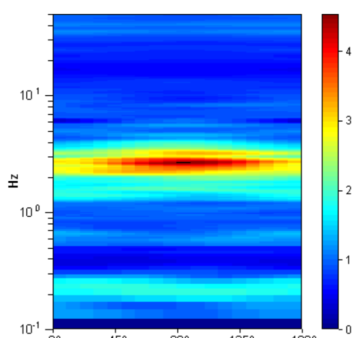
HORIZONTAL TO VERTICAL SPECTRAL RATIO



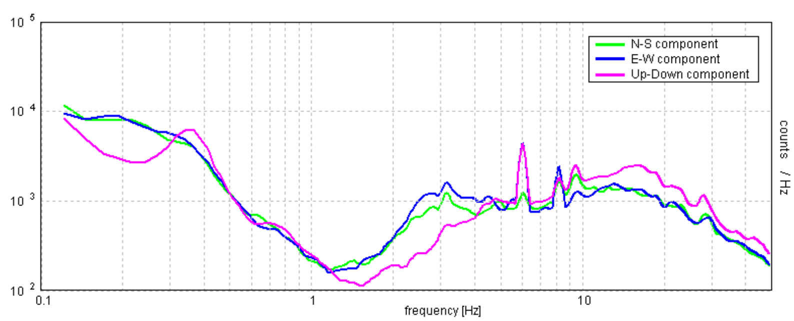
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 2.69 ± 0.44 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	2.69 > 0.33	OK	
$n_c(f_0) > 200$	3625.5 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 166 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	1.807 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	3.589 Hz	OK	
$A_0 > 2$	3.68 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.07982| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.21436 < 0.13428		NO
$\sigma_A(f_0) < \theta(f_0)$	0.6393 < 1.58	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

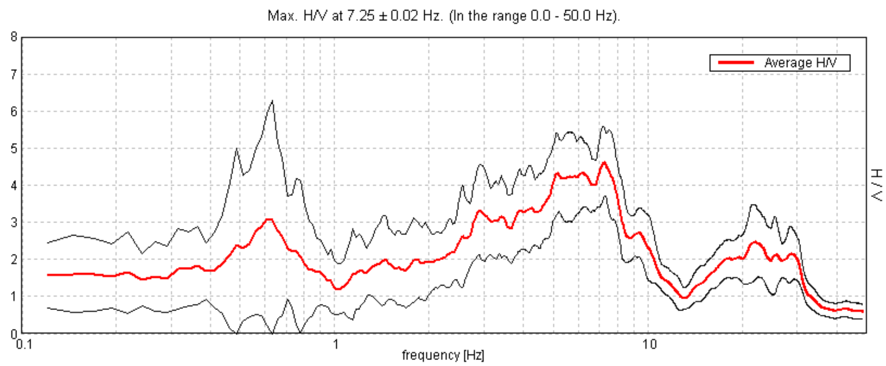
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7043,

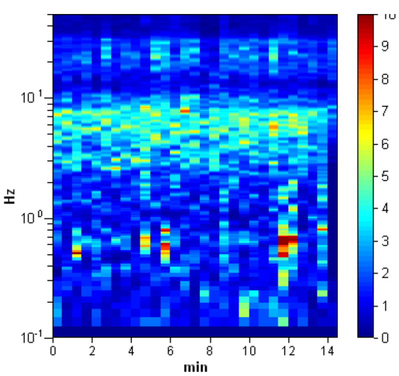
Instrument: EXT-Guralp
Start recording: 26/01/11 20:40:35 End recording: 26/01/11 20:55:06
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h14'31''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

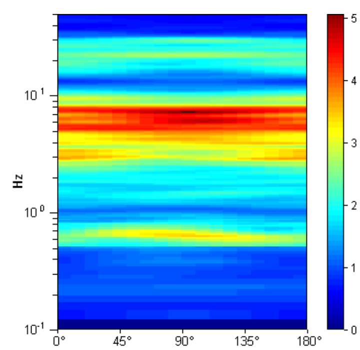
HORIZONTAL TO VERTICAL SPECTRAL RATIO



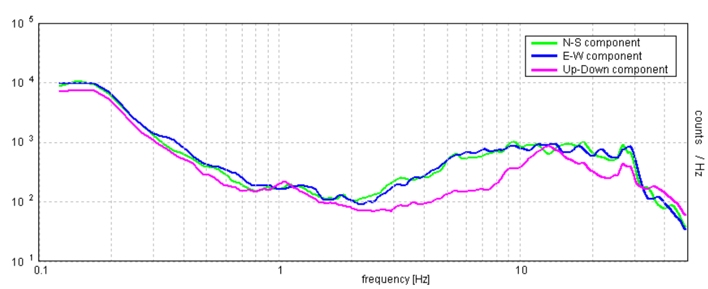
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 7.25 ± 0.02 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	7.25 > 0.33	**OK**	
$n_c(f_0) > 200$	6308.3 > 200	**OK**	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 446 times	**OK**	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	2.441 Hz	**OK**	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	10.059 Hz	**OK**	
$A_0 > 2$	4.62 > 2	**OK**	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.0016| < 0.05	**OK**	
$\sigma_f < \varepsilon(f_0)$	0.01157 < 0.36255	**OK**	
$\sigma_A(f_0) < \theta(f_0)$	0.4554 < 1.58	**OK**	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

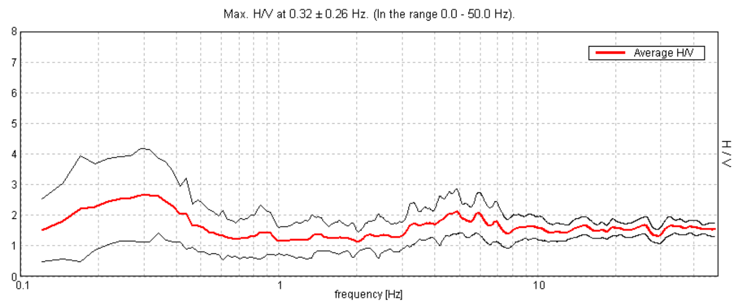
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7051,

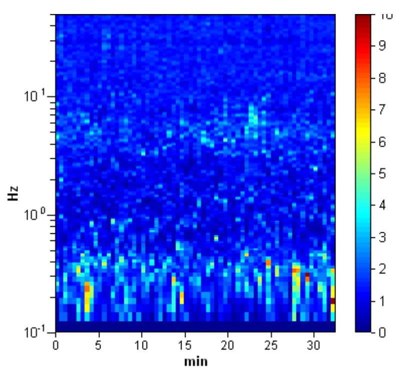
Instrument: EXT-Guralp
Start recording: 02/02/11 22:51:28 End recording: 02/02/11 23:24:01
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h32'33''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

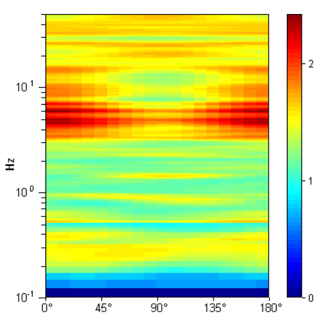
HORIZONTAL TO VERTICAL SPECTRAL RATIO



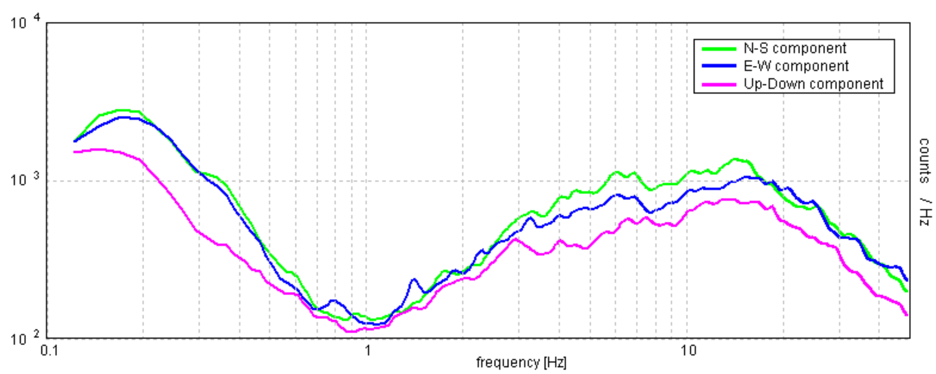
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.32 ± 0.26 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.32 > 0.33		NO
$n_c(f_0) > 200$	618.9 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5$Hz **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5$Hz**	Exceeded 0 out of 20 times	OK	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.098 Hz	OK	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.635 Hz	OK	
$A_0 > 2$	2.65 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.4063| < 0.05		NO
$\sigma_f < \varepsilon(f_0)$	0.12895 < 0.06348		NO
$\sigma_A(f_0) < \theta(f_0)$	0.7498 < 2.5	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

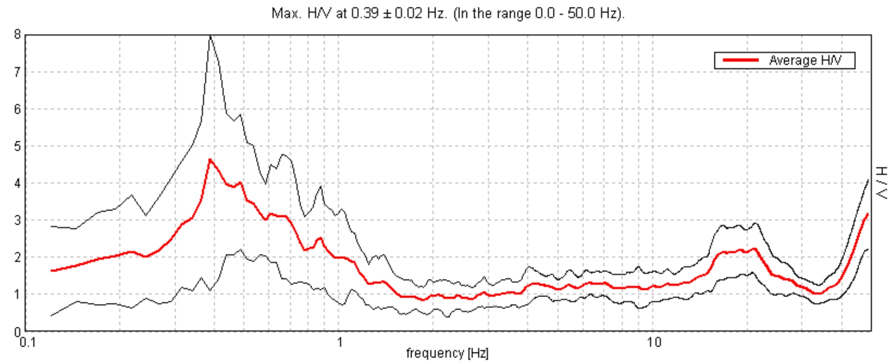
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7054_measurement_1,

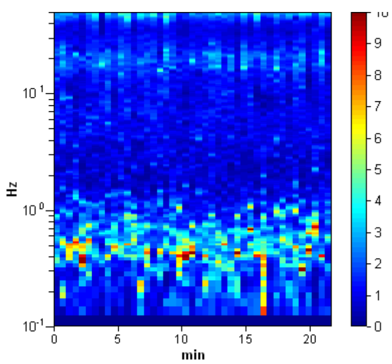
Instrument: EXT-Guralp
Start recording: 20/01/11 23:02:40 End recording: 20/01/11 23:24:26
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h21'46''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

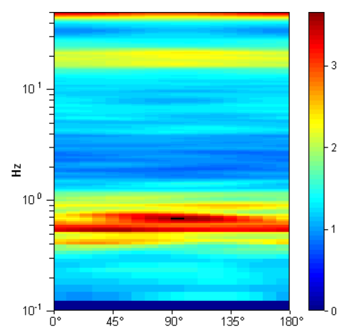
HORIZONTAL TO VERTICAL SPECTRAL RATIO



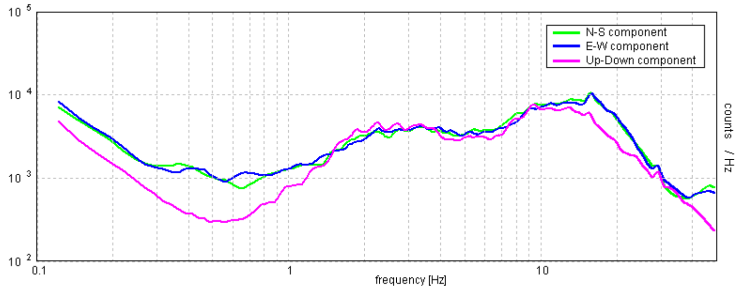
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.39 ± 0.02 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.39 > 0.33	OK	
$n_c(f_0) > 200$	503.9 > 200	OK	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 1 out of 25 times		NO
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$	0.269 Hz	OK	
Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$	0.781 Hz	OK	
$A_0 > 2$	4.63 > 2	OK	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.02576| < 0.05	OK	
$\sigma_f < \varepsilon(f_0)$	0.01006 < 0.07813	OK	
$\sigma_A(f_0) < \theta(f_0)$	1.726 < 2.5	OK	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

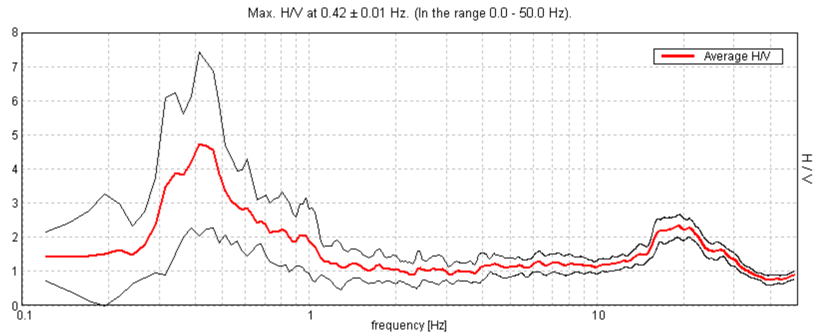
Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20

SITE_7054_measurement_3,

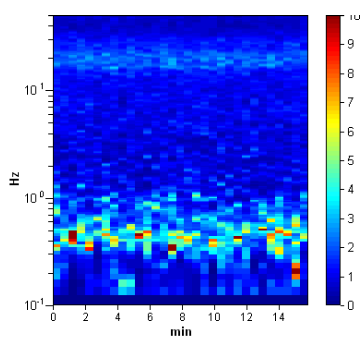
Instrument: EXT-Guralp
Start recording: 21/01/11 00:00:00 End recording: 21/01/11 00:15:48
Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
GPS data not available

Trace length: 0h15'48''. Analysis performed on the entire trace.
Sampling rate: 100 Hz
Window size: 30 s
Smoothing type: Triangular window
Smoothing: 5%

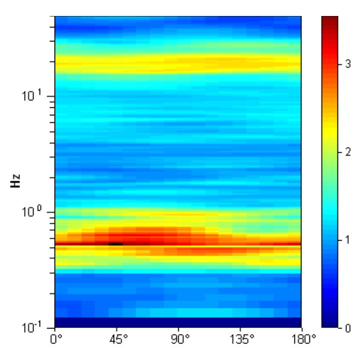
HORIZONTAL TO VERTICAL SPECTRAL RATIO



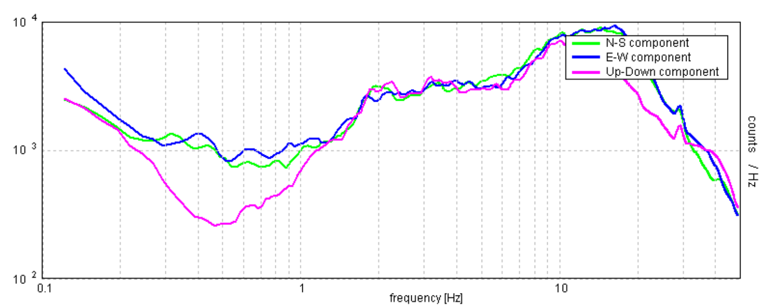
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines.]

Max. H/V at 0.42 ± 0.01 Hz (in the range 0.0 - 50.0 Hz).

Criteria for a reliable H/V curve [All 3 should be fulfilled]			
$f_0 > 10 / L_w$	0.42 > 0.33	**OK**	
$n_c(f_0) > 200$	386.0 > 200	**OK**	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 26 times	**OK**	
Criteria for a clear H/V peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	0.293 Hz	**OK**	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$	0.708 Hz	**OK**	
$A_0 > 2$	4.73 > 2	**OK**	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.0142| < 0.05	**OK**	
$\sigma_f < \varepsilon(f_0)$	0.00589 < 0.08301	**OK**	
$\sigma_A(f_0) < \theta(f_0)$	1.305 < 2.5	**OK**	

L_w	window length
n_w	number of windows used in the analysis
$n_c = L_w n_w f_0$	number of significant cycles
f	current frequency
f_0	H/V peak frequency
σ_f	standard deviation of H/V peak frequency
$\varepsilon(f_0)$	threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$
A_0	H/V peak amplitude at frequency f_0
$A_{H/V}(f)$	H/V curve amplitude at frequency f
f^-	frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$
f^+	frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$
$\sigma_A(f)$	standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided
$\sigma_{logH/V}(f)$	standard deviation of log $A_{H/V}(f)$ curve
$\theta(f_0)$	threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$

Threshold values for σ_f and $\sigma_A(f_0)$					
Freq. range [Hz]	< 0.2	0.2 – 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0
$\varepsilon(f_0)$ [Hz]	0.25 f_0	0.2 f_0	0.15 f_0	0.10 f_0	0.05 f_0
$\theta(f_0)$ for $\sigma_A(f_0)$	3.0	2.5	2.0	1.78	1.58
log $\theta(f_0)$ for $\sigma_{logH/V}(f_0)$	0.48	0.40	0.30	0.25	0.20