EASTMONT SCHOOL DISTRICT

Douglas County, Washington

2024 School Seismic Safety Project Site Class Report

The **School Seismic Safety Project (SSSP)** is a multi-year, statewide effort by the Washington Geological Survey (WGS) and the Office of Superintendent of Public Instruction (OSPI) to assess seismic vulnerability at Washington schools. This report provides the site class—a critical design parameter for seismic retrofits and new building construction—for each of the schools in the district named at the top of this report. This report contains seismic site class information and is not a comprehensive evaluation of all seismic or other geologic hazards that may be present (such as tsunami, volcano, landslide, or liquefaction hazards). For more information on geologic hazards visit: https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards-and-environment. For site specific hazard assessments contact a qualified professional.

SOIL AMPLIFICATION DURING EARTHQUAKES

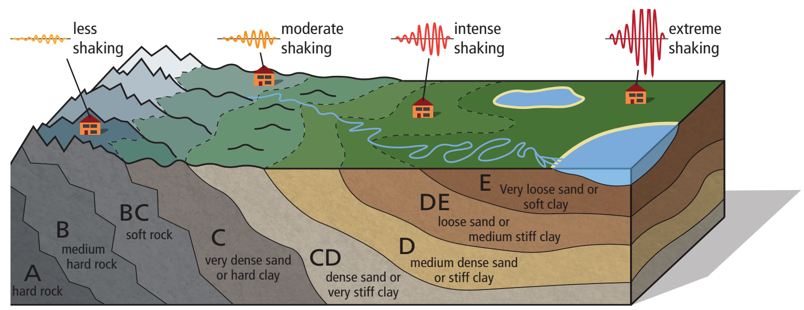
The most destructive seismic waves produced during an earthquake are shear waves (side-to-side shaking) and surface waves (large waves that travel along the surface of the Earth). As these seismic waves spread outward from the epicenter of an earthquake, they are amplified or dampened depending on the material they pass through. In general, softer soils and sediments produce more shaking than harder soils or bedrock.

SITE CLASS: MEASURING SOIL AMPLIFICATION

Site class is an estimate of the degree to which the soil and rock properties of a given location will amplify shaking during an earthquake. Site class is a national standard defined by the the National Earthquake Hazards Reduction Program (NEHRP) that is incorporated into all major building codes, including the American Society of Civil Engineers (ASCE) and state and international building codes.

Site class can be determined by measuring how fast shear waves travel through the upper 30 m (~100 ft) of soil and rock, a measurement known as the time-averaged shear wave velocity down to 30 m or 100 ft (we abbreviate this as the symbol $\overline{V}_S$). Soft soils that amplify earthquake shaking exhibit low $\overline{V}_S$ values, while hard soils and bedrock that shake less exhibit high $\overline{V}_S$ values (see table on right).

At each campus we use geophysical analyses to measure the $\overline{V}_S$, and then assign a site class to each school according to table 20.2-1 of ASCE 2022 (a publication that describes the standards of ASCE). Site classes A, B, and E have additional diagnostic criteria related to the thickness of overlying soil, presence of clay, and other material properties, that may require a separate geotechnical assessment before being used to guide seismic retrofits or construction (see ASCE section 20.2).



Seismic waves are amplified or damped when traveling through different geologic materials. Site class (labels A, B, BC...) is an estimate of the degree to which soil or bedrock may amplify or dampen shaking during an earthquake.

Site class	Material description	$\overline{V}_S$ (ft/sec)	Ground shaking amplification
A*	Hard rock	>5,000	Low
B*	Medium hard rock	3,000–5,000	
BC	Soft rock	2,100–3,000	
C	Very dense sand, hard clay	1,450–2,100	
CD	Dense sand, very stiff clay	1,000–1,450	
D	Medium dense sand, stiff clay	700–1,000	
DE	Loose sand, medium stiff clay	500–700	
E*	Very loose sand, soft clay	<500	High

* Site classes A, B, and E have additional diagnostic criteria that may require a separate geotechnical assessment (see section 20.2 in ASCE 2022).

Site class definitions based on table 20.2-1 in ASCE 2022. $\overline{V}_S$ is the time-averaged shear wave velocity down to 30 m (~100 ft). Ground shaking amplification generally increases with lower measured $\overline{V}_S$.

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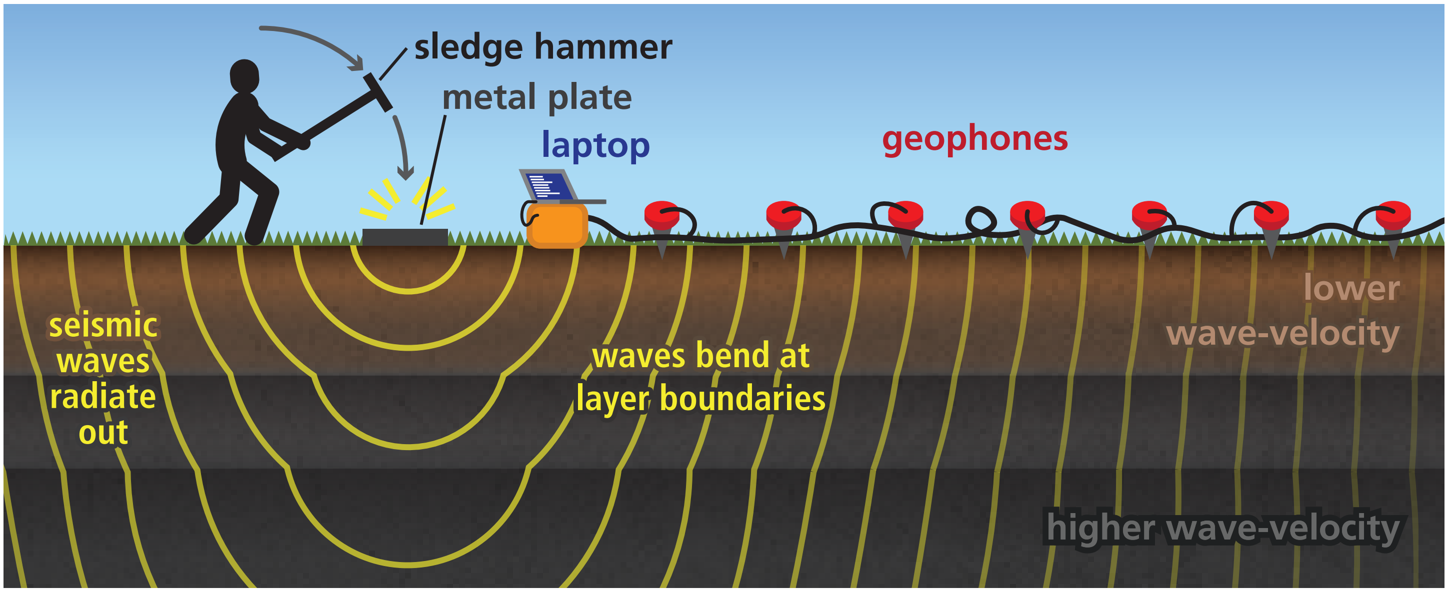

Schematic showing how the MASW site classification method works. The strike of a sledge hammer produces seismic waves that propagate through the subsurface and are recorded along an array of geophones. $\overline{V}_S$ can then be calculated from these recordings.

HOW WE MEASURE $\overline{V}_S$

For each campus, we select a site located on representative geologic material while also considering the possible influence of ambient seismic noise—for example, noise from roads or construction. After laying out a 230–310 ft (70–95 m) array of approximately 48 geophones (ground motion sensors), we collect two types of data. In the first, for a technique called Multi-Channel Analysis of Surface Waves (MASW), we strike the ground with a sledge hammer to produce seismic waves that propagate through the subsurface and are recorded along the array of geophones (see figure above). We also collect a passive recording of ambient ground vibrations for a technique called Microtremor Array Measurements (MAM). Both datasets are then used to calculate a single $\overline{V}_S$ for that site using specialized software. For details on the MASW and MAM techniques, see *Technical Methods* near the end of the report.

A WGS scientist generates seismic waves by striking a metal plate with a sledge hammer. The waves are recorded by an array of geophones visible on the ground in the background.

HOW TO USE THIS REPORT

Engineers use site class as a key parameter in ensuring retrofits and new building construction adhere to seismic design principles. Therefore, this report should be archived with any geotechnical/soil reports and blueprints associated with your schools. The $\overline{V}_S$ and site class results in this report have been shared with OSPI and entered into their Information and Condition of Schools (ICOS) database. The results, including data collection parameters and analysis details for each seismic array, are available through the Washington Geologic Information Portal (found under *Earthquakes > Shear Wave Data*). Raw data are also available upon request. Our contact information is below.

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Table of results: Names of the schools included in the study, their site class assessment result, $\overline{V}_s$ measurement (reported in metric and standard units), Information and Condition of Schools (ICOS) site ID, and a unique site class array identification number. $\overline{V}_s$ is the time-averaged shear wave velocity down to 30 m (~100 ft). 'Site Class Array ID' is a unique ID for the geophone array used at a school and consists of the 4-digit year, 2-digit month, 2-digit day, and 2-digit enumeration of the surveys collected that day. Note that schools may share the same array (and therefore Site Class Array ID) if they are located close together.

Row	School Name	Site Class	$\overline{V}_s$ (ft/s)	$\overline{V}_s$ (m/s)	ICOS Site ID	Site Class Array ID (yyyymmdd##)
1	Cascade Elementary School	CD	1415	431.2	20367	2022061301
2	Clovis Point Elementary School	CD	1326	404.1	20370	2022061601
3	Eastmont Junior High School	CD	1322	403.0	20369	2022061401
4	Eastmont Senior High School	CD	1190	362.8	20374	2022061501
5	Grant Elementary School	CD	1032	314.7	20372	2022061502
6	Kenroy Elementary School	CD	1031	314.2	20368	2022061402
7	Lee Elementary School	C	1510	460.4	20373	2022061302
8	Rock Island Elementary School	C	1702	518.9	20366	2022061602
9	Sterling Junior High School	CD	1322	403.0	20371	2022061401

‡ School participated in SSSP1
‡ ‡ School participated in SSSP2

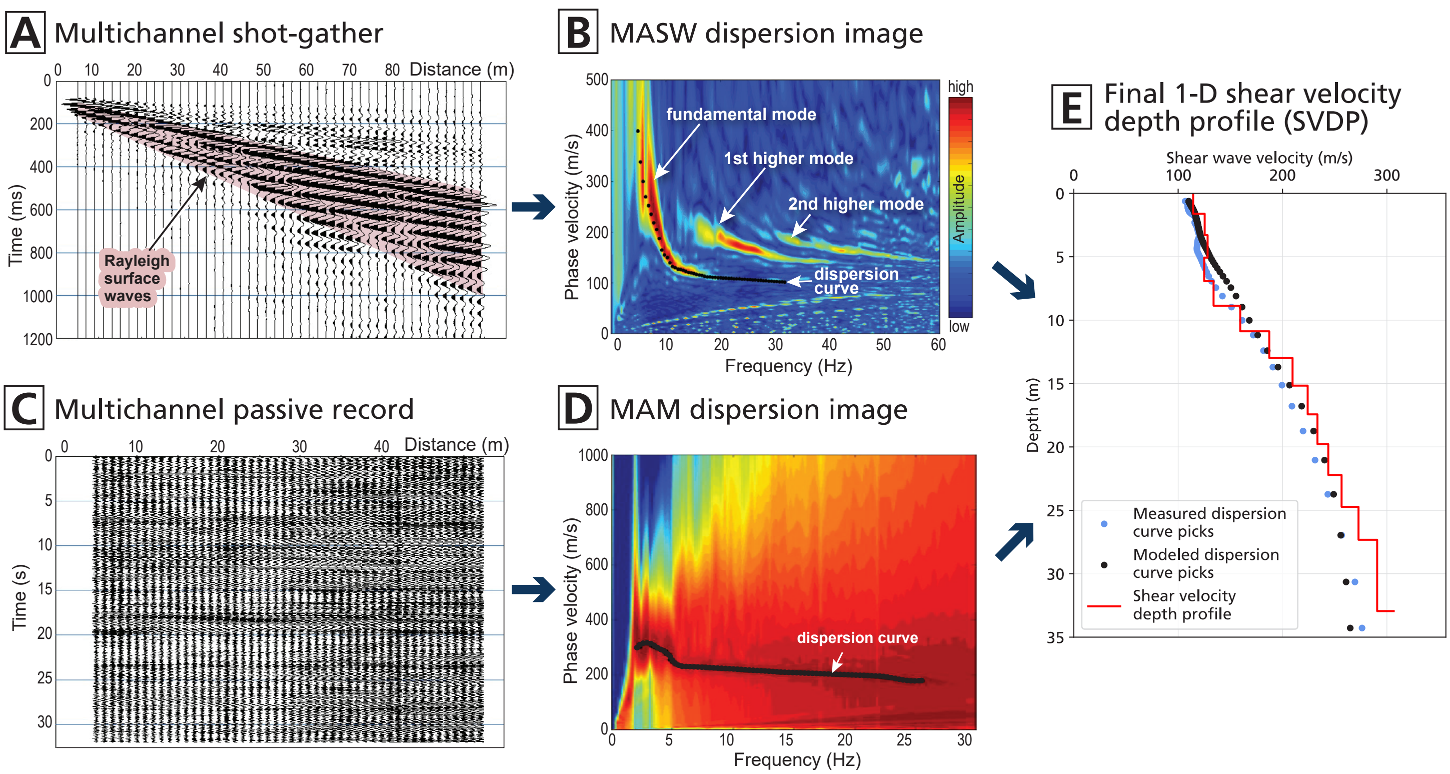
SSSP1 and SSSP2 were statewide multi-year projects to assess school vulnerability across the state. Project information and final reports can be found here:
www.dnr.wa.gov/school-seismic-safety

* Site classes A, B, and E have additional diagnostic criteria that may require a separate geotechnical assessment (see ASCE 2022 section 20.2).

TECHNICAL METHODS: DETERMINING SITE CLASS

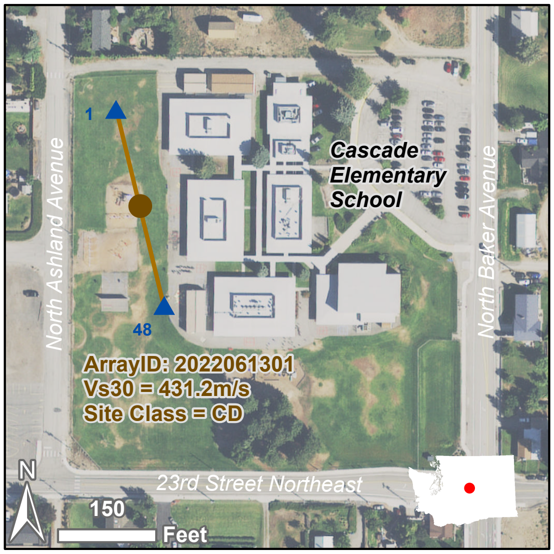
At each school campus, WGS geophysicists lay out a seismic array that typically includes 24 to 48 geophones (ground motion sensors). They then conduct two surveys: (1) an active seismic survey in which a steel plate is struck with a 16-lb sledgehammer, producing seismic waves that are recorded and later analyzed via multi-channel analysis of surface waves (MASW) (Park and others, 1999; Xia and others, 1999); and (2) a passive seismic survey that analyzes microtremor using the Microtremor Array Measurements (MAM) method (Hayashi and others, 2022). The same geophone array is used for both data types and the geophone array deployment usually occurs in grassy ballfields or along sidewalks. If multiple schools are located close together, and the local geology is not too complex, we may use a single array to measure the $\overline{V}_S$ and determine the site class for all of the schools.

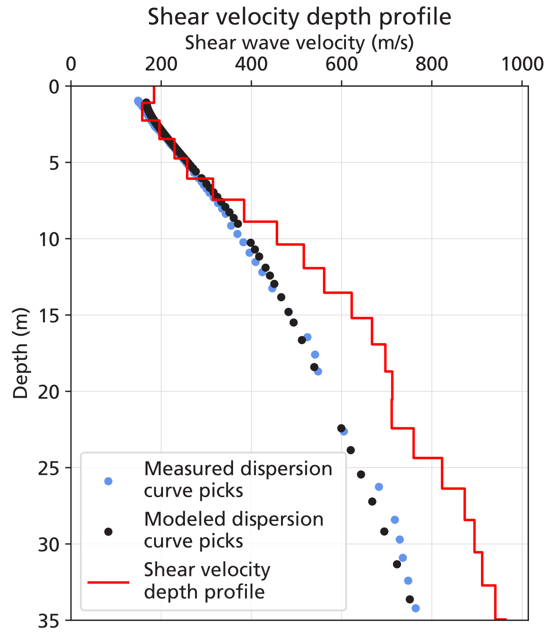
After data collection in the field, the next step is data processing and interpretation. The raw seismic data are transformed from the time domain (panels A and C in figure below) into the frequency domain (panels B and D below) to generate dispersion images from which we identify the fundamental mode of vibration and pick dispersion curves for both MASW and MAM (West and others, 2019). Since sampling depth is a function of wavelength, and MASW typically samples higher frequencies (shallower depths) while MAM samples lower frequencies (deeper depths), we consider the dispersion curves generated by both methods, often combining them into a single dispersion curve. Using the dispersion curves, we generate an initial model and invert it to generate a 1-D shear-velocity depth profile (SVDP) down to 30 m (panel E below). The SVDP is a non-unique 1-D model that depicts the shear-wave velocity of the subsurface as a function of depth. Using the SVDP, we calculate the $\overline{V}_S$, and after carefully considering possible subsurface heterogeneity, we then assign a site class to each school (West and others, 2019). We use the midpoint of the geophone array as the point location of the SVDP and site class assessment.



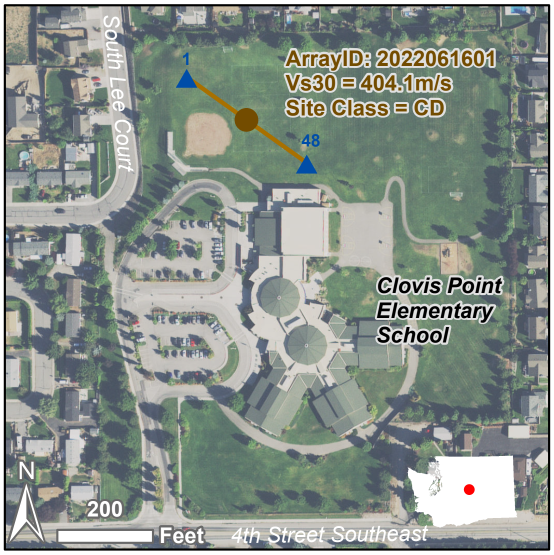
Typical analysis workflow for the active MASW and passive MAM methods. A. MASW shot-gather in which the source, a metal plate struck by a sledge hammer, was outside the array. The propagation of Rayleigh surface waves is highlighted in red. B. MASW-derived phase-velocity vs. frequency dispersion image with the fundamental mode of surface waves. The fundamental mode, shown with black circles, is identified as the line of highest spectral amplitude (warmer colors) with the lowest phase velocity. Two higher modes of vibration are labeled. C. Passive MAM 30-second multi-channel record. D. MAM-derived phase-velocity vs. frequency dispersion image with the trend of the fundamental mode identified with black dots. E. The final inverted 1-D SVDP.

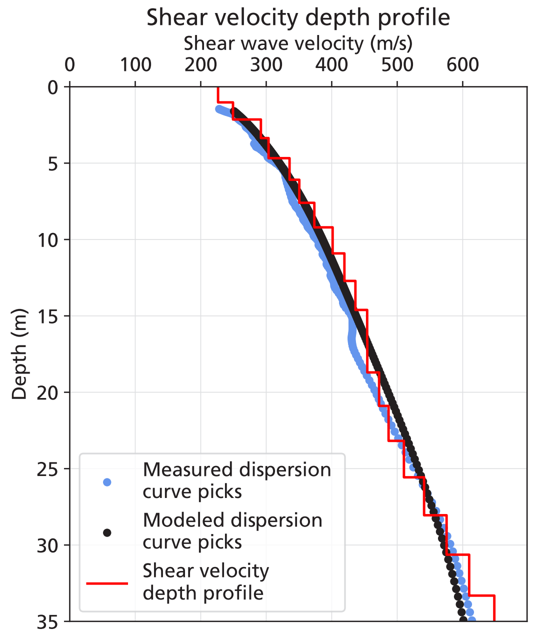
Cascade Elementary School

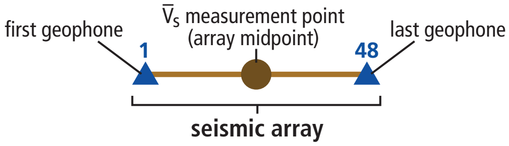




Clovis Point Elementary School







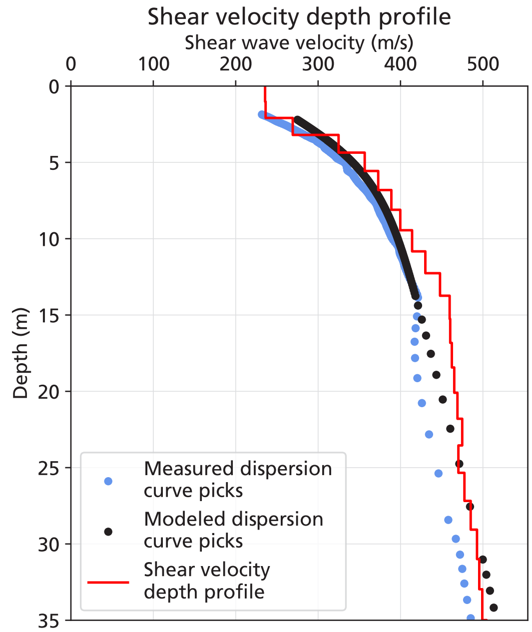
Above: Location maps showing where the seismic surveys were conducted at each campus.

Above: Final Shear Velocity Depth Profiles (SVDP). If the final SVDP is based on the initial model, then only the measured dispersion curve picks are shown (blue dots).

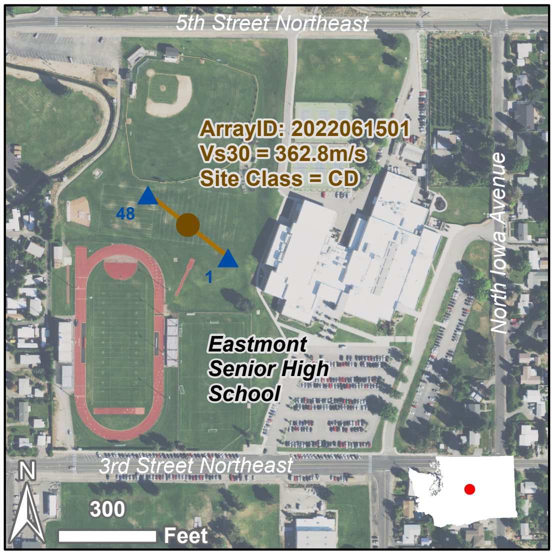
$$\overline{V}_s = \frac{30}{\sum_i \left(\frac{h_i}{Vs_i}\right)}$$

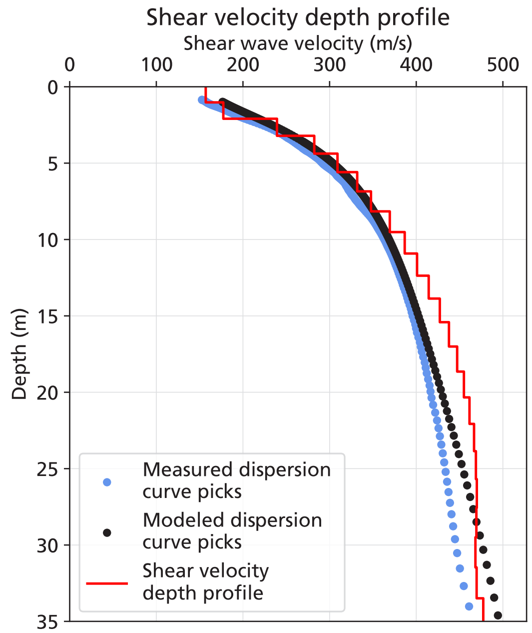
Left: The equation for $\overline{V}_s$ (in m/s), where h_i is the thickness of any layer between 0 m and 30 m, and Vs_i is the shear wave velocity of that layer.

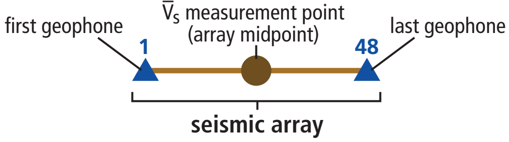
Eastmont Junior High School, Sterling Junior High School



Eastmont Senior High School







Above: Location maps showing where the seismic surveys were conducted at each campus.

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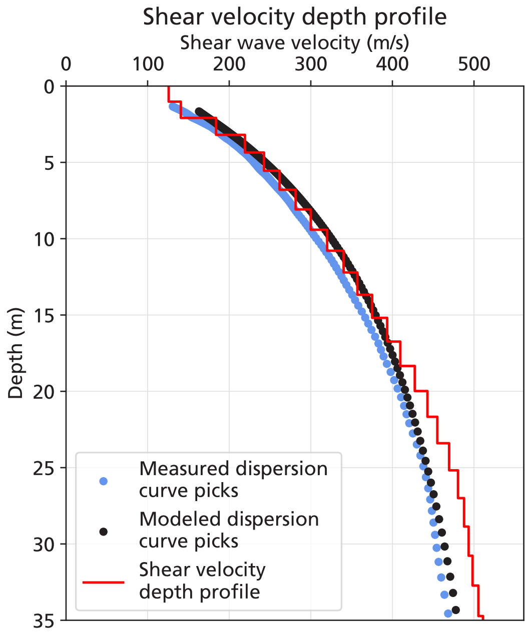
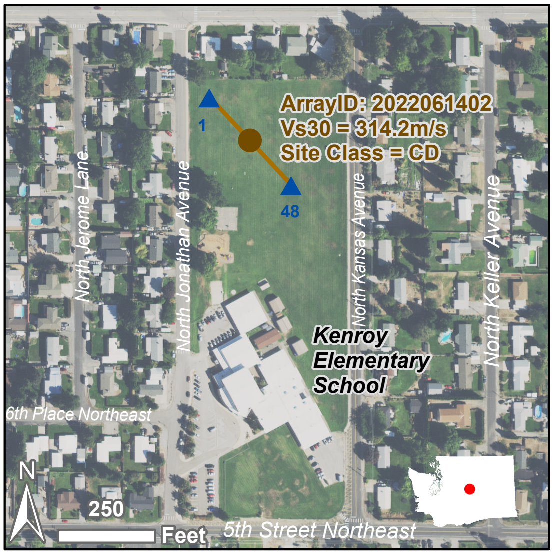
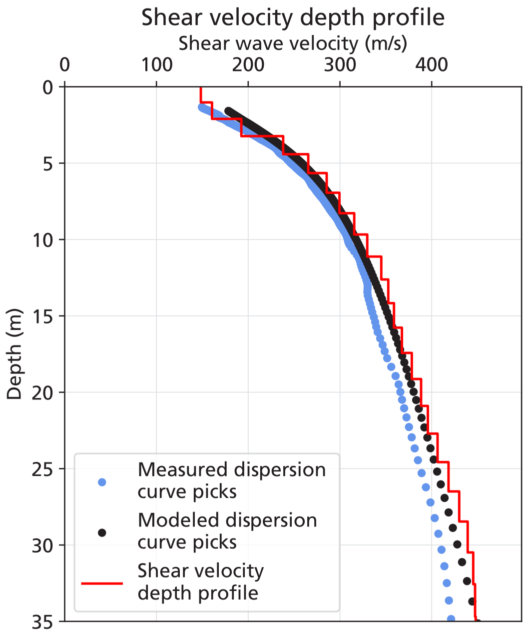
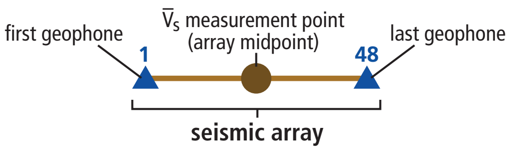
Grant Elementary School



Kenroy Elementary School







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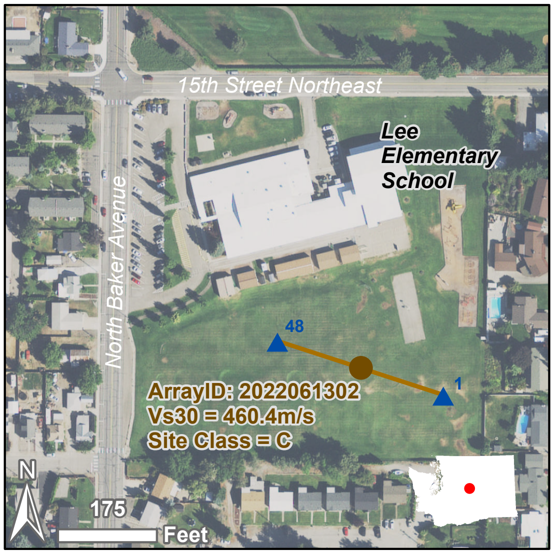
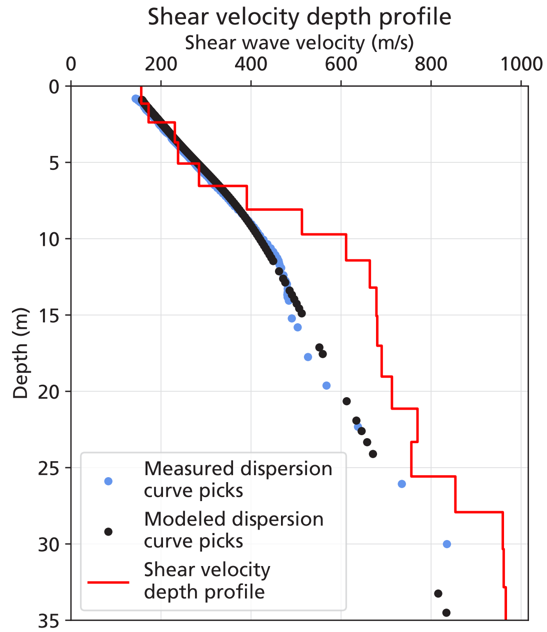
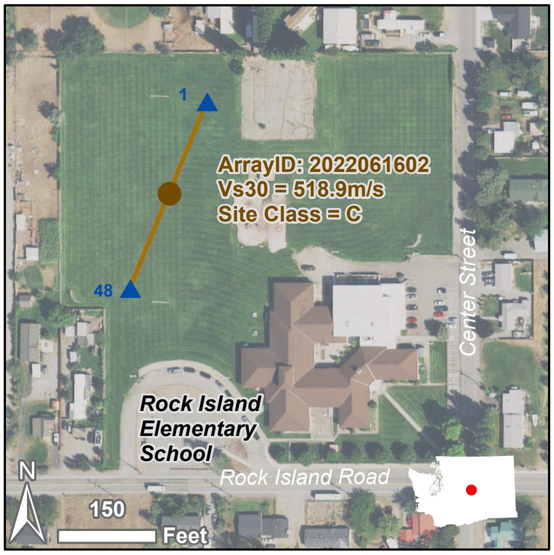
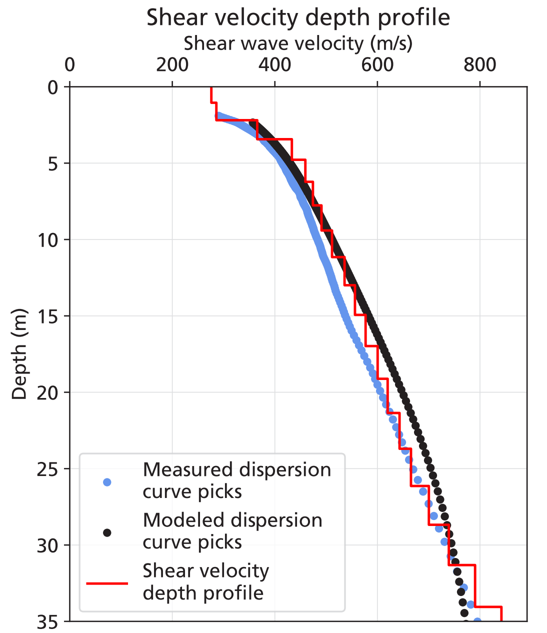
Lee Elementary School

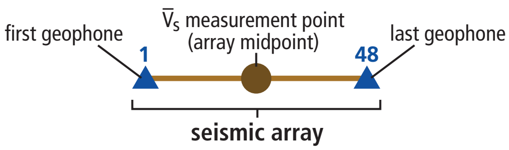




Rock Island Elementary School







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Left: The equation for $\overline{V}_s$ (in m/s), where h_i is the thickness of any layer between 0 m and 30 m, and Vs_i is the shear wave velocity of that layer.

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