

# School Seismic Safety Project

## 2019–2021 Legislative Report

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Engineering and geologic site assessments at 339  
Washington public school buildings

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WASHINGTON STATE DEPARTMENT OF  
**NATURAL RESOURCES**

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# Executive Summary

The purpose of this study is to assess the seismic safety of permanent, public, K–12 school buildings in Washington State. This assessment is based on local geology and the engineering and construction of the buildings. This report summarizes the seismic risk at 561 school buildings (274 schools at 245 campuses) across the state and is the culmination of two biennia of work; Phase 1, which was funded by the 2017–2019 capital budget, and Phase 2, which was funded by the 2019–2021 capital budget. This report presents the results of Phase 2 (2019–2021 biennium appropriation), with some high level conclusions from Phases 1 and 2 combined.

## Summary of Methods

The project involves both geological and engineering assessments at each school. Geologists collect seismic data to measure how local soils amplify earthquake shaking at school campuses, usually on playing fields. This seismic data greatly improves estimates of potential ground shaking by more accurately evaluating site-specific soil conditions under the school buildings. In addition to this, a group of licensed professional structural engineers collect building data at the schools. The structural and nonstructural adequacy of the school buildings are evaluated and safety ratings and damage estimates for these buildings are developed. Combined, these assessments provide a detailed view of how earthquake shaking might affect each school. A selection of high-risk buildings were studied in more detail to determine what a seismic retrofit design would look like and estimate how much it would cost to complete that upgrade. These are called ‘concept-level seismic upgrade designs’.

## Major Findings and Conclusions

- Washington State has many older school buildings built prior to the adoption of modern seismic safety codes. Older and more vulnerable construction types are more susceptible to earthquake damage and have a greater percentage of seismically noncompliant structural and non-structural components.
- Unreinforced masonry buildings constructed before the 1940s and non-ductile concrete buildings (without seismic upgrades) constructed before the mid-1970s located in high seismic hazard areas are especially vulnerable to collapse during earthquakes. The risks of these buildings should be mitigated as soon as practical.
- Older school buildings built prior to 1975 and constructed out of reinforced masonry and wood frame materials are vulnerable to collapse.
- Geologic site class measurements showed that 59 campuses of the 245 studied have a measured site-specific site class that differs from the predicted site class based on reconnaissance-scale mapping. The more accurate site-specific measurements help to inform detailed engineering plans and affect building costs.

- In total, 67 school buildings on 30 school campuses that were assessed in Phase 1 and Phase 2 are located within tsunami inundation zones. These schools serve more than 10,000 students. Tsunami loads and impacts were not considered in the geologic or engineering assessments. For schools to be safe from a tsunami, they would need to be moved from the tsunami inundation zone or designed to withstand tsunami loads with options for vertical evacuation.
- Preliminary structural safety sub-ratings for 561 school buildings assessed in both Phase 1 and Phase 2 were determined. Ninety-three percent of the 561 school buildings assessed have one-star Structural Safety sub-ratings (This is out of a five-star system. One being the lowest, and most vulnerable, and five being the highest, or safest) based on the information available. Four percent of the school buildings assessed have two-star ratings and 3 percent of the school buildings have three-star ratings.
- The concept-level seismic upgrade design results indicate that for many buildings, the cost to seismically upgrade the structure will cost less than the costs to repair major damage following an earthquake, or significantly less than the cost to replace an irreparably damaged building. For less vulnerable structures, especially structures in low seismicity areas, however, it may not be financially worth implementing seismic upgrades.
- Seismically upgrading a vulnerable structure will generally make the building stronger, stiffer, safer, and more resilient, therefore decreasing the damage costs the building will incur in an earthquake.
- A range of cost estimates were developed for each of the select buildings that received a concept-level designs and estimated costs to retrofit. Phase 1 concept-level design building cost estimates ranged from a median of \$63K to \$5.01M, where the median represents the range of cost estimates for a single building. Phase 2 median concept level design building cost estimates ranged from \$1.24M to \$15.26M. Cost estimate methods for Phase 2 were improved from Phase 1 and now include projected soft costs. Phase 1 concept design schools were selected to represent a variety of building construction types and vintages in different seismic hazard areas. Alternatively, Phase 2 concept design schools were selected based on available information to be some of the highest risk buildings based on seismic hazard and engineering design.
- A significant portion of the structural upgrade costs are due to the fact that the seismic upgrades take place in existing buildings with existing finishes and existing nonstructural components. The costs to temporarily remove and replace the architectural, mechanical, electrical, and plumbing equipment is significant. If the costs associated with the architectural, mechanical, electrical, plumbing, and fire protection elements were deleted from the cost estimates, the average seismic upgrade cost sees a 70 percent reduction. Significant savings can be realized by combining seismic upgrades with other types of work, such as re-roofing projects or school modernizations.
- Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Of the 561 buildings studied, 63 percent were high or very high priority, 18 percent were moderate priority, and 19 percent were lower priority.
- The EPAT data show that the median building is expected to be 55 percent damaged in a design-level earthquake (Table 10). EPAT also estimates that the majority of buildings in this study are expected to receive a “Red—Unsafe” post-earthquake building safety placard following a design-level earthquake, meaning that they will be unsafe to occupy. In addition, the EPAT data show that approximately one-half of buildings studied will not be repairable following a design-level

earthquake, and will require demolition. The EPAT results are summarized in Table 10 and results for Phase 1 and 2 building damage estimates are shown in Figure 16 below.

The School Seismic Safety Project (Phases 1 and 2) has been an important opportunity to study and evaluate school buildings across the state and has demonstrated the need for dedicated funding for seismic retrofits. Following the Phase 1 report and project, the Legislature funded the Office of the Superintendent of Public Instruction (OSPI) \$13 million in 2019 and \$40 million in the 2021–2023 biennium for the School Seismic Safety Retrofit Program (SSSRP). This program is the first of its kind in Washington and is a critical step in repairing the most vulnerable schools. The study team applauds and further encourages the state for continued funding of school seismic safety retrofits.

## Recommendations

The cost of inaction on seismic safety is too great for children, parents, teachers, and our communities if we slow down. Washington’s legislators, agencies, school districts, and design professionals are actively turning seismic knowledge into action. And although we have learned a great deal about the seismic vulnerabilities to school buildings and now have a SSSRP, there is still a great deal more to be done. The following are recommendations to continue to improve the seismic safety and resiliency of our schools and communities:

- A study to evaluate the feasibility and cost benefit of increasing the seismic performance for the design of new school buildings to enhance the seismic resilience of communities.
- A study to identify which schools in tsunami inundation zones need vertical evacuation structures.
- A study of school sites suspected of having moderate to high risk of liquefiable soils, to determine cost-efficient methods of assessing the risk, and identify mitigation strategies for existing school buildings on liquefiable soils.
- Conduct a statewide inventory of school districts to collect data about which facilities have already had seismic upgrades.
- Continue to update OSPI’s database with structural and seismic information about each school building (construction type, year of construction, previous seismic upgrades, site class, seismicity, seismic irregularities).
- Continue doing American Society of Civil Engineers (ASCE) Tier 1 seismic evaluations of school buildings.
- OSPI should develop a panel of experts to advise the SSSRP on spending and how to estimate actual construction costs based on inflation, soft costs, and other factors.
- Develop a policy and provide funding to conduct seismic upgrades when school facilities are undergoing major modernizations. A substantial cost of seismic upgrades is the removal and replacement of architectural, mechanical, electrical and plumbing systems. This study shows that if seismic upgrades are combined with modernizations, the costs of seismic upgrades can be reduced, on average, by 70 percent.

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# Introduction

This statewide study constitutes a major step taken by Washington State to improve the understanding of seismic risks to public school buildings. These schools are important to local communities, as they house hundreds or even thousands of students and staff on a typical day. Many of these buildings are also historic structures, and they are often culturally or societally important. Additionally, parents are legally required to have their children attend school, making it mandatory for children to spend time in these buildings. In urban and rural communities alike, public schools not only educate the next generation of Washington residents but also serve as gathering spaces for communities to come together over interscholastic athletics, meetings, and other events. Schools often serve as the gathering space or shelter after a natural disaster and are a community staple. Without seismically upgrading buildings, earthquakes will be not only devastating and economically damaging, and will have a significant social impact as well.

This study aims to assess the seismic safety of permanent, public, K–12 school buildings in Washington State. This assessment is based on local geology and the engineering and construction of the buildings. This report summarizes the seismic risk at 561 school buildings (274 schools at 245 campuses) across the state and is the culmination of two biennia of work; Phase 1, which was funded by the 2017–2019 capital budget, and Phase 2, which was funded by the 2019–2021 capital budget. The Department of Natural Resources (DNR) Washington Geological Survey (WGS) was the project lead, with significant contributions from structural engineering contractors led by Reid Middleton, Inc., and the Office of Superintendent of Public Instruction (OSPI).

DNR geologists assessed site-specific geology to determine the National Earthquake Hazard Reduction Program (NEHRP) site class category at each school campus. Geologists also determined if the school campuses are in mapped tsunami inundation zones, and if there are any other mapped geologic hazards on or proximal to the school campuses. Structural engineers performed the following assessments: (1) American Society of Civil Engineers (ASCE) 41-17 Tier 1 seismic screening evaluations, (2) Federal Emergency Management Agency (FEMA) P-154 Rapid Visual Screenings (RVS), (3) earthquake performance rating system (EPRS) developed by the Structural Engineers Association of Northern California (SEAONC), and (4) Earthquake Performance Assessment Tool (EPAT) assessments. These assessments were completed for 561 individual school buildings (339 buildings were assessed in Phase 2 and 222 were assessed in Phase 1) and seven fire stations located within one mile of a school (five in Phase 1 and two in Phase 2). Following the completion of the seismic screening evaluations, a total of 32 school buildings (15 in Phase 1, and 17 in Phase 2) received more detailed concept-level seismic upgrade designs and seismic upgrade cost estimates. All of these assessments provide valuable information on the condition of the school building and can inform school districts about the seismic risk and expected performance of these buildings in an earthquake.

There are also negative economic impacts associated with loss of life, injuries, and the prolonged closure of damaged schools. Prolonged closures can lead to increased costs for school districts, and can require

parents to find childcare or alternative educational activities for their children, as we have learned with school closure due to the COVID-19 pandemic. Economic setbacks due to earthquakes (or other natural disasters) can also cause long-term disinvestments that can permanently change the character of a community. The results of this study highlight the critical need for investment in resilience planning, policy updates, and significant funding to seismically upgrade all Washington schools to improve their seismic safety.

The main body of this report presents the results of the school building assessments. The fire station assessments and results are discussed separately at the end of the report in a section titled *Fire Stations*.

## Funding and Scope

This project has been funded by the Washington State capital budget with Phase 1 in the 2017–2019 biennium at \$1,200,000 and Phase 2 during the 2019–2021 biennium at \$2,200,000. These appropriations were largely similar in their scope, however there are differences in school prioritization criteria, among other things. A comparison of the appropriations is provided below (Table 1).

**Table 1.** Phase 1 (2017–2019) and Phase 2 (2019–2021) appropriation comparison.

| Appropriation Conditions                        | “Phase 1” 2017–2019 Biennium Appropriation Summary   | “Phase 2” 2019–2021 Biennium Appropriation Summary  |
|---|--|---|
| <b>Prioritized seismic risk assessment</b>      | DNR, in consultation with OSPI, Emergency Management Division (EMD), and the State Board of Education (SBE), shall develop a prioritized seismic risk assessment that includes seismic safety surveys of public facilities that are subject to high seismic risk as a consequence of high seismic hazard and soils that amplify that hazard.   |   |
| <b>Prioritization of the facilities studied</b> | <ul style="list-style-type: none"> <li>• A minimum of 25 public school facilities that have a capacity of 250 or more persons and are used for the instruction of students in K–12. The Survey must be a representative sample of urban and rural school districts located in different geographical areas of the state.</li> <li>• Public school facilities that have a capacity of fewer than 250 persons.</li> <li>• Fire stations located within a one-mile radius of school facilities with 250 person capacity.</li> </ul> | <ul style="list-style-type: none"> <li>• The survey must be a representative sample of public facilities located in high priority areas as determined in the 2017–19 survey of public school seismic safety assessments and tsunami inundation zones as published by DNR. The survey must use the results of the 2017–2019 survey's findings to prioritize school buildings based on geologic and engineering results.</li> <li>• A portion of public school facilities that are routinely used for the instruction of students in kindergarten through twelfth grade and in school districts that have held</li> </ul> |



|  |  |  |
|--|--|--|
|  |  | <p>successful bond elections within the previous 3 years.</p> <ul style="list-style-type: none"> <li>• A portion of the remaining public school facilities that are routinely used for the instruction of students in kindergarten through twelfth grade.</li> <li>• Fire stations located within a one-mile radius of a public K–12 school facility.</li> </ul> |
| <b>Assessments of facilities shall include</b> | <ul style="list-style-type: none"> <li>• An on-site assessment, under the supervision of licensed geologists, of the seismic site class of the soils at the facilities.</li> <li>• An on-site inspection of the facility buildings, including structural systems (using structural plans where available), condition, maintenance, and nonstructural seismic risks following standardized methods by licensed structural engineers.</li> <li>• An estimate of costs to retrofit a prioritized subset of the school facilities specified above to life safety standards as defined by ASCE.</li> <li>• An estimate of costs to retrofit a prioritized subset of fire station facilities to immediate occupancy standards as defined by the ASCE.</li> </ul> |  |
| <b>Submitting survey data to OSPI</b>          | DNR must collect and submit survey data to the superintendent of public instruction in a format compatible with the Information and Condition of Schools (ICOS) database. The department must enter into an agreement with the superintendent of public instruction to make any necessary modifications to the ICOS database to receive and report the survey data.  |  |
| <b>Data sharing plan</b>                       | <p>DNR must share data with:</p> <ul style="list-style-type: none"> <li>• The governor and the appropriate legislative committees.</li> </ul>  | <p>DNR must share data with:</p> <ul style="list-style-type: none"> <li>• The school districts and schools where the surveys were conducted.</li> <li>• The governor and the appropriate legislative committees.</li> </ul>  |
| <b>School safety plans</b>                     | DNR and OSPI must provide technical assistance to the school facilities sampled to incorporate survey information into their school safety plans.  |  |
| <b>Reporting</b>                               | A preliminary report on the progress of the statewide seismic needs assessment shall be submitted to the appropriate committees of the legislature by October 1, 2018. The final report and statewide seismic needs assessment shall be submitted to the Office of Financial Management (OFM) and the appropriate committees of the legislature by June  | The statewide seismic needs assessment shall be submitted to the Office of Financial Management (OFM) and the appropriate committees of the legislature by June 30, 2021.  |

|                |             |             |
|----------------|-------------|-------------|
|                | 30, 2019.   |             |
| <b>Funding</b> | \$1,200,000 | \$2,200,000 |

DNR, OSPI, Emergency Management Division (EMD), and SBE, along with help from the United States Geological Survey (USGS) and the University of Washington Civil Engineering Department, developed a committee—the School Seismic Safety Steering Committee (SSSSC)—to determine how to accomplish as much as possible with time and funding allotted in both the 2017–2019, and 2019–2021 biennia. The SSSSC conducted a competitive interview process and ultimately selected Reid Middleton Inc., an Everett, WA-based engineering firm with seismic engineering and evaluation expertise and experience in the design of K–12 schools and statewide resources, to conduct the structural engineering assessments and seismic upgrade design concepts and cost estimates for both phases of this project. As the prime contractor, Reid Middleton partnered with and led teams from three other structural engineering firms to provide DNR, OSPI, and school districts with distributed access to experienced experts and licensed structural engineers throughout the state of Washington – experts invested in the communities and regions around them.

## Seismic Hazard

The beautiful mountains, plains, and waterways that are the backdrop for Washington schools are the result of complex geologic processes that have been active for billions of years. Off the coast of western Washington, the Juan de Fuca tectonic plate is being pulled underneath the North American plate in a process known as subduction. This type of geologic action is partly responsible for Washington’s tall mountains and volcanoes. This terrain directly affects Washington’s climate, which causes heavy snowfall in the mountains and creates the bountiful agricultural region in central and eastern Washington.

Washington’s complex plate tectonics have the additional effect of making the state one of the highest seismic risk regions in the United States. When built-up stress from the subduction process is released, it causes the crust of the Earth to vibrate and move—an earthquake. Washington State can experience three major types of tectonic earthquakes (Fig. 1). In the past thousand years or so, Washington State has experienced deep intraplate earthquakes (such as the 2001 Nisqually Earthquake), earthquakes occurring on shallow surface faults (~930 A.D. Seattle Fault Earthquake), and subduction zone earthquakes (1700 Cascadia). Major earthquakes in western Washington in 1946, 1949, 1965, and 2001 cumulatively killed 15 people and caused billions of dollars’ worth of property damage (Walsh and others, 2011). In eastern Washington, earthquakes near Chelan in 1872 and near Walla Walla in 1936 also caused significant damage (Walsh and others, 2011). The presence of all three earthquake sources and the relatively high likelihood of having another earthquake in the not too distant future constitutes a significant seismic hazard, and when considered alongside the high population density in areas where these seismic hazards exist, creates a high seismic risk for our state. A large seismic event, such as a magnitude 9 Cascadia

event, will have an enormous impact for most of western Washington, where approximately 75% of public school children attend school.

### Cascadia Subduction Fault

Giant earthquake every  
300-600 years  
15 - 25% probability in next  
50 years

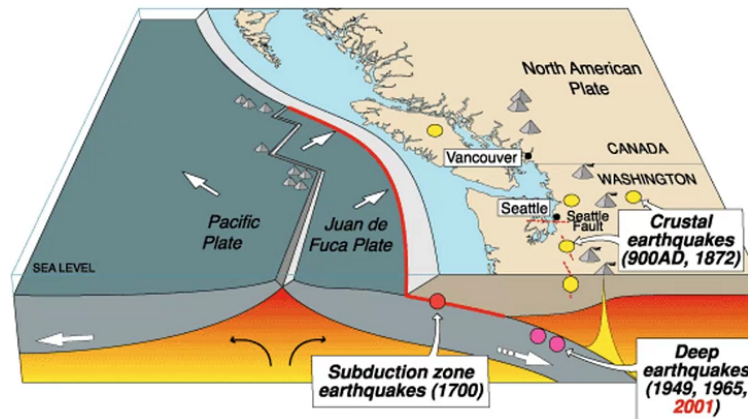
### "Shallow" Crustal Faults

Magnitude 7-ish  
1872 (largest historic)  
~15% probability in 50 yr.

### Deep Slab Earthquakes

Magnitude 7-ish  
Nisqually 2001  
Our most common quake  
~85% chance in 50 yr.

## How likely are major earthquakes?



**Figure 1.** Earthquake sources and probabilities in Washington State. Figure from the Pacific Northwest Seismic Network, adapted from the United States Geological Survey (USGS).

## Design-Level Earthquake

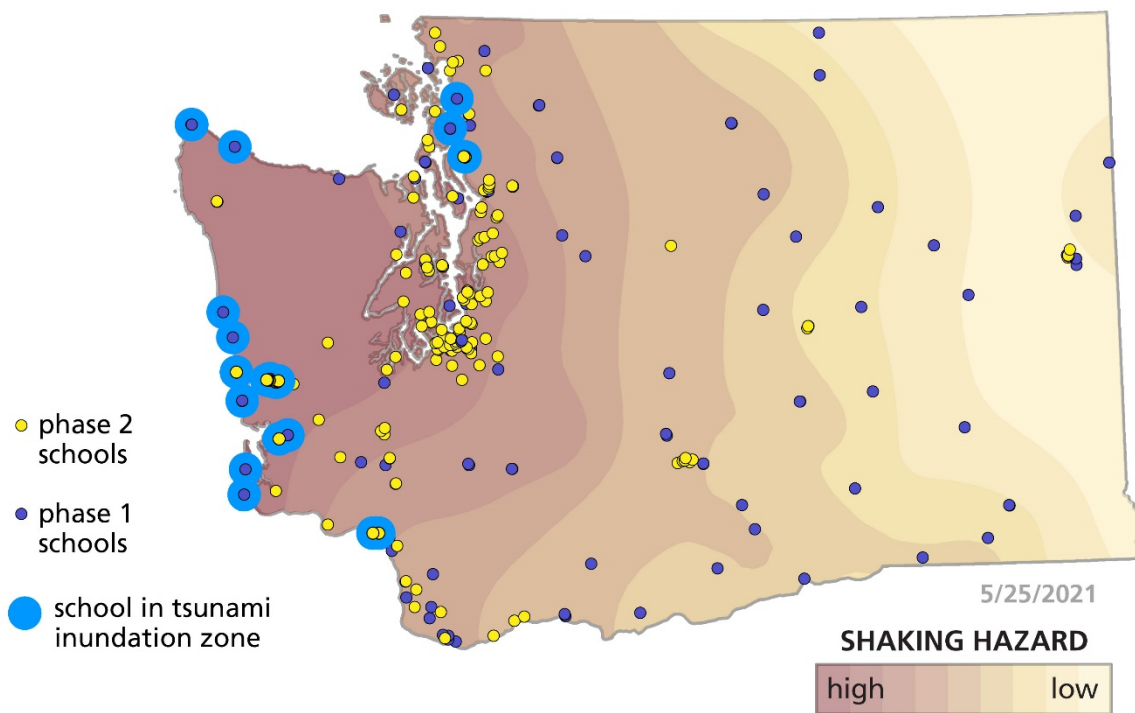
Because the range of potential earthquakes varies so greatly, and the worst-case earthquake is not the most likely, engineers use what is called a “design-level earthquake” when engineering new buildings. A “design-level earthquake” is a theoretical earthquake event, which is defined by ASCE 7-16 as being two-thirds of the magnitude of the maximum considered earthquake ( $MCE_R$ ), and is used in the design of buildings to ensure that the building behaves in a predictable way if that design-level earthquake event should occur. The  $MCE_R$  is a risk-adjusted probabilistic event that is based on an earthquake with a 2,475-year return period. The earthquake level is adjusted with the intent that new buildings designed to the current building code will have a 1% probability of collapse in 50 years due to a seismic event (ASCE 41-17, 2017). While not exact, the magnitude of the design-level earthquake event is similar to the magnitude of an earthquake event with a 475-year return period for many locations on the west coast of the United States. Earth scientists expect the average return period of a Cascadia Subduction Zone (CSZ) earthquake to be approximately 500 years. It is possible that a CSZ earthquake could be approximately the magnitude of the design-level earthquake for many parts of Washington State, depending on the particular earthquake characteristics. The design-level earthquake is mandated by the building code to represent the most likely source of earthquake shaking hazard for the region where the building is located; this includes shaking from large earthquakes, such as the Cascadia subduction zone, but also shaking hazard from active crustal faults such as the Seattle fault or the Southern Whidbey Island fault zone.

## Tsunami Hazard

Washington is also at risk for tsunamis generated by earthquakes, landslides, and volcanic eruptions. Part of the directive in the 2019–2021 capital budget was to assess the seismic safety of schools in mapped tsunami inundation zones. Schools in tsunami inundation zones are vulnerable to both earthquake and tsunami hazards and thus are some of the highest risk facilities. In Phases 1 and 2 of this project, we assessed 59 buildings at 28 schools in mapped tsunami inundation zones based on mapping conducted and published by DNR (Fig. 2). These schools were assessed solely on seismic risk (as this was the legislative directive) and the schools assessed in this study did not receive an assessment of their buildings’ deficiencies in regards to expected tsunami loads. It was outside of the scope of this study to provide any information or recommendations on tsunami vertical evacuation structure necessity for these schools. Additionally, of those schools in the tsunami inundation zone that received concept-level design studies, tsunami hazards and the engineering necessary to withstand a tsunami were not considered in necessary upgrades to the facility.

For many facilities in a mapped tsunami inundation zone, particularly those in southwest Washington, in order for a school facility to be “seismically safe” it is recommended in the *Future Studies* section that future work should also consider the tsunami risk.

## WASHINGTON SCHOOL SEISMIC SAFETY PROJECT PHASE 2 AND PHASE 1 SCHOOLS, TSUNAMI INUNDATION



**Figure 2.** Map showing the location of the schools assessed for Phase 1 (purple dots) and Phase 2 (yellow dots) of this project and highlighting the schools studied that are located in tsunami inundation zones (outlined in blue). The basemap is of the seismic hazard in Washington State, expressed as contours of peak ground acceleration (anticipated ground shaking, or acceleration in bedrock) as a fraction of standard gravity. These values are from the USGS two percent probability of exceedance in 50 years map of peak ground acceleration, which is a proxy for shaking hazard (Petersen and others, 2015). Warmer colors indicate higher hazard areas.

## Phase 2 School Selection

For Phase 1 school survey selection, please refer to the [Phase 1 legislative report](#) (Washington Geological Survey, 2019) and Table 1 summarizing the differences in funding and scope. In Phase 2, the survey of schools were selected based on the criteria provided in the 2019–2021 Capital Budget language:

- The survey was a representative sample of public facilities located in high priority areas as determined in the 2017–19 Phase 1 and tsunami inundation zones as published by the department.

The survey used the results of the 2017–19 survey's findings to prioritize school buildings based on geologic and engineering results.

- A portion of public school facilities that are routinely used for the instruction of students in K-12 grade and in school districts that have held successful bond elections within the previous three years.
- A portion of the remaining public school facilities that are routinely used for the instruction of students in kindergarten through twelfth grade.
- Fire stations located within a one-mile radius of a public K–12 school facility.

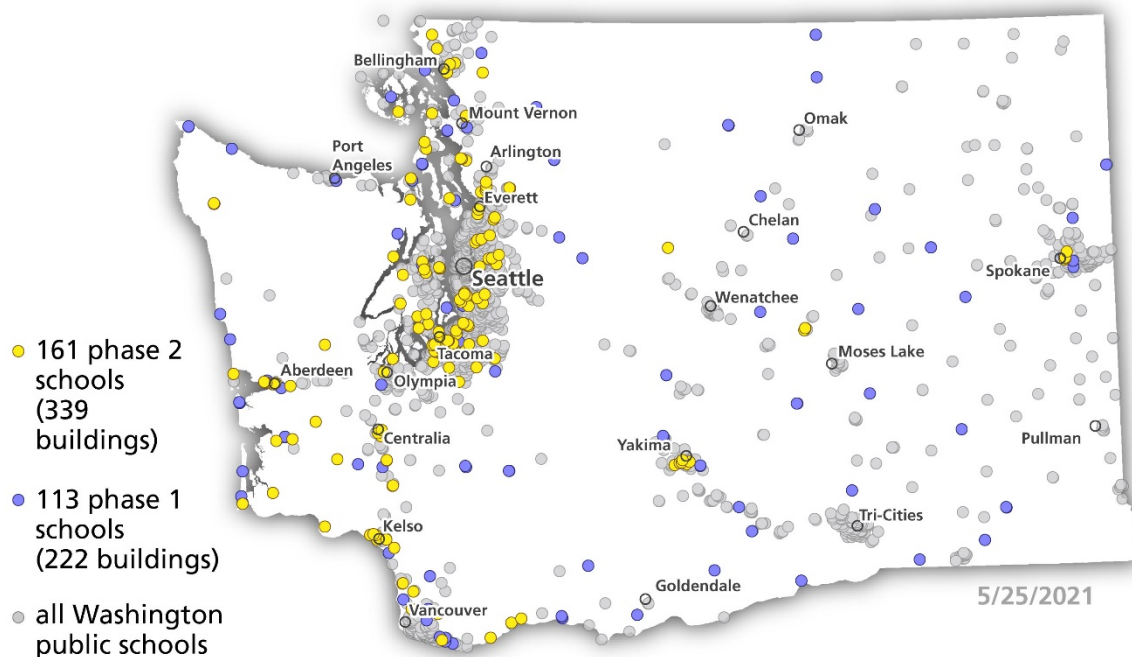
We utilized the results from Phase 1, which indicated that the highest risk schools are: those in high seismic hazard areas, buildings that are older (particularly those built prior to 1975 when the State adopted a building code), and those that are made of vulnerable construction types (URM, and non-ductile concrete being the worst).

DNR worked with OSPI to gather information on school districts that have passed a successful bond election within the previous three years and to select vulnerable buildings in a sample of those districts. Figure 3 shows the schools assessed in Phases 1 and 2 of this project as well as all of the other public K-12 Washington school buildings. The 561 buildings assessed in Phases 1 and 2 are a small sample (~12 percent) of the entire school building stock. Note that in total 561 buildings have been assessed, at 274 schools, on 245 campuses (multiple schools can share the same campus). The engineers performed seismic assessments at each individual building (561 buildings total for Phases 1 and 2), whereas the geologic site assessments are performed at each school campus (245 campuses total for Phases 1 and 2).



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## WASHINGTON SCHOOL SEISMIC SAFETY PROJECT ALL SCHOOLS



**Figure 3.** Map showing the schools assessed for Phase 1 and Phase 2 of this project as well as the locations for all other public K–12 Washington schools.

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# Methods

## Geologic Site Assessments

### Site Class

Site class is an approximation of how much the soils and rocks at a site will amplify or attenuate ground motion relative to hard rock during an earthquake (Fig. 4). Using the empirical observations of Bordchert (1994), the National Building Safety Council (BSSC, 1997; 2004) developed the site class parameter to categorize the potential for amplification of seismic waves by the local soils, where the relative hardness is proportional to how fast shear waves travel through the soils. The site class parameter also correlates the potential for amplification of seismic waves with the fundamental frequency of a building (i.e. shorter buildings are more affected by short-period or high frequency ground motions, taller buildings are more affected by longer-period or lower frequency shaking). The NEHRP provisions BSSC (2010, 2015), define the standardized site classes (Table 2) and the associated range of the time-averaged shear wave velocity in the upper 100 ft (30 m) of the ground (a value known as  $V_{s30}$ ; BSSC, 2004; 2015). Softer soils with a lower  $V_{s30}$  (site classes E and D) will typically increase the amplification of ground shaking, and have a higher seismic hazard than harder soils or rock, which have a higher  $V_{s30}$  (site classes A–C).

From a seismic design standpoint, site class is an integral parameter for determining the level of acceleration (and force) that a building needs to be designed for, specific to the underlying soils which the building is built upon. This in turn also determines the Seismic Design Category (SDC) of a structure. The SDC is a categorization scheme that dictates the seismic risk that buildings must be designed to meet. Site class is also incorporated into all the major U.S. and international building codes, including the American Society of Civil Engineers 7-16 (ASCE, 2017b), the International Building Code (IBC, 2017), and the International Residential Code (IRC, 2017), all of which have been adopted in Washington State.

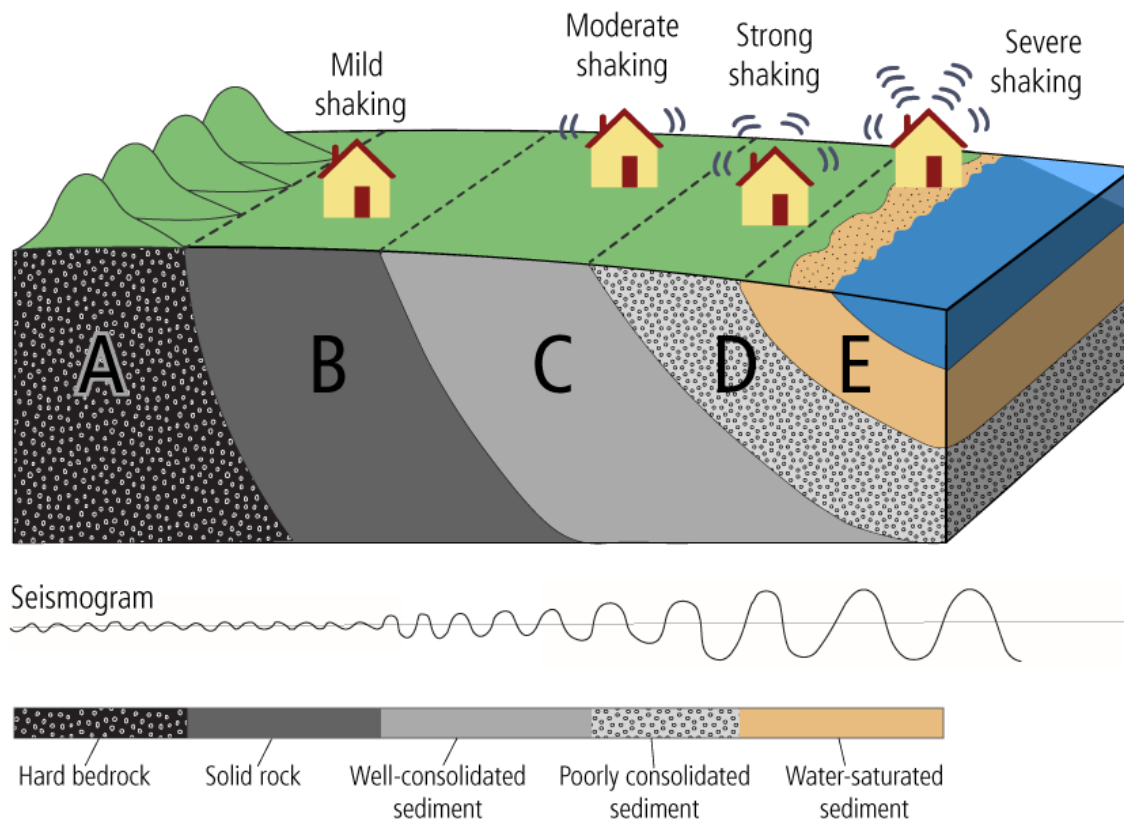
An accurate site class also has direct implications for seismic design and related construction costs. As previously mentioned, seismic ground motions can be amplified depending on the soils the seismic waves travel in. When soil properties are not known in enough detail to classify a site class, site class D is often used as a default, as allowed by the building code or authority having jurisdiction. In shorter buildings that are governed by short-period ground motions, having a site class C can increase seismic accelerations and forces by as much as 20% when compared to a default site class D. In taller buildings governed by long-period ground motions and for buildings in less seismic active areas, site class C can decrease seismic accelerations and forces by as much as 15% and 30% respectively. Furthermore, buildings built on soils classified as site class E are often times associated with soils that are susceptible to liquefaction, the phenomenon where underlying soils liquefy in a seismic event which drastically decreases the strength of the soil that supports the building. Buildings in liquefiable soils require more robust foundation systems, thereby increasing the cost of construction or rehabilitation. Having site-specific



Vs30 measurements to classify the site class at a given site will more accurately define the seismic engineering criteria, risk, and parameters for the structural design and detailing of a building which thereby influences the construction costs of a building. In higher seismic areas, having a defined site class can more accurately estimate costs for buildings for budgetary and programming purposes, as well as for prioritizing seismic upgrades of vulnerable buildings. In less seismic areas, having a defined site class can help to reduce the conservatism in the seismic design and associated construction costs.

At each school campus, WGS geologists and geophysicists used geophysical methods as described in West and others (2019) to measure Vs30. From this measurement, site class was assigned to the school buildings at each campus or fire station. The final results for each campus and fire station are condensed into an individual site class assessment report for that campus (Fig. 5) and distributed to each school, school district, and (or) fire station (*Appendix A*). The results are also entered into OSPI's ICOS statewide database.

The site class assessment reports summarize the key results and observations for each site. The results are in two parts: a non-technical front page and a more technical summary back page (Fig. 5). The non-technical summary provides information about field deployment, methods used, the measured site class, an overview of the soils mapped at the campus, and available information about other mapped geologic hazards. The technical overview expands on the data processing results, briefly discussing the quality of the dispersion images, as well as the methods and the Shear-Velocity Depth Profile (SVDP) used to determine Vs30. This more technical information can be useful for any further geotechnical analysis at the school campus. If there is a change in the site class from a previously published value, or if there is complicated geology mapped at the site, a section is included that summarizes how the velocity model fits into the larger geological context. The technical overview includes a figure of the SVDP, and may also contain a 2D Multi-channel Analysis of Surface Waves (MASW) velocity model or a 2D P-wave velocity model, if relevant.



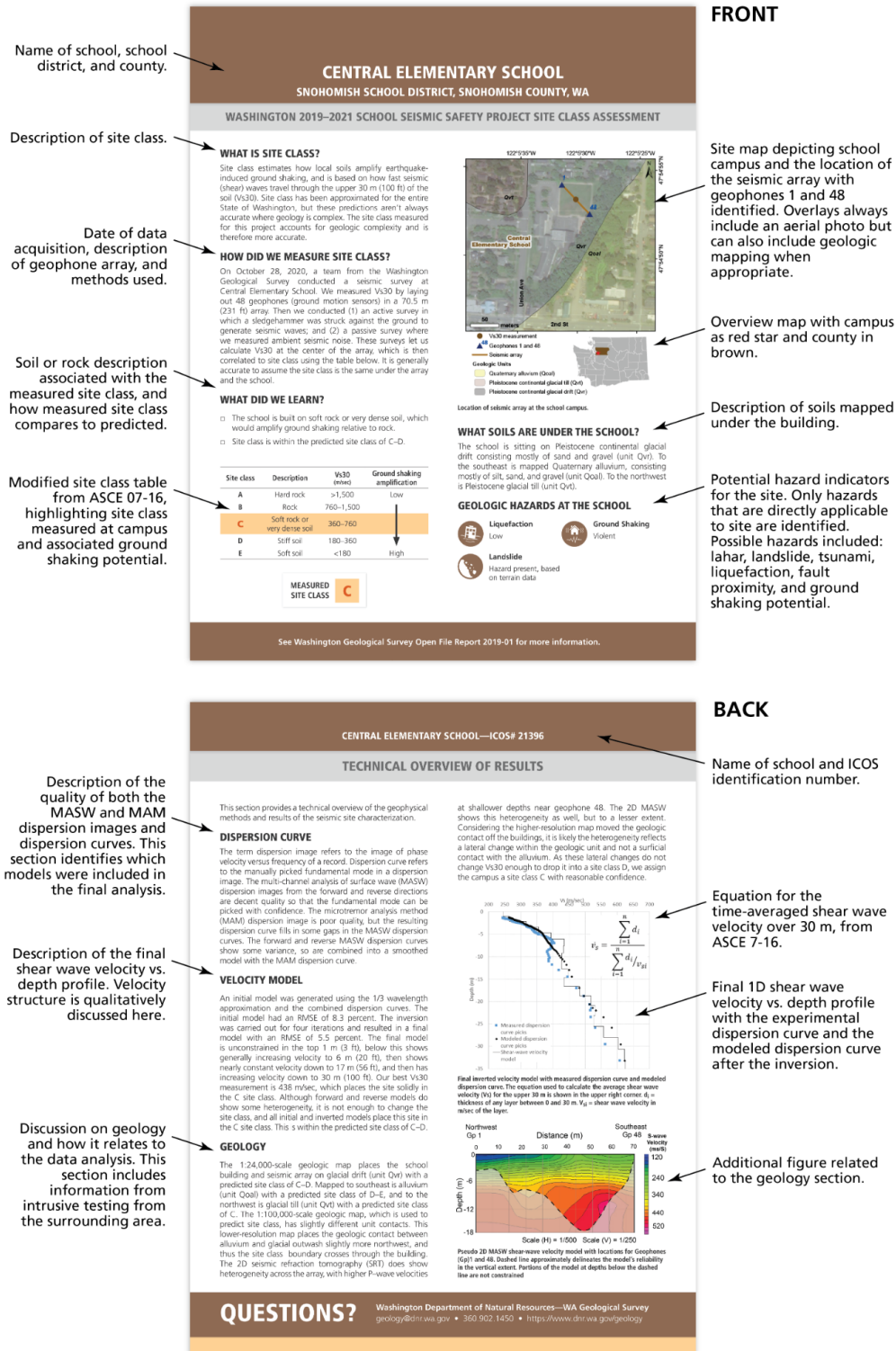
**Figure 4.** Schematic figure illustrating how seismic waves travel through different rock and soil types and the simplified site class associated with those rock/soil types (site class is labeled A–E). The type of rock or soil beneath a structure greatly affects how a building responds to earthquake shaking. Geologists measure the time it takes seismic waves to travel through the ground at each school campus to determine the rock/soil type and correlate it to a site class value. This value is then incorporated into the engineering assessment. Figure modified from: <https://slideplayer.com/slide/6132863>

**Table 2.** NEHRP site class categories. Softer soils typically increase shaking amplification and thus seismic hazard. Under certain circumstances where soils are vulnerable to collapse under seismic loading, such as liquefiable soils like peat, a special site class F may be designated.

| NEHRP site class | Description               | Vs30 (meters/second) | Ground shaking amplification |
|------------------|---------------------------|----------------------|------------------------------|
| <b>A</b>         | Hard rock                 | greater than 1,500   | Low                          |
| <b>B</b>         | Rock                      | 760–1,500            |                              |
| <b>C</b>         | Soft rock/very dense soil | 360–760              | Moderate                     |
| <b>D</b>         | Stiff soil                | 180–360              |                              |
| <b>E</b>         | Soft soil                 | less than 180        | High                         |

Because measuring site class requires either a geophysical survey or boreholes, it can be prohibitively expensive. As a result, state and federal agencies and researchers have developed regional site class maps based on Vs30 proxies. These site class maps are based on topography (Wald and Allen, 2007; Allen and Wald, 2009), geology (Wills and Clahan, 2006; Palmer and others, 2004), or a combination of the two (Thompson and others, 2014). However, these reconnaissance-scale site class maps must make assumptions to account for lateral and vertical changes in geology. These assumptions can significantly over- or under-estimate site class in areas of complex geology. Regional reconnaissance-scale site class maps therefore provide a good approximation for routine building design and seismic screening, but are not intended to replace site-specific testing needed for the design of essential facilities.

In the state of Washington, Palmer and others (2004) utilized surficial geologic mapping and a limited number of Vs30 measurements to construct a 1:100,000-scale predictive statewide site class map. The scale of the geologic mapping is not appropriate for site-specific use. The SSSP site class assessments account for 3D geology and are correlated with newer more accurate 1:24,000-scale geologic mapping and boreholes for ground-truthing where available.



**Figure 5.** Site class assessment reports, with a non-technical front page shown on top and a technical summary back page shown on bottom. Site class reports for Phase 2 schools are located in *Appendix A*.

## Information for Schools on Other Geologic Hazards

Along with our site class assessment, we also reviewed available maps and datasets to screen for other geologic hazards (lahars, landslides, tsunamis, liquefaction, nearby faults, and estimated ground shaking) that could affect the campus. Although these geologic hazards have no direct influence on the measured site class, some are co-seismic (phenomena directly associated with seismic activity) and all pose varying levels of risk to school structures and their occupants. However, an extensive characterization of how each identified hazard could affect the campus is beyond the scope of the site class assessment. Instead, hazard flags are intended simply to notify school authorities and others interested in these reports of the possible geologic risks. If identified, a flag associated with the geologic hazard is placed in the bottom right corner of the front page of the site class assessments (Fig. 5). Below are the short definitions of the hazards and the parameters used to determine if a geologic hazard was flagged:

- **Lahars** are fast-moving destructive mud or debris flows that originate from the flanks of volcanoes and usually travel along river valleys. A school is identified as having a lahar hazard if the campus is in a mapped lahar hazard area (Washington Division of Geology and Earth Resources, 2016).
- **Landslide** hazard was identified by WGS landslide geologists based on high-resolution lidar, orthoimagery, and the landslide activity of an area. The site class assessment reports do not thoroughly assess landslide hazard. If a hazard is suspected and flagged, it should be reviewed by a licensed engineer or engineering geologist.
- **Tsunami** hazard is identified using WGS tsunami inundation modeling (Washington Geological Survey, 2021 b). Not all of Washington is mapped for tsunami hazards. If the school is not flagged as being in a mapped tsunami hazard zone it does not necessarily mean there is not a tsunami hazard present.
- **Liquefaction** hazard is the susceptibility of soils to liquefy during an earthquake. This hazard is identified based on the statewide liquefaction maps by Palmer and others (2004) and expressed as: bedrock, very low, low, moderate, high, very high, or extreme based on the statewide liquefaction mapping. For sites that were mapped as bedrock sites (where liquefaction potential is negligible) but are determined to not actually be a bedrock site through our geologic site assessment, we assign the modified description: unknown, not negligible.
- Mapped **active faults** are derived from the WGS database of Quaternary faults (Bowman and Czajkowski, 2019). If any of these active faults are within a roughly five-mile radius of a school campus, the campus is flagged.

- Ground Shaking** hazard is estimated by using the Dynamic Conterminous U.S. 2014 (updated) (v. 4.2.0) model of the USGS Earthquake Hazards Program Unified Hazard Tool (UHT) (U.S. Geological Survey, 2021). The measured site class results are incorporated as an input into the UHT to more accurately predict the peak ground acceleration (here we use the model that has a two percent chance of being exceeded in the next 50 years) from the USGS National Seismic Hazard Map (Petersen and others, 2020). The ground shaking intensity (severe, violent, extreme and so on) is then classified based on the classification of Worden and others (2012). Some Schools may have a high ground shaking hazard and yet may be located on hard rock (site class A or B), this is likely due to geologic factors such as their close proximity to an active fault or within a large basin. Conversely, some campuses may have a low ground shaking hazard and be sitting on soils with a measured site class of C, D, or E, in these cases the campus may be located in a low seismic hazard area (likely far away from any mapped faults).

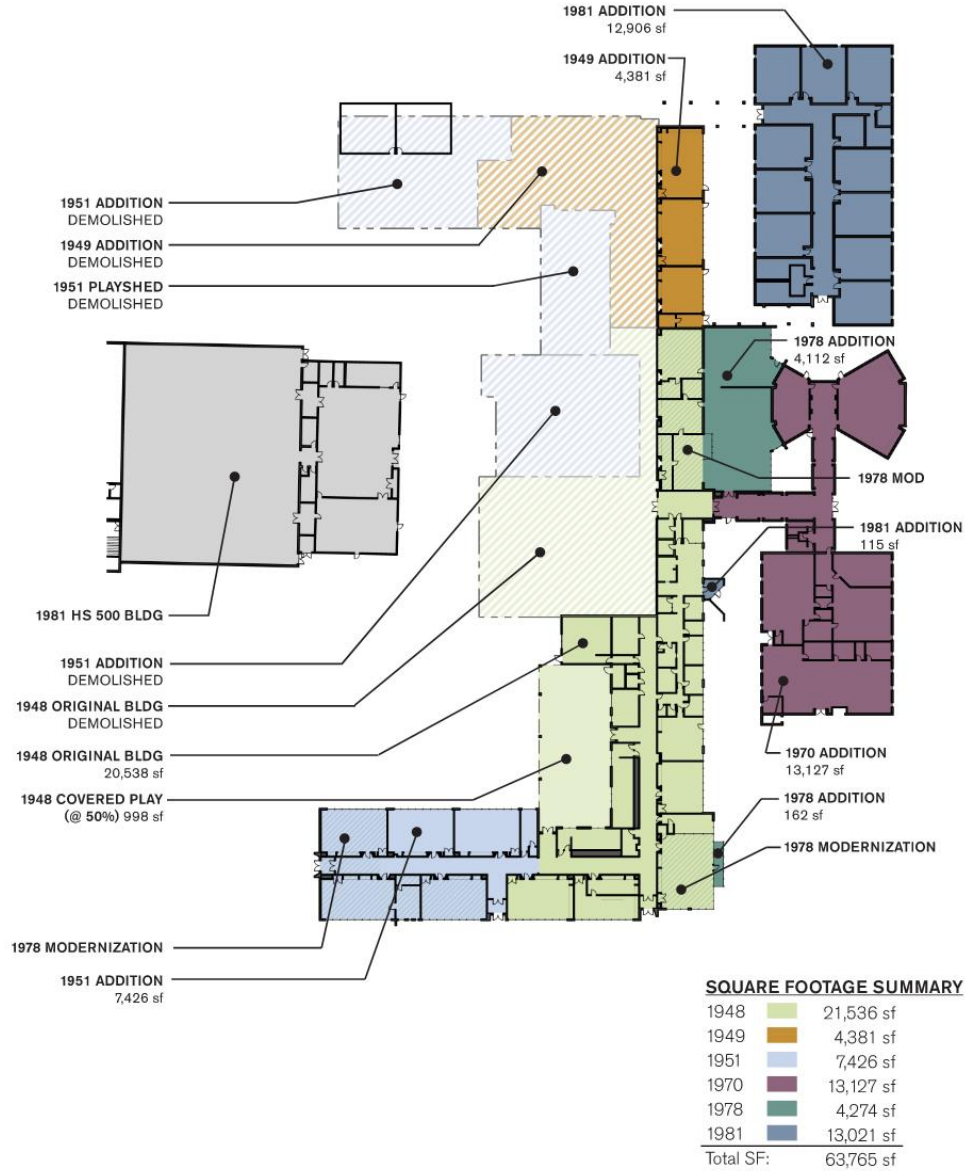
## Engineering Assessments

### Field Investigation and Data Collection Process

Engineering field investigations were conducted at each school building to observe existing conditions and collect existing building data. Visual observations were limited to areas and building elements that were safely accessible and observable without requiring the removal of finishes. Significant effort was also spent collecting and scouring through existing building drawings (blueprints) and databases provided by the school districts. Existing building structural drawings are essential for conducting the structural seismic evaluations because most structural elements are not visible during field investigations. For buildings assessed in Phase 2, 63 percent had a full set of structural drawings, 20 percent had partial drawing sets (some with only partial architectural drawings), and 17 percent had no drawings available whatsoever.

Additional building data from OSPI's ICOS database and Study and Survey database were also collected and used in the seismic assessments of the buildings. These data were provided by OSPI and became extremely valuable in the absence of existing drawings. The Study and Survey documents often included previous condition assessment reports, area plans, and area analysis tables that provided floor areas, floor plan layout, and years of construction. Some of the Study and Survey documents provided also included architectural and structural building descriptions and narratives that described the structural systems, lateral force resisting systems, and construction history, including seismic retrofits that occurred over the years. Many older school buildings have undergone multiple additions that are interconnected and contain a variety of structural systems and construction materials. The area plans and Study and Surveys provided by OSPI helped tell the school building's history. See Figure 6 as an example of a building with multiple areas and construction types.

## CONSTRUCTION HISTORY



**Figure 6.** Area plan from ICOS Study and Survey project showing a summary of the years of construction and the square footage of the different building areas at Commodore Options School, Bainbridge Island School District, Washington.



## Seismic Performance of Nonstructural Components

For much of the 20th century, little attention was given to designing nonstructural components and their anchorage for forces induced by earthquakes, yet these nonstructural systems can pose a safety risk to building occupants. Nonstructural components of buildings are architectural features, finishes, building envelop and cladding systems, and the various building systems such as mechanical, electrical, plumbing, heating, cooling. These components are essentially everything but the building's structural systems and framing and can comprise of approximately 60% of the construction costs in a new school building.

In addition to the life safety hazards posed by nonstructural components, the cost to repair nonstructural components following an earthquake can be high and significantly delay the reopening of a school. In many cases, the cost to repair or replace nonstructural components can be higher than the cost of repairing structural components following an earthquake.

As was done in Phase 1 of this study, school buildings screened in Phase 2 also include nonstructural seismic evaluations using the ASCE 41 Tier 1 Nonstructural Checklists that evaluates items pertaining to nonstructural systems that can pose a life safety risk to the building's occupants if these systems are inadequately braced, anchored, or fail to operate during or after an earthquake.

The nonstructural checklists can provide immediate guidance on the seismic adequacy of nonstructural elements, some of which may be easily mitigated such as anchoring tall cabinets and bookshelves to backing walls, moving heavy contents to the bottom of shelving, independently supporting light fixtures in suspended ceilings, and adding seismic strapping, bracing, or flexible connections to water tanks and overhead elements (for example, mechanical units, piping, and fire protection systems).

It is often most economical to mitigate nonstructural seismic hazards when the building is already undergoing mechanical, electrical, plumbing, or architectural upgrades or modernizations. Summaries of nonstructural items that require mitigation or further investigation are included in each screening report (*Appendix B*). In addition, school districts are provided with excerpts from the Federal Emergency Management Agency (FEMA) publication E-74 entitled, 'Reducing the Risks of Nonstructural Earthquake Damage' (FEMA E-74) that have helpful illustrations of typical seismic mitigation measures that can potentially be implemented by district facilities and maintenance personnel.

## American Society of Civil Engineers 41-17 Tier 1 Screening and Checklists

The seismic evaluation of building structures is based on performance-based earthquake engineering (PBEE) guidelines presented in ASCE 41-17 Seismic Evaluation and Retrofit of Existing Buildings. ASCE 41-17 provides a three-tiered seismic screening and evaluation procedure using performance-based criteria. The evaluation process consists of the following three tiers: Screening Procedure (Tier 1), Deficiency-Based Evaluation Procedure (Tier 2), and Systematic Evaluation Procedure (Tier 3). Only the Tier 1 evaluations were completed as part of this study. For more information and a better understanding of the building's necessary retrofit designs and costs, Tier 2 and 3 screenings are recommended.



The Tier 1 seismic screening procedure was used in this study to seismically evaluate structural and nonstructural building components. The Tier 1 seismic screening is a checklist of evaluation items (building components) designed to identify the seismic safety flaws and weaknesses of a building. The checklist items consist of positively-affirmed (desirable) evaluation statements of various building geometry and structural characteristics that are seismically essential to meeting a stated structural performance objective such as Collapse Prevention, Life Safety, or Immediate Occupancy (Table 3).

The ASCE 41 Tier 1 screening procedure has a checklist for basic structural configuration, different checklists for each common building type, and a checklist for select nonstructural systems. The checklists for each common building type have evaluation items unique to that building type, based on seismic vulnerabilities and past observed failures that are unique to that building type. The common building types classification in ASCE 41 are the same as the building types used in FEMA guideline documents and provide a consistent nomenclature across the pre-disaster and post-disaster earthquake standards.

After reviewing existing drawings and performing field investigations, engineers deem each positively-affirmed evaluation statement of the checklists as either Compliant (C), Noncompliant (NC), Unknown (U), or Not Applicable (N/A). Evaluation items marked as Compliant are those that the engineer deems as acceptable in meeting the positively-affirmed and desirable evaluation statements. Items the engineer marks as Noncompliant are those they assess as not meeting the evaluation statements and require mitigation or further investigation and analysis. Items the engineer marks as Unknown indicate that further investigation and analysis is required, usually as a result of having insufficient existing drawings or field observations to make a C or NC assessment. Where ASCE 41 Tier 1 seismic screening checklist items were unknown due to lack of available information, the checklist items were assessed as Unknown.

## **Seismic Hazard Levels**

Every earthquake is different. An earthquake's intensity and energy magnitude depend on fault type, fault movement, depth to epicenter, and geology of the subsurface. The precise location, intensity, and start time of an earthquake cannot be predicted before an event occurs. However, earthquake hazards for certain geographic areas are relatively well understood based on historical patterns of earthquakes from the geologic record, measured earthquake ground motions, understanding of plate tectonics, and seismological studies.

Geologists, seismologists, and geotechnical engineers have categorized the seismic hazard for particular locations using models based on the probability of a certain magnitude earthquake occurring in a given time period. ASCE 41-17 specifies four different Seismic Hazard Levels at which to seismically screen, evaluate, and (or) upgrade school buildings and other structures. For voluntary seismic evaluations and voluntary seismic upgrades, the owner of a school and the structural engineer can collaborate and decide the seismic hazard level at which it is appropriate to evaluate or upgrade a structure.

All the school buildings were evaluated as Risk Category III structures as defined by the Washington State Building Code. Generally, schools with more than 250 occupants are classified as Risk Category III

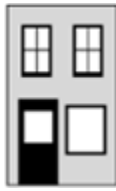


and schools with less than 250 occupants are classified as Risk Category II. While it is possible that some school buildings may technically be classified as Risk Category II based on their current occupancy (number of occupants), the study team elected to evaluate all structures as Risk Category III to keep the risk categories consistent for the relatively small sample size.

### School Building Performance Levels and Seismic Upgrade Options

A target building performance level must be selected for the seismic design of an upgrade of a school building. The terminology used for target building performance levels is intended to represent goals for design, but not necessarily predict building performance during an earthquake.

The ASCE 41-17 standard identifies the following Structural Performance Levels in a design-level earthquake: Immediate Occupancy (IO), Life Safety (LS), Limited Safety (LTD-S), and Collapse Prevention (CP) (Table 3). The nonstructural Performance Levels identified in the standard are: Operational (OP), Position Retention (PR), and Life Safety (LS). For this study the engineers used the Life Safety performance objective.

**Table 3.** Structural performance level definitions following ASCE 41-17 and FEMA P-424.

| Structural Performance Level                            | Description of building state following a design-level earthquake  | Schematic diagram of building following earthquake                                    |
|---|--|---|
| <b>Immediate Occupancy (IO)</b>                         | Buildings are expected to sustain minimal damage to their structural elements and only minor damage to their nonstructural components. While it is safe to re-occupy a building designed for this performance level immediately following a major earthquake, nonstructural systems may not function due to power outage or damage to fragile equipment. |  |
| <b>Life Safety (LS) and Limited Life Safety (LTD-S)</b> | Buildings may experience extensive damage to structural and nonstructural components. Repairs may be required before re-occupancy, though in some cases extensive restoration or reconstruction may not be cost effective. The risk of casualties at this target performance level is low.   |  |
| <b>Collapse Prevention (CP)</b>                         | Although buildings that meet this building performance level may pose a significant hazard to life safety resulting from failure of nonstructural components, significant loss of life may be avoided by preventing collapse of the entire building. However, many buildings designed to meet this performance level may be complete economic losses.    |  |

## Engineering Performance Assessment Tool

The Washington State School Earthquake Performance Assessment Tool (EPAT) is a spreadsheet tool developed for the State of Washington by the Earthquake Engineering Research Institute (EERI). The spreadsheet uses FEMA Hazus fragility curves to calculate expected earthquake performance of schools based on basic school seismic screening characteristics. Hazus is a natural hazards loss estimation tool initially developed by FEMA in the 1990s. Hazus uses basic building information, construction type fragility functions, and expected ground shaking intensity to estimate the probable losses of buildings from a design-level earthquake. These results are displayed as a percentage of the building elements that are expected to be damaged in this earthquake. The EPAT spreadsheet only returns performance values for the building's structural systems, but nonstructural systems are likely to also sustain significant damage in a large earthquake.

## Rapid Visual Screening

The standardized tool for performing rapid visual screening of buildings for seismic risks is the 'FEMA P-154: Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards' standard (Applied Technology Council, 2015). Based on extensive data and research on the seismic performance of buildings in previous earthquakes, these standards provide seismic screening criteria specific to each common building archetype, the structural system, configuration, and characteristics of the specific facility, and the seismic risk at each facility site.

This tool uses a scoring system to quantify the potential seismic vulnerability of a structure. A base score is identified based on modeled ground shaking. Other important factors are the buildings' lateral-force-resisting system (for example, wood or concrete shear walls, steel braced or moment frames, and masonry shear walls). This base score is then reduced according to the geological hazards (site class, landslide, and liquefaction hazards) and inherent vulnerabilities in the building's configuration such as vertical and horizontal irregularities. The building score is also adjusted based on the construction year relative to benchmark years in which seismic design code requirements changed significantly.

Scores typically vary between 0.3 and 6.0. Lower scores indicate more hazardous buildings and higher scores indicate buildings that have less risk. There is no official cutoff score that identifies which buildings should receive further evaluation, but, generally, a score of 2.0 or less is used to identify buildings that require further evaluation.

## Earthquake Performance Rating System Translation of the ASCE 41 Tier 1 Checklists

A lesson learned from our Phase 1 study is the need to simplify the ASCE 41 Tier 1 checklists for each assessed building to better communicate to people without an engineering background the most important structural seismic deficiencies that need to be mitigated or further investigated. The Phase 2 study attempts to do this by providing both an engineering-based risk rating (described in this section) that characterizes the seismic safety risk of the building in each screening report, and then combining these ratings with other engineering and geologic hazard information to determine prioritization of buildings

studied (discussed in the *Results* section *Prioritized Rankings of Phase 1 and 2 School Buildings by Relative Risk*).

The project team used the ‘Earthquake Performance Rating System (EPRS) ASCE 41-13 Translation Procedure’ developed by the Structural Engineers Association of Northern California (SEAONC) (SEAONC, 2017) and the ‘Earthquake Performance Rating System User’s Guide’ (SEAONC, 2015) to determine a structural safety risk rating to prioritize the seismic evaluation items that need to be addressed. The EPRS procedure and user’s guide was published by the Existing Buildings Committee of SEAONC and its methodology has been adopted by the US Resiliency Council (USRC, <https://www.usrc.org>) in determining their building earthquake ratings.

The EPRS includes guidelines that translate the ASCE 41 Tier 1 seismic evaluation structural checklists into star-ratings that address three focus areas of seismic performance: Safety, Repair Cost, and Recovery. Each of the focus areas have three sub-ratings: Structural, Geologic, and Nonstructural. However, based on the information gathered by the project team in both phases of this study, only a preliminary Structural Safety sub-rating could be determined for each building assessed. See the Engineer’s Seismic Assessment Report in *Appendix B* for an in-depth discussion regarding the risk rating translation procedure. Although preliminary, the Structural Safety sub-rating will be helpful in informing school districts of the seismic risks and needs of their buildings, especially when accompanied by a list of seismic evaluation checklist items that can improve the Structural Safety sub-rating if mitigated. See the *Results* and *Recommendations* sections below for additional discussion on how to use the seismic screening reports and EPRS risk rating.

The definitions of the Structural Safety sub-ratings used in this study are based on definitions used in the EPRS User’s Guide and by the USRC and have been adapted for use in this study. The EPRS is a five-star rating system, with one star being the lowest, or worst-performing building, and five stars being the highest, or best-performing building. The ratings are communicated in each of the seismic screening reports for each school building assessed in Phase 1 and 2 as follows:

- ★ **Risk of collapse in multiple or widespread locations**—Expected performance as a whole would lead to multiple or widespread conditions known to be associated with earthquake-related collapse resulting in injury, entrapment, or death.
- ★★ **Risk of collapse in isolated locations**—Expected performance in certain locations within or adjacent to the building would lead to conditions known to be associated with earthquake-related collapse resulting in injury, entrapment, or death.
- ★★★ **Loss of life unlikely**—Expected performance results in conditions that are unlikely to cause severe structural damage and loss of life. A three-star rating meets the Tier 1 Life Safety (LS) structural performance objective.
- ★★★★ **Serious injuries unlikely**—Expected performance results in conditions that are associated with limited structural damage and are unlikely to cause serious injuries.



**Injuries and entrapment unlikely**—Expected performance results in conditions that are associated with minimal structural damage and are unlikely to cause injuries or keep people from exiting the building. A five-star rating meets the Tier 1 Immediate Occupancy (IO) structural performance objective.

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# Results

## Geologic Site Class

The measured site class results were used by the engineers to determine the design ground motions for each of the school buildings and fire stations. The design ground motion is what engineers use when determining if a building will be able to withstand the expected amount of ground shaking for a given seismic event. For new buildings and seismic retrofits this is the design-level earthquake.

By incorporating the measured site class (what is known about the soil beneath the school campus) and the probable earthquake shaking/acceleration, the engineers can more accurately determine how an existing structure is expected to perform and they can better design seismic upgrades for a particular seismic event.

The measured site class results are also entered into the EERI EPAT worksheet (Goettel and others, 2017). The EPAT worksheets can complement more detailed building-specific ASCE 41-17 Tier 1 seismic screenings. These tools can provide school districts with a preliminary assessment of the level of seismic risk (low to very high) at school buildings and can help classify the level of life safety risk and priority for further evaluation.

The Vs30 and EPAT results are inventoried into the OSPI ICOS database, which is integrated into the Pre-disaster Mitigation Program (PDM) module (Goettel and Dengel, 2014). This database and module provide detailed data that school district administrators can use to guide seismic upgrades of buildings and steer future funding strategies.

See *Appendix A* for site class measurements and school ‘one-page reports’ at the 245 campuses studied (99 for Phase 1 and 146 for Phase 2). For the Vs30 measurements download the WGS shear wave database (Washington Geological Survey, 2021 a). The published Vs30 measurements are identified as single points representing the midpoint of the geophone array.

Of the total 245 school campuses assessed, 59 have measured site classes (*Appendix A*) that differ from those predicted/assigned by the reconnaissance-scale statewide site class map (Palmer and others, 2004) (Table 4). Site classes incorrectly predicted by the reconnaissance-scale map are typically due to one or any combination of three main categories: (1) *subsurface changes from different geologic units*, such as alluvium (river deposits) overlying shallow bedrock (2) *variance within a single geologic unit*, such as lava flows, large boulders, and sediment layers, and (3) *mismatching*, which is any shortcoming of the reconnaissance-scale mapping of the geologic units on which site class is based. For an example of how the predicted site class and geology differ significantly from the measured see Figure 7.

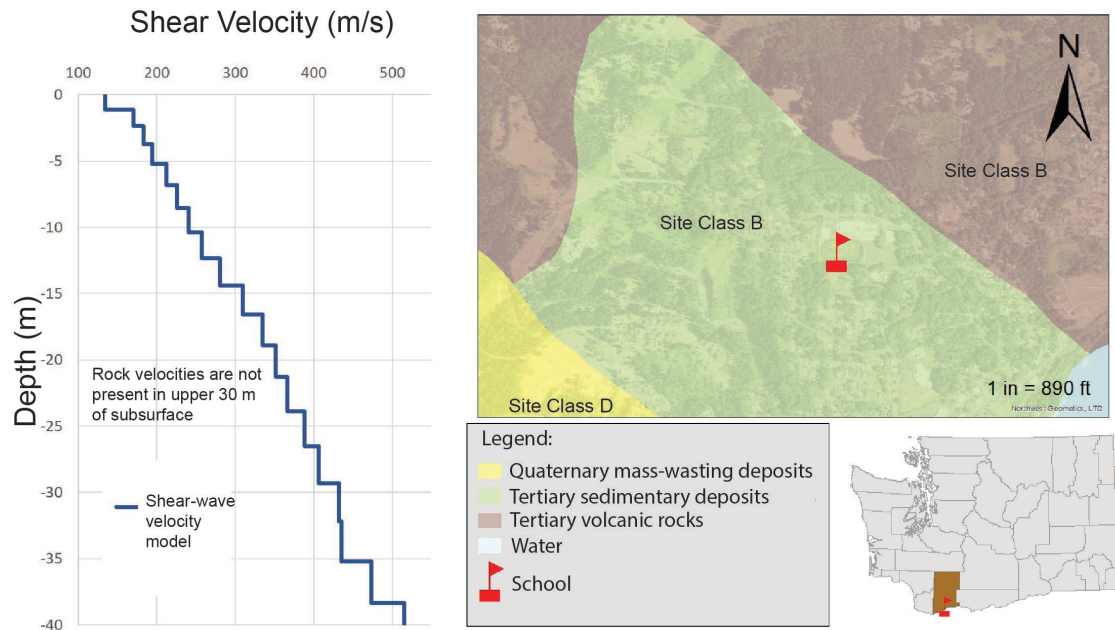
**Table 4.** Distribution of Phase 1 and 2 predicted site class (gold) versus measured site class (blue), as well as individual totals of measured site class values.

| Predicted site class | Measured site class |    |     |   |       |
|----------------------|---------------------|----|-----|---|-------|
|                      | E                   | D  | C   | B | Total |
| <b>F</b>             | 0                   | 1  | 0   | 0 | 1     |
| <b>D-E</b>           | 26                  | 29 | 16  | 1 | 73    |
| <b>D</b>             | 0                   | 21 | 9   | 0 | 29    |
| <b>C-D</b>           | 0                   | 17 | 29  | 1 | 47    |
| <b>C</b>             | 0                   | 15 | 60  | 0 | 75    |
| <b>B</b>             | 0                   | 4  | 12  | 4 | 20    |
| <b>Total</b>         | 26                  | 87 | 126 | 6 | 245   |

# Stevenson High School, Skamania County

## SSSP 2 Predicted site class B measured as site class D

1:100,000-scale geologic map, no 1:24,000-scale map available



**Figure 7.** Geologic map of the campus at Stevenson High School in Skamania County, Washington (red flag). The site is mapped on sedimentary rocks (green), and to the north and east are mapped volcanic deposits (brown). According to the reconnaissance-scale mapping both of these have a predicted site class of B. Mapped to the south are mass-wasting deposits (yellow) with a predicted site class of D. The velocity model (the graph in the left of the figure) shows steadily increasing velocity down past 30 m (100 ft), with no sign of hard rock velocities (760 m/sec or above) in the upper 40 m (120 ft). This suggests that the reconnaissance-scale mapping was not accurate at this location, as the measured site class was D, which is more consistent with the mass wasting deposits to the west.

## Engineering Assessments Phase 2 Results

### American Society of Civil Engineers 41-17 Checklists

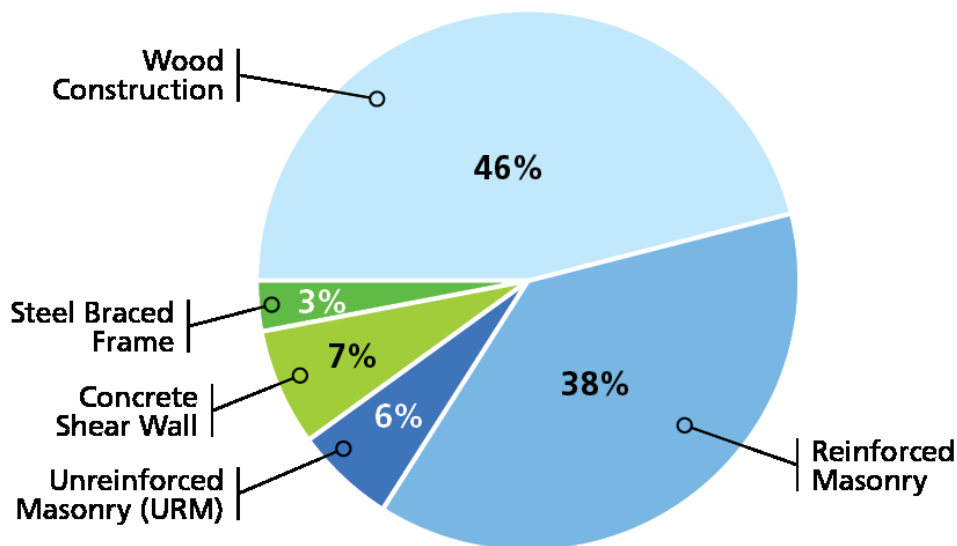
ASCE 41 Tier 1 seismic screening evaluations were conducted on all of the 561 Phase 1 and 2 school buildings. This section describes the findings and trends associated with these seismic screening evaluations for Phase 2 buildings. A discussion of Phase 1 and Phase 2 results combined is presented later in this report.

Original building structural drawings were available for review for about 63 percent of the buildings studied. Twenty percent of buildings had partial or incomplete drawings available for review, and 17 percent had no available record drawings for review. Where existing building drawings or other



information were not available for review, the engineering data-gathering was limited to visual observations by the project team of licensed structural engineers. Where building component compliance or noncompliance was unknown due to lack of available information, the unknown conditions were indicated on the ASCE 41-17 Tier 1 seismic screening checklists. The findings are as follows:

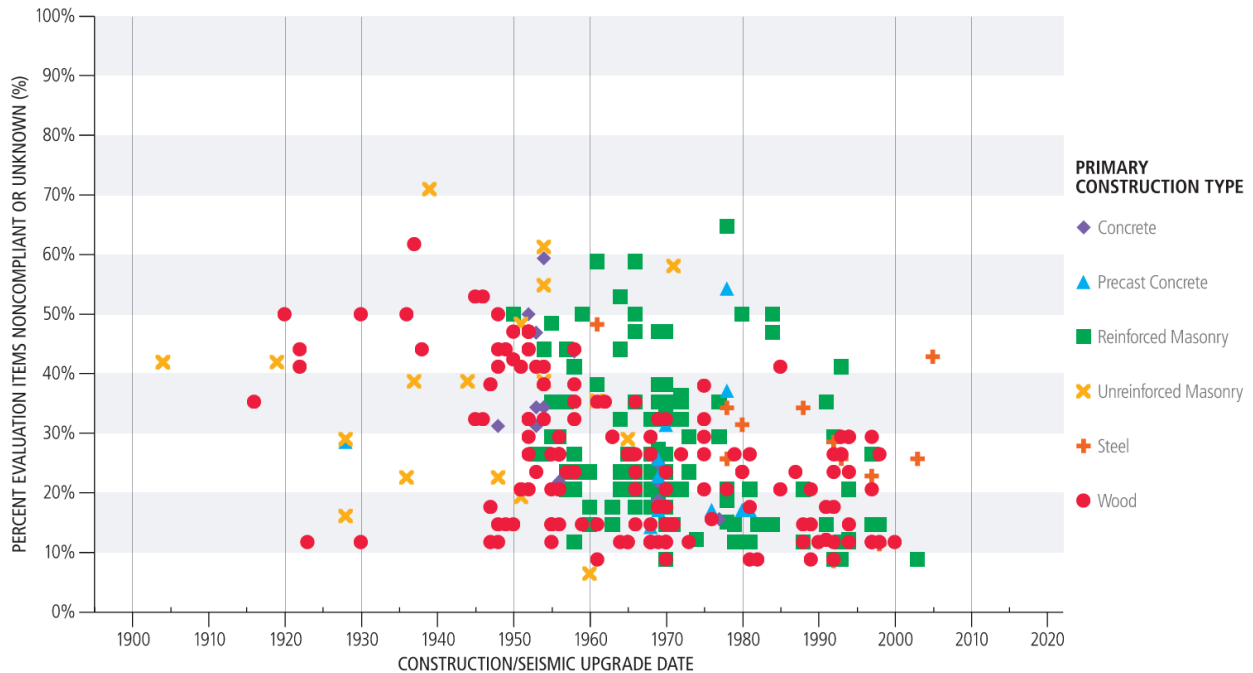
1. The average year of construction was 1967 and the median year of construction was 1968.
2. The average and median occupied space area is 28,472 square feet, and 17,364 square feet, respectively.
3. Figure 8 illustrates the distribution of building material types represented in the Phase 2 study.



**Figure 8.** Distribution of Building Material Types of Phase 2 School Buildings Studied.

As was expected, most of the ASCE 41 Tier 1 Screening Evaluation noncompliant features were related to building elements that were likely not strong enough or not interconnected enough to reliably resist seismic loads. Additionally, many of the buildings utilize archaic building materials that do not possess adequate toughness (ductility) or reliable load path for design-level earthquake loads. These seismic weaknesses are typically found in walls, roofs, floors, and where these structural elements are weakly interconnected. These weak structural elements or weak connections are typically not strong enough to reliably transfer (or resist) earthquake loads to the foundations.

Figure 9 shows the percent of items on the checklist that were classified as either noncompliant or unknown (vertical axis), with the horizontal axis showing construction or seismic upgrade date. In general, older buildings, particularly those made of wood, have a higher percentage of seismically noncompliant or unknown items. This relationship is to be expected, as these buildings were built with outdated building codes, or, in some cases, no building code at all. The highest noncompliant or unknown percentage of 71 percent is held by a URM building. There is no building within the sample of Phase 2 school buildings that has zero noncompliant or unknown seismic screening evaluation items.



**Figure 9.** Phase 2 buildings symbolized by primary building construction type. The vertical axis shows the percent of ASCE 41 Tier 1 items identified as noncompliant or unknown and plotted on the horizontal axis are the construction or seismic upgrade dates of the buildings.

### Engineering Performance Assessment Tool (EPAT) Results

Table 5 shows the EPAT median, average, maximum, and minimum results for the buildings included in the Phase 2 study. The information displayed in the table is based on each building's existing configuration and estimations of loss, life safety risk level, and post-earthquake tagging as expected for the design earthquake. An EPAT 'scoresheet' for each school building is included in the final engineering report and can be downloaded from the links in *Appendix B*.

**Table 5.** Washington State schools EPAT summary results for Phase 2 school buildings.

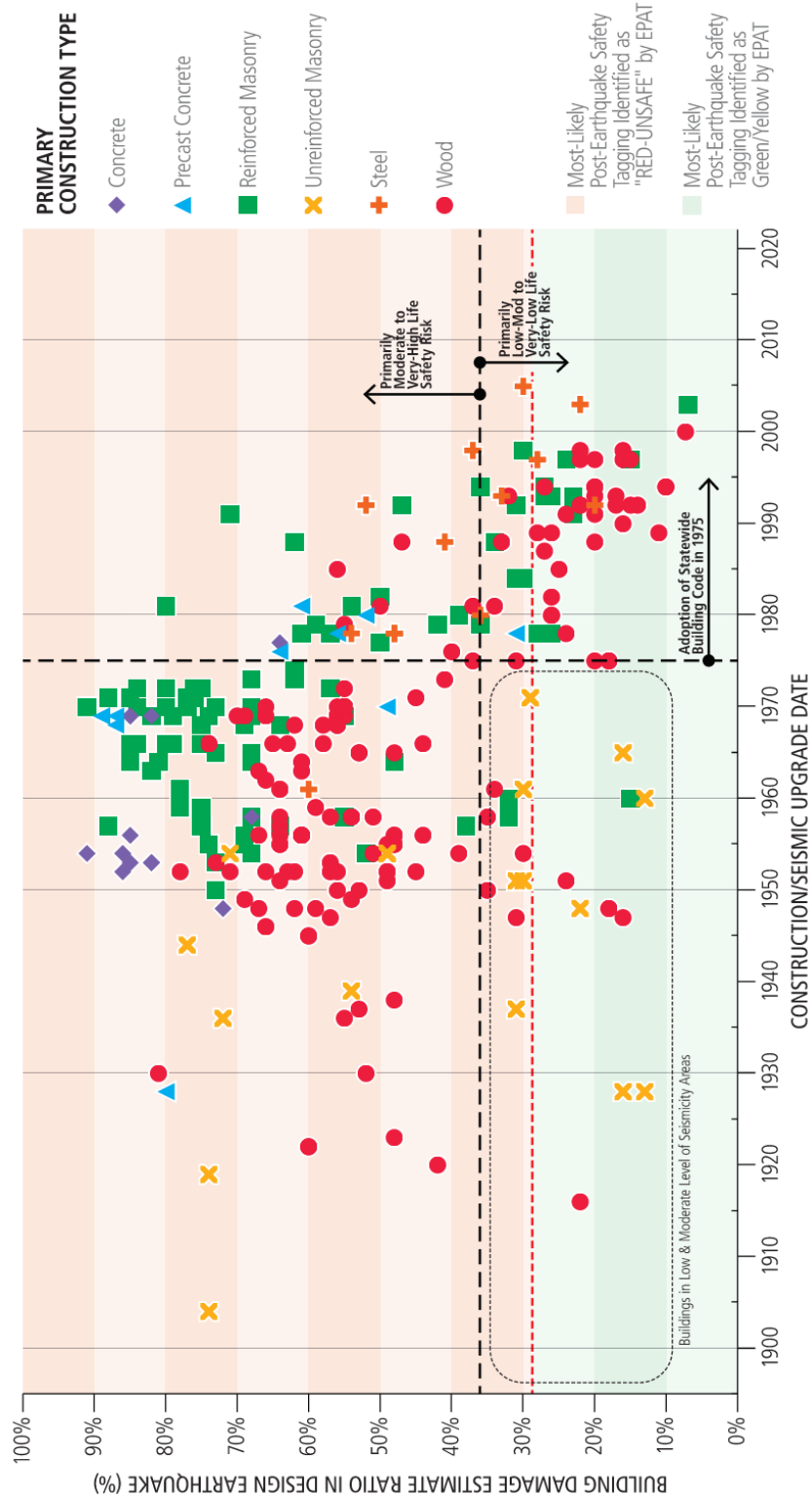
| EPAT Calculated Value  | Median | Average | Max       | Min      |
|--|--------|---------|-----------|----------|
| Building damage estimate ratio<br>(Amount of building that is damaged) | 56%    | 54%     | 91%       | 7%       |
| Probability that building is not repairable                            | 52%    | 51%     | 93%       | 5%       |
| Life safety risk level   | High   | -       | Very High | Very Low |
| Most likely post-earthquake tagging                                    | Red*   | -       | Red*      | Green*   |

\*Red = Unsafe to Occupy, Yellow = Restricted Building Access, Green = No Restrictions on Building Access

The primary value calculated for each building from the EPAT spreadsheet is the amount of damage each existing building is expected to sustain in a design-level earthquake event. This value is displayed as a percentage of the building elements that are expected to be damaged. The EPAT spreadsheet only returns performance values for the building's structural systems, but nonstructural systems are likely to also sustain significant damage in a large earthquake.

The EPAT summary results in Table 5 above show that the median building is expected to have more than half its building elements damaged. Similarly, it is expected that about half the buildings included in the study will not be repairable, meaning these buildings will likely need to be demolished. The most likely post-earthquake tagging identified by EPAT is "Red," meaning the majority of school buildings included in the study are expected to not be safe to occupy following the design-level earthquake event.

Building damage estimate ratios are loosely correlated to building type and seismic risk as shown in Figure 10, which depicts building damage estimate ratios against building construction or seismic upgrade date. The figure also includes different symbols for the building lateral system's primary construction material type. As illustrated in the figure, the dominant school construction types prior to the 1940s were unreinforced masonry and wood construction. Starting in the 1950s, many of the school buildings were constructed of reinforced masonry, wood, concrete, and steel. During the 1950s and after, the most prominent building construction types were wood and reinforced masonry.



**Figure 10.** Phase 2 building EPAT damage estimate ratios in ASCE 7/41 design-level earthquake categorized by primary construction type and year built.

Unreinforced masonry buildings and non-ductile concrete buildings (older concrete buildings) are especially vulnerable to earthquakes due to their weight and brittle nature, and these buildings have well-known seismic risks in high seismic hazard areas. As seen in Figure 10, many of these school buildings possess damage estimate ratios in the range of 70 to 80 percent, or higher. However, the figure also shows that many unreinforced masonry school buildings display damage estimate ratios of between 10 and 30 percent. These buildings are typically located in low or moderate seismic zones. Figure 10 also shows that school buildings built after 1975 have precipitously decreasing damage estimate ratios, with school buildings constructed in the 1990s and the 2000s generally possessing the lowest damage estimate ratios of all the school buildings evaluated.

One significant factor in earthquake performance is the building code standard to which a building was originally designed. The EPAT spreadsheet separates Washington State into zones where the design standards at the time of construction were different. Historically, western Washington and more specifically, the Puget Sound region, has had the strictest seismic code requirements. Buildings in the Puget Sound region were also designed for the highest level of earthquake shaking due to the high seismicity of the region. Buildings in the rest of Washington State were historically designed to lower seismic forces and detailing (toughness) standards.

### Rapid Visual Screening Results

Table 6 shows the median, average, maximum, and minimum calculated FEMA P-154 Rapid Visual Screening (RVS) scores for the Phase 2 schools. RVS is a method of assigning a score to a building based on a building's basic features (building type, building age, soil type, seismicity, and structural irregularities). The primary intent of the scoring is to identify potentially hazardous buildings that require further seismic evaluation. There is no official cutoff score, but generally a score of 2.0 or less is used to identify buildings that require further evaluation. Lower scores indicate more hazardous buildings and higher scores indicate buildings that have less risk. Sixty-eight percent of the Phase 2 buildings possess an RVS score that is less-than-or-equal to 2.0, indicating that further evaluation work may be warranted to more accurately determine their seismic risk.

**Table 6.** Washington State schools RVS summary results for Phase 2 school buildings.

| RVS Result    | Value |
|---------------|-------|
| Median Score  | 1.7   |
| Average Score | 2.1   |
| Max Score     | 5.5   |
| Min Score     | 0.3   |

## Earthquake Performance Rating System Structural Safety Sub-Ratings (Star-Ratings) Results

Preliminary structural safety sub-ratings for 561 school buildings assessed in both Phase 1 and Phase 2 were determined using the findings from the ASCE 41 Tier 1 seismic evaluation checklists. The EPRS is a five-star rating system, with one star being the lowest, or worst-performing buildings, and five stars being the highest, or best-performing buildings. Ninety-three percent of the 561 school buildings assessed have one-star Structural Safety sub-ratings based on the information available. Four percent of the school buildings assessed have two-star ratings and three percent of the school buildings have three-star ratings. Such a high percentage of one-star ratings was not surprising given that the criteria for selecting school buildings for this study was heavily weighted toward buildings that are older structures and lack the seismic durability and interconnection that more modern buildings have.

Most of the school buildings assessed in Phase 1 and Phase 2 are also considered “pre-benchmark” buildings, many of which were also built before Washington State adopted its first statewide building code in 1975. The buildings assessed were selected in large part because of their older age and need for seismic evaluation. Benchmark buildings are those that are considered compatible with “modern” building code provisions and designed and constructed to relatively recent building codes (typically buildings constructed in 1999 or later). ASCE 41 infers that Benchmark buildings, based on past observed earthquake damage, can be expected to provide Life Safety structural performance at a lower than current code seismic event. Consequently, it was expected that the vast majority of these buildings would have a preliminary one-star Structural Safety sub-rating.

In addition, many buildings assessed did not have existing drawings or limited site observation to confirm critical seismically desirable attributes such as complete load paths, out-of-plane wall anchorage, interconnection of structural components, and diaphragm integrity. This resulted in many ASCE 41 Tier 1 seismic screening checklist items being evaluated as Unknown (U). To be consistent with the EPRS Translation Procedure, the preliminary Structural Safety sub-ratings for this study considered Unknown conditions as Noncompliant (NC). These Unknown conditions being considered as Noncompliant resulted in many Structural Safety sub-ratings of one star, and therefore these Structural Safety star-ratings should not be used as an absolute condemnation of a building but instead as an indication that these buildings need further seismic investigation and analysis.

The overwhelming number of one-star Structural Safety ratings further reinforces the need to voluntarily upgrade or replace older buildings in high seismicity areas. It is highly encouraged and recommended that school districts and structural engineers further study the ratings and assessments of their oldest and most vulnerable buildings and discuss how best to improve the seismic safety of their school facilities. The use of the EPRS results is further discussed in the *Recommendations for Schools on How to Use These Data* section of this report.

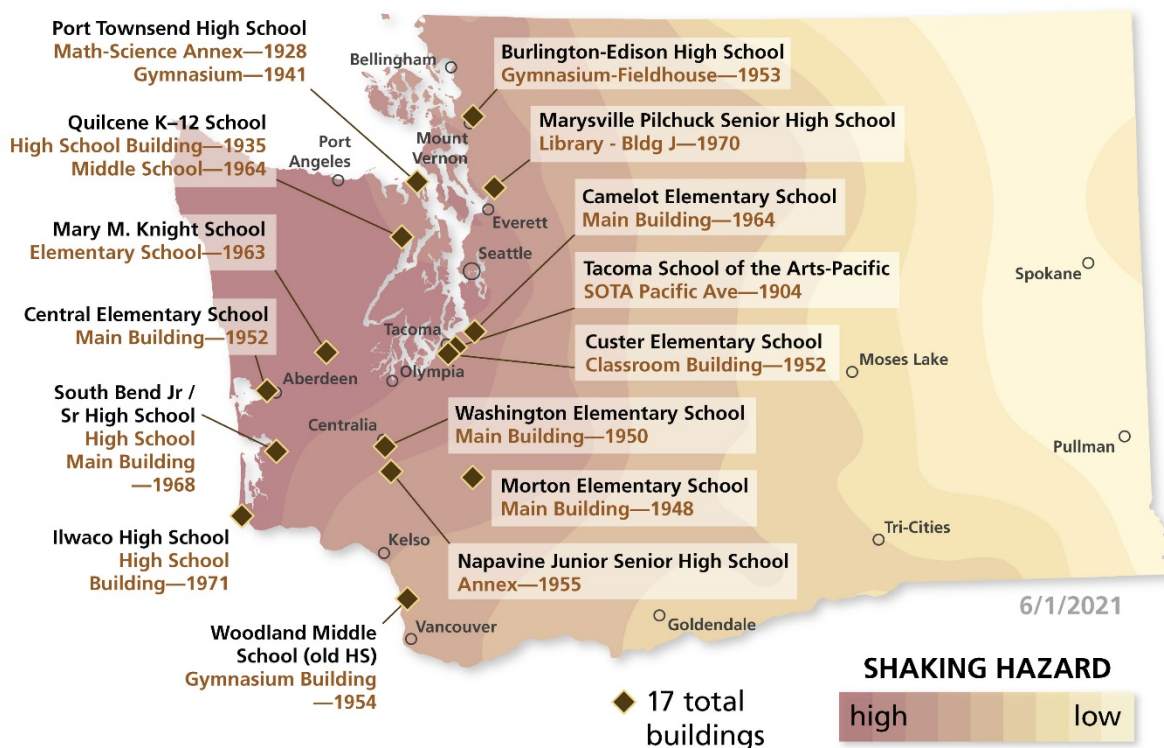
## **Schools Located in Tsunami Inundation Zones**

In total, 67 school buildings on 30 school campuses that were assessed in Phase 1 and Phase 2 are located within tsunami inundation zones. These schools serve over 10,000 students and while assessment of these buildings to withstand tsunami effects was not part of this study, it is the engineers' opinion that none of these buildings will be able to adequately resist the hydrostatic and hydrodynamic forces; waterborne debris accumulation and impact; and foundation subsidence and scour from a code-level maximum considered tsunami. Of these 67 buildings, 45 percent are wood-framed structures, 37 percent are masonry structures, 13 percent are concrete structures, and 4 percent are steel structures. Of the 30 school campuses located in tsunami inundation zones, only Ocosta Elementary School has a vertical evacuation structure for the safety of the students and school district faculty during a major tsunami event. In order for a school in a tsunami zone to be seismically safe, it is also our opinion that it needs to be designed to withstand the design level tsunami. Additionally, many school campuses in tsunami inundation zones are located in places with no high ground nearby. This means that even if the school building was able to withstand the earthquake shaking and the tsunami loads there would be nowhere for the students and staff to go to evacuate and be safe from the tsunami flooding.

## **Concept-Level Design and Cost Estimate Summary for Phase 2**

Cost estimates were developed for the 17 school buildings selected to receive concept-level seismic upgrade designs as part of Phase 2 (Fig. 11). The buildings were selected from the list of both Phase 1 and Phase 2 schools. Initially, a list of high-risk school buildings was generated by the project team. Then, the school districts who owned those buildings were surveyed to see if they wanted to participate in receiving concept-level seismic upgrade designs. The intent was also to see if any work was already planned to occur on the buildings, to confirm that the buildings had not already received seismic upgrades, and to confirm that the school districts are not planning to replace the buildings in the next 10-15 years. Most school districts replied to the survey, but some did not. From an initial list of approximately 50 high-risk schools, 17 were selected. Additionally, the concept-level upgrade design school buildings were selected prior to the completion of the Phase 2 seismic evaluations, so not all the data from the Phase 2 seismic evaluations were available to review in selecting the buildings.

## WASHINGTON SCHOOL SEISMIC SAFETY PROJECT PHASE 2 CONCEPT LEVEL DESIGN SCHOOLS



**Figure 11.** Map showing the location, names, buildings, and year built for the Phase 2 concept-level design school buildings. Basemap shows shaking hazard (modified from Petersen and others, 2015).

When the Phase 1 cost estimates were developed, the OSPI School Seismic Retrofit Program (SSRP) did not yet exist. As such, the Phase 1 cost estimates were not developed with the idea that they would be used as part of that program. The Phase 1 cost estimates only included estimates of the construction costs and did not include any soft cost items such as architecture/engineering design fees, project administration fees, building permitting fees, construction testing fees, or other fees. The Phase 1 cost estimates also did not include any escalation to account for inflation and cost increases over time because it was not known when/if construction would start. Conversely, the Phase 2 cost estimates were developed with the knowledge that the OSPI School Seismic Retrofit Program exists, and the project team worked closely with OSPI to develop cost estimates that could work within that program.

Even so, it is important to emphasize that the estimated costs developed for these buildings are preliminary in nature, as they are based on the results of the Tier 1 seismic screening checklists and



engineering design judgment, and have not been substantiated by more detailed analyses. Relative to construction cost estimates that are based upon construction drawings prepared by architecture and engineering firms for a defined scope of work, these concept-level seismic upgrade reports constitute a pre-design level scope of information due to the screening level of engineering and field investigation. Thus, for cost estimating and contingency purposes, these concept-level seismic upgrade designs would be considered as a design that is approximately 1 percent complete. This is in comparison to a 30 percent schematic design cost estimate where a full architecture and engineering design team has spent significantly more time observing existing conditions, performing other assessment studies (such as hazmat abatement, accessibility, energy and so on), and coordinating with school districts to accurately define the scope and phasing considerations in developing a set of construction documents for a renovation project. The concept upgrade designs received some input and review from architects, however, no architectural design has been completed at this time. In addition, there has been no involvement from mechanical, electrical, or fire protection engineers. The estimated costs for the seismic upgrade will change as the designs are further developed.

For this preliminary assessment of probable costs, an estimate of the current year (2021) construction costs of the probable scope of work was developed. Then a -20 percent (low) to +50 percent (high) range variance was used to develop the construction cost estimate range for the concept-level scope of work. The -20 percent to +50 percent range variance guidance is from table 1 of the AACE International Recommended Practice 56R-08, *Cost Estimate Classification System for Class 5 Estimates*. The range of a Class 5 construction cost estimate is due to the limited design completeness of 0 percent to 2 percent and is defined as -20 percent to +50 percent as noted. It is unlikely that the actual construction costs will equal the median estimated cost values, but it is the intent that the actual construction costs will fall within the -20 percent to +50 percent ranges.

Cost estimates also factor in when the construction phase of a project will commence to account for escalation in construction costs. Because these cost estimates are used to assist OSPI and school districts with future funding requests or programming needs, it is not known at this time if or when these seismic upgrades will be implemented. To account for some cost escalation however, the cost estimates prepared for this study assume a mid-point of construction occurring at the end of 2022. The cost estimates were developed in the beginning of 2021 and escalated at a rate of 6 percent per year to the end of 2022, effectively adding a 12 percent markup to the 2021 cost estimates.

Soft costs were included in the cost estimates as 40 percent of the estimated construction costs. Soft costs can include things like the owner's general overhead costs, project management costs, financing/bond costs, administration/contract/accounting costs, review of plans, value engineering studies, equipment, fixtures, furnishings and technology, and relocation of the school staff and students during construction. The soft costs used for the projects that total 40 percent are:

|                      |     |
|----------------------|-----|
| <b>A+E Design</b>    | 10% |
| <b>QA/QC Testing</b> | 2%  |

|   |     |
|---|-----|
| <b>Project Administration</b>             | 2%  |
| <b>Owner Contingency</b>                  | 11% |
| <b>Average Washington State Sales Tax</b> | 9%  |
| <b>Building Permits</b>                   | 6%  |

It is normal for soft costs to vary from owner to owner. However, based upon the engineering firm's experience in K–12 school projects in Washington, a 40 percent of the probable construction cost was incorporated in the cost estimates as a reasonable and appropriate soft cost allowance for budgeting purposes. Therefore, it is also strongly suggested that each owner develop their own soft costs as part of their budgeting process and not rely solely on the recommended percentage that is stated here.

Table 7 lists the estimated total cost of each seismic upgrade concept design for Phase 2 buildings. The costs listed include both construction costs and soft costs.

**Table 7.** Seismic upgrade total cost summary grouped by building type (Construction Costs + Soft Costs).

| School District, School Building, Bldg. Type                                     | Original Date of Constr. | ASCE 41 Level of Seismicity / Site Class | Perform. Objective | Bldg. Gross Area (SF) | Total Upgrade Cost Range \$/SF (Total) |          |                 | Median Total, \$/SF (Total) |
|--|--------------------------|--|--------------------|-----------------------|--|----------|-----------------|-----------------------------|
| Hoquiam, Central Elementary School, Main Building, <b>Reinforced Concrete</b>    | 1952                     | High / D                                 | Life Safety        | 38,946                | \$110 (\$4.27M)                        | -        | \$205 (\$8.01M) | \$137 (\$5.34M)             |
| Morton, Morton Elementary School, Main Building, <b>Reinforced Concrete</b>      | 1948                     | High / C                                 | Life Safety        | 12,360                | \$182 (\$4.60M)                        | -        | \$342 (\$8.62M) | \$228 (\$5.75M)             |
| Quilcene, Quilcene K–12 School, High School Building, <b>Reinforced Concrete</b> | 1935                     | High / D                                 | Life Safety        | 7,860                 | \$199 (\$1.59M)                        | -        | \$373 (\$2.99M) | \$249 (\$1.99M)             |
| <i>Concrete Shear Wall</i>   | <i>1945</i>              |  |                    | <i>25,653</i>         | <i>\$164</i>                           | <i>-</i> | <i>\$307</i>    | <i>\$205</i>                |

|   |             |          |             |               |                    |          |                     |                    |
|---|-------------|----------|-------------|---------------|--------------------|----------|---------------------|--------------------|
| <i>Averages</i>   |             |          |             |               |                    |          |                     |                    |
| Burlington-Edison,<br>Burlington-Edison High School,<br>Gym/Fieldhouse Building,<br><b>Reinforced Masonry</b> | 1953        | High / D | Life Safety | 50,133        | \$100<br>(\$5.00M) | -        | \$187<br>(\$9.37M)  | \$124<br>(\$6.25M) |
| Centralia,<br>Washington Elementary School, Main Building,<br><b>Reinforced Masonry</b>                       | 1950        | High / D | Life Safety | 51,063        | \$151<br>(\$7.73M) | -        | \$284<br>(\$14.49M) | \$189<br>(\$9.66M) |
| Mary M. Knight, Mary M. Knight School, Elementary School Building,<br><b>Reinforced Masonry</b>               | 1963        | High / D | Life Safety | 13,333        | \$91<br>(\$1.22M)  | -        | \$171<br>(\$2.29M)  | \$114<br>(\$1.53M) |
| Marysville,<br>Marysville-Pilchuck High School, Library (Building J),<br><b>Reinforced Masonry</b>            | 1970        | High / D | Life Safety | 19,772        | \$131<br>(\$2.59M) | -        | \$245<br>(\$4.85M)  | \$163<br>(\$3.23M) |
| <i>Reinforced Masonry Averages</i>  | <i>1959</i> |          |             | <i>33,575</i> | <i>\$118</i>       | <i>-</i> | <i>\$221</i>        | <i>\$148</i>       |
| Port Townsend,<br>Port Townsend High School, Gym Building,<br><b>Unreinforced Masonry</b>                     | 1941        | High / D | Life Safety | 34,112        | \$49<br>(\$1.68M)  | -        | \$92<br>(\$3.15M)   | \$61<br>(\$2.10M)  |

|   |             |          |             |               |                 |   |                  |                 |
|---|-------------|----------|-------------|---------------|-----------------|---|------------------|-----------------|
| Port Townsend, Port Townsend High School, Math-Science Annex, <b>Unreinforced Masonry</b> | 1928        | High / D | Life Safety | 13,169        | \$90 (\$1.19M)  | - | \$169 (\$2.24M)  | \$113 (\$1.49M) |
| Tacoma, Tacoma School of the Arts, Pacific Building, <b>Unreinforced Masonry</b>          | 1904        | High / C | Life Safety | 21,601        | \$275 (\$5.94M) | - | \$516 (\$11.14M) | \$344 (\$7.43M) |
| Woodland, Woodland Middle School, Gymnasium Building, <b>Unreinforced Masonry</b>         | 1954        | High / E | Life Safety | 15,202        | \$193 (\$4.47M) | - | \$363 (\$8.38M)  | \$242 (\$5.58M) |
| <i>Unreinforced Masonry Averages</i>  | <i>1932</i> |          |             | <i>21,021</i> | <i>\$152</i>    | - | <i>\$285</i>     | <i>\$190</i>    |
| Clover Park, Custer Elementary School, Classroom Building, <b>Wood Framed</b>             | 1952        | High / D | Life Safety | 40,304        | \$179 (\$7.23M) | - | \$336 (\$13.55M) | \$224 (\$9.04M) |
| Federal Way, Camelot Elementary School, Main Building, <b>Wood Framed</b>                 | 1964        | High / C | Life Safety | 41,111        | \$112 (\$4.61M) | - | \$210 (\$8.65M)  | \$140 (\$5.76M) |
| Napavine, Napavine Jr/Sr High School, Annex Building, <b>Wood Framed</b>                  | 1955        | High / C | Life Safety | 11,274        | \$87 (\$988K)   | - | \$164 (\$1.85M)  | \$109 (\$1.24M) |

|  |             |          |             |               |                  |          |                  |                  |
|--|-------------|----------|-------------|---------------|------------------|----------|------------------|------------------|
| Quilcene, Quilcene K-12 School, Middle School Building, <b>Wood Framed</b>     | 1964        | High / C | Life Safety | 9,438         | \$156 (\$1.48M)  | -        | \$293 (\$2.78M)  | \$195 (\$1.85M)  |
| South Bend, South Bend Jr/Sr High School, HS Main Building, <b>Wood Framed</b> | 1968        | High / E | Life Safety | 34,400        | \$152 (\$5.23M)  | -        | \$285 (\$9.81M)  | \$190 (\$6.54M)  |
| Ocean Beach, Ilwaco High School, Main Building, <b>Wood Framed</b>             | 1970        | High / D | Life Safety | 89,249        | \$131 (\$12.20M) | -        | \$246 (\$22.88M) | \$164 (\$15.26M) |
| <i>Wood Framed Averages</i>  | <i>1962</i> |          |             | <i>36,933</i> | <i>\$136</i>     | <i>-</i> | <i>\$256</i>     | <i>\$170</i>     |
| <b>OVERALL AVERAGES</b>  | <b>1951</b> |          |             | <b>30,967</b> | <b>\$141</b>     | <b>-</b> | <b>\$264</b>     | <b>\$176</b>     |

A significant portion of the structural upgrade costs are due to the fact that the seismic upgrades take place in existing buildings with existing finishes and existing nonstructural components. The costs to temporarily remove and replace the architectural, mechanical, electrical, and plumbing equipment is significant. If the costs associated with the architectural, mechanical, electrical, plumbing, and fire protection elements were deleted from the cost estimates, the average seismic upgrade cost sees a 70 percent reduction. Significant savings can be realized by combining seismic upgrades with other types of work, such as re-roofing projects or school modernizations. Seismically upgrading a roof diaphragm with a plywood sheathing overlay on older tongue-and-groove roof decking, for example, can be done as part of a future re-roofing project where over 90 percent of the cost would be to remove and replace the nonstructural roofing system.

The median estimated cost to seismically upgrade the 32 school buildings that received the concept level design study ranged from \$63,000 to \$5,000,000 in Phase 1 and from \$1,240,000 to \$15,260,000 in Phase 2. It should be noted that the Phase 1 costs do not include soft costs or escalation to the year 2022. The Phase 1 costs are construction costs only. In addition, the Phase 1 concept upgrade schools included several schools in moderate seismicity areas and low seismicity areas. Consequently, the costs from Phase 1 and Phase 2 are not directly comparable.

## Extrapolation of Phase 2 Concept-Level Seismic Upgrade Design Costs to Other School Buildings

The State of Washington has over 4,000 permanent K–12 school buildings. Hundreds of school buildings have been built in Washington State every decade starting in the 1950s. Prior to the 1950s, on average, between 25 and 90 school buildings were built each decade. Buildings built in similar time periods tend to have similar construction types and tend to have been built with similar construction methods. It is reasonable to believe that there will be similarities in costs to seismically upgrade buildings of similar construction type that were built in similar eras. Costs can vary and caution should be taken when extrapolating costs from one building to the next. Nonetheless, it is our opinion that the buildings that received concept-level upgrade designs and cost estimates as part of this study have sufficient similarities that this information can be reasonably extrapolated for similar types of school buildings across Washington State. All concept upgrade designs in Phase 2 of this study were developed with the intent of upgrading buildings for the Life Safety Performance Objective (Table 3) and all buildings are located in high seismic zones as defined by ASCE 41. Table 8 indicates the range of features for each building type included in the study to receive concept-level upgrade designs. The costs listed include both construction costs plus soft costs. The low cost listed is the lowest cost value from the study’s cost estimates for the building type using the -20 percent variance. The high cost listed is the highest cost value from the study’s cost estimates for the building type using the +50 percent variance. There is a high likelihood that other buildings in Washington State whose features match the ranges of the buildings listed in Table 8 will have total seismic upgrade costs that fall within the ranges listed.

In reviewing ICOS data provided by OSPI, over 1,000 recognized and permanent school buildings were built 1960 and earlier, 70 percent of which are west of the Cascade mountains and in relatively higher seismic areas. Of these roughly 700-plus buildings west of the Cascades, over 300 buildings have no record in ICOS of having modernizations done to them since their original construction, totaling approximately 10 million square feet. Applying extrapolated ranges of cost in Table 8 below, retrofitting or replacing the state’s oldest and most vulnerable buildings is a multi-billion dollar endeavor that will also need the support of communities in the form of passing capital bonds and levies.

**Table 8.** Extrapolated range of total seismic upgrade costs for certain building types (Construction Costs + Soft Costs).

| Building Type            | Date Range of Buildings in Study | ASCE 41 Level of Seismicity | Bldg. Square Footage Range (SF) | Total Upgrade Cost Range (Low-High) \$/SF |   |       |
|--------------------------|----------------------------------|-----------------------------|---------------------------------|---|---|-------|
| Reinforced Concrete      | 1935–1952                        | High                        | 7,860–38,946                    | \$110                                     | – | \$373 |
| Reinforced Masonry       | 1950–1970                        | High                        | 13,333–51,063                   | \$91                                      | – | \$284 |
| Unreinforced Masonry     | 1904–1954                        | High                        | 13,169–34,112                   | \$49                                      | – | \$516 |
| Wood Framed Construction | 1952–1970                        | High                        | 9,438–89,249                    | \$87                                      | – | \$336 |

## Prioritized Rankings of Phase 1 and 2 School Buildings by Relative Risk

Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Engineering judgment was used to assign buildings to one of four categories: Very High Priority, High Priority, Moderate Priority, and Lower Priority (Figures 12–15 and for the full lists see *Appendix C*). The prioritization of schools compares buildings to one another by selected parameters using engineering judgment. The parameters for building comparison include: building construction date, construction type, level of site seismicity, extents of previous seismic upgrade work (if any), soil liquefaction potential, EPRS Structural Safety star rating, EPAT expected building damage, FEMA 154 RVS score, and an ASCE 41 Tier 1 checklist percent of “noncompliant” or “unknown”. A small adjustment was made for buildings of larger square footage to slightly prioritize larger buildings over smaller ones with the idea that more people may be at risk in buildings of larger area. Finally, the engineers who evaluated each building also used their judgment to adjust the building category, if they felt the scoring system did not accurately capture the building risk. See *Appendix C* for a more detailed description of the prioritized ranking scoring system used and the final prioritized lists.

Table 9 lists the prioritization categories, the definition of the category, and the types of buildings that are typically in each category. Figures 12 through 15 show the spatial distribution of these buildings and those that received concept-level design studies in phases 1 and 2.

**Table 9.** Prioritized building ranking categories summary.

| Prioritization Category   | Category Definition  | Typical Buildings in Category   |
|---------------------------|--|---|
| <b>Very High Priority</b> | These buildings have the highest seismic risk and have a clear and strong need to receive seismic upgrades. The benefits of seismic performance and structural integrity gained by performing seismic upgrades are likely to significantly exceed the cost of the upgrades by a large margin.  | Typically unreinforced masonry buildings and non-ductile concrete buildings built before the 1960s and located in high seismic zones. Some very high risk reinforced masonry buildings are also in this category.                         |
| <b>High Priority</b>      | These buildings also have a strong need to receive seismic upgrades and would greatly benefit from voluntary seismic upgrades or seismic improvements that are incorporated with other systems upgrade projects or modernizations. The benefits of seismic performance and structural integrity gained by performing seismic upgrades likely | Typically reinforced masonry and wood buildings built in the 1950s, 1960s, and 1970s and located in high seismic zones. Some unreinforced masonry buildings located in moderate and low seismic zones are also included in this category. |

|                          |   |   |
|--------------------------|---|---|
|                          | exceed the cost of the upgrades.  |   |
| <b>Moderate Priority</b> | These buildings are not as high risk as the buildings in the High and Very High categories. Depending on level of seismicity, some buildings may or may not have a need to receive seismic upgrades. In areas of high seismicity, these buildings would still benefit from voluntary seismic upgrades that may be able to achieve seismic performance similar to modern buildings. However, the financial benefits of seismic upgrades may or may not exceed the costs. | Typically, buildings of various construction types built in the 1960s through the 1990s located in high, moderate, and low seismic zones. |
| <b>Lower Priority</b>    | The benefits of seismic performance and structural integrity gained by performing seismic upgrades would likely not exceed the costs. Some buildings in this category already meet the Life Safety structural performance objective and were built to modern seismic standards where seismic upgrades would not be needed.  | Typically buildings of various construction types built in the 1980s through the 2010s located in high, moderate, and low seismic zones.  |

The following are some notes and caveats about the prioritized rankings.

1. The list of buildings only includes school buildings assessed in Phase 1 and Phase 2 of the Washington State School Seismic Safety Project. This represents approximately 12 percent of recognized school buildings in the ICOS database. Prioritization of the rest of the schools in Washington State requires further study and updates to the information in ICOS.
2. The main seismic evaluation portion of this study evaluated buildings using ASCE 41 Tier 1 procedures. In addition, many buildings had incomplete information, which required the assessment team to make notes where items were unknown. Tier 1 procedures are typically the first step taken in identifying building-specific seismic risks. However, Tier 1 evaluations must be followed up with ASCE 41 Tier 2 or Tier 3 evaluations prior to conducting seismic upgrades. In addition, the buildings have not been evaluated by architects, mechanical engineers, electrical engineers, fire protection engineers, or geotechnical engineers. Further assessments by a structural engineering and architectural/engineering team are required to further determine the extent of seismic upgrades and the building-specific benefits and costs of seismic upgrades.
3. Data used for prioritizing the school buildings assessed in this study were gathered from 2018–2021. Some school buildings listed are undergoing renovations or have subsequently been upgraded, modernized, or seismically improved voluntarily. These buildings should move down



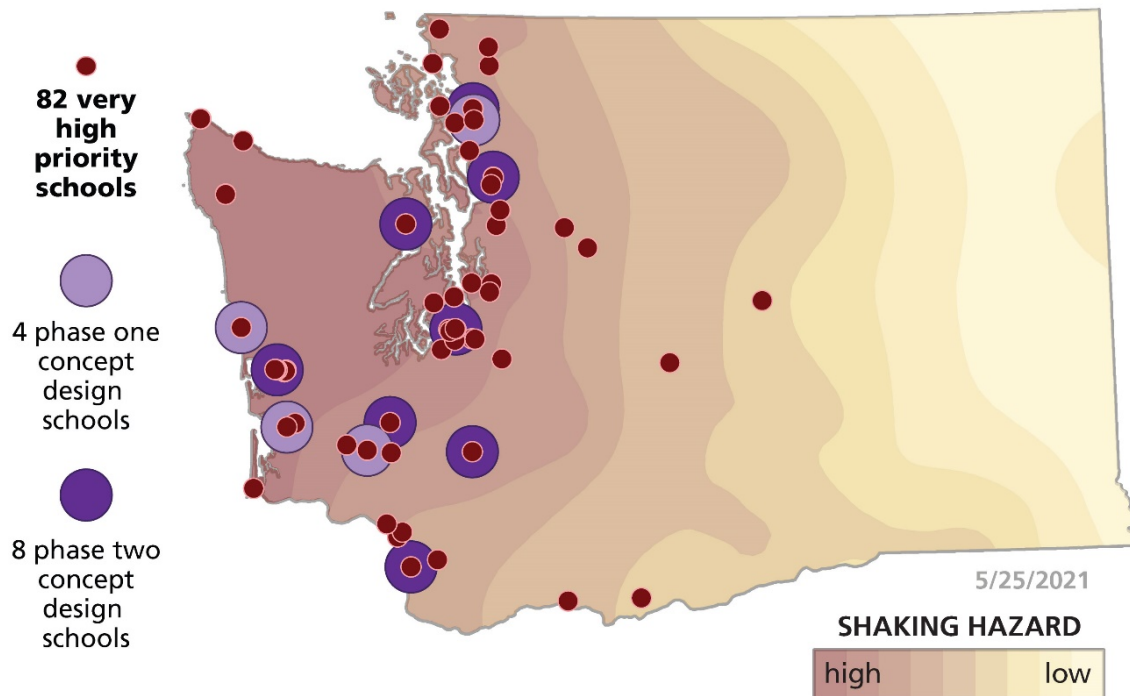
on the priority list once the seismic improvements are implemented and reviewed by a structural engineer.

4. Whether or not a building was located in a tsunami inundation zone was not used as a component of the development of the prioritized rankings. Buildings that are located in tsunami inundation zones may need to be further evaluated to determine the optimum course of action. In many cases, it may be more cost effective to relocate a school outside of a tsunami inundation zone than to upgrade the building. Alternatively, constructing purpose-built tsunami vertical evacuation structures or hardening evacuation routes may be a cost-effective way to improve the survivability of people located in tsunami inundation zones. In these cases, seismically upgrading buildings with the purpose of allowing people to evacuate and reach higher ground may be appropriate. Evaluation of tsunami hazards was outside the scope of this project. It may be appropriate to evaluate structural loads from tsunamis in future studies.
5. The table that lists the prioritized rankings categorizes buildings into one of four categories. Within each category, the school buildings are listed alphabetically. Alphabetization was chosen to provide some amount of organization to the table. The buildings in each category should be construed as possessing approximately equal risk to one another. That is, the buildings within each category are not further prioritized beyond each of the four categories.
6. Some buildings within the study have multiple additions constructed over multiple years. In addition, different portions of the same building may be constructed of multiple structural building types. Generally, the highest risk portion of each building was used to prioritize the buildings. It may be the case that only part of a building is the highest risk portion, with other portions of a building being less at-risk.



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## WASHINGTON SCHOOL SEISMIC SAFETY PROJECT VERY HIGH PRIORITY SCHOOLS

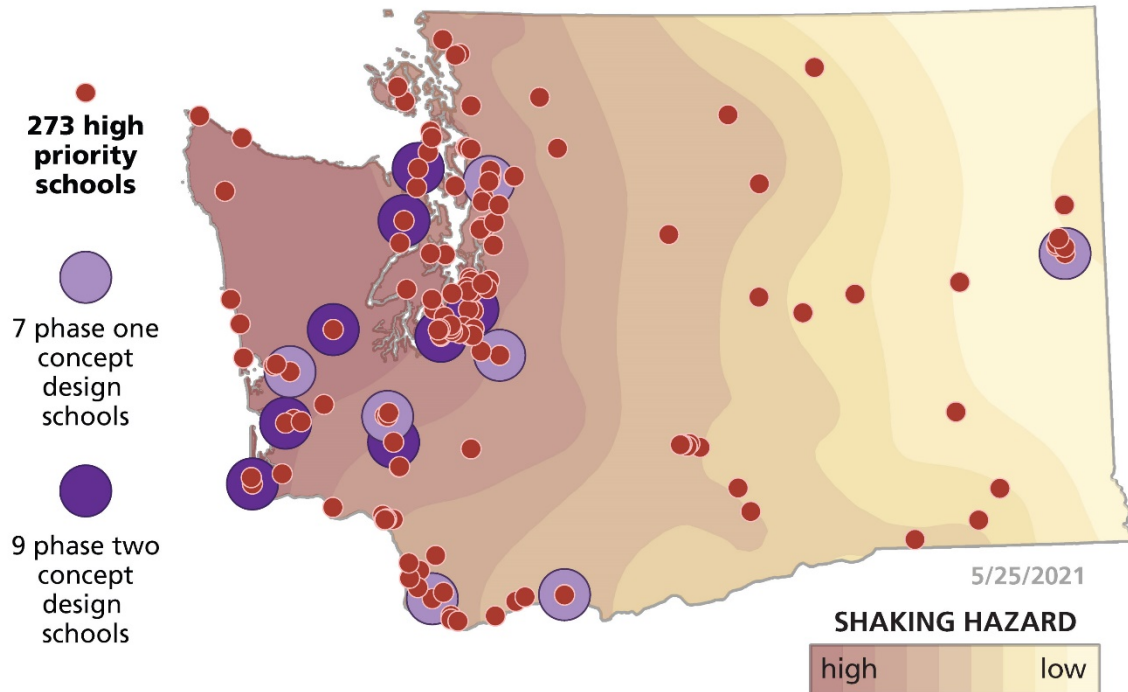


**Figure 12.** Map showing the very high-priority schools (dark red dots) and those which received concept-level designs in Phase 1 (light purple) and Phase 2 (dark purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).



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## WASHINGTON SCHOOL SEISMIC SAFETY PROJECT HIGH PRIORITY SCHOOLS

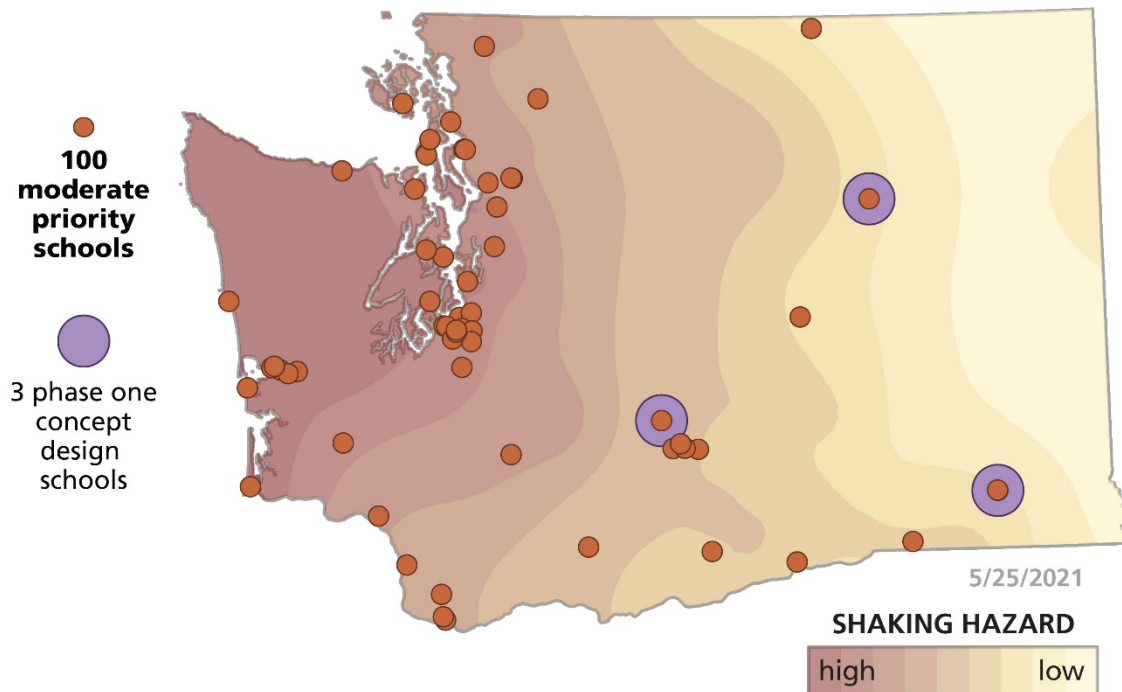


**Figure 13.** Map showing the high- priority schools (red dots) and those which received concept-level designs in Phase 1 (light purple) and Phase 2 (dark purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).



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## WASHINGTON SCHOOL SEISMIC SAFETY PROJECT MODERATE PRIORITY SCHOOLS

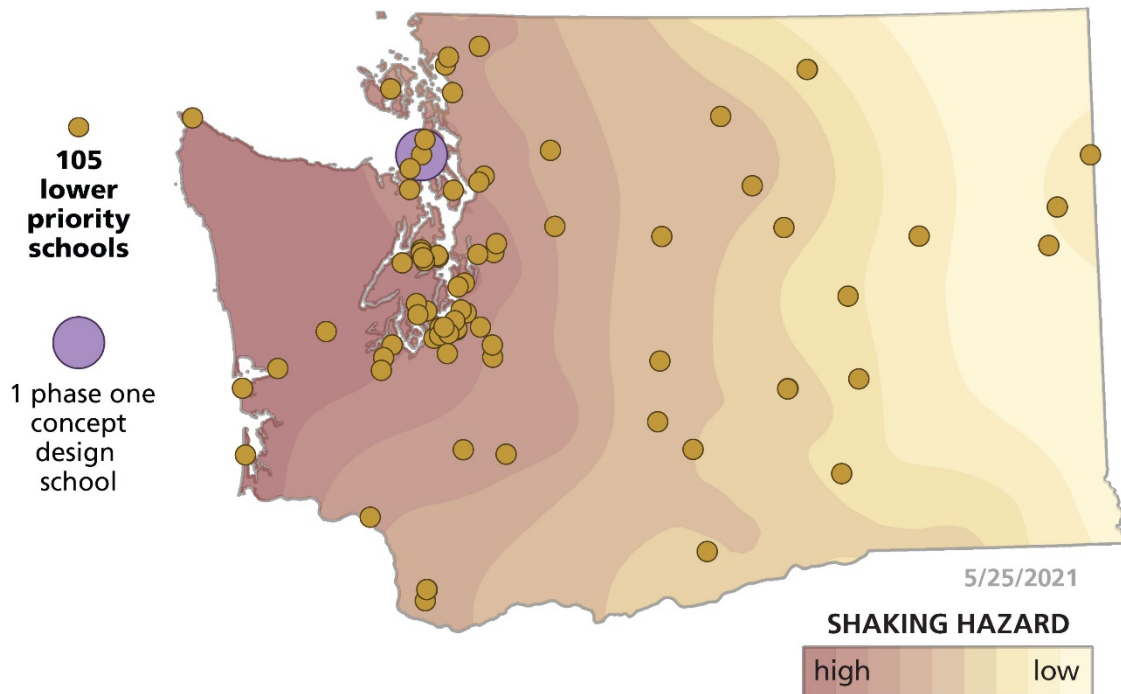


**Figure 14.** Map showing the moderate-priority schools (orange dots) and those which received concept-level designs in Phase 1 (light purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).



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## WASHINGTON SCHOOL SEISMIC SAFETY PROJECT LOWER PRIORITY SCHOOLS



**Figure 15.** Map showing the lower priority-schools (yellow dots) and those which received concept-level designs in Phase 1 (light purple). Basemap shows shaking hazard (Modified from Petersen and others, 2015).

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# Conclusions

Below is a summary of high-level findings from Phases 1 and 2 combined.

- Washington State has many older school buildings built prior to the adoption of modern seismic safety codes. Older and more vulnerable construction types are more susceptible to earthquake damage and have a greater percentage of seismically noncompliant structural and non-structural components.
- Unreinforced masonry buildings constructed before the 1940s and non-ductile concrete buildings (without seismic upgrades) constructed before the mid-1970s located in high seismic hazard areas are especially vulnerable to collapse during earthquakes. The risks of these buildings should be mitigated as soon as practical.
- Older school buildings built prior to 1975 and constructed out of reinforced masonry and wood frame materials are vulnerable to collapse.
- Geologic site class measurements showed that 59 campuses of the 245 studied have a measured site-specific site class that differs from the predicted site class based on reconnaissance-scale mapping. The more accurate site-specific measurements help to inform detailed engineering plans and affect building costs.
- In total, 67 school buildings on 30 school campuses that were assessed in Phase 1 and Phase 2 are located within tsunami inundation zones. These schools serve more than 10,000 students. Tsunami loads and impacts were not considered in the geologic or engineering assessments. For schools to be safe from a tsunami, they would need to be moved from the tsunami inundation zone or designed to withstand tsunami loads with options for vertical evacuation.
- Preliminary structural safety sub-ratings for 561 school buildings assessed in both Phase 1 and Phase 2 were determined using the findings from the ASCE 41 Tier 1 seismic evaluation checklists. Ninety-three percent of the 561 school buildings assessed have one-star Structural Safety sub-ratings based on the information available. Four percent of the school buildings assessed have two-star ratings and 3 percent of the school buildings have three-star ratings.
- The concept-level seismic upgrade design results indicate that for many buildings, the cost to seismically upgrade the structure will cost less than the costs to repair major damage following an earthquake, or significantly less than the cost to replace an irreparably damaged building. For less vulnerable structures, especially structures in low seismicity areas, however, it may not be financially worth implementing seismic upgrades.
- Seismically upgrading a vulnerable structure will generally make the building stronger, stiffer, safer, and more resilient, therefore decreasing the damage costs the building will incur in an earthquake.
- A range of cost estimates were developed for each of the select buildings that received a concept-level designs and estimated costs to retrofit. Phase 1 concept level design building cost estimates ranged from a median of \$63K to \$5.01M, where the median represents the range of cost estimates for a single building. Phase 2 median concept level design building cost estimates ranged from \$1.24M to \$15.26M. Cost estimate methods for Phase 2 were improved from Phase

1 and now include projected soft costs. Phase 1 concept design schools were selected to represent a variety of building construction types and vintages in different seismic hazard areas.

Alternatively, Phase 2 concept design schools were selected based on available information to be some of the highest risk buildings based on seismic hazard and engineering design.

- A significant portion of the structural upgrade costs are due to the fact that the seismic upgrades take place in existing buildings with existing finishes and existing nonstructural components. The costs to temporarily remove and replace the architectural, mechanical, electrical, and plumbing equipment is significant. If the costs associated with the architectural, mechanical, electrical, plumbing, and fire protection elements were deleted from the cost estimates, the average seismic upgrade cost sees a 70 percent reduction. Significant savings can be realized by combining seismic upgrades with other types of work, such as re-roofing projects or school modernizations.
- Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Of the 561 buildings studied, 63 percent were high or very high priority, 18 percent were moderate priority, and 19 percent were lower priority.
- The EPAT data show that the median building is expected to be 55 percent damaged in a design-level earthquake (Table 10). EPAT also estimates that the majority of buildings in this study are expected to receive a “Red—Unsafe” post-earthquake building safety placard following a design-level earthquake, meaning that they will be unsafe to occupy. In addition, the EPAT data show that approximately one-half of buildings studied will not be repairable following a design-level earthquake, and will require demolition. The EPAT results are summarized in Table 10 and results for Phase 1 and 2 building damage estimates are shown in Figure 16 below.

**Table 10.** Washington State schools EPAT summary results for Phase 1 and Phase 2 school buildings combined.

| EPAT Calculated Value  | Median | Average | Max       | Min      |
|--|--------|---------|-----------|----------|
| Building damage estimate ratio<br>(Amount of building that is damaged) | 55%    | 51%     | 95%       | 6%       |
| Probability building is not repairable                                 | 50%    | 47%     | 96%       | 2%       |
| Life safety risk level   | High   | -       | Very High | Very Low |
| Most likely post-earthquake tagging                                    | Red*   | -       | Red*      | Green*   |

*\*Red = Unsafe to Occupy, Yellow = Restricted Building Access, Green = No Restrictions on Building Access.*

## Percentage Damage Estimate for School Buildings

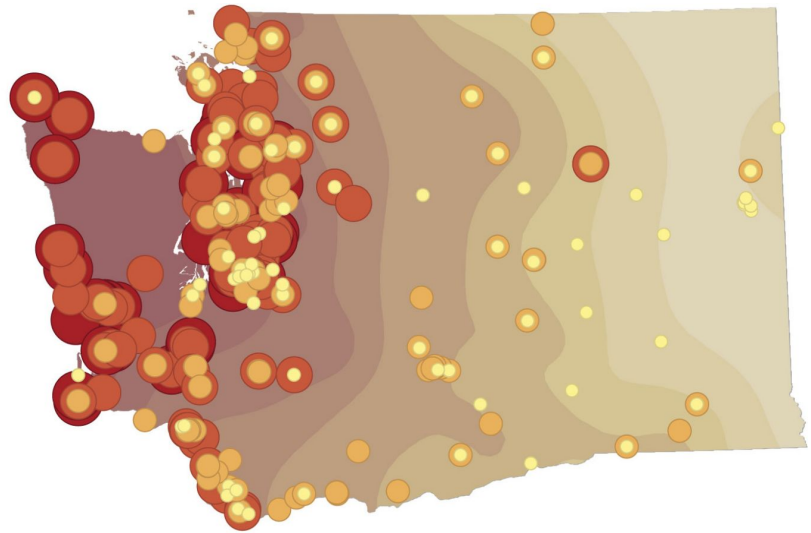
### Damage Estimate

- 75-100%
- 50-75%
- 25-50%
- 0-25%

SHAKING HAZARD

high

low



**Figure 16.** Map of Washington showing school buildings assessed in Phase 1 and 2, symbolized by percent damage estimate using the EPAT tool. Basemap shows shaking hazard (Modified from Petersen and others, 2015).



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# Information for Schools on How to Use Reports and Data

All of the data generated from these studies were provided to the districts and schools that participated in this project. The following are the major deliverables and a summary of their intended use that were sent to each district and school as part of Phase 2 of this project:

1. A copy of this **legislative report** summarizing the methods and major findings of the project. This report may be useful to get a high-level understanding of the geologic and engineering assessments and how their individual schools fit into the larger study. For schools that participated in Phase 1, the [Phase 1 report](#) and appendices were sent to them in June 2019.
2. The final engineering reports summarizing the results of the seismic screenings, available via the following links and also in *Appendix B* of this report:
  - a. [Volume 1: Seismic Assessment Report](#)—This volume provides an overview of the engineering seismic assessments, which is useful for understanding the process and all of the information included in the school reports.
  - b. [Volume 2: EPAT & FEMA 154 RVS Summaries](#)—This volume presents the results of the EPAT worksheets and Rapid Visual Screenings.
  - c. [Volume 3: ASCE 41-17 Screening Reports](#)—This volume presents the results of the ASCE 41-17 assessments at 339 school buildings.
  - d. [Volume 4: Seismic Upgrades Concept Design Reports, 17 School Buildings](#)—This volume presents the results of the concept-level seismic upgrade designs conducted for 17 school buildings. These reports provide information on the designs, costs, and suggested upgrades that were included in the concept design reports.
3. The individual geologic site class assessment reports for each of the school campuses. These are useful for understanding the local geology at your school campus and for learning about any other potential geologic hazards near the school. These reports are included in *Appendix A* of this report.

Per the state building code, a school district is under no obligation to upgrade its school buildings to the suggested upgrade recommendations presented here unless there is: (1) a change in use or occupancy, (2) an addition that is attached to the existing building and increases the seismic demands on the lateral system, (3) an alteration to a work area exceeding 50 percent of the building area, or (4) an alteration made to the structure's lateral system that would trigger such upgrades. An important thing to also note is that modernizations (that only alter architectural, mechanical and electrical components of a building) often do not count as a significant alteration, therefore, structural seismic upgrades are often not required when nonstructural modernizations occur.

# Earthquake Performance Rating System Reporting

## Recommendations for Use

The goal of this study was to inform school districts of the seismic deficiencies of their buildings and possible ways to mitigate them. As stated earlier, a lesson learned from Phase 1 was that the screening reports were complicated to a non-engineering audience; in this phase the study team attempts to simplify the engineering jargon from the ASCE 41 Tier 1 checklists in order to (1) let school districts know where their buildings stand with regards to seismic safety, and (2) let them know the most important seismic deficiencies that need to be mitigated or further investigated to improve the seismic safety of the school buildings assessed. The ‘Earthquake Performance Rating System (EPRS) ASCE 41-13 Translation Procedure’ was chosen to help communicate and prioritize the seismic deficiency mitigation in the seismic screening reports. This process extracts evaluation items (building components) from the ASCE 41 Tier 1 checklists that need to be determined as “Compliant” in order to increase a building’s structural safety rating from a one-star rating (risk of collapse in multiple or widespread locations) to a two-star rating (risk of collapse in isolated locations) and then to the recommended goal of a three-star rating (the Life Safety structural performance objective). Extracting and categorizing these evaluation items in this manner creates a prioritized list of seismic deficiencies, as shown in Figure 17. This is intended to be used as a mitigation strategy to provide further engineering investigation and analysis, and seismic improvement projects (either done voluntarily or as part of a modernization), to increase the seismic safety of the building and consequently increase its structural safety risk rating. The risk rating and prioritized list of deficiencies are provided to schools in their individual building screening reports.

**Table -5. Identified Seismic Evaluation Items to Address for an improved  2-STAR Rating**

| Evaluation Item                              | Tier 1 Screening | Description   |
|--|------------------|---|
| Vertical Irregularities                      | Noncompliant     | It does not appear that vertical elements are continuous to the foundation. Further investigation should be performed prior to retrofit. Lateral system strengthening, such as infilling with CMU or adding new shear walls or braced frames may be appropriate to mitigate seismic risk.   |
| Wall Anchorage                               | Noncompliant     | Out-of-plane wall anchoring is not present based on structural drawings provided. Further investigation should be performed prior to retrofit. Diaphragm reinforcement, including tension ties, blocking, strapping, and diaphragm nailing to provide out-of-plane connection at masonry walls may be appropriate to mitigate seismic risk. |
| Wood Ledgers                                 | Noncompliant     | Connections that induce cross-grain bending in wood ledgers are present. Strengthening of connections through the addition of blocking and anchor straps may be appropriate to mitigate seismic risk.   |
| Transfer to Shear Walls                      | Unknown          | Likely noncompliant condition based on year of construction for pre-benchmark building. Further investigation should be performed.  |
| Cross Ties                                   | Noncompliant     | There are no continuous cross ties between diaphragm chords. Further investigation should be performed prior to retrofit. The addition of new cross ties between diaphragm chords or the addition of strap plates to connect existing framing members together may be appropriate to mitigate seismic risk.                                 |
| Diagonally Sheathed and Unblocked Diaphragms | Noncompliant     | Diaphragm is unblocked with spans greater than 40 feet in locations. Further investigation should be performed prior to retrofit. Diaphragm strengthening through the addition of blocking or additional diaphragm nailing may be appropriate to mitigate seismic risk.   |

Table -6. Identified Seismic Evaluation Items to Mitigate or Further Investigate for an improved  3-STAR Rating

| Evaluation Item    | Tier 1 Evaluation | Description  |
|--------------------|-------------------|--|
| Adjacent Buildings | Unknown           | Limited existing drawings and inadequate access to verify. Further investigation should be performed. Diaphragm reinforcement, shear wall addition, or tying joints together may be appropriate to mitigate seismic risk.  |
| Reinforcing Steel  | Noncompliant      | The masonry walls are under-reinforced and will likely need to be strengthened for in-plane and out-of-plane seismic loads. FRP or new shear walls may be appropriate to reduce in-plane demand. Steel strongbacks may be appropriate to strengthen out-of-plane capacity. |

**Figure 17.** EPRS output screening reports highlighting an example of a building’s evaluation items (building components) that could be retrofitted for the building to increase to either a two-star rating (top) or a three-star rating (bottom).

## Incorporating Seismic Data into School Safety Plans

DNR, in coordination with OSPI, delivered all of the engineering and geology results to the participating schools and districts. The information in these documents can be useful for safety planning. Both DNR and OSPI are available for assistance incorporating this information into safety plans as requested. When OSPI meets with districts to help them develop comprehensive safety plans, they encourage them to use geologic hazards in their planning efforts.

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# Recommendations

## Recommendations for Future Studies and Evaluations

The School Seismic Safety Project (Phases 1 and 2) has been an important opportunity to study and evaluate 561 school buildings across the state. These assessments have characterized the seismic risk at ~12 percent of Washington’s permanent, public K–12 school buildings and demonstrated the need for dedicated funding for seismic retrofits. We have learned a great deal about different methods for assessing risk, and there is still a great deal more to be done. This section summarizes some of the major recommendations for continuing to assess seismic risk for Washington Schools (Table 11). They are ordered based on our recommendation for greatest impact for life safety of school building occupants and priority for school seismic safety.

**Table 11.** Recommendations for future studies and evaluations for the school seismic safety of Washington’s schools.

| Recommendation   | Description   |
|--|---|
| <b>A study to evaluate the feasibility and cost benefit of increasing the seismic performance for the design of new school buildings to enhance the seismic resilience of communities.</b> | A well-known trend is that with each building code cycle, new discoveries in geology and lessons learned from recent earthquakes generally result in increases in seismic design forces and more stringent seismic design requirements. It is also understood that incorporating structural enhancements into the design of new buildings has high benefit-to-cost ratios. The first and main benefit is that a building designed and constructed above minimum building code standards will result in better seismic performance. This provides added safety for the building occupants and increases the likelihood that the building can be re-occupied following an earthquake. A second benefit is that enhanced seismic systems above minimum code standards will also better adapt the building to future building codes and seismic design requirements. Both benefits in turn will improve the seismic resiliency of the school buildings themselves and thereby the resiliency of the communities they serve. A simple way to do this is to encourage school buildings, or portions thereof, to be structurally designed to a higher Risk Category IV (similar to that of essential facilities) instead of what buildings codes currently require: Risk Category II for school buildings with 250 or less occupants, or Risk Category III for school buildings with greater than 250 occupants. Additional ways to enhance the seismic performance such as performance-based design and resiliency-based design can also be encouraged at the state and local levels in further protecting some of the most publicly used buildings in the communities. |
| <b>A study to identify which schools in tsunami</b>  | Tens of thousands of Washington students go to school in areas subject to tsunami inundation during a large earthquake. Not only are these  |

|   |   |
|---|---|
| <p><b>inundation zones need vertical evacuation structures.</b></p>   | <p>structures not designed to withstand tsunami loads, many of these schools are in locations where there are no evacuation options from tsunamis. In addition to seismically upgrading these facilities, it is our recommendation that there be a comprehensive assessment to determine which schools would need vertical evacuation structures to ensure students would have a safe place to evacuate in case of a tsunami.</p>   |
| <p><b>A study of school sites suspected of having moderate to high risk of liquefiable soils, to determine cost-efficient methods of assessing the risk, and identify mitigation strategies for existing school buildings on liquefiable soils.</b></p> | <p>More subsurface investigation is required to confirm the presence of liquefiable soils and to anticipate what the liquefaction-induced settlements would be across a site or across a given building. This type of additional investigation typically requires deep exploration borings, soil testing, groundwater determination, liquefaction hazard analyses, and additional geophysics; these are then applied to the design parameters for the seismic design or retrofit of a building. This type of enhanced subsurface investigation can be costly for school districts and the State to incur when applied to existing school sites that are suspected of having moderate to high risk of liquefiable soils. A geologic study that includes licensed geotechnical engineers with expertise in liquefaction hazard analysis and mitigation will help provide the State with:</p> <p>More accurate assessments of liquefaction risks at existing school buildings suspected of having liquefiable soils.</p> <p>Cost-efficient methods and strategies in determining the level of liquefaction risk, leveraging the Vs30 measurements already gathered from previous geologic studies (that include the school sites in Phase 1 and Phase 2 of this study).</p> <p>Strategies and rough order of magnitude costs to mitigate liquefiable soils or to enhance and strengthen existing different types of building foundation systems to attain a Life Safety Performance Objective in considering post-earthquake liquefaction-induced settlements.</p> |
| <p><b>Conduct a statewide inventory of school districts to collect data about which facilities have already had seismic upgrades.</b></p>   | <p>Many school districts have already completed seismic retrofits on many of their most vulnerable buildings. These retrofit projects are not necessarily captured in OSPI's ICOS database. In order to fully understand what needs to be done to complete seismically retrofitting our most vulnerable buildings, we need to understand what has already been done. This recommendation would allow OSPI to survey school districts to collect the engineering designs and costs for these upgrades to complete the seismic safety inventory process.</p>  |
| <p><b>Continue to update OSPI's ICOS database with structural and seismic information about each school building (construction type, year of</b></p>  | <p>Prior condition assessment reports, area plans, and Study and Survey information in OSPI's ICOS database can be used to perform RVS and EPAT as the first step in identifying buildings that could use a further detailed ASCE 41 Tier 1 Seismic Evaluation. This requires trained input of structural building data gathered by architects and engineers through visiting the buildings or reviewing available existing drawings and geotechnical reports. Also, cataloging building description and</p>  |

|  |   |
|--|---|
| <b>construction, previous seismic upgrades, site class, seismicity, seismic irregularities).</b> | construction history narratives, similar to many of the older Study & Survey information, will be extremely valuable to engineers and facility managers in understanding the structural history of the buildings being assessed, a history that often spans multiple generations and school district personnel. These data will be instrumental for future seismic retrofit projects.   |
| <b>Continue doing ASCE 41 Tier 1 seismic evaluations of school buildings.</b>                    | ASCE 41 Tier 1 Seismic Evaluations continue to be the preferred structural engineering standard to identify seismic deficiencies specific to each building and can be used to provide a seismic mitigation strategy to school districts. RVS and EPAT can be used as an initial metric to prioritize buildings that should get further Tier 1 seismic evaluations, however engineers will need to review existing drawings and perform field investigations to adequately assess the seismic safety of a school building. |

## Recommendations to Enhance School Seismic Safety and Resiliency

Following the Phase 1 study and report that was published in 2019, the 2020 Supplemental Capital Budget appropriated \$13.24M to OSPI for the School Seismic Safety Retrofit Program (SSSRP) signed into law by the Governor on April 2, 2020. We commend the State on taking action in creating the SSSRP and for publicly funding the design and construction for the seismic upgrades of the selected school buildings. The assessment team further commends the State's effort in further funding this program in the 2021–2023 capital budget for an additional \$40M to continue providing funding to seismically upgrade some of the state's more seismically vulnerable buildings. Additionally, state funding was allocated to DNR for conducting site class assessments at school campuses that are participating in OSPI's Study and Survey program. These site class assessments in conjunction with the enhanced Study and Survey funding for RVS and EPAT assessments will help to further our understanding of school seismic risk.

The SSSRP and DNR's recent work is already paying off. Based on Phase 1 results and the 2020 Supplemental Budget for OSPI's SSSRP funding, Centralia School District's Edison Elementary School is expected to begin the installation of its seismic retrofit in June, 2021. Edison Elementary School will be the first school in the state to install a seismic retrofit under the SSSRP. North Beach School District's Pacific Beach Elementary Gym Building is expected to begin the installation of their seismic retrofit shortly after. In addition, there are many schools ready to begin their seismic retrofits in the near future, as funding permits.

Despite some progress, there are still many more buildings that need seismic improvements, and a lot of school districts in need of state-level funding. OSPI's new SSSRP is a tremendous push toward a long-term program in providing seismically safe public school buildings. The results of this study are very useful in determining which buildings are the highest priority and provide valuable guidance for how the

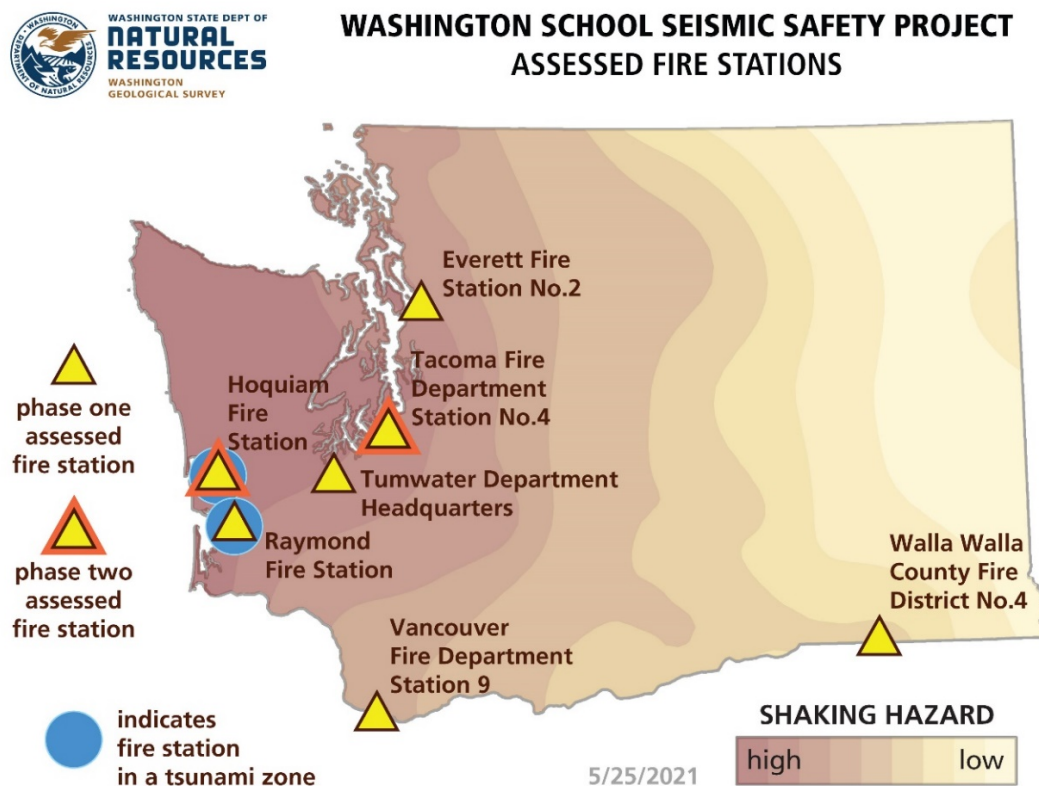
SSSRP could begin prioritizing other similar schools that did not receive an assessment as part of this project. Additionally, the costs that are presented as estimates in the concept level design studies are valuable for estimating the amount it may take to seismically retrofit the selected school buildings. However, it is our recommendation that the SSSRP develop a panel of experts to advise the program on spending and how to estimate actual construction costs based on inflation, soft costs, and other factors. It is our recommendation for OSPI to continue to consult with other states or educational agencies such as Oregon, California, and Alaska (Anchorage School District in particular), to enhance the way the SSSRP is administered and awarded. And, it is our recommendation that the SSSRP eventually includes an application process by which school districts can submit seismic upgrade designs and objectives, and potentially qualify to receive seismic upgrade funding from the State based on a benefit-costs determination.

Washington State spends millions of dollars in each biennium to modernize schools. For the most part, these modernization projects do not (and are not required to) include seismic upgrades. A substantial cost of seismic upgrades is the removal and replacement of architectural, mechanical, electrical and plumbing systems. This study shows that if seismic upgrades are combined with modernizations, the costs of seismic upgrades can be reduced, on average, by 70 percent. Combining seismic upgrades with modernizations has the potential to save Washington State millions of dollars each biennium and allows for much more efficient spending of funds while improving the seismic safety and resilience of communities. For example, the federal government requires all buildings in high seismic zones that are undergoing renovations/modernizations that exceed 30 percent of the building's value to receive seismic upgrades; Washington State could consider developing similar policies for school buildings. Performing seismic retrofits during a school modernization project would require additional funding from the Legislature to ensure that all school districts can participate in the SSSRP, regardless of their ability to pass a capital bond or levy.

# Fire Stations

## Fire Stations Studied

In Phase 1 of this study, five fire stations located within a mile of a public school were seismically screened to an Immediate Occupancy structural performance objective. In Phase 2, two more fire stations within a mile of a public school were similarly assessed. See Figure 18 for Phase 1 and 2 fire station locations. The selection criteria for these two Phase 2 fire stations were based on seismic hazard, availability of existing drawings, tsunami risk, and construction type. In Phase 2, these two fire stations also received a conceptual seismic upgrade design report and cost estimate to determine possible upgrade solutions and probable cost to seismically upgrade these buildings to meet an Immediate Occupancy structural performance objective.



**Figure 18.** Map showing the five fire stations assessed for Phase 1 (yellow triangle) and Phase 2 (yellow triangle with an orange outline) of this project and highlighting (in blue) those in a mapped tsunami inundation zone. Basemap shows shaking hazard (Modified from Petersen and others, 2015).



## Methods

Similar to the seismic screenings of the school buildings, structural engineers reviewed available existing drawings, performed site investigations, and seismically evaluated the fire stations using the Tier 1 checklists of the ASCE 41-17 ‘Seismic Evaluation and Retrofit of Existing Buildings’ standard. Different from the school buildings however, these fire stations were seismically evaluated to the Immediate Occupancy structural performance objective compared to the Life Safety and Collapse Prevention structural performance objectives. The Immediate Occupancy structural performance objective is intended to result in a very low overall risk of life-threatening injury, and though there may be some minor structural repairs required, these repairs would generally not be necessary to allow for re-occupancy following an earthquake.

Following the Tier 1 seismic screenings, a conceptual seismic upgrade design report and cost estimate was prepared for each fire station to upgrade to an Immediate Occupancy structural performance objective (*Appendix D*).

For each fire station (except Tacoma Fire Station, No. 4) WGS personnel deployed to a nearby location and measured site class using the same techniques and methodologies employed at school campuses. From this measurement we assigned site class to each fire station. The final results are condensed into a site class assessment report (Fig. 5) and distributed to each fire station (*Appendix D*). The Vs30 measurements are also included in the WGS shear wave database (Washington Geological Survey, 2021 a). For the Tacoma fire station, WGS personnel could not deploy to the area to conduct a survey measurement, due to travel restrictions from COVID-19; therefore the site class used for the engineering analysis is based on the default D site class.

## Results and Recommendations for Fire Stations

This study’s seismic assessments of seven fire stations resulted in similar observations to the school buildings that were assessed. Older fire stations (pre-1975) and fire stations constructed of heavier materials (URM, reinforced masonry, non-ductile concrete) are significantly more vulnerable than more modern wood or steel-framed fire stations. Fire stations are considered essential facilities that need to be functioning and occupant-ready to perform essential community services following an earthquake. As a result, older fire station buildings should be highly prioritized for seismic retrofit or replacement by State, City, and County agencies as funding becomes available.

The seven fire stations assessed in Phase 1 and Phase 2 of this study are a very small sampling of the fire stations throughout the state. Based upon the structural engineers’ experience in working with fire districts and city agencies in and around the greater Puget Sound area, there are many other fire stations in operation that were built prior to 1975 and have vulnerable URM, reinforced masonry, and non-ductile concrete structural systems. There are a number of fire districts and communities that have successfully passed capital bonds and levies over the past couple of decades, to replace or retrofit their older fire

stations. However, similar to schools, there are many other fire districts and communities statewide that have not had the economic means or support to upgrade or replace their aging fire stations and may need state assistance to do so.

Assessments of probable construction costs for the two Phase 2 fire stations have been prepared as part of this study. The estimated upgrade costs range from approximately \$82 per square foot to \$192 per square foot for the reinforced masonry and unreinforced masonry fire stations, respectively. These are merely two data points of approximate renovation costs needed to bring these fire stations to an Immediate Occupancy structural performance objective, but can be used with other planning level estimates of fire stations to help quantify the financial need at a higher overview level. Past studies of fire station seismic upgrades that the structural engineers have worked on had similar ranges of probable costs per square foot. However, like any other fire station or school building, these costs are highly variable depending on building age, construction type, historic significance, area, seismicity, and site conditions. Specific seismic upgrade costs for a given fire station will require further study by a structural engineer and architect team.

This study recommends consideration of a state-funded grant program similar to the SSSRP that will assist in seismically upgrading the most seismically vulnerable fire stations, and ideally other public essential and critical facilities (Table 12). Further study of the state's inventory of fire stations could be performed by structural engineers and architects to help the State administer and prioritize which fire stations receive assistance. Alternatively, an application program could be administered where fire districts apply and demonstrate their need for seismic upgrade funding assistance through fire district-funded seismic evaluation reports, seismic upgrade designs, and benefit-cost analysis.

**Table 12.** Recommendations for future studies and retrofits of fire stations.

| Recommendation   | Description  |
|--|--|
| <p><b>Develop a long-term program to seismically upgrade or replace all vulnerable Washington State fire stations.</b></p> | <p>Washington State has many older fire station buildings that are highly vulnerable to earthquakes. This is an issue shared by fire districts all across the state. As essential facilities, these buildings will be called upon to provide emergency services following an earthquake and should be prioritized for retrofit projects.</p> <p>There are organizations that could be used as models for a long-term program with the goal of improving seismic safety and resiliency. For example, Seattle Public Utilities has developed seismic resilience goals they plan to achieve for their drinking water system by the years 2045 and 2075. Due to the extent of the seismic vulnerability of fire stations, it is not financially feasible to seismically upgrade all vulnerable facilities in a short period of time. Therefore, developing a long-term program to systematically improve seismic safety and resiliency is essential to ensure the future well-being of our fire stations and the communities they serve.</p> |

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|---|---|
| <p><b>Conduct an inventory of all Washington fire stations and develop a plan to conduct seismic safety assessments to prioritize seismic resilience efforts.</b></p> | <p>To our knowledge there is no comprehensive inventory of Washington fire stations that captures the building construction information and any seismic retrofits that have been conducted. It is our recommendation that a comprehensive inventory of fire station building information be conducted to prioritize seismic retrofits of these critical facilities.</p> |
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# Appendices

## Appendix A: Site Class One-Page Reports

The results of the geological seismic site class assessments are provided in the form of one-page reports. The front side of each report is directed at a general audience and provides a brief explanation of the work done at each school, the final site class determination, and flags for any geologic hazards that might affect the school. The back side of each report is a technical explanation of the geophysical analysis used to determine site class, as well as a discussion of any geologic complexity encountered at each site.

- The one-page reports can be downloaded at the following link. Note that all of the site class reports developed for Phase 2 are combined into a single PDF file for ease of download.

[https://fortress.wa.gov/dnr/geologydata/school\\_seismic\\_safety/phase2/SSSP\\_Site\\_Class\\_Assessment\\_Reports\\_2021.pdf](https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_Site_Class_Assessment_Reports_2021.pdf)

- You can also download combined Phase 1 and Phase 2 one-page site class assessment reports bundled by school district from our website:

<https://www.dnr.wa.gov/school-seismic-safety>

**Table A1.** Phase 1 and 2 school districts, school names, phase participation (SSSP1 or SSSP2 for phases 1 and 2 respectively) and measured site classes. The asterisk (\*) Denotes schools with buildings that have been assessed in both Phase 1 and Phase 2.

| District Name | Site Name                             | SSSP Phase | Measured site class |
|---------------|---------------------------------------|------------|---------------------|
| Aberdeen      | A.J. West Elementary School           | SSSP2      | E                   |
| Aberdeen      | Central Park Elementary School        | SSSP2      | D                   |
| Aberdeen      | Hopkins Building (Harbor High School) | SSSP2      | E                   |



|                   |                              |       |   |
|-------------------|------------------------------|-------|---|
| Aberdeen          | J. M. Weatherwax High School | SSSP2 | E |
| Aberdeen          | McDermoth Elementary School  | SSSP2 | D |
| Anacortes         | Mount Erie Elementary School | SSSP2 | C |
| Bainbridge Island | Bainbridge High School       | SSSP2 | D |
| Bainbridge Island | Commodore Options School     | SSSP2 | D |
| Bainbridge Island | Ordway Elementary School     | SSSP2 | D |
| Bainbridge Island | Woodward Middle School       | SSSP2 | C |
| Battle Ground     | Maple Grove K-8              | SSSP1 | D |
| Battle Ground     | Prairie High School          | SSSP1 | D |
| Battle Ground     | River Homelink               | SSSP1 | D |
| Bellingham        | Fairhaven Middle School      | SSSP2 | C |
| Bellingham        | Roosevelt Elementary School  | SSSP2 | D |
| Bellingham        | Whatcom Middle School        | SSSP2 | D |

|                   |                                      |       |   |
|-------------------|--------------------------------------|-------|---|
| Bethel            | Camas Prairie Elementary School      | SSSP2 | C |
| Bethel            | Rocky Ridge Elementary School        | SSSP2 | C |
| Bickleton         | Bickleton Elementary and High School | SSSP1 | B |
| Boistfort         | Boistfort Elementary                 | SSSP1 | D |
| Brinnon           | Brinnon Elementary School            | SSSP2 | C |
| Burlington-Edison | Edison Elementary School             | SSSP1 | E |
| Burlington-Edison | Burlington-Edison High School        | SSSP2 | D |
| Burlington-Edison | West View Elementary School          | SSSP2 | D |
| Camas             | Lacamas Heights Elementary School    | SSSP1 | C |
| Camas             | Liberty Middle School                | SSSP1 | C |
| Camas             | Skyridge Middle School               | SSSP1 | D |
| Camas             | Dorothy Fox Elementary School        | SSSP2 | C |

|                |  |       |   |
|----------------|--|-------|---|
| Cape Flattery  | Clallam Bay High and Elementary School | SSSP1 | D |
| Cape Flattery  | Neah Bay Elementary School             | SSSP1 | D |
| Cape Flattery  | Neah Bay Junior/ Senior High School    | SSSP1 | D |
| Carbonado      | Carbonado Historical School 19         | SSSP1 | C |
| Cascade        | Beaver Valley School                   | SSSP2 | C |
| Centerville    | Centerville Elementary School          | SSSP1 | C |
| Central Kitsap | Ridgetop Junior High                   | SSSP1 | C |
| Central Kitsap | Silver Ridge Elementary                | SSSP1 | C |
| Central Kitsap | Cottonwood Elementary School           | SSSP2 | C |
| Central Kitsap | Emerald Heights Elementary             | SSSP2 | C |
| Central Kitsap | Green Mountain Elementary              | SSSP2 | C |
| Central Kitsap | Pinecrest Elementary                   | SSSP2 | C |
| Central Kitsap | Woodlands Elementary                   | SSSP2 | D |

|             |                              |       |   |
|-------------|------------------------------|-------|---|
| Centralia   | Edison Elementary School     | SSSP1 | C |
| Centralia   | Centralia Middle School      | SSSP2 | C |
| Centralia   | Oakview Elementary School    | SSSP2 | C |
| Centralia   | Washington Elementary School | SSSP2 | D |
| Chimacum    | Chimacum High School         | SSSP2 | D |
| Chimacum    | Chimacum Middle School       | SSSP2 | D |
| Clover Park | Custer Elementary School     | SSSP2 | D |
| Clover Park | Oakbrook Elementary School   | SSSP2 | C |
| Clover Park | Tillicum Elementary School   | SSSP2 | C |
| Concrete    | Concrete High School         | SSSP1 | C |
| Concrete    | Concrete K-6 School          | SSSP1 | C |
| Cosmopolis  | Cosmopolis Elementary School | SSSP1 | D |
| Coupeville  | Coupeville Elementary School | SSSP1 | C |

|                      |                                   |       |   |
|----------------------|-----------------------------------|-------|---|
| Coupeville           | Coupeville High School            | SSSP1 | D |
| Coupeville           | Coupeville Middle School          | SSSP1 | D |
| Creston              | Creston Junior Senior High School | SSSP1 | D |
| Darrington           | Darrington Elementary School      | SSSP1 | D |
| Darrington           | Darrington Senior High School     | SSSP1 | D |
| Dayton               | Dayton High School                | SSSP1 | B |
| Dayton               | Dayton K-8 School                 | SSSP1 | B |
| Dieringer            | North Tapps Middle School         | SSSP2 | C |
| Dixie                | Dixie Elementary School           | SSSP1 | D |
| East Valley (Yakima) | East Valley Central Middle School | SSSP1 | C |
| East Valley (Yakima) | East Valley Elementary School     | SSSP1 | C |
| Ephrata              | Ephrata High School               | SSSP2 | D |
| Ephrata              | Grant Elementary School           | SSSP2 | D |

|             |                             |       |   |
|-------------|-----------------------------|-------|---|
| Ephrata     | Parkway School              | SSSP2 | C |
| Evaline     | Evaline Elementary School   | SSSP1 | D |
| Everett     | Jackson Elementary School   | SSSP2 | D |
| Everett     | Madison Elementary School   | SSSP2 | C |
| Federal Way | Brigadoon Elementary School | SSSP2 | C |
| Federal Way | Camelot Elementary School   | SSSP2 | C |
| Federal Way | Kilo Middle School          | SSSP2 | C |
| Federal Way | Nautilus K-8 School         | SSSP2 | C |
| Federal Way | Sacajawea Middle School     | SSSP2 | C |
| Ferndale    | Beach Elementary            | SSSP1 | C |
| Ferndale    | Central Elementary School   | SSSP2 | E |
| Ferndale    | Custer Elementary           | SSSP2 | D |
| Fife        | Columbia Junior High School | SSSP1 | E |

|                  |   |       |   |
|------------------|---|-------|---|
| Fife             | Fife High School                          | SSSP1 | E |
| Glenwood         | Glenwood School                           | SSSP1 | C |
| Grand Coulee Dam | Lake Roosevelt K-12                       | SSSP1 | D |
| Granite Falls    | Crossroads High School (form. MS)         | SSSP2 | D |
| Granite Falls    | Granite Falls Middle School (form. HS)    | SSSP2 | C |
| Granite Falls    | Mountain Way Elementary School            | SSSP2 | C |
| Green Mountain   | Green Mountain School                     | SSSP1 | D |
| Harrington       | Harrington Elementary & High School       | SSSP1 | C |
| Highline         | Woodside Site                             | SSSP1 | D |
| Highline         | Beverly Park @ Glendale Elementary School | SSSP2 | C |
| Highline         | Chinook Middle School                     | SSSP2 | C |
| Highline         | Hilltop Elementary School                 | SSSP2 | D |
| Highline         | Seahurst Elementary School                | SSSP2 | C |

|           |  |        |   |
|-----------|--|--------|---|
| Highline  | Southern Heights Elementary School         | SSSP2  | D |
| Highline  | Sylvester Middle School                    | SSSP2  | D |
| Hockinson | Hockinson Heights Elementary School (East) | SSSP2  | D |
| Hoquiam   | Lincoln Elementary School                  | SSSP1  | E |
| Hoquiam   | Hoquiam High School                        | SSSP1* | D |
| Hoquiam   | Central Elementary School                  | SSSP2  | E |
| Hoquiam   | Emerson Elementary School                  | SSSP2  | E |
| Index     | Index Elementary School                    | SSSP1  | C |
| Kelso     | Carrolls Elementary School                 | SSSP1  | B |
| Kelso     | Coweeman Middle School                     | SSSP2  | E |
| Kelso     | Rose Valley Elementary School              | SSSP2  | C |
| La Center | La Center Elementary & Middle Schools      | SSSP2  | D |
| La Conner | La Conner High School                      | SSSP1  | D |



|                 |                                       |       |   |
|-----------------|---------------------------------------|-------|---|
| La Conner       | La Conner Middle School (form. Elem.) | SSSP1 | D |
| Lake Washington | Dickinson Elementary School           | SSSP2 | C |
| Lake Washington | Einstein Elementary School            | SSSP2 | C |
| Lake Washington | Emerson Campus                        | SSSP2 | D |
| Lake Washington | Rockwell Elementary School            | SSSP2 | D |
| Lake Washington | Wilder Elementary School              | SSSP2 | C |
| Longview        | R. A. Long High School                | SSSP1 | E |
| Longview        | Mint Valley Elementary School         | SSSP2 | E |
| Longview        | Mt. Solo Middle School                | SSSP2 | E |
| Longview        | Northlake Elementary School           | SSSP2 | D |
| Longview        | Olympic Elementary School             | SSSP2 | E |
| Longview        | Robert Gray Elementary School         | SSSP2 | E |
| Lopez Island    | Lopez Elementary School               | SSSP2 | C |

|               |  |       |   |
|---------------|--|-------|---|
| Lopez Island  | Lopez Middle High School               | SSSP2 | C |
| Mabton        | Mabton Jr/Sr High School               | SSSP1 | D |
| Mansfield     | Mansfield Elem and High School         | SSSP1 | B |
| Mary M Knight | Mary M. Knight School                  | SSSP2 | C |
| Marysville    | Liberty Elementary School              | SSSP1 | D |
| Marysville    | Marysville Middle School               | SSSP1 | D |
| Marysville    | Totem Middle School                    | SSSP1 | D |
| Marysville    | Cascade Elementary School              | SSSP2 | D |
| Marysville    | Marysville Pilchuck Senior High School | SSSP2 | D |
| Marysville    | Pinewood Elementary School             | SSSP2 | D |
| Marysville    | Quil Ceda Tulalip Elementary School    | SSSP2 | D |
| Marysville    | Shoultes Elementary School             | SSSP2 | D |

|                            |  |       |   |
|----------------------------|--|-------|---|
| Methow Valley              | Liberty Bell Junior Senior High School | SSSP1 | D |
| Methow Valley              | Methow Valley Elementary School        | SSSP1 | D |
| Morton                     | Morton Elementary School               | SSSP1 | C |
| Morton                     | Morton Junior Senior High School       | SSSP1 | E |
| Mount Baker                | Mount Baker Junior High School         | SSSP1 | D |
| Mount Baker                | Mount Baker Senior High School         | SSSP1 | D |
| Mount Baker                | Acme Elementary School                 | SSSP2 | D |
| Mount Vernon               | Lincoln Elementary School              | SSSP1 | C |
| Naches Valley              | Naches Valley High School              | SSSP1 | D |
| Naches Valley              | Naches Valley Middle School            | SSSP1 | C |
| Napavine                   | Napavine Elementary School             | SSSP2 | C |
| Napavine                   | Napavine Junior Senior High School     | SSSP2 | C |
| Naselle-Grays River Valley | Naselle K-12 School                    | SSSP2 | D |

|             |   |       |   |
|-------------|---|-------|---|
| Newport     | Newport High School                               | SSSP1 | C |
| North Beach | Pacific Beach Elementary School                   | SSSP1 | D |
| North Beach | North Beach Junior/Senior High School             | SSSP2 | D |
| North Mason | Belfair Elementary School                         | SSSP2 | C |
| North River | North River School                                | SSSP2 | D |
| Northshore  | Canyon Creek Elementary School                    | SSSP2 | C |
| Northshore  | Crystal Springs Elementary School                 | SSSP2 | D |
| Northshore  | Shelton View Elementary School                    | SSSP2 | C |
| Oak Harbor  | Clover Valley School (new name is HomeConnection) | SSSP2 | D |
| Oak Harbor  | Oak Harbor Middle School                          | SSSP2 | C |
| Ocean Beach | Ilwaco (Hilltop) Middle School                    | SSSP1 | D |
| Ocean Beach | Ilwaco High School                                | SSSP1 | D |

|             |                                  |         |   |
|-------------|----------------------------------|---------|---|
| Ocean Beach | Long Beach Elementary School     | SSSP1   | D |
| Ocean Beach | Ocean Park Elementary School     | SSSP1   | D |
| Ocean Beach | Kaino Gym                        | SSSP1** | D |
| Ocosta      | Ocosta Elementary School         | SSSP1   | D |
| Ocosta      | Ocosta Junior Senior High School | SSSP1   | D |
| Olympia     | Boston Harbor Elementary School  | SSSP2   | C |
| Olympia     | Thurgood Marshall Middle School  | SSSP2   | C |
| Oroville    | Oroville Elementary School       | SSSP1   | D |
| Orting      | Orting Primary School            | SSSP2   | D |
| Palisades   | Palisades Elementary School      | SSSP1   | D |
| Pasco       | Edwin Markham Elementary School  | SSSP1   | D |
| Pateros     | Pateros K-12 School              | SSSP1   | D |
| Paterson    | Paterson Elementary School       | SSSP1   | B |

|               |                                |       |   |
|---------------|--------------------------------|-------|---|
| Pe Ell        | Pe Ell School                  | SSSP2 | C |
| Peninsula     | Discovery Elementary School    | SSSP2 | C |
| Peninsula     | Gig Harbor High School         | SSSP2 | C |
| Peninsula     | Minter Creek Elementary School | SSSP2 | C |
| Peninsula     | Peninsula High School          | SSSP2 | C |
| Peninsula     | Voyager Elementary School      | SSSP2 | D |
| Port Angeles  | Roosevelt Elementary School    | SSSP1 | C |
| Port Townsend | Port Townsend High School      | SSSP1 | D |
| Port Townsend | Blue Heron Middle School       | SSSP2 | D |
| Puyallup      | Maplewood Elementary School    | SSSP1 | E |
| Puyallup      | Puyallup High School           | SSSP1 | E |
| Puyallup      | Spinning Elementary School     | SSSP1 | D |
| Puyallup      | Meeker Elementary School       | SSSP2 | E |
| Puyallup      | Mt View Elementary School      | SSSP2 | C |

|                   |                                     |       |   |
|-------------------|-------------------------------------|-------|---|
| Puyallup          | Waller Road Elementary School       | SSSP2 | C |
| Puyallup          | Wildwood Elementary                 | SSSP2 | C |
| Quilcene          | Quilcene High And Elementary School | SSSP1 | C |
| Quillayute Valley | Forks Elementary School             | SSSP2 | C |
| Quillayute Valley | Forks Intermediate School           | SSSP2 | C |
| Quillayute Valley | Forks Junior-Senior High School     | SSSP2 | C |
| Raymond           | Raymond Elementary School           | SSSP1 | D |
| Raymond           | Raymond Junior Senior High School   | SSSP1 | D |
| Renton            | Hazen Senior High School            | SSSP2 | C |
| Renton            | Lindbergh Senior High School        | SSSP2 | C |
| Renton            | Renton Senior High School           | SSSP2 | D |
| Ridgefield        | Union Ridge Elementary School       | SSSP1 | D |

|             |                               |        |   |
|-------------|-------------------------------|--------|---|
| Ridgefield  | South Ridge Elementary School | SSSP2  | D |
| Riverside   | Chattaroy Elementary School   | SSSP1  | D |
| Royal       | Red Rock Elementary School    | SSSP1  | C |
| Royal       | Royal High School             | SSSP1  | C |
| Royal       | Royal Middle School           | SSSP1  | C |
| Shaw Island | Shaw Island School            | SSSP1  | B |
| Skamania    | Skamania Elementary School    | SSSP2  | D |
| Skykomish   | Skykomish School              | SSSP1  | D |
| Snohomish   | Cathcart Elementary School    | SSSP2  | C |
| Snohomish   | Central Elementary School     | SSSP2  | C |
| Snohomish   | Emerson Elementary School     | SSSP2  | C |
| South Bend  | South Bend Jr/Sr High School  | SSSP1* | E |



|                  |  |       |   |
|------------------|--|-------|---|
| South Whidbey    | South Whidbey Grades K-4                                 | SSSP1 | C |
| South Whidbey    | South Whidbey Grades 5 & 6 - (Formerly S. Whid. Primary) | SSSP2 | C |
| Spokane          | Adams Elementary School                                  | SSSP1 | C |
| Spokane          | Audubon Elementary School                                | SSSP1 | C |
| Spokane          | Libby Center   | SSSP1 | C |
| Spokane          | Bancroft (The Community School)                          | SSSP2 | C |
| Spokane          | Bryant Center  | SSSP2 | C |
| Spokane          | Havermale (Montessori)                                   | SSSP2 | C |
| Spokane          | Madison Elementary School                                | SSSP2 | D |
| Stanwood-Camano  | Stanwood Elementary School                               | SSSP2 | E |
| Stanwood-Camano  | Stanwood Middle School                                   | SSSP2 | E |
| Stanwood-Camano  | Twin City Elementary School                              | SSSP2 | D |
| Stevenson-Carson | Carson Elementary School                                 | SSSP2 | C |

|                  |                                |       |   |
|------------------|--------------------------------|-------|---|
| Stevenson-Carson | Stevenson High School          | SSSP2 | D |
| Stevenson-Carson | Wind River Education Center    | SSSP2 | C |
| Sunnyside        | Outlook Elementary School      | SSSP1 | D |
| Tacoma           | Fern Hill Elementary School    | SSSP1 | C |
| Tacoma           | Oakland High School            | SSSP1 | C |
| Tacoma           | DeLong Elementary School       | SSSP2 | C |
| Tacoma           | Edison Elementary School       | SSSP2 | C |
| Tacoma           | Foss High School               | SSSP2 | C |
| Tacoma           | Franklin Elementary School     | SSSP2 | C |
| Tacoma           | Larchmont Elementary School    | SSSP2 | C |
| Tacoma           | Lister Elementary School       | SSSP2 | C |
| Tacoma           | Manitou Park Elementary School | SSSP2 | C |
| Tacoma           | Mann Elementary School         | SSSP2 | C |

|          |  |       |   |
|----------|--|-------|---|
| Tacoma   | Northeast Tacoma Elementary School             | SSSP2 | C |
| Tacoma   | Point Defiance Elementary School               | SSSP2 | C |
| Tacoma   | Reed Elementary School                         | SSSP2 | C |
| Tacoma   | Roosevelt Elementary School                    | SSSP2 | C |
| Tacoma   | Sheridan Elementary School                     | SSSP2 | C |
| Tacoma   | Stanley Elementary School                      | SSSP2 | C |
| Tacoma   | Tacoma School of the Arts-Pacific              | SSSP2 | C |
| Tacoma   | Willie Stewart Academy                         | SSSP2 | C |
| Taholah  | Taholah School                                 | SSSP1 | D |
| Thorp    | Thorp Elementary and Junior Senior High School | SSSP1 | C |
| Toledo   | Toledo Elementary School                       | SSSP2 | D |
| Toledo   | Toledo Middle School                           | SSSP2 | C |
| Tonasket | Tonasket Elementary School                     | SSSP1 | D |

|                      |   |       |   |
|----------------------|---|-------|---|
| Tonasket             | Tonasket Middle-High School                             | SSSP1 | D |
| Touchet              | Touchet Elementary and High School                      | SSSP1 | C |
| Tumwater             | Black Lake Elementary School                            | SSSP1 | C |
| University Place     | Curtis Senior High School                               | SSSP2 | D |
| University Place     | Sunset Primary School                                   | SSSP2 | C |
| Vashon Island        | Vashon Island High School                               | SSSP1 | C |
| Wahkiakum            | Julius A. Wendt Elementary/John C. Thomas Middle School | SSSP2 | C |
| Warden               | Warden K-12   | SSSP1 | C |
| Washougal            | Hathaway Elementary School                              | SSSP1 | C |
| Washtucna            | Washtucna Elementary High School                        | SSSP1 | C |
| West Valley (Yakima) | West Valley Junior High School                          | SSSP2 | C |
| White Pass           | White Pass Elementary School                            | SSSP1 | D |
| White Pass           | White Pass Junior Senior High School                    | SSSP1 | D |

|                     |                                    |       |   |
|---------------------|------------------------------------|-------|---|
| White River         | Mountain Meadow Elementary School  | SSSP2 | C |
| White Salmon Valley | Columbia High School               | SSSP1 | C |
| White Salmon Valley | Hulan L. Whitson Elementary School | SSSP1 | C |
| White Salmon Valley | Wayne M. Henkle Middle School      | SSSP1 | C |
| Willapa Valley      | Willapa Elementary School          | SSSP2 | D |
| Wilson Creek        | Wilson Creek K-12                  | SSSP1 | C |
| Woodland            | Woodland Middle School (old HS)    | SSSP2 | E |
| Woodland            | Woodland Primary School            | SSSP2 | E |
| Yakima              | Adams Elementary School            | SSSP2 | C |
| Yakima              | Hoover Elementary School           | SSSP2 | C |
| Yakima              | Nob Hill Elementary School         | SSSP2 | C |
| Yakima              | Robertson Elementary School        | SSSP2 | C |
| Yakima              | Wilson Middle School               | SSSP2 | C |

## Appendix B: Engineering School Seismic Assessment Reports

All of the data generated from the engineering assessments as part of Phase 2 have been bundled into four volumes. Download these volumes by clicking the blue links below. A link to our website is also provided below. There you can access all downloadable material for both Phase 1 and Phase 2.

- **Volume 1: Seismic Assessment Report**—This volume provides an overview of the engineering seismic assessments, which is useful for understanding the process and all of the information included in the school reports.

[https://fortress.wa.gov/dnr/geologydata/school\\_seismic\\_safety/phase2/SSSP\\_2021\\_Engineering\\_Vol1\\_Seismic\\_Assessment\\_Report.pdf](https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol1_Seismic_Assessment_Report.pdf)

- **Volume 2: EPAT & FEMA 154 RVS Summaries**—This volume presents the results of the EPAT worksheets and Rapid Visual Screenings.

[https://fortress.wa.gov/dnr/geologydata/school\\_seismic\\_safety/phase2/SSSP\\_2021\\_Engineering\\_Vol2\\_EPAT\\_RVS\\_Forms.pdf](https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol2_EPAT_RVS_Forms.pdf)

- **Volume 3: ASCE 41-17 Screening Reports**—This volume presents the results of the ASCE 41-17 assessments at 339 school buildings.

[https://fortress.wa.gov/dnr/geologydata/school\\_seismic\\_safety/phase2/SSSP\\_2021\\_Engineering\\_Vol3\\_ASCE41\\_Screening\\_Reports.pdf](https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol3_ASCE41_Screening_Reports.pdf)

- **Volume 4: Seismic Upgrades Concept Design Reports, 17 School Buildings**—This volume presents the results of the concept-level seismic upgrade designs conducted for 17 school buildings. These reports provide information on the designs, costs, and suggested upgrades that were included in the concept design reports.

[https://fortress.wa.gov/dnr/geologydata/school\\_seismic\\_safety/phase2/SSSP\\_2021\\_Engineering\\_Vol4\\_Concept\\_Level\\_Design\\_Reports\\_17\\_Schools.pdf](https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol4_Concept_Level_Design_Reports_17_Schools.pdf)

- **Washington Geological Survey School Seismic Safety Project website**—Contains overview information about this project and a map where you can download the seismic screening reports for each school district.

<https://www.dnr.wa.gov/school-seismic-safety>

## Appendix C: Prioritized Rankings of Phase 1 and 2 School Buildings

Phase 1 and 2 school buildings were ranked to prioritize buildings for seismic retrofit by relative risk. Engineering judgment was used to assign buildings to one of four categories: Very High Priority, High Priority, Moderate Priority and Lower Priority (Appendix Tables C1–C4). The prioritization of schools was done by comparing buildings to one another by selected parameters using engineering judgment. The parameters used for comparison include: building construction date, construction type, level of site seismicity, extents of previous seismic upgrade work (if any), soil liquefaction potential, SEAONC EPRS structural star rating, EPAT expected building damage, FEMA 154 RVS score, and an ASCE 41 Tier 1 checklist percent of “noncompliant” or “unknown”. A small adjustment was made for buildings of larger square footage to slightly prioritize larger buildings over smaller ones with the idea that more people may be at risk in buildings of larger area. Finally, the engineers who evaluated each building also used their judgment to adjust the building category if they felt the scoring system did not accurately capture the building risk. Within each priority grouping the buildings are listed in alphabetical order by district. The buildings in each group are considered equally at risk.

**Table C1.** List of schools labeled as very high priority for seismic retrofits, organized in alphabetic order. Dark purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 2, light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

| VERY HIGH PRIORITY SCHOOL BUILDINGS |                                       |                         |       |
|-------------------------------------|---------------------------------------|-------------------------|-------|
| District Name                       | Facility Name                         | Building Name           | ICOS# |
| Aberdeen                            | Hopkins Building (Harbor High School) | Hopkins Building        | 57394 |
| Aberdeen                            | J. M. Weatherwax High School          | 1964 Gymnasium Building | 57378 |
| Aberdeen                            | McDermoth Elementary School           | Main Building           | 57397 |

|                   |  |                             |       |
|-------------------|--|-----------------------------|-------|
| Anacortes         | Mount Erie Elementary School           | 1955 Original Main Building | 54084 |
| Boistfort         | Boistfort Elementary                   | Gymnasium Building          | 57720 |
| Boistfort         | Boistfort Elementary                   | Main Building               | 57717 |
| Burlington-Edison | Burlington-Edison High School          | Art/Tiger TUB Building      | 50119 |
| Burlington-Edison | Burlington-Edison High School          | Cafeteria and 400 Wing      | 50117 |
| Burlington-Edison | Burlington-Edison High School          | CTE                         | 50110 |
| Burlington-Edison | Burlington-Edison High School          | Fieldhouse 1953 and 1975    | 50109 |
| Burlington-Edison | West View Elementary School            | Main Building               | 50095 |
| Cape Flattery     | Clallam Bay High and Elementary School | High School Building        | 57823 |
| Cape Flattery     | Neah Bay Elementary School             | Elementary School           | 57829 |
| Cape Flattery     | Neah Bay Junior/ Senior High School    | Neah Bay High School Gym    | 57832 |
| Carbonado         | Carbonado Historical School 19         | A - Main Building           | 57837 |



|  |                |                                    |                                  |       |
|--|----------------|------------------------------------|----------------------------------|-------|
|  | Centerville    | Centerville Elementary School      | Main Building                    | 51688 |
|  | Centralia      | Washington Elementary School       | Main Building                    | 57962 |
|  | Clover Park    | Tillicum Elementary School         | Classroom Building - TL1         | 50186 |
|  | Evaline        | Evaline Elementary School          | Main Building                    | 58128 |
|  | Ferndale       | Beach Elementary                   | Main Building                    | 55002 |
|  | Ferndale       | Custer Elementary                  | Main Building                    | 54976 |
|  | Green Mountain | Green Mountain School              | Main Building                    | 58305 |
|  | Highline       | Southern Heights Elementary School | Building C - Admin/Multi Purpose | 55188 |
|  | Hoquiam        | Central Elementary School          | Main Building                    | 58356 |
|  | Hoquiam        | Emerson Elementary School          | Main Building                    | 58357 |
|  | Hoquiam        | Hoquiam High School                | A-Administration                 | 58350 |
|  | Hoquiam        | Hoquiam High School                | B-Science                        | 58341 |

|            |                                       |                               |       |
|------------|---------------------------------------|-------------------------------|-------|
| Hoquiam    | Hoquiam High School                   | H-Gymnasium                   | 58342 |
| Index      | Index Elementary School               | Main Building                 | 55232 |
| Kelso      | Carrolls Elementary School            | Main Building                 | 58401 |
| Kelso      | Rose Valley Elementary School         | Main Building                 | 58396 |
| La Conner  | La Conner High School                 | High School Auditorium        | 55667 |
| La Conner  | La Conner Middle School (form. Elem.) | Old Auditorium/Cafeteria Bldg | 55672 |
| Longview   | R. A. Long High School                | Gym                           | 58425 |
| Longview   | R. A. Long High School                | Main Building                 | 58427 |
| Longview   | R. A. Long High School                | Shop Bldg                     | 58428 |
| Marysville | Marysville Pilchuck Sr High School    | Auditorium - Bldg K           | 56248 |
| Marysville | Marysville Pilchuck Sr High School    | Library - Bldg J              | 56244 |
| Marysville | Marysville Pilchuck Sr High School    | Pool Building - Bldg L        | 56233 |

|              |                                 |                        |       |
|--------------|---------------------------------|------------------------|-------|
| Marysville   | Totem Middle School             | Cafeteria Gym Building | 56224 |
| Morton       | Morton Elementary School        | Main Building          | 58501 |
| Mount Baker  | Acme Elementary School          | Main Building          | 56410 |
| Mount Baker  | Mount Baker Senior High School  | Field House            | 56426 |
| Mount Vernon | Lincoln Elementary School       | Main Building          | 50960 |
| North Beach  | Pacific Beach Elementary School | Gym/Lunchroom          | 58523 |
| Ocean Beach  | Ilwaco (Hilltop) Middle School  | Auditorium             | 58642 |
| Ocean Beach  | Ilwaco (Hilltop) Middle School  | Main Building          | 58643 |
| Palisades    | Palisades Elementary School     | Main Building          | 52634 |
| Pe Ell       | Pe Ell School                   | Main Building          | 51321 |
| Peninsula    | Peninsula High School           | Main Building (100     | 58796 |
| Puyallup     | Puyallup High School            | Main Building          | 58962 |

|                   |                                     |                                      |       |
|-------------------|-------------------------------------|--------------------------------------|-------|
| Puyallup          | Spinning Elementary School          | Main Building                        | 59065 |
| Quilcene          | Quilcene High And Elementary School | Elementary                           | 59185 |
| Quilcene          | Quilcene High And Elementary School | High School                          | 59184 |
| Quillayute Valley | Forks Intermediate School           | Main Building - 1952 Portion         | 59203 |
| Quillayute Valley | Forks Jr-Sr High School             | Main Jr High Building - 1949 Portion | 59193 |
| Raymond           | Raymond Junior Senior High School   | Main Building                        | 59223 |
| Renton            | Hazen Senior High School            | Bldg 1 Main Building                 | 56888 |
| Renton            | Hazen Senior High School            | Bldg 1 Music                         | 56888 |
| Renton            | Lindbergh Senior High School        | Main Building - North                | 56945 |
| Renton            | Lindbergh Senior High School        | Main Building - South                | 56945 |
| Skykomish         | Skykomish School                    | Main Building                        | 57083 |
| Snohomish         | Cathcart Elementary School          | 100 Building                         | 57090 |

|  |                 |  |                                      |       |
|--|-----------------|--|--------------------------------------|-------|
|  | Snohomish       | Central Elementary School                      | Main Building - Gym                  | 57085 |
|  | Snohomish       | Central Elementary School                      | Main Building                        | 57085 |
|  | South Bend      | South Bend Jr/Sr High School                   | Koplitz Field House                  | 51399 |
|  | South Bend      | South Bend Jr/Sr High School                   | Vocational Building                  | 51398 |
|  | Stanwood-Camano | Stanwood Middle School                         | Main Building (Bldg 1) Units E and F | 51448 |
|  | Tacoma          | Fern Hill Elementary School                    | Main Building                        | 59748 |
|  | Tacoma          | Foss High School                               | Gym-Pool-Cafeteria                   | 59802 |
|  | Tacoma          | Foss High School                               | Main Building - South                | 59802 |
|  | Tacoma          | Oakland High School                            | Main Building                        | 59698 |
|  | Tacoma          | Tacoma School of the Arts-Pacific              | SOTA Pacific Ave                     | 59768 |
|  | Tacoma          | Willie Stewart Academy                         | Main Bldg                            | 59727 |
|  | Thorp           | Thorp Elementary and Junior Senior High School | Brick Building                       | 53670 |

|  |                     |                                    |                                   |       |
|--|---------------------|------------------------------------|-----------------------------------|-------|
|  | Vashon Island       | Vashon Island High School          | Building D - Gymnasium            | 57368 |
|  | White Salmon Valley | Hulan L. Whitson Elementary School | Main Building                     | 51619 |
|  | Woodland            | Woodland Middle School             | Gymnasium Building                | 60193 |
|  | Woodland            | Woodland Middle School             | Main Building                     | 60193 |
|  | Woodland            | Woodland Middle School             | Performing Arts                   | 60193 |
|  | Woodland            | Woodland Middle School             | Shared High School /Middle School | 60192 |
|  | Woodland            | Woodland Middle School             | Vocational Building               | 60193 |

**Table C2.** List of schools labeled as high priority for seismic retrofits, organized in alphabetic order. Dark purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 2, light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

| HIGH PRIORITY SCHOOL BUILDINGS |                             |                          |       |
|--------------------------------|-----------------------------|--------------------------|-------|
| District Name                  | Facility Name               | Building Name            | ICOS# |
| Bainbridge Island              | Bainbridge High School      | 500 Building             | 57410 |
| Bainbridge Island              | Commodore Options School    | Commodore Options School | 57422 |
| Bainbridge Island              | Ordway Elementary School    | Education Pod            | 57416 |
| Bainbridge Island              | Ordway Elementary School    | K-4 Building             | 57416 |
| Bainbridge Island              | Ordway Elementary School    | Main Building            | 57416 |
| Battle Ground                  | Praire High School          | 500 Building             | 50021 |
| Battle Ground                  | Praire High School          | 600 Building             | 50024 |
| Bellingham                     | Roosevelt Elementary School | Main Building            | 54493 |
| Bellingham                     | Whatcom Middle School       | Industrial Arts Building | 54467 |

|                   |  |   |       |
|-------------------|--|---|-------|
| Brinnon           | Brinnon Elementary School              | Main Building                           | 57777 |
| Burlington-Edison | Burlington-Edison High School          | 500 Wing                                | 50112 |
| Burlington-Edison | Burlington-Edison High School          | Admin/Classroom Building                | 50118 |
| Camas             | Lacamas Heights Elementary School      | 100 Pod                                 | 57802 |
| Camas             | Lacamas Heights Elementary School      | Multipurpose                            | 57803 |
| Camas             | Liberty Middle School                  | Main Building                           | 57790 |
| Camas             | Liberty Middle School                  | Music Building                          | 57791 |
| Cape Flattery     | Clallam Bay High and Elementary School | Big Gym                                 | 57827 |
| Cape Flattery     | Clallam Bay High and Elementary School | Elementary Building                     | 57824 |
| Cape Flattery     | Clallam Bay High and Elementary School | Elementary Gym                          | 57822 |
| Cape Flattery     | Clallam Bay High and Elementary School | Shop and Art Building                   | 57825 |
| Cape Flattery     | Neah Bay Jr/ Sr High School            | Neah Bay High School Classroom Building | 57833 |



|                |                                |                                    |       |
|----------------|--------------------------------|------------------------------------|-------|
| Cape Flattery  | Neah Bay Jr/ Sr High School    | Neah Bay High School Shop Building | 57835 |
| Carbonado      | Carbonado Historical School 19 | B - Community Gym                  | 57838 |
| Cascade        | Beaver Valley School           | Old Winton School House            | 51677 |
| Central Kitsap | Cottonwood Elementary School   | Gym                                | 57901 |
| Centralia      | Centralia Middle School        | Classroom Wings                    | 57953 |
| Centralia      | Centralia Middle School        | Gym Wing                           | 57953 |
| Centralia      | Centralia Middle School        | Main Building                      | 57953 |
| Centralia      | Edison Elementary School       | Main Building                      | 57958 |
| Centralia      | Oakview Elementary School      | Main Building                      | 57970 |
| Chimacum       | Chimacum Middle School         | Middle School Bldg 100 B           | 58032 |
| Clover Park    | Custer Elementary School       | Second Classroom Building          | 50240 |
| Clover Park    | Oakbrook Elementary School     | First Classroom Building           | 50244 |

|  |             |                               |                        |       |
|--|-------------|-------------------------------|------------------------|-------|
|  | Clover Park | Oakbrook Elementary School    | Gym / MPR              | 50245 |
|  | Concrete    | Concrete High School          | Main Building          | 54519 |
|  | Concrete    | Concrete High School          | Tech Building          | 54518 |
|  | Cosmopolis  | Cosmopolis Elementary School  | Auditorium Building    | 58041 |
|  | Cosmopolis  | Cosmopolis Elementary School  | Main Building          | 58038 |
|  | Cosmopolis  | Cosmopolis Elementary School  | Multipurpose Building  | 58037 |
|  | Coupeville  | Coupeville Elementary School  | Cedar Pod              | 54538 |
|  | Darrington  | Darrington Senior High School | Darrington High School | 54547 |
|  | Darrington  | Darrington Senior High School | Woodshop               | 54546 |
|  | Dayton      | Dayton High School            | Ag Shop                | 51839 |
|  | Dayton      | Dayton High School            | High School Building   | 51838 |
|  | Dayton      | Dayton High School            | Wood Shop              | 51840 |
|  | Dixie       | Dixie Elementary School       | Main Building          | 51843 |

|                         |                                      |   |       |
|-------------------------|--------------------------------------|---|-------|
| East Valley<br>(Yakima) | East Valley Central<br>Middle School | Gymnasium Building                        | 50350 |
| Ephrata                 | Ephrata High School                  | 1937 Annex (Former Beezley<br>Springs ES) | 51934 |
| Ephrata                 | Ephrata High School                  | Performing Arts Center PAC                | 51932 |
| Ephrata                 | Grant Elementary School              | Main Building                             | 51927 |
| Everett                 | Jackson Elementary<br>School         | Main Building                             | 54780 |
| Everett                 | Madison Elementary<br>School         | Main Building                             | 54831 |
| Federal Way             | Camelot Elementary<br>School         | Main Building                             | 50675 |
| Federal Way             | Kilo Middle School                   | Building E Little Theater                 | 50809 |
| Federal Way             | Kilo Middle School                   | Building G                                | 50805 |
| Federal Way             | Sacajawea Middle School              | 100 Building                              | 50706 |
| Federal Way             | Sacajawea Middle School              | 300 Building/Cafeteria                    | 50704 |
| Federal Way             | Sacajawea Middle School              | 400 Building                              | 50702 |

|                |  |                           |       |
|----------------|--|---------------------------|-------|
| Federal Way    | Sacajawea Middle School                | 600/700/800 Building      | 50703 |
| Federal Way    | Sacajawea Middle School                | 900 Building              | 50699 |
| Federal Way    | Sacajawea Middle School                | Gym (500) Building        | 50705 |
| Federal Way    | Sacajawea Middle School                | Main Office Building      | 50700 |
| Ferndale       | Central Elementary School              | Main Building             | 54971 |
| Fife           | Fife High School                       | Building IV 400 Library   | 58147 |
| Fife           | Fife High School                       | Building V 500 Main       | 58144 |
| Fife           | Fife High School                       | Building VIII 800 Shop    | 58145 |
| Granite Falls  | Crossroads High School (form. MS)      | Main Building             | 55015 |
| Granite Falls  | Granite Falls Middle School (form. HS) | Main Building - Gym       | 55028 |
| Granite Falls  | Granite Falls Middle School (form. HS) | Main Building (Excl. Gym) | 55028 |
| Green Mountain | Green Mountain School                  | Gymnasium                 | 58303 |
| Harrington     | Harrington Elementary & High School    | Main Building             | 52039 |

|          |   |                          |       |
|----------|---|--------------------------|-------|
| Highline | Beverly Park @ Glendale Elementary School | Main Building A          | 55096 |
| Highline | Beverly Park @ Glendale Elementary School | Multi-Purpose Building B | 55097 |
| Highline | Chinook Middle School                     | 100 Building             | 55065 |
| Highline | Chinook Middle School                     | 200 Building             | 55067 |
| Highline | Chinook Middle School                     | 300 Building - Gymnasium | 55063 |
| Highline | Chinook Middle School                     | 400 Building - Cafeteria | 55066 |
| Highline | Chinook Middle School                     | 800 Building             | 55064 |
| Highline | Hilltop Elementary School                 | 100 Building - Bldg A    | 55177 |
| Highline | Hilltop Elementary School                 | 200 Building - Bldg B    | 55176 |
| Highline | Hilltop Elementary School                 | 300 Building - Bldg C    | 55178 |
| Highline | Sylvester Middle School                   | 100 Building             | 55128 |
| Highline | Sylvester Middle School                   | 200 Building             | 55131 |

|           |   |                                       |       |
|-----------|---|---------------------------------------|-------|
| Highline  | Sylvester Middle School                       | 300 Building -<br>Gymnasium/Cafeteria | 55134 |
| Highline  | Sylvester Middle School                       | 400 Building                          | 55130 |
| Highline  | Sylvester Middle School                       | 500 Building - Library                | 55133 |
| Highline  | Sylvester Middle School                       | 600 Building                          | 55129 |
| Highline  | Sylvester Middle School                       | 700 Building - Band/Drama             | 55132 |
| Highline  | Woodside Site                                 | Annex                                 | 55073 |
| Highline  | Woodside Site                                 | Main Building                         | 55072 |
| Hockinson | Hockinson Heights<br>Elementary School (East) | Building 800 H                        | 58325 |
| Hoquiam   | Hoquiam High School                           | D-Business Education                  | 58347 |
| Hoquiam   | Hoquiam High School                           | E-Library                             | 58344 |
| Hoquiam   | Hoquiam High School                           | F-Humanities                          | 58345 |
| Hoquiam   | Hoquiam High School                           | G-Little Theater                      | 58346 |
| Hoquiam   | Lincoln Elementary<br>School                  | East Wing                             | 58355 |

|  |                 |                                       |                                 |       |
|--|-----------------|---------------------------------------|---------------------------------|-------|
|  | Hoquiam         | Lincoln Elementary School             | Multipurpose Building           | 58354 |
|  | Hoquiam         | Lincoln Elementary School             | West Wing                       | 58353 |
|  | Kelso           | Coweeman Middle School                | Main Building                   | 58393 |
|  | La Center       | La Center Elementary & Middle Schools | Building 300 - ES Main Building | 50901 |
|  | Lake Washington | Rockwell Elementary School            | Main Building                   | 55771 |
|  | Longview        | Mint Valley Elementary School         | Building A - 1                  | 58459 |
|  | Longview        | Mint Valley Elementary School         | Building B - 2                  | 58458 |
|  | Longview        | Mint Valley Elementary School         | Building D - 4                  | 58461 |
|  | Longview        | Northlake Elementary School           | Main Building                   | 58447 |
|  | Longview        | Olympic Elementary School             | Annex Building                  | 58438 |
|  | Longview        | Olympic Elementary School             | Main Building                   | 58436 |
|  | Longview        | Olympic Elementary School             | Multipurpose Building           | 58437 |

|               |                           |                              |       |
|---------------|---------------------------|------------------------------|-------|
| Longview      | R. A. Long High School    | RA Long Annex                | 58426 |
| Longview      | R. A. Long High School    | Science Wing                 | 58424 |
| Lopez Island  | Lopez Middle High School  | Junior Senior High Building  | 56068 |
| Mabton        | Mabton Jr/Sr High School  | Main Building                | 52288 |
| Mabton        | Mabton Jr/Sr High School  | Shop/Ag Building             | 52289 |
| Mary M Knight | Mary M. Knight School     | Elementary School            | 50921 |
| Marysville    | Cascade Elementary School | Unit A                       | 56103 |
| Marysville    | Cascade Elementary School | Unit B                       | 56101 |
| Marysville    | Cascade Elementary School | Unit C                       | 56104 |
| Marysville    | Cascade Elementary School | Unit D                       | 56102 |
| Marysville    | Liberty Elementary School | Main Building                | 56194 |
| Marysville    | Marysville Middle School  | Building C - Shop Classrooms | 56213 |



|            |                                    |  |       |
|------------|------------------------------------|--|-------|
| Marysville | Marysville Middle School           | Main Building                            | 56214 |
| Marysville | Marysville Pilchuck Sr High School | Arts and Crafts Building - Bldg B        | 56254 |
| Marysville | Marysville Pilchuck Sr High School | Business Ed and Home Learning - Bldg C   | 56242 |
| Marysville | Marysville Pilchuck Sr High School | East Building - Bldg H                   | 56240 |
| Marysville | Marysville Pilchuck Sr High School | Gym & New Food Commons - Bldg M          | 56246 |
| Marysville | Marysville Pilchuck Sr High School | Life Science Building - Bldg F           | 56253 |
| Marysville | Marysville Pilchuck Sr High School | Mech Plant and Former Cafeteria - Bldg E | 56235 |
| Marysville | Marysville Pilchuck Sr High School | Occupational Center - Bldg A             | 56245 |
| Marysville | Pinewood Elementary School         | Bldg E                                   | 56134 |
| Marysville | Pinewood Elementary School         | Bldg L (Library)                         | 56141 |
| Marysville | Pinewood Elementary School         | Bldg M (Gym)                             | 56139 |

|               |                                  |                         |       |
|---------------|----------------------------------|-------------------------|-------|
| Marysville    | Pinewood Elementary School       | Building A              | 56135 |
| Marysville    | Pinewood Elementary School       | Building D              | 56142 |
| Marysville    | Shoultes Elementary School       | B Building              | 56264 |
| Marysville    | Shoultes Elementary School       | Gym Building A          | 56266 |
| Marysville    | Shoultes Elementary School       | D Building              | 56265 |
| Marysville    | Shoultes Elementary School       | C Building              | 56267 |
| Marysville    | Totem Middle School              | Home Economics Building | 56232 |
| Marysville    | Totem Middle School              | Main Building           | 56231 |
| Marysville    | Totem Middle School              | School House Cafe       | 56227 |
| Marysville    | Totem Middle School              | Science Building        | 56226 |
| Methow Valley | Methow Valley Elementary School  | Main Building           | 52355 |
| Morton        | Morton Junior Senior High School | Gymnasium               | 58506 |
| Morton        | Morton Junior Senior High School | Main Building           | 58505 |

|                            |                                       |                               |       |
|----------------------------|---------------------------------------|-------------------------------|-------|
| Morton                     | Morton Junior Senior High School      | Shop                          | 58507 |
| Napavine                   | Napavine Elementary School            | Main Building                 | 58512 |
| Napavine                   | Napavine Junior Senior High School    | Annex                         | 58513 |
| Napavine                   | Napavine Junior Senior High School    | Main                          | 58514 |
| Naselle-Grays River Valley | Naselle K-12 School                   | Administration/Misc. Building | 51032 |
| Naselle-Grays River Valley | Naselle K-12 School                   | Elementary                    | 51032 |
| North Beach                | North Beach Junior/Senior High School | Main Building                 | 58529 |
| North Beach                | Pacific Beach Elementary School       | Main Building                 | 58524 |
| North Beach                | Pacific Beach Elementary School       | Quad Building                 | 58525 |
| North Mason                | Belfair Elementary School             | Gymnasium Building            | 58613 |
| North Mason                | Belfair Elementary School             | Main Building                 | 58614 |
| North River                | North River School                    | Elementary                    | 58630 |

|             |                                   |                                 |       |
|-------------|-----------------------------------|---------------------------------|-------|
| North River | North River School                | Gym Home Ec-Cafeteria           | 58634 |
| North River | North River School                | High School & Admin Building    | 58631 |
| North River | North River School                | Talley Building (Music/Art)     | 58636 |
| Northshore  | Canyon Creek Elementary School    | Building A - Classroom/Library  | 56750 |
| Northshore  | Canyon Creek Elementary School    | Building C - Cafeteria/Gym      | 56753 |
| Northshore  | Crystal Springs Elementary School | Building 1 - Admin              | 56775 |
| Northshore  | Crystal Springs Elementary School | Building 2 - Classrooms/Kitchen | 56774 |
| Northshore  | Crystal Springs Elementary School | Building 3/4 - Classrooms       | 56772 |
| Northshore  | Crystal Springs Elementary School | Building 5 - Classrooms         | 56770 |
| Northshore  | Shelton View Elementary School    | Building A1/10 - Classroom      | 56732 |
| Northshore  | Shelton View Elementary School    | Building C - Gym                | 56727 |
| Oak Harbor  | Clover Valley School              | Main Building                   | 51299 |

|  |             |                              |                    |       |
|--|-------------|------------------------------|--------------------|-------|
|  | Oak Harbor  | Oak Harbor Middle School     | Band Building      | 51291 |
|  | Oak Harbor  | Oak Harbor Middle School     | C Wing - Cafeteria | 51290 |
|  | Oak Harbor  | Oak Harbor Middle School     | D Wing             | 51294 |
|  | Ocean Beach | Ilwaco High School           | Ilwaco High School | 58649 |
|  | Ocean Beach | Ilwaco High School           | Stadium Complex    | 58650 |
|  | Ocean Beach | Long Beach Elementary School | Main Building      | 58645 |
|  | Orting      | Orting Primary School        | Main Building      | 58761 |
|  | Palisades   | Palisades Elementary School  | Grange Hall        | 52635 |
|  | Pateros     | Pateros K-12 School          | Main Building      | 52831 |
|  | Pateros     | Pateros K-12 School          | Metal Shop         | 52830 |
|  | Pateros     | Pateros K-12 School          | Music Building     | 52832 |
|  | Peninsula   | Discovery Elementary School  | Main Building      | 58839 |
|  | Peninsula   | Gig Harbor High School       | Main Building      | 58821 |

|               |                             |                                |       |
|---------------|-----------------------------|--------------------------------|-------|
| Peninsula     | Gig Harbor High School      | Voc-Ed Building                | 58820 |
| Peninsula     | Peninsula High School       | 500 Building                   | 58793 |
| Peninsula     | Peninsula High School       | 600 Building                   | 58795 |
| Peninsula     | Peninsula High School       | 800 Building - Auditorium Area | 58792 |
| Peninsula     | Peninsula High School       | 900 Building - Pool Building   | 58794 |
| Port Townsend | Port Townsend High School   | Gym                            | 58899 |
| Port Townsend | Port Townsend High School   | Main Building                  | 58898 |
| Port Townsend | Port Townsend High School   | Math Science Annex             | 58900 |
| Port Townsend | Port Townsend High School   | Stuart Building                | 58901 |
| Puyallup      | Maplewood Elementary School | Main Building                  | 59005 |
| Puyallup      | Meeker Elementary School    | Main Building                  | 59062 |
| Puyallup      | Mt View Elementary School   | Multipurpose Building          | 58954 |

|                   |                                     |                                      |       |
|-------------------|-------------------------------------|--------------------------------------|-------|
| Puyallup          | Puyallup High School                | Gymnasium and Swimming Pool Building | 58961 |
| Puyallup          | Puyallup High School                | Library Science Building             | 58959 |
| Puyallup          | Spinning Elementary School          | East                                 | 59065 |
| Puyallup          | Waller Road Elementary School       | Main Building                        | 59011 |
| Quilcene          | Quilcene High And Elementary School | Middle School                        | 59188 |
| Quillayute Valley | Forks Elementary School             | Main Building - 1969 Portion         | 59199 |
| Raymond           | Raymond Elementary School           | Raymond elementary                   | 59222 |
| Renton            | Hazen Senior High School            | 700 Building                         | 56887 |
| Renton            | Hazen Senior High School            | Bldg 1 Gym/Pool                      | 56888 |
| Renton            | Hazen Senior High School            | Gym Addition                         | 56885 |
| Renton            | Lindbergh Senior High School        | Gym Addition                         | 56944 |
| Renton            | Lindbergh Senior High School        | Gymnasium                            | 56944 |

|             |                               |                            |       |
|-------------|-------------------------------|----------------------------|-------|
| Renton      | Renton Senior High School     | Cafeteria/Gym              | 56901 |
| Ridgefield  | South Ridge Elementary School | Main Building              | 59234 |
| Ridgefield  | Union Ridge Elementary School | Main Building              | 59224 |
| Riverside   | Chattaroy Elementary School   | 35 Wing Building           | 53052 |
| Shaw Island | Shaw Island School            | Admin/RR Building          | 57007 |
| Shaw Island | Shaw Island School            | Primary Classroom Building | 57009 |
| Skamania    | Skamania Elementary School    | Main Building              | 59377 |
| Snohomish   | Cathcart Elementary School    | 200 Building               | 57091 |
| Snohomish   | Cathcart Elementary School    | 300 Building               | 57089 |
| Snohomish   | Cathcart Elementary School    | 400 Building               | 57088 |
| Snohomish   | Cathcart Elementary School    | 500 Building               | 57092 |
| Snohomish   | Cathcart Elementary School    | 600 Building               | 57094 |



|  |               |                                 |                            |       |
|--|---------------|---------------------------------|----------------------------|-------|
|  | Snohomish     | Cathcart Elementary School      | 700 Building               | 57093 |
|  | Snohomish     | Emerson Elementary School       | Main Building              | 57132 |
|  | South Bend    | South Bend Jr/Sr High School    | Main Building High School  | 51397 |
|  | South Whidbey | South Whidbey Grades 5 & 6      | A- Classrooms              | 57247 |
|  | South Whidbey | South Whidbey Grades 5 & 6      | C - Classrooms/Admin       | 57245 |
|  | South Whidbey | South Whidbey Grades 5 & 6      | D - WIA Office/Classrooms  | 57249 |
|  | South Whidbey | South Whidbey Grades 5 & 6      | E - Classrooms             | 57250 |
|  | South Whidbey | South Whidbey Grades 5 & 6      | F - Multipurpose           | 57248 |
|  | Spokane       | Adams Elementary School         | Gym and Cafeteria Building | 53538 |
|  | Spokane       | Adams Elementary School         | Main Building              | 53538 |
|  | Spokane       | Bancroft (The Community School) | Main Building              | 53586 |
|  | Spokane       | Bryant Center                   | Main Building              | 53558 |

|                  |                             |                                   |       |
|------------------|-----------------------------|-----------------------------------|-------|
| Spokane          | Havermale (Montessori)      | Main Building 1928 Gym            | 53500 |
| Spokane          | Havermale (Montessori)      | Main Building 1928 and 1940 Areas | 53500 |
| Spokane          | Havermale (Montessori)      | Main Building 1965 Areas          | 53500 |
| Spokane          | Libby Center                | Main Building                     | 53496 |
| Spokane          | Madison Elementary School   | Main Building                     | 53579 |
| Stanwood-Camano  | Stanwood Elementary School  | Main Building Unit C 1981         | 51456 |
| Stanwood-Camano  | Stanwood Middle School      | Building 3 - Music                | 51449 |
| Stanwood-Camano  | Twin City Elementary School | Main Building                     | 51411 |
| Stevenson-Carson | Carson Elementary School    | Main Building                     | 59495 |
| Stevenson-Carson | Stevenson High School       | Main Building                     | 59488 |
| Stevenson-Carson | Stevenson High School       | Vocational Building               | 59491 |
| Stevenson-Carson | Wind River Education Center | Main Building                     | 59499 |

|  |           |                                    |                                  |       |
|--|-----------|------------------------------------|----------------------------------|-------|
|  | Sunnyside | Outlook Elementary School          | Outlook Elementary Main Building | 53661 |
|  | Tacoma    | DeLong Elementary School           | Original Bldg-Bldg A             | 59597 |
|  | Tacoma    | Foss High School                   | Main Building - North            | 59802 |
|  | Tacoma    | Mann Elementary School             | Main Building                    | 59664 |
|  | Tacoma    | Point Defiance Elementary School   | Main Building                    | 59730 |
|  | Tacoma    | Reed Elementary School             | Main Building                    | 59628 |
|  | Tacoma    | Stanley Elementary School          | Gym Bldg                         | 59635 |
|  | Taholah   | Taholah School                     | Main Building                    | 59810 |
|  | Toledo    | Toledo Elementary School           | Main Building                    | 59838 |
|  | Toledo    | Toledo Middle School               | Classroom Bldg. (Bldg #2)        | 59842 |
|  | Toledo    | Toledo Middle School               | Main Building (Bldg. #1)         | 59844 |
|  | Touchet   | Touchet Elementary and High School | Elementary - Main Building       | 53697 |

|                     |                                      |                             |       |
|---------------------|--------------------------------------|-----------------------------|-------|
| Touchet             | Touchet Elementary and High School   | Secondary Facility          | 53695 |
| University Place    | Curtis Senior High School            | 500 Building                | 59969 |
| University Place    | Sunset Primary School                | Main Building               | 59982 |
| Vashon Island       | Vashon Island High School            | Building K - Annex          | 57366 |
| Wahkiakum           | Julius A. Wendt ES/John C. Thomas MS | J A Wendt Elementary School | 53717 |
| Washougal           | Hathaway Elementary School           | Main Building               | 60133 |
| Washtucna           | Washtucna Elementary High School     | Ag Shop/ Music Room         | 53815 |
| Washtucna           | Washtucna Elementary High School     | Main Building               | 53817 |
| White Salmon Valley | Columbia High School                 | C Court - Gym               | 51632 |
| White Salmon Valley | Columbia High School                 | Libray                      | 51631 |
| White Salmon Valley | Columbia High School                 | Metal /Wood Shop            | 51628 |
| White Salmon Valley | Wayne M. Henkle Middle School        | Middle School               | 51638 |

|  |                |                            |                         |       |
|--|----------------|----------------------------|-------------------------|-------|
|  | Willapa Valley | Willapa Elementary School  | Main Building           | 60150 |
|  | Wilson Creek   | Wilson Creek K-12          | Main - Gym & Classrooms | 53893 |
|  | Woodland       | Columbia Elementary School | Main Building           | 60181 |
|  | Yakima         | Adams Elementary School    | 8 Plex Bldg D           | 53950 |
|  | Yakima         | Adams Elementary School    | BLDG C-1                | 53950 |
|  | Yakima         | Adams Elementary School    | Old Gym C               | 53953 |
|  | Yakima         | Hoover Elementary School   | Main Building - Area A  | 54023 |
|  | Yakima         | Hoover Elementary School   | Main Building - Area B  | 54023 |
|  | Yakima         | Nob Hill Elementary School | Main Building           | 53961 |
|  | Yakima         | Wilson Middle School       | Main Building           | 53968 |
|  | Yakima         | Wilson Middle School       | Science Building        | 53969 |

**Table C3.** List of schools labeled as moderate priority for seismic retrofits, organized in alphabetic order. Dark purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 2, light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

| MODERATE PRIORITY SCHOOL BUILDINGS |                                      |                                    |       |
|------------------------------------|--------------------------------------|------------------------------------|-------|
| District Name                      | Facility Name                        | Building Name                      | ICOS# |
| Aberdeen                           | A.J. West Elementary School          | 1952 Building                      | 57384 |
| Aberdeen                           | A.J. West Elementary School          | Annex Building                     | 57385 |
| Aberdeen                           | Central Park Elementary School       | Annex Building                     | 57391 |
| Aberdeen                           | Central Park Elementary School       | Main Building                      | 57392 |
| Bainbridge Island                  | Commodore Options School             | Art and Classrooms                 | 57422 |
| Bethel                             | Rocky Ridge Elementary School        | Main Building                      | 57514 |
| Bickleton                          | Bickleton Elementary and High School | Bldg B - Vocational/Transportation | 51647 |
| Camas                              | Dorothy Fox Elementary School        | Main Building                      | 57808 |
| Camas                              | Skyridge Middle School               | Main Building                      | 57782 |

|                      |                               |                                       |       |
|----------------------|-------------------------------|---------------------------------------|-------|
| Central Kitsap       | Emerald Heights Elementary    | Main                                  | 57877 |
| Chimacum             | Chimacum High School          | High School 100 Bldg A - North Wing   | 58034 |
| Chimacum             | Chimacum High School          | High School 100 Bldg A - South Wing   | 58034 |
| Concrete             | Concrete K-6 School           | Gym                                   | 54520 |
| Concrete             | Concrete K-6 School           | Main Building                         | 54521 |
| Cosmopolis           | Cosmopolis Elementary School  | Gymnasium Building                    | 58040 |
| Coupeville           | Coupeville Elementary School  | Main                                  | 54540 |
| Coupeville           | Coupeville Elementary School  | Multipurpose                          | 54539 |
| Coupeville           | Coupeville High School        | Annex                                 | 54534 |
| Dayton               | Dayton High School            | Gymnasium                             | 51841 |
| Dayton               | Dayton K-8 School             | Elementary and Middle School Building | 51842 |
| East Valley (Yakima) | East Valley Elementary School | Main Building                         | 50345 |
| Ephrata              | Parkway School                | Main Building                         | 51938 |

|                  |                             |                            |       |
|------------------|-----------------------------|----------------------------|-------|
| Federal Way      | Brigadoon Elementary School | Main Office Building - E   | 50844 |
| Federal Way      | Brigadoon Elementary School | Multipurpose Building - C  | 50838 |
| Federal Way      | Kilo Middle School          | Building A Main Office     | 50808 |
| Federal Way      | Kilo Middle School          | Building B                 | 50803 |
| Federal Way      | Kilo Middle School          | Building C                 | 50806 |
| Federal Way      | Kilo Middle School          | Building F1-F4 and Library | 50811 |
| Federal Way      | Kilo Middle School          | Building F5-F8             | 50807 |
| Federal Way      | Kilo Middle School          | Building H Gymnasium       | 50810 |
| Federal Way      | Kilo Middle School          | Building I Cafeteria       | 50802 |
| Federal Way      | Kilo Middle School          | Building J                 | 50812 |
| Fife             | Fife High School            | Building IX 900 Science    | 58141 |
| Fife             | Fife High School            | Building VI 600 Gyms       | 58143 |
| Glenwood         | Glenwood School             | Main Building              | 51977 |
| Grand Coulee Dam | Lake Roosevelt K-12         | CTE Building               | 51986 |
| Grand Coulee Dam | Lake Roosevelt K-12         | Wood Shop                  | 51988 |



|  |               |  |                        |       |
|--|---------------|--|------------------------|-------|
|  | Granite Falls | Granite Falls Middle School (form. HS)     | Multi-Purpose Building | 55030 |
|  | Granite Falls | Mountain Way Elementary School             | Main Building          | 55012 |
|  | Highline      | Southern Heights Elementary School         | Building A             | 55185 |
|  | Highline      | Southern Heights Elementary School         | Building B             | 55186 |
|  | Hockinson     | Hockinson Heights Elementary School (East) | Building 100 A         | 58331 |
|  | Hockinson     | Hockinson Heights Elementary School (East) | Building 200 C         | 58332 |
|  | Hockinson     | Hockinson Heights Elementary School (East) | Building 300 D         | 58328 |
|  | Hockinson     | Hockinson Heights Elementary School (East) | Building 400 B         | 58326 |
|  | Hockinson     | Hockinson Heights Elementary School (East) | Building 500 E         | 58327 |
|  | Hockinson     | Hockinson Heights Elementary School (East) | Building 600 F         | 58329 |

|  |                 |                                |                                     |       |
|--|-----------------|--------------------------------|-------------------------------------|-------|
|  | Hoquiam         | Lincoln Elementary School      | Administrative and Library Building | 58352 |
|  | La Conner       | La Conner High School          | High School Main Building           | 55668 |
|  | Lake Washington | Einstein Elementary School     | Main Building                       | 55836 |
|  | Longview        | Robert Gray Elementary School  | Main Building                       | 58432 |
|  | Lopez Island    | Lopez Elementary School        | Elementary                          | 56065 |
|  | Lopez Island    | Lopez Middle High School       | Gym/Tech Building                   | 56067 |
|  | Marysville      | Marysville Middle School       | Building B                          | 56212 |
|  | Mount Baker     | Mount Baker Senior High School | 800 Building (Former Deming Elem.)  | 56430 |
|  | Naches Valley   | Naches Valley High School      | Gym Building                        | 52476 |
|  | Naches Valley   | Naches Valley High School      | Main Building                       | 52476 |
|  | Naches Valley   | Naches Valley High School      | Vocational Building                 | 52475 |
|  | Oak Harbor      | Oak Harbor Middle School       | C Wing                              | 51290 |

|              |                                  |                       |       |
|--------------|----------------------------------|-----------------------|-------|
| Oak Harbor   | Oak Harbor Middle School         | Gym                   | 51293 |
| Oak Harbor   | Oak Harbor Middle School         | Main Building A       | 51289 |
| Ocean Beach  | Kaino Gym                        | Kaino Gym             | 58644 |
| Ocosta       | Ocosta Junior Senior High School | Junior Senior High    | 58651 |
| Oroville     | Oroville Elementary School       | Main Building         | 52577 |
| Paterson     | Paterson Elementary School       | Main Building         | 52838 |
| Pe Ell       | Pe Ell School                    | Fitness Center        | 51320 |
| Peninsula    | Peninsula High School            | 700 Building - Voc Ag | 58791 |
| Port Angeles | Roosevelt Elementary School      | Main Building         | 58869 |
| Puyallup     | Mt View Elementary School        | Main Building         | 58954 |
| Puyallup     | Wildwood Elementary              | Main Building         | 58921 |
| Snohomish    | Emerson Elementary School        | Annex                 | 57133 |

|                      |                                    |                                   |       |
|----------------------|------------------------------------|-----------------------------------|-------|
| Stanwood-Camano      | Stanwood Elementary School         | Main Building Unit C 1966         | 51456 |
| Stanwood-Camano      | Stanwood Elementary School         | Main Building Units A             | 51456 |
| Stanwood-Camano      | Stanwood Middle School             | Main Building (Building 1) Unit D | 51448 |
| Stanwood-Camano      | Stanwood Middle School             | Main Building (Building 1) Unit G | 51448 |
| Tacoma               | DeLong Elementary School           | First Bldg-Bldg B                 | 59598 |
| Tacoma               | Franklin Elementary School         | Main Building                     | 59589 |
| Tacoma               | Larchmont Elementary School        | Original Building                 | 59804 |
| Tacoma               | Lister Elementary School           | Main Building                     | 59790 |
| Tacoma               | Roosevelt Elementary School        | Main Bldg                         | 59688 |
| Taholah              | Taholah School                     | Covered Court                     | 59808 |
| Touchet              | Touchet Elementary and High School | CTE Building                      | 53696 |
| West Valley (Yakima) | West Valley Junior High School     | WVJH (Gym Building)               | 51547 |

|                         |                                   |                         |       |
|-------------------------|-----------------------------------|-------------------------|-------|
| West Valley<br>(Yakima) | West Valley Junior<br>High School | WVJH (Main Building)    | 51546 |
| White Pass              | White Pass Elementary<br>School   | Main Building           | 51565 |
| Woodland                | Columbia Elementary<br>School     | 1991 Addition           | 60181 |
| Yakima                  | Hoover Elementary<br>School       | Area D - Annex Building | 54025 |
| Yakima                  | Hoover Elementary<br>School       | Classrooms - Area F     | 54021 |
| Yakima                  | Robertson Elementary<br>School    | 100 Building - Bldg "B" | 53918 |
| Yakima                  | Robertson Elementary<br>School    | 200 Building - Bldg "C" | 53917 |
| Yakima                  | Robertson Elementary<br>School    | 300 Building - Bldg "D" | 53919 |
| Yakima                  | Robertson Elementary<br>School    | 400 Building - Bldg "E" | 53930 |
| Yakima                  | Robertson Elementary<br>School    | 500 Building - Bldg "G" | 53920 |

**Table C4.** List of schools labeled as lower priority for seismic retrofits, organized in alphabetic order. Light purple rows indicate school buildings that received a concept-level upgrade design and cost estimate during Phase 1.

| LOWER PRIORITY SCHOOL BUILDINGS |                              |                        |       |
|---------------------------------|------------------------------|------------------------|-------|
| District Name                   | Facility Name                | Building Name          | ICOS# |
| Aberdeen                        | J. M. Weatherwax High School | Main Building          | 57378 |
| Bainbridge Island               | Bainbridge High School       | 300 Building           | 57407 |
| Bainbridge Island               | Commodore Options School     | Eagle Harbor HS        | 57422 |
| Bainbridge Island               | Woodward Middle School       | 2-Story Classroom Wing | 57424 |
| Bainbridge Island               | Woodward Middle School       | Gym                    | 57424 |
| Bainbridge Island               | Woodward Middle School       | Main Building          | 57424 |
| Battle Ground                   | Maple Grove K-8              | Gym                    | 50043 |
| Battle Ground                   | Maple Grove K-8              | Main Building          | 50044 |
| Battle Ground                   | Praire High School           | 400 Building           | 50013 |
| Battle Ground                   | River Homelink               | Main Building          | 50050 |

|                   |                                      |                              |       |
|-------------------|--------------------------------------|------------------------------|-------|
| Bellingham        | Fairhaven Middle School              | Main Building - Classrooms   | 54454 |
| Bellingham        | Fairhaven Middle School              | West Wing                    | 54455 |
| Bellingham        | Whatcom Middle School                | Music Building               | 54468 |
| Bethel            | Camas Prairie Elementary School      | Main Building                | 57577 |
| Bickleton         | Bickleton Elementary and High School | Main Building                | 51649 |
| Burlington-Edison | Edison Elementary School             | Original Building            | 50089 |
| Cape Flattery     | Neah Bay Junior/ Senior High School  | Neah Bay Middle School & Gym | 57834 |
| Carbonado         | Carbonado Historical School 19       | Computer Lab and Library     | 57840 |
| Cascade           | Beaver Valley School                 | Main Building                | 51675 |
| Central Kitsap    | Emerald Heights Elementary           | Gym                          | 57877 |
| Central Kitsap    | Green Mountain Elementary            | Gymnasium                    | 57875 |
| Central Kitsap    | Green Mountain Elementary            | Main                         | 57875 |
| Central Kitsap    | Pinecrest Elementary                 | Gymnasium                    | 57854 |

|                      |                                   |                                 |       |
|----------------------|-----------------------------------|---------------------------------|-------|
| Central Kitsap       | Pinecrest Elementary              | Main                            | 57854 |
| Central Kitsap       | Ridgetop Junior High              | Main                            | 57855 |
| Central Kitsap       | Silver Ridge Elementary           | Main                            | 57857 |
| Central Kitsap       | Woodlands Elementary              | Main                            | 57903 |
| Chimacum             | Chimacum Middle School            | Middle School Bldg 200          | 58031 |
| Clover Park          | Custer Elementary School          | Library                         | 50243 |
| Coupeville           | Coupeville High School            | Gymnasium                       | 54537 |
| Coupeville           | Coupeville Middle School          | Middle and High School Building | 54544 |
| Creston              | Creston Junior Senior High School | Creston K-12 School Building    | 51821 |
| Darrington           | Darrington Elementary School      | Main Elementary School          | 54550 |
| Dieringer            | North Tapps Middle School         | Main Building                   | 58058 |
| East Valley (Yakima) | East Valley Central Middle School | 6th Grade Building              | 50349 |
| East Valley (Yakima) | East Valley Central Middle School | Computer Lab Building           | 50351 |
| Federal Way          | Kilo Middle School                | Building D                      | 50804 |



|                 |                             |                            |       |
|-----------------|-----------------------------|----------------------------|-------|
| Federal Way     | Nautilus K-8 School         | Multipurpose Rm Bldg       | 50826 |
| Federal Way     | Nautilus K-8 School         | Rooms 15-20 Bldg           | 50827 |
| Federal Way     | Nautilus K-8 School         | Rooms 1-6 Bldg             | 50828 |
| Federal Way     | Nautilus K-8 School         | Rooms 22-25 Bldg           | 50829 |
| Federal Way     | Nautilus K-8 School         | Rooms 7-14 Bldg            | 50830 |
| Fife            | Columbia Junior High School | Main Building              | 58132 |
| Fife            | Fife High School            | Building VII 700 Cafeteria | 58142 |
| Highline        | Hilltop Elementary School   | 400 Building - Bldg D      | 55175 |
| Highline        | Seahurst Elementary School  | Main Building              | 55100 |
| Index           | Index Elementary School     | Enclosed Covered Play      | 55233 |
| Lake Washington | Dickinson Elementary School | Main Building              | 55935 |
| Lake Washington | Emerson Campus              | Emerson                    | 55920 |
| Lake Washington | Wilder Elementary School    | Main Building              | 55846 |

|               |  |   |       |
|---------------|--|---|-------|
| Longview      | Mt. Solo Middle School                 | Main Building                           | 58466 |
| Mansfield     | Mansfield Elem and High School         | Main Building                           | 52291 |
| Mary M Knight | Mary M. Knight School                  | High School Building                    | 50924 |
| Marysville    | Marysville Pilchuck Senior High School | Physical Science Building - Bldg S      | 56251 |
| Marysville    | Marysville Pilchuck Senior High School | South Building - Bldg N                 | 56247 |
| Marysville    | Quil Ceda Tulalip Elementary School    | Main Building                           | 56204 |
| Methow Valley | Liberty Bell Junior Senior High School | Main Building                           | 52358 |
| Morton        | Morton Elementary School               | Gymnasium                               | 58504 |
| Mount Baker   | Mount Baker Jr High School             | 200 Building - JHS                      | 56405 |
| Mount Baker   | Mount Baker Jr High School             | Pro-Rate Portion of Commons - Bldgg 100 | 56404 |
| Mount Baker   | Mount Baker Sr High School             | 300 North                               | 56443 |
| Mount Baker   | Mount Baker Sr High School             | 300 South                               | 56436 |

|               |                                 |  |       |
|---------------|---------------------------------|--|-------|
| Mount Baker   | Mount Baker Sr High School      | 700 Building                           | 56425 |
| Mount Baker   | Mount Baker Sr High School      | Pro-rate Portion of Commons - Bldg 100 | 56440 |
| Naches Valley | Naches Valley Middle School     | Main Building                          | 52487 |
| Newport       | Newport High School             | Main Building                          | 52500 |
| Oak Harbor    | Oak Harbor Middle School        | Building B                             | 51288 |
| Ocean Beach   | Ocean Park Elementary School    | Main Building                          | 58647 |
| Ocosta        | Ocosta Elementary School        | Primary Addition                       | 58652 |
| Olympia       | Boston Harbor Elementary School | Main Building                          | 58698 |
| Olympia       | Thurgood Marshall Middle School | Gym Building                           | 58671 |
| Olympia       | Thurgood Marshall Middle School | Main Building                          | 58672 |
| Pasco         | Edwin Markham Elementary School | Main Building                          | 52770 |
| Pateros       | Pateros K-12 School             | Wood Shop                              | 52829 |

|               |                                 |                                 |       |
|---------------|---------------------------------|---------------------------------|-------|
| Peninsula     | Gig Harbor High School          | Two-Story Building              | 58819 |
| Peninsula     | Minter Creek Elementary School  | Main Building                   | 58834 |
| Peninsula     | Voyager Elementary School       | Main Building                   | 58817 |
| Port Townsend | Blue Heron Middle School        | Main Building                   | 58917 |
| Riverside     | Chattaroy Elementary School     | Main Building                   | 53054 |
| Royal         | Red Rock Elementary School      | Main Building                   | 53072 |
| Royal         | Royal High School               | B Main Building                 | 53076 |
| Royal         | Royal Middle School             | Main Building                   | 53080 |
| Shaw Island   | Shaw Island School              | Intermediate Classroom Building | 57008 |
| South Whidbey | South Whidbey Elementary School | Main Building                   | 57240 |
| Spokane       | Audubon Elementary School       | Main Building                   | 53564 |
| Tacoma        | Edison Elementary School        | Main Building                   | 59747 |

|          |  |                               |       |
|----------|--|-------------------------------|-------|
| Tacoma   | Foss High School                       | Main Building - 2003 Addition | 59802 |
| Tacoma   | Manitou Park Elementary School         | Main Building                 | 59601 |
| Tacoma   | Northeast Tacoma Elementary School     | Gym Bldg-Bldg 2               | 59627 |
| Tacoma   | Northeast Tacoma Elementary School     | Main Bldg-Bldg 1              | 59626 |
| Tacoma   | Sheridan Elementary School             | Main Building                 | 59723 |
| Tacoma   | Stanley Elementary School              | First Bldg                    | 59636 |
| Thorp    | Thorp Elementary and Jr-Sr High School | Thorp Elem/Jr/Sr High School  | 53671 |
| Tonasket | Tonasket Elementary School             | Tonasket Elementary           | 53674 |
| Tonasket | Tonasket Middle-High School            | High School/Middle School     | 53673 |
| Tumwater | Black Lake Elementary School           | Building A                    | 59890 |
| Tumwater | Black Lake Elementary School           | Building B                    | 59893 |
| Tumwater | Black Lake Elementary School           | Building C                    | 59892 |

|  |              |                                      |                            |       |
|--|--------------|--------------------------------------|----------------------------|-------|
|  | Warden       | Warden K-12                          | Cafeteria                  | 53814 |
|  | Warden       | Warden K-12                          | Middle School/High School  | 53812 |
|  | White Pass   | White Pass Junior Senior High School | Main Building              | 51568 |
|  | White River  | Mountain Meadow Elementary School    | Main Building              | 51616 |
|  | Wilson Creek | Wilson Creek K-12                    | Business Building/Home Ec. | 53895 |
|  | Wilson Creek | Wilson Creek K-12                    | Gym/Commons                | 53894 |
|  | Wilson Creek | Wilson Creek K-12                    | Vo-Ag / Science Bldg       | 53892 |

The following scoring rationale and methodology was used to initially rank buildings before engineers used their engineering judgment to adjust the ranking category. Higher scores indicate a building that is more at-risk. The scores used for each category are shown in Tables C5–12.

**Table C5.** Date of construction score.

| <b>Year Category</b> | <b>Assigned Score</b> |
|----------------------|-----------------------|
| <1935                | 12                    |
| 1935-1955            | 10                    |
| 1955-1964            | 9                     |
| 1965-1975            | 8                     |
| 1976-1985            | 6                     |
| 1986-1998            | 4                     |
| >1998                | 1                     |

**Table C6.** Construction type score.

| <b>Construction Type Category</b> | <b>Year Cutoff</b> | <b>Assigned Score</b> |
|-----------------------------------|--------------------|-----------------------|
| Older Wood Construction           | 1955               | 9                     |
| Intermediate Age Wood             | 1981               | 6                     |
| Late 20th Century Wood            | 1999               | 2                     |
| Post-1998 Wood                    | 2020               | 1                     |
| URM                               | -                  | 12                    |
| Intermediate Age Masonry          | 1981               | 10                    |
| Late 20th Century Masonry         | 1999               | 3                     |
| Post-1998 Masonry                 | 2020               | 1                     |
| Nonductile Concrete               | 1955               | 12                    |
| Intermediate Age Concrete         | 1984               | 9                     |
| Late 20th Century Concrete        | 1999               | 3                     |
| Post-1998 Concrete                | 2020               | 1                     |
| Older Steel                       | 1984               | 7                     |
| Intermediate Age Steel            | 1999               | 3                     |
| Post-1998 Steel                   | 2020               | 1                     |
| Other                             | -                  | 3                     |



**Table C7.** Spectral acceleration adjustment.

| <b>S<sub>DS</sub><br/>(Less than Value)<br/>(g)</b> | <b>Assigned Score</b> |
|---|-----------------------|
| 1.50  | 6                     |
| 1.25  | 5                     |
| 1.00  | 4                     |
| 0.75  | 3                     |
| 0.50  | 2                     |
| 0.25  | 1                     |

**Table C8.** Square footage adjustment.

| <b>Square Footage<br/>(Less Than Value)</b> | <b>Adjustment Factor Applied to<br/>Spectral Acceleration Adjustment</b> |
|---|--|
| 9000  | 1  |
| 18000                                       | 1.1  |
| 42000                                       | 1.2  |
| 52000                                       | 1.3  |
| 75000                                       | 1.4  |
| 105000                                      | 1.5  |
| 2320000                                     | 1.6  |

**Table C9.** Liquefaction adjustment, for schools in a mapped liquefaction zone they were given a higher score.

| Value | Assigned Score |
|-------|----------------|
| Yes   | 3              |
| No    | 0              |

**Table C10.** SEAONC Earthquake Performance Rating System Adjustment when unknowns equal noncompliant.

| Value | Assigned Score |
|-------|----------------|
| 1     | 2              |
| 2     | 1              |
| 3     | 0              |

**Table C11.** SEAONC Earthquake Performance Rating System Adjustment when unknowns equal compliant.

| Value | Assigned Score |
|-------|----------------|
| 1     | 4              |
| 2     | 2              |
| 3     | 0              |

**Table C12.** EERI EPAT adjustment.

| Cutoff Value<br>(Less than Value) | Assigned Score |
|-----------------------------------|----------------|
| 100%                              | 3              |
| 67%                               | 2              |
| 33%                               | 1              |

**Table C13.** FEMA 154 Rapid Visual Screening adjustment.

| <b>Cutoff Value<br/>(Less than Value)</b> | <b>Assigned Score</b> |
|---|-----------------------|
| 1.01                                      | 3                     |
| 2.01                                      | 2                     |
| 4.01                                      | 1                     |
| 7.01                                      | 0                     |

**Table C14.** ASCE 41 Tier 1 percent noncompliant adjustment.

| <b>Cutoff Value<br/>(Less than Value)</b> | <b>Assigned Score</b> |
|---|-----------------------|
| 46%                                       | 9                     |
| 30%                                       | 7                     |
| 20%                                       | 6                     |
| 10%                                       | 4                     |
| 6%  | 2                     |
| 3%  | 0                     |

**Table C15.** ASCE 41 Tier 1 percent noncompliant plus unknown adjustment.

| <b>Cutoff Value<br/>(Less than Value)</b> | <b>Assigned Score</b> |
|---|-----------------------|
| 91%                                       | 3                     |
| 70%                                       | 2                     |
| 50%                                       | 2                     |
| 30%                                       | 1                     |
| 17%                                       | 1                     |
| 5%  | 0                     |

## Appendix D: Fire Station Reports

All of the data generated from the engineering assessments for the Phase 2 fire stations are downloadable below as an engineering volume. For fire stations that participated in Phase 1, the [Phase 1 report](#) and appendices are available to download the engineering and geology data for those stations.

[https://fortress.wa.gov/dnr/geologydata/school\\_seismic\\_safety/phase2/SSSP\\_2021\\_Engineering\\_Vol5\\_Concept\\_Level\\_Design\\_Reports\\_2\\_Fire\\_Stations.pdf](https://fortress.wa.gov/dnr/geologydata/school_seismic_safety/phase2/SSSP_2021_Engineering_Vol5_Concept_Level_Design_Reports_2_Fire_Stations.pdf)