BEAVERTON SCHOOL DISTRICT RESILIENCE PLANNING FOR HIGH SCHOOL AT SOUTH COOPER MOUNTAIN AND MIDDLE SCHOOL AT TIMBERLAND

BEAVERTON, OREGON

July 10th, 2015
SEFT Project Number: B14030.00

New High School at South Cooper Mountain

New Middle School at Timberland

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Starfish Story

“ Once, on ancient Earth, there was a human boy walking along a beach. There had just been a storm, and starfish had been scattered along the sands. The boy knew the fish would die, so he began to fling the fish to the sea. But every time he threw a starfish, another would wash ashore. An old Earth man happened along and saw what the child was doing. He called out, “Boy, what are you doing?”

“Saving the starfish!” replied the boy.

“But your attempts are useless, child! Every time you save one, another one returns, often the same one! You can't save them all, so why bother trying? Why does it matter, anyway?” called the old man.

The boy thought about this for a while, a starfish in his hand; he answered, “Well, it matters to this one.” And then he flung the starfish into the welcoming sea. ”

— Loren Eiseley, *The Star Thrower*

Foreword

At the behest of the State Legislature, the Oregon Seismic Safety Policy Advisory Commission completed *The Oregon Resilience Plan* in February 2013. This Plan outlines the risks and challenges facing Oregonians from the next Cascadia Subduction Zone mega-earthquake, which seismologists say is inevitable. The Plan provides very sobering predictions about the impacts from this earthquake, including durations for restoring the critical service lifelines of electricity, water, and highways ranging from months to a year or more in the Willamette Valley. *The Oregon Resilience Plan* is a call to action for all Oregonians, especially for those of us in public service.

Schools are different from most public facilities. Not only do they shelter thousands of our children, they are distributed in neighborhoods and walkable from homes nearby. With enlightened forward planning, they could be significant resources in helping their communities recover in the aftermath of the earthquake…if we plan.

Beaverton School District has a special opportunity—perhaps even a responsibility. Our community approved a very large capital construction bond program in 2014 that includes building three brand new school buildings and replacing four more. In order to better support our community during an emergency, our District has determined that we should build these seven schools to exceed building code requirements in certain critical aspects in order to respond to *The Oregon Resilience Plan*. Operating within a very compressed timeframe to keep our projects on schedule and within constrained budgets, we launched an effort to translate the concepts of the Plan for our first two schools into design criteria for our architects and engineers.

This report summarizes that effort and provides the conclusions we reached. It is imperfect, and will only affect seven of our 50 schools and only seven of the 1,200 public schools in Oregon. But we must start somewhere, with the hope that Oregon has decades to build many new schools and other public buildings before the mega-earthquake strikes. Beaverton School District hopes that publishing this report and sharing our work with other school districts will provide a beginning framework for creating a new standard for resilient school buildings.

Richard L. Steinbrugge, P.E.
Executive Administrator for Facilities

BEAVERTON SCHOOL DISTRICT

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Acknowledgements

We would first like to acknowledge the Beaverton School District for their courageous response to *The Oregon Resilience Plan* and the challenge of a Cascadia Subduction Zone earthquake. Stepping up to this challenge, they are seeking to make their schools safe, be available as a community shelter, and be ready to re-open schools within 30 days following the earthquake. The District's willingness to engage community stakeholders such as the city and county emergency management agencies, Tualatin Valley Fire & Rescue, American Red Cross, and others has initiated a unique and useful collaboration that will bear fruit in the years to come.

We have appreciated the participation and contributions by the design teams (led by Boora Architects for the new High School at South Cooper Mountain and Mahlum Architects for the new Middle School at Timberland) and the Beaverton School District project management teams for both schools (Richard L. Steinbrugge, David Etchart, Leslie Imes, Patrick O'Harrow, Scott Johnson, and Ryan Hendricks). The goal of making the high school and middle school resilient was introduced to them after the start of the design process. Their participation and feedback allowed us to incorporate resilient design features that will make a difference.

As part of this project, the Beaverton School District convened a resilience workshop to bring together the various stakeholders to discuss what would be necessary to achieve the goals of utilizing the new high school and new middle school as emergency shelters and to generally improve the disaster resilience of Beaverton schools. We would like to thank the workshop participants and the organizations they represent for their time and participation in this groundbreaking resilience planning effort. Workshop participants included:

Jerry Abdie	KPFF Consulting Engineers
Bruce Barney	Portland General Electric
Aaron Boyle	Beaverton School District
Mike Britch	Tualatin Valley Water District
Brian Butler	Interface Engineering
David Chesley	Interface Engineering
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Siobhan Kirk	Tualatin Valley Fire & Rescue
Michael Kummerman	NW Natural
Bobby Lee	Portland Metro Regional Solutions
Steve Muir	Washington County Emergency Management Cooperative
Michael Mumaw	City of Beaverton
Patrick O'Harrow	Beaverton School District
Curtis Peetz	American Red Cross
Scott Porter	Washington County Emergency Management Cooperative
Jeff Rubin	Tualatin Valley Fire & Rescue
Dick Steinbrugge	Beaverton School District
Brandon Watt	PAE Engineers
Dave Winship	City of Beaverton
Kurt Zenner	Mahlum Architects

Tualatin Valley Fire & Rescue graciously provided access to their Command & Business Operations Center to host the resilience workshop convened as part of this project. We would like to thank Deputy Chief Dustin Morrow and Tualatin Valley Fire & Rescue for their support.

Washington County is very interested in improving the resilience planning process by continuing the efforts to breakdown the silo mentality, as initiated by this project. We would like to thank the Assistant County Administrator for Washington County, Don Bohn and Washington County for their active engagement in this project.

Lastly, we would like to thank State Representative Tobias Read for his overwhelming support of this project and the goal of improving the resilience of Beaverton schools.

Project Team

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Executive Summary

Oregon has come to understand that there is an uncomfortably high probability that a Magnitude 9.0 Cascadia Subduction Zone earthquake will occur off the coast, triggering strong ground shaking that will last for 3 to 5 minutes and generating a tsunami that will cover the coast line, not unlike what happened in Japan in 2011. Seismologists tell us that this type of event has occurred 41 times in the last 10,000 years and there is no reason to expect that it will not occur again. Fortunately, the recently published *The Oregon Resilience Plan* has provided a comprehensive evaluation of what will happen and what can be done in the short and long term to mitigate our state's vulnerabilities to an acceptable level.

Elementary, middle, and high schools will have an important role in the response and recovery of the state from this catastrophic event. Because of their location and layout, they are perfectly suited to serve as emergency shelters and community resource centers within 72 hours after the event and during the response period. Once the initial response period passes in a few weeks, schools need to re-open and contribute to their communities return to normalcy. For this to occur, the school buildings need to be "safe and usable" immediately after the event and served by the infrastructure systems they depend on (including transportation, energy, water, wastewater, communication, and information systems). Unfortunately, current design standards and codes do not provide for this level of performance.

In February of 2013, the Oregon Seismic Safety Policy Advisory Commission submitted a report to the 77th Legislative Assembly entitled *The Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami*. The report discusses the risk that is faced by the citizens of Oregon from an impending Cascadia Subduction Zone earthquake and accompanying tsunami, and the gaps that exist between the current state of Oregon's infrastructure and where it needs to be. *The Oregon Resilience Plan* goes on to outline steps that can be taken over the next 50 years to bring the state closer to resilient performance through a systematic program of vulnerability assessments, capital investments in public infrastructure, new incentives to engage the private sector, and policy changes that reflect current understanding of the Cascadia threat.

The Oregon Resilience Plan established a goal of opening shelters almost immediately and re-opening schools within 30 days following a large earthquake. The plan estimates that Oregon's existing school buildings and emergency shelters may take up to 18 months to reopen in the Coast and Valley regions.

In 2014, voters within the Beaverton School District passed a major bond measure to help reduce school overcrowding and modernize schools. This has provided the District a unique opportunity to not only address daily operational needs, but also respond to the findings of *The Oregon Resilience Plan*. This effort is establishing the Beaverton School District as a leader in the design and construction of disaster resilient schools that are also capable of supporting their surrounding communities as emergency shelters.

This report summarizes resilience planning activities that have been conducted in support of the design of the new High School at South Cooper Mountain and the new Middle School located at the Timberland Development. SEFT Consulting Group has coordinated with the Beaverton School District, various stakeholder groups (city and county emergency managers, American Red Cross, Portland General Electric, Tualatin Valley Water District, Clean Water Services, etc.) and the design teams (led by Boora Architects and Mahlum Architects) for the two new schools to establish resilient design features that can reasonably be incorporated in design and construction, given project schedule and budget limitations.

It was determined that an emergency shelter at the high school could accommodate approximately 860 people and at the middle school could accommodate approximately 725. This represents a significant population that can remain in their neighborhood and speed the return of the neighborhood to normalcy after the earthquake.

The stakeholder workshop and subsequent meetings identified a wide variety of features that could be added to the projects that would improve the school's ability to be used as shelters and re-open in a few weeks for teaching. The American Red Cross made it clear that, as a minimum, they only need a willing building owner and a secure facility that could be naturally ventilated, would get people out of the weather and keep them warm. Beyond that, the availability of electricity for lighting and cooking, water and removal of waste water would be significant additions that would improve the efficiency and livability for the shelter.

The key resilience features that are recommended for both schools to support that population and allow the schools to re-open quickly include the following. These recommendations represent an affordable balance between permanent and temporary (brought in after the earthquake) solutions:

- Design structural systems of the schools as essential facilities (Risk Category IV) resulting in improved seismic performance over typical Risk Category III school design (which is intended to achieve life-safety performance, and will likely require lengthy and costly repair prior to re-occupation);
- Design seismic bracing or anchorage for nonstructural components per Risk Category III requirements, provided that those components needed for use of the school as an emergency shelter satisfy Risk Category IV seismic design requirements;

- Confirm equipment that is expected to be operational after an earthquake (emergency generator, automatic transfer switch, ventilation fans, etc.) satisfy the special certification requirements of ASCE 7-10 Section 13.2.2 (i.e., seismic rated);
- Increase the size and fuel capacity of the emergency generator to the level needed to support shelter operations including additional outlets in the kitchen;
- Provide building connection points to hook up an external water supply tank, in lieu of adding bulk water storage on site;
- Provide water piping from the school building to the utility piping that is better able to resist earthquake ground displacement to allow water to be supplied to the school more reliably after water utility system resilience improvements are completed;
- Provide wastewater piping from the school building to the utility piping that is better able to resist earthquake ground displacement to allow wastewater to be discharged into the wastewater utility system and minimize the need for holding tanks; and
- Plan for the use of open areas on the grounds to support community relief efforts.

The cost of these additions was estimated to be about $900,000 for the high school and $750,000 for the middle school.

The report goes on to recommend that (1) all new and existing Beaverton School District campuses undergo the same type of stakeholder resilience planning workshop, (2) reasonable resilience features be implemented with a proper design, detailed peer review and plan check during design, and comprehensive inspection during construction, and (3) Beaverton School District develop a site-specific post-event inspection procedure that allows the rapid and conclusive assessment of the buildings. New schools should have similar features added to the project scope and existing schools should be retrofitted to these performance levels during their eventual rehabilitation. The report also recommends continued collaboration with the various stakeholder groups including the development of memorandum of understanding with each utility provider regarding the timing for the restoration of service.

1.0 Introduction

1.1 School District Overview

We are pleased to present this report of the Resilience Plan for the new High School at South Cooper Mountain, the new Middle School at the Timberland Development, and resilience recommendations for future Beaverton School District capital improvement projects. The Beaverton School District (BSD) resides within Washington County located at the northern end of the Willamette Valley. The District overlaps with the un-incorporated Bethany area, the City of Beaverton, and a small portion of the City of Tigard. It is the third largest school district in Oregon, and has 33 elementary schools, 8 middle schools, 5 high schools, and 5 options schools, with an enrollment close to 40,000 students. The population within the school district is estimated to be around 265,000. Much of the population works for Nike, Intel, Genentech, and other numerous high-tech companies.

The voters within BSD approved a major bond measure in May 2014 to increase the District's school capacity to adapt to expanding student populations, modernize existing schools, and address regulatory requirements. The District has hired design teams to design a new high school in the South Cooper Mountain area and a new middle school at the Timberland Development.

The District's planning and construction philosophy consists of: (1) making schools safe and secure, (2) promoting efficiency and sustainability features to ensure long term operational savings through focusing on life-cycle costs vs. first-cost of construction, and (3) integrating well with and enhancing the communities they reside in and providing opportunities for community partnerships.

1.2 Beaverton School District's Opportunity

BSD became aware of *The Oregon Resilience Plan* (*ORP*) that was developed at the request of the Oregon Legislature by the Oregon Seismic Safety Policy Advisory Commission (OSSPAC). The *ORP* calls for a 50-year effort to prepare Oregon for a Magnitude 9.0 Cascadia Subduction Zone earthquake and resulting tsunami. The plan outlined the current low state of preparedness and made specific recommendations for improvements. BSD realized that it had an opportunity to make its schools better prepared, not only for the safety of the students and staff, but also to ensure that it could continue its mission of educating the students following the earthquake. The District also has embraced the goal of providing the use of schools as community emergency shelters, in the aftermath of a Cascadia or other large earthquake, or other natural disasters.

2.0 Project Background

2.1 Disaster Resilience

In recent years, Hurricanes Katrina and Sandy have illustrated the importance of improving the ability of our Nation's communities to prepare for, respond to, and recover from disasters. The resilience goal is that because of risk reduction measures and pre-disaster planning, communities will recover more quickly and with less continuing vulnerability following a disaster (adapted from OSSPAC, 2013). Due to the unique opportunity presented by the construction of the new High School at South Cooper Mountain and the new Middle School at Timberland, BSD has chosen to complete this disaster resilience planning project, with the goal of identifying measures it can implement while these new schools are being designed and constructed that will lead to improved disaster resilience.

2.2 Regional Seismicity

On a regional scale, BSD facilities lie at the northern end of the Willamette Valley, a north-south trending topographic feature separating the Coast Range to the west from the Cascade Mountains to the east. The valley lies approximately 100 miles inland from the surface expression of the Cascadia Subduction Zone (CSZ). The CSZ is an active plate boundary along which the remnants of the Farallon Plate (the Gorda, Juan de Fuca and Explorer plates) are being subducted beneath the western edge of the North American continent. Figure 2.1 shows that the subduction zone off the coast of Oregon is a mirror image of the subduction zone off the coast of Northern Japan that produced the deadly 2011 Magnitude 9.0 Tohoku earthquake. We anticipate that the strong shaking from a Cascadia Subduction Zone earthquake will last from 3 minutes to 5 minutes, much longer than the 30-second strong shaking experienced in a typical California earthquake.

The geologic and seismologic information available for identifying the potential seismicity at BSD facilities is incomplete, and large uncertainties are associated with estimates of the probable magnitude, location, and frequency of occurrence of earthquakes that might affect the District. The available information indicates the potential seismic sources that may affect District facilities can be grouped into three independent categories: *subduction zone events* related to sudden slip between the upper surface of the Juan de Fuca plate and the lower surface of the North American plate, *subcrustal events* related to deformation and volume changes within the subducted mass of the Juan de Fuca plate, and *local crustal events* associated with movement on shallow, local faults within and adjacent to the Portland Basin.

Seismologists' understanding of the damaging earthquakes produced by the Cascadia Subduction Zone has steadily increased over the past 25 years. Research by the Oregon Department of Geology and Mineral Industries (DOGAMI), Oregon State University, and others has provided evidence of the timeline of historic great Cascadia Subduction Zone earthquakes. The timeline of these 41 earthquakes over the last 10,000 years is provided in Figure 2.2, showing that past earthquakes have occurred at highly variable intervals, and can range widely in size and in which parts of the Pacific Northwest they affect. The rupture distance for these Cascadia Subduction Zone earthquakes varies from a short rupture along the Northern California and Southern Oregon Coast, to a rupture along the entire length of the subduction zone from Northern California to British Columbia. There is about a 37% chance in the next 50 years of a Magnitude 8+ earthquake originating on the southern portion of the Cascadia Subduction Zone and up to a 15% chance in the next 50 years of a great earthquake affecting the entire Pacific Northwest. The scenario involving rupture of the northern Oregon portion would significantly impact BSD facilities.

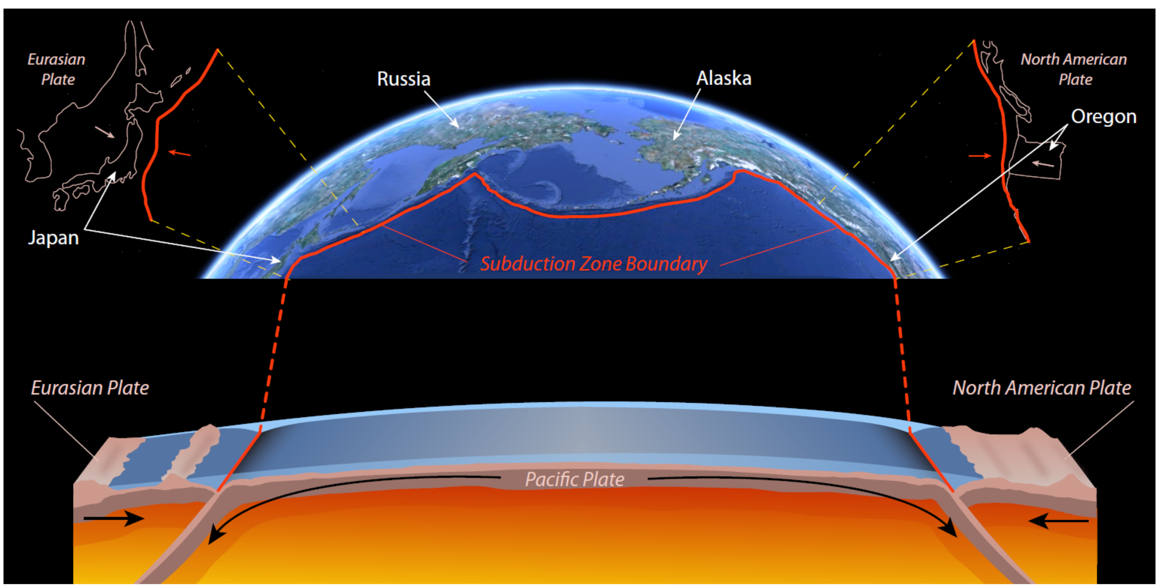


Figure 2.1 Oregon and Northern Japan Mirror Image Subduction Zones (OSSPAC, 2013)

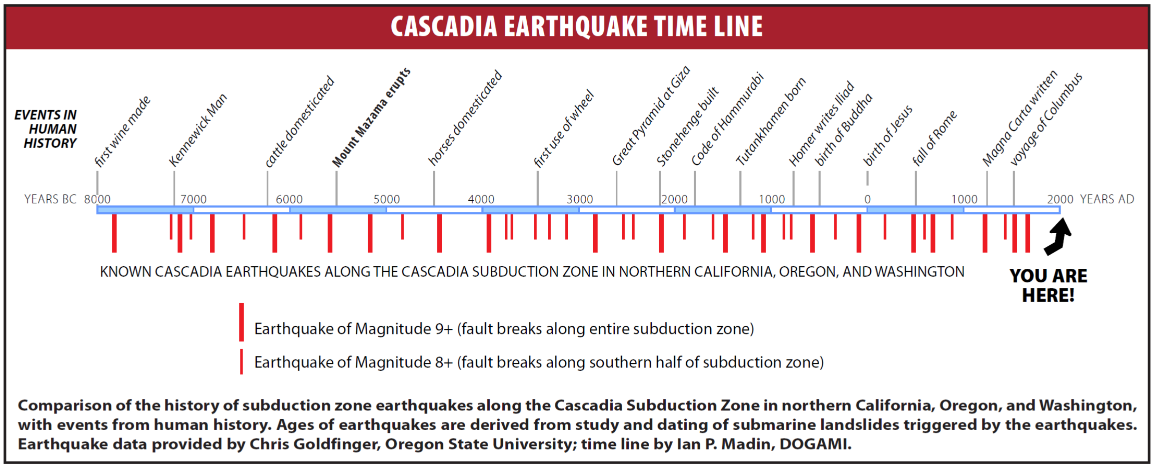


Figure 2.2 Historic Cascadia Subduction Zone Earthquake Timeline (DOGAMI, 2010)

2.3 *The Oregon Resilience Plan*

Awareness of the risk of a Cascadia Subduction Zone earthquake has been increasing as scientific information has been made available since the mid-1980's and validated by recent events worldwide. Motivated by this better understanding of the likelihood of a Cascadia earthquake, the Oregon Department of Transportation and some forward-thinking utility providers have taken voluntary steps to assess seismic vulnerability of their systems and have conducted limited seismic rehabilitation. However, these systems were assessed and/or rehabilitated by their public operators and private owners without coordination and without consistent understanding of their dependencies on other systems, let alone the consequences of their systems' failure on the overall pace of community recovery. These efforts have improved safety but have done little to improve community resilience, that is, improve the ability to recover rapidly.

Communities rely on their built environment to support their social and economic institutions that meet the basic needs of individuals, households, and the community at large. The built environment includes buildings that support housing, schools, hospitals, grocery stores, etc. and infrastructure systems that provide transportation, energy, water, wastewater treatment, communication, and information systems and are dependent on one another.

In order to better understand community resilience and prepare to recover rapidly from a disaster, there has been growing interest in breaking down the "silo" mentality and taking a holistic look at comprehensive steps to mitigate the Cascadia earthquake risk to our economy and to our businesses, homes, and communities. After the 2011 Tohoku, Japan earthquake, the Oregon Legislature directed OSSPAC to develop a holistic, comprehensive resilience plan to prepare the state to withstand and recover from a Cascadia Subduction Zone earthquake and tsunami. The report titled *The Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami* was released on February 28, 2013. *The Oregon Resilience Plan* (*ORP*) outlines steps that can be taken over the next 50 years to bring the state closer to resilient performance through a systematic program of vulnerability assessments, capital investments in buildings and infrastructure systems, new incentives to engage the private sector, and policy changes that reflect current understanding of the Cascadia threat.

OSSPAC assembled eight task groups, comprising over 160 volunteer subject-matter experts from government, universities, the private sector, and the general public. Task Groups included: (1) Cascadia earthquake scenario, (2) business and workforce continuity, (3) coastal communities, (4) critical and essential buildings, (5) transportation, (6) energy, (7) information and communications, (8) water and wastewater. Task Group activities were overseen by OSSPAC and an Advisory Group. Each Task Group was charged to:

1) Determine the likely impacts of a magnitude 9.0 Cascadia earthquake and tsunami on its assigned sector, and estimate the time required to restore functions in that sector if the earthquake were to strike under present conditions;
2) Define acceptable timeframes to restore functions after a future Cascadia earthquake to fulfill expected resilient performance; and
3) Recommend changes in practice and policies that, if implemented during the next 50 years, will allow Oregon to reach the desired resilience targets.

The *ORP* divided the state into four zones to reflect different levels of risk from a Cascadia earthquake (see Figure 2.3). The Tsunami zone in red is the low lying coastal zone which will be inundated by the tsunami that will likely result from the earthquake. The Coastal zone is the area with the strongest shaking due to its proximity to the fault (the red line located offshore). The Valley zone, where BSD is located, includes the Willamette Valley and still has significant levels of shaking, especially in areas with poor soils. It should be noted that even the fourth zone of Eastern Oregon will feel shaking and experience damage to its buildings and infrastructure systems.

The various task groups used estimates of the seismic hazard and expected ground motions developed by the Cascadia Earthquake Scenario Task Group in combination with knowledge of the construction era and condition of existing infrastructure to estimate the expected performance and service restoration times in the four geographic zones if the scenario event were to occur at the time the *ORP* was being developed.

The *ORP* also developed timeline targets for restoration of services after a Cascadia earthquake. These restoration targets were established assuming system resilience enhancements would be implemented over the next 50 years. These targets were set for three levels of service. A minimal level of service restored for the use of emergency response, a functional level of service up to 50% of capacity that is sufficient to get the economy moving again, and an operational level of service where restoration is up to 90% of capacity (which may still be relying on temporary fixes). Table 2.1 summarizes the *ORP's* goals for the restoration of minimal service for the Willamette Valley (after 50 years of resilience improvements) for the critical buildings (i.e., those facilities that are needed immediately) and compares it to current expected conditions. The time differences between the *ORP* restoration target goal and current expected performance illustrates the current resilience gaps that require investment in resilient buildings and infrastructure systems, and the public policy enhancements over the next 50 years. It is expected that emergency shelters will be connected to hardened backbone infrastructure systems or otherwise provided with priority access to services and repairs.

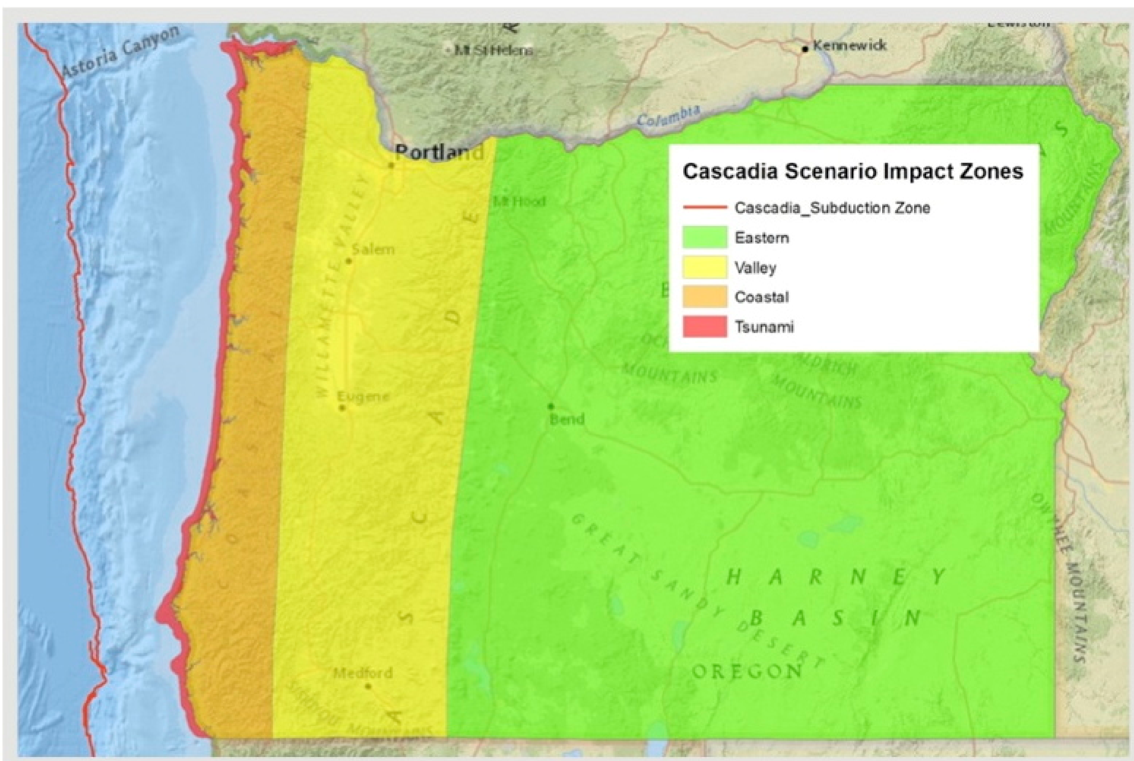


Figure 2.3 Cascadia Earthquake Scenario Impact Zones (OSSPAC, 2013)

Table 2.1 Level of Service Goals and Current Performance Expectations for Critical Buildings and Infrastructure that Supports Critical Buildings for Willamette Valley (OSSPAC, 2013)

	Goal for Level of Service:	**Current Level of Service:**
CRITICAL BUILDINGS		
Emergency Operations Centers	Immediate	4 months
Fire Stations	Immediate	2 months
Police Stations	Immediate	
Healthcare Facilities structural	Immediate	4 months
Healthcare Facilities non-structural		18 months
Primary K-8	**30 days***	**18 months**
High School	**30 days***	**18 months**
Emergency Shelters	**72 hours**	**18 months**
Critical Government Facilities	30 days	30 days
Residential Housing	72 hours	72 hours
Community Retail Centers	30 days	30 days
Financial/Banking	30 days	30 days
Vulnerable Buildings		18 months

TRANSPORTATION		
Oregon Highway System		
State Highway System - Tier 1	1-3 days	1-3 years
State Highway System - Tier 2	1-3 days	3+ years
State Highway System - Tier 3	1-3 days	3+ years
Airports		
Airports - Tier 1	0-24 hours	1-3 years
Airports - Tier 3	1-3 days	1-3 years
Rail WES Commuter Rail	1-3 days	6-12 months

PUBLIC TRANSIT		
Admin & Maintenance Facilities	1-3 months	3+ years
Local Area Paratransit On-demand (critical)	1-4 weeks	1-3 years
Local Area Paratransit On-demand (full)	1-3 months	3+ years
Local Roadway Fixed Route Service (emergency)	3-7 days	6-12 months
Local Roadway Fixed Route Service (regular)	1-3 months	3+ years
Intercity & Commuter Bus	1-3 months	3+ years

Table 2.1 Level of Service Goals and Current Performance Expectations for Critical Buildings and Infrastructure that Supports Critical Buildings for Willamette Valley (cont.)

	Goal for Level of Service:	**Current Level of Service:**
ENERGY		
Electric	1-3 days	3-4 weeks
Natural Gas	1-3 days	3-4 weeks
Liquid Fuel	Undetermined	

INFORMATION & COMMUNICATIONS		
Buildings repair	0-24 hours	6-12 months
Buildings replace	0-24 hours	6-12 months
Equipment in Buildings	0-24 hours	1-3 months
Towers	0-24 hours	1-3 months
Underground Lines	0-24 hours	1-3 months
Overhead Lines	0-24 hours	1-2 weeks

WATER & WASTEWATER		
Water Systems		
Potable water at supply source	0-24 hours	3-6 months
Main transmission backbone	0-24 hours	1-3 months
Water supply to critical facilities	0-24 hours	1-3 months
Water for fire suppression-key points	0-24 hours	3-7 days
Water for fire suppression-hydrants	3-7 days	6-12 months
Water available at community distribution centers/points	1-3 days	1-2 weeks
Distribution system operational	1-3 days	6-12 months
Wastewater Systems		
Threats to public safety & health controlled	1-3 Days	6-12 months
Raw sewage contained & routed away from population	0-24 hours	6-12 months
Treatment Plants operational to meet regulatory standards	1-2 weeks	3+ years
Major trunk lines and pump stations operational	1-2 weeks	3+ years
Collection system operational	1-3 months	1-3 years

*30 day time frame for reopening schools is preferred. A longer period of up to 60 days may be tolerable in some areas.

The Oregon Department of Transportation (ODOT) has been working with the Oregon Legislature to strategically improve the state highway system in order to maximize statewide connectivity (ODOT, 2013). Two major highways going through, or near the School District - Highways 99 and 26 have been designated as Tier 1 and Tier 2 lifeline routes, respectively (See Figure 2.4). These routes will receive priority funding for seismic upgrades and post-disaster cleanup/repairs. Tiered systems have also been developed for other modes of transportation. In the next five years, it is anticipated that other infrastructure systems (wastewater, power, and telecommunication, etc.) will assess their seismic vulnerabilities and take actions to enhance their resilience.

Since the release of the *ORP*, several state agencies and utility providers have started comprehensive seismic vulnerability assessments. Tualatin Valley Water District (TVWD), a major water provider in the Beaverton School District has started a Willamette Water Supply Project (WWSP) to address potential seismic vulnerabilities of its water source by bringing a redundant water source into its system. TVWD has also determined that it will be important to have water available at critical facilities and community distribution centers/points (at 20~30% capacity level) within 3 to 7 days.

In 2013, Senate Bill 33 established a Governor's Task Force on Resilience Plan Implementation (ORTF). The charge of the ORTF was to study the over 140 recommendations from the *ORP* and distill them down to the most critical to be implemented in the 2015-17 biennium. The ORTF presented their report to the 77th Legislative Assembly on October 1, 2014 that identified 21 critical issues for immediate implementation. In the 2015 Legislative session, there were over 15 bills considered to help improve Oregon's resilience.

These actions demonstrate that improving the State's resilience for a Cascadia Subduction Zone earthquake is important to Oregonians. The *ORP* can be seen as a call to action and this resilience planning project by the Beaverton School District as part of the answer, whereby a number of coordinated projects over the coming years make a major impact to improve Oregon's disaster resilience.

2.4 *The Oregon Resilience Plan* Recommendations for Schools

The reopening of schools is an important milestone after a major disaster, and symbolically marks the transition from the response phase to the recovery phase. In accordance with the *ORP*, schools need to be safe, and should be opened preferably within 30 days to ensure the workforce can go back to work and their children can return to a normal routine. To make schools functional, performance-based design, coupled with improved plan review and construction oversight, should be used on the buildings and civil infrastructure to ensure they will be usable. That requires deliberate planning for interim and long-term solutions, coordination with service providers, and implementation by the District and service providers.

The findings of the *ORP* indicate that "the current average estimated state of recovery for K-12 school facilities in the Coast and Valley regions of Oregon falls significantly short of the recommended target state, despite an existing statute directing seismic retrofit by January 1, 2032." The report makes the recommendation to "fully fund state investment in seismic retrofit of schools; prioritize the replacement of structure types that present the greatest hazard to their occupants in a seismic event" (OSSPAC, 2013). The goal of reopening schools within 30 days implies that only very minor structural damage is acceptable. If these schools are relatively undamaged after an earthquake, then they can be used as emergency shelters for residents of the local community.

Schools can play a significant role as shelters and resource centers in the response and recovery phases after a major disaster event (see Appendix A for US and International examples of Schools as Emergency Shelters). As an elementary school is likely within walking distance for the community it is serving, they are well positioned to be community distribution centers/points for water and emergency relief supply, and could be a hub for day-to-day community needs, such as information transfer, assistance with obtaining needed resources, charging cell phones, etc. Middle schools and high schools have larger facilities with gymnasiums, locker rooms, kitchen, cafeteria, athletic fields, etc. that make them ideally suited for use as emergency shelters. If elementary schools have larger gymnasium and cafeteria spaces, they may also be considered for use as emergency shelters.

In countries such as Japan, which experience many earthquakes, schools are pre-designated as shelters and built to the highest seismic safety levels to shelter students, staff and displaced community members after a major earthquake. In the United States, the approach is typically more ad-hoc. The local communities are responsible for providing emergency shelter and look to the American Red Cross (ARC), or other agencies for support in selection and staffing of shelters. If schools are deemed safe for re-occupation, and are not in session during a disaster/emergency situation, the schools may be used by the ARC as community emergency shelters. If schools are in session or are needed to shelter students and staff, sometimes the school district will determine that portions of the schools (such as a gym) can be made available to the ARC to shelter community members. This system has worked for the smaller disasters, but given the general low levels of seismic safety in Oregon's existing schools and other buildings, it will be problematic in the event of a Cascadia earthquake.

There is an opportunity to improve the capability of schools to serve as post-disaster centers during the design process for new facilities, or when scheduled for rehabilitation. If schools are built or retrofitted to higher seismic design standards, they can serve as pre-designated emergency shelters.

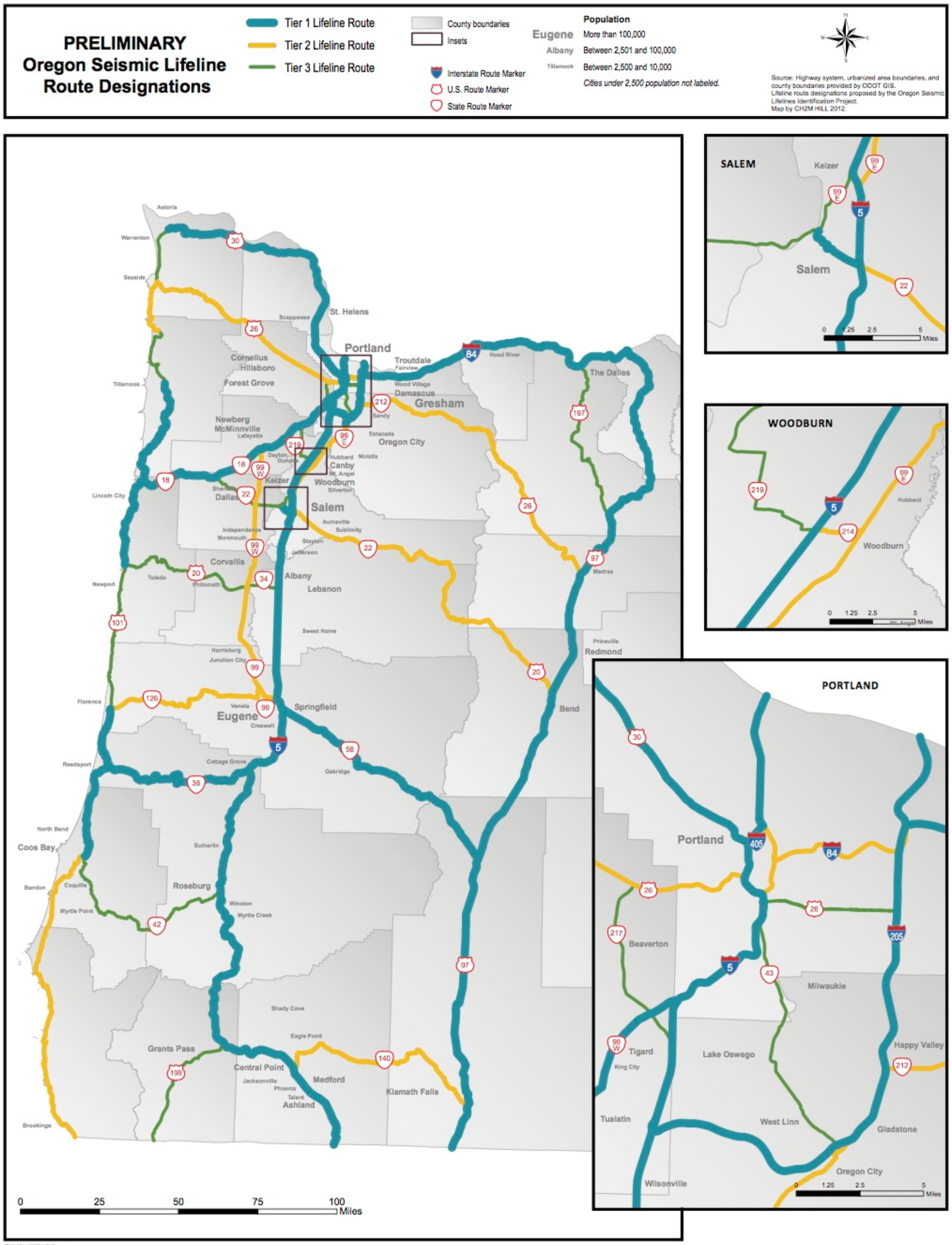


Figure 2.4 Oregon Seismic Lifeline Routes (ODOT, 2013)

2.5 Disconnect between Community Planning, Public Works and Emergency Planning

The typical community planning and infrastructure design process involves professionals working in relative isolation from other disciplines. Rarely are emergency managers involved in the infrastructure planning and design process, but are simply left to pick up the pieces in the aftermath of a disaster. The "silo" mentality has resulted in a disconnect between community planning, public works, and emergency planning. We need to integrate our emergency response planning into community planning and public works planning. Taking a holistic look will facilitate cooperation and promote taking comprehensive steps to mitigate the Cascadia earthquake risk to our economy and to our businesses, homes, and communities.

Communities also need to more clearly understand the significant dependencies between the various infrastructure systems. Failure of one system can result in cascading failures in others. For instance, loss of commercial electrical power can result in the inability to operate water pumps needed to refill water storage reservoirs. The lack of adequate water flow can in turn result in clogged wastewater collection pipes (not to mention inability to operate wastewater pump stations because of the original loss of commercial electrical power). These dependencies also impact the sequence and speed of service restoration following a major disaster. It is currently uncommon for utility providers in the various sectors to discuss how failure of one system impacts the operations of another.

The current approach used by the ARC is to have a list of facilities pre-identified that may be utilized as emergency shelters after a disaster. Buildings that are on the list have not necessarily been structurally evaluated to determine their expected performance after an earthquake, or any other disaster. The ARC relies on post-disaster building assessments to identify buildings from the list that are safe to be used as shelters. When there is a lack of utility services, the ARC provides temporary workarounds so that the buildings can function as an emergency shelter. To address this, we need to: (1) design and construct the building such that it will experience little damage and people feel safe to use it, and (2) deliberately coordinate with service providers so that measures can be taken prior to an event to best support functionality of the emergency shelter.

> "We cannot solve our problems with the same thinking we used when we created them." — Albert Einstein

3.0 Vision of the Beaverton School District

The vision of BSD has been to explore how to prepare the District and the surrounding communities for the eventual Cascadia Subduction Zone earthquake. The District recently passed a significant bond measure that includes the construction of seven (7) new schools. Using the *ORP* as the guide, the District sees these schools acting as a groundbreaking demonstration project to explore how they can be used as shelters following the disaster, and be able to re-open in a timely manner to aid recovery efforts.

The District recognizes that it is not possible to have all the desired infrastructure systems (water storage tank, wastewater storage tank, dual-fuel kitchen equipment, etc.) to operate a completely self-sufficient emergency shelter in place when the schools open, and seeks to have adaptable schools with the ability to add systems as resources become available.

3.1 Emergency Shelter and Supply Hub

The shelters and distribution of supplies and services are the responsibility of local government (i.e., Washington County and Cities of Beaverton and Tigard). They are supported in this mission by the American Red Cross (ARC), the Oregon Office of Emergency Management (OEM), and the Federal Emergency Management Agency (FEMA). Schools are often used as emergency shelters following a disaster. Schools are ideal for this purpose since they are often centers of the communities. They are places where people come to obtain information, and they have common spaces and classrooms that are easily adaptable for shelter needs.

In addition, the school grounds also provide open space to allow for the distribution of supplies and services for others in the community. These services include information distribution, cell phone battery charging, care of pets, etc.

Currently, following a disaster the ARC inspects existing facilities using a set of criteria. These criteria include:

- Determination of whether the shelter is for the general population or for those with special needs.
- Determination of number of occupants based on 40 square feet per person for sleeping capacity.
- Determination of restroom capacity (1 fixture per 20 people for toilets and shower heads), including ADA accessibility.
- Availability of spaces for health and mental health services.
- Availability of spaces for children's activities, play and health needs.

The selection of the schools and other buildings to be a shelter is currently done on an ad-hoc basis following a disaster. In considering schools, the ARC needs to know what the business continuity plans are for resumption of school, and whether students will be staying at the school immediately following a disaster. The ARC takes on the responsibility, liability and training for the shelters.

The use of the schools as shelters is voluntary and depends on the willingness of the school districts to enter into an agreement with the ARC. The ARC does not envision using the school as a shelter until at least three days following a Cascadia earthquake. It will take that long for them to take stock and organize. This delay provides a timeframe where the District can take care of students, staff and volunteers at the school, if the earthquake occurs during a school day. During this time, efforts to reunite families can take place as well as the initial coordination with the ARC to transition facilities for shelter purposes.

3.2 Reopening School in 30 Days

The *ORP* recommends that schools reopen within 30 days following a Cascadia earthquake. This recommendation was based on the review of recovery efforts in other disasters and the observation that getting schools reopened was a critical step in successful recovery efforts. It often marks the shift from response efforts to recovery efforts. Reopening schools within this time period fills two basic functions, it allows parents to know that their children's education is continuing and it makes them able to return to work. These two concerns are primary reasons why workers leave communities following a disaster.

3.3 Description of Vision for High School and Middle School

The vision for the new High School and the new Middle School is to construct a facility that can efficiently and effectively be used as a shelter and create a pre-agreement with the local governments and the ARC for their use as shelters in the case of a Cascadia earthquake or any other major disaster. This offers advantages for all parties. Local emergency service agencies and the ARC would have more certainty in planning for shelter needs following a disaster. Since the schools are new, they can be planned to meet higher seismic design standards to ensure their use following an earthquake (both to reopen in 30 days and to be used as a shelter within 72 hours after an event). In addition, other measures can be included to facilitate use as a shelter, such as increased emergency power capacity that can meet limited power needs.

Pre-designating schools as shelters also provides an impetus for infrastructure system providers to designate the schools as priority service areas following the disaster. If feasible, the schools can then be connected to the various backbone systems the providers are planning in response to a Cascadia event, reducing the time the schools will be without services. It is the community that benefits the most, since they can count on a dedicated shelter for times of emergency.

4.0 Resilience Planning Approach

A resilience planning approach looks not just at the individual needs of a building or community, but looks at dependencies that underlie these needs. Being able to use a building following an earthquake depends not just on the building performance being structurally adequate, but also the various systems in the building need to survive and be usable. But even this is not sufficient for the building to be usable. A community still needs to be able to travel to and from the site, as well as provide water, eliminate waste, and provide power and telecommunications. This means that it is necessary to look outside to the utility providers to understand how they provide these services to the site/building. The impacts of the damage to roads, bridges, fuel distribution, and other infrastructure systems also need to be taken into account.

Since knowledge of the risk of a Cascadia earthquake is recent, most of Oregon's infrastructure systems were not designed and built with this in mind. This means that our current vulnerabilities are quite high. With the current low resilience level, the *ORP* estimated that if the Cascadia event occurs in the near-term, then there will be a need for emergency shelters for a significant portion of the population. It set a 50-year time frame for Oregon to become resilient, at which time the need for emergency shelters would be reduced because the majority of individuals would be sheltering in-place in their homes. These two BSD projects are two small but significant steps in providing the shelters that are needed now.

Figure 4.1(a) qualitatively shows how the resilience level may be expected to gradually increase over time and shelter demand gradually decrease over time with a steady investment in resilience improvements (although we cannot predict the exact resilience and shelter demand versus time relationships). The intersection point of these two curves, at approximately 25 years, represents the point in time when the community resilience has increased to a point that available shelter capacity would be able to accommodate the shelter demand for a major disaster. Figure 4.1(b) qualitatively shows how the time at which this intersection point occurs might be pushed out into the future (to approximately 40 years) if a community's investment in resilience is delayed.

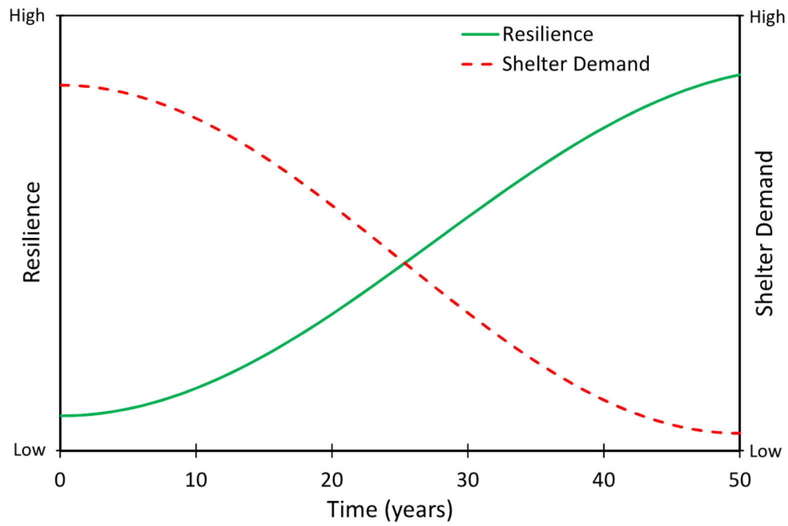
Due to the expected variability in community resilience and shelter demands over the next 50 years, this resilience planning project for BSD has considered short-, intermediate-, and long-term strategies for emergency shelter needs. In the short-term, before significant resilience improvements have been made to utility systems, the plan assumes that the school building will be safe to use as a shelter, but utility services and other necessities will need to be provided by emergency management agencies. In the long-term, after the 50-year resilience targets are achieved, the school building will be safe to use as a shelter and utility services are expected to be quickly restored to the shelter. This approach is intended to strike a balance between current and future emergency shelter needs of the community, and limited economic resources available to invest in resilience improvements.

The resilience planning process conducted as part of this project has involved four key steps: (1) work with BSD to determine the appropriate performance goals and functional recovery for BSD school buildings; (2) coordinate with the county and surrounding cities to determine desirable emergency shelter needs; (3) work with BSD to explore potential funding sources to cover the financial gap between a standard school design and the community emergency shelter needs; and (4) coordinate with the infrastructure systems to understand their resilience plan and assist BSD to develop a long-term strategy and an interim solution. It will require a community partnership among the county, the cities, and infrastructure system providers to meet the needs for school buildings to be effectively used as emergency shelters.

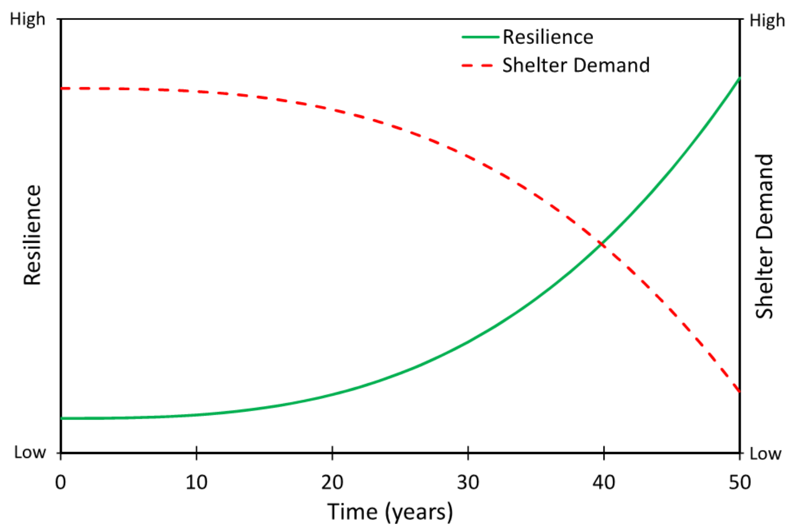
A key component of the planning process was the Beaverton School District Resilience Workshop held on February 10, 2015. The workshop agenda included the following major discussion topics:

1) Vision for new BSD schools and 2014 bond program
2) Emergency shelter: current practice (capacity, duration, level of human services)
    a. Perspectives from American Red Cross and Emergency Service Providers (County, City, and TVFR)
    b. Perspectives from utility service providers
    c. Perspectives from Beaverton School District
3) New, integrated approach: building resilience into school design
    a. Identifying shelter needs: capacity, duration, and level of human services
    b. Categorize added support for human services into three areas: brought-in, design flexibility, and hard construction
    c. Built-in facility features
    d. Utility services required
    e. Resources, challenges, and champions

The workshop was attended by 33 individuals representing BSD, high school and middle school design teams, city and county emergency managers, American Red Cross, and utility service providers. The workshop was very useful in establishing a common understanding of the project and opening the lines of communication between the various interdependent stakeholders. Workshop attendees and meeting minutes are included in Appendix C of this report.



(a) Steady Resilience Investment



(b) Delayed Resilience Investment

Figure 4.1 Resilience and Shelter Demand versus Time

4.1 Identified Stakeholders

A number of stakeholders have been identified that are essential for creating a resilient school that can be used as a shelter. The stakeholders who would be directly involved in the operation of the shelters and relief efforts include:

- Washington County Emergency Management Cooperative
- City of Beaverton Emergency Management
- American Red Cross (ARC)

- Tualatin Valley Fire & Rescue (TVFR)
- Oregon Office of Emergency Management

The stakeholders providing utilities include:
- City of Beaverton Water Division (BWD)
- Tualatin Valley Water District (TVWD)
- Clean Water Services (CWS)
- Portland General Electric (PGE)
- NW Natural

Other stakeholders include:
- Portland Metro Regional Solutions
- Federal Emergency Management Agency

4.2 Emergency Shelter Requirements

To serve as a shelter, a building needs to meet certain requirements established by the shelter provider. The essential requirement is that the building be safe and usable. One approach that may be used to provide a high probability that the building will be safe to occupy after a large earthquake, is to design the building as an essential facility (Risk Category IV) per the requirements of the currently adopted Oregon Structural Specialty Code (OSSC). Schools are currently required to meet Risk Category III seismic design standards. The school buildings are intended to achieve life safety performance objective (i.e., ensuring building occupants will not suffer life-threating injuries), and will likely be damaged and may not be usable without potentially lengthy and costly repair. While making the full building meet Risk Category IV is preferred, one option is to only upgrade common spaces to meet this standard, and count on using only these areas for shelter use. This option would only be possible if the facility was divided into multiple buildings separated by seismic joints that permit relative movement between the individual buildings.

It is also important that non-structural components (building skin, partition walls, ceiling systems, storage cabinets, mechanical equipment, electrical equipment, plumbing equipment, etc.) be adequately braced or anchored. Components that are required for use of the school as an emergency shelter should satisfy Risk Category IV requirements. Equipment that is expected to be operational after an earthquake (emergency generator, automatic transfer switch, ventilation fans, etc.) should satisfy the special certification requirements of the current edition of ASCE 7 referenced by the OSSC. Appendix B describes the differences in seismic design requirements for nonstructural components in Risk Category III (i.e. school) and Risk Category IV (i.e. emergency shelter) buildings.

Achieving a safe and usable performance level in these buildings requires identifying an appropriate performance-based design criteria (as stated above) along with a proper design, detailed peer review and plan check during design, and comprehensive inspection during construction. The need for this multi-faceted process is illustrated in every major earthquake when it is observed that excessive damage is caused by a deficiency in one or more of these areas.

The American Red Cross indicated that once the question of a having a safe and usable building is addressed, the minimum shelter requirements are very basic:

- Thermal Comfort: A wide temperature range is acceptable.
- Natural Ventilation: Being able to bring in fresh air is important.
- Lighting: They can make do with battery lanterns and flashlights if necessary.

Other desirable shelter features include:

- Emergency Power: A source of electricity for lighting, powering medical devices and recharging personal electronic devices.
- Water Supply: A source of water for drinking and personal hygiene.
- Wastewater: An operating wastewater system or holding tank if building restroom and shower facilities are being utilized.

4.3 Utility Services

The general approach to providing critical infrastructure services discussed at the workshop and in subsequent meetings is described below. More specific information is provided in Chapters 5 and 6 for the high school and the middle school, respectively.

4.3.1 Power

The electrical power service provider for schools within BSD is Portland General Electric (PGE). Schools are required to have emergency power and standby power systems to provide for smoke control systems, exit signs, egress lighting and emergency voice/alarm communications in assembly areas of the school. The emergency power is supplied by a stationary emergency and standby power generator. The size of the generator is typically around 150 kW. This emergency power is fed to an automatic transfer switch that is set up to provide power to critical circuits. The transfer switch also prevents power from back-feeding the power company's electrical lines and potentially harming workers performing repairs, who would expect the lines to be dead. Fuel backup supplies are only required to maintain operation of the critical systems noted above for two (2) hours.

Providing emergency power for illumination of common areas and the gym for shelter use, connecting exhaust and ventilation fans, and power to the kitchen to boil water will increase shelter effectiveness and functionality. However, this will increase electrical loads, the size of the electrical room and emergency generators, and cost. Increasing the fuel backup supply to provide for ninety-six (96) hours of operation of emergency power also needs to be considered.

4.3.2 PV Array

Oregon state law requires that public entities spend 1.5 percent of the total contract price of a public improvement contract for new construction or major renovation of a public building on green energy technology. BSD has been a leader in the green energy field, with three 100 kW PV systems already installed on school roofs. Additional PV systems will be installed with the new school construction. The PV systems are typically connected directly to the power grid and are not able to function if the power grid is down. However, it is possible to enable their use as emergency power for the building with the use of inverters that have the Secure Power Supply (SPS) function. These inverters have been expensive in the past, but newer, less expensive inverters are coming into the market. The power from PV arrays would only be available during the day, unless battery storage is provided. It is recommended that BSD investigate the possibility of incorporating the PV system as part of the emergency power system for the building, or incorporate system flexibility to hook the PV system into the emergency power system as the technology improves and back-feeding PV power directly into building electrical systems becomes more economical and future funding becomes available.

4.3.3 Dispatchable Standby Generation

There was the possibility for BSD to partner with PGE on their Dispatchable Standby Generation program. This is part of their Smart Power program in which, in exchange for running BSD generators when needed, PGE would provide some funding to upgrade switchgear and install control and communications hardware, assume routine maintenance and operations costs, pay for fuel, provide funding for additional fuel storage, and do monthly testing under high load. The minimum size generator for this program is typically 500 kW. While this option would be able to provide more than sufficient power to the school, this system has much higher front-end costs (even with PGE subsidies) than the required base emergency generator. It would require BSD to build an extra 300 square feet of electrical room for each school to accommodate additional equipment necessary for transmitting generated power to the grid. Associated coordination with PGE and early bid package revision would also create additional challenges for the design teams on top of an already compressed design schedule. Based on all the reasons above, BSD felt that for these two school projects, it was not advantageous to partner with PGE to include the Dispatchable Standby Generation program. Instead, the District elected to include up-sized generators as a project cost.

An alternative to Dispatchable Standby Generation is to provide hookups for additional portable generators to increase power within the building as needed following a disaster. This approach relies on the availability of portable generators.

4.3.4 Natural Gas

Natural gas in the schools is used for providing heating, hot water, and fuel for the kitchen's warming ovens. It is supplied by NW Natural. A Cascadia earthquake will likely disrupt gas supplies, but NW Natural is making improvements to their piping and flow control systems. NW Natural does have limited capacity for trucking in compressed natural gas (CNG) or liquefied natural gas (LNG) after a disaster.

Given the level of insulation in the building, heating will not likely be an issue, since the heat generated by people will keep the temperature within acceptable comfort levels. Providing dual fuel appliances for the gas hot water heaters and warming ovens would allow their use until natural gas services can be re-established at the school. This is expected to take several months at current levels of system reliability. Propane is the most likely fuel alternative for the gas appliances.

4.3.5 Water and Water Quality

The Beaverton School District has schools serviced by two different water suppliers, the Tualatin Valley Water District (TVWD) and the City of Beaverton Water Division (BWD). BWD will serve the High School at South Cooper Mountain and TVWD will serve the Middle School at Timberland.

TVWD is just starting to incorporate resilience into its planning goals. To start this process, they are determining the level of service goals and looking at critical locations such as hospitals and schools. This goal setting will include community participation. At this time, they envision creating a tiered system built around a robust backbone system. They have 800 miles of pipes and are looking at developing new design standards that will include restrained joints and seismic valves. They are currently in the initial design stage of building a new water treatment plant and supply pipeline from the Willamette River.

For schools located near this new backbone system, water will eventually be available within 24 hours after an earthquake. For schools not close to the backbone system, the long term goal would range from 1-3 days up to 2-4 weeks depending on their location in the tiered supply system. To supply water until the TVWD meets its long term goals and for facilities not on a high priority pipe lines, TVWD is anticipating providing valves at key reservoirs that will allow tanker trucks to obtain water. The schools should consider installing pipes and valves that would allow for connection to external water tanks to provide water within the building.

Water supplies are needed for drinking water, personal hygiene, flushing toilets, and cleaning. Even if water is available from the water district, water quality will likely suffer following a disaster and provisions are needed either to provide bottled water or treating the tap water, until the water supplier can confirm water quality or alternative water supplies are found. Assuming that emergency relief supplies from ARC, FEMA, and local emergency management will become available after 72 hours, one recommendation that was discussed at the BSD Resilience Workshop was to provide a 72-hour supply of bottled water, if BSD desires to provide shelters for its displaced students and staff members. Another option may be to provide an in-line water storage system to stock water for a 3- to 5-day period. These systems are used in Japan, but are not common in the US. Untreated water and harvested rain water can be used for flushing toilets and cleaning.

The City of Beaverton Water Division has an operating Aquifer Storage and Recovery (ASR) well in the high school area that may be utilized as a component of the emergency supply. The water quality of water from the ASR would need to be reviewed to determine if it can be considered potable or whether it would need additional treatment.

To ensure that the shelter water system works following an earthquake, standards need to be developed for piping and connections that are used for both the primary mains and the connections between the school buildings and utility water mains. Various pipe materials and joint types are available for use, but the seismic performance of the various options is not equal (See Table 4.1). For schools that are not on the priority water lines, consideration of water storage tanks or provisions of hookup connections for pumping water from the tanker trucks into the building until service can be restored should be considered.

4.3.6 Wastewater

The High School at South Cooper Mountain and the Middle School at Timberland are both served by Clean Water Services (CWS). CWS is working to establish a plan to evaluate the resilience of their current system and develop strategies to close identified resilience gaps. Their preliminary intention is to create a backbone system that would strengthen the main trunk lines, major pump stations and treatment plants. The wastewater system requires water to maintain the flow of sewage and power to run pump stations. Part of their planning process will include consideration of providing priority services for essential facilities and emergency shelters.

To ensure that the shelter wastewater system works following an earthquake, standards need to be developed for piping and connections that are used for both the primary mains and the connections between the school buildings and sewer mains. For schools that are not on the priority waste lines and near pump stations, consideration of a sewage holding tank and provisions for pumping the tank until service can be restored should be considered. In the short-term, before these wastewater system improvements can be implemented, shelter plans should include potential use of portable toilets.

Creating a gray water system is one alternative to reduce potable water usage for both typical operation and after natural disasters disrupt water supplies. However, given the current costs of such systems, they were not considered as part of this project.

Table 4.1 Commonly Used Water Pipeline Materials, Standards, and Vulnerability to Ground Deformation (AWWA, 1994)

Material Type and Diameter	AWWA Standard	Joint Type
Low Vulnerability		
Ductile Iron	C100 series	Bell-and-spigot, rubber gasket, restrained
Polyethylene	C906	Fused
Steel	C200 series	Arc welded
Steel	No designation	Riveted
Steel	C200 series	Bell-and-spigot, rubber gasket, restrained
Low to Moderate Vulnerability		
Concrete cylinder	C300, C303	Bell-and-spigot, restrained
Ductile iron	C100 series	Bell-and-spigot, rubber gasket, unrestrained
Polyvinyl chloride	C900, C905	Bell-and-spigot, restrained
Moderate Vulnerability		
Asbestos cement (> 8-in. dia.)	C400 series	Coupled
Cast iron (> 8-in. dia.)	No designation	Bell-and-spigot, rubber gasket
Polyvinyl chloride	C900, C905	Bell-and-spigot, unrestrained
Steel	C200 series	Bell-and-spigot, rubber gasket, unrestrained
Moderate to High Vulnerability		
Asbestos cement (≤ 8-in. dia.)	C400 series	Coupled
Cast iron (≤ 8-in. dia.)	No designation	Bell-and-spigot, rubber gasket
Concrete cylinder	C300, C303	Bell-and-spigot, unrestrained
Steel	No designation	Gas welded
High Vulnerability		
Cast iron	No designation	Bell-and-spigot, leaded or mortared

5.0 Recommendations for High School at South Cooper Mountain

5.1 Site Layout

In addition to the potential use of the High School at South Cooper Mountain for a shelter, the County Emergency Management Cooperative and the American Red Cross both see important uses for the school grounds as well. The school site can provide services for the on-site distribution of supplies and services for both the initial 30 days (before school reopens), and for additional time as required.

The most important element for on-site distribution is the proposed parking, loading, and circulation system off of SW 175th Avenue and SW Scholls Ferry Road. This circulation is sized for bus circulation and will allow one-way traffic for vehicles to enter and obtain supplies and services from semi-trailers or tents situated in the parking areas on either side of the roadway (See Figure 5.1). The fact that the site has two such circulation systems allows flexibility of use. It would also allow this function to continue past 30 days (after an event), allowing the school to reopen (albeit with reduced parking capacity).

The high school site has provisionary sites for up to six portable classrooms. If these sites are not occupied by future classrooms, they would be available for use during relief efforts. It was noted that it is possible, at little cost, to provide electrical, water and wastewater interfaces on the west side of the gym for these sites, which would add operational flexibility.

The high school has a loading area that can accommodate semi-trucks. There is no loading dock as the school relies on delivery vehicles that have their own ramps or lift-gates.

5.2 Structural System and Shelter Characteristics

To serve as a shelter, the building needs to meet certain requirements established by the shelter provider. The essential requirement is that the building be safe to occupy. To provide a high probability that the building will be safe to occupy after a large earthquake, the lateral-force resisting system of the building should be designed as an essential facility (i.e., Risk Category IV) per the requirements of the 2014 Oregon Structural Specialty Code (OSSC, 2014), resulting in improved performance over typical Risk Category III school design.

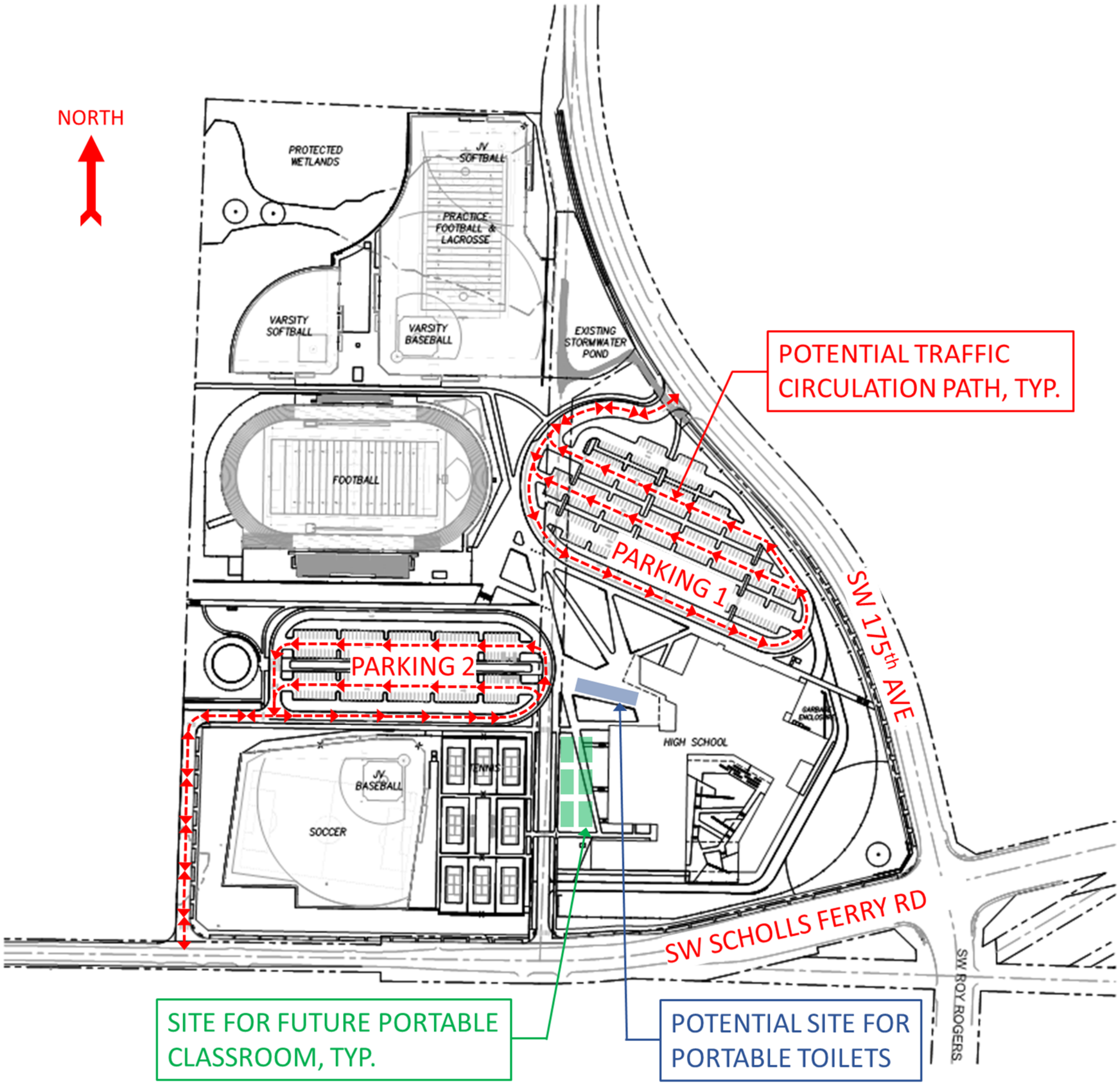


Figure 5.1 High School at South Cooper Mountain Site Plan
(adapted from Boora Architects drawings dated January 30, 2015)

The American Red Cross indicated that once the question of having a safe building is addressed, the minimum shelter requirements are very basic:

- Thermal Comfort: A wide temperature range is acceptable.
- Natural Ventilation: Being able to bring in fresh air is important.
- Lighting: They can make do with battery lanterns and flashlights if necessary.

To meet and/or exceed the above ARC minimum shelter requirements, it is also important that nonstructural components be adequately braced or anchored. Although it is desirable for all nonstructural components to meet Risk Category IV seismic requirements, Risk Category III requirements would still be reasonably adequate to meet and/or exceed the minimum shelter requirements provided that (1) those components required for use of the school as an emergency shelter (as specified in Sections 5.5 and 5.6) satisfy Risk Category IV requirements and (2) equipment that is expected to be operational after an earthquake (i.e., emergency generator, automatic transfer switch, ventilation fans, etc.) satisfies the special certification requirements of ASCE 7-10 Section 13.2.2 (ASCE, 2010).

The approximate shelter sleeping capacity for the identified usable spaces is indicated in Table 5.1 (provided by Boora Architects). Figure 5.2 shows the location of these different sleeping areas as well as other planning considerations for shelter operation. The Commons has a total seating capacity of approximately 900 people, however part of this space is included in the shelter sleeping capacity indicated in Table 5.1. The remaining portion of the Commons has seating capacity for approximately 336 people.

Table 5.1 High School at South Cooper Mountain - Shelter Approximate Sleeping Capacity

Area	Capacity
Main Gym	160
Auxiliary Gym	80
Aerobics/Dance Room	30
Commons	90
Classrooms (50 rooms @10 people/room)	500
Total	**860**

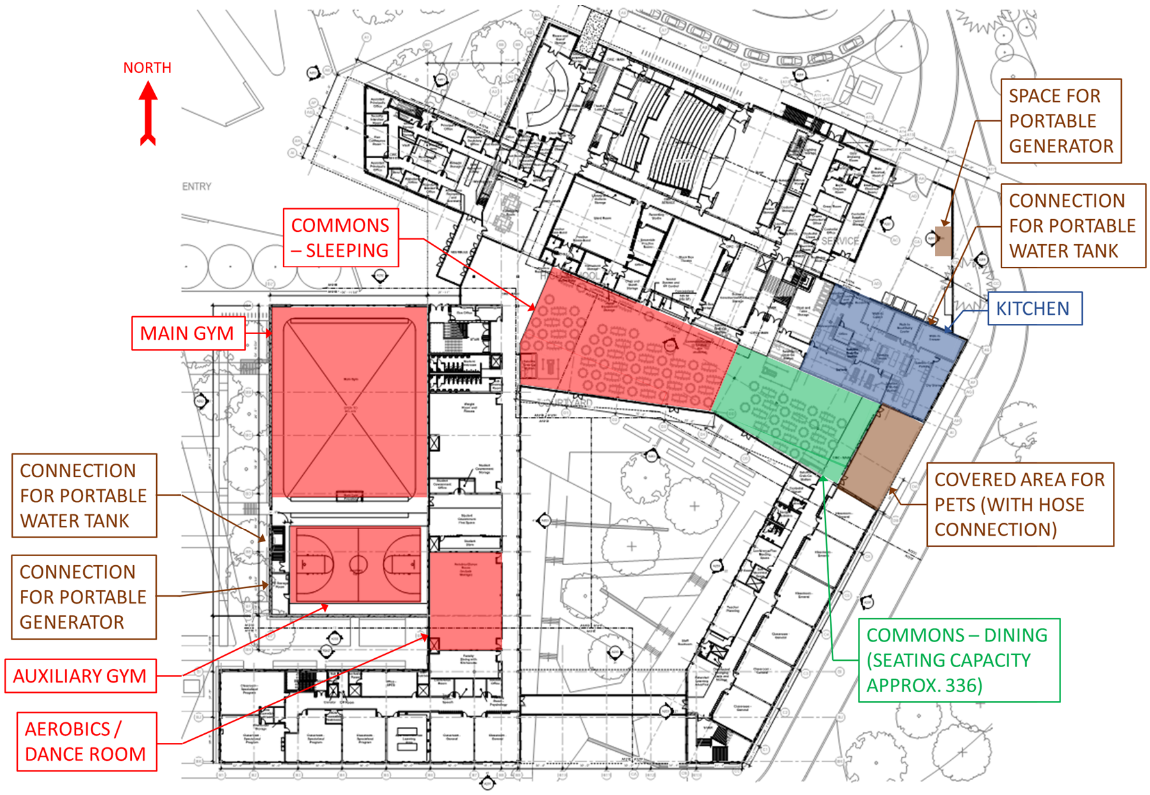


Figure 5.2 High School at South Cooper Mountain First Floor Plan
(adapted from Boora Architects drawings dated January 30, 2015 and March 3, 2015)

5.3 Shelter Agreement and Memorandum of Understanding

Before the school is used as a shelter, the ARC has an agreement form that will be used to delineate limitations and responsibilities. This agreement is currently based on the ad-hoc selection process following a disaster. With the school being prepared in advance, a memorandum of understanding should be developed between BSD, the local emergency service agencies, and the ARC.

5.4 Heating, Ventilation and Cooling

In discussions with the design team, a base performance level was identified:

- Heating: With the amount of insulation provided and the heat generated by people, lights, and equipment, the space temperature will likely be at acceptable levels without the need for additional heating in the heating months, assuming occupants will be dressed in jackets or wrapped in blankets.

- Ventilation and Cooling: The goal for desirable indoor temperature in the building during hot weather will be no more than the outside temperature. This would be achieved by adequate natural ventilation from doors, windows, and exhaust fans (which would need to be on the emergency power circuit).

5.5 Emergency Power

Emergency power is a basic building code requirement, but code only establishes a minimal level of service that provides power for egress lighting and for the operation of elevators (as required) for egress purposes. This power only needs to be provided for a short time frame. While emergency power is not a requirement for using the building as a shelter, there are a number of potential actions that would increase the school's usefulness as a shelter.

- Provide largest sized generator the budget will allow.
- Provide for hooking up additional emergency power generators.
- Have exhaust fans, common-lighting and other functions useful for shelter use be part of an emergency power circuit.
- Provide for on-site use of PV power array with inverter.

BSD has selected to provide a 500 kW emergency generator with 96-hour run time fuel storage. The emergency generator will provide electrical service to power lighting and ventilation fans in common areas and gymnasium and two electrical outlets in kitchen to allow hot plates for water boiling, etc. BSD will not provide emergency power for heated or conditioned air.

Seismic bracing of electrical system components intended for emergency shelter use should be designed to satisfy Risk Category IV seismic bracing requirements, in order to provide a high probability of remaining operational after an earthquake. Emergency generator, automatic transfer switch, ventilation fans (in common areas and gymnasium), and other equipment that is expected to be operational after an earthquake should satisfy the special certification requirements of ASCE 7-10 Section 13.2.2 (i.e., seismic rated).

The proposed kitchen of the high school is for serving of prepared meals that either are heated in gas fueled ovens or electric soup kettles (which can be used to boil water). BSD does not intend to provide emergency power to operate kitchen refrigerators, freezers, or perform any significant cooking. BSD assumes that ARC or other disaster services agency will bring in prepared food to the shelter.

5.6 Utilities

The long-term goal is that the high school site be on the backbone systems for the service providers. This would minimize the disruption time and make use of the school as a shelter much easier. The expected return to service for each of the utility providers should be determined and reviewed over time. The use of emergency power has been discussed in the section above.

5.6.1 Water

For water service, the high school should be on the backbone system to receive water within 24 hours once the system is upgraded to its resilience goals. We recommend that the piping installed by BSD between the utility main and the school building be specifically designed to consider seismic resilience. Until BWD has completed their backbone system improvements, water would need to be brought in to the site. BSD has selected to provide stub-outs at the building exterior to allow use of a portable water tank and associated pump to supply water to key building areas including: kitchen, locker rooms & showers (cold water only), drinking fountains in common spaces, and restroom serving the Dining Commons. An electrical connection for this pump would be beneficial, however it is not essential. Seismic bracing of plumbing system components intended for emergency shelter use should be designed to satisfy Risk Category IV seismic bracing requirements in order to provide a high probability of remaining operational after an earthquake. There is potential access to connect the school to the BWD Aquifer Storage and Recovery (ASR) well. This water is not necessarily potable, and the water quality needs to be reviewed to determine if additional treatment is required.

BSD does not intend to provide a hot water heater on a backup energy source at the shelter. BSD assumes that ARC or other disaster services agency will provide portable shower units, if necessary.

BSD assumes that ARC or other disaster services agency will provide an appropriate fire watch if there is no water available for the fire suppression system, or if the fire suppression system is damaged by the earthquake.

5.6.2 Wastewater

Similar to the water supply, the long-term goal is for the school be connected to the wastewater backbone system that could provide services in 1-2 weeks. This assumes that wastewater capacity of the downstream system is sufficient to hold waste generated by the school and surrounding area. We recommend that the piping installed by BSD between the utility main and the school building be specifically designed to consider seismic resilience. Seismic bracing of plumbing system components intended for emergency shelter use should be designed to satisfy Risk Category IV seismic bracing requirements in order to provide a high probability of remaining operational after an earthquake. In the short-term, before these wastewater system improvements can be implemented, shelter plans should include potential use of portable toilets. BSD assumes that ARC or other disaster services agency will provide portable toilets to meet the shelter needs.

5.6.3 Natural Gas

The operation of the school as an emergency shelter is not dependent on natural gas. A seismic shutoff valve will be installed at the meter in order to reduce the potential fire hazard associated with natural gas leaks following an earthquake.

5.6.4 Telecommunication

For telecommunications, telecommunication suppliers should be contacted to determine what their level of resilience is, how long they would expect a return to service would take, and if there are any measures that could be taken by BSD to facilitate the return to service. Following a disaster, the emergency management agencies can arrange a portable communication system that can be used on the school campus [such as cell on wheels (COWs) or cell on light trucks (COLTs)]. BSD has its own radio system, which may be operational.

5.7 Summary of Adopted Resilience Design Features

Due to budget and design schedule limitations, not all the resilience features that were discussed as part of this project could be incorporated into the design, construction, and operation of the High School at South Cooper Mountain. The resilience features that have been adopted are summarized in Table 5.2. The intent behind these selected options was to build-in as much flexibility as possible in order to facilitate future resilience upgrades as funding becomes available.

5.8 Long-term Strategies

The resilient design features being implemented as part of this project are intended to provide a building structure that is safe to occupy after a large earthquake and that incorporates certain features (limited emergency power, ventilation fans in common areas, building connections for portable water tanks, etc.) that will reasonably facilitate use of the High School at South Cooper Mountain as an emergency shelter.

As additional funding becomes available or the cost of certain technology (PV inverters, storage batteries, etc.) decreases, it may be possible to provide additional resilience features that will make using the school as an emergency shelter easier or enable additional services to be provided by the shelter.

In this project, it has been assumed that the post-disaster availability of certain infrastructure services (i.e., water, wastewater, liquid fuel for generator, etc.) will improve over time as Oregon undertakes a concerted effort to invest in resilience. It is recommended that BSD continue to engage Stakeholders in an ongoing dialogue to keep track of the pace of these assumed improvements. For instance, if CWS decides that it will not be able to provide a future hardened backbone wastewater collection system at the High School at South Cooper Mountain, then it may be appropriate to consider adding on-site wastewater storage capacity.

Table 5.2 High School at South Cooper Mountain - Adopted Resilience Design Features

(330,000 SF, 2,200 students, 3-story plus partial basement, building cost $90M)

Resilience Feature	Cost Estimate
1) Design building structure's lateral-force resisting system for seismic Risk Category IV	$500,000
2) Provide 500 kW emergency generator with 96-hour run time fuel storage. Emergency generator, switch gear, ventilation fans, and other equipment that is expected to be operational after an earthquake should satisfy the special certification requirements of ASCE 7-10, which is referenced by the OSSC	$330,000
3) Provide electrical service to power lighting and ventilation fans in common areas and gymnasium on emergency power; does not provide heated or conditioned air	$8,000
4) Provide stub-outs at building exterior to allow use of portable water tank and associated pump to supply water to key building areas: kitchen, locker rooms & showers, drinking fountains in common spaces and restrooms serving the Dining Commons	$15,000
5) Provide two electrical outlets in kitchen on emergency power to allow hot plates for water boiling, etc.	$5,000
6) Provide natural gas seismic shutoff valve at meter	Negligible
7) Provide hardened water service line from BWD water line to building	TBD
8) Provide hardened sanitary sewer service line from CWS sewer line to building	TBD
9) Provide seismic bracing/anchorage design of nonstructural components based on Risk Category III requirements except that those components required for use of the school as emergency shelter (as specified in Sections 5.5 and 5.6) satisfy Risk Category IV requirements	Negligible
Approximate Total	**$900,000**

6.0 Recommendations for Middle School at Timberland

6.1 Site Layout

In addition to the potential use of the Middle School at Timberland for a shelter, the County Emergency Management Cooperative and the American Red Cross both see important uses for the school grounds as well. The school site can provide services for the on-site distribution of supplies and services for both the initial 30 days (before school reopens), and for additional time as required.

The most important element for on-site distribution is the proposed parking, loading, and circulation system off of NW 118th Avenue and NW Stone Mountain Lane. This circulation is sized for bus circulation and will allow one-way traffic for vehicles to enter and obtain supplies and services from semi-trailers or tents situated in the parking areas on either side of the roadway (see Figure 6.1). The fact that the site has two such circulation system allows flexibility of use. It would also allow this function to continue past 30 days (after an event), allowing the school to reopen (albeit with reduced parking capacity).

The middle school site has provisionary sites for up to six portable classrooms. Provided these are not occupied by future classrooms, these sites would be available for use during relief efforts as well. It was noted that there is one water/sewer connection for an "Umbilical cord" to an emergency shelter and shower, which would add operation flexibility.

The middle school has a loading dock that can accommodate small trucks. Semi-trucks can unload in the bus loading area and move supplies into the loading area. There is also a dock lift for trucks or supplies that cannot be unloaded at the dock.

6.2 Structural System and Shelter Characteristics

To serve as a shelter, the building needs to meet certain requirements established by the shelter provider. The essential requirement is that the building be safe to occupy. To provide a high probability that the building will be safe to occupy after a large earthquake, the lateral-force resisting system of the building should be designed as an essential facility (i.e., Risk Category IV) per the requirements of the 2014 Oregon Structural Specialty Code (OSSC, 2014), resulting in improved performance over typical Risk Category III school design.

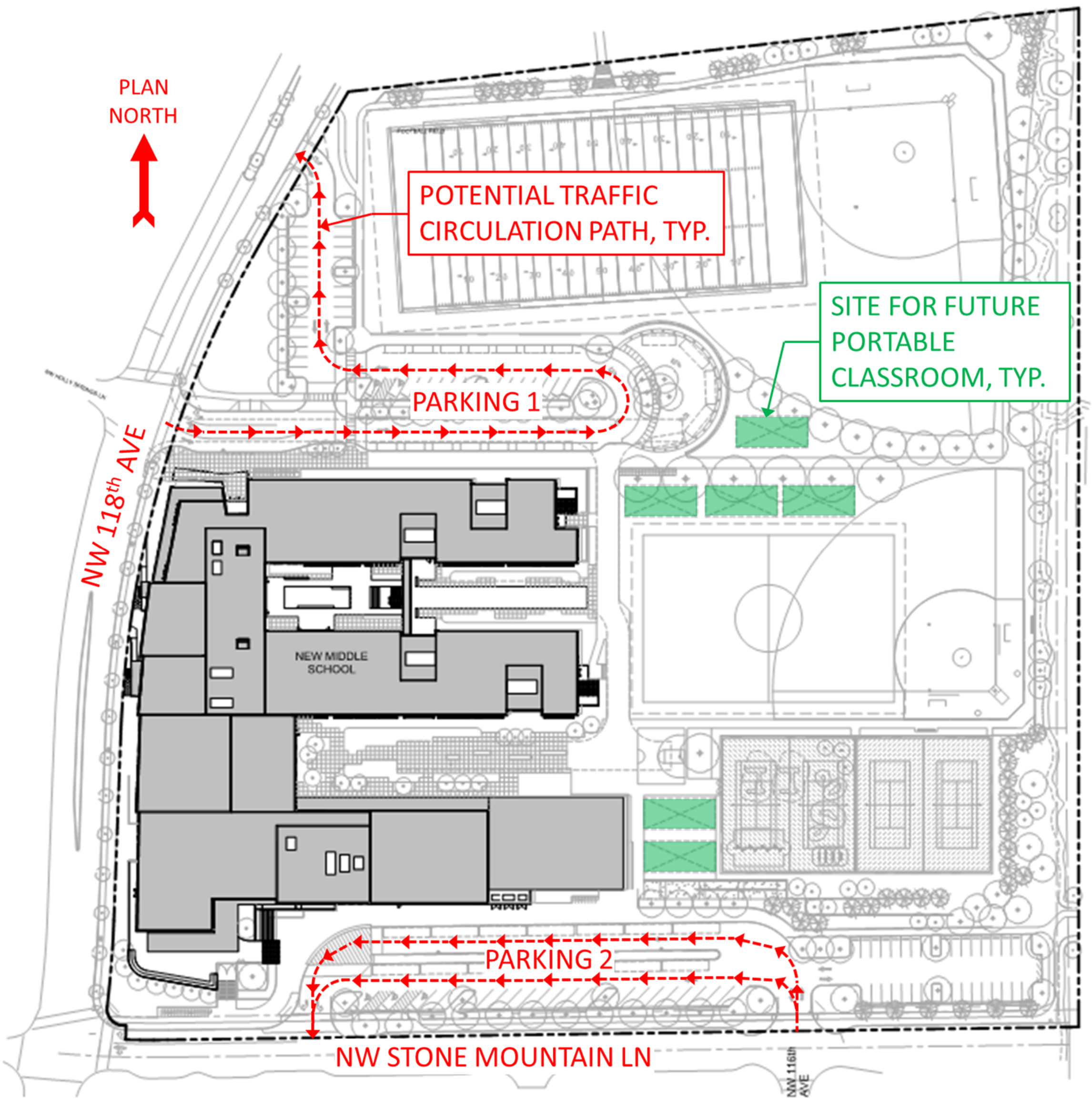


Figure 6.1 Middle School at Timberland Site Plan
(adapted from Mahlum Architects drawings dated January 26, 2015)

The American Red Cross indicated that once the question of having a safe building is addressed, the minimum shelter requirements are very basic:

- Thermal Comfort: A wide temperature range is acceptable.
- Natural Ventilation: Being able to bring fresh air is important.
- Lighting: They can make do with battery lanterns and flashlights if necessary.

To meet and/or exceed the above ARC minimum shelter requirements, it is also important that nonstructural components be adequately braced or anchored. Although it is desirable for all nonstructural components to meet Risk Category IV seismic requirements, Risk Category III requirements would still be reasonably adequate to ensure the building to meet and/or exceed the minimum shelter requirements provided that (1) those components required for use of the school as an emergency shelter (as specified in Sections 6.5 and 6.6) satisfy Risk Category IV requirements and (2) equipment that is expected to be operational after an earthquake (i.e., emergency generator, automatic transfer switch, ventilation fans, etc.) satisfies the special certification requirements of ASCE 7-10 Section 13.2.2 (ASCE, 2010).

The approximate shelter sleeping capacity for the identified usable spaces is indicated in Table 6.1. Figure 6.2 shows the location of these different sleeping areas as well as other planning considerations for shelter operation. The Commons (dining area) on the lower level has seating capacity for approximately 360 people.

Table 6.1 Middle School at Timberland - Shelter Approximate Sleeping Capacity

Area	Capacity
Main Gym	140
Auxiliary Gym	80
Multi Purpose	50
Choir Room	25
Band Room	30
Classrooms (40 rooms @10 people/room)	400
Total	**725**

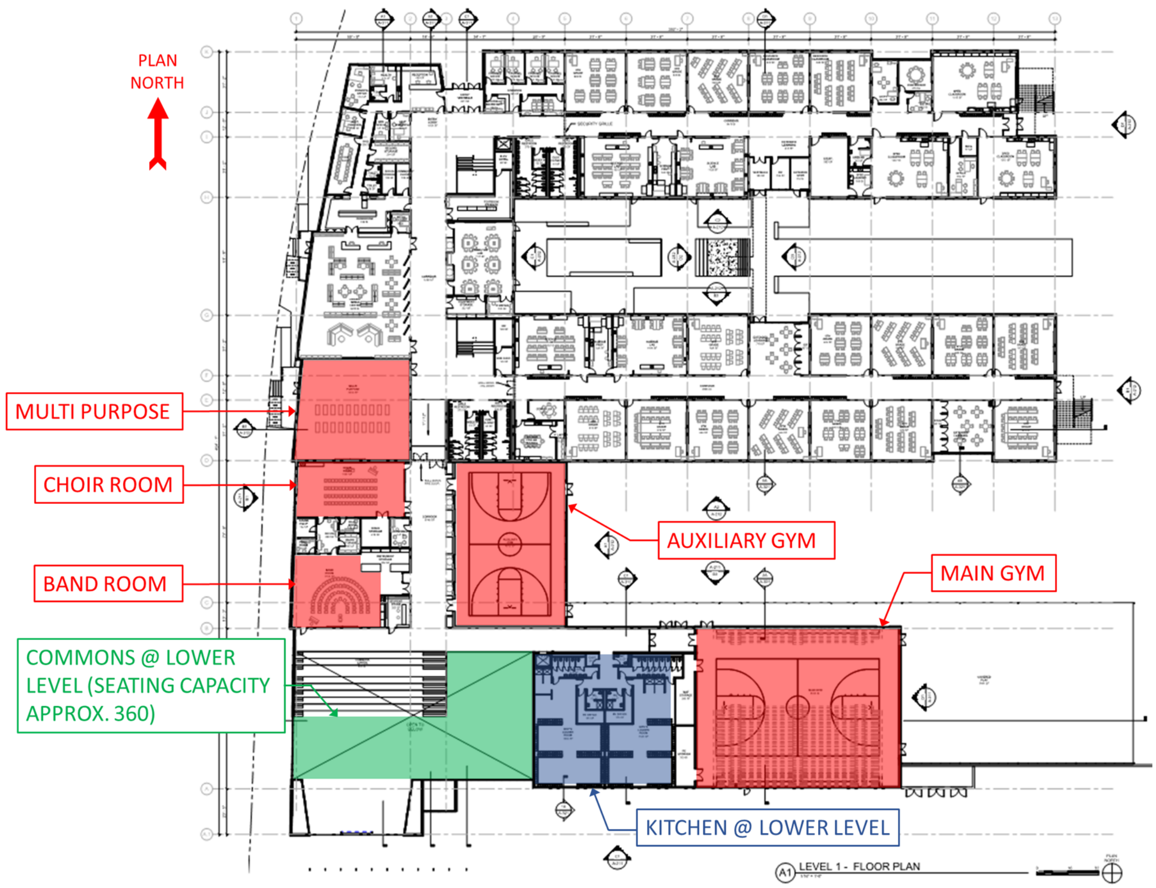


Figure 6.2 Middle School at Timberland First Floor Plan
(adapted from Mahlum Architects drawings dated January 26, 2015)

6.3 Shelter Agreement and Memorandum of Understanding

Before the school is used as a shelter, the ARC has an agreement form that will be used to delineate limitations and responsibilities. This agreement is currently based on the ad-hoc selection process following a disaster. With the school being prepared in advance, a memorandum of understanding should be developed between BSD, the local emergency service agencies, and the ARC.

6.4 Heating, Ventilation and Cooling

In discussions with the design team, a base performance level was identified:

- Heating: With the amount of insulation provided and the heat generated by people, lights, and equipment, the space temperature will likely be at acceptable levels without the need for additional heating in the heating months, assuming occupants will be dressed in jackets or wrapped in blankets. Heating is only provided for the commons, gymnasium, administrative wing and locker room area.

- Ventilation and Cooling: The goal for desirable indoor temperature in the building during hot weather will be no more than the outside temperature. This would be achieved by adequate natural ventilation from doors, windows, and exhaust fans (which would need to be on the emergency power circuit).

6.5 Emergency Power

Emergency power is a basic building code requirement, but code only establishes a minimal level of service that provides power for egress lighting and for the operation of elevators (as required) for egress purposes. This power only needs to be provided for a short time frame. While emergency power is not a requirement for using the building as a shelter, there are a number of potential actions that would increase the school's usefulness as a shelter.

- Provide largest sized generator the budget will allow.
- Provide for hooking up additional emergency power generators.
- Have exhaust fans, common-lighting and other functions useful for shelter use be part of emergency circuit.
- Provide for on-site use of PV power array with inverter.

BSD has selected to provide a 450 kW emergency generator with 96-hour run time fuel storage. The emergency generator will provide electrical service to power lighting and ventilation fans in common areas, gymnasium and administrative offices, and two electrical outlets in kitchen to allow hot plates for water boiling, etc. BSD will not provide emergency power for conditioned air.

Seismic bracing of electrical system components intended for emergency shelter use should be designed to satisfy Risk Category IV seismic bracing requirements, in order to provide a high probability of remaining operational after an earthquake. Emergency generator, automatic transfer switch, ventilation fans (in common areas and gymnasium), and other equipment that is expected to be operational after an earthquake should satisfy the special certification requirements of ASCE 7-10 Section 13.2.2 (i.e., seismic rated).

The proposed kitchen of the middle school is for serving of prepared meals that either are heated in gas fueled ovens or electric soup kettles (which can be used to boil water). BSD does not intend to provide emergency power to operate kitchen refrigerators, freezers, or perform any significant cooking. BSD assumes that ARC or other disaster services agency will bring in prepared food to the shelter.

6.6 Utilities

The long-term goal is that the middle school site be on the backbone systems for the service providers. This would minimize the disruption time and make use of the school as a shelter much easier. The return to service for each of the services should be determined and reviewed over time. The use of emergency power has been discussed in the section above.

6.6.1 Water

For water service, the middle school should be on the backbone system to receive water within 24 hours once the system is upgraded to its resilience goals. The piping installed by BSD between the utility main and the school building will be specifically designed to consider seismic resilience. Until TVWD has completed their backbone system improvements, water would need to be brought in to the site. BSD has selected to provide quick-connect stub-outs at the building exterior to allow use of a portable water tank and associated pump to supply water to key building areas including: kitchen, locker rooms & showers (cold water only), and drinking fountains in common spaces. An electrical connection for this pump would be beneficial, however it is not essential. Seismic bracing of plumbing system components intended for emergency shelter use should be designed to satisfy Risk Category IV seismic bracing requirements in order to provide a high probability of remaining operational after an earthquake.

BSD does not intend to provide a hot water heater on a backup energy source at the shelter. BSD assumes that ARC or other disaster services agency will provide portable shower units, if necessary.

BSD assumes that ARC or other disaster services agency will provide an appropriate fire watch if there is no water available for the fire suppression system, or if the fire suppression system is damaged by the earthquake.

6.6.2 Wastewater

Similar to the water supply, the long-term goal is for the school be connected to the wastewater backbone system that could provide services in 1-2 weeks. This assumes that wastewater capacity of the downstream system is sufficient to hold waste generated by the school and surrounding area. The piping installed by BSD between the utility main and the school building will be specifically designed to consider seismic resilience. Seismic bracing of plumbing system components intended for emergency shelter use should be designed to satisfy Risk Category IV seismic bracing requirements in order to provide a high probability of remaining operational after an earthquake. In the short-term, before these wastewater system improvements can be implemented, shelter plans should include potential use of portable toilets.

6.6.3 Natural Gas

The operation of the school as an emergency shelter is not dependent on natural gas. A seismic shutoff valve will be installed at the meter in order to reduce the potential fire hazard associated with natural gas leaks following an earthquake.

6.6.4 Telecommunication

For telecommunications, telecommunication suppliers should be contacted to determine what their level of resilience is, how long they would expect a return to service would take, and if there are any measures that could be taken by BSD to facilitate the return to service. Following a disaster, the emergency management agencies can arrange a portable communication system that can be used on the school campus [such as cell on wheels (COWs) or cell on light trucks (COLTs)]. BSD has its own radio system, which may be operational.

6.7 Summary of Adopted Resilience Design Features

Due to budget and design schedule limitations, not all the resilience features that were discussed as part of this project could be incorporated into the design, construction, and operation of the Middle School at Timberland. The resilience features that have been adopted are summarized in Table 6.2. The intent behind these selected options was to build-in as much flexibility as possible in order to facilitate future resilience upgrades as funding becomes available.

6.8 Long-term Strategies

The resilient design features being implemented as part of this project are intended to provide a building structure that is safe to occupy after a large earthquake and that incorporates certain features (limited emergency power, ventilation fans in common areas, building connections for portable water tanks, etc.) that will reasonably facilitate use of the Middle School at Timberland as an emergency shelter.

As additional funding becomes available or the cost of certain technology (PV inverters, storage batteries, etc.) decreases, it may be possible to provide additional resilience features that will make using the school as an emergency shelter easier or enable additional services to be provided by the shelter.

In this project it has been assumed that the post-disaster availability of certain lifeline services (i.e., water, wastewater, liquid fuel for generator, etc.) will improve over time as Oregon undertakes a concerted effort to invest in resilience. It is recommended that BSD continue to engage Stakeholders in an ongoing dialogue to keep track of the pace of these assumed improvements. For instance, if TVWD decides that it will not be able to provide a future hardened backbone water supply at the Middle School at Timberland, then it may be appropriate to consider adding on-site water storage capacity

Table 6.2 Middle School at Timberland - Adopted Resilience Design Features

(165,000 SF, 1,100 students, 2-story, building cost $43M)

Resilience Feature	Cost Estimate
1) Design building structure's lateral-force resisting system for seismic Risk Category IV	$310,000
2) Provide 450 kW emergency generator with 96-hour run time fuel storage. Emergency generator, switch gear, ventilation fans, and other equipment that is expected to be operational after an earthquake should satisfy the special certification requirements of ASCE 7-10, which is referenced by the OSSC	$400,000
3) Provide electrical service to power lighting and ventilation fans in common areas and gymnasium on emergency power; heating is only provided for the commons, gymnasium, administrative wing and locker room area, does not provide conditioned air	Included in Total
4) Provide quick-connect stub-outs at building exterior to allow use of portable water tank and associated pump to supply water to key building areas: kitchen, locker rooms & showers, and drinking fountains in common spaces	$20,000
5) Provide two electrical outlets in kitchen on emergency power to allow hot plates for water boiling, etc.	$5,000
6) Provide natural gas seismic shutoff valve at meter	Negligible
7) Provide hardened water service line from TVWD water line to building	TBD
8) Provide hardened sanitary sewer service line from CWS sewer line to building	TBD
9) Provide seismic bracing/anchorage design of nonstructural components based on Risk Category III requirements except that those components required for use of the school as emergency shelter (as specified in Sections 6.5 and 6.6) satisfy Risk Category IV requirements	Negligible
Approximate Total	**$750,000**

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7.0 Recommendations for Future Beaverton School Projects

The lessons learned from the resilience planning process for the High School at South Cooper Mountain and the Middle School at Timberland demonstrate that the availability and effectiveness of BSD school sites to serve as shelters can be achieved at an affordable price. The reasoning and logic behind the adoption of resilient design features should be tailored to each school, though the overarching concepts are, in general, directly applicable to the design and construction of other new schools and seismic retrofit of existing schools. For the next new BSD schools, we recommend that the District carry out this style of site-specific planning that includes a stakeholder workshop during the scoping and siting phase of the projects. This will alert the design teams during the team selection phase of the District's intentions and desire to implement the most efficient solutions. Design team selection criteria should include consideration of the design team's resilience experience, desire to embrace resilient design, and ability to implement fresh and improved resilient solutions.

For existing schools undergoing seismic rehabilitation and infrastructure modernization, we recommend a similar site-specific study and workshop that includes in the program a seismic retrofit to an appropriate performance level using the performance-based design and quality assurance features defined in ASCE 41-13 *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2013). We would recommend evaluating and retrofitting middle and high school buildings (and elementary schools, as appropriate) that may be added to the emergency shelter inventory to achieve the Immediate Occupancy performance objective for a BSE-1N level earthquake and the Life-Safety performance objective for a BSE-2N level earthquake. This is essentially equivalent to designing the retrofit to be consistent with the expected structural performance of new schools designed as Risk Category IV buildings (emergency shelters) per the Oregon Structural Specialty Code, as recommended in this report.

BSD should apply for the Oregon Seismic Rehabilitation Grant Program to assist in funding the seismic retrofit of its existing school buildings.

8.0 Next Steps

The resilient design features being implemented by the Beaverton School District in the new High School at South Cooper Mountain and the new Middle School at Timberland will result in safer schools that will be more easily used for shelters following a Cascadia earthquake (or any other disaster). These resilient design features, along with other proposed concepts, can be used as the basis for improved resilient design in other new school construction or renovations.

In addition, there are a number other measures that should be considered to improve resilience. These measures are described in the following sections and include: the implementation of a memorandum of understanding with other stakeholders, post-event inspection, ongoing dialogue with utility providers and emergency management agencies, 10-year review, resilience implementation, resilience and sustainability coordination, documentation of construction process for education materials, and resilience funding.

8.1 Memorandum of Understanding between Stakeholders

We recommend a memorandum of understanding (MOU) between the Beaverton School District, the local emergency service agencies, and the American Red Cross be created to replace the ad-hoc shelter selection process that currently is in place. The memorandum would delineate responsibilities and limitations on each of the parties to help give certainty to the use of the school as a shelter to allow for coordinated emergency planning and recovery efforts. The MOU would provide for the smooth transition of the school into shelter mode following a declared disaster and allow effective use of the school site. This would include procedures of how the transition would take place in case the school needs to provide shelter to students and staff.

Separate MOU's should be established with Tualatin Valley Water District, City of Beaverton Water Division, Clean Water Services, PGE, and NW Natural to help ensure that the High School at South Cooper Mountain, the Middle School at Timberland, and other schools in the District (that would potentially be used for shelters) would be part of the priority locations that need to be served by their backbone systems.

The development of the MOU should include community participation. While these resilience measures improve emergency response and recovery efforts, they do come at a cost and it is important the community understands and supports these efforts. It also will help the community understand the interconnections between these various efforts.

8.2 Resilience Implementation

Resilient design features have not yet been adopted as common design and construction practices, therefore additional project oversight by BSD may be required to ensure proper implementation. We recommend that BSD develop project management procedures that ensure resilience concepts are being implemented on all new construction and renovation projects.

Achieving a safe and usable performance level in these buildings requires identifying an appropriate performance-based design criteria along with a proper design, detailed peer review and plan check during design, and comprehensive inspection during construction. The need for this multi-faceted process is illustrated in every major earthquake when it is observed that excessive damage is caused by a deficiency in one or more of these areas.

After the emergency generator and the fuel tank are installed at each school, BSD shall rely on qualified facility staff to develop a comprehensive maintenance program for both the generator and the fuel. Routine maintenance and testing of the generator on an appropriate schedule will help to ensure it will run properly when needed. The facility staff needs to pay attention to the fuel level in the tank, and take appropriate samples to ensure that the fuel has not degraded beyond acceptable limits.

8.3 Post-event Inspection

Before these schools (or any building) can be used for an emergency shelter, they will need to be inspected for safety following an earthquake or other disaster. The minimum inspection protocol for the safety inspection would be to follow ATC-20 *Procedures for Postearthquake Safety Evaluation of Buildings* (ATC, 1989). The ATC-20 procedure can be used by engineers and architects who have had appropriate training and have been deputized by the local building official after an event to assist in performing building safety inspections. It is our understanding that the database of ATC-20 trained professionals in Oregon is not up to date and that ongoing efforts are attempting to improve the program, given how important these inspections will be in the immediate response to a Cascadia earthquake.

Given the importance of using the schools as an emergency shelter, the Stakeholders should consider establishing a more stringent inspection program based on an engineering evaluation of the structural and non-structural features of the buildings. After construction of each school is completed, we recommend that BSD retain a structural engineer to conduct a seismic evaluation of the building's structural and nonstructural components using ASCE 41-13 *Seismic Evaluation and Retrofit of Existing Buildings* Tier 1 checklists, and develop a Building Occupancy Resumption Program (BORP) – a pre-certified emergency inspection program for the selected facilities. The structural engineer would assess a buildings structural performance, identify areas with potential vulnerability, and summarize in the BORP the locations where structural and nonstructural damage would likely occur during a major seismic event. The purpose of a BORP is to allow a quick and thorough evaluation of possible damage to a structure by qualified persons familiar with the structural design and life-safety systems of the building after a major seismic event. This private emergency inspection could facilitate rapid decisions regarding the use of the building as an emergency shelter. Pre-arranged emergency inspection could reduce inspection delays, as personnel would be assigned to respond to the designated BSD facilities within hours after an earthquake impacting the region and would have pre-authorization by the local building official to tag the building with the findings of their inspection.

This requirement can be part of the Memorandum of Understanding between the Beaverton School District, County and the American Red Cross. Please note, that with the potential for aftershocks, the school buildings will likely need to be re-inspected following each aftershock above a certain threshold level of shaking.

8.4 Annual Ongoing Dialogue between Stakeholders

As part of the MOU, there should be annual ongoing dialogue between the Beaverton School District, emergency management agencies, American Red Cross, and utility providers to monitor progress in implementation of their emergency planning and resilience efforts. This will be especially true as the State, local communities, and local utility providers begin implementing resilience plans. The Oregon Legislature has legislation for implementing the first phase of the *ORP* recommendations, and other legislation is likely to follow in future sessions. Utility service providers also are starting to develop resilience plans to ensure that their systems can provide minimum services levels and recover quickly. As this information becomes available, it will allow testing and review of the assumptions from this report and help improve future school resilience design.

8.5 10-year Review

Since conditions will change over time, it is recommended that BSD conduct 10-year reviews of resilience efforts at the High School at South Cooper Mountain, the Middle School at Timberland, and other schools where similar resilience concepts will be integrated into design, construction, and operation. This review should include examining the existing conditions at the school, the emergency planning of the County and City Emergency Management, the status of the service providers' systems, and the status of all stakeholders' resilience plans. In addition, it should review the current level of technology that may be ready of economical implementation (i.e. connection of PV array to emergency power system, batteries, etc.).

8.6 Resilience and Sustainability Integration

While not explored extensively as a part of this project, there are many potential overlaps between the BSD's sustainability goals and resilience. As BSD continues the resilience planning process in the future, it is recommended that they explore how resilient design features can be integrated with sustainability and become a part of the District's culture.

The high performance school concepts utilized for sustainable design often deal with the exterior envelope of the building, which is often the area where lateral bracing for seismic design takes place. The structural shell and the building envelope are both areas that are difficult to change or adapt later, so doing as much as possible during construction pays dividends later. They are the backbone upon which performance adjustments can be added.

The sustainability standards, which BSD has already embraced, utilize natural lighting and ventilation, reduce energy usage for heating and cooling all reduce power needs and make the school functional when the power is disrupted. Likewise efforts to reduce water usage, especially potable water usage, means that there can be more water available for emergency uses. The use of non-potable water resources can also free up potable water when supplies are limited.

8.7 Document Process for Educational Materials

The current effort to create resilient schools that can be used for shelters following a major earthquake and other disasters presents a unique educational opportunity. By documenting the planning, design and construction process, educational materials can be developed to help students understand the risk of the disaster themselves, how they will affect the school and the community, and let them know what will happen in the case of a disaster. This approach has been shown to be effective in transmitting information to parents, and given that there is likely time before a Cascadia earthquake happens, it can help provide generational knowledge in the community about preparedness. The *ORP* established the concept of improving Oregon's disaster resilience over the next 50 years. The BSD has the opportunity to educate today's students on the importance of enhancing the disaster resilience of local communities, the region, state, and nation. This is especially important since today's students will be among main drivers advancing Oregon's resilience over this 50-year journey.

8.8 Resilience Funding

Available funding for disaster resilience improvements is currently very limited. Discussions with City, County, State and federal government officials have indicated broad support for improving Oregon's disaster resilience, but funding sources are few and far between. This project has demonstrated that it does not necessarily take a large investment to improve disaster resilience on a project by project basis, however increased financial resources can lead to even higher levels of resilience. The Beaverton School District and the community that it serves are encouraged to work with their legislative representatives to develop incentive-based resilience funding programs (similar to those established by Energy Trust of Oregon). These programs can be applied across the state for increased investments in resilience upgrade design for new and existing school buildings to enhance statewide disaster resilience.

9.0 Look Ahead

Following the President's Climate Action Plan issued in June of 2013, the National Institute of Standards and Technology (NIST) convened a team to develop a community-based resilience framework against all hazards and provide planning guidelines for buildings and infrastructure systems. Building upon SEFT's experiences from the development of the *ORP* and as one of the authors for the NIST framework, we feel strongly that building community resilience is still in its developing stage and is rapidly evolving. It is clear that there is a lot of work ahead of us and many ideas have yet to be explored. Although SEFT is at the forefront of developing resilience guidelines, we are far from knowing everything about resilience; throughout this project SEFT has worked with the BSD team and regional stakeholders to develop strategies to bring the latest resilience thinking, concepts, and ideas to the District.

These resilience planning efforts have been based on the information available to the team at the time this project was conducted. It is expected that, as additional resilience planning activities are conducted by the various stakeholders, additional and evolving information on the expected post-earthquake performance of infrastructure systems will become available. Additionally, strategies to address identified gaps in the disaster performance of infrastructure systems will adapt over time. As discussed in Sections 8.4 and 8.5, it is recommended that BSD maintain an ongoing dialogue with stakeholder partners and update this BSD Resilience Plan on a routine basis.

The concept of resilience planning is still in its formative stages. BSD has chosen to position themselves at the leading edge of resilient schools because of the unique opportunity afforded to them by the design and construction of the High School at South Cooper Mountain and the Middle School at Timberland. As highlighted by Dick Steinbrugge's telling of the "Starfish story" at the BSD Resilience Workshop, doing something now is better than waiting to find a perfect solution in the future.

"Don't let the perfect be the enemy of the good." — adapted from Voltaire

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Appendix A: US and International Examples of Schools as Emergency Shelters

A.1 US Examples

A.1.1 Hurricane Sandy (2012)

When Hurricane Sandy struck the East Coast of the US in the fall of 2012, thousands of people were displaced from their homes due to flood waters. Emergency shelters, like the one shown in Figure A.1 were opened at schools in New York, New Jersey, and Rhode Island (US Department of Education, 2012).

Figure A.1 Red Cross Shelter in School Gymnasium
(American Red Cross)

A.1.2 Florida Enhanced Hurricane Protection Areas

Florida Building Code (FBC, 2014) requires new educational facilities for school boards and community college boards to have appropriate areas designed as enhanced hurricane protection areas (with certain exceptions). These spaces are intended to provide emergency shelter and protection for people for a period of up to 8 hours during a hurricane. The building code provisions include criteria for basic occupant life safety and health requirements, including: means of egress lighting, sanitation, ventilation, fire safety, and minimum required floor area per occupant.

A.1.3 California Planning Guide

After the 1994 Northridge Earthquake, the California Office of Emergency Services prepared *Schools as Post-Disaster Shelters: Planning and Management Guidelines for Districts and Sites* (OES, 1995) to aid in preparation of school facilities and personnel for emergency shelter operations. The guide provides several examples of how community members converged on schools, before any official shelter locations were announced, because the schools were perceived to be a safe shelter location. Examples are also presented that demonstrate the importance of proper coordination and communication for effective shelter operations.

A.1.4 Anchorage School District

The Anchorage, Alaska School District has developed plans to shelter their students and staff for up to 72 hours if a disaster prevents students from reuniting with their parents or guardians (ASD, 2015). The district has designated 22 of their elementary, middle, and high schools to serve as potential emergency shelter sites and has stocked each site with emergency supplies (see Figure A.2). The shelters can also generate their own power and heat for a minimum of 72 hours, if commercial utility services are disrupted.

Figure A.2 Emergency Supplies Stocked in 20-foot Trailer
(ASD, 2015)

A.2 International Examples

A.2.1 Great Sumatra Earthquake and Tsunami (2004)

After the Great Sumatra earthquake and tsunami, government personnel set up relief camps to provide temporary shelter and food to individuals impacted by the disaster. The majority of these shelters were set up in school buildings (see Figure A.3), college buildings, and government offices (Murty, et al., 2006). Medical support offices were integrated into many shelters to provide efficient access to medical care (see Figure A.4). Schools were closed around the time of the earthquake because of the Christmas and Pongal festivals, so use of the schools as shelters did not initially impact the normal operation of the schools. Individuals were transferred to more permanent shelters approximately one month after the earthquake so that schools could re-open, a little later than they normally would have after the Pongal festival.

Figure A.3 School being used as government relief camp in Port Blair
(Murty, et al., 2006)

Figure A.4 Medical support as part of relief camp in a Port Blair school
(Murty, et al., 2006)

A.2.2 Tohoku Earthquake and Tsunami (2011)

Within minutes after the Tohoku earthquake a tsunami warning was issued and residents near the coastline evacuated to pre-designated evacuation sites (several of which are schools) as practiced regionally on September 1st of each year as part of Disaster Reduction Day (Brittingham and Wachtendorf, 2013). These school evacuation sites were later transformed into general population shelters and food distribution points, as shown in Figure A.5. School parking lots and playing fields were also used as locations to erect temporary housing.

Figure A.5 Food distribution at a shelter in school gymnasium
(AP Photo/Matt Dunham)

A.2.3 Nepal Earthquake (2015)

Based on news reports and early field reconnaissance, there is a widespread use of schools as emergency shelters and supply distribution points following the April 25, 2015 earthquake in Nepal (EERI, 2015). School classrooms are being occupied as shelters (see Figure A.6) and individual schools are reportedly housing between 100 to 1,500 displaced individuals. Beginning in about 1998, the National Society for Earthquake Technology in Nepal has spearheaded the seismic retrofit of a number of schools as part of the School Earthquake Safety Program. Observations indicate that these retrofit school buildings performed reasonably well in the earthquake.

Figure A.6 School classroom transformed into a shelter
(The Times Photo/Bhirkuti Rai)

A.3 References

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Appendix B: Seismic Design Requirements for Nonstructural Components for Risk Category III and IV

The table on the following page summarizes the seismic design requirements for nonstructural components for Risk Category III and IV buildings per the *2014 Oregon Structural Specialty Code* and ASCE 7-10 *Minimum Design Loads for Buildings and Other Structures*.

Importance Factor = 1.5[a]	
Risk Category III (i.e., school)	*Risk Category IV (i.e., emergency shelter)*
1. Components required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems and egress stairways. 2. Components that convey, support, or otherwise contain toxic, highly toxic, or explosive substances in sufficient quantities to pose a threat to the public is released.	1. Components required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems and egress stairways. 2. Components that convey, support, or otherwise contain toxic, highly toxic, or explosive substances in sufficient quantities to pose a threat to the public is released. 3. Component is attached to a Risk Category IV structure and it is needed for continued operation of the facility.
Importance Factor = 1.0	
All other components.	
Exemptions	
1. Furniture (except permanent floor supported storage cabinets and shelves over 6 ft. in height). 2. Temporary or moveable equipment. 3. Mechanical and electrical components where all the following apply a. The component importance factor is equal to 1.0; b. The component is positively attached to the structure; c. Flexible connections are provided between the component and associated ductwork, piping, and conduit; and either i. The component weights 400 lb or less and has a center of mass located 4 ft or less above the adjacent floor level; or ii. The component weighs 20 lb or less or, in the case of distributed systems 5 lb/ft or less.	
Special Seismic Certification Requirements for Designated Seismic Systems	
Risk Category III (i.e., school)	*Risk Category IV (i.e., emergency shelter)*
None	Mechanical and electrical equipment that must remain operable following the design earthquake shall be certified by the manufacturer as operable on the basis of approved shake table testing or experience data.

[a] Component importance factor equal to 1.5 is used to increase the design forces on certain nonstructural building components.

Appendix C: Workshop Attendees and Meeting Minutes

Name	Affiliation	Contact Information
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Scott Johnson	Beaverton School District, Construction Project Manager	(503) 356-4552 Scott_Johnson@beaverton.k12.or.us
Siobhan Kirk	Tualatin Valley Fire & Rescue	Siobhan.Kirk@tvfr.com
Michael Kummerman	NW Natural Emergency Manager	(503) 333-7904 Michael.Kummerman@nwnatural.com
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Steve Muir	Washington County Emergency Cooperative, Emergency Manager	(503) 846-7582 Steven_Muir@co.washington.or.us

Name	Affiliation	Contact Information
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Kent Yu	SEFT Consulting Group	(503) 702-2065 kentyu@seftconsulting.com
Kurt Zenner	Mahlum Architects	(503) 224-4032 kzenner@mahlum.com

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4800 SW Griffith Drive, Suite 135
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Meeting Minutes

ATTENDEES:	See attached sign-in	**PROJECT:**	BDS Resilience Planning
		PROJECT #:	B14030.00
		DATE:	2/10/15
		TIME:	1 PM to 4 PM
		LOCATION:	TVF&R Command Center
		BY:	Jay Raskin

SUBJECT: Beaverton School District Resilience Planning

General Meeting Description:
The purpose of this meeting was (1) to understand current practice for emergency shelters, including capacity, duration, and level of human services; and (2) to formulate a new integrated approach for building resilience into school design.

Specific Discussion Items:

1) Introductions – Attendee's introduced themselves and indicated their affiliation.

2) Vision for New BSD Schools & 2014 Bond Program – Richard Steinbrugge indicated that the District was interested in exploring how to prepare the District and the surrounding communities for the eventual Cascadia earthquake. He felt that building these seven new schools properly will make a difference and perhaps become a model for other schools.
    a. The Oregon Resilience Plan (ORP) is the guide BSD is using to design the schools to a higher standard and to use the schools to be a refuge and shelter following an earthquake.
    b. There is lot we don't know and the District is looking for this group to form decisions.
    c. The District is also looking for financial and technical partners to help, such as the offer by PGE for Dispatchable Power Generation for the high school.
    d. The effort needs to plan for future solutions, not everything has to be in place when the school opens. There needs to be the ability to add systems to the schools as resources become available.
    e. It is also understood that we may make "wrong" (or less than perfect) decisions, but that this is okay since it shows we tried to consider everything.

3) Current Practice for Shelter. – Kent Yu asked Curtis Peetz from the American Red Cross (ARC) what the current practice is for providing emergency shelter, including what ARC does with schools for disasters other than a Cascadia earthquake.
    a. ARC has a close relationship with city, county and state partners.
    b. Following a disaster, the ARC uses a set of criteria to inspect existing facilities. They do not have pre-designated shelters, but rather a list of potential public and private facilities that could be used as shelters.

c. The criteria include:
   I. 40 sf/person for sleeping capacity
   II. Fire Marshall approval for dining occupancy
   III. Restroom capacity (1 fixture per 20 people for toilets and shower heads).
   IV. Determination of whether the shelter is for the general population or for those with special needs.
   V. ADA accessibility
   VI. Availability of spaces for health and mental health services.
   VII. Availability of spaces for children's play activities.
d. Schools are ideal for shelters but there are a number of questions that need to be determined before they can be used for shelter:
   i. What are the school district plans for business continuity and the resumption of school?
   ii. Will students be staying at the school immediately following the earthquake?
e. There is a question of who will be the shelter workforce.
   i. Need to keep in mind that in Cascadia everyone will be a victim and it takes time to bring in outside help, especially if arrangements need to be made to house and feed shelter workers.
f. In addition to shelter, the school can also serve as a central point of distribution and additional services (information distribution, cell phone battery charging, etc.).
g. Getting students back to school is part of the recovery process (Note: The ORP recommends school back in session after 30 days as an essential part of recovery efforts).
h. Curtis indicated that the ARC has the right to request the use of facilities for shelter, but the facility owner has the right to refuse, even if there has been a pre-agreement.
i. The ARC takes on responsibility, liability and training for shelters and has agreement forms with the facilities (which can include other groups).
   i. Training is a big issue for support facilities.
   ii. It is possible to pre-position supplies, but ARC needs community buy-in. This has happened in coastal communities.

4) Insuring use of school – Kent asked a series of questions.
   a. Whose responsibility is it to do the post-earthquake inspection assessments to determine whether the building is safe to occupy?
   b. How does ARC handle fire-protection?
      i. They follow fire marshal recommendations and rules, which typically involves a 24 hour fire watch.
      ii. ARC also follows public health official's recommendations and rules.
   c. Levels of service.
      i. ARC initially seeks to get people out of elements. Emergency power is nice but not required.
      ii. Meals woud initially be MRE or self serve if only limited utility services are available.
      iii. Looks to provide for people with special needs.

5) Emergency Management Role – Scott Porter indicated that Emergency Management is the agency that will set up shelters and that the ARC supports the agency. It is the communities to responsibility to provide emergency shelters.
    a. Emergency Management and ARC pick and choose shelters and coordinate for shelter needs.
    b. Jeff Rubin indicated that it is possible to do create a pre-plan for shelter, but this would be ad-hoc due to changing circumstances for each disaster.
    c. TVF&R won't require additional fire protection over what has already been provided for building. It would be helpful to have additional water, but fire-watch is an acceptable solution.
    d. FEMA does not provide basic services, it only offers support to local efforts.
    e. Mike Mumaw indicated the most important thing is to have a safe structure, whether it is entire building or just a part of a building.
        i. He would like to see hook-ups for power generation. It would be ideal if the electrical system was configured to facilitate providing different levels of electrical service within the shelter based on need and the size/number of generators available.
        ii. They can bring in their own communication packs, so there is no need for onsite communications.
    f. Steve Muir mentioned that taking care of pets was part of County services.

6) Long-Term Temporary Shelter:
    a. The ARC looks at long-term temporary shelter and reviews space needs for that as well. They look at the status of buildings surrounding the shelter to see if that population needs to be housed for longer periods. They also look at the percentage of at-risk populations who will need shelter for longer periods.
    b. Jeff Rubin noted that looking at lessons learned from other disasters such as hurricanes, that 30 days is a reasonable time frame, but should consider that these disasters have prior warning, which we will not be the case for earthquakes.

7) Critical Lifelines – Waste Water
    a. Nate Cullen said that there are currently no plans in place to provide wastewater services following a large earthquake, but that they are working towards them. Their first priority is for public health.
    b. They will need lifeline connections to water to maintain flow of sewage and for power to run pump stations.
    c. They have 40 pump stations and are identifying priority pump stations to create a backbone system. They are planning on direct flow to tributaries to keep sewage out of people's back yards.
    d. They need to figure out how schools and essential facilities fit into the prioritization strategy for the system.

8) Critical Lifelines – Water
    a. Mike Britch indicated that TVWD was completing a water master plan that is incorporating resilience, but no road map currently exists.

b. They are determining level of service goals and looking at critical locations such as hospitals and schools. There needs to be community discussion on setting these goals and locations.
c. The improvements will be tiered and built around the backbone system. It will also be opportunistic so it can serve a school if it is close to backbone system.
d. There is around 800 miles of pipe and they are developing new design standards, which will include restrained joints and seismic valves on some tanks.
e. To help create a resilient water supply, they are building a new water treatment plant and supply pipeline from the Willamette River.
f. They also have on-going discussions with their partners.
g. There is a well at the high school site and another well that is part of an Aquifer Storage and Recovery (ASR) system a quarter mile from the site which can provide 1 million gallons a day.
    i. The ASR water is potable.
    ii. The well water is not potable. Uses for well water needs to be determined. This may require a dual piping system. An alternative is to convert this water to potable water.
    iii. Rainwater catchment uses should be factored in with well use.
h. The middle school is not far from Providence St. Vincent Hospital, so the school could potentially be supplied with water from a future backbone system.
i. For schools not close to backbone system, options for water truck distribution are being considered. A new TVWD reservoir will have the ability for direct connections for use by TVF&R, which also could be used for water trucks if they were available.
j. Another option for schools not close to backbone system is utilizing an in-line water storage system. These have been used in Japan but not in the US. The in-line system should be part of the potable water system. It would be fairly easy to stock a three day (3) day supply of water.

9) Critical Lifelines – NW Natural
    a. Mike Kummerman indicated he didn't know the recovery elements of the NW Natural gas system. The earthquake will impact their structures, infrastructure, supplies and communication.
    b. They have made upgrades to their piping and their flow control.
    c. They have compressed natural gas (CNG) and liquid natural gas (LNG) capabilities
    d. They will need power to run their gas supply system.

10) Critical Lifelines – PGE
    a. Bruce Barney indicated that the PGE infrastructure will be okay following the earthquake, but that the switches will be tripped. They will restore critical infrastructure and essential facilities first, followed by shelters.
    b. They will need fuel to run their generators.
    c. PV systems can be used with and without power grid, but there have been problems with inverters, but better ones are now available. This capability comes with additional costs.
    d. PV are only useful during the day unless there is battery backup, but current battery systems have issues. PV should be considered a supplement for now.

e. PAE is looking at PV array for high school and is looking at coordinating it with back up power.
f. There will not be PV used on the middle school.

11) Generator -General discussion
a. Fuel to generators is a concern. The question was raised to what type of fuel should be used. If diesel fuel is used, there will be transportation dependency problems following an earthquake.
b. There is also the question of how much fuel needs to be stored onsite.
c. Ruwan Jayaweera of PAE suggested a duel fuel generator set that relied on natural gas during normal operation and run on propane as back-up.
d. The areas to be powered were discussed as well. Current emergency backup generator needs are based on providing egress lighting. Power of shelter use will need larger generator. The areas to have emergency power need to be determined. Brandon Watt (PAE) suggested that there needed to be minimal lighting in all areas. He posed the question of being able to shed power loads in parts of the building to provide the emergency power.
e. With the dispatchable power generator at the high school, the generator capacity is not as much of an issue.
f. A dispatchable power generator is not an option for the middle school, due to insufficient power loads. For the middle school, one strategy would be the ability to have a small base generator along with the capacity of adding additional generators as the need and availability arises. It was suggested to talk to St. Vincent Hospital to see if power resources could be shared.
g. David Etchart (BSD) reminded us that continuous power generation has planning zone issues.

12) Middle School shelter capacity
a. Kurt Zenner indicated that the middle school is about 162,000 sf and will have 1,100 students plus staff.
b. The middle school common areas will be have 24,000 sf which comes to 600 people based on the 1:40 sf ratio mentioned by ARC. However, this number includes common space that would likely be used for eating. ARC generally uses separate spaces for sleeping and feeding.

13) High School shelter capacity
a. Jim Harold indicated that the high school will have 2,200 students plus staff. The common areas will house 850 people. However, this number includes common space that would likely be used for eating. ARC generally uses separate spaces for sleeping and feeding.
b. Dick thought it would be good to have heat and power to common spaces and asked the question if classrooms could be used as dorm rooms. Brandon Watt (PAE) …
c. Jerry Abdie (KPFF) indicated that the cost increase to Category IV seismic standards for structural system was a small increase from Category III standards.
d. There is a need to look closely at costs of Category IV building standards which includes non-structural elements. Besides seismic bracing for MEP elements,

building elements such as large openings need to be considered. The building will need to look safe as well as be safe.

14) Duration – How long will the school need to function on its own?
   a. Dick indicated that the schools will not be operating as a school until the lifeline infrastructure catches up. There is also the question of how long it will take to resupply and whether prepositioning is needed.
   b. Since the schools may need to house their own students if an earthquake happens during school hours, the School should count on providing for students and staff for 3 to 5 days. The end of this time frame establishes when the school could be expected to become a general population shelter.
   c. Will need to assume that additional supplies will need to be brought in after the initial time frame. Major food chain suppliers are having a discussion about supplying communities following a disaster. Supply chain issues are outside of our control.
   d. Storage of supplies is best in conditioned space since the supplies will keep longer. Current architectural plans for the schools do not include this type of storage space.
   e. The District has a decentralized food distribution system. It does not have a warehouse for food supplies.

15) In general, resilience solutions can be viewed in three categories: brought-in, design flexibility, and built-in.

16) The features to be discussed were divided between the two design teams, BSD and SEFT:
   a. BSD will look at food service/storage and communication.
   b. The high school design team will look at warmth (comfort range), power, and solar.
   c. The middle school design team will look at water and wastewater.
   d. SEFT will look at liquid fuel, natural gas, propane.

17) Information as it is developed should be copied to Kent Yu at SEFT Consulting.

18) The next steps include:
   a. Decentralized meetings with High School and Middle School design teams.
   b. Meetings between the two design teams and different sectors, starting with the water sector.
   c. Review school design narratives.

Action Required	**By**	**Done**
Set up decentralized meetings	SEFT	

Signed: Jay Raskin and Kent Yu