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Big Steps Before the Big One: How the Portland Area Can Bounce Back After a Major Earthquake

City Club of Portland (Portland, Or.)

Big Steps Before the Big One:

How the Portland area can bounce back after a major earthquake

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City Club members will vote on this report between Friday, Feb. 24 and Wednesday, March 1, 2017. Until the membership votes, City Club of Portland does not have an official position on this report. The outcome of the vote will be reported in the City Club of Portland Bulletin Vol. 99, No. 3, dated March 2, 2017, and online at pdxcityclub.org.

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EXECUTIVE SUMMARY

A 9.0 megathrust earthquake at the Cascadia subduction zone will shake the Pacific Northwest to its foundations. This geological event is rare, inevitable and outside humanity's control. How much death and destruction it will deliver, on the other hand, depends very much on how prepared and resilient the Portland area becomes.

Minimizing damage and maximizing community capacities to respond will speed Portland's recovery after a catastrophic earthquake. Identifying those measures that will increase the Portland metro region's resilience was the task given to your committee.

Your committee did not focus on the responses that will be required immediately following an earthquake. Those rescue operations are already being developed, tested and refined. Instead, we identified actions that will help ensure that our unique culture and strong economy can continue to thrive after a major earthquake. This report provides findings, evidence-based conclusions, and recommendations that further two vital goals:

- Mitigating risk to vulnerable physical systems by protecting key transportation and energy lifelines, conserving our natural environment and increasing the seismic resilience of buildings.

- Empowering communities by strengthening social connections, linking diverse organizations and ensuring that critical human needs can be met after a major earthquake.

Your committee was encouraged to find several mitigation initiatives already underway. Most promising were those of the Portland Water Bureau and of the gas and electricity utilities. Programs that prepare residents to help themselves and their neighbors in a quake's aftermath are in place throughout the region, but all of these efforts have a long way to go.

Your committee identified five areas that are linchpins of resilience. For each, this report recommends practical, often relatively low-cost, steps to reduce damage from a Cascadia quake and shorten the time required for the region to rebound.

Fuel

Liquid fuel will power both rescue and recovery. Yet, as Oregon's Resilience Officer told your committee, "Fuel is our Achilles heel." Almost 90 percent of the state's liquid fuel is funneled through fuel tanks at the Critical Energy Infrastructure (CEI) Hub, a six-mile stretch on the west bank of the Willamette River in Northwest Portland. These tanks, some of them more than 100 years old, have been built on dredged soils likely to liquefy in a quake. That would cause the tanks to tilt and rupture, triggering a massive environmental disaster and creating a fuel shortage that would hobble both short-term rescue and long-term rebuilding.

Your committee recommends that state geologists study the CEI Hub's soils and identify techniques for soil hardening that can mitigate this hazard. Furthermore, the governor and Legislature should designate a single

state agency to monitor the CEI Hub's seismic risks, oversee soil hardening, and develop standards for fuel tank construction and retrofitting.

Buildings

In a resilient city, most people would remain in their homes and return to their workplaces after a disaster. But few Portland structures – new construction as well as old – would be functional after a Cascadia earthquake. Buildings constructed after 1994 meet current earthquake standards, but these standards only protect the lives of those inside. A higher seismic standard is necessary to ensure that newly constructed buildings will remain usable, particularly office buildings and multi-family housing.

Existing dangerous buildings, especially older unreinforced masonry buildings, should at a minimum be retrofitted to meet current life safety standards. Your committee also recommends that the Legislature pass a proposed bill requiring seismic resilience disclosure statements for single-family homes at the time of sale.

Lifelines

Portland's brittle transportation network could be devastated by a Cascadia earthquake. Roads, runways, marine terminals, rail tracks, and bridges and their approaches are at high risk from soil liquefaction, landslides and debris from damaged buildings. Immediately after a major quake, our rivers will become barriers to recovery. Even the Sellwood Bridge and Tilikum Crossing likely will be unusable for some time.

It is vital that at least one Willamette River bridge be operational immediately after an earthquake, ideally one on a designated lifeline route such as Burnside Street. The 2002 Burnside Bridge upgrade to life safety standards does not ensure that it will remain usable post-quake. Multnomah County has commissioned an engineering study to determine if it is more cost-effective to retrofit or replace the bridge to meet this higher standard. Your committee recommends this process be expedited so that work can begin within three years.

People

Fuel, buildings and even bridges don't make Portland. The families and neighbors, executives and food cart operators, bikers and brewers, everyone together energize the city. They have kept Portland weird, and in so doing created a uniquely vibrant national treasure.

If people abandon the city in large numbers after an earthquake, they will take with them Portland's essence. Preparedness and resilience require that people are fully educated on the risks they face, the challenges they will likely endure following a disaster and the steps they can take to become more prepared so that they can remain in place or quickly return.

Your committee recommends that all schools provide children and their parents with comprehensive information about earthquake risks and preparedness strategies. Your committee also recommends expanding the capacity of programs like Portland's Neighborhood Emergency Teams to train a more diverse group of citizen crisis responders. These programs help strengthen neighborhoods and promote public trust in government. Grassroots participation in resilience work can help

ensure that benefits of preparedness are experienced equitably by all residents.

To better meet response and recovery needs of our most vulnerable neighbors, your committee recommends that all metro area human services providers develop continuity of operations plans. Ultimately, strengthening our civic infrastructure is a shared enterprise. It depends not only on government initiatives but also on the work of non-government organizations, neighborhood associations, church groups and community organizations. We are all in this resilience-building enterprise together.

Coordinated planning and investment in resilience

The complexity of impacts resulting from a major earthquake is difficult to imagine. A multitude of physical, financial, business, education and social networks will be damaged. Because these systems intertwine, earthquake impacts will be compounded. Coordinated planning that links governments, community organizations and businesses to support resilience will better prepare the region to rebound from a Cascadia earthquake and other disasters.

Your committee recommends that Portland and other local governments designate a high-level staff member to act as a resilience officer, prioritizing needs, measuring progress and reporting to the public. Coordinated regional planning for resilience is also essential.

Your committee recommends that the region's governments and businesses leverage the work of the Regional Disaster Preparedness Organization by increasing investment in its staffing.

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Sustained investment in strengthening physical and social infrastructure is essential to prepare the region for recovery from a megathrust earthquake. Support for research, especially by the Oregon Department of Geology and Mineral Industries, is necessary to clarify risks and more-precisely target resilience investments. Incremental investments in resilience, like saving for retirement, will eventually yield a high return.

These high priority actions are achievable in the short term, many at comparatively low cost. By taking these actions, the region also will strengthen its ability to rebound from other calamities.

More must be done, and many required actions will not be quick fixes. In fact, the time horizon your committee envisions stretches 50 years and beyond. As each area is addressed, new priorities will emerge. Improving preparedness and resilience is a continuous learning process.

Portland and Oregon must start cultivating a culture of resilience right now. An essential first step is educating our children about risks and resilience so they will be prepared to continue this vital work in their own time.

Portland-area communities are built atop tectonic forces beyond anyone's control, but the region is not helpless. The Portland area is not yet prepared, but leaders and the public are learning what must be done to reduce damage and recover quickly from the earthquake's impacts. This knowledge confers responsibility and opens opportunities to continue along the path to a resilient future in which our unique regional culture will not just survive but thrive.

INTRODUCTION

Portland has been warned

In the past, great earthquakes have surprised people living in Lisbon, Portugal; San Francisco; Chile; Christchurch, New Zealand; and Tokyo. Those quakes killed thousands and left cities in ruins. Portland, however, has been warned of approaching disaster. The danger originates in a massive geological fault off Oregon's coast. The Cascadia Subduction Zone (often referred to as CSZ) stretches 600 miles from southern Canada to northern California, and its rupturing has caused at least seven great quakes with tsunamis in the last 3,500 years. The last great Cascadia quake occurred in January 1700. According to leading Cascadia experts, the likelihood of the next big earthquake occurring sometime in the next 50 years is 14 to 20 percent.

Scientists have warned that the next CSZ earthquake likely will be a rare megathrust quake, one of the planet's most powerful seismic events.

A megathrust quake will cause the coast to suddenly drop six to eight feet, and within minutes a tsunami, possibly 50 to 100 feet high, will overwhelm the Northwest's coastal areas. Meanwhile, the ground-shaking energy from Cascadia's magnitude 9.0 earthquake will radiate inland, reaching Portland within a few short minutes.

Geologists and structural engineers report that as Cascadia's tremors sweep across the Portland metropolitan area, they will unleash landslides; buckle bridges and roads; sever water, power and fuel lines; shake apart buildings, filling streets with their rubble; turn solid ground into sludge in places; kill and maim people; and transform Portland forever.

Shaky ground

Not all earthquakes are the same. Many occur along faults where pieces of the earth's crust suddenly slide in opposite directions along the fault line, like California's San Andreas Fault. The quakes these strike-slip faults generate are jolts, rarely reaching a magnitude of 6.0 and lasting for a few seconds.

Subduction zones are areas where one tectonic plate (a massive piece of the earth's crust) slides, diagonally – and with great difficulty – under another crustal plate. The sliding causes tension to build like a spring. (See Appendix A for more details about subduction zones and megathrust quakes.)

Off of the Oregon coast, the Cascadia subduction zone fault occurs where the Juan de Fuca Plate is being forced beneath the North American Plate, pushing up land along the coast in the process. At some point, the accumulating tension will be released and the coast will suddenly sink downward. This abrupt event will release energy in the form of ground vibrations and launch a tsunami.

Maps often depict the westernmost portion of the CSZ with a line that is offshore. The CSZ is actually a wide zone that extends from the offshore line in an eastward direction toward North America and underlies Oregon's coastal towns. Scientists are researching the inland extent that is capable of earthquake rupture, and it's possible that it extends as close as 30 miles from Portland.[1]

Source: FEMA

Subduction quakes pose unique dangers. In addition to causing tsunamis, these quakes always approach magnitudes of 9.0 or greater. A 9.0 Cascadia quake will generate 200 times more energy than the 7.5 that destroyed San Francisco in 1906.[2]

Some of the energy released at the fault will dissipate as it travels 200 miles to Portland. Chris Goldfinger, a professor of geology and geophysics at Oregon State University, is a leading expert on the Cascadia Subduction Zone. He told your committee that the felt experience in the city would be similar to a 5.0 or 6.0 earthquake.

But subduction quakes, uniquely, produce ground shaking that lasts not seconds but three to five minutes. This continuous shaking will cause most unreinforced masonry (URM) buildings to shake apart, killing and injuring people and blocking roads.

Portland has about 1,800 URM buildings (with more yet to be enumerated in the metro area), and an unknown number of other structures particularly vulnerable to earthquakes.

While many newer buildings will survive and could appear undamaged, many of them are unlikely to be reoccupied after a great

quake. Current Oregon building codes demand that buildings protect the lives of occupants during an earthquake. But the code does not require that structures be useful after an earthquake. As a result, people should survive, but the activities normally conducted in these buildings will be thrown into disarray. Many damaged buildings that cannot be certified as safe or are too costly to repair will be demolished. The office building that houses Oregon's top geologist was not built for reoccupation.

During the prolonged shaking caused by a CSZ earthquake, many buildings constructed on liquefiable soils are at risk, but the most significant risk is centered in the Critical Energy Infrastructure Hub. Recent geological mapping of vulnerable ground reveals that the soil beneath Portland's CEI Hub will liquefy. Ninety percent of the state's liquid fuel passes through the Hub's tanks, dotted along a six-mile stretch of the west bank of the Willamette River in Northwest Portland. Engineers believe that tank subsidence into liquefied soil will cause the tanks to buckle and perhaps split open, releasing their contents into the river and igniting an environmental disaster that will greatly exacerbate damage done by any earthquake.

Many brick buildings collapsed and caused considerable damage around them during the 2011 magnitude 6.3 earthquake in Christchurch, New Zealand.

Wake Up Call

Recognition and acknowledgment of the dangers posed by the Cascadia subduction zone are relatively recent in Oregon. Scientists did not identify it as an active fault until the 1980s. Ten years later, in response to the newly identified danger, building codes regulating new construction were upgraded to reduce loss of life. In 1999, the state's geology office released a study of a Cascadia quake's potential damage.[3] Although scientists continued to uncover more information about the CSZ, incremental public policy advances led to the issue largely disappearing from public view for more than a decade.

In early 2011, things changed rapidly. In January, an op-ed published in the Oregonian warned that a Cascadia quake would cause 1,000 bridges around the state to fail, that many of the state's 1,306 schools were at high risk of collapse, and 10 coastal communities could be completely inundated by a tsunami. The authors proposed a 10-year, $1.5 billion state resilience plan.[4]

In March of 2011, Japan's Tohoku quake and tsunami demonstrated the destruction a subduction quake could inflict on a nation well prepared for it. In April, the Oregon Legislature officially commissioned a study on the risks of a great Cascadia quake and recommendations to enhance resilience.[5]

Damage Report

The job of compiling that study fell to the Oregon Seismic Safety Policy Advisory Commission (OSSPAC). OSSPAC organized 150 experts. This all-volunteer group released the Oregon Resilience Plan (ORP) in February 2013. The report's central finding stated, "Very large earthquakes will occur in Oregon's future, and our state's infrastructure will remain poorly prepared to meet the threat unless we take action now to start building the necessary resilience."[6]

OSSPAC put the state's liquid fuel supply at the top of its list of vulnerabilities. This supply, concentrated in Portland, is located on "liquefiable riverside soils."

"Disrupting the transportation, storage and distribution of liquid fuels would rapidly disrupt most, if not all, sectors of the economy critical to emergency response and economic recovery," the report stated.[7]

OSSPAC offered recommendations that if implemented over the next 50 years would enable Oregon to be more resilient. The recommendations focus on assessing critical buildings, transportation lifelines and utilities – especially energy, water and wastewater services. Using assessment results, a sustained program of replacement and retrofitting can be undertaken to upgrade these resources. OSSPAC also called for strengthening school buildings and emergency response centers, and seismically upgrading lifeline transportation routes.

One shortcoming of ORP was that except for a brief mention in its conclusion, it did not address social resilience. One of OSSPAC's chairs told your committee that the Legislature directed it to emphasize physical infrastructure.[8] The commission noted that the report was "less comprehensive than we might have wished," and that future planning was needed to "strengthen human resilience and civic infrastructure."[9]

To do nothing in the face of the approaching disaster, the commission concluded, could lead to "a post-earthquake future that could consist of decades of economic and population decline – in effect, it could create a 'lost generation' that will devastate our state and ripple beyond Oregon to affect the regional and national economy."[10]

In July 2015, The New Yorker magazine headlined a story that captured the attention of many Pacific Northwest residents: "The Really Big One – An earthquake will destroy a sizable portion of the coastal Northwest. The question is when."

The story was a vivid description of the havoc a great Cascadia quake could cause if the region does not act now to become more resilient. It quoted the regional administrator for the Federal Emergency Management Agency's (FEMA's) Northwest office who said that given our current state of preparedness, "Our operating assumption is that everything west of Interstate 5 will be toast."[11]

Oregon Public Broadcasting [12] followed with its series "Unprepared: Will we be ready for the megaquake in Oregon?" that brought further attention to the risks.[13]

City Club's response

In the spring of 2016, City Club of Portland, through its Research Board, impaneled your committee to study earthquake preparedness and resilience. Your committee was

charged with assessing Portland's current state of preparedness and recommending "realistic steps to increase the resilience of the city's services, infrastructure and economic vitality."

Pursuing this charge, your committee carefully reviewed the findings of the 2013 Oregon Resilience Plan. We looked at a number of other studies describing the earthquake preparedness of Portland, the metro area and the state of Oregon. We investigated documents and websites describing promising and proven strategies for enhancing earthquake preparedness and resilience. And we heard from 85 witnesses with diverse areas of expertise, including geology, engineering, earthquake science, disaster preparedness and recovery, and economics. These individuals came from local and state governments, public and private nonprofit agencies, and private sector companies. Witnesses testified before our whole committee or spoke with subcommittees.

In its charge to the committee, the Research Board provided guidance to focus our research. Overall, the board asked your committee to look at ways to enhance "proactive preparedness efforts" rather than hone "reactive responses to the emergency." Your committee embraced this focus on resilience-building, which we have learned "isn't easy and involves combining multiple initiatives and variables into a workable, comprehensive framework of deliverables that may eclipse a city and involve a county, region, state or even multiple states."[14]

Enhancing resilience depends on collaboration among levels of government, experts in a variety of disciplines and public and private sector leaders.

Recognizing the complexity of earthquake preparedness and resilience issues, the Research Board also indicated that our committee should narrow its focus to a few "functional categories" for which we could produce meaningful assessments and achievable proposals that will help improve the metro region's capacity to more quickly recover from a CSZ earthquake.

After a preliminary review of literature and hearing from several key experts, your committee narrowed its focus to four broad topic areas: energy, buildings, transportation and social resilience.

Your committee focused on these four functional areas in part because of their urgency. Failure to act will greatly impede successful recovery and rebuilding following a CSZ quake. These are pivotal areas because they are linchpins, essential to strengthening overall resilience and ensuring Portland metro's capacity to meet human needs and recover from an earthquake's impacts.

Your committee chose not to research in depth two other physical infrastructure categories addressed in the ORP: information and communications technology and water and wastewater systems. Although much work remains to be done to make these vital systems more resilient to a Cascadia quake, we note several metro area service providers that have made significant progress in enhancing preparedness since the ORP was published.

The Portland Water Bureau has embarked on a multiyear plan to retrofit or replace key assets, including reservoirs, pumping stations, and the pipes and conduits that form the backbone of that system. By 2019, there will be a new seismically resilient pipe under the Willamette River to carry water to the west

side of Portland and Washington County. The pipe will be located 80 feet below the bottom of the river at its deepest point and will be in soils that are not anticipated to liquefy during a seismic event.[15]

Although much remains to be done, ongoing planning for and investment in seismic retrofits to our metro water system can serve as a model for other lifeline service systems with seismically vulnerable infrastructure.

In choosing social resilience as one of our focal areas, your committee was guided by the Research Board's observation that the ORP, "while a model in many regards … was weak on social resilience." Many experts agree that supporting the social resilience of human communities is as essential to recovering from a disaster as is strengthening the seismic resilience of physical infrastructure.

Judith Rodin, president of the Rockefeller Foundation, emphasizes that "resilience is increased where there is an optimal combination of hard and soft solutions. Superior infrastructure alone cannot ensure resilience, nor can resilience be maximized with only human effort."[16]

Recognizing that recovery from a CSZ quake will depend as much on the resilience of human communities as on seismically resilient infrastructure, your committee examined both physical and social dimensions of resilience.

As your committee's work unfolded, we became convinced that increasing public awareness of the risks our community faces and strengthening our physical and social resilience should be an ongoing, high-priority mission of government and civil society.

We also have learned that creating a more resilient community is a complex and long-term process. Resilience-building for our region will require inclusive, coordinated planning and sustained investments through the foreseeable future.

State geotechnical engineer Yumei Wang suggested approaching enhancing resilience in the same way that people should approach retirement: By making modest but steady investments over the long term, someday in the future we and our descendants will be safer and more prosperous than if we had not made these contributions.[17]

The ORP suggests that Oregonians view this work as a 50-year project, but your committee believes that enhancing regional and statewide resilience to tomorrow's uncertainties must be an ongoing commitment that extends beyond 50 years.

In this report, we present our research findings, offer evidence-based conclusions, and make recommendations for changes in statutes, policies and resource allocations. These recommendations are intended to further two broad goals:

- Mitigating risk to vulnerable physical systems by protecting key transportation and energy lifelines, conserving our natural environment and increasing the seismic resilience of buildings.

- Empowering communities by strengthening social connections, linking diverse organizations and ensuring that critical human needs can be met after a major earthquake.

Several of your committee's 14 recommendations propose actions to be taken by the city of Portland. City initiatives can directly benefit the 36 percent of metro area residents who live within its boundaries. Because Portland is the economic center of the metro region,[18] enhancing its resilience is essential to preserving the region's economic vitality. If Portland's resilience-building policies and programs prove successful, other metro jurisdictions may choose to adapt them to their needs.

This report was written collaboratively by all members of City Club's Earthquake Preparedness and Resilience Research Committee.

We offer it in hopes of inspiring policymakers, public agencies, private non-profits, businesses and citizens to work together to build a more resilient Portland metro region that will be better able to survive and quickly rebound from the Cascadia earthquake we know is in our future.

> A resilience-based approach encourages strategies that will facilitate more rapid and complete socioeconomic recovery following initial crisis responses.
>
> *– Your committee*

NURTURING A CULTURE OF RESILIENCE IN THE PORTLAND METRO AREA

Defining resilience

Establishing a culture and practice of resilience across the metro area will make the region more ready to respond effectively to the immediate impacts of a CSZ earthquake. Resilience-focused policies can also help the regional and state economy to recover more swiftly and completely. Ideally, a resilient community, city or region understands its strengths and vulnerabilities and has developed capabilities to:

- Plan for and mitigate the impact of a major earthquake or other disaster,
- Rapidly restore itself to a state of basic well-being, and
- Rebuild to achieve even greater resilience.[19]

Foundations of resilience

There are four building blocks essential to building a culture of resilience across the Portland metro region.

Educating residents

Residents of the region must become more familiar with the risks of a major earthquake, the challenges they will face in its immediate aftermath, and the ways they can help prepare themselves and their communities for a faster recovery. A survey of Oregon residents conducted in 2014 by ECONorthwest and DHM Research found that Oregonians expect "lifeline services" (electricity, water and sewer, police and fire, and highways) to be restored much more quickly than do experts familiar with these systems and the likely impacts of a CSZ quake.

Engaging citizens

All disaster preparedness and resilience planning endeavors should encourage active participation of citizens and community-based organizations. It is especially important to involve vulnerable populations, i.e., those with disabilities or special needs, and their advocates in setting priorities for crisis response and long-term recovery.

Coordinating preparedness planning

The anticipated scope and interconnectivity of CSZ earthquake impacts requires coordinated planning to enable the region's public and private sectors to rebound from this disaster. Although bringing together the multitude of people, organizations and systems involved is a daunting task, linking communities that will likely experience the same disaster can greatly leverage resilience.[20] The Association of Bay Area Governments emphasizes that "quick, confident, and coordinated actions that foresee the long-term future can be very powerful in instilling confidence and faith in residents and business leaders."[21]

Investing in resilience

Local and state governments, partnering with private sector non-profits and businesses, must commit to consistent, persistent investments in resilience planning and activities for the foreseeable future. Traditional disaster preparedness efforts focus on implementing post-disaster responses to minimize

losses. A resilience-based approach encourages strategies that will facilitate more rapid and complete socioeconomic recovery following initial crisis responses. Successful recovery from a major earthquake requires that Oregonians invest in physical infrastructure better designed to be usable following a quake. Leaders also must commit to funding programs and practices that will enable communities, businesses and vital human services to rebound more rapidly.

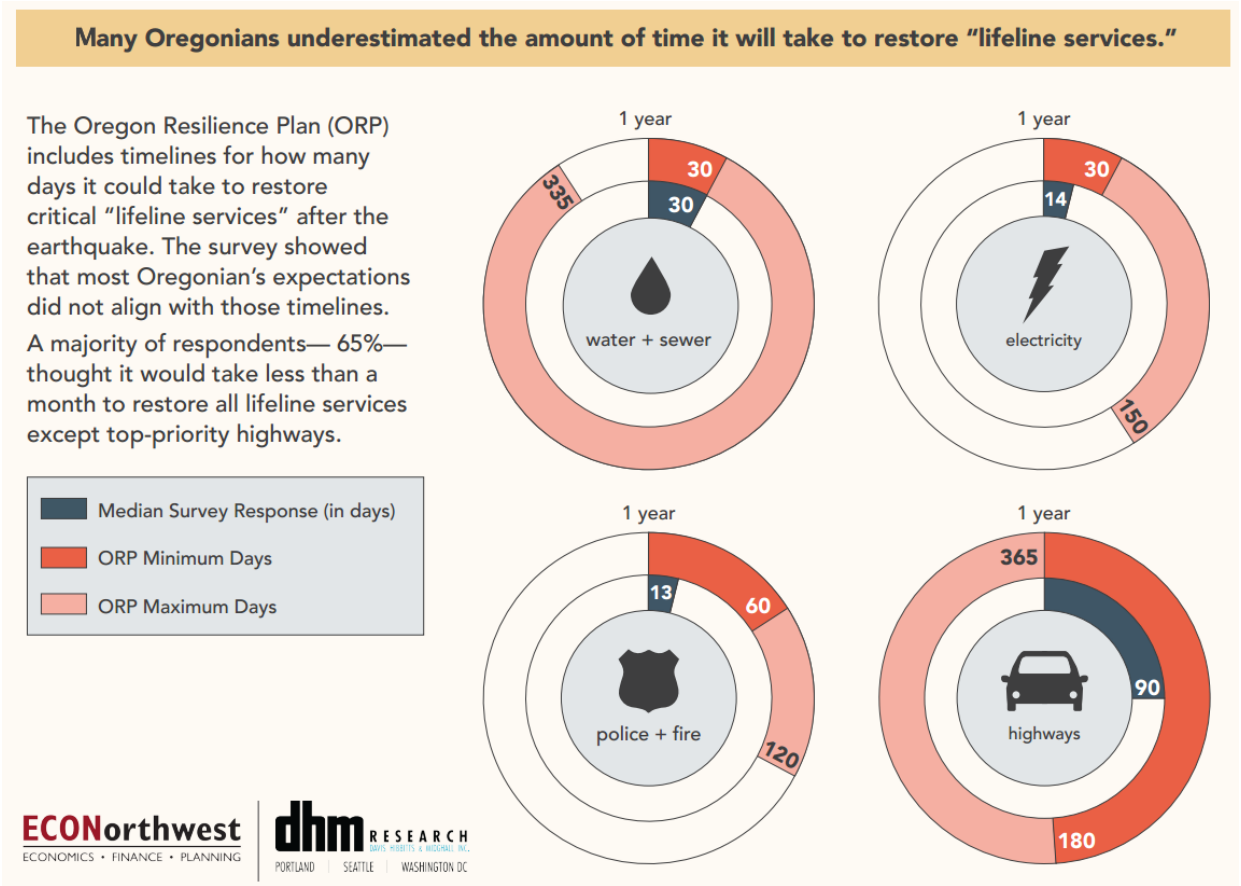
Strategies to enhance resilience

Building a culture of resilience is a multi-faceted process that must continue indefinitely. Your committee recommends key actions and initiatives that can, over 5-10 years, move the Portland metro area further along its path to a resilient future.

Your committee's resilience-building strategy focuses on three action areas:

- Strengthening physical infrastructure,
- Enhancing social resilience, and
- Investing in and planning for resilience.

The remainder of this report is organized into sections corresponding to these action areas. Each section provides background information and recommendations relevant to these key elements. Our report concludes with sections summarizing findings, conclusions and action recommendations.



Mitigating vulnerabilities of the metro area's physical infrastructure is essential to ensuring the region's resilience in the aftermath of a CSZ earthquake. Without energy sources; buildings that provide places to live, work and attend school; and transportation lifelines, the communities' vitality will wither, perhaps never to recover to its current levels. Your committee has studied these vulnerabilities and recommends mitigation strategies, policy changes and public investments that will significantly advance our region's earthquake preparedness and resilience.

STRENGTHENING PHYSICAL INFRASTRUCTURE: ENERGY SOURCES

The lifeblood of the region and its economy is its energy supply, but that could vanish in the aftermath of a major quake. Without energy, the risk to regional recovery is substantial. Immediately after a disaster, emergency response and rescue operations will need electric and natural gas service to power equipment and liquid fuel for vehicles. While emergency generators might supply electrical power needs in the short-term, those generators also require liquid fuel to run. Hospitals and emergency shelters will need power and heat. Repair crews called upon to fix roads and clear debris also will need fuel. Long-term recovery will require energy.

Electricity and gas

The agencies and utilities responsible for electricity and natural gas service are making significant and encouraging efforts to prepare for "the big one." Bonneville Power Administration (BPA), which distributes the power from 31 federal dams on the Columbia and Snake Rivers, reports that its primary generation sources are not at risk in a CSZ 9.0 event. BPA has developed a redundant dispatch center in Spokane which can operate the system if its main center in Vancouver is damaged. It has conducted geotechnical reviews of each of its transformer sites, and has substantially completed anchoring each of them to facilitate re-routing if any of the sites is damaged. It has also converted from a rigid to a flexible bus design.*

Northwest Natural is dependent on the Williams Pipeline from the north for most of its natural gas supply. That pipeline has been converted from cast iron and bare steel to more flexible protected steel, but it is still vulnerable at several river crossings.

Northwest Natural has three storage locations, two of which may be impacted by a CSZ event. The company's distribution pipelines have been converted to polyethylene (for lower pressure) or coated steel (for higher pressure). Because some pipelines cross rivers attached to bridges that are seismically vulnerable, the company is considering alternatives. It has built an operations and training

* A bus is a metallic strip that conducts electricity within a transmission tower structure.

center in Sherwood with high seismic capability and is evaluating its current headquarters location two blocks from the Willamette River and thus on possibly liquefiable soil.

Portland General Electric (PGE) obtains its electricity either from BPA or other earthquake-remote sources. PGE has an alternate control center built to a high seismic standard. The company has completed geotechnical surveys of each of its 14 major transmission substations and is now analyzing how best to harden each of them, a process that may take several years. Its 158 distribution substations operate on a radial basis, which limits capacity to route around affected areas.

Pacificorp serves a small but critical area of Portland, including the Portland Airport. It has plans for emergency relief utilizing its affiliated utility Utah Power and Light. It has a redundant control center in Salt Lake City fully able to operate its Oregon facilities if necessary, and it is in the process of obtaining geotechnical analysis of key transmission tower sites. Each of these agencies has developed staffing plans for an emergency, and system shutdown mechanisms if necessary.

All of the distribution utilities are subject to the jurisdiction of the Oregon Public Utility Commission, which requires them to submit on a confidential basis their geotechnical analyses of the soils at each location relevant to their critical facilities as well as their plans to harden or bury those assets over time. The costs of this mitigation are added to their rate base and thus passed on to consumers.

Notwithstanding these planning and mitigation efforts, some damage to electric and gas distribution systems is to be expected after a major earthquake, requiring repairs to restore service.

All of the utilities your committee interviewed said that one of their major concerns is liquid fuel. Without fuel, their repair vehicles cannot run and vital repairs cannot be made. While the Portland metro region is taking steps to reduce its dependence on liquid fuel, the reality is that for the foreseeable future, liquid fuel will be essential for a post-quake recovery. We agree with Mike Harryman, Oregon's resilience officer, who told your committee: "Fuel is our Achilles heel."

BPA and the electric and gas utilities are evaluating whether they should develop their own fuel storage facilities to operate repair vehicles during the immediate post-earthquake recovery. Another option that your committee urges them to consider is to assure that fuel stored at existing retail gasoline and diesel service stations can be accessed even if electrical service is disrupted.

Using generators to pump stored fuel requires that service stations be wired appropriately. In 2016 the Legislature passed a small grant program for up to 25 cardlock stations to be generator-wired.*

The locations that will receive grants have not yet been determined but are expected to be located on lifeline routes, especially those to the coast. Making this short-term fuel supply accessible to BPA and other utilities should not require additional state funding. Indeed, if utilities inventory the service stations most accessible to their respective fleets, they could help fund installing proper wiring at

* Cardlocks are automated, unattended fueling sites designed for commercial fleet vehicles that use cards for payment.

those stations. Similarly, emergency response agencies (police, fire, ambulance) might consider funding rewiring at those service locations most accessible to their vehicles.

The Oregon Department of Energy has adopted an emergency fuel allocation plan that gives crisis response vehicles the highest priority, followed by utility repair vehicles and equipment. However, because the closest stations to a given provider might be far from other providers, there might be some fuel available to each.

Critical Energy Infrastructure Hub

Oregon's liquid fuel supply is concentrated in Northwest Portland on a six-mile stretch on the west bank of the Willamette River from Sauvie Island to the Fremont Bridge known as the Critical Energy Infrastructure (CEI) Hub. Approximately 90 percent of the liquid fuel for the entire state of Oregon and 100 percent of the jet fuel for Portland's airport comes through the CEI Hub. In addition to fuel in the 46 large, above-ground tanks, the hub holds all of Oregon's major liquid fuel port terminals, liquid fuel transmission pipelines and transfer stations, and a liquefied natural gas storage facility. Three high-voltage transmission lines pass overhead and electrical substations dot the complex.

The liquid fuel storage facilities were located in this area in the early 1900s because at that time fuel was delivered by water, and a riverfront site was required for ships to dock. Today only 10 percent of the fuel is delivered by vessel. Gasoline, diesel and jet fuel arrive through the Olympic Pipeline from the north. This pipeline is projected to suffer as many as 250 breaks and 82 leaks. Pump stations along it could also be damaged.[22]

The U.S. Department of Transportation Pipeline and Hazardous Materials and Safety Administration has jurisdiction over such pipelines. The administration advised your committee that due to the risk of a CSZ event pipeline operators have implemented numerous remediation measures including, but not limited to, installation of remotely-operated valves, check valves, enhanced leak detection systems and increased surveillance. The administration provided no estimate of the time for post-quake recovery of the system.[23]

The rivers will not provide immediate relief. In the event of a CSZ quake river access will be impeded for a protracted period because of tsunami debris at the mouth of the Columbia, bridge collapses and dredged-channel slope failure. The docks at the CEI Hub are quite old and are likely to fail. Emergency delivery of fuel by vessel will be impossible until river access can be reopened and docks replaced.

Many storage tanks within the facility were erected long before construction standards took earthquake risks into account. Some were built more than 100 years ago, and some have been replaced. At least one major owner, Chevron, reports that many of its major tanks are of fairly recent vintage.[24] But those familiar with the CEI Hub said that many older tanks remain in use there. Even tanks built to current standards are not required to withstand the impacts of a CSZ earthquake or to retain functionality after one.

The risk of tank failure is particularly severe due to the nature of the soil upon which the CEI Hub stands. It is primarily fill material from dredging, which makes the liquefaction-prone riverfront even more vulnerable to significant subsidence.

The Critical Energy Infrastructure (CEI) Hub stretches along six miles of the west bank of the Willamette River, approximately from Sauvie Island to Fremont Bridge. Many of the fuel tanks there would likely collapse in a major earthquake.

Geologists who have studied the area say prolonged shaking from a CSZ quake will likely cause the soil beneath the hub to lose its integrity, essentially becoming mush. Lateral movement could be as much as 20-30 feet.

Moreover, the site is located adjacent to a steep hillside that could slide into the hub area. As portions of the ground shift and liquefy, the tanks are likely to shift and potentially sink, split, tilt or leak. Some might release their contents into the air, soil and the Willamette River.

BPA and PGE electric transmission lines that cross the Willamette at the CEI Hub are carried by towers also built on liquefiable soil, but the companies expect the system to shut down in a quake.

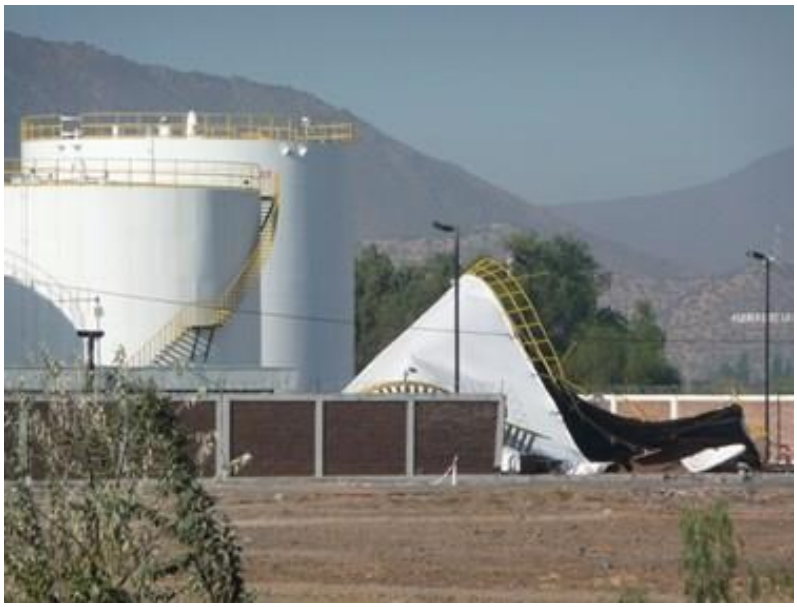
A BPA spokesman explained about their equipment, "Vibration of substation equipment, from very strong ground motions, potential damage to buildings housing control equipment, and earthquake generated landslide transmission line damage will most likely de-energize this river-crossing before it potentially fails." He acknowledged a "small probability" that energized lines could fall into the river. [25]

PGE's line adjacent to BPA's lines is also expected to be de-energized early in a CSZ event due to ground shaking.

In the unlikely event that an energized line strikes leaking fuel, it could ignite it.

The vulnerability of the CEI Hub poses significant environmental risks apart from disruption of the region's fuel supply. Emergency planners believe that fumes from fires feeding on fuel released from tanks could render the air so toxic that a planned emergency staging area at the University of Portland would be rendered unusable. The existing CEI hub facilities have capacity to hold 830 million gallons of liquid fuel and other hazardous materials. By comparison, the environmentally disastrous Exxon Valdez incident in 1989 involved a spill of only 31 million gallons.

Each of the tank farms includes a secondary containment wall designed to retain the contents of its largest tank plus the highest 24-hour rainfall recorded during the past 10 years. Unfortunately, those walls have foundations of four feet or less, were designed before the CSZ risk was understood and could fail in an earthquake. FEMA Region X Administrator Ken Murphy', in assessing the CEI Hub, said, "Everything that could be wrong is wrong right here."



Source: Technical Council on Lifeline Earthquake Engineering

Structural damage to water tank located in fuel tank farm in Santiago from the 2010 Chile earthquake.

One major concern identified by your committee is lack of information regarding the seismic vulnerabilities of the individual tanks within the CEI Hub.

Many federal, state and local agencies regulate various aspects of the tanks at the CEI Hub, but none has responsibility or authority to regulate them for seismic risk. Some organizations that people might believe have oversight roles do not.

At the federal level, the Pipeline and Hazardous Materials and Safety Administration has jurisdiction over interstate hazardous liquid pipelines and "break-out tanks"— ones where the liquid fuel enters by interstate pipeline and leaves by various other pipelines. However, that does not include many of the CEI Hub tanks, and the administration does not audit for seismic risks other than assurance that tanks were built in accordance with local code. The Environmental Protection Agency has a Spill Prevention, Control and Counter Measure Plan, but that program requires no permit or registration, has resources for only about 20 inspections per year nationally and is focused on spill prevention, not seismic resilience. U.S. Coast Guard inspections of loading docks do not include a seismic component.

The Oregon Public Utility Commission regulates facilities for storage of hazardous substances, but staff told your committee that the agency had never exercised that authority with respect to private operators other than regulated utilities.

The Oregon Building Codes Division has authority to set standards for new tanks but not for existing structures. The Oregon Seismic Safety Policy Advisory Commission and the Department of Geology and Mineral Industries, though concerned with seismic risk, are not regulatory agencies.

At the municipal level, the Portland Building Codes Division has no authority to reclassify the tanks. The Portland Bureau of Emergency Management is responsible for emergency response, not regulating seismic mitigation. The Portland Fire Bureau is responsible for inspecting hazardous material storage tanks for fire safety purposes.

That amalgamation of oversight – and lack of oversight – means that no single agency is directly charged with collecting information about seismic risks or regulating them. Tank owners are not required to assess their facilities' vulnerabilities or to report to any oversight body concerning those vulnerabilities.

Despite the potentially catastrophic risk these facilities pose to the region, tank owners have no legal obligation to retrofit or otherwise harden their facilities to reduce risk. While three recently-constructed tanks have been designed with much deeper foundations, the cost of removing and rebuilding seismically vulnerable tanks is quite high—estimated at $5-10 million per tank, or $1-2 billion if all the tanks were removed and rebuilt.

One major owner of tanks, Chevron, told your committee that it is already in compliance with current American Petroleum Institute standards for repair and new construction.[26] However, these standards are designed solely to prevent tank collapse, not to retain functionality following a major CSZ earthquake.

Oregon building codes, applicable to new construction or significant alterations, classify these storage tanks only as a Category II risk, requiring mitigations designed to preserve life safety but not functionality.* Reclassifying to Category III (toxic and hazardous) or Category IV (essential facility) would be a complex process, and there is no clear consensus as to what new standards should be enacted.

Source: Your committee

A portion of the CEI Hub downstream from the St. Johns Bridge.

Although Portland has limited authority to require some structures to be seismically retrofitted, there is no clarity as to how to upgrade older tanks.

In December 2016, the Portland City Council passed an ordinance that bans new bulk fossil fuel storage facilities with a capacity in excess of 2 million gallons. The ban includes any expansion of existing facilities. The council considered but rejected a proposal for expansion credits to encourage tank owners to retrofit or replace current tanks with more seismic-resistant tanks. A coalition

* See Appendix C for definitions of Oregon Structural Specialty Code risk categories for buildings and other structures.

of labor, business and oil industry groups has filed an appeal against the ordinance with the State Land Use Board of Appeals.[27]

Even if facility owners were interested in retrofitting or replacing their existing tanks, this prohibition on construction of new tanks precludes or limits such actions. And even if the ban were waived for current CEI Hub tank owners, applicable codes and standards regulating replacement or retrofitting are insufficient given present knowledge of the consequences of a CSZ earthquake.

Mitigating CEI Hub vulnerabilities

Industry representatives with whom your committee spoke* suggested that the region's post-quake fuel supply could best be assured by locating redundant facilities in less seismically vulnerable areas such as Pasco, which receives fuel via pipeline, or The Dalles. However, facility owners have little market incentive to invest in redundant facilities.

In light of the costs of retrofitting or replacing tanks, many operators have chosen not to make this investment. This may be a reasonable business decision for large international organizations whose Oregon assets and revenues are a tiny fraction of their overall business. But the debilitating impacts of a CSZ earthquake are an unacceptable risk for our region. For Portland-area residents, the future of the economy and the community is very much entwined with the prospects for the CEI Hub or its replacement.

Short of replacing or retrofitting tanks, another promising option for reinforcing the CEI Hub is hardening liquefiable soils either under existing tanks or around them.

The infrastructure hardening already carried out by BPA and being implemented by the regulated utilities suggests that geotechnical study and seismic design for vulnerable energy infrastructure are effective approaches. No such research has yet been done with respect to the CEI Hub site. Research at Oregon State University suggests several methods of ground mitigation that may prove useful, including jet grouting, deep soil mixing, inserting pilings, horizontal drilling and other techniques.[28]

New Zealand conducted significant research in hardening liquefiable soils following the 2010-11 Canterbury quakes.[29] Your committee was advised that the cost of initial geotechnical research for the CEI Hub site is estimated at $1 million, a very small investment given the magnitude of the problem. We do not have an estimate for the cost of soil mitigation measures.

Because destruction of the CEI Hub facilities will severely limit Oregon's energy supply and presents significant environmental risks, geotechnical research into soil remediation measures is advisable. If this research points to practical, cost-effective mitigation options, an incentive program or mandates could convince tank owners to act.

Requiring all tank owners to address this risk would eliminate the competitive disincentives that currently prevent individual owners from taking action.

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* Your committee thanks representatives of Chevron, Kinder Morgan and Western States Petroleum Association for discussing these challenging issues. We were disappointed that several other owners declined to meet with us or to respond to our questions.

The cost of an incentive program or mandate likely would be substantial and could cause taxes or fuel prices to increase. That would, however, be a fair burden for taxpayers or consumers to bear. Seismic vulnerability of the CEI Hub is the result of past ignorance, not industry malfeasance.

The environmental challenges of constructing a major new fuel storage facility and the pipelines to serve it at a different location are almost certainly insurmountable in today's political climate.

However, when a CSZ event occurs, it will behoove the Oregon Department of Energy to have in place a plan to relocate fuel storage facilities. Rebuilding in the same location would be foolish, and without a plan in place, years of indecision could stall relocation and recovery.

The Legislature should designate or create a state agency to work with tank owners and other stakeholders to develop seismic risk analyses and remedial measures, and to plan for effective crisis response and recovery for the CEI Hub.

One approach to this regulatory relationship is illustrated by California's Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) program. While the specific standards used by MOTEMS are not applicable to the CEI Hub, its regulatory process could be adapted.

MOTEMS

California's Marine Oil Terminal Engineering and Maintenance Standards were developed through a collaborative process with extensive industry involvement.

Under MOTEMS, the state's marine oil terminals are divided into three risk classes – high, medium and low – based on the volume of oil exposed to spillage and other factors.

Each terminal operator is required to perform periodic audits and inspections of its facilities according to a schedule determined by its risk category. Audits involve both fieldwork and engineering analysis, must comply with MOTEMS guidelines, and must be performed and certified by registered professional engineers.

Based on the audits, each facility is assigned an assessment rating that includes a seismic assessment. Facility operators are responsible for identifying deficiencies in accordance with MOTEMS standards and for proposing corrective actions. Deficiencies must be corrected on a timeline mutually agreed between MOTEMS and the facility operator, taking into account the costs involved.

Recommendations to reduce risk of catastrophic CEI Hub failure

Recommendation 1

The Oregon Department of Geology and Mineral Industries should commission a geotechnical study of the soils in the Critical Energy Infrastructure (CEI) Hub and alternatives for soil hardening. If grant funding is unavailable, the Legislature should appropriate funds for the study.

Recommendation 2

The Governor and Legislature should designate a single state agency to oversee seismic risks at the CEI Hub. That agency should have the authority to:

- Require all owners of CEI Hub facilities to provide an engineering assessment of their facilities' vulnerability to a CSZ earthquake and other information relevant to mitigating the current risks.
- Develop and implement, in collaboration with industry stakeholders, standards for construction and retrofit of storage tanks at the CEI Hub. The standards should be designed to prevent releases and to preserve substantial functionality in the event of a CSZ earthquake.

STRENGTHENING PHYSICAL INFRASTRUCTURE: BUILDINGS

Your committee explored a number of issues affecting the safety and resilience of buildings, and chose to focus on three goals that must be pursued to ensure that the metro area, and particularly Portland, can rebound vigorously from a Cascadia earthquake:

- Strengthening seismic resilience standards for new construction,
- Retrofitting dangerous building stock,
- Improving residential housing resilience

With the exception of a small class of buildings categorized as "essential facilities" (Category IV in the Oregon Structural Specialty Code), resilience requirements for Portland area buildings range from hardly any to meeting "life safety" standards, which require minimizing the risk of death or serious injury of building occupants.

Many structures built before seismic code upgrades were enacted in 1994 could suffer major damage or collapse in a strong earthquake, with consequent loss of life.[30] These are "dangerous" buildings, and they are of the highest priority for retrofit or replacement.

While most structures built after 1994 might preserve life, they might not be functional after a major earthquake. Many are likely to be so heavily damaged that they would be demolished.

Immediately after a major seismic event, areas around buildings deemed at risk of toppling over must be cordoned off by 1.5 times the building height. Collapsed and severely

Ratings systems and market forces

The U.S. Resiliency Council earthquake building rating system was launched in November 2015, modeled in part after the LEED rating system. It expresses the effect a seismic event would have on a building by assessing likely performance in terms of safety, damage (repair cost) and recovery (time to regain basic functions). Ratings are from Bronze to Platinum. This rating system "delivers information on the expected safety, damage and recovery of the buildings we use and occupy."

It "considers many aspects of a building's performance, including its structure, mechanical, electrical and plumbing systems, and architectural components such as cladding, windows, partitions and ceilings."

The cost of repairing these non-structural elements can often exceed that of remedying structural damage. A national seismic resilience rating system for new buildings could raise public awareness and provide market incentives for more cost-effective seismically resilient construction.

See: usrc.org/building-rating-system

damaged buildings could thus have the outsized effect of blocking access to huge areas of Portland for months, as occurred in Christchurch, New Zealand, after its magnitude 6.3 earthquake in 2011.[31]

Significant loss of building stock would likely cause mass emigration of businesses and employees, severely damaging the regional economy and extending the time required for recovery. Changing seismic resilience standards to ensure that as many buildings as possible will be usable post-earthquake is essential to ensure the resilience of our communities and economy.

Strengthening seismic standards for new construction

When your committee began its investigation, many committee members assumed that structures built to current code would not only protect the lives of their occupants during a major earthquake but also remain usable afterwards. That was a misperception.

Building codes do not align with building owners' or the public's expectations.[32] Only a small set of buildings, defined as "essential facilities" (Risk Category IV) are designed to be operational during a CSZ earthquake and for immediate occupancy afterward.

In contrast, most buildings in which Portlanders live and work are built to only life safety standards, which do not require that the building be usable after a major earthquake.

Severe seismic events in other locales have shown that many buildings built to life safety standards are so damaged that it is cheaper to demolish them than to try to repair them. In Christchurch, New Zealand, for example, 70 percent of buildings built or retrofitted to life safety standards had to be demolished.[33] New construction of seismically resilient buildings is more cost-effective than retrofitting existing structures or tearing down and replacing non-resilient structures.

Constructing a seismically-resilient building to the highest performance level (Platinum Rating, see sidebar above) can add 1 to 10 percent to the overall project cost.[34] The extra cost as a percentage generally decreases as the size of the project increases. For example, a nearly completed skyscraper in San Francisco has been built to an immediate occupancy standard at no extra cost.[35]

The relatively modest initial investment to achieve the highest level in seismic resilience (Platinum Rating) for new buildings likely can be offset by reduced insurance costs, increased rental revenue and greater selling prices. For example, owners of a Platinum building might forego earthquake insurance and recoup the resilience cost increment in 3-7 years.[36] Developers or owners who advertise a building's resilience may find buyers and renters willing to pay more for this assurance.

However, according to the Portland Bureau of Development Services, few, if any, recently constructed buildings have been built to exceed the code minimum standards. For a typical building, the code minimum standard is life safety. Consequently, relatively low-cost opportunities to enhance Portland's resilience continue to be lost every day amid the city's current building frenzy.[37]

Portland and other US cities at risk of major seismic events can learn from San Francisco's current efforts to enact stringent seismic building codes. Recognizing that long-term community and economic resilience are

Source: Beaverton School District

The Beaverton School District is building seven schools to withstand a major earthquake and remain usable in its aftermath.

not protected by building codes that ignore post-disaster occupancy requirements, San Francisco city officials are working together with design professionals and community members to amend San Francisco seismic building code standards by 2018.[38]

In the metro area, one inspiring example of building beyond code requirements is new construction by the Beaverton School District.[39, 40] District policymakers see schools as essential to community resilience and believe that these publicly-funded facilities should be built to meet the communities' needs for decades to come.

The district has chosen to upgrade the structural/seismic design of their new schools beyond levels required by current codes. Seven schools are being constructed to Risk Category IV standards so they will withstand a major earthquake and remain usable in its aftermath.

The additional costs associated with this resilience upgrade have been relatively minimal – 1 percent for a high school and about 1.5 percent for a middle school. These additional costs include not only seismic upgrades but also critical building components, such as generators, that will prepare schools to serve as emergency shelters in the immediate aftermath of an earthquake.

While the example of Beaverton School District is encouraging, experience suggests that relying on voluntary efforts is unlikely to result in significant resilience gains on a broad basis. If the region is to recover quickly after a CSZ earthquake, residents will need places to live and work that are "safe enough to stay."[41] Therefore, your committee advocates revising the code that regulates construction of multi-unit dwellings, schools and office buildings.

Oregon is one of just a few states to set statewide building codes that preempt local

communities from establishing their own building standards. Other than legislative action, there are two pathways for changing current building codes: through the Oregon Building Codes Division's periodic code adoption process or through a local jurisdiction's request for a code amendment.

The code adoption process includes minor updates every three years and major updates every six years. The Oregon Seismic Safety Policy Advisory Commission intends to submit a proposal in the current window.[42] It would increase the standards for construction of school cafeterias and gymnasiums in high seismic risk areas (coast and valley) to those required for earthquake relief shelters. This would upgrade these building components to Risk Category IV and impose additional requirements, including emergency power and water. This proposal affects only new school construction.

Since the window for major updates to the commercial building code is effectively closed at this point, your committee recommends that Portland request approval for a local code amendment to enhance seismic resilience of new construction. State statute allows local jurisdictions to seek approval for amendments that exceed the state code.[43]

The Building Codes Division has approved a number of requests by local jurisdictions for code amendments addressing other issues. The Bureau of Development Services would submit the proposal on behalf of Portland. The process is demanding and would likely require a shift in resources to focus on this effort. The statute requires localities that request a code amendment to include cost-benefit analyses, robust stakeholder outreach and allowances for trade-offs or incentives. Nevertheless, your committee believes Portland can make a very strong case for local code amendments to require increased seismic resilience of commercial buildings.

Amending building codes will take time. Until that can be accomplished, Portland and other metro area jurisdictions could construct new government buildings to higher standards. They also could condition public financing of new affordable housing on compliance with higher standards. Those buildings are held in public trust and should be built to be "safe enough to stay" post-quake.

Retrofitting dangerous buildings

When studying "dangerous buildings," your committee focused primarily on unreinforced masonry buildings (URMs). Such structures are notoriously prone to heavy damage and collapse in earthquakes with significant loss of life.[44,45,46]

Because Portland has studied URMs for regulation, your committee could access a great deal of information about URMs in the city of Portland. We are not aware of similar surveys of other nearby cities or counties, despite the value such surveys could provide in those communities as they, too, prepare to rebound from a major earthquake.

URMs in the City of Portland

Portland has more than 1,800 existing URMs, including "about 45 schools, 35 churches, and 270 multifamily structures with at least 6,000 residential units. Of the residential units, at least 1,800 are publicly-financed affordable housing."[47]

Tens of thousands of people are at risk as these buildings endanger the lives of occupants and passersby. Even more people will

be affected if these buildings are not usable after an earthquake.

Portland implemented rules in 1995 that rely on passive triggers for mandatory seismic upgrades. Since then, only 15 percent of URM buildings have had any upgrades.

Recognizing the grave danger these buildings pose and the inadequacy of the existing URM retrofit requirements, City Council asked staff to investigate and recommend a mandatory retrofit policy. Beginning in 2014, three advisory committees convened to provide expert and stakeholder guidance in the development of recommendations: a Retrofits Standards Committee, a Support Committee to look at incentives and financial support for property owners, and a Policy Committee tasked with bringing together the work of the previous two committees and making final recommendations to City Council in early 2017.

URM owners face increasing pressure from insurers and lenders to make their buildings resilient. [48] Because commercial loans are typically on a 10-year cycle, insurance requirements may help solve the problem and should be monitored by the City. However, voluntary retrofit policies in other localities have resulted in very slow progress.[49] Of Portland's existing URM stock, only about 5 percent has been fully retrofitted and about

Portland's schools: Retrofit or replace?

Many schools in the Portland area are partly or entirely URM and do not meet even life safety standards. The safety of our children and educators depends on the capacity of school buildings to withstand a major earthquake.

Portland Public Schools (PPS) plans to retrofit schools to life safety standards over time. However, this will not make the buildings sufficiently resilient to allow re-occupancy after a major earthquake. Continued functioning of the school system will be vital to the community's socioeconomic future.

Only a handful of the district's 85 schools fully satisfy life safety standards. Using funds from its 2012 bond measure, PPS is retrofitting three more high schools and plans "phased retrofits" of other schools on a triage basis. Oregon's Seismic Rehabilitation Grant Program has also funded seismic upgrades. A 2009 KPFF Consulting Engineers study estimated the cost to retrofit all PPS buildings at $422 million. More-recent experience suggests that total costs could exceed $1 billion.

Your committee urges PPS and taxpayers to consider whether funding expensive retrofits for schools that have other structural challenges (lead in water supplies, asbestos) is cost-effective. Investing in gradual replacement of aging schools with new buildings that meet a post-earthquake occupancy standard will yield significantly greater long-range benefits. Beaverton School District's recent experience (see above) demonstrates that building new schools to be usable after a CSZ quake will not significantly increase construction costs.

New seismically resistant school buildings can be designed to better support PPS' and parents' goals of equity, safety and educational quality.

9 percent partially upgraded. The rest have had no retrofits at all.[50]

The proposed city policy, as drafted at the time of this report, would mandate retrofits for all URMs in Portland within a 25-year timeframe, with up to five additional years for hardship. Several types of incentives for prompt action are incorporated in the policy. Exact URM classes, retrofit standards and timelines were still being fine-tuned when this report was written, but the project website[51] is constantly updated to keep stakeholders and the public informed of the policy development process.

Portland's legislative agenda for 2017 includes a measure that would allow cities and counties to give full or partial property tax exemptions for up to 10 years to offset retrofitting costs. It has been introduced as SB311.[52] Tax exemptions could provide vital support for building owners to retrofit their buildings. Additionally, the Portland Development Commission (PDC) has $5 million in grant funding for the river district that could potentially help with URM upgrades.

Your committee recognizes that a mandatory retrofit policy presents serious budgetary challenges for groups unable to take advantage of tax exemptions, such as public schools, religious institutions and affordable housing owners.

Private property owners unable to make the numbers work may be forced to raise rents, sell their property or demolish buildings.[53] However, risks of loss of life and collateral damage outweigh financial arguments against mandatory retrofitting of URMs.

Results of a recent benefit-cost analysis support the proposed mandatory URM retrofit policy. Analysts found that overall benefits exceed costs for a "defined typical building" retrofit for each class of URM identified.[54]

The current URM retrofit policy proposal does not include a system to prioritize URMs for retrofits based on their location. Incentives to retrofit URMs could prioritize those located along lifeline transportation routes in order to help ensure that these critical roadways will remain open for use by first responders after a major earthquake.

Non-URM dangerous buildings

Your committee did not find data for the Portland metro area on the prevalence or retrofit status of three other dangerous building types. Non-ductile concrete structures are buildings lacking adequate steel reinforcing bars. Tilt-up concrete structures are built from reinforced concrete slabs built on-site, tilted vertically and braced together. Soft-story buildings are structures with ground floors weakened by extensive store front windows, wide doors, or large unobstructed commercial space. These three building types are subject to collapse in earthquakes.

Given their elevated seismic risk and likely high occupancy, your committee strongly recommends that governments in the metro region identify such buildings and their seismic retrofit status. If necessary, some combination of incentives and mandates could be enacted to motivate owners of these types of building to invest in seismic retrofitting.

Cities in California are leading the way in mandating buildings' seismic resilience. After California passed a URM Law in 1986, San Francisco, Los Angeles and other cities passed mandatory URM retrofit ordinances. In 2013, San Francisco passed a mandatory soft story

retrofit ordinance, and the city/county now plans to evaluate and require retrofits of non-ductile concrete structures within its boundaries. In 2015, Los Angeles passed an ordinance requiring mandatory retrofits of both soft-story and non-ductile concrete buildings.[55]

Improving resilience for single-family homes

Your committee looked at ways to enhance the seismic resilience of single-family residential housing in the Portland metro area. Wood frame buildings, which compose the largest proportion of metro area single-family homes, are flexible and thus can perform well in earthquakes with minimal loss of life. However, if such structures are not adequately tied to their foundations, they could suffer major damage during a CSZ earthquake, rendering them unlivable. Many metro area homes were built before a 1974 code upgrade that requires bolting houses to foundations, and even those built subsequent to that code change may not be adequately secured.

Improving the seismic resilience of single-family homes is critical to the region's social and economic recovery. Every family that is able to remain in its home is one less family that will need post-earthquake shelter. Families that are able to remain in their own home are less likely to relocate out of the area.

FEMA's Region X Director, Ken Murphy, suggests that retrofitting single-family homes by securing them to their foundations would be one of the most cost-effective resiliency measures the Portland area could implement. A typical retrofit costs between $3,000 and $8,000.[56] One witness estimated that 80 percent of single-family homes in the region could be retrofitted for $5,500 or less.[57]

Concerned about the risks presented by unbolted homes, the Portland Bureau of Emergency Management recently started tracking voluntary retrofits. From 2000 to 2010, there were only about 69 upgrades, and about 1,187 were made after 2010. Reliable data is difficult to acquire, though, because not everyone takes out a permit or seismic retrofit might be done as part of a larger renovation.[58]

A home that is not properly bolted to its foundation could slide off of it during a CSZ earthquake, making it unsafe for occupation

Rough estimates of how many homes still need to be bolted to their foundations range up to 100,000.[59] Through FEMA pre-disaster mitigation grant funds, Portland, in partnership with the nonprofit Enhabit, has been able to offer small grants to homeowners to cover 50 percent of retrofitting costs. However, this program was able to accommodate only about 200 homes between 2014 and 2016.

In a broader effort to encourage homeowners to retrofit, part of the city's legislative agenda for 2017 is to incorporate a "seismic" section into the mandatory point-of-sale home disclosures. Sen. Arnie Roblan and Rep. Deborah Boone are the chief sponsors of SB312, which would require disclosure.[60]

This section would include two questions: whether the house was built prior to 1974 and whether it has been bolted to its foundation. The city has worked with key stakeholders and does not anticipate opposition to this change in disclosure requirements.[61] Previous legislation proposed but not passed in 2015 would have relied on home inspectors rather than sellers to disclose whether homes have been retrofitted.[62]

Currently, home retrofits in the metro area are done to a wide range of standards. While there are prescriptive seismic retrofitting standards published by FEMA (the source of Portland's current grant funding for single-family home retrofits), homeowners able to finance their homes' retrofits are not required to follow those standards.

The city grants permits to make any renovations to a single-family home that "do no harm," and the permitting process does not guarantee the quality of work done.

The pace of single-family home seismic retrofits must be accelerated. In addition to a point-of-sale disclosure requirement, there should be a more robust inspection program.

"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 Resilience Planning for High School at South Cooper Mountain and Middle School at Timberland

Recommendations to improve building safety and resilience

Recommendation 3

Portland should seek approval from the Oregon Building Codes Division for a local amendment that requires office buildings and multifamily housing to be built to a standard that would allow them to be used and occupied after a CSZ earthquake. The BCD should grant the waiver.

> *Current building codes are aimed at preserving life safety only. For new construction, building to higher standards of resiliency is a relatively low-cost measure with high returns.*

Recommendation 4

All local governments in the Portland metropolitan area should require that structures built or significantly remodeled using any public financing meet standards that will allow the buildings to be used and occupied after an earthquake.

Recommendation 5

Portland should adopt the mandatory unreinforced masonry (URM) retrofit policy now under consideration and should continue to lead a multi-stakeholder collaborative process to develop a range of incentives to assist property owners in retrofitting.

Recommendation 6

The Legislature should allow cities and counties to grant property tax exemptions to offset retrofitting costs.

Recommendation 7

Portland and other local governments should inventory non-URM building stock at high risk in a CSZ earthquake, such as non-ductile concrete and soft story structures.

> *The work should catalogue these buildings, determine which have been seismically retrofitted, and develop plans to encourage and support owners to retrofit to the highest feasible seismic resilience standards.*

Recommendation 8

The Legislature should require a seismic resilience disclosure statement at the point of sale for single-family homes.

> *Requiring disclosure of whether a house is bolted to the foundation sends a message to buyers and sellers that doing so is necessary and creates an incentive to pursue this relatively inexpensive upgrade prior to sale or as part of the closing agreement.*

STRENGTHENING PHYSICAL INFRASTRUCTURE: TRANSPORTATION LIFELINES

Given the transportation system's current seismic readiness, metro area transport via water, rail, roads and bridges will be severely compromised by a CSZ quake. When transportation systems fail, many other things follow. Emergency response, utility restoration, access to essential goods and services, reopening schools, and business recovery all depend on the viability of the transportation network. Although a few recently completed projects have increased network resilience, many significant challenges remain.[63]

Port of Portland marine terminals and the runways and terminals at Portland International Airport are located on liquefiable soils and will be badly damaged in a CSZ quake. Air and marine traffic to the Portland metro area therefore will be severely hindered.

Meanwhile, bridges, including those that are part of the Interstate 5 corridor, will be unusable in the days following a quake due to damage to spans and approaches. Many bridges will be damaged beyond repair or will be out of service for months or years. Some bridges, especially those on the lower Columbia River, are likely to collapse, blocking river routes vital to delivering emergency supplies and the materials and equipment needed for long-term recovery.

Many metro area roads also will be severely damaged by a major earthquake. Landslides in the West Hills and other steeply sloped areas will isolate neighborhoods and hinder response and recovery efforts. Liquefaction of soils along the Columbia and Willamette rivers will severely damage major highways and local arterials.

Debris from landslides and damaged structures also will block essential transportation corridors. Damage to roads, bridges and marine terminals will complicate getting heavy machinery into place to remove that debris. Repairing damage to utility lines, often located under roadways, will require significant coordination with transportation officials.

Every transportation agency that your committee interviewed has completed or is performing an inventory of its facilities for seismic vulnerability. Some agencies are now preparing design studies, to be followed by permitting and then construction or substantial retrofitting. These agencies are in the early stages of a 30- to 50-year process that will greatly improve the resilience of the Portland metro area's transportation system.

Airports

Portland International Airport (PDX) is located behind a levee on the floodplain of the Columbia River on soils prone to liquefaction. The levee could fail during a major quake. If that occurs when the river is at a high level, PDX would likely flood.

The two main PDX runways also are likely to be unusable for a time after a CSZ quake. Repairing damage to the runways could take from a few days to as long as two years.[64] The pace of repairs depends not only on the extent of damage but also on availability of construction materials, equipment, fuel, and engineering expertise. Access to these resources is likely to be compromised in the immediate aftermath of after a major earthquake.

PDX is the only airport in the metro regions that can accommodate passenger plane traffic, including jumbo jets. Damage to the passenger terminal caused by a major quake will require between two months and two years to repair.[65]

Current disaster response plans anticipate routing air shipments and passengers to Oregon through Roberts Field in Redmond, which will likely not be damaged by the CSZ quake. Hillsboro Airport is more seismically resilient than PDX and might offer some relief for the metro area, but its capacity to accommodate passengers and air freight is limited. Inability to provide major air shipments to the Portland metro area for weeks or months would greatly impede response and recovery efforts.

A three year PDX runway reconstruction project was completed in 2011.[66] A 2015 seismic risk study then identified the need to harden one runway, but port officials are considering postponing that work until the next routine runway maintenance is scheduled. Airlines traditionally pay as a consortium for routine runway maintenance, directed by the Port of Portland. Given the risk of delay and the public benefit to the Portland metro area and beyond, a mix of public and private funding for upgrades could expedite the upgrades to runways and terminal buildings. Just accelerating plans to harden one runway would help.

Marine facilities

Very few marine facilities are expected to survive a CSZ quake. All marine facilities in the Portland metro area are located on soils subject to liquefaction and lateral spreading during a large earthquake. While the floating dock at Port of Portland's Berth 601 will likely not be damaged during a quake, access to the dock will be impaired. The port's recent seismic risk study[67] estimates that it will take from 12 to 39 months to repair its various marine facilities. The port is investigating ways to mitigate the vulnerability of its marine facilities through a variety of ground improvement engineering strategies. We urge the port to accelerate its marine facility mitigation plan in the coming years.

Rail lines

Almost all rail lines in the region are privately owned, and local representatives of the rail industry declined to meet with members of your committee. Like the engineers who studied transportation systems for the Oregon Resilience Plan, your committee has no information on the seismic status of the tracks and bridges on which Oregon's rail service depends. We also are unaware of any plans these companies may have to improve railroad earthquake resilience.

Based on the experiences of other regions, it is likely that many railroad beds will shift during a CSZ event. Railroad bridges are also vulnerable, especially those in the Columbia River Gorge, through which many trains serving the metro area pass. Nevertheless, the Department of Homeland Security foresees rail transport as the first mode of transportation to recover following a CSZ quake.[68]

I-5 corridor connectivity

Interstate 5 is a major economic corridor for Oregon, the Pacific Northwest and the West Coast between Mexico and Canada. In the Portland metro area, three interstate crossings are expected to be badly damaged in a CSZ quake. The Marquam Bridge (I-5) and Fremont Bridge (I-405) in downtown Portland

Source: Wikimedia Commons

The Interstate 5 bridge across the Columbia River is particularly vulnerable to catastrophic failure during a seismic event.

have had some basic life safety upgrades, but they are not expected to be useable for months following a CSZ quake due to damaged approaches.

The Interstate Bridge, which carries I-5 over the Columbia River, is expected to perform very poorly. Its northbound span was constructed about 100 years ago, and the counterweights associated with its lift spans make it particularly vulnerable to catastrophic failure during a seismic event.

In light of the Interstate Bridge's extreme vulnerability, the Oregon Department of Transportation has prioritized preserving the more resilient I-205 corridor for I-5 corridor connectivity after a major quake.

The Glenn Jackson Bridge, which carries I-205 over the Columbia River, was completed in 1982. While not built to current seismic standards, it is expected to perform far better than the Interstate Bridge in a CSZ quake.[69]

The I-205 Abernethy Bridge in Oregon City is the primary "lifeline route" identified by the state for traffic crossing the Willamette in northern Oregon and continuing into Washington. Lifeline routes are the main transportation corridors that will be used to deliver aid to regions affected by a major earthquake.

The Abernethy Bridge was completed in 1970. Although it has been retrofitted to life safety standards, the Abernethy is expected to incur considerable damage in a CSZ quake. At the time of this report, ODOT anticipates launching an update of the Abernethy Bridge that would make it likely to be immediately operational after a CSZ quake and is conducting preliminary engineering work. The project will include modest freeway widening that could reduce traffic congestion frequent at this location. The retrofit will likely cost hundreds of millions of dollars and require both state and federal support. Preserving the I-205 corridor is crucial for effective crisis response, transport of vital goods and services, and jumpstarting the region's economic recovery after a major earthquake.

Metro-area roads

Your committee found that authorities responsible for most of the major roads in the Portland metro area – ODOT, the Portland Bureau of Transportation and Multnomah County – are aware of the risks a CSZ earthquake poses. These agencies have inventoried

areas in their networks most vulnerable to landslides, liquefaction and lateral spreading. Most highway authorities in the metro area have included funding for strategies to mitigate these hazards, including improved retaining walls and other re-engineering efforts, in their ongoing capital plans.

The Metro regional government, in partnership with the Regional Disaster Planning Organization and others, is developing plans for post-earthquake debris removal. Debris removal will depend on access to a reliable supply of liquid fuel for vehicles and equipment. The vulnerability of Oregon's fuel supply and possible remedies are discussed in a preceding section of this report.

Portland-area bridges

Portland, known as "Bridge City," hosts the confluence of two major rivers. On any given workday, nearly 100,000 people work in downtown Portland, [70] and many of these people live east of the Willamette or north of the Columbia.[71] If a big quake happens during the workday, commuters from other counties or east of the river are likely to be stranded for a time, unable to assist their families in the immediate aftermath. If the quake occurs outside of the normal workday, Portland emergency responders who live in Clark County or East Multnomah County will not be able to get to work. Over the long term, our rivers will become barriers to economic recovery unless the resilience of the bridges that cross the Willamette can be increased.

The spans of the new Sellwood and Tilikum Crossing bridges have been designed to survive a major earthquake. However, the western approach to the Tilikum is located on liquefiable soils that are expected to suffer considerable damage, requiring repair or construction of the new approach before the bridge and light rail can be functional. Approaches to the Sellwood also might suffer some damage. And, the Sellwood's western landing is located against a steep hillside

Source: TriMet

Tilikum Crossing, one of Portland's newest bridges, likely will survive a major earthquake. Approaches to the bridge, however, might not, making the bridge unusable until repairs are done.

where landslides may block Oregon Highway 43 north and south of the bridge.

Although the spans of the Sellwood and Tillikum bridges are likely to remain standing, accessibility to these bridges is less certain due to potential landslides or damage to their approaches.

Multnomah County operates most downtown bridges over the Willamette: the Broadway, Burnside, Morrison and Hawthorne. Only the Burnside has been seismically retrofitted, and that only to life safety standards. None of the county's downtown bridges is expected to perform well in a CSZ quake. Even the Burnside will be unusable by motorized vehicles for a long time after.

In and near downtown Portland, ODOT is responsible for the St. Johns, Fremont, Marquam and Ross Island bridges. All are expected to be out of service for a long time after a CSZ quake. The Ross Island may fail catastrophically, rendering it irreparable. The Fremont and Marquam bridges have long approaches that are likely to require extensive repair or reconstruction to make the bridges usable. Union Pacific operates the Steel Bridge, which is not expected to perform well.

Bridges across the Willamette River south of Portland are expected to perform very poorly in a CSZ earthquake. Their collapse will temporarily isolate much of northwest Oregon, blocking delivery of assistance by road from the east.

ODOT has explored alternative means of crossing our rivers that might be put in place temporarily. Studies of temporary bridges, including floating spans, indicate that they likely are not an option for Portland's river crossings. Most temporary bridges can span only relatively short distances, not wide rivers like the Willamette or Columbia. River-borne debris from collapsed bridges could also complicate placement and maintenance of floating spans. Identifying shorter crossings that could safely host temporary bridges or floating spans is therefore essential.

Ferry service will likely be the most feasible stopgap solution while bridges are being repaired. Civilian-operated river crossing, using private boats, will likely be an effective element of providing crossings in the immediate aftermath of a major earthquake.

Burnside Bridge: A potential lifeline

Burnside Street has been designated a lifeline route. In 2002, the Burnside Bridge had a life safety seismic retrofit focused on holding the span in place during an earthquake. The concrete in the piers is minimally reinforced and overall the bridge is not expected to perform well in a CSZ quake.

At the time of this report, Multnomah County is beginning a feasibility study, in concert with an engineering consultant, to determine what should be done to ensure that a bridge at this location will be usable immediately after a CSZ quake.

This study will determine whether seismic retrofit or replacement of the Burnside Bridge is the more cost-effective option. Factors likely to be considered are impacts on traffic and surrounding communities, accessibility for bike riders and pedestrians, comparative costs to achieve seismic goals and long-term operating costs.

Following completion of that study, expected in 2018, the county will develop a project concept to be used in the environmental impact assessment process.

The Burnside Bridge was placed on the historic registry in 2012, which adds some complexity to the project. The current placeholder cost estimate for the Burnside retrofit/replacement project is $515 million. Multnomah County is considering a wide range of funding sources. One possible model is the successful Sellwood Bridge financing plan.

Roughly half of that $324 million project was funded from collected and future county vehicle registration fee increases, with the remainder coming from the city of Portland, state of Oregon and federal funds.

A seismically resilient Burnside Bridge will provide a lifeline route across the Willamette for first responders and repair equipment, as well as a means for family members to reconnect post-quake. A new or updated bridge could provide benefits to the Portland community such as user-friendly access for bikers and walkers. A fixed span bridge could offer lower ongoing operating and maintenance costs.

Metro-area transportation agencies have begun to plan for retrofitting and replacement of their seismically vulnerable infrastructure over the next three to five decades. Most of these projects will be very costly and must be implemented over time, as funding becomes available.

Because Burnside Street is a lifeline route, your committee views retrofit or replacement of the Burnside Bridge as a pivotal project. Multnomah County has begun studying options, so study timelines can feasibly be accelerated with concerted efforts by Multnomah County and other funding sources.

Recommendation to reinforce transportation lifelines

Recommendation 9

Multnomah County should begin upgrading or replacing the Burnside Bridge within three years. Voters, public officials and the Legislature should support local and state funding measures to make this timetable feasible.

Although Multnomah County has identified the project as a high priority, its current timeline for the project would begin construction after 2020, with completion in 2026 at the soonest. The county likely will pursue funding in the next few years. That funding will require pooling state and local resources, the latter coming from voter-approved bonding, a countywide vehicle registration fee, tolling or some combination of those and other sources.

ENHANCING SOCIAL RESILIENCE

To build a resilient community requires a "holistic and integrated approach that is concerned with connections and relationships and not just the structural integrity of buildings"[72] and other physical infrastructure. The capacity of people to support one another during and after a disaster is most often termed "social resilience."[73] The Oregon Resilience Plan concluded that "human resilience supported by Oregon's civic infrastructure (community-based, nongovernmental, and faith-based organizations) is needed to achieve full community resilience."[74]

Natural disasters around the world have demonstrated the critical importance of civic infrastructure during the first weeks after a disaster, before organized governmental assistance can be delivered. Our socioeconomic recovery depends on communities working together to rebuild and rebound.

Why focus on social resilience?

Building social resilience yields benefits beyond improved disaster response. When people are engaged in preparedness planning and crisis response training, their knowledge of and connections to one another naturally grow. Involving existing community organizations in preparing for disasters, such as a CSZ earthquake, builds enduring connections that enable people to rebuild and revitalize their communities more quickly and completely.

One of the central lessons learned from natural disasters such as Hurricane Katrina in 2005 is that "underlying issues of lack of trust and the absence of sustainable engagement with community-based organizations, faith-based organizations, and other neighborhood-level organizations create significant disparities in population health outcomes following emergencies and disasters."[75] Not surprisingly, many researchers have documented that "those with mental health problems, chronic medical conditions, developmental disabilities, or extreme poverty are often most at risk for poor survival outcomes."[76] But experience has also demonstrated that all communities can strengthen their capacity to rebound from adversity and to become "informed, trained, and empowered survivors and a capable source of human capital for response and recovery."[77] Neighborhoods that engage in preparing for disaster response and recovery can also receive immediate benefits in the form of greater public safety, improved dialogue with and trust of public agencies, and stronger relationships among neighbors.[78]

There are three key components of social resilience that affect communities' vulnerability to disaster and their capacity to recover: public awareness of risks and preparedness strategies, effective citizen engagement in planning and response activities, and strategic planning for continuity of vital human services and economic drivers. The following sections profile some metro area initiatives in these areas and highlight opportunities for improvement.

Enhancing public awareness

The 2015 New Yorker article, "The Really Big One," alerted many Pacific Northwest residents to the risks the region will face when a CSZ quake occurs.[79] But many people remain insufficiently aware of the challenges they will face immediately after a major earthquake. Many are also uninformed about how they

can prepare themselves and their families as well as prepare to assist neighbors and coworkers. By becoming better-informed, citizens can "prepare to the best of our ability to get through the initial emergency" and "for the many months and years of recovery and rebuilding after a devastating event occurs."[80]

Public information messages that focus solely on the devastating impacts of a CSZ can leave people feeling powerless, anxious or even apathetic, preventing them from taking actions that could lessen the risks they face. Although it is important to have a realistic view of likely challenges, this knowledge must be balanced with information about actions individuals and communities can take to increase their preparedness and resilience.

Public awareness campaigns should provide consistent and regularly updated information not only about CSZ risks but also about preparedness strategies and opportunities at the individual, neighborhood and community levels. Collaborative efforts by local media, government, and community based organizations can help ensure that this vital information reaches diverse citizens across the metro area.

Examples of ongoing public awareness efforts include:

- Oregon Public Broadcasting's "Unprepared" series[81] and its Aftershock[82] website, which allows users to view seismic risks of areas identified by address or ZIP code.
- The information-packed website of Cascade Regional Earthquake Workgroup, "a geographically and professionally diverse group of volunteers who are committed to making the Cascadia region more resilient to earthquakes and tsunamis."[83]
- Local government websites that provide detailed information about earthquake preparedness and response.[84] Multnomah County's website provides "earthquake primers" in 11 languages.[85]

Community-based organizations such as churches, neighborhood associations, condominium and other property associations, and athletic venues are also essential partners in distributing earthquake preparedness information to their stakeholders. In addition to materials available from local governments and from nongovernmental organizations such as the Red Cross, there are many other sources of emergency preparedness publications.[86]

Enhancing preparedness education in local schools

Local school systems are uniquely situated to play a key role in raising public awareness about earthquake risks and preparedness strategies. Currently, all Oregon schools are required to instruct students on emergency procedures and to conduct earthquake drills.[87] The Great Oregon Shakeout provides earthquake preparedness information for use by schools.[88]

The Federal Emergency Management Agency also publishes curricular packages appropriate for various grade levels.[89]

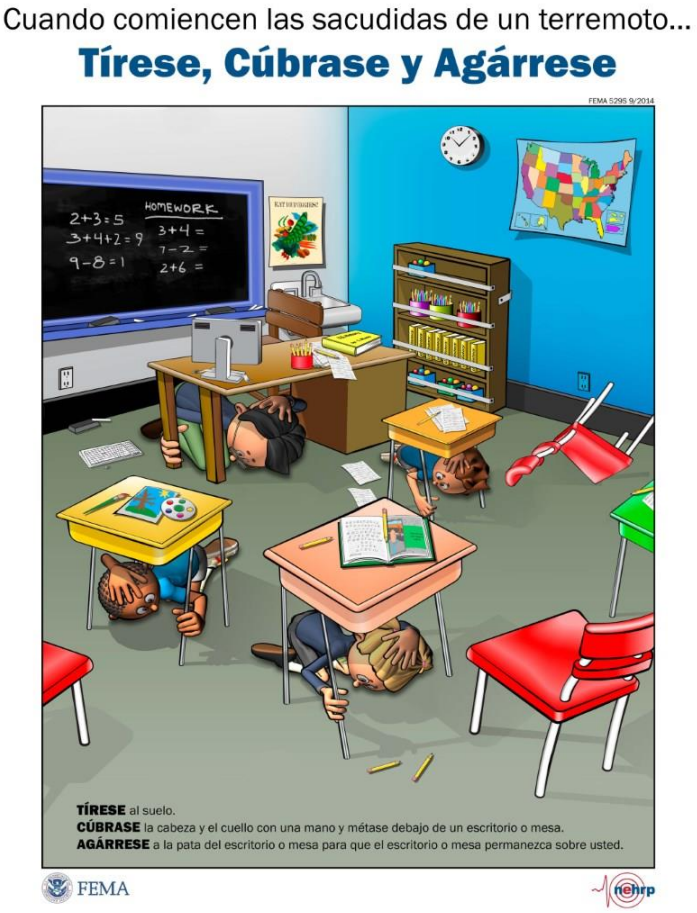
By educating K-12 students using age-appropriate materials and methods, schools can also expand awareness of staff and parents. In Portland, a parent group interested in promoting awareness of and preparedness for

the CSZ earthquake is working with Portland Public Schools to encourage a year-round focus on crisis response and resilience-building.[90]

Mercy Corps,[91] in collaboration with the American Red Cross, is working with Portland school administrators and parents to bring its knowledge of community preparedness to parents and community members during the 2016-17 school year. Mercy Corps hopes to continue the program. [92] Neighborhood Emergency Team volunteers in each school's neighborhood have been invited to participate in the events.

Mercy Corps has developed a simple Geographic Information System tool that allows agencies to note schools where they are doing preparedness outreach so that partners can ensure their efforts are complementary, not duplicative.[93]

These events are reportedly making a difference in student and parent awareness of and preparedness for a CSZ quake.[94] However, much more remains to be done to fully realize schools' potential for promoting public awareness.



The Federal Emergency Management Agency's "Drop, Cover and Hold" earthquake poster intended for schools is available in several languages, including Spanish.

Engaging citizens in building resilience

A recent survey of Oregonians showed a plurality (42 percent) would rather stay than evacuate following a CSZ quake.[95] However, a sizeable portion of respondents (28 percent) were unsure. The remaining 30 percent said they would choose to evacuate. The region's socioeconomic recovery from a CSZ quake will be swifter and more complete if a larger proportion of residents choose to stay. Providing opportunities for citizens to invest their energies in preparing to stay is an essential component of regional recovery strategies.

Public participation in planning is as important as strong social networks in delivering effective post-earthquake responses and sustaining long-term recovery efforts.[96,97] Metro residents should especially be involved in shaping social resilience strategies that depend on residents to participate in response and recovery.

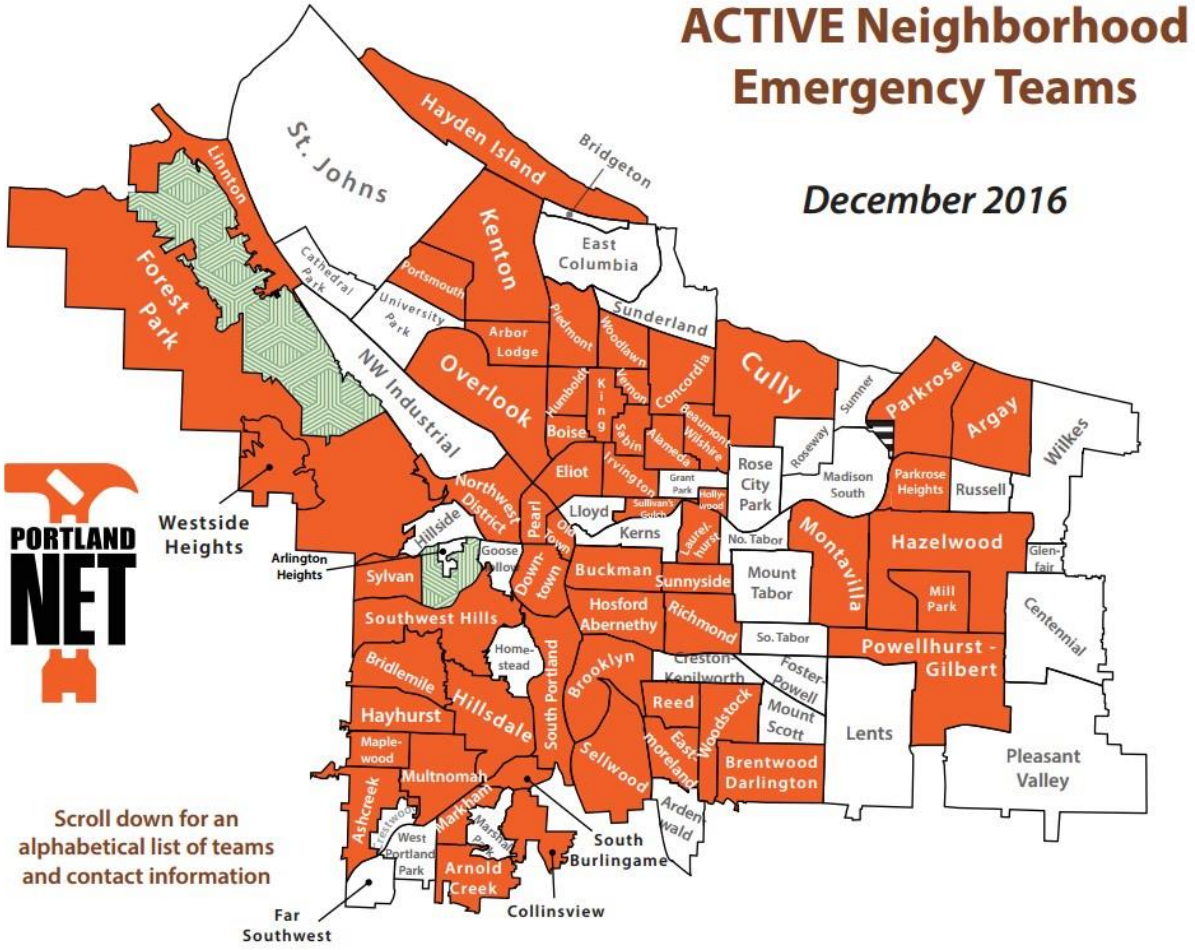
In our region, planning for community resilience has largely been conducted by experts and government officials with limited citizen involvement.

One exception is Portland's process for updating its Mitigation Action Plan. Organizers of that update reached out to numerous community organizations for input. Planning was directed by a diverse 32-member steering committee. The process included stakeholder meetings, utilized a community survey, and applied an equity lens to its process and recommendations.[98,99]

It is essential to ensure that all voices, including communities of color and vulnerable populations, are heard in discussions about and planning for a CSZ earthquake.

FEMA's Whole Community Approach, a framework for community engagement in resilience planning, "is a means by which residents, emergency management practitioners, organizational and community leaders, and government officials can collectively understand and assess the needs of their respective communities and determine the best ways to organize and strengthen their assets, capacities, and interests."[100]

San Francisco's Empowered Communities Program, [101] modeled on FEMA's initiative, places "ownership of community resilience at



the neighborhood level, where it rightfully belongs. The program offers communities a bottom-up planning and implementation process that puts community leadership in charge of creating their resilience strategy from the very beginning."

Your committee urges metro governments to support communities and neighborhoods in setting their own resilience goals. Empowered communities are more able to adapt and grow no matter what chronic stresses or acute shocks they may experience. Greater citizen involvement in planning and decision-making can enhance citizens' trust in government, strengthen post-disaster resilience and speed recovery.[102]

Training citizens to be emergency responders

In places that have suffered major disasters, most people who require rescue are saved by their neighbors, not by professional emergency responders. In the metro area, it could take as long as two weeks before professional help arrives following a CSZ quake. The Oregon Resilience Plan emphasizes that the 72-hour supply of survival necessities suggested by traditional disaster preparedness guidelines will fall far short of actual needs in the wake of a CSZ quake.[103]

Regional emergency management agencies have established programs that recruit and train citizens to save their family and neighbors' lives, restore basic communications and help to provide emergency shelter. These programs include:

- Portland's Neighborhood Emergency Teams;
- Portland's Basic Earthquake Emergency Communication Nodes Program;
- Multnomah County's Shelter Volunteers Program;
- Community Emergency Response Teams (CERT) in Washington, Multnomah and Clackamas counties;
- *Listos de Washington County*, a culturally specific preparedness training for Latino community members developed by Washington County Public Health Emergency Preparedness staff.

Although these volunteer training programs contribute significantly to metro area social resilience, their geographic coverage and capacities have not yet been maximized. The programs face several interrelated challenges, as exemplified by Portland Bureau of Emergency Management's NET program.

These programs depend on volunteers who must be recruited and trained. Because disasters occur infrequently, it is challenging to sustain volunteers' interest and commitment. The NET program reports that, on average, trained volunteers remain active for 23 months.[104] To keep volunteers engaged, the NET program recently has partnered with the Portland Fire Bureau to provide volunteers who can help keep citizens from encountering downed power lines until repairs can be made. NET volunteers also have begun to assist Mercy Corps and its partners with preparedness training events in schools.

Because crisis response volunteers must invest considerable time, these programs are not active in all communities. Currently, NETs are active in 60 percent of Portland's neighborhoods.[105] Racial and ethnic disparities also exist. Less than 2 percent of active NET volunteers are black compared to 6 percent of the city population. Similarly, less than 2 percent

of volunteers are Latino or Hispanic, compared to 9 percent of the city. [106,107]

Many programs have insufficient funding to hire additional staff to enable more intensive recruitment, training and volunteer support efforts. Currently there are 1,175 active NET volunteers, and 1,554 applicants awaiting training. [108] The sole NET coordinator employed by the Portland Bureau of Emergency Management is planning a basic NET training for 500 volunteers in spring 2017 to reduce the backlog.[109]

Many crisis volunteer training programs are not yet well-connected to other community-based organizations and initiatives. Therefore their capacity to leverage and build on the strengths and experience of metro-area grass-roots organizations is limited.

These programs can be strengthened and new social resilience initiatives launched using multiple strategies backed by public sector and philanthropic funding. These strategies depend in large part on having sufficient numbers of paid staff to expand the number of trained volunteers, retain the interest and commitment of volunteers over the long term and forge sustainable linkages with community- and neighborhood-based organizations.

One promising approach is using community mapping projects to maintain volunteers' interest and enhance neighborhoods' social connectivity. Cities across the nation have implemented needs and assets mapping focused on disaster preparedness.[110] There are also other social resilience assessment tools and scorecards, including social vulnerability indexes[111] and urban risk assessments.[112]

Your committee suggests that Portland and other jurisdictions explore ways to engage crisis response volunteers in mapping the needs and resources of their neighborhoods. Residents of Portland and surrounding communities have demonstrated willingness to step forward and help their neighbors in the wake of natural disasters.

Given sufficient human and fiscal resources, government programs designed to train and support citizen volunteers can not only expand the region's crisis response capacity but also enhance our capacity to rebound from a disaster.

Planning for continuity of essential services

Effective response to a major earthquake requires supporting vulnerable populations. These include persons with mental health challenges, seniors, children and those experiencing physical disability.[113] Public and non-profit sector providers of human services should be required to develop continuity of operations plans for promptly restoring the human service systems on which many individuals in Portland depend for their wellbeing and survival.

Many local government agencies, especially those with emergency management responsibilities, have developed continuity of operations plans. Multnomah County's Department of Human Services works with contractors to create such plans, and that approach could serve as a model for other departments to help contracted service providers develop continuity of operations plans.

"These plans and the thought that is put into creating them have the potential to greatly increase disaster resilience among our service providers," Alice Busch, division chief of operations at the Multnomah County Office of Emergency Management.[114]

Continuity planning also is crucial for private businesses, which employ the majority of metro residents. According to FEMA, 40 percent of businesses do not reopen after a disaster and another 25 percent fail within one year.[115]

The U.S. Small Business Administration notes that more than 90 percent of businesses fail within two years after being struck by a disaster.[116] Businesses that provide access to food and medicine, along with financial institutions and insurance companies, will be called upon to provide vital goods and services as the region recovers from a CSZ quake.

In the Portland area, many large businesses already have continuity plans in place.[117] Small- to medium-sized businesses also should have pragmatic continuity plans that enable them to minimize the effects of disasters, facilitate their employees' return to work as quickly as possible, and provide goods and services essential to human life and to the region's economic recovery.

Business organizations such as the Portland Business Alliance, Oregon Business Council, and local chambers of commerce should emphasize the importance of emergency preparedness and business continuity planning among their members. A wide array of materials is available to guide businesses motivated to do continuity planning.[118]

In addition, the Strategic Economic Development Corporation, the lead economic development entity for Oregon's Mid-Willamette Valley, works to promote business resilience. It offers a Cascadia Threat Series that includes education sessions and workshops to help businesses improve their ability to recover from disaster.[119] The Red Cross Cascades Region also offers free emergency preparedness presentations for local businesses tailored to their needs.[120]

> "It's the kids that are going to drive the cultural shift, the change from a concept to an actual way of life."
>
> *– Cynthia Valdivia,*
> *Emergency Preparedness Program Educator,*
> *Washington County*

Recommendations to enhance social resilience

Recommendation 10

School districts in the Portland metro area should provide students and their parents with comprehensive information about earthquake risks and preparedness strategies.

> *Annual earthquake drills are not enough. Schools can tap a variety of supportive resources, including information organized by the Oregon Department of Education and curricular packages published by the Federal Emergency Management Agency. Community partners such as Mercy Corps, the Red Cross and Portland's NET program are already assisting Portland schools with preparedness training.*

Recommendation 11

Portland should allocate funds to enable the Portland Bureau of Emergency Management to hire a second Neighborhood Emergency Team coordinator who will increase the number, diversity and retention of trained NET volunteers.

> *This position would cost an estimated $125,000. The ideal candidate would help the NET program to adapt its curriculum for immigrant communities, conduct trainings in Spanish and strengthen connections to community-based organizations.*

Recommendation 12

Metro-area governments that contract with nonprofit service providers should use the contracting process and periodic audits to require them to have continuity of operations plans.

> *Jurisdictions should commit staff resources sufficient to provide any technical assistance required by contracted service providers to develop and regularly update their continuity of operations plans.*

INVESTING IN AND PLANNING FOR RESILIENCE

To enhance the metro area's resilience, regional decision-makers must commit to investing a significant proportion of public and private resources, both fiscal and human, in this vital work over the long term. Equally essential is improving coordination of the wide array of essential public and private sector preparedness, planning and recovery efforts.

Public sector policies and programs are key to enhancing community resilience. Non-governmental organizations and private sector companies also have unique capabilities to contribute to this essential work. Though your committee's recommendations focus on actions that can be taken by governments, we have also highlighted opportunities for fruitful public-private collaboration. Public-private partnerships can "ensure economic, cultural, societal and infrastructural continuity" by making "effective use of the partners' collective capabilities" to increase resilience to hazards and risks.[121]

Investing in Resilience

Strategies designed to enhance social resilience cost much less to implement than retrofitting or replacing buildings and other critical infrastructure. Investments in both human and infrastructure resilience are essential. Both types of investments have opportunity costs (the value of benefits that must be given up) as well as co-benefits (sometimes called "extended benefits" by economists) that go beyond improved disaster resilience. Co-benefits can include improved delivery and reliability of basic services (e.g., water, sewage and utilities), upgraded transportation systems, increased environmental sustainability, strengthened social connectivity, improved public health and safety, enhanced citizen engagement and greater trust in government.[122]

A review of literature on the economics of investing in disaster risk reduction notes that "economic assessments of the benefits and costs of reducing disaster risk face both technical and policy challenges." [123] Developing cost-benefit analyses for recommendations in this report is beyond the expertise of your committee, and local economists have only just begun to develop such analyses.

In 2015, the Rockefeller Foundation 100 Resilient Cities initiative launched a 10 percent Resilience Pledge. Mayors of participating cities around the world were asked to devote 10 percent of their cities' annual budgets toward resilience-building goals and projects without raising additional funds or taxes. Projects could include neighborhood revitalization, energy or seismic retrofits, and improved public transit systems. Each city defines its own resilience goals in which to invest resilience funds.

The cities are also asked to update their strategies and goals as circumstances and priorities change and impacts are assessed. At the outset of this initiative, 22 cities worldwide agreed to pledge 10 percent of their budgets toward resilience-enhancing strategies.

Persistent public and private sector investments in resilience strategies over the next 50 years will help ensure that the Portland metro area's economy and communities can bounce back more quickly after a CSZ earthquake.

Ed MacMullan, an economist with ECONorthwest specializing in environmental

economics, suggests that resilience issues should not be relegated to an afterthought or add-on to municipal policies and developments. Rather, local governments should treat resilience on par with other municipal responsibilities such as water and transportation services. He recommends that government dedicate 1 to 5 percent of general funds or department budgets each year to resiliency upgrades and improvements. He and other economists also emphasize the importance of developing and supporting public-private partnerships to promote the socioeconomic resilience of the Portland region and the state of Oregon.[124]

Coordinating planning, preparedness and recovery efforts

The complexity of impacts resulting from a major earthquake disaster is difficult to imagine. A multitude of physical infrastructure, financial, business, education and social networks will be damaged, and because these networks and systems interact with each other, earthquake impacts will be intertwined and compounded. For example, people cannot get paid if they cannot travel to work because of broken transportation systems or if the businesses at which they are employed do not reopen. Families cannot get supplies they need if they cannot access bank accounts or if grocery stores and other suppliers of basic needs are unable to reopen or be restocked. Schools cannot reopen if buildings are destroyed or deemed unusable and alternative locations cannot be found.

And because the CSZ quake will likely have significant impacts not only on the Portland metro region but on all of western Oregon and Washington, residents will not be able to rely on neighboring jurisdictions to step in as they might with more localized disasters such as forest fires or flooding. Regional planning and action that bands together communities experiencing the same disaster together can advance resilience.[125]

Oregon State Resilience Officer

The governor's appointment of a state resilience officer, first recommended by the Oregon Seismic Safety Policy Advisory Commission in the Oregon Resilience Plan, signals the state's recognition that planning, advocacy and implementation of policies and programs to enhance earthquake preparedness and resilience will be most effective if they are coordinated and collectively prioritized.

Mike Harryman, the state resilience officer, is still mapping out his job description and clarifying his planning and advocacy priorities. He is committed to forging alliances with state and local government policymakers and advocating for shared priorities with legislative and executive branch decision-makers.[126]

City resilience officers

Another approach to coordinating urban resilience-building has been pioneered by a few large U.S. cities, with the support of the Rockefeller Foundation's 100 Resilient Cities worldwide initiative. These cities have elevated the pursuit of resilience by appointing a resilience officer.

The Foundation's approach to helping cities build resilience is not limited to natural disasters but also encompasses other "physical, social, and economic challenges that are a

growing part of the 21st century." Those include climate change, affordable housing shortages and aging infrastructure.[127]

San Francisco, for example, has appointed a resilience officer and created an Office of Resilience and Recovery within the city administrator's office charged with "managing the city's ongoing resilience challenge, and with championing our city's earthquake preparedness and recovery work. This challenge involves working across departments and agencies to determine and continue clear action, to build the narrative around resilience internally, and to find connection points with ongoing strategic planning and comprehensive planning processes."[128]

Resilience officers serve as boundary spanners, linking together the many agencies and organizations involved in preparedness, response and recovery. In San Francisco, the resilience officer's charge includes bridging "the practice gaps between social justice, sustainability and disaster recovery" to help create a more integrated and resilient community and governance system.[129]

Regional Disaster Preparedness Organization

Collaborative planning for the Portland metro region — linking governments, community organizations, and businesses together to support resilience — is already in process under the aegis of the Regional Disaster Preparedness Organization (RDPO). The RDPO was launched in 2012 and was formalized under an intergovernmental agreement in early 2015.

It was formed "out of a desire to build upon and unify various regional preparedness efforts in the Portland Metropolitan Region, including the Regional Emergency Management Group established in 1993, the Urban Areas Security Initiative Program (a federal Homeland Security initiative) originally founded in 2003, and several discipline-specific coordination groups." [130] Counties encompassed by the RDPO include Clackamas, Columbia, Multnomah and Washington in Oregon and Clark in Washington.

The RDPO welcomes as members all local jurisdictions, nongovernmental organizations and private sector businesses in the five-county region that have an interest in disaster preparedness, response and recovery. Meetings of RDPO's numerous committees are open to the public. Voting members represent a range of political, geographical and discipline perspectives.

The RDPO's vision is to "create a secure and disaster-resilient region in which local agencies, organizations, and communities are coordinated and prepared to prevent, protect against, mitigate, respond to, and recover from threats and hazards of great risk to the Portland Metropolitan Region." [131] This "all-hazards" perspective is not focused exclusively on the CSZ or other earthquake risks, but looks to enhance resilience in general.

A core group of members provides financial support to the RDPO. In 2016, that group included Clark, Clackamas, Columbia, Multnomah and Washington counties; Portland; and three regional government entities – Metro, TriMet and the Port of Portland. Their contributions fund the salary and other costs associated with the full-time administrator position ($175,000 in FY2016). Core members contribute amounts determined by a formula that allocates 80 percent of costs proportionately (to population) across the five

counties and Portland, with the remaining 20 percent divided evenly among the regional entities.[132]

Other municipal governments, state and federal agencies, businesses and NGOs have contributed to specific projects or initiatives, and substantial funding has come from Urban Areas Security Initiative grants.

Those grants currently fund one professional staff position, a planner who supports the work of the RDPO's three standing committees. These all-volunteer committees are composed of elected officials, agency CEO's and managers, and discipline-specific representatives.

The willingness of RDPO's core members to sustainably fund RDPO Administrator Denise Barrett's planning and coordination efforts is a testament to the value they place on the position and her work.

However, dependence on grant funding to support the RDPO's only other professional staff member as well as the Portland Bureau of Emergency Management grant and finance staff that support the RDPO, has made recruitment and retention challenging during the first years of RDPO's operations.[133]

Barrett, who has managed the RDPO since its formation, reports significant "churn" in the planner and grants and finance positions. Several other professional positions were lost when the region did not receive Urban Areas Security Initiative funding in FY2013-14 and have not been reinstated. Unreliable funding has at times negatively affected the continuity and service capacity of the RDPO.

"We cannot avoid the future earthquake, but we can choose either a future in which the earthquake results in grim damage and losses and a society diminished for a generation, or a future in which the earthquake is a manageable disaster without lasting impact."

– Oregon Resilience Plan

Recommendations to coordinate and expand resilience planning

Recommendation 13

Portland and other local governments should appoint a resilience officer or designate an existing high-level position to be responsible for resilience efforts, including:

- Linking together the many agencies, planning bodies and governance structures engaged in planning and preparing for major earthquakes and other challenges the jurisdiction is likely to face,
- Coordinating and expanding public outreach and awareness efforts focused on earthquake preparedness,
- Cultivating public-private partnerships that support resilience enhancement, and
- Working with the Regional Disaster Preparedness Organization to support coordinated planning for resilience across the region.

Recommendation 14

Government and private sector members of the Regional Disaster Preparedness Organization should increase their funding commitment to a level sufficient to support two full-time professional staff in addition to the administrator.

Each position is estimated to cost $140,000 annually. This investment would fully fund the RDPO's planner position, now supported by a grant, and would enable a new position to focus on initiatives such as coordinating regional messaging and public information efforts, managing a diverse array of grant-funded projects, strengthening linkages between public and private sector partners, and monitoring and evaluating the impacts of RDPO's work. With more reliable personnel funding, the RDPO could stabilize its coordination capacity and monitor the impacts of its resilience-building efforts for all the region's residents.

FINDINGS & CONCLUSIONS

During your committee's nine-month research process, we learned much about the risks posed by the Cascadia Subduction Zone (CSZ) and the catastrophic damage the region will suffer if it ruptures before the region has adequately prepared.

Unless citizens and public policymakers act now to strengthen the region's resilience, the economic and social fabric of communities will be devastated by a CSZ earthquake. At the current level of preparedness, recovery from a major quake would take many years.

Your committee also learned much about ways to reduce damage and to recover more quickly from an earthquake's impacts. Many proven and promising approaches to strengthening our physical and social resilience are available. Your committee is optimistic that collectively the region and state can build a culture of resilience that will enable communities and the economy to rebound strongly after an earthquake.

Your committee's key findings and conclusions are:

General

1. Public awareness and scientific understanding about the dangers posed by the Cascadia Subduction Zone (CSZ) have grown over the past few decades.
2. Recovery from a CSZ quake will depend as much on the resilience of human communities as on seismically resilient infrastructure.
3. Creating a more resilient metro region is a complex process requiring sustained investment over the next 50 years and beyond.
4. Coordinated planning that links governments, community organizations and businesses to support resilience will better prepare the region to rebound from a CSZ earthquake and other disasters.

Some good news

5. Ongoing mitigation initiatives of the Portland Water Bureau and regional electric and gas utilities are making progress in preparing vital systems to withstand a CSZ quake.
6. Most metro area transportation agencies have begun a 50-year process of gradual infrastructure improvements that will enable essential elements of the transportation system to survive a major quake.
7. Programs such as Portland's Neighborhood Emergency Teams (NETs) are in place throughout the region, training residents to help themselves and their neighbors in the event of a disaster.

Physical infrastructure resilience

Critical Energy Infrastructure (CEI) Hub

8. In a CSZ quake, privately-owned tanks composing the CEI Hub, through which 90 percent of Oregon's liquid fuel supply passes, are likely to collapse.
9. No federal, state or local agency requires companies that own CEI Hub tanks to assess and report the vulnerability of their facilities, nor do they require companies to retrofit or replace tanks to reduce risk.
10. Hardening liquefiable soils under existing tanks and in the areas surrounding them would reinforce the CEI Hub.

Building Standards

11. Current building codes regulating construction for the vast majority of buildings are aimed at life safety only, not ensuring that structures remain usable after a major quake.
12. Significant loss of building stock would likely lead to mass emigration, severely damaging the regional economy and extending the time required for recovery.
13. For new construction, building to higher standards of seismic resilience is relatively inexpensive, adding only 1 to 10 percent to most construction costs.
14. Changing seismic resilience standards to ensure that buildings will be usable post-earthquake would bolster the resilience of our communities and the regional economy.
15. Government and market incentives encourage property owners to retrofit at-risk buildings, including single-family homes, sooner rather than later.

Transportation Networks

16. Metro area transportation via air, water, rail, roads and bridges would be severely compromised if a CSZ quake occurred today.
17. Recent retrofits of the Burnside Bridge are not sufficient to ensure that it will be immediately usable by motorized vehicles after a CSZ quake.

Social resilience

18. Building social resilience improves disaster response, strengthens connections among citizens, and enhances public dialogue with and trust in government agencies.
19. Schools are uniquely positioned to expand public awareness by educating children and their parents about earthquake risks and preparedness strategies.
20. The region's crisis response volunteer training programs are not funded sufficiently to support the intensive recruitment and culturally relevant training needed to expand the number and diversity of volunteers.
21. Grassroots participation in resilience work can help ensure that benefits of preparedness are experienced equitably by all residents, particularly our most vulnerable neighbors.
22. Continuity of operations plans enable human service providers and businesses to prepare to resume operations promptly in the wake of a disaster.

> "The fact that we have not had an earthquake of note in living memory is a good news/bad news story. We live in a highly seismic area, but we are not wired to be concerned about events that we do not recall."
>
> *– Mike Stuhr,*
> *Director, Portland Water Bureau*

RECOMMENDATIONS

In developing its recommendations, your committee assessed the feasibility and utility of potential changes in laws, policies, programs and practices. The goal was to propose recommendations that:

- Draw from current scientific consensus and expert opinions about the CSZ and effective preparedness approaches,
- Leverage current initiatives in the metro area and beyond,
- Encourage collaborative solution-building,
- Have the potential to be financed by public and private funding streams,
- Have demonstrable co-benefits beyond disaster preparedness,
- Ameliorate inequitable impacts of disasters on disadvantaged and vulnerable populations, and
- Add to our knowledge base about promising approaches to building regional preparedness and resilience.

With those goals in mind, your committee recommends:

Reducing risk of catastrophic CEI Hub failure

1. The Oregon Department of Geology and Mineral Industries should commission a geotechnical study of the soils in the Critical Energy Infrastructure (CEI) Hub and alternatives for soil hardening. If grant funding is unavailable, the Legislature should appropriate funds for the study.

2. The Governor and Legislature should designate a single state agency to oversee seismic risks at the CEI Hub. That agency should have the authority to:

    - Require all owners of CEI Hub facilities to provide an engineering assessment of their facilities' vulnerability to a CSZ earthquake and other information relevant to mitigating the current risks.
    - Develop and implement, in collaboration with industry stakeholders, standards for construction and retrofit of storage tanks at the CEI Hub. The standards should be designed to prevent releases and to preserve substantial functionality in the event of a CSZ earthquake.

Improving building safety and resilience

3. Portland should seek approval from the Oregon Building Codes Division for a local amendment that requires office buildings and multifamily housing to be built to a standard that would allow them to be used and occupied after a CSZ earthquake. The BCD should grant the waiver.

4. All local governments in the Portland metropolitan area should require that structures built or significantly remodeled using any public financing meet standards that will allow the buildings to be used and occupied after an earthquake.

5. Portland should adopt the mandatory unreinforced masonry (URM) retrofit policy now under consideration and should continue to lead a multi-stakeholder collaborative process to develop a range of incentives to assist property owners in retrofitting.

6. The Legislature should allow cities and counties to grant property tax exemptions to offset retrofitting costs.

7. Portland and other local governments should inventory non-URM building stock at high risk in a CSZ earthquake, such as non-ductile concrete and soft story structures.

8. The Legislature should require a seismic resilience disclosure statement at the point of sale for single-family homes.

Reinforcing transportation lifelines

9. Multnomah County should begin upgrading or replacing the Burnside Bridge within three years. Voters, public officials and the Legislature should support local and state funding measures to make this timetable feasible.

Enhancing social resilience

10. School districts in the Portland metro area should provide students and their parents with comprehensive information about earthquake risks and preparedness strategies.

11. Portland should allocate funds to enable the Portland Bureau of Emergency Management to hire a second Neighborhood Emergency Team coordinator who will increase the number, diversity and retention of trained NET volunteers.

12. Metro-area governments that contract with nonprofit service providers should use the contracting process and periodic audits to require them to have continuity of operations plans.

Coordinating and expanding resilience planning

13. Portland and other local governments should appoint a resilience officer or designate an existing high-level position to be responsible for resilience efforts, including:
    - Linking together the many agencies, planning bodies and governance structures engaged in planning and preparing for major earthquakes and other challenges the jurisdiction is likely to face,
    - Coordinating and expanding public outreach and awareness efforts focused on earthquake preparedness,
    - Cultivating public-private partnerships that support resilience enhancement, and
    - Working with the Regional Disaster Preparedness Organization to support coordinated planning for resilience across the region.

14. Government and private sector members of the Regional Disaster Preparedness Organization should increase their funding commitment to a level sufficient to support two full-time professional staff in addition to the administrator.

SIGNATURES

Respectfully and unanimously submitted by your committee:

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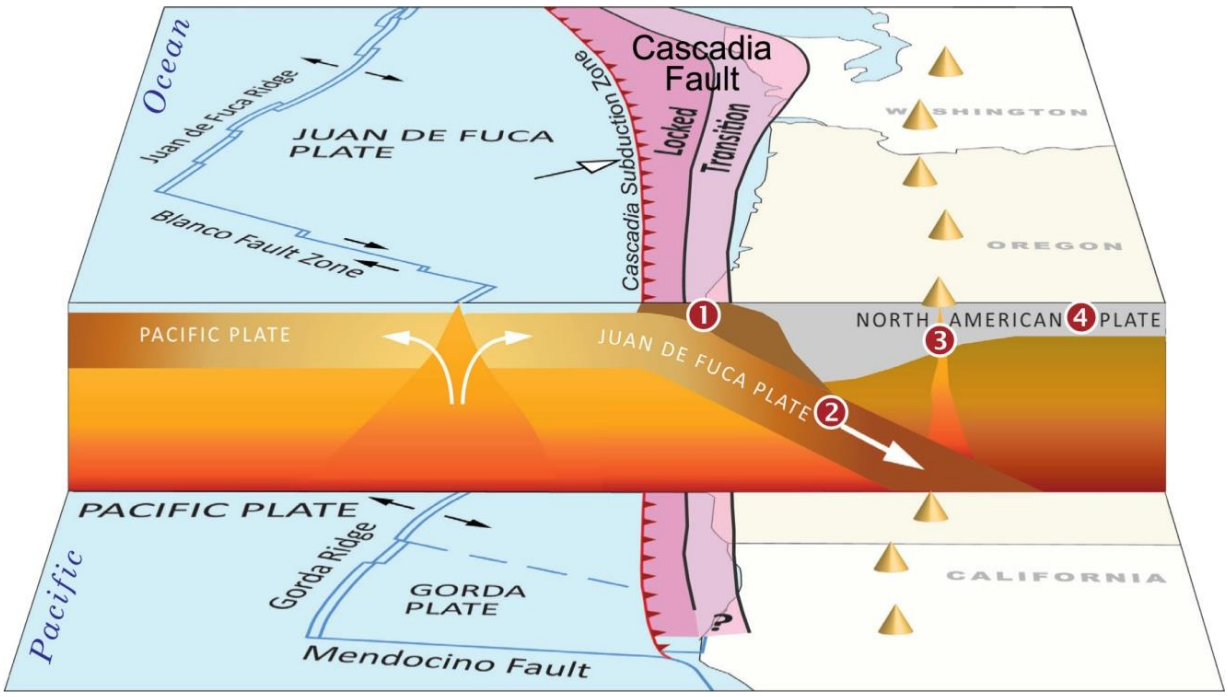
APPENDIX A:
The science of Cascadia Subduction Zone earthquakes

Actions to promote earthquake preparedness should be founded on an assessment of Cascadia Subduction Zone science that embraces both its accomplishments and limitations. We offer this summary analysis of the current state of the science so that policymakers advancing preparedness initiatives will be better prepared to address skeptics who may wish to minimize the urgency of such work.

To recover the Pacific Northwest's past, geologists sail off the Pacific coast to coordinates along the Cascadia Subduction Zone. There they drill and pull from the seafloor cores of marine sediment. These cores are like tree rings in that they have stories to tell. The cores are gray to brown and segmented into thin layers of sand, silt and mud. The samples can look like supermarket UPC codes in a grocery store. Most layers in the cores were laid down millennia before Lewis and Clark or any other non-Native American arrived to record geological events. These segments are the written testimony of the great earthquakes – quakes larger than any ever thought to have been experienced in California – quakes that have shaken the Pacific Northwest for 10,000 or more years.

These data are coupled with findings from the land, where ghost forests – swaths of gray, dead trees – can be found along coastal waterways and sometimes on hillsides. Forests can "drown" when a megathrust quake drops land into the sea. Over time, as pressure grows along the subduction zone, the land rises again and the forest of dead trees surfaces.

Linking data from seafloor cores, ghost forests and other evidence, some geologists infer they have found a periodicity to the great quakes. Based on interpretation of the



geological records, the most current estimate of the likelihood of the next great magnitude 9 earthquake and tsunami to hammer the region is 14 to 20 percent in the next 50 years.

While the science and risk calculations may seem to be settled, there are relatively few core samples taken from the CSZ, and both methods and findings of some of this research have been called into question, which is part of the normal evolution of any science.

Earthquake prediction has been a longstanding goal of geologists and the planners who rely on their guidance, but it has also been elusive. Some of the most intensively studied and highly instrumented faults have repeatedly surprised geologists with quakes that gave no warning.

For example, in Japan, five major universities have been investigating the local subduction zone for decades, providing data used by scientists to calculate the country's vulnerability to big earthquakes. Yet the magnitude 9 earthquake and tsunami of 2011 that killed more than 15,000 people and destroyed 272,000 buildings surprised experts.

Forecasts of the timing of major or even minor quakes, even of those most well-studied faults, remain unreliable. Because the CSZ is a relatively recent discovery, there is relatively less evidence on which to base predictions or probabilistic analyses.

Even less is known about the crustal faults that lie under the Portland region that could generate a magnitude 6 earthquake that would inflict as much damage in the Portland Metro Area as a CSZ rupture, albeit more localized.

Basic research on the CSZ and on the vulnerabilities of the Portland area's soils and substrates has been hampered by lack of sustainable, prioritized funding. Efforts to develop an early warning system for the CSZ are in early stages and will also require continued support from federal, state and private sector sources.

The 2013 Oregon Resilience Plan states that "there is no scientific doubt that another great subduction earthquake will strike the Pacific Northwest; the questions now are how soon, how large and how destructive that earthquake will be."[134] To ignore this threat, to neglect to invest in community preparedness, and to fail to require new construction, retrofitted buildings and other infrastructure to meet stringent seismic resilience standards would be supremely irresponsible.

APPENDIX B:
Regional populations

2015 Population of Portland Metro Region: Three Regional Definitions (U.S. Census Bureau)

				Population	Metro	UASI & RDPO	MSA
Metropolitan Statistical Area	UASI and RDPO	Metro	Multnomah County	790,294	45%	35%	33%
			Clackamas County	401,515	23%	18%	17%
			Washington County	574,326	33%	25%	24%
			Total Metro:	**1,766,135**	**100%**		
			Columbia County	49,600		2%	2%
			Clark County, Wash.	459,495		20%	19%
			Total UASI and RDPO:	**2,275,230**		**100%**	
			Yamhill County	102,659			4%
			Skamania County, Wash.	11,339			0.5%
			Total MSA:	**2,389,228**			**100%**

Forty-four percent of all Oregonians live in the three metro counties (Multnomah, Clackamas and Washington).

Oregon's estimated total population in 2015 was 4,028,977.

2015 Population of Largest Cities in Metro Government Region (U.S. Census Bureau)

	Population	Pct. of County	Pct. Of Metro
Multnomah County	**790,294**	**100%**	**45%**
Portland	632,309	80%	36%
Gresham	105,595	13%	6%
Washington County	**574,326**	**100%**	**33%**
Beaverton	89,817	16%	5%
Hillsboro	92,158	16%	5%
Clackamas County	**401,515**	**100%**	**23%**
Lake Oswego	38,496	10%	2%
Oregon City	32,646	8%	2%
All cities total:	**991,021**	**-**	**56%**

APPENDIX C:
Risk category of buildings and other structures

"Most of the building sectors that are critical to the response to a seismic event are recognized by the current building code. Oregon's current seismic design standard for new buildings, the Oregon Structural Specialty Code (OSSC), classifies buildings according to four distinct occupancy categories based on their relative importance to life safety in the event of a natural disaster. … Occupancy Categories III and IV are structures that have large assembly areas (such as schools), or that are deemed essential to emergency response (such as hospitals, police and fire stations, and emergency operations centers). ... Under current code, occupancy category type III buildings are designed for a 25-percent higher seismic load than Category I and II buildings. Category IV buildings are designed for a 50-percent higher load." [135]

Risk Category of Buildings and Other Structures
2014 Oregon Structural Specialty Code[136]

Risk Category	Nature of Occupancy
I	Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to: • Agricultural facilities. • Certain temporary facilities. • Minor storage facilities.
II	Buildings and other structures except those listed in Risk Categories I, III and IV
III	Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to: • Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300. • Buildings and other structures containing elementary school, secondary school or day care facilities with an occupant load greater than 250. • Buildings and other structures containing adult education facilities, such as colleges and universities, with an occupant load greater than 500. • Group I-2 occupancies with an occupant load of 50 or more resident care recipients but not having surgery or emergency treatment facilities. • Group I-3 occupancies. • Any other occupancy with an occupant load greater than 5,000.

	• Power-generating stations, water treatment facilities for potable water, wastewater treatment facilities and other public utility facilities not included in Risk Category IV. • Buildings and other structures not included in Risk Category IV containing quantities of toxic or explosive materials that: Exceed maximum allowable quantities per control area as given in Table 307.1(1) or 307.1(2) or per outdoor control area in accordance with the Fire Code; and Are sufficient to pose a threat to the public if released.
IV	Buildings and other structures designated as essential facilities, including but not limited to: • Group I-2 occupancies having surgery or emergency treatment facilities. • Fire, rescue, ambulance and police stations and emergency vehicle garages. • Designated earthquake, hurricane or other emergency shelters. • Designated emergency preparedness, communications and operations centers and other facilities required for emergency response. • Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures. • Buildings and other structures containing quantities of highly toxic materials that: Exceed maximum allowable quantities per control area as given in Table 307.1(2) or per outdoor control area in accordance with the Fire Code; and Are sufficient to pose a threat to the public if released • Aviation control towers, air traffic control centers and emergency aircraft hangars. • Buildings and other structures having critical national defense functions. • Water storage facilities and pump structures required to maintain water pressure for fire suppression.

WITNESS LIST

- Daniel Aldrich, Professor & Director of Security and Resilience Studies, Northeastern University, July 24, 2016.
- Brian Atwater, Geologist, United States Geological Survey, Aug. 30, 2016.
- Denise Barrett, Manager (Administrator), Regional Disaster Preparedness Organization, Nov. 16, 2016.
- Larry Bekkedahl, Vice President, Transmission and Distribution, Portland General Electric, Nov. 16, 2016.
- Dana Buhl, Parents for Preparedness, July 7, 2016.
- Steven Bullock, Business and Community Preparedness Manager, Multnomah County Office of Emergency Management, July 14, 2016.
- Alice Busch, Division Chief of Operations, Multnomah County Office of Emergency Management, July 14, 2016.
- Danielle Butsick, Project Manager, Natural Hazards Mitigation Plan, Portland Bureau of Emergency Management, July 19, 2016.
- Ian Cannon, Transportation Director/ County Engineer, Multnomah County, July 11, 2016.
- Marian Catedral-King, Policy, Government and Public Affairs Representative Northern California and the Pacific Northwest, Chevron Corporation, Aug. 8, 2016.
- Emily Chamlee-Wright, Provost & Dean, Washington College, July 22, 2016.
- Daniel Cox, Professor of Civil and Construction Engineering & Director of Cascadia Lifelines Program, Oregon State University, Aug. 8, 2016.
- Brian Doherty, Partner, Miller Nash Graham & Dunn LLP (represents Western States Petroleum Association), June 14, 2016.
- Elizabeth Edwards, Interim Director, Office of Government Relations, Portland, Dec. 30, 2016.
- Molly Emmons, Emergency Preparedness Manager, Portland Public Schools. Aug. 24, 2016.
- Bruce Gilles, Manager, Cleanup and Emergency Response Program, Oregon Department of Environmental Quality, Aug. 2, 2016.
- Chris Goldfinger, Professor of Marine Geology and Geophysics & Director of Active Tectonics and Seafloor Mapping Laboratory, Oregon State University, Nov. 1, 2016.
- Brent Griffiths, Program Coordinator, Community Right to Know Program, Office of State Fire Marshal, Oregon State Police, Aug. 16, 2016.
- Debbie Guerra, Director, T&D Operations Support & Emergency Management, PacifiCorp, Oct. 10, 2016.

- Hosny Hakim, Senior Engineer, Petroleum Structures, California State Lands Commission, Aug. 12, 2016.
- Mike Harryman, State Resilience Officer, State of Oregon, Sept. 27, 2016.
- Eric Heidmann, Manger, Continuity of Operations, Bonneville Power Administration, U.S. Department of Energy, Aug. 16, 2016.
- Jerry Henderson, Portland Terminal Manager, Chevron Corporation, Sept. 15, 2016.
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- Sharon Hofer, Public Health Nurse, Washington County Communicable Disease Program, Aug. 9, 2016.
- Andrew Holbrook, Operations Manager, Northwest, Kinder Morgan Energy Partners, July 13, 2016.
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- Jay Jewess, Director, Business Continuity & Emergency Management, Portland General Electric, July 20, 2016.
- Bruce Johnson, State Bridge Engineer, Oregon Department of Transportation, July 5, 2016.
- Albyn Jones, Professor of Statistics, Reed College, Aug. 16, 2016.
- Ernest Jones, Volunteer Program Development, Portland Bureau of Emergency Management, June 28, 2016.
- Douglas Kelsey, Chief Operating Officer, TriMet, Sept. 16, 2016.
- Leon Kempner, Seismic Engineer, Bonneville Power Administration, U.S. Department of Energy, Sept. 26, 2016.
- Lori Koho, Administrator Safety, Reliability, & Security Division, Public Utility Commission of Oregon, July 18, 2016.
- Steve Kountz, Senior Economic Planner, Portland Bureau of Planning and Sustainability, Aug. 15, 2016.
- Amit Kumar, Senior Structural Engineer, Portland Bureau of Development Services, Sept. 16, 2016.
- Jay Landstrom, Manager, Transmission & Distribution Asset Management, Portland General Electric, July 20, 2016.
- Mark Long, Administrator, Oregon Building Codes Division, Nov. 16, 2016.
- Ed MacMullan, Project Director & Senior Economist, ECONorthwest and member of Salus Resilience, Oct. 4, 2016.

- Ian Madin, Chief Scientist, Oregon Department of Geology & Mineral Industries, June 24, 2016.
- Ronald L. Mayes, Executive Director, US Resiliency Council, Staff Consultant, Simpson Gumpertz & Heger, July 27, 2016.
- Sean M. McCormick, Director, Financial Administration Division, Oregon Military Department, Nov. 17, 2016.
- Sandra McDonough, President and CEO, Portland Business Alliance, Jan. 4, 2017.
- Walter McMonies, Attorney with Lane Powell P.C. representing Masonry Buildings Owners of Oregon; Stakeholder Member of Portland URM Policy Committee, Aug. 5, 2016.
- Carmen Merlo, Director, Portland Bureau of Emergency Management, May 31, 2016.
- Sue Mohnkern, Public Health Emergency Preparedness Program Supervisor, Washington County, July 18, 2016.
- Samir Mokashi, Principal, Code Unlimited, July 22, 2016.
- Dave Mulligan, Community Liaison, Western Region U.S. DOT, PHMSA, Pipeline Safety, Aug. 16, 2016.
- Kenneth D. Murphy, Region X Administrator, Federal Emergency Management Agency, Oct. 11, 2016.
- Darren Murtaugh, Manager, Transmission & Distribution Planning/ Project Management, Portland General Electric, July 20, 2016.
- Avinash Nafday, Lead Senior Engineer, Petroleum Structures, California State Lands Commission, Aug. 12, 2016.
- Steve Novick, Former City Commissioner (2013-2017), City of Portland, Aug. 16, 2016.
- Kendra Oliver, Senior Engineer, Petroleum Structures, California State Lands Commission, Aug. 12, 2016.
- Patrick Otellini, Former Chief Resilience Officer, City & County of San Francisco, Oct. 12, 2016.
- Courtney Patterson, Emergency Management Operations Manager, Portland Bureau of Emergency Management, July 26, 2016.
- Andy Peterson, Manager, Plan Review and Permitting Services Division, Portland Bureau of Development Services, Sept. 16, 2016.
- Wayne Pipes, Senior Manager, Facilities, Security and Energy Management, NW Natural, June 22, 2016.
- Jay Raskin, Vice Chair, Oregon Seismic Safety Policy Advisory Commission, Principal, Jay Raskin Architect, July 1, 2016.
- Richard Rogers, Chief Building Official, Oregon Building Codes Division, Nov. 2, 2016.

- Susan Romanski, U.S. Director for Disaster Preparedness & Community Resilience, Mercy Corps, Aug. 30, 2016.
- Mike Rookstool, Structural Engineer, Chevron Corporation, Sept. 15, 2016.
- Joel Scruggs, Public Affairs Specialist, Bonneville Power Administration, U.S. Department of Energy, Sept. 26, 2016.
- Tricia Sears, Former Project Manager for City of Portland LEAP (Local Energy Assurance Plan), Natural Hazards Planner, Department of Land Conservation & Development, State of Oregon, June 17, 2016.
- Robert Simpson, Director, Asset – Risk & Strategy, PacifiCorp, Oct. 10, 2016.
- Jen Sohm, Design Quality Manager, Portland Public Schools, via e-mail July 6, July 13 and Dec. 7, 2016.
- Dick Steinbrugge, Executive Administrator for Facilities, Beaverton School District, Nov. 30, 2016.
- Armin W. Stuedlein, Associate Professor of Geotechnical Engineering, Oregon State University, Oct. 17, 2016.
- Mike Stuhr, Director, Portland Water Bureau, June 14, 2016.
- Kathleen Tierney, Professor and Director Natural Hazards Center, University of Colorado, July 22, 2016.
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- Jeremy Van Keuren, NET Coordinator, Portland Bureau of Emergency Management, June 28, 2016.
- Maria J. Vorel, Senior Vice President Disaster Operation, Catholic Charities, March 3, 2016.
- Chris Voss, Director of Emergency Management, Multnomah County, July 26, 2016.
- Jack Vranish, Director, Asset Management, PacifiCorp, Oct. 10, 2016.
- Stan Watters, Chief Project & Technical Services Officer, Port of Portland, July 12, 2016.
- Yumei Wang, Geotechnical Engineer, Oregon Department of Geology and Mineral Industries, May 18, 2016.
- Rob Weik, Manager, Strategic Asset Management and Geo-Spatial Information, Portland General Electric, July 20, 2016.
- Michael Wieber, Director of Operations, NW Seismic, Sept. 2, 2016.
- Jay Wilson, Chair, Oregon Seismic Safety Policy Advisory Commission; Resilience Coordinator, Clackamas County Emergency Management, May 24, 2016.

- Duncan Wyse, President, Oregon Business Council, Jan. 4, 2016.
- Grant Yoshihara, Vice President, Utility Operations, NW Natural, June 22, 2016.
- Kent Yu, Former Chair (2011-2013), Oregon Seismic Safety Policy Advisory Commission; Principal, Structural, Earthquake, Forensic, and Tsunami Engineering (SEFT) Consulting Group, May 24, 2016.

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