Chapter 3 – Hazard Identification and Risk Assessment

The hazard identification and risk assessment chapter identifies the most significant natural hazards in Multnomah County and describes how each of the has impacted communities in the past, and what we know about the potential for future impacts. Mitigation strategies are then built from this analysis of risk.

There are six natural hazards used in this plan with some additional subsets of hazards within those six hazards. All of the participating entities in the plan could face some risk from all of the hazards, but the risk to each is not equal. Each participating jurisdiction or district has conducted a local risk analysis to prioritize hazard risk in order to identify mitigation strategies that will address the hazards of highest risk. The local risk analysis is included in each jurisdiction/district chapter.

Human-caused and technological hazards are not included in this plan, but hazard identification and risk assessment for some of those hazards are included in a 2017 report included in this plan as an annex.

For each of the six natural hazards, assessment of risk is determined by looking at four dimensions:

- An **Overview**, which defines the hazard, and explores different ways the hazard can happen,
- A **History**, which lists recent and historic events to provide context on frequency and impact when these disasters have occurred,
- An analysis of **Probability –** how likely the event is to happen again, using data from the history section and from research conducted when available.
- A consideration of **Scope and Extent**, which parts of the county will be impacted by the hazard and how the impact may differ between locations, using research data when available, and
- A description of **Vulnerability** – once understanding how likely the event is to occur and where it is most likely to cause impacts, an analysis of people, property, infrastructure and natural resources that would be impacted by a disaster, with consideration around who would face disparate impacts from the event.

3.1 Earthquake

All of the jurisdictions and districts in this plan face dangerous susceptibility to earthquakes, with damage expected to be primarily caused by ground shaking, soil liquefaction and landslides. Different areas in Multnomah County will see differing levels of damage intensity from an earthquake event, based on the location from the earthquake epicenter, the depth and type of earthquake, local bedrock and soils, and the types of building construction where people are located when the earthquake hits. Infrastructure—including levees, major transportation facilities, roads, bridges and buried and aboveground utilities—are also expected to suffer severe, long-term damage across Multnomah County from future earthquakes.

Large earthquakes are rare in Multnomah County, which somewhat moderates risk. However, the long time period between earthquakes allowed development to occur without awareness of this danger, and seismically-resilient construction standards were not broadly adopted in Oregon until state building code updates in 1993. Updated building codes have made new construction significantly more resilient, but many vulnerabilities remain and a significant earthquake remains the natural hazard event most likely to cause widespread and long-term damage and displacement in Multnomah County.

Risk awareness of a Cascadia Subduction Zone megathrust earthquake has been heightened over the last 20 years, because of powerful similar earthquakes in the Indian Ocean and off the coast of Japan, and popular reporting of potential impacts of a similar earthquake off the coast of Oregon.

Earthquake Types

There are four types of naturally-occurring earthquakes that could impact Multnomah County. All types of earthquakes are measured by their magnitude with instruments that amplify and record ground movements. Magnitude is noted using a number and decimal point – such as the M6.8[28] Nisqually earthquake in Washington in 2001. Magnitude does not always directly determine the amount of damage caused, because impacts may depend on how close the epicenter is to development and how deep the epicenter is located below the ground. Amounts of damage caused will also be affected by types of soils, seasonal conditions, and the density and type of development closest to the epicenter.

- *Subduction Zone Earthquakes*

A subduction zone occurs where two continental plates meet and one is pushed under the other. As the plate is pushed under, or subducted, it creates a tremendous amount of pressure. When the plate eventually ‘rips’ and bounces back it creates a massive shock wave. The largest recorded earthquakes on the planet have all been subduction zone earthquakes. The Ring of Fire - a huge circle of geologically active locations around the Pacific Ocean from Asia to South America to the Pacific Northwest - is caused by a number of subduction zones.

[28] M6.8 means a magnitude of 6.8. Magnitudes are based on a calculation of recorded levels of shaking and converted to a familiar scale. The magnitude scale is logarithmic, meaning that each whole number increase (4.0 to 5.0 for example) represents a tenfold increase in shaking.

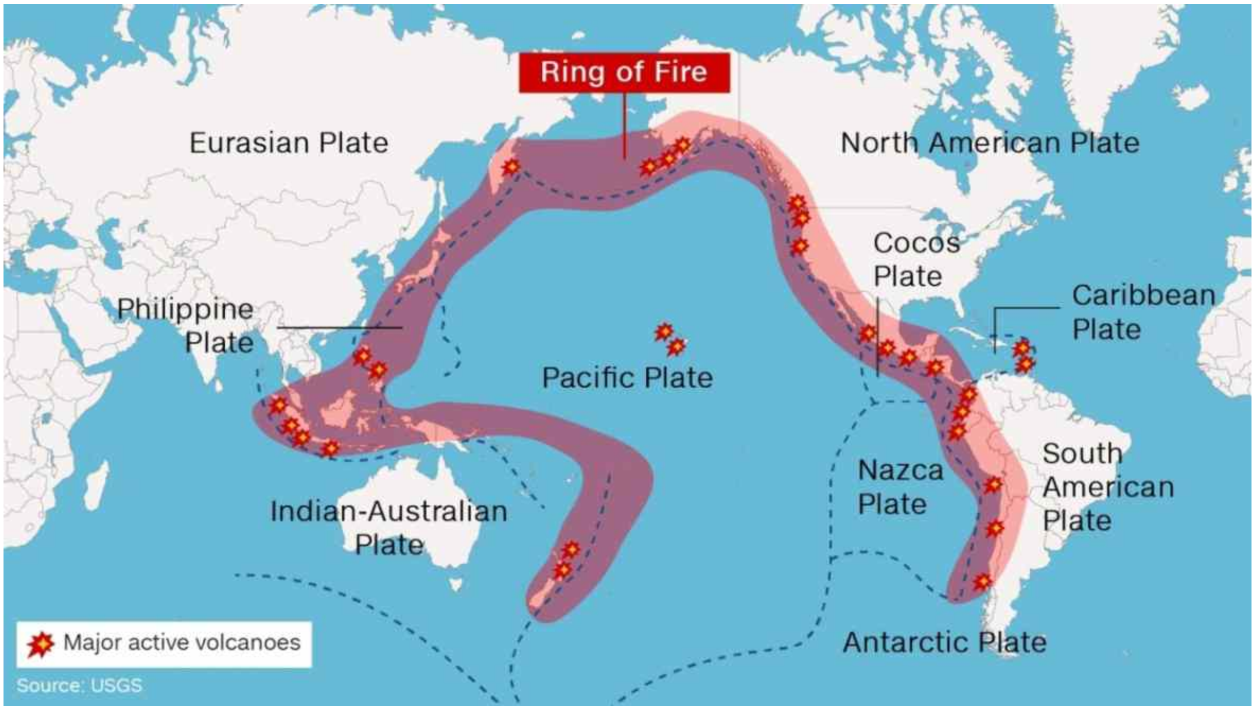

Figure 26 - Map showing the Ring of Fire, including active volcanoes located along the ring.

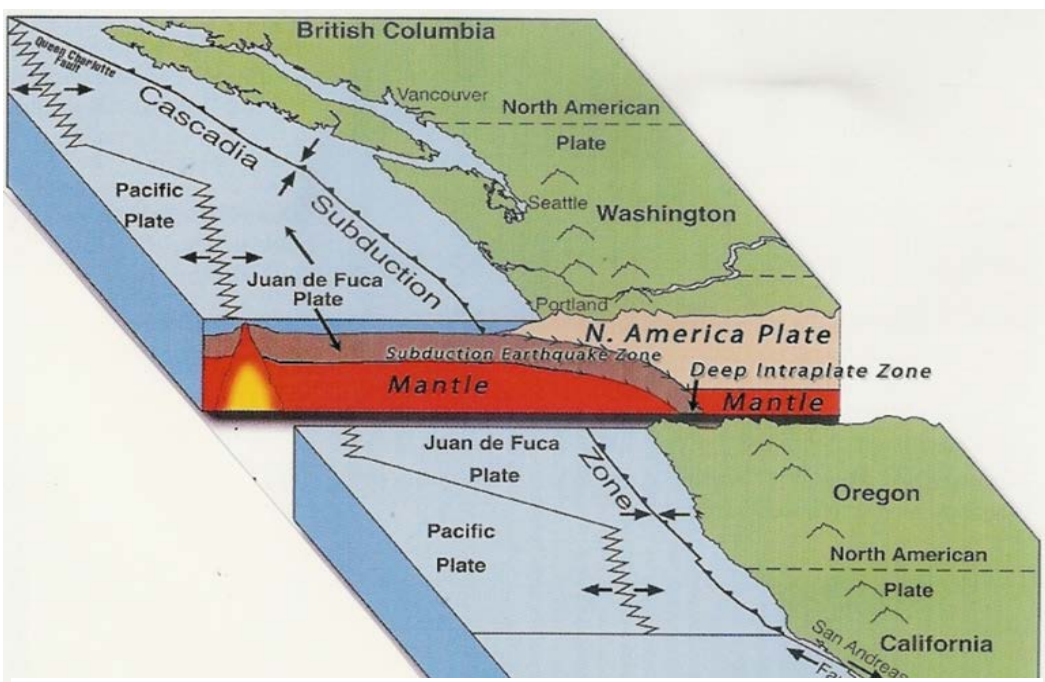

Figure 27 – USGS Diagram showing the subduction of plates below the Cascadia region. The Subduction Zone line shows where plates meet and one is pushed under the other, eventually being pushed into the mantle beneath the Pacific Northwest landmass.

Local risk of subduction zone earthquake comes from the pushing of several pieces of oceanic floor (Juan de Fuca Plate, Gorda Plate, and other smaller pieces) under the North American continental crust about 70-100 miles off the western coast of the United States and Canada. This subduction zone extends about 600 miles from British Columbia in Canada to Northern California.

Since subduction zones occur at continental boundaries in coastal locations, tsunamis are a common associated hazard. Subduction zone earthquakes often have long gaps of time between events, but in Oregon they have historically occurred more frequently than damaging crustal earthquakes. The last major earthquake of this type in the Pacific Northwest occurred in 1700 and has been estimated to have had a magnitude of around 9.0.

- *Crustal Earthquakes*

Crustal earthquakes occur when blocks of rock slip against each other, much closer to the earth's surface than subduction zones. These earthquakes are mapped by faults—fractures in the rock that cause these slips and may be very short or extend hundreds of miles. Many faults in Multnomah County have been mapped, but there may be more that have not yet been discovered, because of a lack of study and no currently understood evidence of past seismic activity.

An interactive version of this map can be found here (Earthquake Hazard – Active Faults)

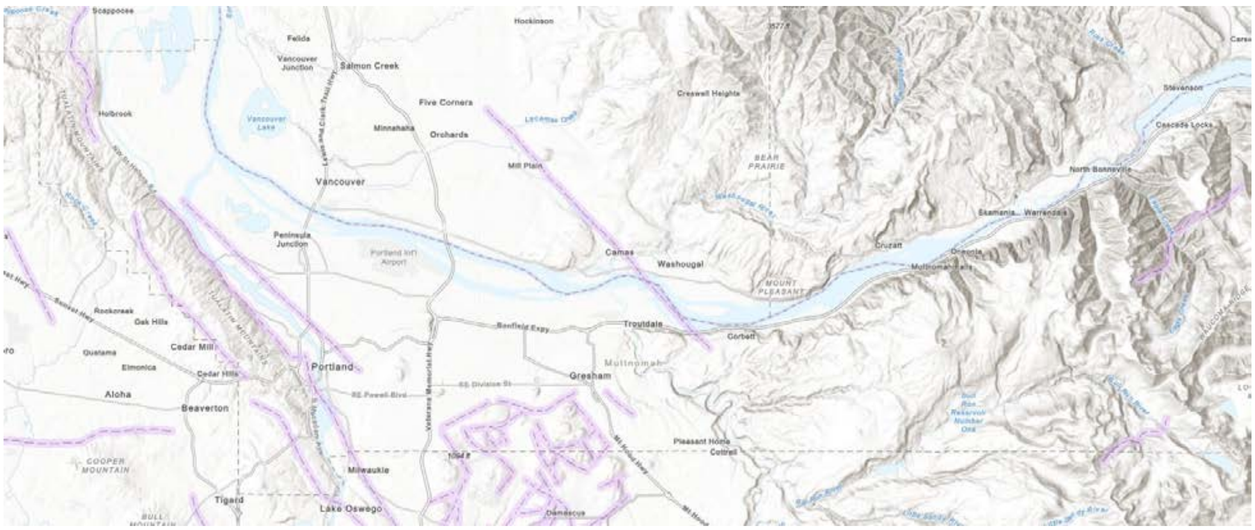

Figure 28 - Map showing known earthquake faults in Multnomah County. Map hosted on DOGAMI's HazVu website.

Crustal earthquakes are less powerful than subduction zone earthquakes, but because they occur closer to the surface and faults may run directly under populated areas, they also have tremendous damage potential. These types of earthquakes are common in California, with the San Andreas Fault being a well-known example.

Oregon has not had the same historical frequency of crustal earthquakes as neighboring states, and the likelihood of a large event in Multnomah County is considered to be significantly less likely than a subduction zone earthquake. However, a major earthquake on the Portland Hills fault could cause more local damage than a Cascadia Subduction Zone event.

- *Intraplate Earthquakes*

Unlike subduction zone and crustal quakes, intraplate earthquakes happen within a single plate. This may occur because of subduction effects above the plate or in locations where old rifts have been reactivated. This type of earthquake is difficult to predict both in frequency and location.

The 2001 Nisqually Earthquake was a recent intraplate earthquake, causing billions in damage in the Southern Puget Sound area of Washington and making buildings sway in Portland. The last known significant intraplate earthquake to occur in Oregon was in 1962—a 4.5 magnitude event near Corvallis[29]. Because the frequency and location of future intraplate earthquakes are largely unknown, risk is managed through preparation for the more predictable types of earthquakes. Intraplate earthquakes are not as strong as subduction zone earthquakes and are much deeper than crustal quakes, but can still cause considerable damage.

- *Volcanic Earthquakes*

Volcanic earthquakes usually occur in swarms as magma moves beneath a volcano. This type of earthquake is not usually strong enough to cause damage to structures or infrastructure, but can indicate increasing volcanic activity (see Volcano section). Small earthquake swarms continue to occur beneath Mount Hood, but very few have been large enough to be felt even in communities at the mountain.

Five-Year Report, 2017-2022

- *Events*

No significant earthquakes occurred in Multnomah County between 2017 and 2022. A number of normal low-intensity tremors have occurred, but no injuries or damages have occurred due to earthquakes over the last five years.

- *New Data and Analyses*

Since the Adoption of the 2017 Plan, the Regional Disaster Preparedness Organization (RDPO) provided funding in 2018 for the Oregon Department of Geology and Mineral Industries (DOGAMI) to create the *Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon*. This report contains the best available data for understanding impacts from the two most likely earthquake scenarios in the Portland Metropolitan Region.

An additional crustal earthquake scenario was modeled for another DOGAMI analysis – the 2020 *Natural Hazards Risk Report for the Lower Columbia-Sandy Watershed, Oregon*. The analysis provides building damage estimates within this East County watershed for a large crustal earthquake in the Mount Hood Fault Zone.

In July 2021, a Resiliency Assessment (RRAP) for Oregon transportation systems was published to resolve knowledge gaps, inform risk management decisions, identify opportunities for increasing transportation system resilience, and improve critical partnerships. The State of Oregon had previously published a 2018 report on improving resilience by 2025, including a planned update of the 2013 Oregon Resilience Plan.

Also in 2021, the first phase of an update to Regional Emergency Transportation Routes (ETRs) was published through the RDPO. The first phase of the update revised selected routes, based on improved road and bridge vulnerability information, detailed landslide mapping, and enhanced understandings of social vulnerability. A second phase, to be completed in 2023, will

[29] Lifelines and earthquake hazards along the Interstate 5 Urban Corridor: Cottage Grove to Woodburn, Oregon; United States Geological Survey, 2004

prioritize routes and provide operational guidance. The Oregon Department of Transportation (ODOT) simultaneously worked on a statewide analysis of triage routes, looking to identify the highest priority infrastructure programs to ensure post-disaster movement through counties and regions statewide.

A 2022 study, *Impacts of Fuel Releases from the CEI Hub Due to a Cascadia Subduction Zone Earthquake* was commissioned by the Portland Bureau of Emergency Management (PBEM) and the Multnomah County Office of Sustainability. The study quantifies risk and impacts from fuel storage tank seismic failure at the Critical Energy Infrastructure Hub in Northwest Portland. An overview, and risks to participating entities in this plan, is included later in this chapter.

- *Early Warning System*

ShakeAlert, a United States Geological Service earthquake early warning system, became available in Oregon on March 11, 2021. The system uses sensitive field sensors to detect earthquake shock waves and send out a signal that can be received before a shock wave reaches populated areas. Warnings can be sent seconds to tens of seconds before the effects of the earthquake are felt, giving people time to quickly take protective action. This warning can be received on cell phones, with some communication methods being automatic and some opt-in, depending on a person's phone.

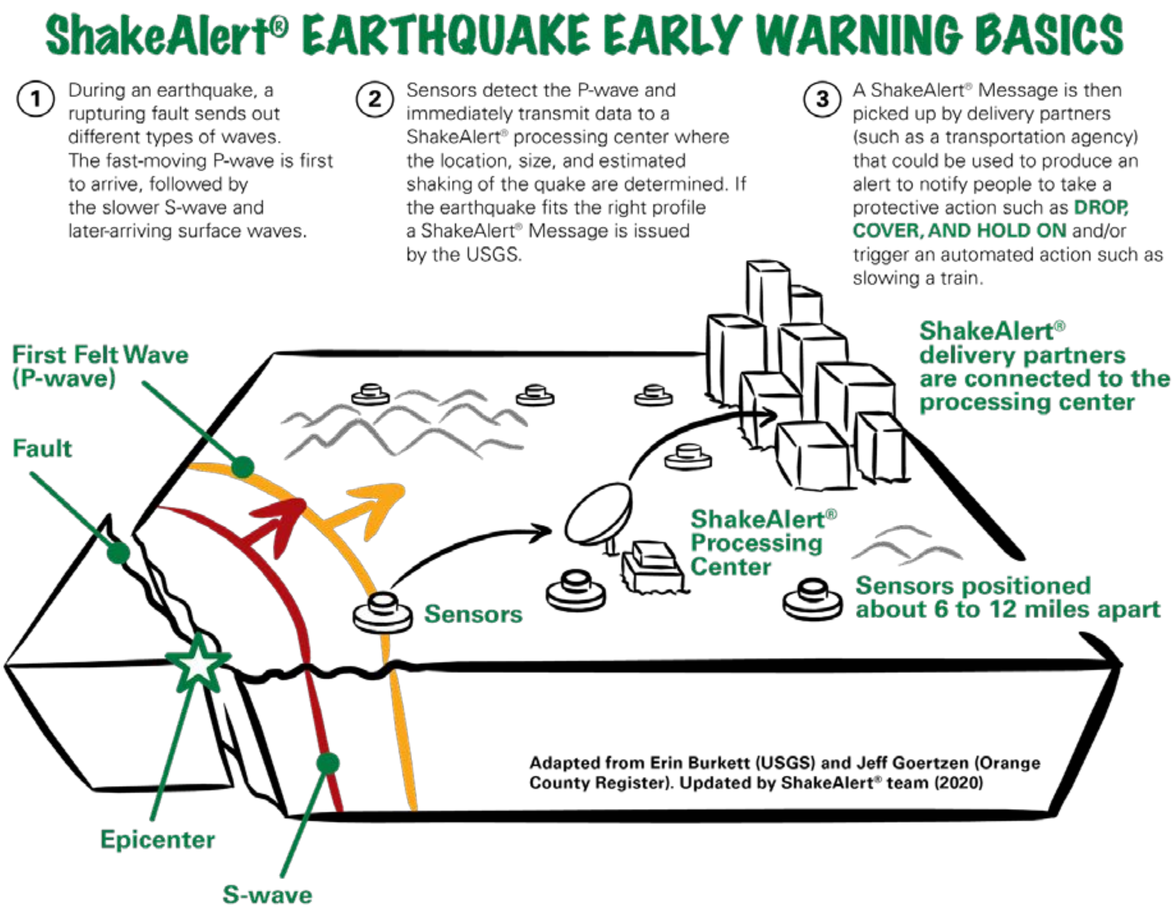

Figure 29 - ShakeAlert Basics

For participating entities in this plan, ShakeAlert offers potential for creating automatic infrastructure responses to the early warning. Some possibilities include opening or closing valves, opening automatic doors to prevent them from being stuck closed when power is lost, starting backup generators, halting air operations, and opening or closing bridges. Developing programs to take advantage of the system will be an ongoing mitigation opportunity for county jurisdictions and districts in coming years.

Other Mitigation Trends

Many notable improvements to resilience of critical infrastructure have been initiated or completed in the last five years. A number of these projects are described in the jurisdictional/district chapters, and include assets with regional and statewide significance, such as a resilient Portland International Airport runway, the Columbia River Levee System and the Burnside Bridge.

Because so much of the planning area related to this document is located in earthquake impact zones, all new built development carries some earthquake risk. New development occurring within the Urban Growth Boundary in areas with significant soil liquefaction hazard will still be threatened.

Continued public engagement around earthquake risk continues to be essential. Public awareness attained a high level around 2015, with factors such as the major earthquakes in Japan and New Zealand in 2011, and the publication of a 2015 article in *The New Yorker*[30] about the extreme risks of a Cascadia Subduction Zone earthquake. Risk awareness of earthquakes remained relatively high in survey responses gathered for this plan update, but the continuing influx of new residents, the infrequency of earthquakes, and the higher current visibility of weather hazards makes risk communication for earthquakes an ongoing need.

Climate Change Impacts

There is no proven link that a warmer climate will lead to increased earthquake risk. There is some evidence that small earthquakes can be affected by increased precipitation, drought, and groundwater pumping—but these effects are not likely to increase the likelihood of the earthquakes that are the focus of this plan.

3.1.1 Earthquake Impacts, Locations and Extent

All parts of Multnomah County are at risk from large earthquakes. Almost any large earthquake regionally will be felt across the area. However, some parts of Multnomah County will see greater impacts, depending on the location of the earthquake, the types of soils, and the types of buildings and infrastructure present. Based on expected locations of future earthquakes, eastern Multnomah County has somewhat less vulnerability than Portland and western portions of the County, except in areas with high susceptibility to soil liquefaction.

[30] The Really Big One, *The New Yorker*, Kathryn Schulz, July 20, 2015

- *Cascadia Subduction Zone*

Effects from a Cascadia Subduction Zone earthquake will be strongest on the Oregon Coast and lessen as the shock wave travels eastward. Effects will be mild east of the Cascades. The western portion of Multnomah County will experience more shaking from a Cascadia Subduction Zone event, and wet, low-lying areas throughout the county will be impacted by soil liquefaction. Landslides will also occur across the county, but especially on the west side of the county in locations where high landslide vulnerability already exists.

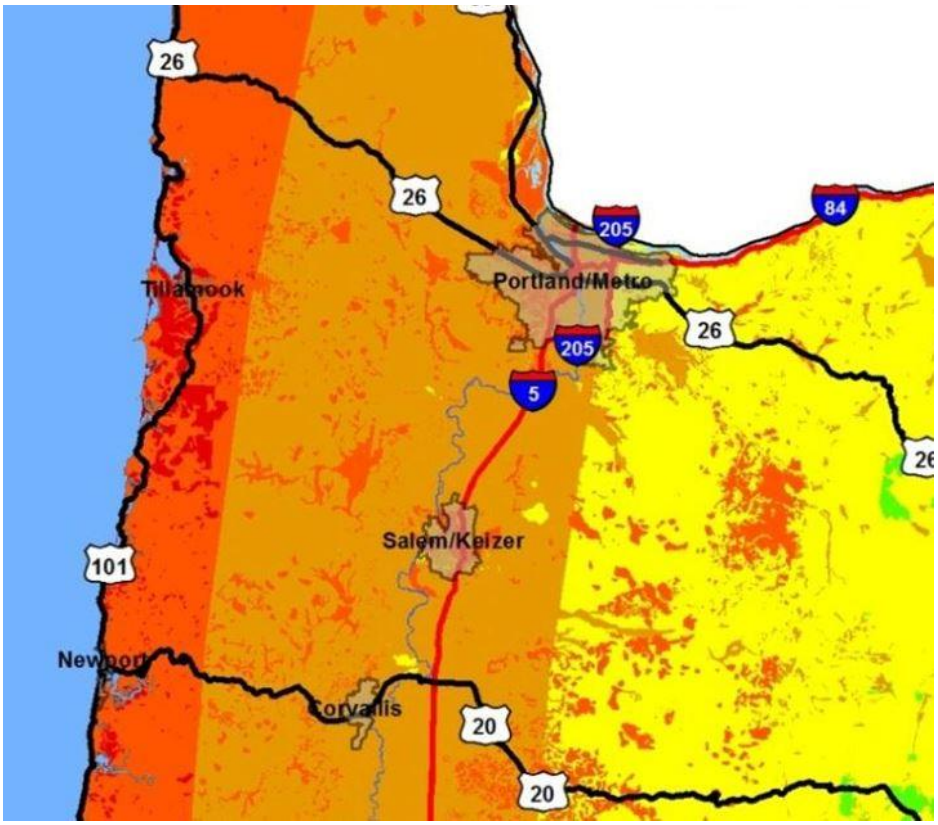

Figure 30 - A diagram showing expected shaking from a Cascadia Subduction Zone Earthquake. Orange is heavy shaking, light orange is moderate shaking, yellow is light shaking, and green is very light shaking. The strongest effects will be felt on the coast and lessen as the shock moves inland – but note that areas with wet soils in the Portland Metropolitan Area will feel shaking about as strongly as many coastal areas. Eastern Multnomah County sees a decline in shaking beginning roughly east of Highway 205. Map from the [2013 Oregon Resilience Plan](#).

Portland Hills Faults

A Portland Hills crustal earthquake will also impact the entire county, but ground shaking effects will be strongest closest to the fault. In those areas closest to the fault line, shaking will be significantly stronger than a subduction zone event, although likely for a much shorter amount of time. Because of the lower magnitude, areas farthest away in East County will feel less shaking in most cases than from a subduction zone event.

Mount Hood Fault Zone

The earthquake scenario modeled for the Lower Columbia-Sandy watershed in the Mount Hood Fault Zone will have its epicenter outside of Multnomah County. Effects will be strongest along Multnomah County's easternmost border with Hood River County all the way to the Columbia River, but impacts will be significantly moderated by the time the shock waves reach densely populated areas west of the Sandy River. Landslides in the Columbia River Gorge could be a significant danger.

Earthquake Impacts

Ground Shaking/Acceleration

The amount of ground shaking that occurs in an earthquake can be increased by the properties of the soil. Seismic waves move faster through hard rock and dense soils, while softer rock or soil will slow down waves and cause them to accumulate and strengthen.

Since ground liquefaction is also most likely to occur in soft, wet soils, severe ground shaking and liquefaction areas are often located in the same place, and the impacts of amplified shaking contribute to the severity of liquefaction in these areas.

Much of the area of participating cities and districts will see fairly uniform ground shaking, although elevated risk is notable in areas within the Columbia River floodplain. Multnomah County has significant differences between unincorporated areas on the east and west sides of the county.

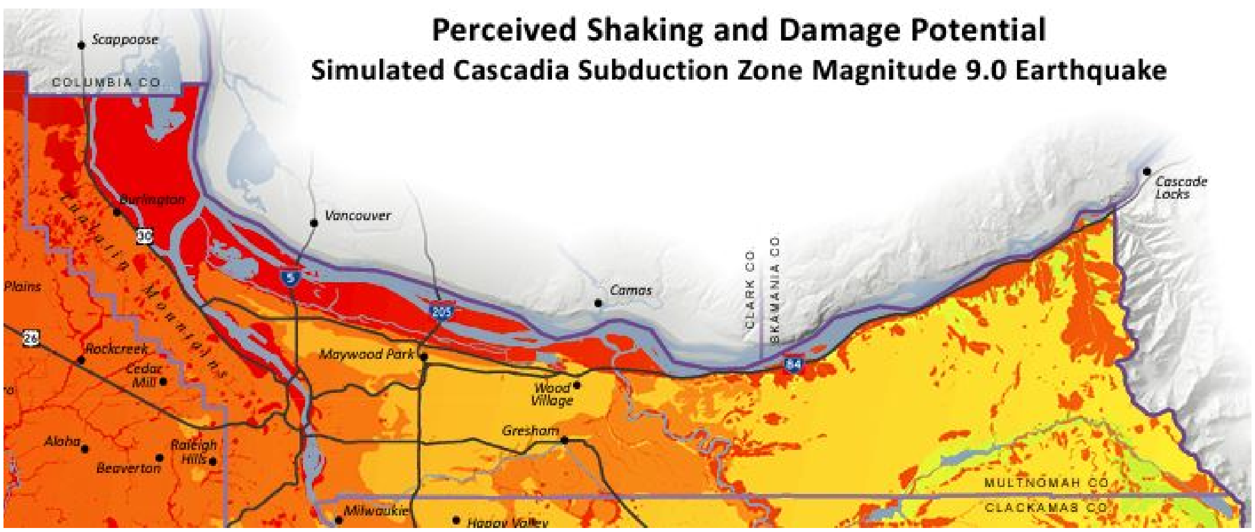

Figure 31 - Shaking and damage from a M9.0 Cascadia Subduction Zone event. Red indicates predicted moderate/heavy shaking and damage, orange indicates moderate shaking and damage and yellow is low/moderate shaking and damage. Graphic from DOGAMI publication O-18-02, Appendix E, Plate 6.

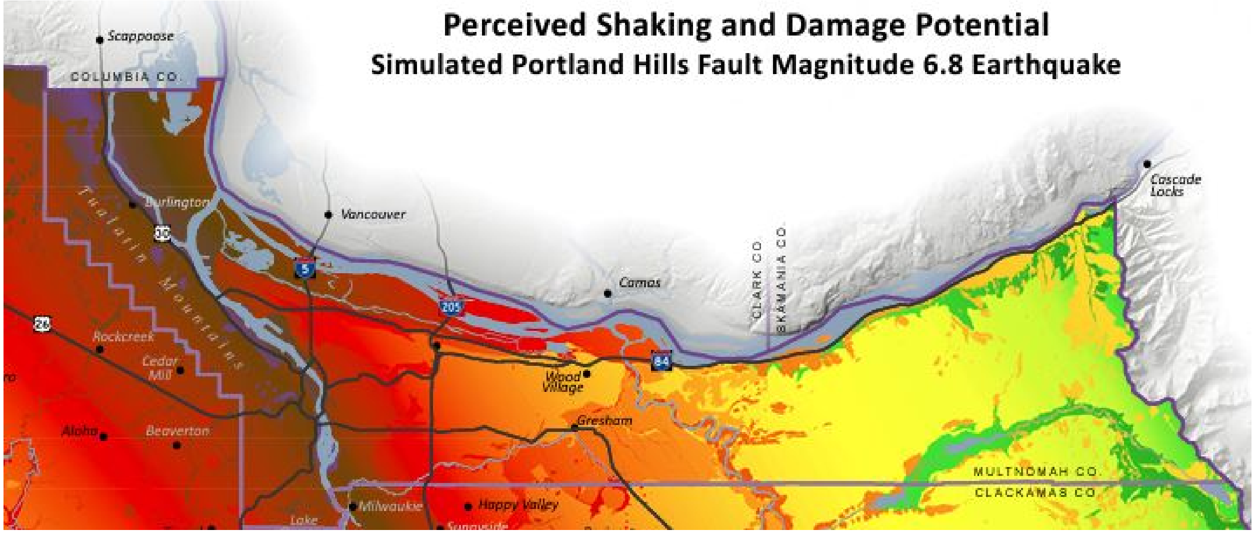

Figure 32 - Shaking and damage from a M6.8 Portland Hills crustal earthquake event. Dark red indicates violent shaking and heavy damage, red indicates moderate/heavy shaking and damage, orange indicates moderate shaking and damage, yellow is low/moderate shaking and damage, and green is low shaking and damage. Graphic from DOGAMI publication O-18-02, Appendix E, Plate 7.

Figure 33 - DOGAMI map showing expected shaking from a M6.9 crustal earthquake on the Mount Hood fault. Map from DOGAMI publication O-20-06, Risk Report for the Lower Columbia-Sandy Watershed, Plate 4.

Soil Liquefaction (including Lateral Spreading and Settling)

Liquefaction is a process where the strength of soil is reduced by water pressure exerted during an earthquake. When this occurs, the soil takes on properties of a liquid and loses much of its ability to support building foundations, bridges, roads, retaining walls, dams, levees and other engineered supports requiring soil stability. This effect is extremely damaging in earthquakes, often causing structural failure, and areas with this risk will suffer the most property damage. Huge amounts of silt may be left behind on the surface as debris.

Multnomah County has significant areas with soils at risk for liquefaction. Loose sandy and silty soils that are saturated with moisture have the highest risk. Areas in historical floodplains and wetlands are the most susceptible.

[An interactive version of this map can be found here (Earthquake Hazard – Earthquake Liquefaction (Soft Soil) Hazard)]

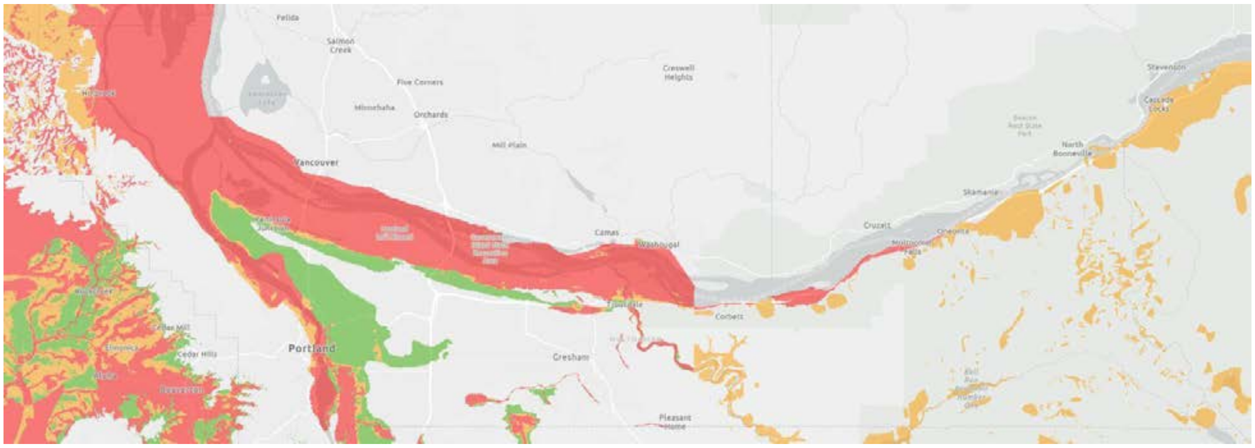

Figure 34 – Map showing liquefaction hazard areas in Multnomah County. Red are areas with high risk of soil liquefaction in an earthquake of any type, orange is moderate risk and green is lower risk. Areas without color are not significantly impacted by liquefaction effects. Map from DOGAMI HazVu site.

Lateral spreading is an effect of soil liquefaction. As the soil begins to act like a liquid, it will spread out even on very slight slopes, causing roads to separate, buried pipelines to break, and shallow foundations to shift and crack.

Figure 35 - Road damage caused by lateral spreading in Thurston County, Washington, an impact of the 2001 Nisqually Intraplate Earthquake. Photo – DOGAMI Archive

Settling is another soil liquefaction effect, when the ground lowers due to soil impacts below the surface. As with spreading, uneven settling will break foundations and roads and threaten underground infrastructure.

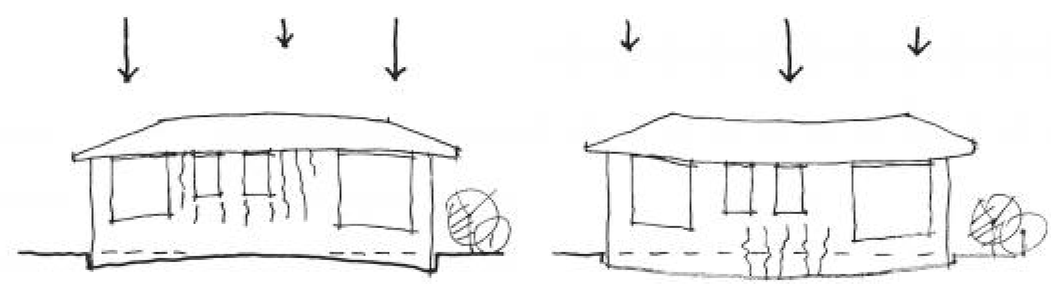

Figure 36 - A form of settling, called differential settling where different areas of soil under a foundation settle at different rates, causing stress to foundations or structural walls. Illustration from BRANZ Seismic Resilience (New Zealand organization to promote building resilience)

Earthquake-Induced Landslides

Earthquakes are a key trigger of large landslides. The risk factors for earthquake-caused landslides are the same as any landslide risk—areas where there have been past landslides and areas with steep slopes and unstable soil types. Landslide risk areas are shown in the Landslide chapter.

Post-earthquake landslides are worrisome because there are likely to be many of them at once, especially if an earthquake occurs during a time of year when soils are wet. These landslides may block roads and reduce the ability to evacuate people or bring in relief supplies to the region. The likely locations of post-earthquake landslides has been a key consideration in determining priority evacuation routes.

Volcanic Activity

Volcanic chains form around subduction zones, as pressure and heat of the grinding plates turn rock into molten magma. However, there is no evidence that a subduction zone earthquake would directly lead to renewed volcanic activity at Mount Hood.

Tsunamis and Seiches

Tsunamis result from earthquakes which cause a sudden rise or fall of the ocean floor, creating an enormous wave. A surge could extend up the Columbia River, perhaps as far inland as Multnomah County. However, because of the considerable distance from the coast, the effects are expected to be minimal.

A similar earthquake phenomenon are seiches—waves from sloshing of inland bodies of waters such as lakes, reservoirs or rivers. Seiches may damage docks, other shorefront structures and dams. Seiches could cause localized damage to reservoirs and tanks in Multnomah County, but this impact has not been studied in detail.

3.1.2 Earthquake Probability and History

- *Probability*

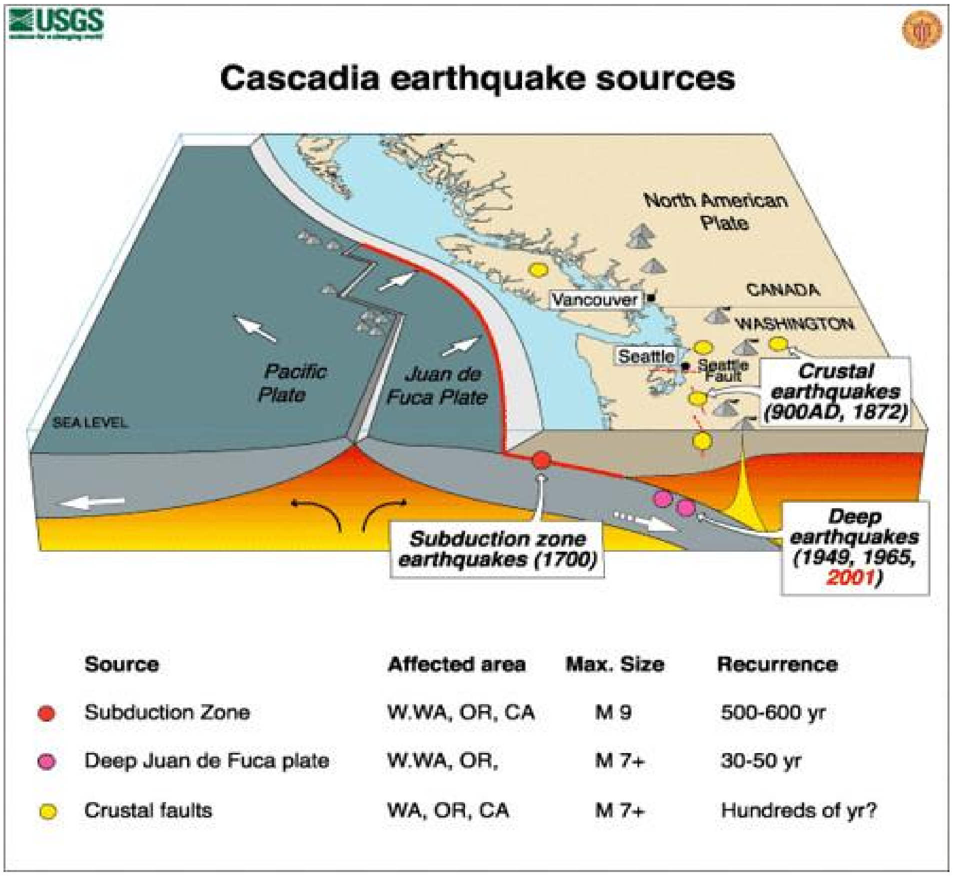

Figure 37 - Graphic showing estimated return periods for the different types of earthquakes in the Pacific Northwest. Deep earthquakes are the same as Intraplate Earthquakes. Diagram from the United States Geological Survey. As noted below, Intraplate and Crustal Earthquakes have not occurred as frequently in Oregon as in other parts of the Cascadia Region.

Cascadia Subduction Zone

The last major earthquake on the Cascadia Subduction Zone occurred on January 26, 1700. The exact date and even time of the earthquake are known through accounts of people living in coastal areas of the Pacific Northwest, tsunami records from Japan, and through study of tree rings of ghost forests that submerged into tidal flats.

The 1700 Cascadia Megathrust was an event comparable to the scenarios currently used for earthquake planning across Oregon. The 1700 earthquake is believed to have been caused by a rip of over 600 miles along the subduction zone and with an estimated magnitude of 8.7-9.2, similar to the Great Tohoku earthquake in Japan in 2011 and the Indian Ocean earthquake and tsunami in 2004.

The 1700 earthquake is believed to have caused complete destruction of coastal communities as the ground suddenly sank three to six feet and large tsunamis swamped low-lying coastal areas.

The paleo-scientific record shows 18 Cascadia Subduction Zone earthquakes of above M9.0 over the last 10,000 years, making an estimated recurrence of about once per 500-800 years. Smaller, but still substantial, quakes (M8.3-M8.5) have occurred another 10-20 times in that time span, although these have tended to occur in the southernmost part of the zone off of Southern Oregon and Northern California. The time between earthquakes has been variable, ranging from decades to centuries.

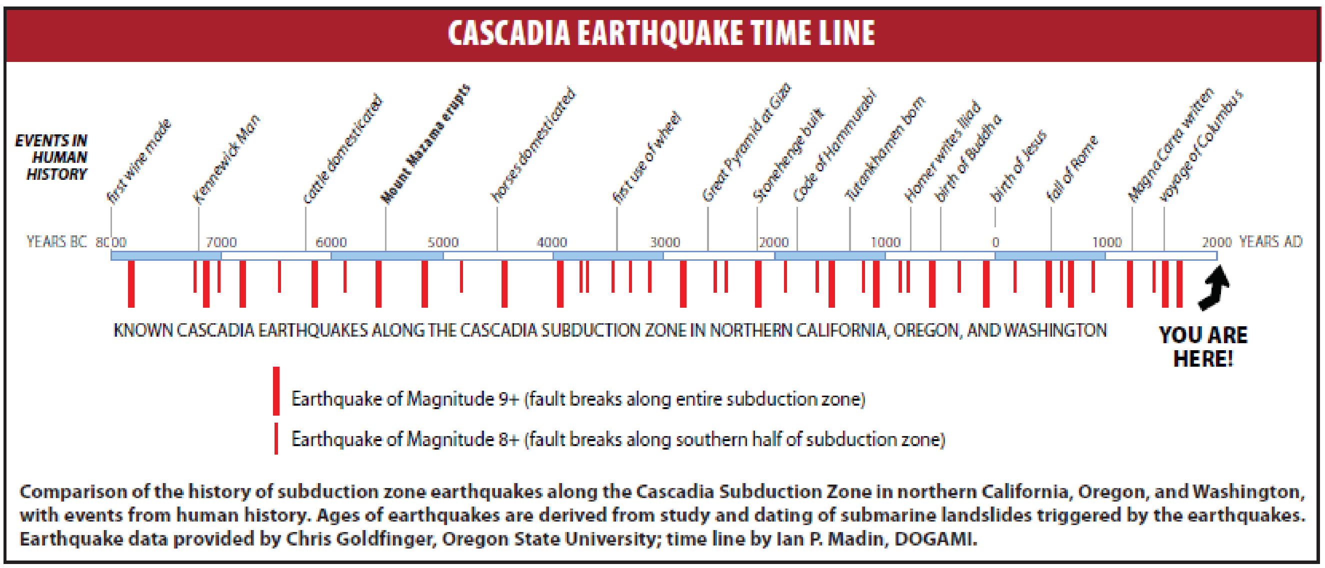

Figure 38 – 2010 Cascadia Earthquake Time Line, published by DOGAMI

Recent research has suggested that because of the length of time since the last event, the chance of Cascadia Subduction Zone earthquake similar to the 1700 event has around a 7-12% chance of occurring over the next 50 years[31]. The chance of a partial rupture that would have little effect to Northern Oregon is estimated at 37-43% over the next 50 years.

Crustal Earthquakes

Much of recent earthquake risk awareness in Oregon has been built around a major Cascadia Subduction Zone (CSV) earthquake. Crustal earthquakes are actually much rarer than CSV earthquakes in the local geological record, yet may be just as dangerous since the faults lie close to the surface and are located directly under densely populated areas. A large, local crustal earthquake would cause the same powerful shaking and liquefaction impacts and could be especially damaging to structures near the epicenter.

Numerous fault lines run through Multnomah County—beneath the West Hills/Tualatin Mountains, around the Gresham East Buttes, and across the Columbia River from the State of Washington to the Corbett area. Of the local faults, the Portland Hills Fault is considered to be

[31] DOGAMI Cascadia Earthquake Knowledge Points for Emergency Managers and the Public, June 2022

the most dangerous, because of its observed history of earthquake and location directly in the county's most densely populated center.

Evidence suggests that the Portland Hills Fault has ruptured twice in the last 15,000 years, which indicates a higher probability (every 7,500 years or so) than was expressed by this plan in 2017. Other fault zones near Multnomah County, such as Gales Creek and Mount Hood, have ruptured more recently and may cause earthquakes more frequently than the Portland Hills Fault. The Gales Creek Fault Zone, just west of Multnomah County, is thought to have last had a major earthquake about 1,000 years ago, with a roughly 4,000 year period between the most recent three events[32]. Another recent discovery has been that a large crustal earthquake occurred on the Mount Hood Fault Zone in the last 500-700 years[33], and may have caused a large landside that blocked the Columbia River in the Bonneville area. There is evidence that Mount Hood Fault Zone earthquakes may be more frequent than in the other zones mentioned here, but there is still uncertainty about recurrence intervals and how ruptures occur.

The most recent significant crustal earthquake in northwestern Oregon was the Scotts Mills earthquake in March 1993. Known as the 'Spring Break Quake', it had a magnitude of 5.6 and was centered on the Mount Angel Fault about 34 miles south of Portland. The earthquake caused about $30 million in damage, primarily to unreinforced masonry buildings. Minor structural damage was reported in Portland and Gresham[34].

For the purposes of estimating vulnerability in their Regional Earthquake Impact Analysis, DOGAMI used a magnitude 6.8 Portland Hills event as a realistic catastrophic scenario. For the multi-hazard study of the Lower Columbia-Sandy River Watershed in Eastern Multnomah County, a magnitude 6.9 event in the Mount Hood Fault Zone was also used for a building damage vulnerability analysis.

- *Case Study: Christchurch Earthquake*

The 2011 earthquake in Christchurch, New Zealand, has been used as a case study for potential earthquake impacts in the Portland Metropolitan Area, and especially as an important reminder of the risk of lower intensity crustal earthquakes. Christchurch has notable similarities to this region, being located near a large water body with developed areas on liquefaction-prone soils and numerous unreinforced masonry buildings in the city center built before the implementation of seismic building codes.

This earthquake had a magnitude of only 6.3, and is believed to have been an aftershock of a M7.1 quake in 2010. The impacts of the 2011 quake were much higher than the larger 2010 quake. The reasons for this was that the epicenter was shallower and located closer to the city than in 2011. It also occurred during a weekday, meaning more people were in large buildings that may have been weakened by the initial quake.

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[32] Multiple Holocene Earthquakes on the Gales Creek Fault, Northwest Oregon Fore-Arc, *Bulletin of the Seismological Society of America*, A.E. Horst, A.R.. Streig, R.E. Wells, J. Bershaw, 2021

[33] The Mount Hood fault zone, active faulting at the crest of the dynamic Cascade Range, north-central Oregon, USA, *From Terranes to Terrains: Geologic Field Guides on the Construction and Deconstruction of the Pacific Northwes*t, Ian Madin, Ashley Streig, Scott Bennett, Geological Society of America, September 2021

[34] The Scotts Mills, Oregon, Earthquake of March 25, 1993: Intensities, Strong-Motion Data and Teleseismic Data, US Geological Service, Open-Fire Report 94-163, 1994, p.8

The Christchurch earthquake killed 185 people and 6,659 people suffered major injuries. Around 7,000 homes were 'red-zoned'—deemed to be on land too unsafe to rebuild. Another 7,000 homes became newly considered to be vulnerable to flood because of land subsidence and the spread of wet soils. 1,354 commercial buildings had to be demolished—826 in the City Center and 528 in suburban areas[35]. Parts of the Central Business District remained cordoned off for 29 months due to the risk of further building collapse.

Figure 39 - Cleanup after the 2011 Christchurch Earthquake

Sixty percent of the 185 deaths occurred in a single building collapse, at a five-story commercial building built in 1986. Another 18 people died in a separate multi-story commercial building collapse, and eight people died when masonry fell from a large building onto a bus.

New Zealand is a seismically active nation, but had not had a high-fatality earthquake since 1931. The location of the 2011 aftershock was on a fault that had only been identified because of the 2010 quake, and this fault system had been considered low-risk, with lengths of time between events similar to crustal faults in Multnomah County. This earthquake indicated the requirement for maintaining awareness of risk, and the continuing vulnerability of buildings built before the implementation of modern seismic standards.

Intraplate Earthquakes

As noted in the introduction to this chapter, estimating probabilities of intraplate earthquakes is difficult, because the forces that cause them are difficult to study. In the lower Puget Sound region, intraplate earthquakes have been the most common major earthquakes over the last century. The region between Olympia and Seattle was struck in 1949, 1965 and 2001 with intraplate quakes that did tens or hundreds of millions of dollars of damage. It is believed that the underground formation of rock below the Cascadia Subduction Zone in Washington is

[35] All data – Insurance Council of New Zealand – Challenges to Recovery

responsible for this cluster, and Oregon has not shown the same risk. The only notable event in Oregon of this type in the last century was a M4.5 earthquake that occurred near Corvallis in 1962. Still, intraplate earthquakes are not yet able to be modeled and estimated for probability, and could still be a risk to Multnomah County.

Intraplate earthquakes have the deepest epicenters of all earthquakes. Other characteristics noted in Washington earthquakes are that intraplate earthquakes are felt over a larger distance and have not had aftershocks.

3.1.3 Earthquake Vulnerability

The 2018 report by the Oregon Department of Geology and Mineral Industries (DOGAMI) is the current standard for evaluating vulnerability in Multnomah County, and is supplemented by other site-specific studies. The DOGAMI report used two scenarios—a large offshore Cascadia Subduction Zone earthquake and a major crustal earthquake on the Portland Fault in Western Multnomah County—to evaluate injury, damage, building loss, displacement, debris and other impacts.

Study Methodology

Daytime vs Nighttime Scenario

The time and day that a significant earthquake hits Multnomah County will likely be a key factor in the number of injuries and deaths caused. During a workday, many more people will be clustered in locations more likely to be built with unreinforced masonry, while single-story wood-framed construction associated with homes is much less likely to collapse. The HAZUS Advanced Engineering Building Model (AEBM) used in the analysis showed that about 3% of completely damaged wood-framed homes would collapse, compared to 15% of completely damaged unreinforced masonry buildings. Most of the unreinforced masonry buildings in Multnomah County are located in the City of Portland, but many residents of communities in this plan commute to Portland for work, school, business, and entertainment – and Multnomah County would support mass sheltering, health and human services throughout the county.

Dry vs Wet Soil Conditions

The time of year is also extremely important for predicting earthquake impacts. When soils are wet, and more prone to liquefaction and landslide, the casualty and building damage in most Multnomah County jurisdictions is more than doubled and the rate of people displaced long-term is increased even more. For the purpose of the study, wet soil was considered to be fully saturated, to develop a worst-case scenario. Actual losses would be likely to fall somewhere between the wet and dry estimates, depending on groundwater depths at the time of the event.

Impacts

Injury and Casualties

The Hazus AEBM model was used to estimate casualties. The estimates use aggregated daytime occupancy rates based on a set people per square foot assumption. The analysis only includes death and injury suffered by those inside buildings. As was seen in Christchurch, significant risk can also occur to people outside buildings from falling stone, debris, and glass. A number of other potential casualty causes were not modeled, such as loss of power to support life-sustaining medical equipment, post-earthquake fires, collapsed bridges, and impacts from hazardous materials spills and fires.

A projection of deaths and life-threatening injuries in jurisdictions in this plan is shown below. DOGAMI also modeled slight and moderate injuries—those able to be treated at the scene or requiring hospitalization but not being life-threatening. In the worst-case scenario (wet soils during the daytime), all of Multnomah County (including Portland and Maywood Park) was projected to experience 11,824 slight injuries, 3,397 moderate injuries, 487 life-threatening injuries and 950 deaths. Based on the numbers shown below, the City of Portland, as expected, would suffer the bulk of loss of life, but Wood Village was the only city to have no death or life-threatening injury in each scenario.

Totals have also been calculated for the census tracts most closely aligned to Columbia Corridor Drainage Districts—these overlap with portions of totals for Portland as well as Gresham, Fairview, Troutdale, and Unincorporated Multnomah County. These have been italicized to indicate that they may be duplicative with other totals—and because of the census tracts not fitting district boundaries, they also duplicate totals within the districts themselves. The higher totals for the PEN1 and PEN2 drainage districts and MCDD underline the greater susceptibility of loss in more western locations in the County.

Table 11 – Cascadia Subduction Zone, M9.0 – Casualties - Death and Life Threatening Injury (DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon)

Community	Dry Soil+Daytime (death/life-threatening injury)	Dry Soil+Nighttime (death/life-threatening injury)	Wet Soil+Daytime (death/life-threatening injury)	Wet Soil+Nighttime (death/life-threatening injury)
All of Multnomah County (Including Cities of Portland and Maywood Park)	621/318	122/62	950/487	236/124
City of Fairview	0/0	0/0	3/2	1/0
City of Gresham	9/5	1/1	27/14	10/5
City of Troutdale	2/1	0/0	12/6	1/1
City of Wood Village	0/0	0/0	0/0	0/0
Unincorporated Multnomah County	5/2	1/1	10/5	4/2
PEN1 and PEN2 (Tract 72.02)	40/21	4/2	78/40	10/5
MCDD (Tracts 72.02, 73, 102)	92/48	12/6	196/100	29/15
SDIC (Tract 102)	5/3	0/0	36/18	2/1

Using the same analysis for the Portland Hills earthquake scenario returned extremely similar casualty results for the participating cities in this plan – but the county total is significantly higher when the City of Portland is included.

Table 12 – Portland Hills Fault, M6.8 – Casualties - Death or Serious Injury (DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon)

Community	Dry Soil+Daytime (death/life-threatening injury)	Dry Soil+Nighttime (death/life-threatening injury)	Wet Soil+Daytime (death/life-threatening injury)	Wet Soil+Nighttime (death/life-threatening injury)
All of Multnomah County (Including Cities of Portland and Maywood Park)	1,805/920	432/223	2,237/1,146	633/335
City of Fairview	0/0	0/0	3/2	1/0
City of Gresham	6/3	1/1	33/17	15/8
City of Troutdale	1/1	0/0	11/6	1/1
City of Wood Village	0/0	0/0	0/0	0/0
Unincorporated Multnomah County	9/5	4/2	16/9	8/4
PEN1 and PEN2 (Tract 72.02)	*67/35*	*7/4*	*95/49*	*11/6*
MCDD (Tracts 72.02, 73, 102)	*112/58*	*14/8*	*212/109*	*30/16*
SDIC (Tract 102)	*3/1*	*0/0*	*34/17*	*2/1*

Long-Term Displacement

Displacement of residents will be heightened by the difficulty in bringing in building inspectors after a disaster and conducting a large amount of home inspections before they can be reoccupied. As shown below, wet soils markedly increase displacement because of the cascading effect of many more buildings with some level of damage that will further slow inspection and re-occupation.

Note again that the City of Portland has much larger amounts of displacement than the cities included in this plan, especially in a Portland Hills disaster.

Table 13 – Cascadia Subduction Zone, M9.0 – Long-Term Displacement (DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon)

Community	Dry Soil - Number of People Displaced	Wet Soil - Number of People Displaced
All of Multnomah County (Including Cities of Portland and Maywood Park)	9,736	37,461
City of Fairview	71	335
City of Gresham	399	4,244
City of Troutdale	12	245
City of Wood Village	55	55
Unincorporated Multnomah County	335	1,891
PEN1 and PEN2 (Tract 72.02)	*131*	*730*
MCDD (Tracts 72.02, 73, 102)	*467*	*1,729*
SDIC (Tract 102)	*53*	*349*

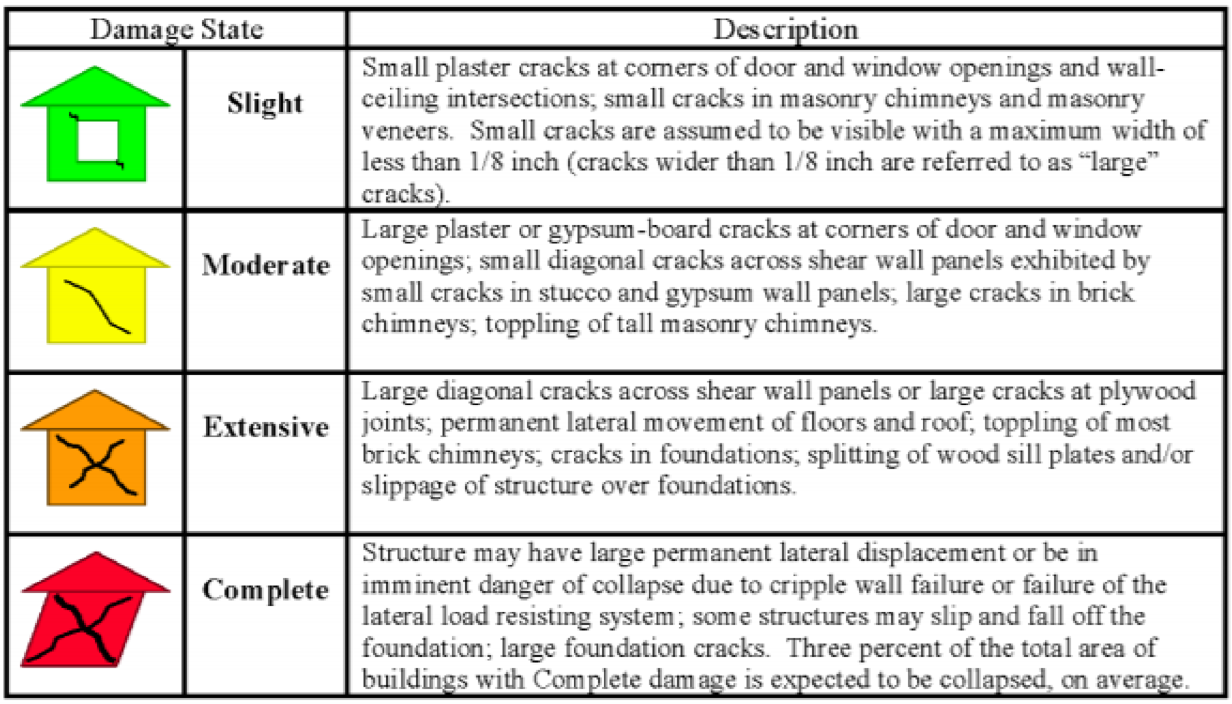
Table 14 – Portland Hills, M6.8 – Long-Term Displacement (DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon)

Community	Dry Soil - Number of People Displaced Long-Term	Wet Soil - Number of People Displaced Long-Term
All of Multnomah County (Including Cities of Portland and Maywood Park)	50,842	120,124
City of Fairview	39	305
City of Gresham	314	6,734
City of Troutdale	11	281
City of Wood Village	12	12
Unincorporated Multnomah County	1,320	3,505
PEN1 and PEN2 (Tract 72.02)	*257*	*833*
MCDD (Tracts 72.02, 73, 102)	*557*	*1,893*
SDIC (Tract 102)	*34*	*355*

Building Damage

The Hazus AEBM model was also used to estimate structural losses. Losses were based on aggregations of generic building models rather than specific building characteristics, due to the large scope of the analysis. As with injury and casualty and displacement totals, these estimates seem very specific but should be understood to represent a point within a range of potential outcomes.

Despite that limitation, DOGAMI was able to use a very accurate building inventory, including the specific information for the structure's type (construction material), age and use. The model divides structures into five potential damage states ('no damage' is not shown in the table below) to calculate total losses.



Damage State		Description
	Slight	Small plaster cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneers. Small cracks are assumed to be visible with a maximum width of less than 1/8 inch (cracks wider than 1/8 inch are referred to as "large" cracks).
	Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
	Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations.
	Complete	Structure may have large permanent lateral displacement or be in imminent danger of collapse due to cripple wall failure or failure of the lateral load resisting system; some structures may slip and fall off the foundation; large foundation cracks. Three percent of the total area of buildings with Complete damage is expected to be collapsed, on average.

Figure 40 - Graphic showing description of different damage levels in a severe earthquake scenario

Total damages by jurisdiction/district are shown below. Note that day or nighttime differences are only relevant to casualties and not to building damage. Wet soils again make a very large difference in building damage, except in Wood Village. The structure loss ratio is the percentage loss of the total structural value in the jurisdiction. Percentage of building loss rises significantly when the City of Portland is included.

Table 15 – Cascadia Subduction Zone, M9.0 – Building Damage Cost and Loss Ratio (DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon)

Community	Dry Soil/Structure Building Repair Cost	Dry Soil/Structure Building Loss Ratio	Wet Soil/Structure Building Repair Cost	Wet Soil/Structure Building Loss Ratio
All of Multnomah County (Including Cities of Portland and Maywood Park)	$13,340,000,000	12%	$20,489,000,000	18%
City of Fairview	$24,000,000	2%	$58,000,000	6%
City of Gresham	$314,000,000	3%	$726,000,000	7%
City of Troutdale	$77,000,000	4%	$169,000,000	10%
City of Wood Village	$9,000,000	2%	$9,000,000	2%
Unincorporated Multnomah County	$249,000,000	7%	$565,000,000	16%
PEN1 and PEN2 (Tract 72.02)	*$1,046,729,792*		*$1,776,308,736*	
MCDD (Tracts 72.02, 73, 102)	*$2,498,733,368*		*$4,248,832,760*	
SDIC (Tract 102)	*$146,673,784*		*$471,622,352*	

As with casualties, the analysis for the Portland Hills earthquake scenario returned similar results for the participating cities and districts. Unincorporated Multnomah County was an exception, because of areas on the west side of the County where shaking would be significantly stronger. For unincorporated Multnomah County as a whole, the structure loss is about double from a Portland Hills earthquake compared to a Cascadia Subduction Zone event. When looking at the county in total, including Portland, damages and loss levels significantly exceed that of a Cascadia Subduction Zone event.

Table 16 – Portland Hills, M6.8 – Building Damage Cost and Loss Ratio (DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon)

Community	Dry Soil/Damage Building Repair Cost	Dry Soil/Loss Building Loss Ratio	Wet Soil/Damage Building Repair Cost	Wet Soil/Loss Building Loss Ratio
All of Multnomah County (Including Cities of Portland and Maywood Park)	$32,287,000,000	28%	$42,747,000,000	37%
City of Fairview	$30,000,000	3%	$65,000,000	6%
City of Gresham	$459,000,000	4%	$1,114,000,000	10%
City of Troutdale	$67,000,000	4%	$167,000,000	10%
City of Wood Village	$10,000,000	2%	$10,000,000	2%
Unincorporated Multnomah County	$636,000,000	18%	$1,030,000,000	28%
PEN1 and PEN2 (Tract 72.02)	*$1,587,720,064*		*$2,118,925, 696*	
MCDD (Tracts 72.02, 73, 102)	*$2,562,585,440*		*$3,010,380,800*	
SDIC (Tract 102)	*$134,851,328*		*$467,413,728*	

Building loss was also modeled for the Mount Hood Fault Zone scenario, but just within the Lower Columbia-Sandy watershed[36]. A slightly different methodology was used, indicating the number of buildings that would be considered uninhabitable (red-tagged) and those with moderate damage and partially inhabitable (yellow-tagged). Loss totals and ratios allow comparison – overall significantly less damage is expected from this earthquake compared to the other scenarios. Note that the totals and ratios are only for structures in the watershed. Unincorporated Multnomah County faces the most impact, with severe loss in the easternmost parts of the County.

[36] Most of Troutdale and portions of Gresham and Unincorporated Multnomah County

Table 17 – Mount Hood Fault, M6.9 – Casualties, Death or Serious Injury
***LOWER COLUMBIA-SANDY WATERSHED ONLY* ([DOGAMI O-20-06 - 2020 Natural Hazard Risk Report for the Lower Columbia-Sandy Watershed])**

Community	Yellow-Tagged Buildings	Red-Tagged Buildings	Structure Loss	Structure Loss Ratio
City of Gresham	8	1	$8,959,000	0.3%
City of Troutdale	5	14	$10,994,000	0.8%
Unincorporated Multnomah County	48	81	$40,903,000	3.0%

Debris

Debris from collapsed or damaged buildings will create a huge task to manage during recovery. Debris will block emergency routes and other forms of movement and require a massive logistical effort to load, move, sort and store heavy materials. Debris totals may be higher than listed in the DOGAMI study, as it does not include debris from landslides, damaged bridges and roads, structures other than buildings, and sand and silt raised to the surface during liquefaction. To put the numbers in perspective, a single truckload may carry about 25 tons of material. When Portland is included, debris is approximately doubled across the county during a Portland Hills quake compared to a Cascadia Subduction quake.

Table 18 – Cascadia Subduction Zone, M9.0 – Tons of Debris Created ([DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon])

Community	Dry Soil/Tons of Debris	Wet Soil/Tons of Debris
All of Multnomah County (Including Cities of Portland and Maywood Park)	7,724,000	10,395,000
City of Fairview	12,000	29,000
City of Gresham	143,000	279,000
City of Troutdale	39,000	83,000
City of Wood Village	6,000	6,000
Unincorporated Multnomah County	117,000	216,000
PEN1 and PEN2 (Tract 72.02)	*596,267*	*882,708*
MCDD (Tracts 72.02, 73, 102)	*1,438,812*	*2,158,201*
SDIC (Tract 102)	*84,213*	*239,944*

Table 19 – Portland Hills, M6.8 – Tons of Debris Created (DOGAMI O-18-02 - 2018 Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon)

Community	Dry Soil/Tons of Debris	Wet Soil/Tons of Debris
All of Multnomah County (Including Cities of Portland and Maywood Park)	15,658,000	19,270,000
City of Fairview	12,000	29,000
City of Gresham	165,000	376,000
City of Troutdale	29,000	77,000
City of Wood Village	4,000	4,000
Unincorporated Multnomah County	205,000	329,000
PEN1 and PEN2 (Tract 72.02)	*824,035*	*1,031,712*
MCDD (Tracts 72.02, 73, 102)	*1,620,815*	*2,323,264*
SDIC (Tract 102)	*71,002*	*231,485*

Transportation System Impacts

Air and Marine

A 2015 Corporate Seismic Risk Assessment completed for the Port of Portland evaluated the seismic performance, identified potential improvements and estimated the benefits of improvements for nineteen high value assets. Separately, these assets were found to deliver approximately two billion dollars in regional economic value.

Since the time, the Port has made seismic resilience investments at Marine Terminal 6 and the Portland International Airport (PDX). Investments at PDX include the construction of new seismically resilient facilities, and the on-going terminal expansion project, which includes many seismic improvements. More recent reviews of the runways at PDX estimate that without mitigation, runways at PDX could be out of service by approximately one year. A 2021 study by the National Institute of Building Sciences found that mitigating one runway at PDX could help avoid more than seven billion dollars in losses in Oregon, and would provide 50 dollars in benefit for every dollar spent.

Port buildings were considered in the DOGAMI analysis, and expected losses can be extrapolated from loss ratios. Damage to runways, marine berths, and other associated non-building structures were not captured.

More details on the Port of Portland's Resilient Runway project and other specific earthquake vulnerabilities and mitigation strategies can be found in the Port of Portland Chapter.

Roads and Bridges

The Regional Emergency Transportation Routes report collected vulnerability information for the susceptibility of prioritized roads to lateral spreading impacts of landslides and of the current seismic stability of bridges. These roads are intended to be the routes needed for emergency vehicles to travel after a disaster and provide services to residents and visitors who may be isolated from relief. There are numerous identified emergency routes across the county that retain high susceptibility to damage. The process of prioritizing routes for improved resilience, or identifying where alternative routes can be established, is an ongoing mitigation project.

The Burnside Bridge replacement project will establish a key lifeline between the east and west sides of the county and will significantly increase the county's ability to create triage routes throughout the region in an emergency.

The DOGAMI analysis considered the probability of identified emergency routes being damaged. The study found that about 75% of all emergency route segments across Multnomah County had a 20-30% chance of being damaged by a Cascadia Subduction Earthquake. The number was even higher for a Portland Hills earthquake, with 95% of road segments having that probability. This analysis did not consider local roads that would not be priority routes for emergency vehicles. Some local roads are more resilient because they do not have bridges or overpasses, but all roads located in liquefaction or landslide threat areas will have risk of failure.

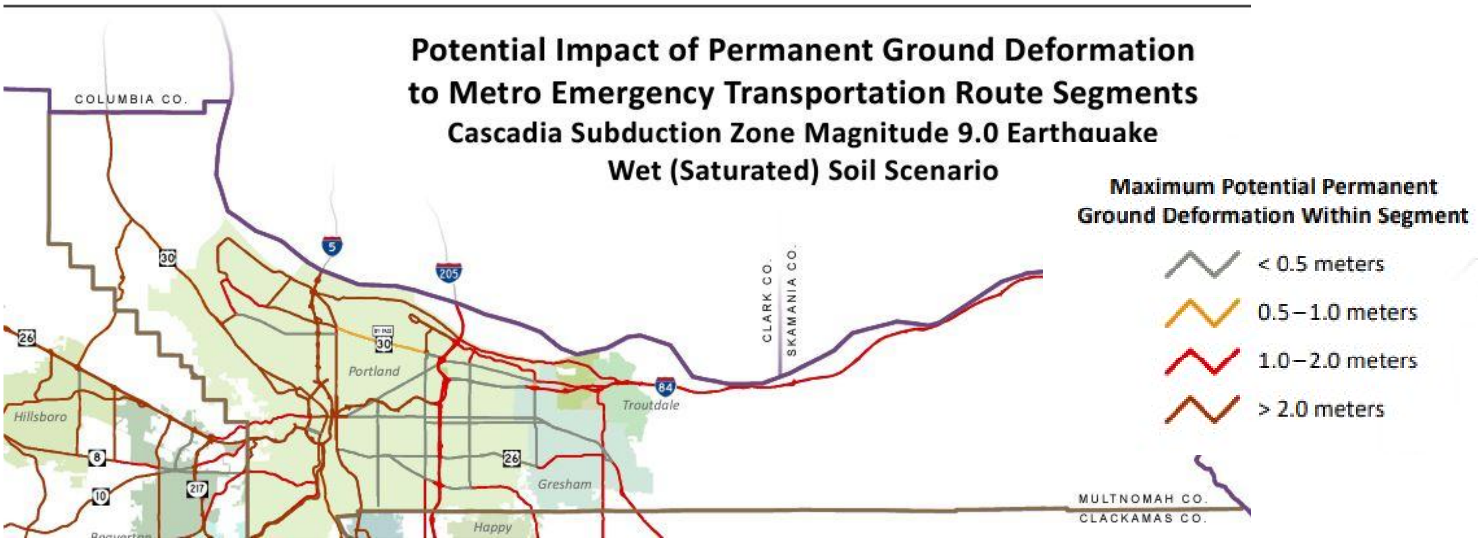


Figure 41 - Emergency Transportation Routes based on expected damage from a Cascadia Subduction Zone earthquake. Levels of damage are based on the amount of ground deformation at the location – levels are shown in the legend, from least impacted at the top to most impacted at the bottom. This map predates updates to Emergency Transportation Routes undertaken by the Regional Disaster Preparedness Organization. Map from the 2018 DOGAMI Earthquake Regional Impact Analysis.

A number of major bridge crossings are still highly vulnerable to seismic failure. Of bridges operated by Multnomah County, the Willamette River crossings at the Burnside Bridge, Broadway Bridge, Morrison Bridge and Hawthorne Bridge are all likely to suffer significant damage, as will the Sandy River crossing at the Stark Street Bridge. The Tilikum Crossing (completed in 2015), Sellwood Bridge (rebuilt in 2016) and Sauvie Island Bridge (rebuilt in 2008) are expected to survive earthquake scenarios, with some damage expected to bridge approaches.

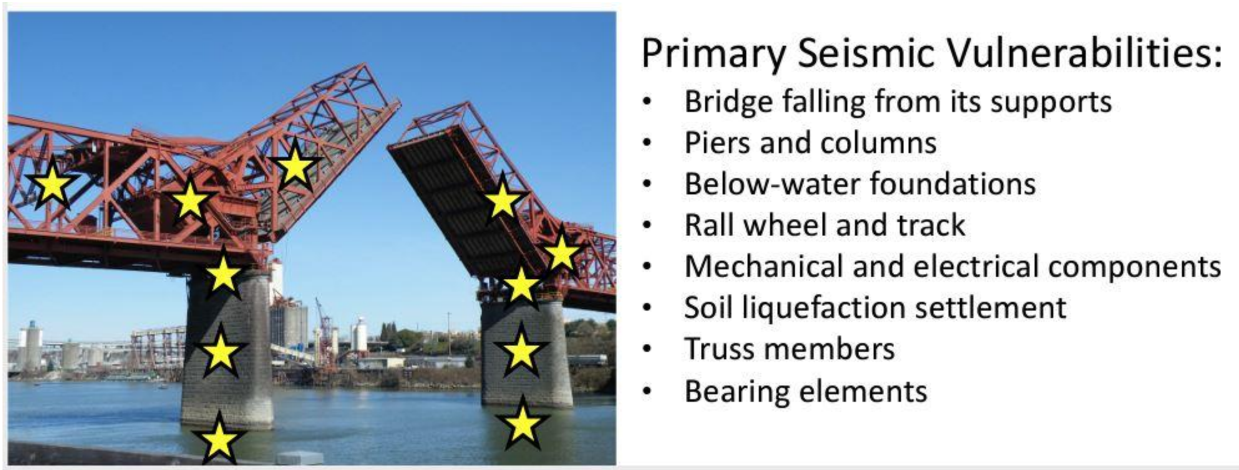


Figure 42 - Graphic showing vulnerabilities of some Willamette River bridges to a seismic event. Multnomah County.

Other major river crossings in Multnomah County that are considered to be highly susceptible to seismic impacts are the Steel Bridge (owned by Union Pacific), the Ross Island Bridge (Oregon Department of Transportation - ODOT), the St. John's Bridge (ODOT), the I-5 Interstate Bridge (ODOT/Washington DOT), and the I-30 Troutdale Bridge (ODOT).

Figure 43 - Photo of the rebuilt Sellwood Bridge during the 2020 September wildfire smoke event. Photo – Motoya Nakamura, Multnomah County Communications.

Other Lifeline Impacts

CEI Hub

The Critical Energy Infrastructure Hub (CEI Hub) is located in Northwest Portland, along the Willamette River in a high-risk liquefaction area. The risk of the CEI Hub being damaged by earthquakes creates two vulnerabilities–the loss of liquid fuel supply to most of the State of

Oregon and a health and environmental catastrophe if the petroleum-based materials run into the river and create an airborne toxic plume.

The report *Impacts of Fuel Releases from the CEI Hub due to a Cascadia Subduction Zone Earthquake* was released in 2022 to quantify the risk of a CEI Hub seismic failure. Tanks built before 1993 (91% of the total) were estimated to lose 50-100% of their stored contents, while those built after 1993 with higher seismic standards were estimated to lose 10% of their stored contents. This amount of projected loss would be roughly equivalent to fuel spilled in the Deepwater Horizon disaster in the Gulf of Mexico in 2010, the largest marine oil spill in history. The fuel loss projections used the more likely Cascadia Subduction Zone quake as the scenario, but a Portland Hills crustal quake could be even more impactful, given the proximity of the hub to that fault.

The CEI Hub has 630 tanks with capacity of 350 million gallons of liquid material. About 90% of Oregon's liquid fuel supply passes through the hub. Over 150 types of material are stored at the hub, including gasoline and all of the jet fuel supplied to the Portland International Airport.

The impact report was developed jointly between the City of Portland Bureau of Emergency Management and the Multnomah County Office of Sustainability. The tanks are located in the City of Portland, but effects of a spill could impact those living and working in unincorporated areas and hazardous air quality could affect much of the county. All participating entities in this plan would likely suffer from fuel shortages and high fuel costs at a time with a critical need for medical evacuation, air and marine response traffic, emergency vehicles, and equipment needed for clearing debris and repairing infrastructure.

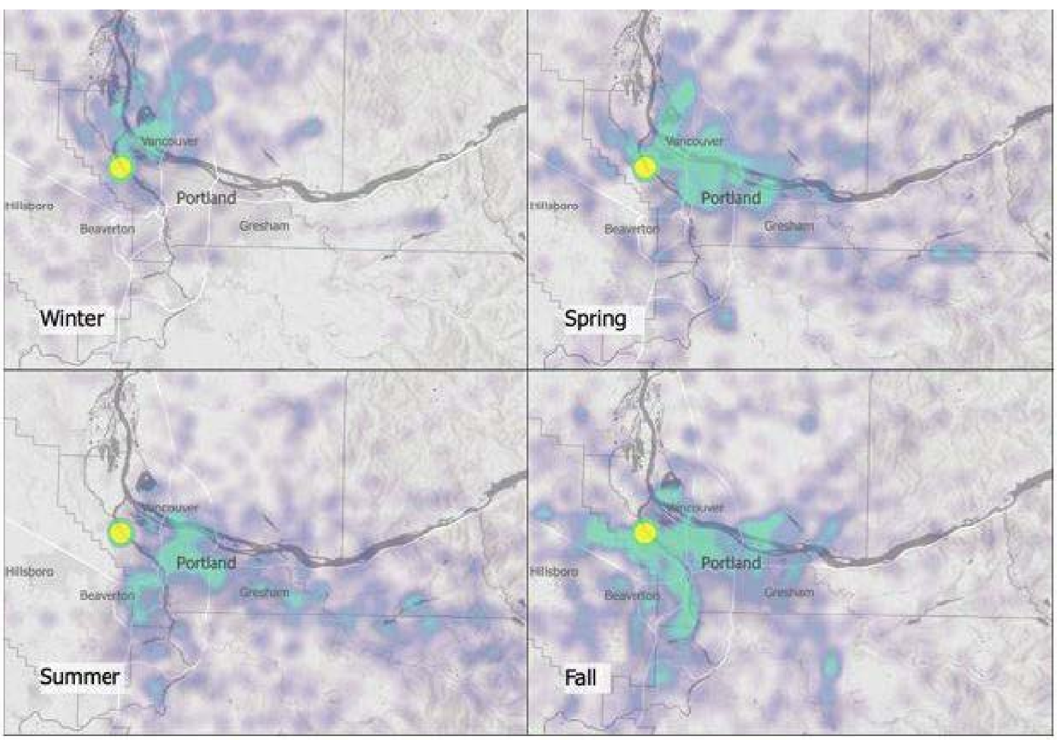


Figure 44 - Four models of a potential hazardous plume from burning material at the CEI Hub show how much of Multnomah County could be impacted by cascading hazards in a severe earthquake.

The report estimated that costs of fuel releases would range from $359 million to $2.6 billion, considering direct impacts to people, property, navigation, fisheries, recreation, human health, habitats and species, cleanup costs, cultural values, and fuel prices. The cost of this disaster making it more difficult to respond to other earthquake damage was not quantified.

Potential mitigation strategies for the CEI Hub were outlined in a 2019 report published by the Oregon Seismic Safety Policy Advisory Commission (OSSPAC). While federal entities such as the Coast Guard oversee safety and maintaining river navigation, those entities do not manage pre-event seismic risk. The report recommended mitigation authority being provided by the State of Oregon, and Senate Bill 1567 was passed in 2022 to require fuel storage site assessments and risk mitigation plans.

Electric Power

DOGAMI's 2018 report attempted to quantify the risk to electric power infrastructure in their scenarios. This analysis was conducted across the three-county report area, without specifics for cities, counties, or other units. The analysis found that in the worst-case wet soil scenario about 12% of power poles would have a 20-30% chance of experiencing major damage from lateral spreading.

The 2013 Oregon Seismic Resilience Plan estimated that communities in the Willamette Valley could expect to lose electricity for one to three months after a Cascadia Subduction Zone earthquake. Besides utility poles, power substations are another significant vulnerability.

Water and Wastewater

DOGAMI did not create estimates for water and wastewater infrastructure damages, but the 2013 Oregon Resilience Plan identified drinking water and sewer services being out of service from one month to one year in this region. Risks to water and wastewater infrastructure are to above and below-ground mains, reservoirs, tanks, pump stations and treatment facilities.

Levee Systems

Local levees are built out of silt and sand on top of a historic floodplain subject to liquefaction and are known for soil subsidence. A 2001 study by the United States Army Corps of Engineers (USACE) found that the likelihood of a major flooding event on the Columbia River and an earthquake happening at exactly the same time is extremely low.

A major earthquake from either the Portland Hills Fault or the Cascadia Subduction Zone could cause significant damage to critical levee system infrastructure, including pump stations, internal conveyance, and levee embankments. Recovering from this damage will likely take months to years, as can be expected based on analysis of comparable facilities in the 2013 Oregon Resilience Plan. Throughout the recovery and reconstruction of critical levee system infrastructure following a major earthquake, the area behind the levees will be exposed to a significantly higher risk of flooding caused by an earthquake, even from relatively frequent Columbia River high-water events. This risk and its duration are not captured in the USACE study.

The Flood section of this plan includes risk and vulnerability data compiled by DOGAMI in 2018, defining the post-earthquake flood risk that may exist for years of flood seasons after a large earthquake. Response planning is needed to prepare for this contingency.

Dam Impacts

Earthquakes can cause dam failures. The most common mode of earthquake-induced dam failure is slumping or settlement of earthen dams where the fill has not been properly compacted. If slumping occurs when a dam is full, overtopping of the dam can lead to rapid erosion, and dam failure is possible. Strong ground motions also can damage concrete dams. Furthermore, earthquakes can trigger landslides that flow into reservoirs and result in dam failure. Hydrologic weirs operated by Columbia Corridor Drainage Districts to control water levels are subject to liquefaction and significant shaking, and will be affected by a large earthquake.

Potential impact from dam failure is included in the Flood Chapter.