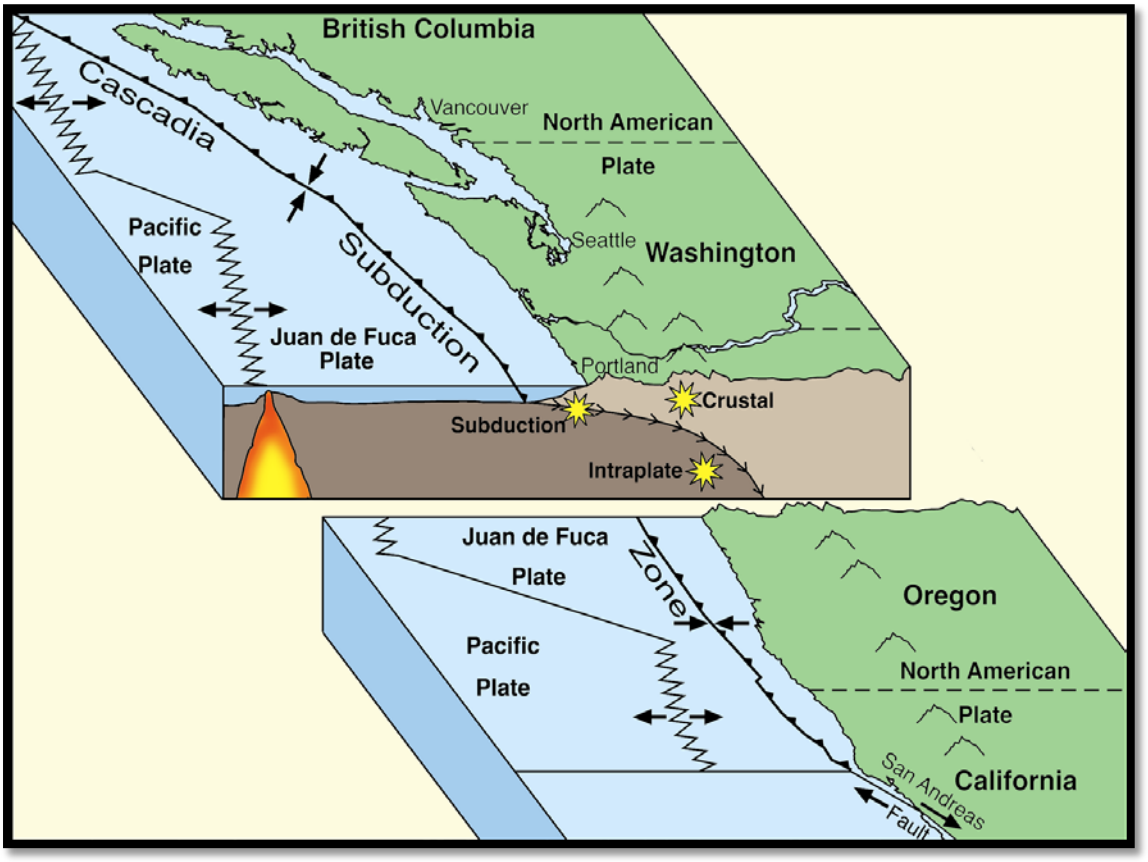
Earthquake Hazard

The Pacific Northwest is "earthquake country" and the lack of a seriously damaging earthquake for the Portland metropolitan region in the last two hundred years means that many old buildings and critical infrastructure are poised for substantial damage. Earthquakes in Oregon happen on a regular basis but mostly at such a low magnitude that communities are woefully under prepared.

Causes and Characteristics of the Hazard

Earthquakes in the Pacific Northwest are generated by the following three fault types: shallow crustal, deep intraplate, or subduction zone earthquakes. These earthquakes can have great impact on Oregon communities.

Figure EQ-1: Cascadia Subduction Zone



Source: Source: Planning for Natural Hazards: The Oregon Technical Resource Guide, Department of Land Conservation and Development (July 2000), Ch. 8, pp. 7.

Crustal Fault Earthquakes

Crustal fault earthquakes are the most common earthquakes and occur at relatively shallow depths of 6-12 miles below the surface.[i] While most crustal fault earthquakes are smaller than magnitude 4 and generally create little or no damage, they can produce earthquakes of magnitudes up to 7, which cause extensive damage. Clackamas County has seven documented crustal faults that could cause serious damage to buildings and infrastructure. These include: Portland Hills, Sandy River, Bolton, Mount Angel, Grant Butte, Clackamas Creek, and Mount Hood. These faults could generate earthquakes 6.5 or larger.

Deep Intraplate Earthquakes

Occurring at depths from 25 to 40 miles below the earth's surface in the subducting oceanic crust, deep intraplate earthquakes can reach up to magnitude 7.5.[ii] The February 28, 2001 earthquake in Washington State was a deep intraplate earthquake. It produced a rolling motion that was felt from Vancouver, British Columbia to Coos Bay, Oregon and east to Salt Lake City, Utah. A 1965 magnitude 6.5 intraplate earthquake centered south of Seattle-Tacoma International Airport caused seven deaths.[iii]

Subduction Zone Earthquakes

The Pacific Northwest is located at a convergent plate boundary, where the Juan de Fuca and North American tectonic plates meet. The two plates are converging at a rate of about 1-2 inches per year. This boundary is called the Cascadia Subduction Zone (CSZ). It extends from British Columbia to northern California. Subduction zone earthquakes are caused by the abrupt release of slowly accumulated stress.[iv]

Subduction zones similar to the CSZ have produced earthquakes with magnitudes of 8 or larger. Historic subduction zone earthquakes include the 1960 Chile (magnitude 9.5) and 1964 southern Alaska (magnitude 9.2) earthquakes[v] with more recent events being the 2004 Indian Ocean (magnitude 9.1) and 2011 Japan (magnitude 9).

Geographic Extent

According to the Relative Earthquake Hazard Map (10), about 45% of the total county land area is in moderate to high hazard zones. In addition, 54% of total tax parcels have moderate to high earthquake hazards. Moderate to High earthquake hazard zones are concentrated along rivers, floodplains, and hill slopes due to the lack of soil stability in these areas.

Earthquake Related Hazards

Ground shaking, landslides, liquefaction, and amplification are the specific hazards associated with earthquakes. The severity of these hazards depends on several factors, including soil and slope conditions, proximity to the fault, earthquake magnitude, and the type of earthquake.

Ground Shaking

Ground shaking is the motion felt on the earth's surface caused by seismic waves generated by the earthquake. It is the primary cause of earthquake damage. The strength of ground shaking depends on the magnitude of the earthquake, the type of fault, and distance from

the epicenter (where the earthquake originates). Buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock.

Earthquake-Induced Landslides

Earthquake-induced landslides are secondary earthquake hazards that occur from ground shaking. They can destroy the roads, buildings, utilities, and other critical facilities necessary to respond and recover from an earthquake. Many communities in Oregon have a high likelihood of encountering such risks, especially in areas with steep slopes.[vi]

Liquefaction

Liquefaction occurs when ground shaking causes wet granular soils to change from a solid state to a liquid state. This results in the loss of soil strength and the soil's ability to support weight. Buildings and their occupants are at risk when the ground can no longer support these buildings and structures.[vii]

To develop a regional liquefaction hazard map (Map 8) for Clackamas County, DOGAMI started by collecting the best available geologic information. Hazard groupings were primarily based on lithologies and checked with individual data points. With the available information compiled, DOGAMI assigned liquefaction susceptibility classes based on the dominant lithologies for each geologic unit in the study area, checked source data boundaries, and simplified the GIS outputs into four relative hazard classes: None/Very Low, Low, Moderate, and High. Areas with Moderate to High liquefaction susceptibilities are concentrated along the rivers and flood plains in the Willamette Valley, Cascade Range tributaries, and major stream valleys within the Cascade Range. Older river terrace and Missoula Flood deposits in the Willamette Valley were assigned a lower liquefaction hazard, yet are still considered susceptible to liquefaction in larger earthquakes. It is important to note that the quality and scale of the available base maps precluded identification of all liquefaction hazard areas, particularly in the eastern portion of the county.

Amplification

Soils and soft sedimentary rocks near the earth's surface can modify ground shaking caused by earthquakes. One of these modifications is amplification. Amplification increases the magnitude of the seismic waves generated by the earthquake. The amount of amplification is influenced by the thickness of geologic materials and their physical properties. The degree of amplification greatly affects the performance of infrastructure in earthquake. Buildings and structures built on soft and unconsolidated soils, for example, face greater risk.[viii] Amplification can also occur in areas with deep sediment filled basins and on ridge tops.

DOGAMI developed the ground shaking amplification map (Map 9) based generally on the NEHRP 1997 method of categorizing relative hazards, and simplified the GIS outputs into relative hazard classes – Low, Moderate, and High. The resulting map is not intended to be used in place of site-specific studies. The high hazard soils are located along and adjacent to streams and rivers in Clackamas County. The eastern portion of the county is varied, with competent bedrock areas mapped as Low hazard, dense soil areas mapped as Moderate

hazard, and younger landslide and alluvial deposit areas mapped as High hazard for ground shaking amplification.[1]

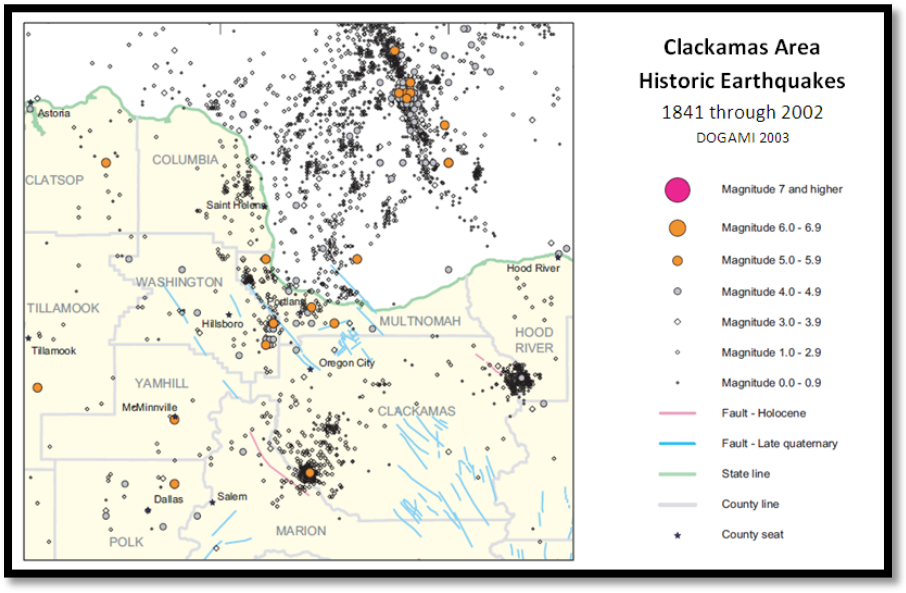
Risk Assessment

History of the Hazard

Dating back to 1841, there have been more than 6,000-recorded earthquakes in Oregon, most with a magnitude below three. Portland and its surrounding region is potentially the most seismically active area within Oregon.[ix] The Portland metropolitan region has encountered seventeen earthquakes of an estimated magnitude of four and greater, with major earthquakes in. 1877 (magnitude 5.3), 1962 (magnitude 5.2), and 1993 (magnitude 5.6). Although seismograph stations were established as early as 1906 in Seattle and 1944 in Corvallis, improved seismograph coverage of the Portland region did not begin until 1980, when the University of Washington expanded its regional network into northwestern Oregon.

Geologic evidence shows that the Cascadia Subduction Zone has generated great earthquakes, most recently about 300 years ago. It is generally accepted to have been magnitude 9 or greater. The average recurrence interval of these great Cascadia earthquakes is approximately 500 years, with gaps between events as small as 200 years and as large as 1,000 years. Such earthquakes may cause great damage to the coastal area of Oregon as well as inland areas in western Oregon. Shaking from a large subduction zone earthquake could last up to five minutes.[x]

Figure EQ-2: Historic Clackamas County Earthquakes



Source: OFR O-03-02, Map of Selected Earthquakes for Oregon,1841 through 2002 by Clark A. Niewendorp and Mark E. Neuhaus, Oregon Department of Geology and Mineral Industries

[1]Hofmeister, Hasenberg, Madin, Wang, 2003. "Earthquake and Landslide Hazard Maps and Future Earthquake Damage Estimates for Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-03-10."

Hazard Identification

Clackamas County partnered with the Department of Geologic and Mineral Industries (DOGAMI) for the purpose of developing earthquake and landslide hazard maps and future damage estimates for Clackamas County, Oregon. The two main objectives of this study were to (a) develop a set of county-wide maps to identify areas of relatively low and high earthquake and landslide hazard (hazard maps), and (b) to improve the county's capabilities for earthquake damage and loss estimation (earthquake damage and loss modeling using HAZUS). The report is entitled, "Earthquake and Landslide Hazard Maps and Future Earthquake Damage Estimates for Clackamas County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-03-10."

Probability of Future Occurrence

The County Hazard Mitigation Advisory Committee ranks the probability of a CSZ event and a damaging crustal fault earthquake equally with a “low” estimate meaning that one incident is likely within a 75 to 100 year time frame. This was a revised estimate down from the 2007 ranking of “high” probability to address the rare nature of damaging earthquakes in Oregon and the Pacific Northwest relative to other more frequent natural hazards. The earlier ranking was based on a the higher probability of more frequent Magnitude 4 earthquakes that have occurred over the last 150 years, but these are rarely damaging.

Paleoseismic studies along the Oregon coast indicate that the state has experienced seven CSZ events possibly as large as M9 in the last 3500 years. These events are estimated to have an average recurrence interval between 500 and 600 years, although the time interval between individual events ranges from 150 to 1000 years. The last CSZ event occurred approximately 300 years ago. Scientists estimate the chance in the next 50 years of a great subduction zone earthquake is between 10 and 20 percent, assuming that the recurrence is on the order of 400 +/- 200 years. (Oregon Geology, Volume 64, No. 1, Spring 2002)

New research from Oregon State University suggests that the CSZ has at least 4 segments that sometimes rupture independently of one another. Magnitude-9 ruptures affecting the entire subduction zone have occurred 19 times in the past 10,000 years. Over that time, shorter segments have ruptured farther south in Oregon and Northern California, producing magnitude-8 quakes. As such, the risks of a subduction zone quake may differ from north to south. Quakes originating in the northern portion of the CSZ tend to rupture the full length of the subduction zone. In southern Oregon and Northern California, quakes along the subduction zone appear to strike more frequently. (Rojas-Burke, Joe. “Predicting the next Northwest mega-quake still a struggle for geologists.” The Oregonian. April 20, 2010.)

Vulnerability Assessment

Clackamas County considers two main earthquake related vulnerability categories: Life and Property and Critical Facilities and Infrastructure. Both categories are discussed in further detail below. In general terms, Clackamas County’s vulnerability to the earthquake hazard is high.

Risk to Life and Property: High

For 2012, 44% of total parcels that are exposed to moderate and high earthquake hazards represent about 48% of total market value of all parcels in the county. This means that a significant amount of public and private property could be damaged from earthquakes. In

addition, the risk to life is extremely great, as much of the building stock was built prior to adoption of building codes designed for earthquake safety. Over 243 vulnerable population sites are in moderate to high hazard zones.

Risk to Critical Facilities and Infrastructure: High

The risk to critical facilities and infrastructure is invariably high. Over 115 critical and essential facilities are in moderate to high hazard zones. Many of these fire stations, law enforcement centers, and schools are unreinforced masonry, which perform extremely poorly to ground shaking. This means that emergency responders will have difficulty assisting others. Many miles of lots of road, water and sewer lines, 388 bridges, 12 cell towers, 30 substations, and 46 dams are in moderate to high hazard zones.

Relative Earthquake Hazards

DOGAMI and Clackamas County GIS worked together to combine the ground shaking, amplification, and liquefaction date to develop a composite Relative Earthquake Hazard Map (Map 10). This map represents the overall earthquake hazards in Clackamas County.

Critical Facility and Schools Assessment

In 2007 the Oregon Department of Geology and Mineral Industries (DOGAMI) released the Statewide Seismic Needs Assessment, which covers public school buildings, acute inpatient care facilities, fire stations, police stations, sheriffs' offices and other law enforcement agency buildings. Over 1,000 K -12 schools qualified for the assessment, covering 90% of enrolled public school students in every county and 100% of the vulnerable coastal community schools were surveyed.

DOGAMI Rapid Visual Screening for Clackamas County Area -Listing of 179 facilities in the unincorporated County and incorporated cities.

http://www.oregongeology.org/sub/projects/rvs/county/county-clackamas.htm

Senate Bill 1566 (2012) amended ORS 329.105 to require all school districts and education service districts to notify the Oregon Department of Geology and Mineral Industries (DOGAMI) of any construction of new school buildings or modification of an existing school building in a manner that may affect the seismic risk category of a school.

Existing Hazard Mitigation Activities

Clackamas County considers seismic hazards from a Cascadia subduction zone earthquake or a strong crustal earthquake as the highest overall threat to the jurisdiction area due to the potential for localized severity and overall regional impacts. Annually the County conducts earthquake drills, provides information and outreach to specific audiences on personal safety measures and preparedness tips, and integrates seismic planning into continuity of operations plans.

County Emergency Management is working with Building Codes and Facilities managers on a process for post-earthquake building safety evaluation and provides the ATC-20 "Post-Earthquake Safety Evaluation of Buildings" training to County staff for free.

The County Hazard Mitigation Coordinator is allowed to serve on the Oregon Seismic Safety Policy Advisory Commission (OSSPAC) as a Public Member. This arrangement helps translate local concerns into policy discussion at the state level and conversely bring state policy direction into consideration at the local implementation level.

Oregon Seismic Rehabilitation Grant Program (SRGP)

Milwaukie Elementary in North Clackamas School District received a SRGP grant in 2010 for $1,088,604. The Milwaukie Elementary project was conducted in 2 phases and will be completed by September 30, 2012. This was an unreinforced masonry (URM) facility with a Very High Collapse Potential, per the 2007 DOGAMI Rapid Visual Screening assessment report.

Seismic Mitigation Project Implementation

Clackamas River Water used a $1.5 million FEMA Pre-Disaster Mitigation grant to complete seismic upgrades to two above-groundwater reservoirs, and integrate external buttress walls and install rebar and bracing to internal walls at their treatment plant facility. They also strengthened their pumping station intake.

Clackamas River Water Seismic Retrofit Project -Left side: Buttress walls added to treatment plant. Right side: Reservoir wrapped with carbon fiber reinforced polymer.

Earthquake Mitigation Action Items

Earthquake actions are listed in Section 3 Mitigation Strategy. For detailed information regarding each action, please refer to Appendix A – Action Items.

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[i] Madin, Ian P. and Zhenming Wang. *Relative Earthquake Hazard Maps Report.* (1999) DOGAMI.

[ii] *Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Ch. 8, pp. 8.

[iii] March 4, 2001. "A region at risk." The Oregonian.

[iv] *Questions and Answers on Earthquakes in Washington and Oregon* (February 2001) www.geophys.washington.edu/seis/pnsn/info_general/faq.html.

[v] "A region at risk." March 4, 2001. The Oregonian.

[vi]Ibid.

[vii]Ibid.

[viii]Ibid.

[ix]Bott, Jacqueline D.J. and Wong, Ivan G. *Historical earthquakes in and around Portland, Oregon.* September (1993). Oregon Geology 55 (5). 116.

[x]*Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Ch. 8, pp. 9.