3.1 Earthquake

Much of the Planning Area is susceptible to earthquake-induced landslides, liquefaction and severe ground shaking. A dense population and built environment in the cities of Gresham and Fairview make them especially vulnerable to earthquake hazards. Some unincorporated areas have high susceptibility to earthquake-induced landslides (West Hills and the Columbia River Gorge) and liquefaction (Sauvie Island). Because the vast majority of the building stock in the cities of Troutdale and Wood Village is wood framed — which generally performs fairly well in earthquakes — impacts from ground shaking are likely to be more moderate for these communities.

Level of Risk* to Earthquake Hazards

High

- Unicorporated Multnomah County
- Gresham

Moderate-High

- Fairview

Moderate

- Troutdale
- Wood Village

Low

- None

Level of risk is based on the local OEM Hazard Analysis scores determined by each jurisdiction in the Planning Area. See **Appendix C for more information on the methodology and scoring.*

3.1.1 Overview

Since the 1980s, awareness of seismic risk in Oregon has increased significantly. This is due in large part to local earthquake events such as the M5.6 1993 Scotts Mills earthquake in Clackamas County; global events like the devastating earthquakes and tsunamis in Indonesia (2004) and Japan (2011), and earthquakes in New Zealand (2011), Chile (2014) and Nepal (2015); and new research about the massive fault off the Pacific Northwest coast called the Cascadia Subduction Zone.

Small to moderate earthquakes up to M5 or M5.5 are possible almost anywhere in the Planning Area. There is also a possibility of larger crustal earthquakes in the M6+ range. There is good reason to believe that the most devastating future earthquakes probably would originate along shallow crustal faults in the region and along the Cascadia Subduction Zone (Oregon Department of Land Conservation and Development [DLCD], 2015).

Types

All jurisdictions in the Planning Area are susceptible to impacts from earthquakes from three sources: (a) the offshore Cascadia Subduction Zone, (b) deep intraplate events within the subducting Juan de Fuca plate, and (c) shallow crustal events within the North America Plate, as shown in **Table 3.1-1**. All have some tie to the subducting or diving of the dense, oceanic Juan de Fuca Plate under the lighter, continental North America Plate.

Table 3.1-1 Types of Earthquake Hazards That Impact Each Jurisdiction

Jurisdiction	Cascadia Subduction Zone	Intraplate	Crustal
Unincorporated Multnomah County	✓	✓	✓
Fairview	✓	✓	✓
Gresham	✓	✓	✓
Troutdale	✓	✓	✓
Wood Village	✓	✓	✓

Source: Oregon Department of Land Conservation and Development (DLCD), 2015; NHMP Steering Committee, 2016

Cascadia Subduction Zone Earthquakes

The Cascadia Subduction Zone is a geologically complex area off the Pacific Northwest coast that extends from Northern California to British Columbia. In simple terms, several pieces of oceanic crust (the Juan de Fuca Plate, Gorda Plate and other smaller pieces) are being subducted (pushed under) the crust of North America. This subduction process is responsible for most of the earthquakes in the Pacific Northwest as well as for creating the volcanoes in the Cascades.

Intraplate Earthquakes

Intraplate earthquakes occur within the subducting oceanic plate. These earthquakes occur quite deep in the earth. Ground shaking from such earthquakes would be very strong near the epicenter, and strong ground shaking would be felt throughout all of the Planning Area, with the level of shaking decreasing toward eastern Multnomah County.

Crustal Earthquakes

Crustal earthquakes occur within the North American plate, above the subducting plate. These earthquakes are possible on faults mapped as active or potentially active as well as on unmapped (unknown) faults.

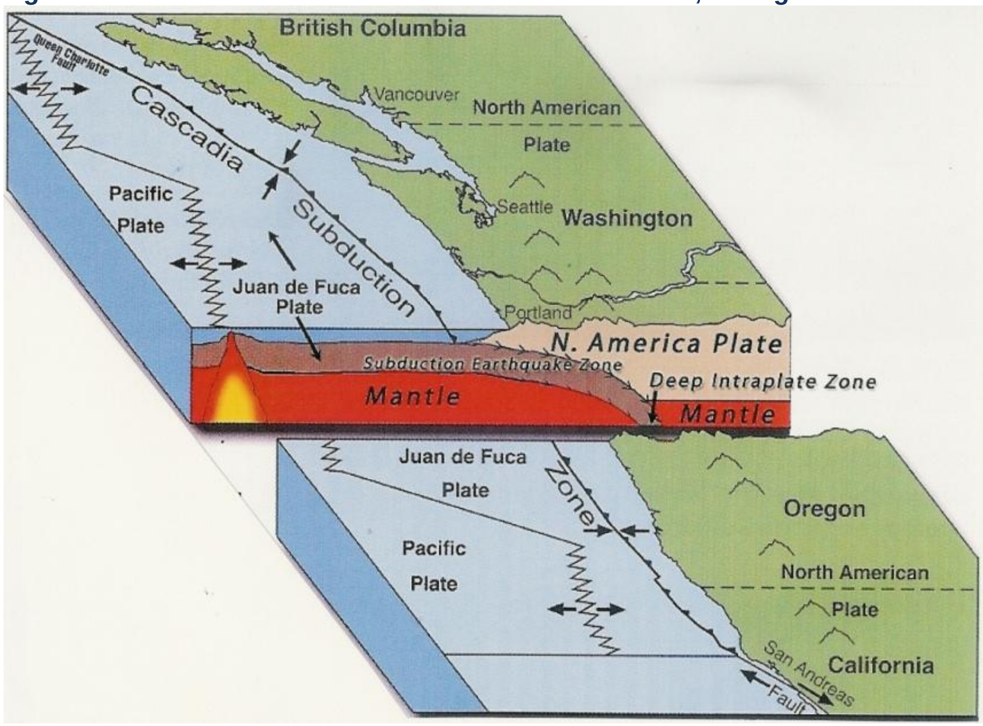
Location and Extent

Earthquake ground motions may be significantly higher for certain soil types. Buildings and infrastructure in the higher-amplification areas will generally suffer more damage in any given earthquake than similar buildings and infrastructure located in low-amplification areas. In general, earthquake-induced ground motions within the Planning Area are higher to the west, and lower to the east. The location and extent of each type of earthquake is described below.

Cascadia Subduction Zone Earthquakes

Figure 3.1-1 shows the geologic (plate-tectonic) setting of the Cascadia Subduction Zone. These earthquakes occur about 20 to 60 kilometers (12 to 40 miles) offshore from the Pacific Ocean coastline.

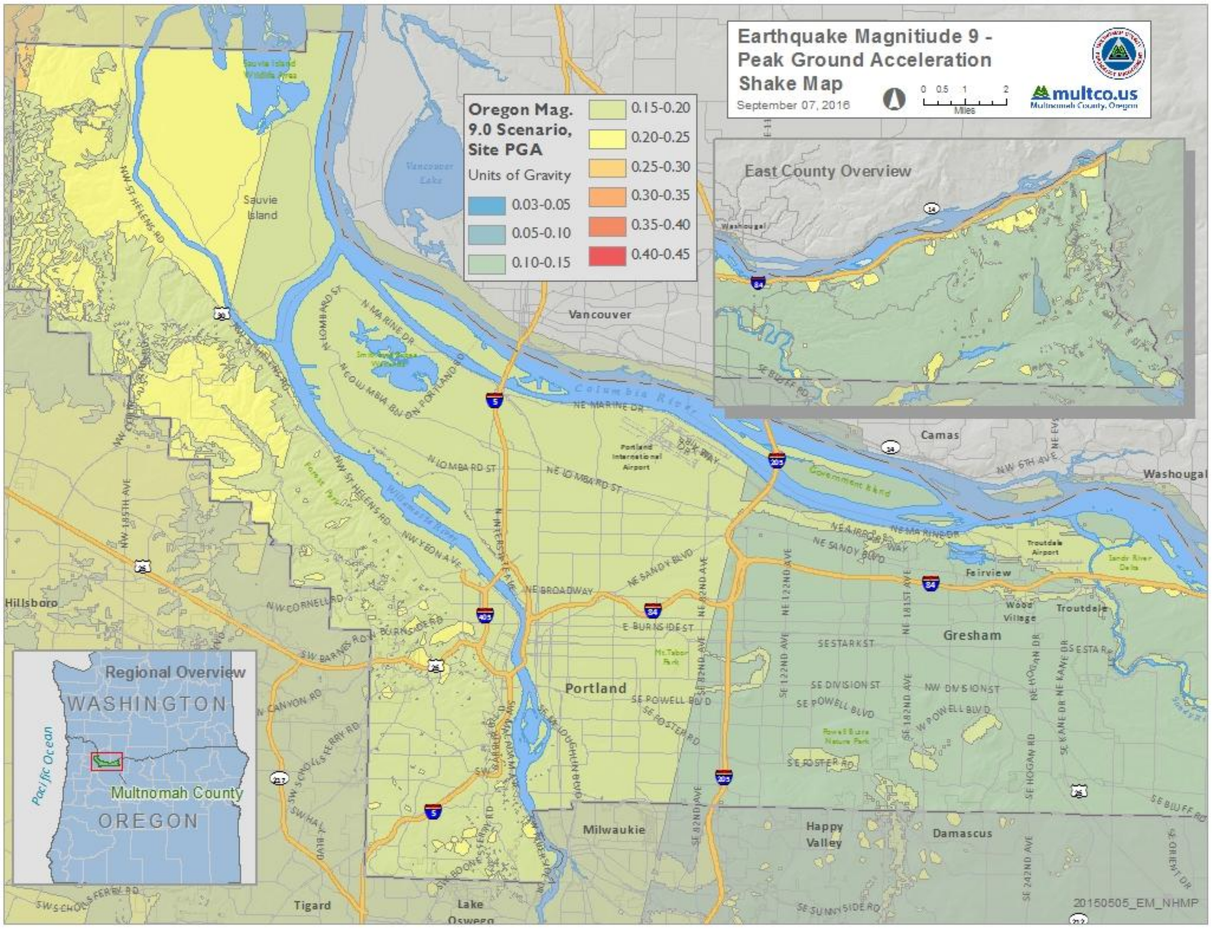
Figure 3.1-1 Cascadia Subduction Zone: Cross Section, A Magnitude 9.0 Earthquake Scenario



Source: Cascadia Region Earthquake Working (CREW) Group, 2005

Figure 3.1-2 shows that ground shaking from a Cascadia Subduction Zone event would be very strong near the coast, and moderately strong ground shaking would be felt throughout the Planning Area, with the level of shaking decreasing toward eastern Multnomah County.

Figure 3.1-2 Cascadia Subduction Zone 9.0 Peak Ground Acceleration Shake Map



Source: Madin and Burns, 2013

Intraplate Earthquakes

Deep-seated intraplate events could generate magnitudes ranging from M6 to as large as M7.5 (Oregon Department of Land Conservation and Development [DLCD], 2015). These earthquakes occur quite deep in the earth, about 30 or 40 kilometers (18 to 25 miles) below the surface, with epicenters that likely would range from near the Pacific Ocean coast to about 50 kilometers (30 miles) inland. Examples of intraplate earthquakes are the 2001 Nisqually earthquake in Washington State and earthquakes near Olympia, Washington, in 1949.

Crustal Earthquakes

The City of Portland has been built on three identified crustal faults that stretch the length of Portland: the Oatfield Fault, the East Bank Fault, and the Portland Hills Fault. Each of these crustal faults is capable of generating large earthquakes of M6.0–6.8 (DLCD, 2015). Three other nearby faults could impact communities in Multnomah County, including the Grant Butte Fault, the Tickle Creek Fault Zone in Damascus, and the Lacamas Lake Fault in Washington. There may also be unknown crustal faults along which quakes could occur. Unknown faults are statistically possible anywhere in Multnomah County. Most likely, earthquakes on as yet unknown faults would be relatively small, most likely with magnitudes less than M6. However, earthquakes as large as M6 or M6.5 on unknown faults are possible.

Other Aspects of Seismic Hazards in Multnomah County

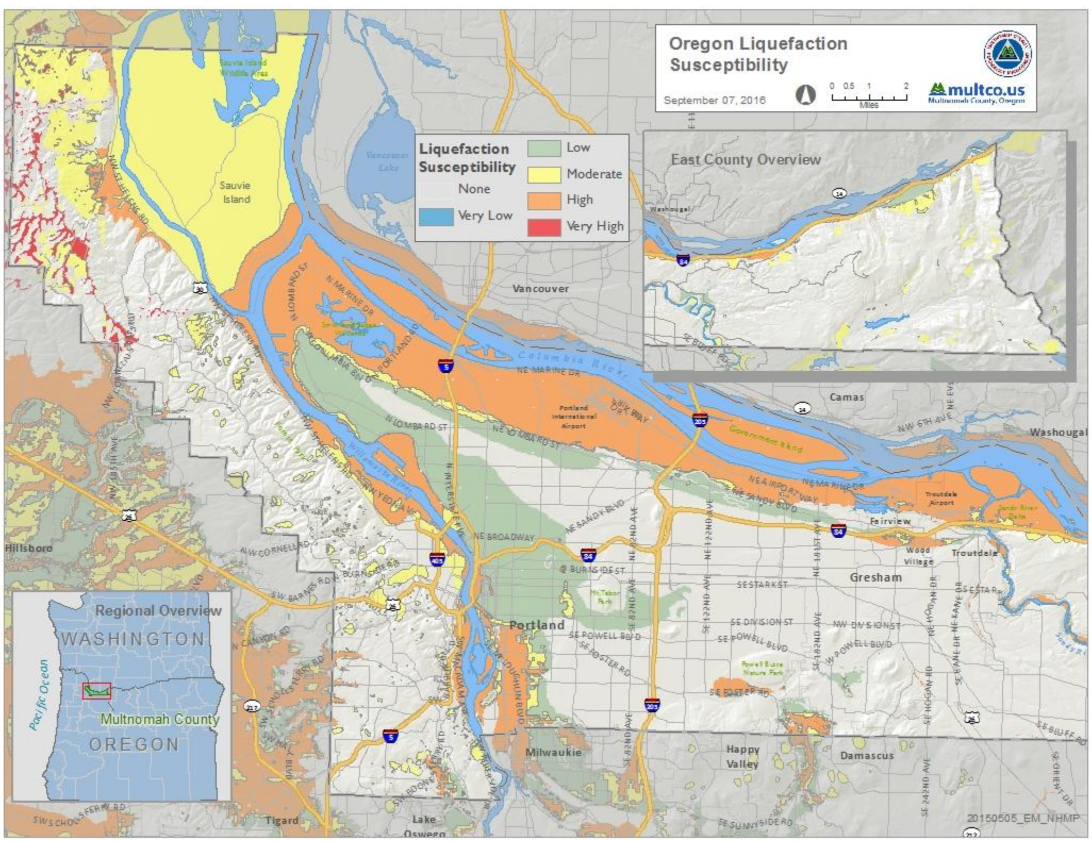
Earthquakes also can trigger liquefaction, settlement, lateral spreading, landslides, volcanic activity, dam failures, levee failures and tsunamis and seiches, which can result in significant damage. Following is a description of the location and extent of these additional seismic-related hazards in the Planning Area.

Liquefaction, Settlement and Lateral Spreading

Liquefaction is a process where loose, wet sediments lose strength during an earthquake and behave similarly to a liquid. Once a soil liquefies, it will tend to settle vertically and/or spread laterally. On even very slight slopes, liquefied soils tend to move sideways downhill creating lateral spreading.

Figure 3.1-6 shows areas in the Planning Area with soils prone to liquefaction in a 9.0 Cascadia Subduction Zone earthquake. The very-high- and high-liquefaction areas include broad areas along the Columbia River, significant areas along both the Willamette and Sandy rivers, and smaller areas along several streams. These areas include Portland International Airport and significant portions of the cities of Portland, Troutdale and Wood Village. Within unincorporated Multnomah County, areas at risk of liquefaction include parts of Sauvie Island, areas along the Columbia River east of Troutdale, and areas along the Sandy River and several streams.

Figure 3.1-6 Liquefaction Potential after a 9.0 Cascadia Subduction Zone Earthquake

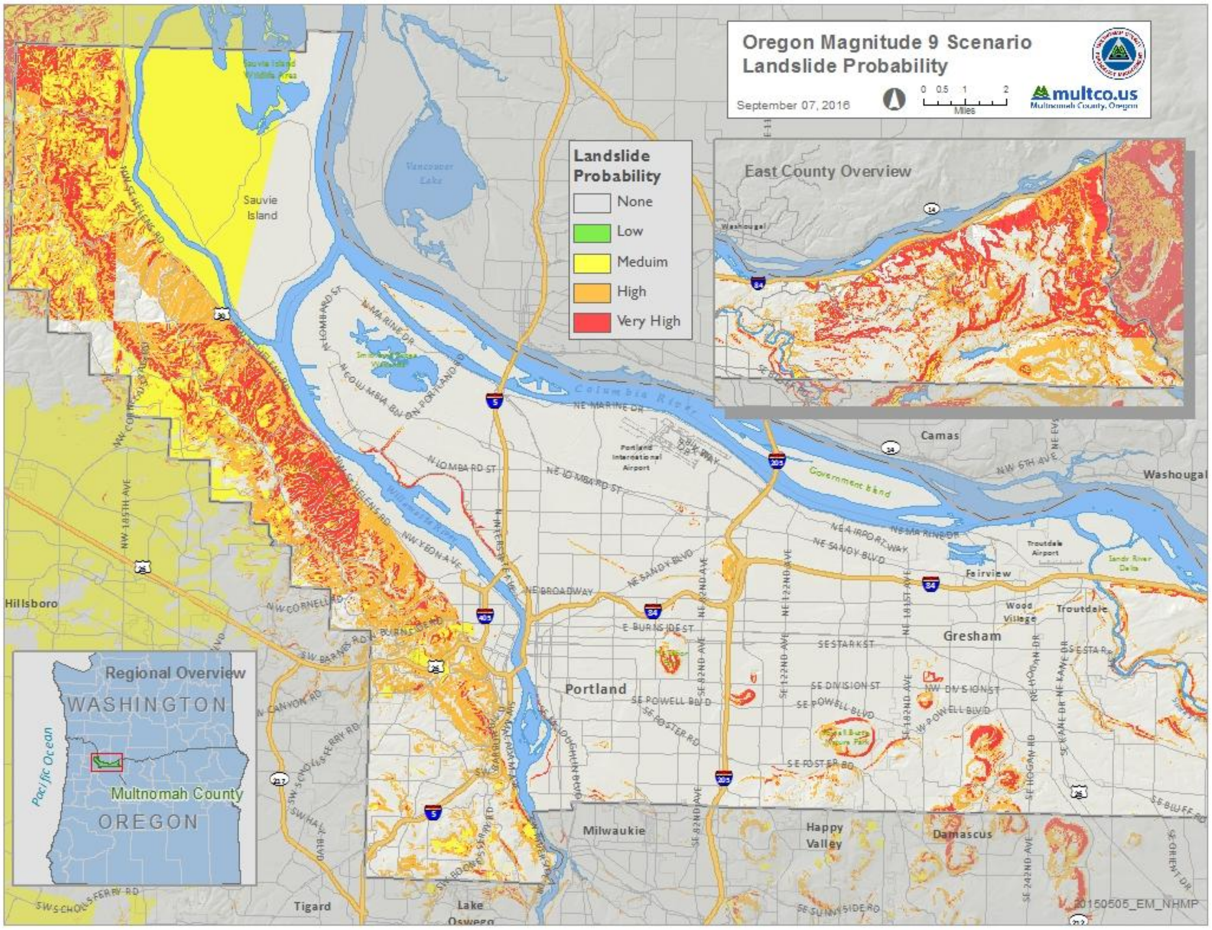


Source: Madin and Burns, 2013

Landslides

Earthquakes can trigger landslides, especially if an earthquake occurs during the rainy season when soils are saturated with water. The areas prone to earthquake-induced landslides are largely the same as those areas prone to landslides in general. Areas with steep slopes and loose rock or soils are most prone to landslides, including those induced by earthquakes**. Figure 3.1-7** shows areas that may be subject to landslides after a 9.0 Cascadia Subduction Zone earthquake. See section **3.3 Landslides** for a more detailed discussion of landslides.

Figure 3.1-7: 9.0 Cascadia Subduction Zone Earthquake-induced Landslides



Source: Madin and Burns, 2013

Volcanic Activity

Despite the fact that Cascade volcanoes are located some distance away from the Planning Area, earthquake shaking and secondary volcano-related hazards such as lahars could cause major damage to our communities (DLCD, 2015). For more information about volcanic hazards in the Planning Area, see section **3.5 Volcano.**

Dam Failures

Earthquakes can cause dam failures. The most common mode of earthquake-induced dam failure is slumping or settlement of earthfill 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 cause dam failures. More information about dams can be found in **Section 3.2 Floods.**

Levee Failures

Based on the U.S. Army Corps of Engineers 2001 study of the seismic performance of the Columbia River Levee, the levee by itself would not result in interior flooding, unless a major flood event was in progress. The study highlights that there is no known correlation between high water periods and earthquakes. Though not all levees perform the same, and the study considered only a small section of the levee north of the Portland International Airport, the fact remains there is no known correlation between high water periods and earthquakes. Therefore, the likelihood of a major flooding event on the Columbia River and an earthquake occurring at the same time is very low.

Tsunamis and Seiches

Tsunamis result from earthquakes which cause a sudden rise or fall of the ocean floor. These ocean floor movements may produce tsunami waves. The Planning Area would not be directly affected by tsunamis. A tsunami 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 would be minimal or zero. That is, the increase in water level would be immeasurable, or perhaps just a few inches, and would not cause damage within the Planning Area.

A similar earthquake phenomenon is 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 or tanks within the Planning Area.

3.1.2 History

The Planning Area been shaken by crustal and intraplate earthquakes and, prehistorically, by subduction zone earthquakes centered outside the area (DLCD, 2015). There have been dozens of mostly small earthquakes recorded in or near Multnomah County. **Table 3.1-2** lists the significant historical earthquakes that have impacted the Planning Area.

Table 3.1-2 Significant Historic Earthquakes Affecting the Planning Area

Date	Location	Size (M)	Description
Approximate years: 1400 BCE*, 1050 BCE, 600 BCE, 400, 750, 900	Cascadia Subduction Zone (Offshore)	Probably 8.0–9.0	Based on studies of earthquakes and tsunamis at Willapa Bay, Washington. These are the mid-points of the age ranges for these six events.
Jan. 1700	Cascadia Subduction Zone	About 9.0	Generated a tsunami that struck Oregon, Washington, and Japan. Destroyed Native American villages along the coast.
Oct. 1877	Portland area	5.2	Two events reported in one day. Estimated affected area was approximately 41,000 square kilometers. Chimney damage.
Feb. 1892	Portland area	5.0	No major damage.
Dec. 1941	Portland area	4.5	Felt by most Portland residents. Shattered windows and cracked plaster in Hillsboro and Sherwood.
Apr. 1949	Olympia, WA	7.1	Significant damage in Washington. Minor damage in NW Oregon.
Dec. 1953	Portland area	4.5	Cracked plaster. Objects fell in Portland.
Nov. 1961	Portland area	5.0	Principal damage from cracked plaster.
Nov. 1962	Portland area	5.5	Shaking up to 30 seconds. Chimneys cracked. Windows broken. Furniture moved.
Dec. 1963	Portland area	4.5	Books and pictures fell in North Plains, OR.
Apr. 1965	Seattle-Tacoma, WA	6.5	Three people killed. Only felt shaking in Multnomah County.
Mar. 1993	Scotts Mills, OR	5.6	DR-985. On Mt. Angel–Gales Creek fault. $30 million damage (including Oregon Capitol Building in Salem) .
Sep. 1993	Klamath Falls, OR	6.0	DR-1004. Earthquake in Klamath Falls, two people killed.
Feb. 2001	Nisqually, WA	6.8	Felt in the region. No damage reported.

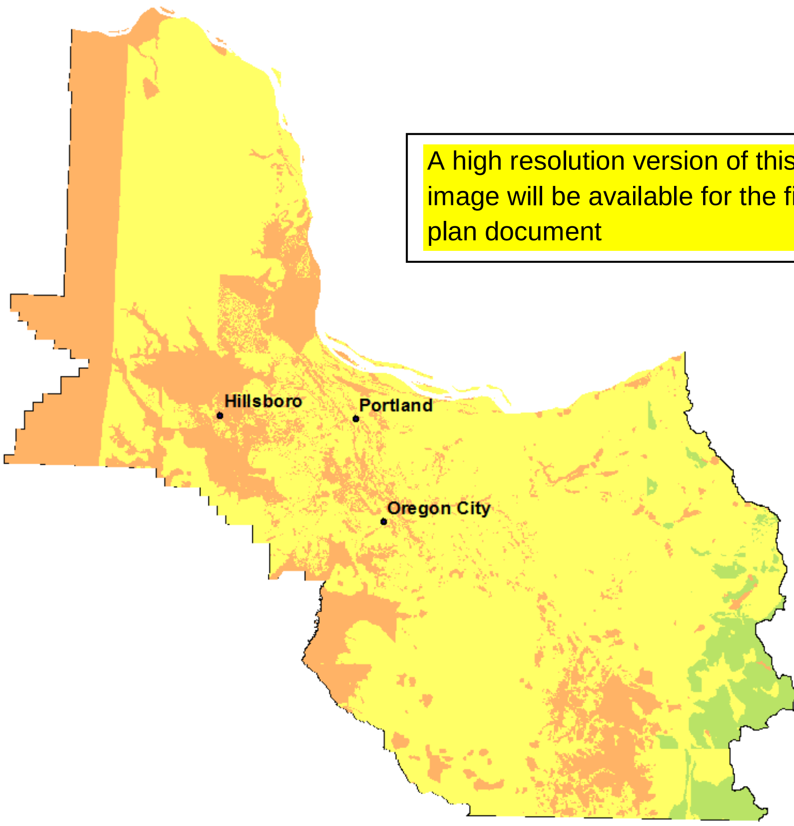
*BCE: Before the Common Era.

Sources: Wong and Bolt, 1995

3.1.3 Probability

The map in **Figure 3.1-8** shows the expected level of earthquake damage along all known faults in Oregon that could impact the North Willamette Valley/Portland metropolitan area, including Multnomah County, that has a 2% chance of occurring in the next 50 years (DLCD, 2015). Based on the Simplified Mercalli Levels defined by Madin and Burns (2013), Multnomah County is subject to Level VIII and IX effects of shaking, meaning significant to substantial damage in vulnerable buildings can be expected. These Simplified Mercalli Levels are described in **Table 3.1-3.**

Figure 3.1-8 Oregon Earthquake Hazard Mercalli Intensity, with a 2% Chance Recurrence in 50 Years, North Willamette Valley/Portland Metropolitan Area*



* The North Willamette Valley/Portland metropolitan area includes Columbia, Washington, Multnomah and Clackamas counties.

Source: Madin and Burns, 2013

Table 3.1-3 Simplified Explanation of Mercalli Levels

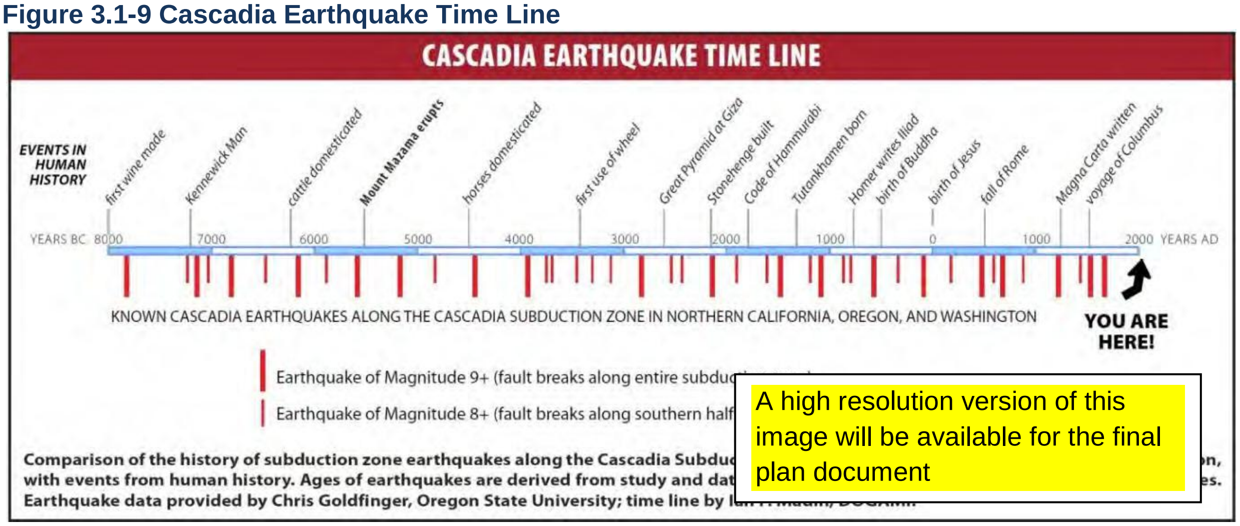
Color	Mercalli Intensity	Effects of Shaking on People and Structures
Dark Green	VI	Felt by all, weak buildings cracked
Light Green	VII	Chimneys break, weak buildings damaged, better buildings cracked
Yellow	VIII	Partial collapse of weak buildings, unsecured wood-frame houses move
Orange	IX	Collapse and severe damage to weak buildings, damage to wood-frame structures
Red	X	Poorly built structures destroyed, heavy damage in well-built structures

Source: Madin and Burns, 2013

According to Madin and Burns (2013) and the 2015 Oregon Natural Hazards Mitigation Plan (NHMP), the probability of seismic activity for all faults that could affect the North Willamette Valley/Portland metro area is as follows.

> *For Oregon west of the crest of the Cascades, the [Cascadia Subduction Zone] is responsible for most of the earthquake hazard shown in **Figure 3.1-9**. The paleoseismic record includes 18 magnitude 8.8–9.1 megathrust earthquakes in the last 10,000 years that affected the entire subduction zone. For Multnomah County, a great magnitude 9.0 earthquake on the Cascadia Subduction Zone would result in widespread damage.*
>
> *The return period for the largest earthquakes is 530 years, and the probability of the next such event occurring in the next 50 years ranges from 7 to 12%. An additional 10 to 20 smaller, magnitude 8.3–8.5, earthquakes affected only the southern half of Oregon and northern California. The average return period for these is about 240 years, and the probability of a small or large subduction earthquake occurring in the next 50 years is 37–43%. These return periods can be seen on the timeline in **Figure 3.1-9.***
>
> *[Cascadia Subduction Zone] earthquakes may have magnitudes of up to 9.0 or perhaps 9.2, with probable recurrence intervals of 500 to 800 years. The last major earthquake in this source region occurred in the year 1700, based on current interpretations of Japanese tsunami records. The timeline in **Figure 3.1-9** compares the 10,000-year-long history of Cascadia earthquakes to events in human history. As stated above, the probability of a small or large subduction earthquake occurring in the next 50 years is 37–43%.*

Figure 3.1-9 Cascadia Earthquake Time Line



Sources: OSSPAC, 2013; Earthquake data provided by Chris Goldfinger, Oregon State University; timeline by Ian P. Madin, DOGAMI, 2013

While a Cascadia Subduction Zone earthquake would have massive regional impacts for the Planning Area and the surrounding Pacific Northwest, a smaller nearby earthquake, such as a M7.1 on the Portland Hills Fault, would result in higher levels of local ground shaking and local damage in Multnomah County (DLCD, 2015).

Crustal faults that can impact the Planning Area are all listed as “Class A” faults by the U. S. Geological Survey (USGS), which means that there is solid geological evidence for fault movements within the past 1.6 million years. The estimated slip rate on all of these faults is less than 0.2 mm per year.

Return periods for earthquakes on these faults are not well-known, but are probably at least several thousand years and perhaps 10,000 years, or more. Estimates for three crustal scenario earthquakes are summarized in **Table 3.1-4.** The return period for the smaller M6.0 Portland Hills scenario is roughly estimated at about ten times less than that for the M7.05 scenario.

Table 3.1-4 Estimated Return Periods for Scenario Crustal Earthquakes

Scenario Earthquake	Return Period (Years)	Probability in 50 Years	Last Event
M 7.05 Portland Hills*	14,000	0.35%	Unknown
M 6.0 Portland Hills*	1,500	3.50%	Unknown
M 6.8 Mount Angel	14,500	0.34%	Unknown

* Return periods for the M7.05 Portland Hills and M6.8 Mount Angel scenarios are based on 2008 USGS estimates.

Source: HAZUS, for 2012 Multnomah County NHMP

3.1.4 Vulnerability

The Planning Area is especially vulnerable to earthquake hazards for two reasons: (a) much of the area is susceptible to earthquake-induced landslides, liquefaction and severe ground shaking; and (b) the region contains the bulk of Oregon’s population and built environment (DLCD, 2015). Multnomah is one of the 15 counties in the state with the highest expected earthquake induced damages and losses, based on a 500-year model (DLCD, 2015)[1].

The level of damage from ground shaking depends upon the intensity and duration of the shaking. Unreinforced structures, roadbeds and bridges will be damaged to varying extents. It is expected that river crossings and areas with limited surface transportation alternatives will isolate some neighborhoods, hindering rescue and recovery activities (DLCD, 2015).

Projected Losses

The Regional Disaster Preparedness Organization (RDPO) has contracted with the Oregon Department of Geology and Mineral Industries (DOGAMI) to conduct a new HAZUS analysis for earthquakes for the Portland Urban Area Security Initiative Area, which includes Multnomah County. That project began in 2016 and will be completed after this NHMP update cycle. Findings from that analysis will inform the next update of this plan.

Countywide Loss Estimates

Until then, the most recent earthquake data reaches back to the mid-1990s, when DOGAMI developed two earthquake loss models for Oregon. Both models are based on the Federal Emergency Management Agency (FEMA) HAZUS software program[2]. Those models include (a) a magnitude 8.5 Cascadia Subduction Zone scenario, and (b) a 500-year probabilistic ground motion scenario, which combines

[1] Earthquake-induced damages and losses include the entire county, including the City of Portland.

[2] DOGAMI investigators caution that the models contain a high degree of uncertainty and should be used only for general planning and policy purposes (DLCD, 2015).

Cascadia Subduction Zone, intraplate and crustal events.[1,2] **Table 3.1-5** shows projected dollar losses for Multnomah County based on those two models.

Table 3.1-5 Project Dollar Losses to Multnomah County[1], M8.5 Cascadia Subduction Zone Event and 500-Year that Combines Cascadia Subduction Zone, Intraplate and Crustal Earthquakes

Impacts	M8.5	500-year[2]
Injuries	1,521	8,659
Death	28	186
Displaced households	2,803	13,777
Economic losses for buildings[2]	$1.9b	$9.2b
Operation "day after" the quake Fire stations Police stations Schools bridges	 78% 76% 81% 94%	 NA[3] NA _ _
Economic losses to Highways Airports Communications	 $21m $2m $3m	 $437m $12m $31m
Debris generated (thousands of tons)	1,598	6,745

[1] Estimates are for all of Multnomah County, which includes the Planning Area and the City of Portland

[2] Every part of Oregon is subject to earthquakes. The 500-year model is an attempt to quantify the risk across the state. The estimate does not represent a single earthquake. Instead, the 500-year model includes many faults. More and higher magnitude earthquakes than used in this model may occur (DOGAMI, 1999).

[3] "…there are "numerous unreinforced masonry structures (URMs) in Oregon, the currently available default building data does not include any URMs. Thus, the reported damage and loss estimates may seriously under-represent the actual threat" (Wang, 1998, p. 5).

[3] Because the 500-year model includes several earthquakes, the number of facilities operational the "day after" cannot be calculated.

Source: Wang and Clark (1999)

Damage and loss estimates also have been estimated for three crustal scenario earthquakes that could create the biggest impact on Multnomah County:

- Portland Hills Fault M7.05,
- Portland Hills Fault M6.0
- Mount Angel Falls Fault M6.8

These estimates are based on USGS-based earthquake hazard data and ground motion attenuation relationships in HAZUS. They also include all of Multnomah County — the Planning Area and the City of Portland. (See **Table 3.1-6.**)

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[1] Neither model considers unreinforced masonry buildings (DLCD, 2015).

[2] The national inventory data used by HAZUS are estimates for each census tract. In some cases, these data may be incomplete or inaccurate. The results should not be interpreted as indicating the exact damages, losses or casualties for each scenario earthquake — the exact levels of damages, losses and casualties cannot be predicted before an earthquake occurs. Rather, the results illustrate the relative severity of consequences for Multnomah County for each of the four earthquake scenarios and the approximate levels of damages and casualties expected.

Table 3.1-6 Summary Impacts for Multnomah County[1] for Three Crustal Scenario Earthquakes

Category	Portland Hills M7.05	Portland Hills M6.0	Mount Angel M6.8
Damages and Losses			
Number of Damaged Buildings – Total	456,165	180,035	65,711
Number of Damaged Buildings – Slight Damage	198,628	139,249	57,867
Number of Damaged Buildings – Moderate Damage	149,973	33,640	7,140
Number of Damaged Buildings – Extensive Damage	62,256	6,338	660
Number of Damaged Buildings – Complete Damage	45,308	808	44
Buildings – Related Damages and Economic Losses	$47,345,000,000	$6,667,000,000	$2,274,000,000
Transportation Systems Damages	$4,064,000,000	$816,000,000	$180,600,000
Utility Systems Damages[2]	$84,000,000	$18,290,000	$9,680,000
Total Damages and Losses	$51,493,000,000	$7,501,290,000	$2,464,280,000
Casualties			
Injuries (2 p.m.)	45,414	2,612	881
Injuries (2 a.m.)	12,074	691	418
Deaths (2 p.m.)	3,417	100	24
Deaths (2 a.m.)	626	12	7

[1] Estimates are for all of Multnomah County, which includes the Planning Area and the City of Portland.

[2] Utility systems damages are for potable water only.

Source: HAZUS for 2012 Multnomah County NHMP

Estimates differ substantially for the three crustal scenario earthquakes because of the combination of two factors: (1) magnitude of the earthquake and (2) location of the earthquake in relation to Multnomah County.

Because the Portland Hills Fault is located within Multnomah County, the levels of ground shaking and consequent local damages, losses and casualties are projected to be much higher than for the larger, but further away, Cascadia Subduction Zone. The vast majority of these losses are expected within the City of Portland. Low levels of damages, economic losses and casualties are expected for the cities of Fairview, Troutdale and Wood Village. In large part this is because (1) these small cities are located a substantial distance to the east of the fault zone, and (2) the vast majority of the building stock consists of wood-frame buildings, which generally perform fairly well in earthquakes. The low loss estimates may also reflect incomplete incorporation of local soils data in the HAZUS calculations. Thus, these results should be interpreted cautiously. In addition, it is important to note that damages and losses from a Portland Hills Fault event will be more locally concentrated. In contrast, a Cascadia Subduction Zone event will have massive regional impacts that further impact transportation systems and response resources throughout the Pacific Northwest.

The estimated deaths and injuries are significantly lower during nighttime hours than during daytime hours, because more people are in wood-frame residential buildings, which generally perform reasonably well in earthquakes.

City Loss Estimates

Additional damage and loss estimates were explored by HAZUS for two seismic scenarios for the cities of Fairview, Troutdale and Wood Village:

- M9.0 interplate earthquake on the Cascadia Subduction Zone
- M6.25 crustal earthquake near Fairview

This analysis was conducted for the 2010 update of the NHMPs for the three small cities. At the time of that data run, the City of Gresham had its own NHMP and therefore was not included in those HAZUS scenarios.

HAZUS data was aggregated by census tracts, which do not match city boundaries. Nine census tracts encompass the cities of Fairview, Wood Village and Troutdale, along with adjacent portions of Gresham and surrounding rural areas. These nine census tracts have a total population of 41,848 people (2000 census).

The building and infrastructure inventory is generally similar across these nine census tracts, with about 97% of the buildings being residential. As a reasonable approximation, we assume that damages, economic losses and casualties for the entire nine-census-tract area are distributed among the cities pro-rata by population. Damages, economic losses and casualties for Fairview and Troutdale are estimated to be approximately one-quarter of the totals, at 23.43%. For Wood Village, they are estimated to be approximately 7.5% of the totals.

For the M9.0 Cascadia Subduction Zone earthquake, HAZUS indicates rather low levels of damages, economic losses and casualties **(Table 3.1-7).** In large part, this is because Fairview, Troutdale and Wood Village are located a substantial distance to the east of the fault zone. Also, the vast majority of building stock in both the incorporated cities and the unincorporated areas consists of wood-frame buildings, which generally perform fairly well in earthquakes. Low loss estimates may also reflect incomplete HAZUS calculations based on the incorporation of incomplete local soils data, shaking capped at one minute, and incomplete information about building fragility, so these results should be interpreted cautiously.

Table 3.1-7 Sudden Impacts for Fairview, Troutdale and Wood Village: M9.0 Interplate Cascadia Subduction Zone Earthquake

Category	9 Census Tracts	Fairview	Troutdale	Wood Village
Damages and Losses				
Number of Damaged Buildings – Total	2,504	587	824	189
Number of Damaged Buildings – Moderate Damage	877	205	289	66
Number of Damaged Buildings – Extensive Damage	178	42	59	13
Number of Damaged Buildings – Complete Damage	4	1	1	0
Buildings – Related Damages and Economic Losses[1]	$69.88	$16.37	$23.01	$5.29
Transportation Systems Damages and Economic Losses[1]	$7.00	$1.64	$2.30	$0.53
Utility Systems Damages and Economic Losses[1]	$11.31	$2.65	$3.72	$0.86
Total Damages and Losses[1]	$68.19	$20.66	$29.03	$6.67
Casualties				
Injuries (2 p.m.)	26	6	9	2
Injuries (2 a.m.)	13	3	4	1
Deaths (2 p.m.)	0	0	0	0
Deaths (2 a.m.)	0	0	0	0

[1] Damage and loss estimates in millions of dollars.

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village

Building-related losses by occupancy, building type and economic losses are shown in **Tables 3.1-8, -9 and -10.** Losses are estimated to be about 25% for Fairview, about 33% for Troutdale, and about 7.5% for Wood Village.

Table 3.1-8 Building Damage by Occupancy for Fairview, Troutdale and Wood Village: M9.0 Interplate Cascadia Subduction Zone Earthquake

Type	None		Slight		Moderate		Extensive		Complete	
	Count	%	Count	%	Count	%	Count	%	Count	%
Agriculture	9	0.08	3	0.15	2	0.27	0	0.25	0	0.23
Commercial	76	0.71	60	4.13	52	5.89	11	6.24	0	8.37
Education	5	0.05	2	0.14	2	0.18	0	0.13	0	0.11
Government	6	0.08	2	0.17	2	6.21	0	0.16	0	0.15
Industrial	28	0.26	22	1.52	26	2.96	6	3.52	0	5.10
Other Residential	934	8.75	606	41.91	765	87.28	159	89.06	3	85.28
Religion	10	0.09	4	0.30	4	0.47	1	0.47	0	0.60
Single-Family	9,614	90.0	747	51.65	24	2.76	0	0.18	0	0.16
Total	10,682		1,446		877		177		3	

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village

Table 3.1-9 Building Damage by Building Type for Fairview, Troutdale and Wood Village: M9.0 Interplate Cascadia Subduction Zone Earthquake

Type	None		Slight		Moderate		Extensive		Complete	
	Count	%	Count	%	Count	%	Count	%	Count	%
Wood	9.954	93.18	774	53.52	24	2.77	0	0.04	0	0.04
Steel	29	0.27	25	1.74	43	4.95	12	6.52	0	9.99
Concrete	32	0.30	31	2.15	29	3.34	4	2.29	0	1.61
Precast	19	0.18	15	1.05	26	3.01	8	4.73	0	5.28
Reinforced Masonry	5	0.05	2	0.15	2	0.25	0	0.16	0	0.03
Unreinforced Masonry	156	1.48	60	4.18	18	2.11	1	0.56	0	0.50
MH	487	4.56	538	37.23	733	83.57	153	85.69	3	82.55
Total	10,682		1,445		877		178		4	

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village

Table 3.1-10 Building-related Economic Losses for Fairview, Troutdale and Wood Village: M9.0 Interplate Cascadia Subduction Zone Earthquake

Category and Area	Single-Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses						
Wage	0	0.20	3.47	0.56	0.18	4.41
Capital Related	0	0.09	2.86	0.34	0.08	3.35
Rental	0.06	0.98	2.37	0.31	0.09	3.82
Relocation	0.11	1.94	3.81	1.27	0.88	8.01
Subtotal	0.17	3.21	12.51	2.48	1.22	19.59
Capital Stock Losses						
Structural	0.88	2.27	5.24	2.84	1.09	12.33
Non Structural	8.69	6.11	6.78	3.83	1.50	28.91
Content	4.36	1.05	2.45	2.10	0.58	10.55
Inventory	0	0	0.11	0.37	0.02	0.51
Subtotal	13.93	9.44	14.58	9.15	3.19	50.29
Total	14.11	12.65	27.09	11.63	4.41	69.88

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village

Overall loss estimates for the three smaller cities in the Planning Area after a M9.0 Cascadia Subduction Zone earthquake include:

- **Fairview:** $20 million damages and economic losses, a small number of injuries, and probably no deaths
- **Troutdale:** $29 million damages and economic losses, a small number of injuries, and probably no deaths
- **Wood Village:** $7 million damages and economic losses, a small number of injuries, and probably no deaths

In addition to building damages, there would be significant damages to transportation and utility systems. HAZUS includes rough estimates of expected utility outages. However, especially for an area as small as Fairview, Troutdale and Wood Village, estimating the specific levels of utility damages and outages with any confidence would require much more detailed analysis of the specific inventory characteristics of utility systems in these cities.

Although much smaller than the megathrust earthquakes, crustal earthquakes may occur much closer to population centers, and are capable of producing severe shaking and damage in localized areas (DLCD, 2015). The worst case scenario earthquake for Fairview, Troutdale and Wood Village is a moderately large crustal earthquake in or very near to Fairview, Troutdale and Wood Village. HAZUS results for a hypothetical M6.25 crustal earthquake with an epicenter near Interstate 84 at latitude 45.539619 and longitude 122.420669 are shown in **Table 3.1-11.**

Table 3.1-11 Summary Impacts: M6.26 Crustal Earthquake near to Fairview, Troutdale and Wood Village

Category	9 Census Tracts	Fairview	Troutdale	Wood Village
Damages and Losses				
Number of Damaged Buildings – Total	10,660	2,498	3,509	806
Number of Damaged Buildings – Moderate Damage	4,258	998	1,402	322
Number of Damaged Buildings – Extensive Damage	2,028	475	668	153
Number of Damaged Buildings – Complete Damage	824	193	271	62
Buildings – Related Damages and Economic Losses[1]	$989.00	$231.72	$325.59	$74.82
Transportation Systems Damages and Economic Losses[1]	$38.50	$9.02	$12.67	$2.91
Utility Systems Damages and Economic Losses[1]	$134.84	$31.59	$44.39	$10.20
Total Damages and Losses[1]	$1,162.34	$272.34	$382.66	$87.94
Casualties				
Injuries (2 p.m.)	671	157	221	51
Injuries (2 a.m.)	345	81	114	26
Deaths (2 p.m.)	36	8	12	3
Deaths (2 a.m.)	11	3	4	1

[1]Damage and loss estimates in millions of dollars.

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village

The HAZUS results shown in the following three tables are for a crustal earthquake for the nine census tracts that encompass Fairview, Wood Village and Troutdale. The pro-rata damages and economic impacts of the values shown in the following tables are estimated to be about 25% for Fairview, 33% for Troutdale, and 7.5% for Wood Village.

Table 3.1-12 Building Damage by Occupancy for Fairview, Troutdale and Wood Village: M6.26 Crustal Earthquake

Type	None		Slight		Moderate		Extensive		Complete	
	Count	%	Count	%	Count	%	Count	%	Count	%
Agriculture	2	.0.08	2	0.07	4	0.09	3	0.16	2	0.30
Commercial	15	0.58	19	0.54	52	1.23	59	2.93	53	6.47
Education	1	0.05	1	0.03	2	0.06	2	0.12	2	0.23
Government	3	0.11	1	0.03	2	0.06	2	0.12	2	0.26
Industrial	6	0.24	7	0.19	20	0.48	26	1.29	23	2.77
Other Residential	234	9.26	340	9.57	677	15.89	732	36.09	455	58.81
Religion	2	0.10	3	0.05	5	0.12	5	0.24	4	0.47
Single-Family	2,263	89.58	3,177	89.48	3,495	82.06	1,198	59.05	253	30.59
Total	2,528		3,550		4,258		2,028		824	

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village.

Table 3.1-13 Building Damage by Building Type for Fairview, Troutdale and Wood Village: M6.26 Crustal Earthquake

Type	None		Slight		Moderate		Extensive		Complete	
	Count	%	Count	%	Count	%	Count	%	Count	%
Wood	2,323	91.98	3,308	93.18	3,646	85.63	1,226	60.91	239	29.00
Steel	8	0.30	6	0.16	22	0.52	47	1.83	37	4.46
Concrete	8	0.32	9	0.26	26	0.61	31	1.55	22	2.71
Precast	4	0.18	4	0.11	15	0.35	24	1.17	23	2.74
Reinforced Masonry	1	0.04	1	0.02	2	0.05	3	0.16	2	0.29
Unreinforced Masonry	20	0.81	26	0.74	58	1.36	62	3.03	69	8.42
MH	161	6.37	197	5.54	489	11.49	636	31.34	431	52.37
Total	2,526		3,550		4,258		2,028		824	

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village.

Table 3.1-14 Building Related Economic Losses for Fairview, Troutdale and Wood Village: M6.26 Crustal Earthquake

Category and Area	Single-Family	Other Residential	Commercial	Industrial	Others	Total
Income Losses						
Wage	0	3.66	23.31	2.67	1.24	30.88
Capital Related	0	1.54	19.29	1.63	0.45	22.92
Rental	9.11	11.53	11.86	1.27	0.70	34.47
Relocation	33.97	10.99	18.21	3.99	6.05	73.21
Subtotal	43.08	27.72	72.67	9.56	8.45	161.48
Capital Stock Losses						
Structural	59.32	20.56	35.55	16.45	9.08	140.97
Non Structural	241.08	94.02	92.99	58.42	21.85	508.36
Content	58.71	19.43	42.77	38.48	10.25	169.63
Inventory	0	0	1.90	6.51	0.33	8.74
Subtotal	359.12	134.01	173.21	119.86	41.51	827.71
Total	402.20	161.73	245.88	129.42	49.96	989.18

Source: HAZUS for 2010 NHMPs for the Cities of Fairview, Troutdale and Wood Village.

Overall, for Fairview, Troutdale and Wood Village, the HAZUS loss estimate for a M6.25 crustal earthquake near these cities suggests much higher damages, losses and casualties than with the further away 9.0 Cascadia Subduction Zone scenario. The losses are higher for a smaller crustal earthquake because the epicenter is much closer to Fairview, Troutdale and Wood Village, and thus the earthquake ground motions are much higher. As stated above, impacts from a crustal event will be more localized, while a Cascadia Subduction Zone event will have massive impacts across the Pacific Northwest region.

The HAZUS results suggest the following for each jurisdiction:

- **Fairview:** about $270 million in damages and losses; about 80 to 160 injuries; and approximately 3 to 8 deaths
- **Troutdale:** about $380 million in damages and losses; about 100 to 200 injuries; and roughly 4 to 12 deaths
- **Wood Village:** about $90 million in damages and losses; several dozen injuries; and a very small number of deaths

In addition to building damages, there would be significant damages to transportation and utility systems. HAZUS includes rough estimates of expected utility outages. However, as noted for Cascadia Subduction Zone earthquakes, especially for areas as small as Fairview, Troutdale and Wood Village, estimating the specific levels of utility damages and outages with any confidence would require much more detailed analysis of the specific inventory characteristics of utility systems in Fairview, Troutdale and Wood Village. However, as would be the case for building damages, damages and outages for utility systems would be much greater for such a nearby crustal earthquake than for a Cascadia Subduction Zone earthquake.

Liquefaction, Settlement and Lateral Spreading Impacts

Even a few inches of settlement or lateral spreading may cause significant damage to affected buildings or infrastructure. Areas with liquefaction vulnerability are shown in **Figure 3.1-6**, including parts of Troutdale and Wood Village, Sauvie Island, and areas along the Columbia River east of Troutdale, the Sandy River and several streams.

Structures in wetland, estuarine, alluvial and other saturated areas may be subject to liquefaction damage. The total area of such impacts will vary with the extent of saturated soils at the time of the event. Bridge approaches, low-lying roadways, and transportation fuel supplies are all at risk. Columbia and Multnomah counties are the most vulnerable counties in Oregon to water related effects, particularly liquefaction (DLCD, 2015).

Seismic Lifelines

In 2012, the Oregon Department of Transportation (ODOT) conducted the Oregon Seismic Lifeline Routes (OSLR) identification project. Seismic lifelines — state highways identified as most able to serve response and rescue operations, reaching the most people and best supporting economic recovery — were identified. According to ODOT, projected transportation impacts from a seismic event on the Portland metro area, including Multnomah County, involve:

- the potential loss of stored fuels and distribution infrastructure
- interruption of services at Portland International Airport
- interruption of intermodal freight capacity due to river channel changes
- damage to onshore facilities and surface transportation facilities
- bridge or bridge approach failures across both the Willamette and Columbia rivers

Oregon Resilience Plan

The Oregon Seismic Safety Policy Advisory Commission (OSSPAC) developed a report in 2013 titled *The Oregon Resilience Plan: Reducing Risk and Improving Recovery for the Next Cascadia Earthquake and Tsunami (ORP*) that was commissioned by a legislative resolution. In the ORP are estimated impacts of an M9.0 Cascadia Subduction Zone earthquake on Oregon's population, buildings and infrastructure.

Communities within the Willamette Valley are projected to experience moderate widespread damage. The focus will be on restoring services quickly to restart the economy. Restoration of services, as shown in **Table 3.1-15**, typically takes several months, and in some cases a year or more. These results are particularly sobering in the face of the report's finding that where services are not restored within two to four weeks, businesses will either fail or leave (OSSPAC, 2013).

> *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.*
>
> *– Oregon Resilience Plan, 2013*

Table 3.1-15 Estimated Times for Restoration of Services after a Cascadia Subduction Zone Earthquake

Critical Service	Zone	Estimated Time to Restore Service
Electricity	Valley	1 to 3 months
Police and Fire Stations	Valley	2 to 4 months
Drinking Water and Sewer	Valley	1 month to 1 year
Top-priority Highways (partial restoration)	Valley	6 to 12 months
Health Care Facilities	Valley	18 months

Source: Oregon Resilience Plan, OSSPAC 2013

The City of Gresham is following recommendations for water systems that are outlined in the ORP. Gresham is developing a Water System Resilience Plan for appropriately investing in its water system to withstand and continue service after a catastrophic earthquake. Gresham's Water System Resilience Plan will inform the next update of this plan.

Critical Energy Infrastructure Hub

The six-mile stretch along the Willamette River in Portland's Northwest Industrial Area known as the Critical Energy Infrastructure (CEI) Hub contains the majority of Oregon's energy infrastructure for petroleum, natural gas, liquefied natural gas, and electricity. A 2013 DOGAMI study, *Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub* (DOGAMI Open-File Report O-13-09), determined significant liquefaction and seismic risks exist within the CEI Hub. For more information about the CEI Hub, see the **Community Profile** section **2.6.2 Energy** and the **Annex: Human-Caused and Technological Hazard Identification and Risk Assessment** section **7 Utility Interruption/Failure.**

Concurrent to the update of this plan, the City of Portland conducted a study to assess the CEI Hub's exposure and vulnerability to each of Portland's key hazards of concern. The study identified nine recommendations to improve resilience of the critical infrastructure in the CEI Hub, including (City of Portland, 2016):

1. Establish a CEI Hub Disaster Resiliency Workgroup
2. Update/Enhance the CEI Hub Risk Assessment
3. Amend City of Portland City Council Resolution No. 37168 to allow for the expansion of an existing facility that has been identified as vulnerable to an identified hazard of concern and targeted for retrofit
4. Identify best practices for emergency response/recovery waivers from federal and state regulatory agencies to improve ease of response and recovery efforts, with adequate assurances for environmental protection
5. Establish a suite of best management practices for a range of resilience-related planning efforts
6. Identify backup power needs
7. Develop a CEI Hub-specific training and exercise program through Portland Bureau of Emergency Management
8. Identify a buffer zone around the CEI Hub and identify land use repurposes within that buffer

A report summarizing this study is provided in the draft Portland Mitigation Action Plan (MAP), and the recommendations have been incorporated as appropriate into the MAP action plan. The Portland MAP is currently in public review and will be presented to the Portland City Council for adoption in October 2016.

The CEI Hub has major implications for the Planning Area, the state and the Pacific Northwest region. As such, the Multnomah County Multi-Jurisdictional Steering Committee will stay informed of Portland's progress on these recommendations and will support these efforts as appropriate for each jurisdiction.

Bridge Seismic Resiliency

Many of the bridges carry critical services, including water distribution pipes, telecommunications and electrical lines across the rivers. If bridges are damaged, these lines could break and disrupt service to parts of the cities and unincorporated areas. As mentioned in the **Community Profile** section **2.5.2 Bridges**, Multnomah County's Willamette River Bridges Capital Improvement Plan prioritizes a 20-year Bridge Seismic Resiliency Plan for the four movable bridges in downtown Portland: the Broadway, Burnside, Hawthorne and Morrison bridges. More information on the risk to bridges as critical infrastructure is in the **Annex: Human-Caused and Technological Hazard Identification and Risk Assessment.**

3.1.5 References

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