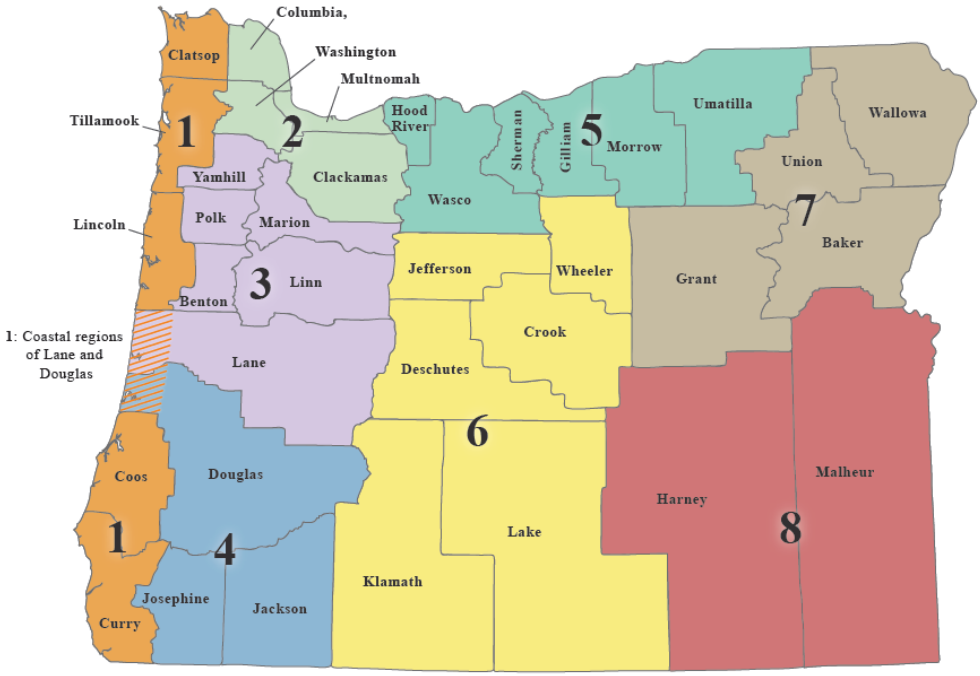
2.3 Regional Risk Assessments

The purpose of the Regional Risk Assessment is to assess risks at a regional scale by profiling the characteristics, natural hazards, and vulnerabilities within the eight Oregon NHMP Natural Hazard Regions (Figure 2-115). Each region has its own Risk Assessment. Together, the eight Regional Risk Assessments combine to describe the State's overall risk to natural hazards.

Figure 2-115. Oregon NHMP Natural Hazards Regions



Each Regional Risk Assessment includes three sections:

1. The **Summary** provides a general overview of (a) the Regional Profile, (b) the Regional Hazards and Vulnerability, and (c) how climate change models predict hazards in the region will be impacted based on statewide data.
2. The **Profile** section provides an overview of the region's unique characteristics including profiles of the natural environment, social and demographic situation, economic environment, infrastructure, and built environment.

   The research of Susan Cutter, Professor of Geography at the University of South Carolina, Columbia, on vulnerability and environmental hazards provides the framework for discussion of vulnerability in the Regional Profile section. Cutter's framework helps to illustrate the geographic variability of vulnerability and allows policy makers to better understand how to

prepare for, mitigate, and reduce vulnerability (Cutter, Boruff, & Shirley, 2003); (Cutter S. L., 2006).

Margin of Error (MOE)

The sociodemographic data in the regional profiles are primarily sourced from the U.S. Census Bureau's American Community Survey (ACS). The ACS's estimates are subject to sampling and nonsampling errors. Nonsampling errors are the product of survey design and measurement flaws, "while sampling error is when the characteristics of the survey group vary from those of the larger population of interest...causing the true value to fall within a range bounded by a margin of error" (Quinterno, 2014).

Through adding and subtracting the MOE from the estimate, users can calculate the 90% confidence interval for that estimate (U.S. Census Bureau, 2018). For example, in **Table 2-81. People with a Disability by Age Group in Region 1**, data from the 2017 ACS 5-year estimates indicate that 19.1% of all people in Clatsop County have a disability with a MOE of 1.4%. Through adding and subtracting the MOE from the estimate, the user can calculate the 90% confidence interval for that estimate (U.S. Census Bureau, 2018). Doing so indicates that we can be 90 percent confident that the true share of residents in Clatsop County with a disability in the 2013-2017 period falls between 17.7% and 20.5%.

Period Estimates

It should also be noted that the ACS estimates in the plan are period estimates, rather than point-in-time or cumulative counts. “A period estimate shows the average value of the variable over a specific reference period” (Quinterno, 2014). The ACS uses period estimates “to compensate for the fact [that] the sampling frame includes too few households to yield reliable annual estimates for small geographies and small population subgroups” (Quinterno, 2014). If the value presented in a table is a period estimate, the period is noted in the table’s source data.

Coefficient of Variation (CV)

In addition to a MOE, many of the estimates in the plan have a coefficient of variation (CV). “The CV is a relative measure of uncertainty and expresses uncertainty as a percentage of the census estimate” (Jurjevich, et al., 2018). Generally, the lower the CV, the more reliable the data. According to the U.S. Census Bureau, there are “no hard-and-fast rules for determining an acceptable range of error in ACS estimates. Instead, data users must evaluate each application to determine the level of precision that is needed for an ACS estimate to be useful” (U.S. Census Bureau, 2018). This plan adopts CV ranges and data reporting methods recommended by the Population Research Center at Portland State University (Jurjevich, et al., 2018).

Icons are used to indicate the reliability of each estimate using the CV. High reliability (CV <15%) is shown with a green check mark, medium reliability (CV 15–30% — be careful) is shown with a yellow exclamation point, and low reliability (CV >30% — use with extreme caution) is shown with a red cross. However, as mentioned above, there are no precise rules and users should consider the MOE and their need for precision (Jurjevich, et al., 2018).

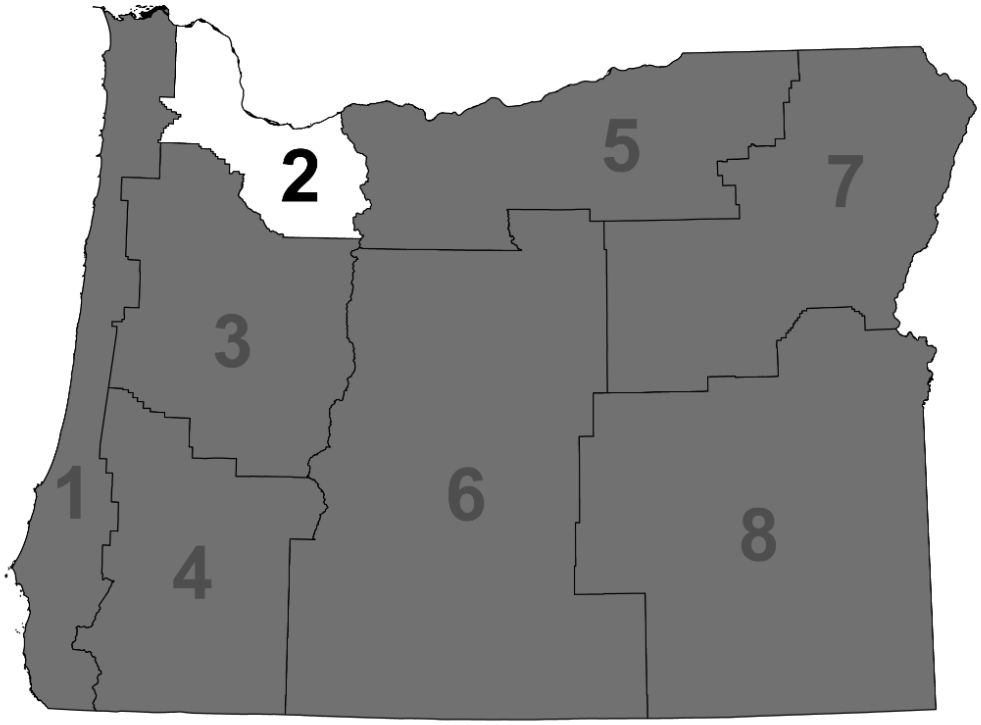
3. The **Hazards and Vulnerability** section first identifies each hazard and its characteristics in the region. Then, the historical events that have impacted the region are listed. Lastly, probabilities and vulnerabilities are discussed as identified by local and state risk assessments. Vulnerabilities

to and potential impacts from each hazard in the region are described including the identification and analysis of the region's State owned/leased facilities and critical/essential facilities located within hazard zones and seismic lifeline vulnerabilities.

Regional Risk Assessments add to the current body of literature and technical resource guides available to Oregon communities. The three levels of government — federal, state, and local — will find the Regional Risk Assessments useful when assessing natural hazards and vulnerabilities and when planning mitigation activities. Local governments can use the Regional Risk Assessments in the development of their jurisdiction's natural hazards mitigation plan. Information from these assessments is intended to be used as a springboard for more detailed community profiles. Likewise, information from local plans helps to inform the Oregon NHMP risk assessment overall.

2.3.2 Region 2: Northern Willamette Valley / Portland Metro

Clackamas, Columbia, Multnomah, and Washington Counties



2.3.2.1 Summary

Profile

The region's demographic, economic, infrastructure, and development patterns indicate that some populations, structures, and places may be more vulnerable to certain natural hazards than others. Mitigation efforts directed at these vulnerabilities may help boost the area's ability to bounce back after a natural disaster.

Regionally, social vulnerability is driven by a high number of tourists who are likely not familiar with the hazard types and level of risk in the region. At the county level, high numbers of disabled persons in Multnomah County; a dramatic increase in the homeless population in Clackamas County; and higher numbers of renters and of persons who do not speak English "very well" in Multnomah and Washington Counties increase the level of risk to these populations. Columbia County's low incomes and high poverty rates make it especially vulnerable to heightened economic hardship that often follows a hazard event.

Compared to other areas of the state, communities around the Portland Metro area weathered the financial crisis that began in 2007 due to the diversity of key industries, employment sectors, and higher wages than the state average. The region's resilience is bolstered by strong Professional and Business Services, Health and Social Assistance, and Government sectors, which have low vulnerability to natural disasters and are key to post-disaster recovery efforts. Columbia County's economy is struggling the most, with higher unemployment and lower wages. However, the impacts of the novel coronavirus pandemic of 2020 on Multnomah and Washington Counties is among the greatest in the State. This is due to the population density and other demographics: the large percentage of population 65 years of age and older with a disability in both counties, and the large homeless population in Multnomah County.

Transportation networks across the state are vulnerable to natural hazard events, especially seismic events. Following a Cascadia earthquake event, access across the Willamette River and along I-5 may be limited due to bridge collapse. The region has two ports with facilities, including the Portland International Airport, that are key to the statewide economy and are vulnerable to disruptions in service that can impact the transport of people, goods, and emergency services.

Older centralized water infrastructure is vulnerable to earthquakes, landslides, flooding, and pollution. Upstream pollution in the Willamette and Columbia Rivers threaten ecosystems and public health.

Eight power-generating facilities and many dams — including Bonneville Power Administration's main dam, the Bonneville Dam — are in this region. Additionally, the site of Oregon's Critical Energy Infrastructure Hub, located in Portland, is subject to seismically induced liquefaction, making it exceptionally vulnerable to a Cascadia earthquake. Disruption or failure to these systems could be devastating to the region and state.

Region 2 is developing at a slightly faster pace than the rest of the state. The majority of growth is occurring in urban areas surrounding Portland. Over half the homes in Multnomah County were built prior to current seismic and floodplain management standards, making them particularly vulnerable to seismic and flood events.

Hazards and Vulnerability

Region 2 is affected by nine of the 11 natural hazards that affect Oregon communities. Coastal hazards and tsunamis do not directly impact this region.

Droughts: The region is affected by droughts to a lesser extent than other areas in the state. Moderate-type drought years have occurred in Region 2 more than a dozen times between 1939 and 2001.

Earthquakes: Four types of earthquakes affect Region 2 (a) shallow crustal events, (b) deep intra-plate events within the subducting Juan de Fuca plate, (c) the offshore Cascadia Subduction Zone (CSZ) Fault, and (d) earthquakes associated with renewed volcanic activity. The CSZ is the chief earthquake hazard for the Northern Willamette Valley. The region is particularly vulnerable to earthquakes due to the amount of area that is susceptible to earthquake-induced landslide, liquefaction, and ground shaking. Region 2 is home to the majority of the state's population, employment, and built environment. A CSZ event will dramatically impact the region's critical infrastructure, including seismic lifelines along Interstate-5 and Oregon's Critical Energy Hub in North Portland. In Region 2, a CSZ event could cause a potential loss of almost $167M in state building and critical facility assets. Columbia County's potential loss is the least, over $1.6M. The other counties' potential losses range from $42.6M to $67.3M with the greatest potential loss in Multnomah County. There is a far greater potential loss in local critical facilities: over $2.1B. Washington County stands to lose the most, about 46% of that total, followed by Multnomah County with about 36% and Clackamas County with about 17%. Again Columbia County's potential loss is the least, at 3%.

Extreme Heat: Climate conditions in the Willamette Valley are described as Mediterranean, with rainy winters and warm dry summers. Historically, extreme heat and heat waves have not been common, but days above 90°F occur nearly every year. Portland has an average of about 10 days per year above 90°F. The frequency of prolonged periods of high temperatures is expected to increase. Because extreme heat is relatively rare in Region 2, many people may not be accustomed or prepared when an extreme heat event occurs. Similar to drought, prolonged elevated temperatures pose risks to agriculture, involving health and welfare to farmers, farm workers, crops and livestock.

Some livestock, especially dairy cattle, are sensitive to heat. Milk production decreases and susceptibility to death increases during and for some time after a heat wave. Since risks to human health and welfare are also elevated during heat waves, Oregon and the federal government have regulations and guidelines to help prevent injury to those who work on farms. Impacts of extreme heat on state-owned facilities related to agriculture may include impacts to research conducted in outdoor settings, such as at extension stations and research farms. The value of state-owned and leased buildings and critical facilities in Region 2 is approximately $1,134,896,000 representing the total potential for loss of state assets due to drought. The value of locally owned critical facilities is $10,224,815,000.

Floods: All counties in the Northern Willamette Valley are affected by riverine flooding. Rain-on-snow events and heavy rain events leading to tributary backups are common in this region. Clackamas and Columbia Counties are most vulnerable to flooding events. Following floods in 1996 and 2007, elevation and acquisition projects initiated by the City of Vernonia helped reduce flood risk in Columbia County. In Region 2, there is a potential loss from flooding of over

$142M in state building and critical facility assets, 95% of it in Multnomah County alone. There is a far greater potential loss due to flood in local critical facilities: close to $484M, almost three-and-a-half times as much. Again the vast majority, 86%, is located in Multnomah County.

Landslides: Landslides can occur throughout the region, though more tend to occur in areas with steeper slopes, weaker geology, and higher annual precipitation. Rain-induced landslides can occur during winter months, and earthquakes can trigger landslides. Vulnerability is increased in populated areas such as the Portland Metro Area and in the Coast and Cascade Mountain Ranges. In general, the counties of Washington, Multnomah, and Clackamas have relatively high vulnerability. Over $25M in value of state facilities is exposed to landslide hazards in Region 2, 32% of it in in Multnomah County with the other counties containing between 21% and 24%. However, the potential loss to local critical facilities is much greater at over $145M. Columbia and Multnomah Counties stand to suffer the greatest losses, $55.7M (38%) and $49.7M (34%), respectively.

Volcanoes: The region can be impacted by volcanic activity, particularly within parts of eastern Clackamas and Multnomah Counties (including Portland) that coincide with the crest of the Cascade Mountain Range. Most volcanic activity is considered local. However, some activity, such as lahars and ashfall, can travel many miles and could impact the communities of Government Camp, Rhododendron, and Welches. Over $26M in value is exposed to volcanic hazards in Region 2, all of it in Clackamas County.

Wildfires: The region's vulnerability to wildfire is moderate at best. Wildfires are most common during the late summer. The areas of greatest vulnerability are within the wildland-urban interface communities. Much of the risk to wildfire in Region 2 is mitigated by large expanses of urban development and quick response times. In Region 2, there is a potential loss to wildfire of close to $16M in state building and critical facility assets, about two-thirds of it in Multnomah County and about one-third in Clackamas County. There is a much smaller potential loss in local critical facilities: about $6M, approximately one-third as much. Neither Columbia County nor Washington County has state assets or local critical facilities located in a wildfire hazard area.

Windstorms: Windstorms affect the region annually. The most frequent and strongest originate in the Pacific Ocean and travel in a northeasterly direction. Columbia, Multnomah, and Washington Counties are most vulnerable to these types of storms. To a lesser degree, east winds traveling through the Columbia River Gorge also affect Region 2 communities. Windstorms can impact the region's buildings, utilities, tree-lined roads, transmission lines, residential parcels, and transportation systems along open areas such as grasslands and farmland.

Winter Storms: Winter storms occur annually. The Columbia River Gorge can bring colder weather, higher precipitation, and high east winds to the region causing severe weather for short periods of time. Because these storms are infrequent and short lived, communities including the Portland Metro Area are often unprepared for them.

Climate Change

The hazards faced by Region 2 that are projected to be influenced by climate change include drought, wildfire, flooding, landslides, and extreme heat.

Climate models project warmer, drier summers for Oregon. Coupled with projected decreases in mountain snowpack due to warmer winter temperatures, Region 2 is expected to be affected by an increased incidence of drought and wildfire. In Region 2, climate change would result in increased frequency of drought due to low spring snowpack (*very likely*, >90%), low summer runoff (*likely*, >66%), and low summer precipitation and low summer soil moisture (*more likely than not*, >50%). It is *very likely* (>90%) that Region 2 will experience increasing wildfire frequency and intensity due to warmer, drier summers coupled with warmer winters that facilitate greater cold-season growth.

It is *extremely likely* (>95%) that the frequency and severity of extreme heat events will increase over the next several decades across Oregon due to human-induced climate warming (*very high confidence*).

Furthermore, flooding and landslides are projected to occur more frequently throughout western Oregon. It is *very likely* (>90%) that Oregon will experience an increase in the frequency of extreme precipitation events and extreme river flows (*high confidence*) that is *more likely than not* (>50%) to lead to an increase in the incidence and magnitude of damaging floods (*low confidence*). Because landslide risk depends on a variety of site-specific factors, it is *more likely than not* (>50%) that climate change, through increasing frequency of extreme precipitation events, will result in increased frequency of landslides.

While winter storms and windstorms affect Region 2, there is little research on how climate change influences these hazards in the Pacific Northwest. For more information on climate drivers and the projected impacts of climate change in Oregon, see Section **2.1.4**, **Introduction to Climate Change**.

2.3.2.2 Profile

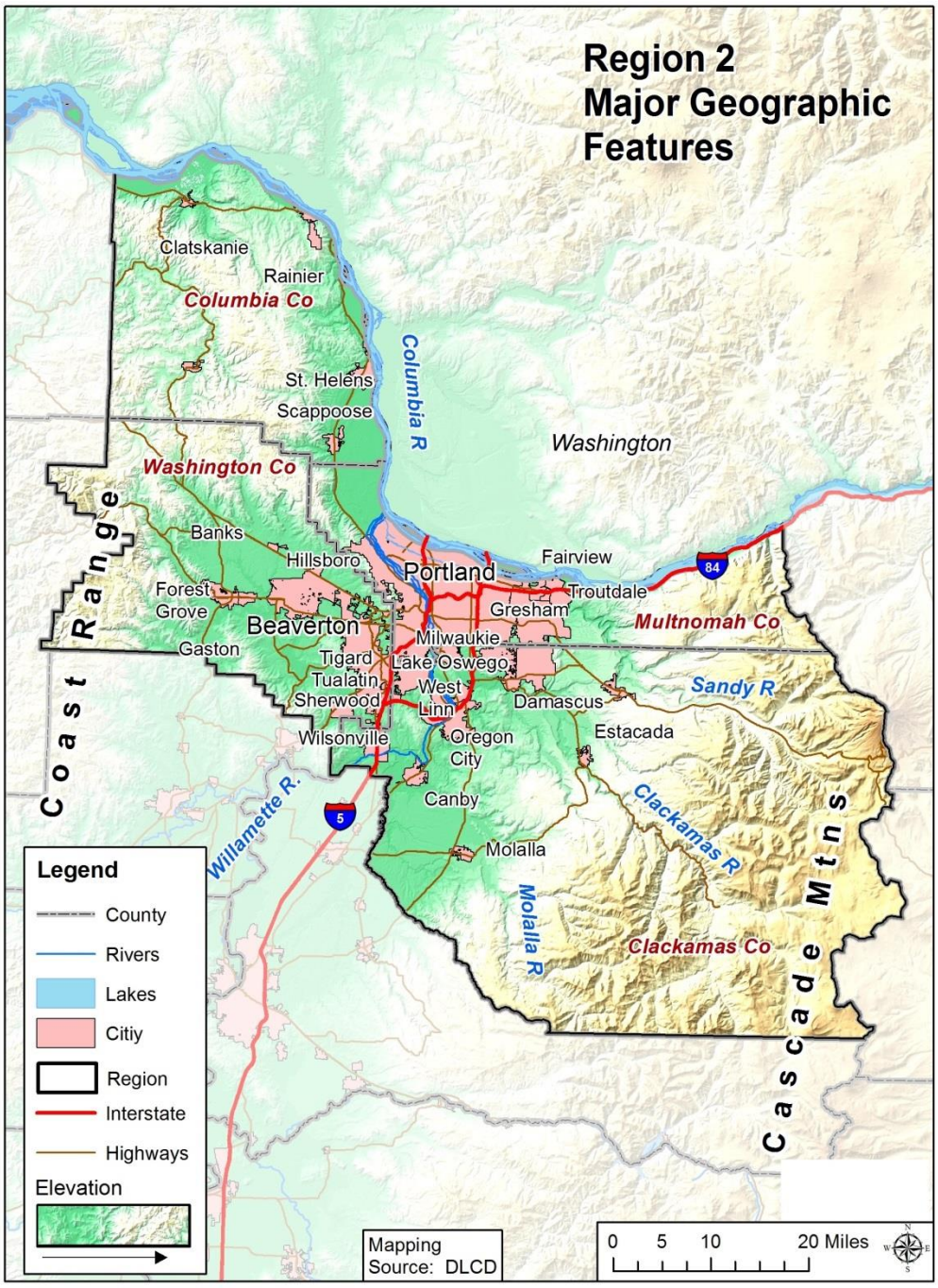
Requirement: 44 CFR §201.4(d): The Plan must be reviewed and revised to reflect changes in development…

Natural Environment

Geography

The Northern Willamette Valley and Portland Metro Area is approximately 3,758 square miles in size, and includes Clackamas, Columbia, Multnomah, and Washington Counties. Mountain ranges and watersheds shape the region's topography. Region 2 begins at the Cascade Mountain Range in the east and extends westward through the Willamette Valley and into the Coast Range and southward from the Columbia River in the North to the Mid-Willamette Valley. Two rivers shape the region's main watersheds, the Columbia River and the Willamette River. **Figure 2-143** shows the dominant mountain ranges, major watersheds, and political boundaries of Region 2.

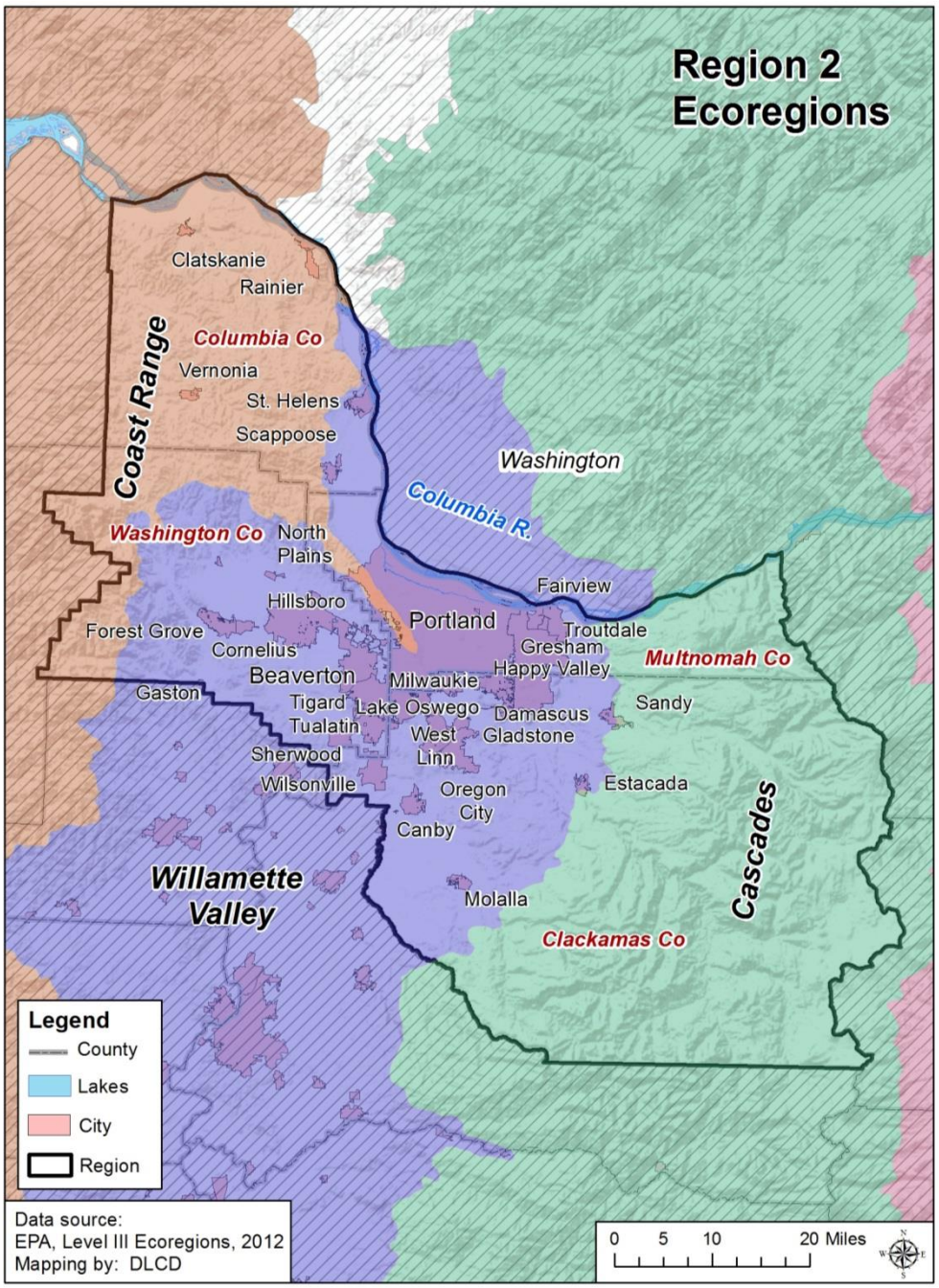
Figure 2-143. Region 2 Major Geographic Features



Source: Department of Land Conservation and Development, 2014

The U.S. EPA's ecoregions are used to describe areas of ecosystem similarity. Region 2 is composed of three ecoregions: the Coast Range, the Willamette Valley, and the Cascades (**Figure 2-144**).

Figure 2-144. Region 2 Ecoregions



Cascades: Soil in this ecoregion is volcanic. Mixed conifer forests have given way to predominantly Douglas fir forests that are managed for commercial logging. Logging activities have put a strain on the ecological health of streams in the area (Thorson, et al., 2003). Waterways in the steeper valleys support threatened cold-water salmonids including Chinook salmon, steelhead, and bull trout. Streams, lakes, reservoirs, rivers, and glacial lakes at higher elevations are key sources of water (Thorson, et al., 2003).

Willamette Valley: Terraces and floodplains dominate the nearly flat central Willamette Valley. The valley floor is dotted with scattered hills, buttes, and bordered by the adjacent foothills. Historically, valley waterways meandered throughout floodplains on the nearly flat valley floor, contributing to the valley's highly fertile soil and supporting the dominance of oak savannah and prairie ecosystems. Today the Willamette River and its tributaries are highly channelized, restricting the flow of these waterways, helping protect property but also threatening stream health. The productive soils and temperate climate make this ecoregion one of the most important agricultural areas in Oregon. The valley's flat terraces have made urban and suburban development possible in the valley (Thorson, et al., 2003).

Coast Range: The east slope of the Coast Range is located within Region 2. Soils are a mix of sedimentary and volcanic composition. Sedimentary soils can create more concerns for stream sedimentation than areas with volcanic soils (Thorson, et al., 2003). Volcanic soils are underlain by basaltic rocks resulting in more consistent summer stream flows. This soil composition supports runs of spring Chinook salmon and summer steelhead. On the other hand, sedimentary soils are prone to failure following clear cuts. This may be of concern as the commercial Douglas fir forests are highly productive commercial logging areas.

Climate

This section covers historic climate information only. For estimated future climate conditions and possible impacts refer to the **State Risk Assessment**.

The Willamette Valley's mild climate, long growing season, and abundant moisture supports the most diversified agriculture in the state. Precipitation generally occurs in the winter months, falling mostly as rain in the valley, but building snowpack in the mid-elevations of the Cascade foothills. The region's wet winters can lead to flood, landslide, and winter storm risks while dry summers can lead to drought and wildfire risks. Localized variations in temperature and precipitation exist across the region's microclimates. **Table 2-184** displays 1981–2010 average precipitation and temperature for counties and climate divisions within Region 2 based on data from the NOAA National Centers for Environmental Information.

Table 2-184. Average Precipitation and Temperature in Region 2 Counties and Climate Divisions

Sub-Region	Annual Precipitation Mean & Range (1981–2010)	January & July Mean Precipitation (1981–2010)	Annual Mean Temperature (1981–2010)	January & July Average Min/Max Temperature (1981–2010)
Clackamas County	74.96" (56.54"–117.92")	Jan: 10.55" Jul: 1.03"	48.4°F	Jan: 31.3°F /42.3°F Jul: 50.7°F /75.3°F
Columbia County	56.42" (37.79"–82.72")	Jan: 8.41" Jul: 0.73"	50.6°F	Jan: 33.9°F /45.0°F Jul: 51.8°F /76.1°F
Multnomah County	62.81" (44.69"–96.98")	Jan: 8.96" Jul: 0.9"	51.4°F	Jan: 34.2°F /44.6°F Jul: 53.6°F /77.9°F
Washington County	55.66" (35.53"–89.01")	Jan: 8.63" Jul: 0.6"	51.0°F	Jan: 34.2°F /44.8°F Jul: 52.4°F /77.2°F
Climate Division 2 "Willamette Valley"	58.11" (39.98"–92.22")	Jan: 8.35" Jul: 0.69"	51.5°F	Jan: 34.6°F /45.9°F Jul: 52.2°F /78.6°F
Climate Division 4 "Northern Cascades"	80.7" (59.67"–127.71")	Jan: 11.41" Jul: 1.05"	45.7°F	Jan: 28.5°F/39.8°F Jul: 48.2°F/74.2°F

Source: NOAA National Centers for Environmental Information, Climate at a Glance: County & Divisional Time Series, published August 2019, retrieved on August 15, 2019 from https://www.ncdc.noaa.gov/cag/.

Demography

Population

Population forecasts are an indicator of future development needs and trends. Community demographics may indicate where specific vulnerabilities may be present in the aftermath of a natural hazard (Cutter, Boruff, & Shirley, 2003). Population change includes two major components: natural increase (births minus deaths) and net migration (in-migrants minus out-migrants) (USDA, 2020). If a population is forecast to increase substantially, a community's capacity to provide adequate housing stock, services, or resources for all populations after a disaster may be stressed or compromised.

Between 2010 and 2018, the region grew more quickly than the state as a whole. Washington County grew most quickly—approximately two and a half percentage points above the statewide rate; growth occurred through both natural increase (the ratio of births to deaths) and net in-migration, with natural-increase contributing more than in-migration (Population Research Center, Portland State University, 2017). Conversely, the primary driver of growth in Clackamas County was in-migration (Population Research Center, Portland State University, 2017).. Over the next decade, Washington and Clackamas Counties are expected to experience the most significant gains, and all counties, except for Multnomah, are expected to experience faster growth than the state as a whole.

Table 2-185. Population Estimate and Forecast for Region 2

	2010	2018	Percent Change (2010 to 2018)	2030 Projected	Percent Change (2018 to 2030)
Oregon	3,831,074	4,195,300	9.5%	4,694,000	11.9%
Region 2	1,690,387	1,890,905	11.9%	2,174,128	15.0%
Clackamas	375,992	419,425	11.6%	490,011	16.8%
Columbia	49,351	51,900	5.2%	58,580	12.9%
Multnomah	735,334	813,300	10.6%	906,904	11.5%
Washington	529,710	606,280	14.5%	718,633	18.5%

Population Research Center, Portland State University (2018), Certified Population Estimates; Population Research Center, Portland State University (2019), Current Forecast Summaries for All Areas & Oregon Final Forecast Table by Age (2019); U.S. Census Bureau, 2010 Decennial Census. Table DP-1

Tourists

Tourists are not counted in population statistics and are therefore considered separately in this analysis. Tourism activities in Region 2 are largely centered on special events (such as fairs, festivals or sporting events), city trips, and touring (traveling to experience scenic beauty, history and culture) (Longwoods International, 2017b). Approximately one-third of all overnight trips in Oregon included time in the Portland Region (Longwoods International, 2017b). The average travel party contains approximately three persons and approximately 74% of these trips originate from Oregon, Washington, or California. Multnomah County receives the greatest number of overnight visitors.

Difficulty locating or accounting for travelers increases their vulnerability in the event of a natural disaster. Furthermore, tourists are often unfamiliar with evacuation routes,

communication outlets, or even the type of hazard that may occur (MDC Consultants, n.d.). Targeting natural hazard mitigation outreach efforts to places where tourists lodge can help increase awareness and minimize the vulnerability of this population.

Table 2-186. Annual Visitor Estimates in Person Nights (x1000) in Region 2

	2016		2017		2018	
	Number	Percent	Number	Percent	Number	Percent
Region 2	28,961	—	29,532	—	29,690	—
Clackamas	7,392	100%	7,430	100%	7,383	100%
Hotel/Motel	1,496	20%	1,524	21%	1,473	20%
Private Home	5,275	71%	5,288	71%	5,285	72%
Other	621	8%	618	8%	625	8%
Columbia	665	100%	677	100%	685	100%
Hotel/Motel	50	8%	51	8%	52	8%
Private Home	521	78%	533	79%	539	79%
Other	94	14%	93	14%	94	14%
Multnomah	12,553	100%	12,745	100%	12,945	100%
Hotel/Motel	6,592	53%	6,745	53%	6,879	53%
Private Home	5,489	44%	5,532	43%	5,591	43%
Other	472	4%	468	4%	474	4%
Washington	8,351	100%	8,680	100%	8,677	100%
Hotel/Motel	2,067	25%	2,330	27%	2,377	27%
Private Home	6,123	73%	6,188	71%	6,137	71%
Other	162	2%	162	2%	163	2%

Source: Oregon Travel Impacts: 1992–2018, March 2019. (Dean Runyan Associates, 2019), http://www.deanrunyan.com/doc_library/ORImp.pdf

Persons with Disabilities

Disabilities appear in many forms. While some disabilities may be easily identified, others may be less perceptible. Disabled populations are disproportionately affected during disasters and can be difficult to identify and measure (Cutter, Boruff, & Shirley, 2003).

As a region, a smaller share of the population identifies as having a disability; however, the share in Columbia County is two percentage points more than the statewide estimate. Columbia County also has the largest share of older adults with a disability, although the margin of error should be noted. In the region as a whole, however, disability status is less prevalent among vulnerable age groups, younger people (< 18) and older adults (≥ 65).

Local natural hazard mitigation plans should specifically target outreach programs toward helping disabled residents better prepare for and recover from hazard events. Planning professionals might take a number of steps to mitigate risk for disabled community members. Inaccessible shelter facilities can pose challenges in a disaster event. Local officials should also strengthen partnerships with the disability community, and work with local media organizations to ensure emergency preparedness and response communications are accessible for all.

Table 2-187. People with a Disability by Age Group in Region 2

	With a Disability (Total Population)*			Under 18 Years with a Disability			65 Years and Over with a Disability		
	Estimate	CV**	MOE (+/−)	Estimate	CV**	MOE (+/−)	Estimate	CV**	MOE (+/−)
Oregon	14.6%	☑	0.1%	4.6%	☑	0.2%	37.1%	☑	0.4%
Region 2	12.0%	☑	0.2%	4.0%	☑	0.3%	34.9%	☑	0.6%
Clackamas	11.8%	☑	0.4%	4.0%	☑	0.5%	32.9%	☑	1.2%
Columbia	16.7%	☑	1.3%	4.2%	⊙	1.2%	40.6%	☑	3.6%
Multnomah	13.1%	☑	0.3%	4.4%	☑	0.5%	37.7%	☑	0.9%
Washington	10.2%	☑	0.1%	3.5%	☑	0.4%	32.2%	☑	1.2%

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% - be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% - use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

Source: U.S. Census Bureau (2018). Table DP02: Selected Housing Characteristics, 2013-2017 American Community Survey 5-Year Estimates. Retrieved from https://data.census.gov/cedsci/

Homeless Population

The U.S. Department of Housing and Urban Development requires Continuums of Care to conduct the Point-in-Time Count (PIT), a biennial count of both sheltered and unsheltered people experiencing homelessness. These are rough estimates and can fluctuate with many factors. They should be understood as the absolute minimum number of people experiencing homelessness in the area (Oregon Housing and Community Services, 2019, Nov. 21). Moreover, the PIT does not fully depict the extent of housing insecurity, as it excludes families or individuals that might be staying with friends or family due to economic hardship. The count also obscures the demographic composition of the houseless population, frequently undercounting people of color, for example (Oregon Housing and Community Services, 2019, Nov. 21).

Approximately 25% of people experiencing homelessness in the State of Oregon are concentrated in the Portland Metropolitan Area (Oregon Housing and Community Services, 2019, Nov. 21). According to the PIT, between 2015 and 2019, the region reported a 5% increase in people experiencing homelessness.

People experiencing homelessness are typically more physically and psychologically vulnerable compared to the general population and natural hazard events exacerbate their vulnerability. Disasters that result in damage to the built environment can place additional stress on temporary shelters, a vital service for many people experiencing homelessness (Peacock, Dash, Zhang, & Van Zandt, 2017). Local emergency management professionals should take a trauma-informed approach to providing services and include people with expertise in providing support to people experiencing homelessness in planning for natural hazard events (U.S. Department of Housing and Urban Development, 2016). Additionally, it is important to plan for episodic natural hazards as well as chronic events. For example, year-around access to shelter is becoming increasingly important as wildfire smoke becomes more common across the state.

Table 2-188. Homeless Population Estimate for Region 2

	2015	2017	2019	Period Average
Oregon	13,077	13,953	15,800	14,277
Region 2	5,103	5,376	5,358	5,279
Clackamas	494	497	471	487
Columbia	317	158	342	272
Multnomah	3,801	4,177	4,015	3,998
Washington	491	544	530	522

Source: Oregon Point in Time Homeless Count, Oregon Housing and Community Services.

Biological Sex and Gender

The concepts of sex and gender are often used interchangeably but are distinct; sex is based on biological attributes (chromosomes, anatomy, hormones) and gender is a social construction that may differ across time, cultures, and among people within a culture (U.S. Census Bureau, 2019, Apr. 3). Moreover, the two may or may not correspond (U.S. Census Bureau, 2019, Apr. 3).

The American Community Survey question was specifically designed to capture biological sex and there are no questions on the survey about gender (U.S. Census Bureau, 2019, Apr. 3). According to the survey, there are slightly more women than men in Region 2 (97.8 men for every 100 women) (U.S. Census Bureau, 2019, Mar. 31). This is similar to the statewide ratio.

Primarily empirical research has begun to emerge about the ways in which gender influences resilience to disasters. It indicates that gender influence is much more pervasive and expressed differently among men, women, LGBTQ+, and non-binary populations than has generally been recognized (Enarson, 2017). This is an area deserving of more attention as the field develops.

Age

Older adults comprise a smaller share of the population in Region 2 than they do in the state as a whole. Clackamas County has a similar proportion to the state while the share in Clatsop County is slightly higher. In Multnomah and Washington Counties, there is a smaller share of older adults; however, due to large populations overall the absolute number of older adults is still significant. An older population requires special consideration due to sensitivity to heat and cold, reliance upon transportation to obtain medication, and comparative difficulty in making home modifications that reduce risk to hazards. In addition, older people may be reluctant to leave home in a disaster event. This implies the need for targeted preparatory programming that includes evacuation procedures and shelter locations accessible to elderly (Morrow, 1999).

The region's share of children is similar to the statewide share, with Washington County's share slightly higher and Multnomah County's share slightly lower. Special consideration should be given to young children, schools, and parents during the natural hazard mitigation process. Young children are more vulnerable to heat and cold, have fewer transportation options, and require assistance to access medical facilities. Parents may lose time and money when their children's childcare facilities and schools are impacted by disasters.

Table 2-189. Population by Vulnerable Age Group, in Region 2

	Total Population	Under 18 Years Old			65 Years and Older		
	Estimate	Percent	CV**	% MOE (+/−)	Percent	CV**	% MOE
Oregon	4,025,127	21.5%	☑	0.1%	16.3%	☑	0.1%
Region 2	1,810,699	21.6%	☑	0.0%	13.3%	☑	0.0%
Clackamas	399,962	22.1%	☑	*	16.5%	☑	0.1%
Columbia	50,207	22.0%	☑	0.1%	17.5%	☑	0.3%
Multnomah	788,459	19.6%	☑	*	12.3%	☑	0.1%
Washington	572,071	24.0%	☑	*	12.1%	☑	0.1%

*Indicates that the estimate has been controlled to be equal to a fixed value and so it has no sampling error.

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% – be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% - use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

Source: U.S. Census Bureau, 20013–2017 American Community Survey 5-Year Estimates, Table DP05

Language

Special consideration in hazard mitigation should be given to populations who do not speak English as their primary language. These populations can be harder to reach with outreach materials. They are less likely to be prepared if special attention is not given to language and culturally appropriate outreach techniques. In the region, Multnomah and Washington Counties have the highest percentages of residents who do not speak English very well. Estimates for Clatsop County should be used with caution due to the sampling techniques used in the American Community Survey. Communities creating outreach materials used to communicate with and plan for populations who do not speak English very well should take into consideration the language needs of these populations.

Table 2-190. English Usage in Region 2

	Speak English Less Than "Very Well"				
	Estimate	CV**	MOE (+/−)	Percent	% MOE (+/−)
Oregon	222,428	☑	4,116	5.9%	0.1
Region 2	128,038	☑	3,115	7.5%	0.2
Clackamas	15,780	☑	1,006	4.2%	0.3
Columbia	671	⊙	224	1.4%	0.5
Multnomah	62,863	☑	2,112	8.5%	0.3
Washington	48,724	☑	2,044	9.1%	0.4

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% – be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% – use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

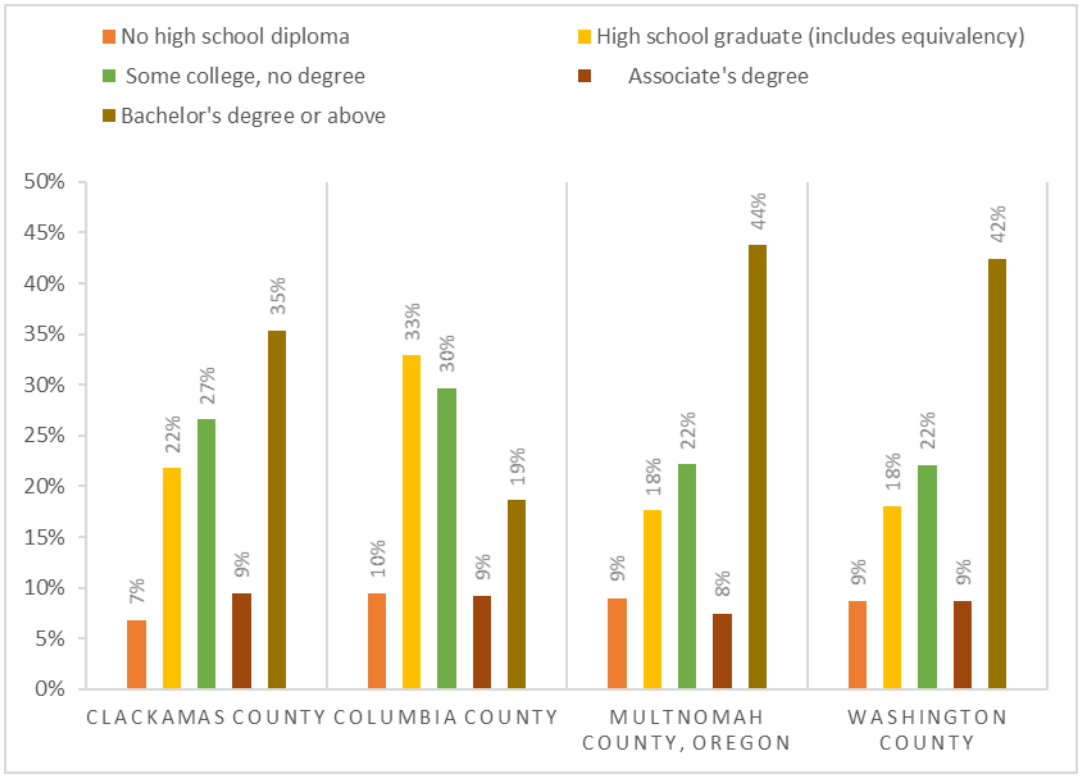
Source: U.S. Census Bureau, 20013–2017 American Community Survey 5-Year Estimates, Table DP02

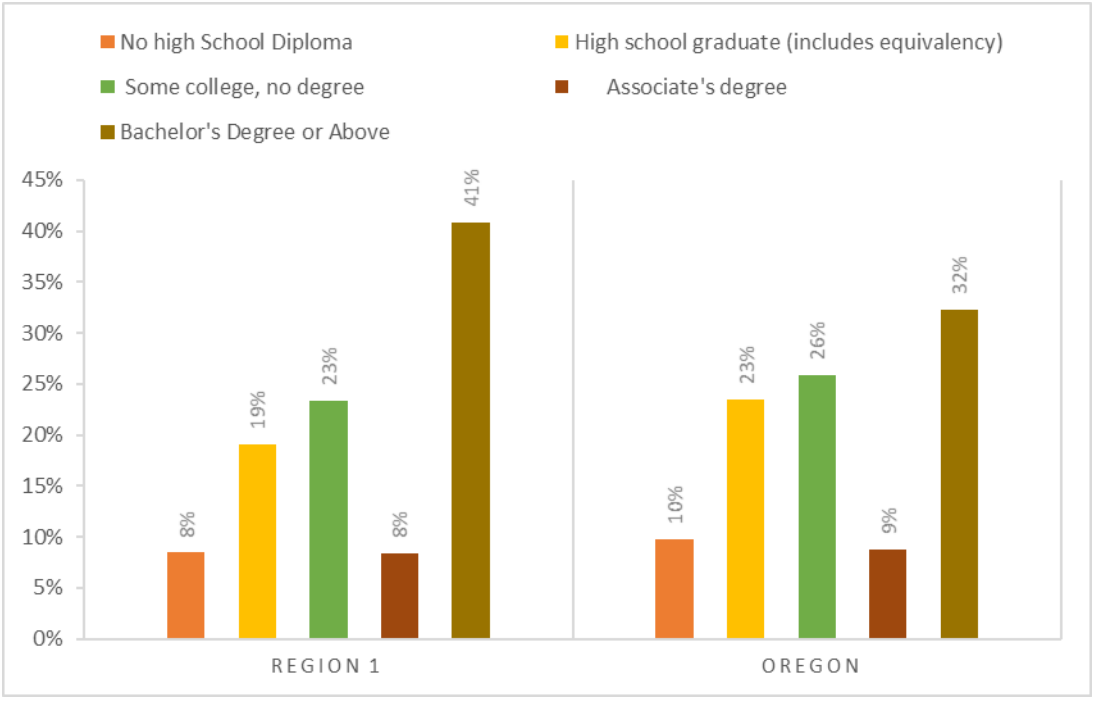
Education Level

Studies show that education and socioeconomic status are deeply intertwined, with higher educational attainment correlating to increased lifetime earnings (Cutter, Boruff, & Shirley, 2003). Furthermore, education can influence an individual's ability to understand and act on warning information, navigate bureaucratic systems, and to access resources before and after a natural disaster (Masozera, Bailey, & Kerchner, 2007).

There is a higher percentage of bachelor's and graduate or professional degrees in the Northern Willamette Valley and Portland Metro Area compared to statewide numbers. Multnomah and Washington County have similar levels of educational attainment. Over 40% of residents in both counties hold a bachelor's degree or higher. Conversely, the share of residents with a four-year degree or more in Columbia County is nearly half that, but approximately 30% of the county's residents have some college credit. The levels of attainment within Clackamas County are similar to the statewide levels, with approximately 35% holding a bachelor's degree or more.

Figure 2-145. Educational Attainment in Region 2: (top) by County, (bottom) Regional vs. Statewide





Source: U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates, Table DP02

Income and Poverty

The impact of a disaster in terms of loss and the ability to recover varies among population groups. "The causes of social vulnerability are explained by the underlying social conditions that are often quite remote from the initiating hazard or disaster event" (Cutter S. L., 2006). Historically, 80% of the disaster burden falls on the public. Of this number, a disproportionate burden is placed upon those living in poverty. People living in poverty are more likely to be isolated, are less likely to have the savings to rebuild after a disaster, and less likely to have access to transportation and medical care.

Across the region, median household income is $1,000 to nearly $18,000 higher than the statewide median. With the exception of Columbia County, all other regional counties saw a statistically significant change in median household income from 2012 to 2017.

Table 2-191. Median Household Income in Region 2

	2008–2012			2012–2017			Statistically Different*
	Estimate	CV**	MOE (+/−)	Estimate	CV**	MOE (+/−)	
Oregon	$53,427	☑	$338	$56,119	☑	370	Yes
Region 2	—	—	—	—	—	—	—
Clackamas	$68,427	☑	$1,133	$72,408	☑	$1,110	Yes
Columbia	$59,154	☑	$2,724	$57,449	☑	$2,724	No
Multnomah	$55,219	☑	$739	$60,369	☑	$846	Yes
Washington	$68,948	☑	$728	$74,033	☑	$851	Yes

Notes: 2012 dollars are adjusted for 2017 dollars. Data not aggregated at the regional level.

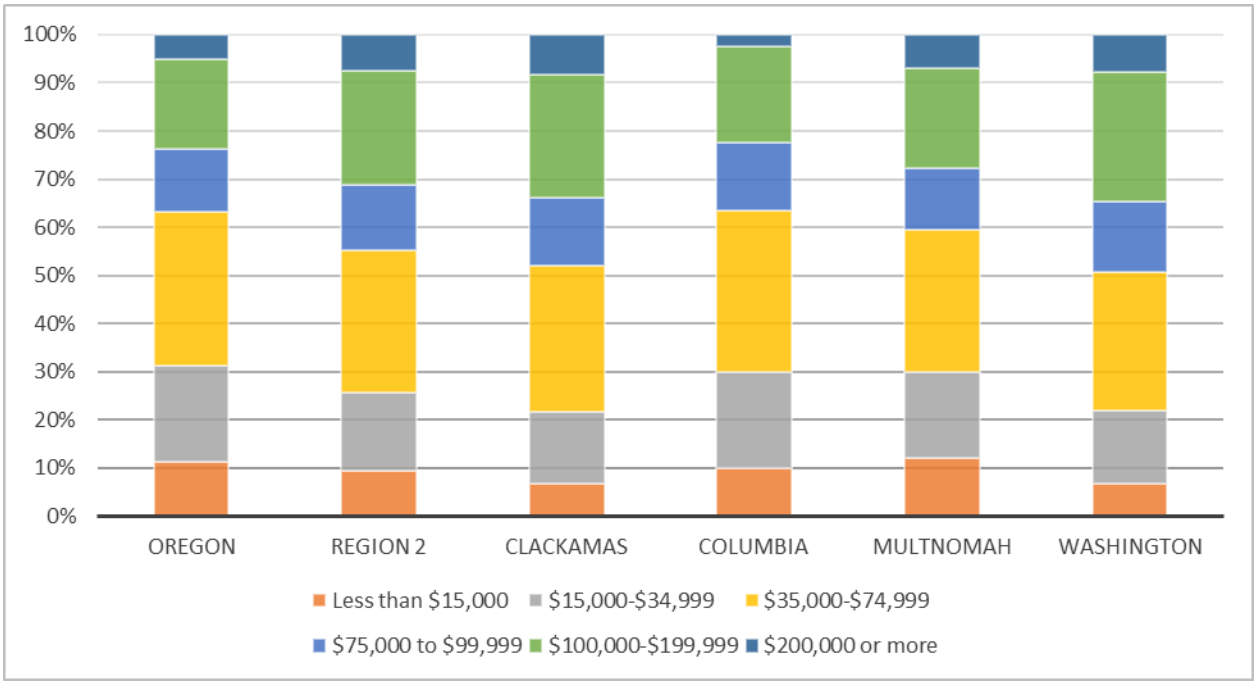
*Yes indicates that the 2013-2018 estimate is significantly different (at a 90% confidence level) than the estimate from 2008-2012. No indicates the two estimates are not statistically different.

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% – be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% – use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

Source: U.S. Census Bureau. 2008-2002 and 2013-2017. American Community Survey – 5-Year Estimates. Table CP03

Compared to the statewide share, regional counties have a smaller percentage of households in the lowest income bracket, earning less than $35,000 per year. With the exception of Columbia County, all regional counties have a greater share of households in the highest income brackets, which are those earning $75,000 or more. Clackamas and Washington Counties have the largest percentages of households earning more than $75,000 per year.

Figure 2-146. Median Household Income Distribution in Region 2



Source: U.S. Census Bureau; 2008–2012 American Community Survey 5-Year Estimates, Table DP03

The American Community Survey uses a set of dollar value thresholds that vary by family size and composition to determine who is in poverty (U.S. Census Bureau, 2018). Moreover, poverty thresholds for people living in nonfamily households vary by age—under 65 years or 65 years and older (U.S. Census Bureau, 2018).

A smaller share of the regional population is living in poverty compared to the state as a whole. Multnomah County has the highest percentage of its population living in poverty; higher than the statewide percentage. However, since 2012, no county has experienced a significant change in the portion of its overall population living in poverty. Conversely, child poverty within the region has decreased by a statistically significant amount since 2012. Moreover, the share of the population under 18 living in poverty has decreased in three of the four regional counties; Washington County, which has a relatively low child poverty rate, is the one exception.

Low-income populations require special consideration when mitigating loss to a natural hazard. Often, those who earn less have little to no savings and other assets to withstand economic setbacks. When a natural disaster interrupts work, the ability to provide housing, food, and basic necessities becomes increasingly difficult. In addition, low-income populations are hit especially hard as public transportation, public food assistance, public housing, and other public programs upon which they rely for day-to-day activities are often impacted in the aftermath of the natural disaster. To reduce the compounded loss incurred by low-income populations post-disaster, mitigation actions need to be specially tailored to ensure safety nets are in place to provide further support to those with fewer personal resources.

Table 2-192. Poverty Rates in Region 2

	Total Population in Poverty						
	2008–2012			2013–2017			Statistical Difference?*
	Estimate	CV**	MOE (+/–)	Estimate	CV**	MOE (+/–)	
Oregon	15.5%	☑	0.3%	14.9%	☑	0.30%	No
Region 2	13.4%	☑	0.3%	12.7%	☑	0.30%	No
Clackamas	9.7%	☑	0.7%	9.0%	☑	0.60%	No
Columbia	13.9%	☑	1.5%	12.3%	☑	1.70%	No
Multnomah	17.1%	☑	0.6%	16.4%	☑	0.50%	No
Washington	10.9%	☑	0.5%	10.3%	☑	0.60%	No

* Yes indicates that the 2013-2017 estimate is significantly different (at a 90% confidence level) than the estimate from 2008-2012. No indicates that the 2013-2017 estimate is not significantly different from the 2008-2012 estimate.

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% – be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% - use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

Source: U.S. Census Bureau (2018). Table S1701: Poverty Status in Past 12 Months, 2013-2018 American Community Survey 5-Year Estimates. Retrieved from: data.census.gov

Table 2-193. Child Poverty in Region 2

	Children Under 18 in Poverty						
	2008–2012			2013–2017			Statistical Difference?*
	Estimate	CV**	MOE (+/–)	Estimate	CV**	MOE (+/–)	
Oregon	20.6%	☑	0.5%	19.0%	☑	0.6%	Yes
Region 2	17.5%	☑	0.7%	15.8%	☑	0.7%	Yes
Clackamas	12.7%	☑	1.4%	10.8%	☑	1.3%	Yes
Columbia	19.6%	☑	3.5%	15.3%	⊙	4.1%	Yes
Multnomah	23.1%	☑	1.3%	20.6%	☑	1.1%	Yes
Washington	14.3%	☑	1.1%	13.7%	☑	1.3%	No

*Yes indicates that the 2013-2017 estimate is significantly different (at a 90% confidence level) than the estimate from 2008-2012. No indicates that the 2013-2017 estimate is not significantly different from the 2008-2012 estimate.

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% – be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% - use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

Source: U.S. Census Bureau (2018). Table S1701: Poverty Status in Past 12 Months, 2013-2018 American Community Survey 5-Year Estimates. Retrieved from: data.census.gov

Housing Tenure

Housing tenure, which captures whether someone owns or rents their home, has long been understood as a determinate of social vulnerability (Cutter, Boruff, & Shirley, 2003). Renters generally experience more housing challenges than homeowners; natural disasters frequently exacerbate those hardships (Lee & Van Zandt, 2019).

Homeownership is correlated with greater wealth, which can increase the ability to recover following a natural disaster (Cutter, Boruff, & Shirley, 2003). Renters often do not have personal financial resources or insurance to help recover post-disaster; they also frequently cannot access the same federal monies homeowners typically leverage following a disaster. They also might lack social resources, such as the ability to influence neighborhood decisions (Lee & Van Zandt, 2019).

Renters tend to be more mobile and have fewer assets at risk, however those assets might be more difficult to replace due to insufficient income. Renters typically have fewer options in terms of temporary shelter following a disaster and are less likely to stay with a relative or friend than in a public or mass shelter (Lee & Van Zandt, 2019).

The quality of construction for multi-family housing—more often rental—tends to be lower and is therefore more vulnerable to destruction during a disaster (Lee & Van Zandt, 2019). Moreover, renters have less ability to make improvements or alterations to their dwellings to enhance durability and structural safety (Lee & Van Zandt, 2019). Following a disaster, rental housing—especially affordable and subsidized housing—is frequently rebuilt more slowly, if at all (Lee & Van Zandt, 2019).

The percentage of people that own their home in Region 2 is nearly identical to the statewide share. However, tenure varies considerably across the region. Homeownership is most common in Columbia County and least in Multnomah County. With the exception of Columbia County, the vacancy rate in each regional county is lower than the statewide rate.

Table 2-194. Housing Tenure in Region 2

	Total Occupied Units	Owner Occupied			Renter Occupied		
		Estimate	CV**	MOE (+/−)	Estimate	CV**	MOE (+/−)
Oregon	1,571,631	61.7%	☑	0.3%	38.3%	☑	0.3%
Region 2	703,986	60.1%	☑	0.4%	39.9%	☑	0.4%
Clackamas	153,822	69.6%	☑	0.8%	30.4%	☑	0.8%
Columbia	19,213	73.0%	☑	1.8%	27.0%	☑	1.8%
Multnomah	318,173	54.3%	☑	0.5%	45.7%	☑	0.5%
Washington	212,778	60.8%	☑	0.6%	39.2%	☑	0.6%

Source: U.S. Census Bureau, 2013–2017 American Community Survey 5-Year Estimates, Table DP04

Families and Living Arrangements

Family care and obligations can create additional hardship during post-disaster recovery, especially for single-parent households (Cutter, Boruff, & Shirley, 2003). Living alone can also be a risk factor—especially in poorer communities that lack adequate social infrastructure (Klinenberg, 2016). The American Community Survey defines a family household as one that contains a householder and one or more other people living in the same unit who are related by birth, marriage, or adoption. Conversely, a nonfamily household is one where someone is either living alone, or with nonrelatives only.

Every county in the region except Multnomah has a higher share of family households when compared to statewide number. In Multnomah County, the share of family households is approximately nine percentage points lower than the statewide share—reflecting a greater proportion of people living either alone, or with nonrelatives only. The region has a slightly higher share of family households with children than the state as a whole. This is also true for all regional counties, with the exception of Multnomah. Excluding Columbia County, the proportion of single parent households across the region is slightly lower than the statewide share.

Table 2-195. Family vs. Non-family Households in Region 2

	Total Households	Family Households			Nonfamily Households			Householder Living Alone		
	Estimate	Estimate	CV **	MOE (+/−)	Estimate	CV **	MOE (+/−)	Estimate	CV **	MOE (+/−)
Oregon	1,571,631	63.3%	☑	0.2%	36.7%	☑	0.2%	27.7%	☑	0.2%
Region 2	703,986	62.0%	☑	0.4%	38.0%	☑	0.4%	28.0%	☑	0.4%
Clackamas	153,822	68.5%	☑	0.6%	31.5%	☑	0.6%	24.5%	☑	0.7%
Columbia	19,213	67.4%	☑	2.2%	32.6%	☑	2.2%	26.1%	☑	2.0%
Multnomah	318,173	54.7%	☑	0.5%	45.3%	☑	0.5%	32.3%	☑	0.6%
Washington	212,778	67.9%	☑	0.7%	32.1%	☑	0.7%	24.2%	☑	0.7%

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% – be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% - use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

Source: U.S. Census Bureau. 2013-2017 American Community Survey. https://data.census.gov/cedsci/. Table DP02: Selected Social Characteristics

Table 2-196. Family Households with Children by Head of Household in Region 2

	Family Households with Children			Single Parent (Male or Female)		
	Estimate	CV**	MOE (+/−)	Estimate	CV**	MOE (+/−)
Oregon	26.2%	☑	0.2%	8.1%	☑	0.2%
Region 2	28.0%	☑	0.3%	7.8%	☑	0.2%
Clackamas	28.9%	☑	0.5%	7.2%	☑	0.5%
Columbia	26.1%	☑	1.6%	8.1%	☑	1.2%
Multnomah	24.7%	☑	0.4%	7.9%	☑	0.3%
Washington	32.3%	☑	0.5%	7.9%	☑	0.5%

**The circle with a checkmark, circle within a circle, and circle with an x-mark indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with a green checkmark, medium reliability (CV between 15-30% – be careful) is shown as a yellow circle within a circle, and low reliability (CV >30% - use with extreme caution) is shown with a red x-mark. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error and the need for precision.

Source: U.S. Census Bureau. 2013-2017 American Community Survey. https://data.census.gov/cedsci/. Table DP02: Selected Social Characteristics

Social and Demographic Trends

- The social and demographic analysis shows that Region 1 is particularly vulnerable during a hazard event in the following categories:
- The region welcomes many tourists annually. In 2018, nearly 8.8 million overnight person-trips, or 29 million person-nights.
- The number of people experiencing homelessness has increased over the past three years. Approximately 25% of people experiencing homelessness in the state are concentrated in the Portland Metropolitan Area
- More people in Region 2 do not speak English "very well" than anywhere else in the state.
- The percentage of renters in Multnomah County exceeds that of the region and the state overall.

Economy

The impact of natural hazards on economic conditions depends on many variables. For example the vulnerability of businesses' labor, capital, suppliers, and customers are all relevant factors (Zhang, Lindell, & Prater, 2009). Some industries rebound quickly and even thrive following a disaster, manufacturing and construction, for example. Others, like wholesale and retail, rebound more slowly or never recover (Zhang, Lindell, & Prater, 2009). Economic resilience to natural disasters is far more complex than merely restoring employment or income in the local community. Building a resilient economy requires an understanding of how employment sectors, workforce participants, financial and natural resources, and critical infrastructure are interconnected and interdependent.

Employment and Unemployment

Natural disasters do not impact all labor market participants equally. Unemployed and underemployed populations are disproportionately affected by disaster events. Research shows that employment outcomes can be especially bad for people physically displaced by a disaster (Karoly & Zissimopoulos, 2010). Moreover, those who are unemployed and many employed in low-wage positions lack access to employee benefit plans that provide income and healthcare supports (Flanagan, Gregory, Hallisey, Heitgerd, & Lewis, 2011). Income deprivation and inaccessible healthcare, ruinous in the best of times, are felt more severely following a disaster. It is important for local policy makers to understand existing labor force characteristics and existing market trends to build a resilient workforce and mitigate the scope and intensity of disruptions and economic pain.

Region 2 accounts for approximately half of all employment in the state. Unemployment rates across the region have been steadily declining since they peaked in May of 2009 during the Great Recession. Columbia County has by far the smallest workforce and consistently has the highest unemployment rates within the region.

Table 2-197. Civilian Labor Force in Region 2, 2018

	Civilian Labor Force	Employed Workers		Unemployed	
	Total	Total	Percent	Total	Percent
Oregon	2,104,516	2,017,155	95.8%	87,361	4.2%
Region 2	1,022,845	985,258	96.3%	37,587	3.7%
Clackamas	218,998	210,750	96.2%	8,248	3.8%
Columbia	24,387	23,148	94.9%	1,239	5.1%
Multnomah	456,886	440,043	96.3%	16,843	3.7%
Washington	322,574	311,317	96.5%	11,257	3.5%

Source: Oregon Employment Department, 2019

Table 2-198. Civilian Unemployment Rates in Region 2, 2014-2018

	2014	2015	2016	2017	2018	Change (2014–2018)
Oregon	6.8%	5.6%	4.8%	4.1%	4.2%	−2.6%
Region 2	5.9%	4.9%	4.2%	3.6%	3.7%	−2.2%
Clackamas	6.1%	5.1%	4.3%	3.7%	3.8%	−2.3%
Columbia	8.4%	7.1%	6.1%	5.1%	5.1%	−3.3%
Multnomah	5.9%	4.9%	4.2%	3.6%	3.7%	−2.2%
Washington	5.6%	4.7%	4.1%	3.5%	3.5%	−2.1%

Source: Oregon Employment Department, 2019

Supersectors and Subsectors

The North American Industry Classification System (NAICS) is a framework used by the United States, Canada, and Mexico to collect, analyze, and publish data about the North American economy. The classification system groups "economic units that have similar production processes" according to a six-digit hierarchical structure (Office of Management and Budget, n.d.). "The first two digits of the code designate the sector, the third digit designates the subsector, the fourth digit designates the industry group, the fifth digit designates the NAICS industry, and the sixth digit designates the national industry" (Office of Management and Budget, n.d.). The U.S. Bureau of Labor Statistics through its Quarterly Census of Employment and Wages program adds to the NAICS hierarchy by grouping NAICS sectors into supersectors (U.S. Bureau of Labor Statistics, 2019, Dec. 20). This plan looks at regional economic activity through these supersectors and then through three-digit NIAICS subsectors.

In 2018 the five major supersectors by share of employment in Region 1 were:

1. Trade, Transportation and Utilities
2. Professional and Business Services
3. Education and Health Services
4. Manufacturing
5. Leisure and Hospitality

Identifying supersectors with a large number of business establishments and targeting mitigation strategies to support them can help the region's resiliency. A business establishment is an "economic unit… that produces goods or provides services. It is typically at a single physical location and engaged in one, or predominantly one, type of economic activity" (U.S. Bureau of

Labor Statistics, 2019, Sept. 4). In Region 2, the following supersectors comprise a significant share of all business establishments.

- The Professional and Business Services supersector includes the highest number of establishments in Region 2, 18% of all businesses (QCEW, 2018).
- Trade Transportation and Utilities is second largest, with 17.1% of all business establishments (QCEW, 2018).
- Other Services is third with 15.7% of the regional share (QCEW, 2018).
- Education and Health Services is fourth, comprising 10.1% of all business (QCEW, 2018).
- Financial Activities is the fifth largest with up 9.1% of all businesses (QCEW, 2018).

While supersectors are useful abstractions, it's important to remember that within are many small businesses employing fewer than 20 employees (Valdovinos, 2020). Due to their small size, these businesses are particularly sensitive to disruptions that may occur following a natural hazard event.

Table 2-199. Covered Employment by Sector in Region 2, 2019

Industry	Region 2	Clackamas		Columbia	
	Percent	Employment	Percent	Employment	Percent
Total All Ownerships	100.0%	166,026	100.0%	11,634	100.0%
Total Private Coverage	88.5%	150,002	90.3%	9,654	83.0%
Natural Resources & Mining	1.0%	4,827	2.9%	396	3.4%
Construction	5.6%	13,517	8.1%	678	5.8%
Manufacturing	10.7%	18,019	10.9%	1,633	14.0%
Trade, Transportation & Utilities	18.3%	34,058	20.5%	2,190	18.8%
Information	2.2%	2,057	1.2%	45	0.4%
Financial Activities	5.4%	7,876	4.7%	391	3.4%
Professional & Business Services	16.3%	21,340	12.9%	877	7.5%
Education & Health Services	14.3%	24,081	14.5%	1,434	12.3%
Leisure & Hospitality	10.6%	16,836	10.1%	1,366	11.7%
Other Services	4.1%	7,272	4.4%	638	5.5%
Unclassified	0.0%	118	0.1%	5	0.0%
Total All Government	11.5%	16,025	9.7%	1,980	17.0%
Total Federal Government	1.4%	1,022	0.6%	70	0.6%
Total State Government	0.8%	1,297	0.8%	161	1.4%
Total Local Government	9.2%	13,705	8.3%	1,749	15.0%

Industry	Region 2	Multnomah		Washington	
	Percent	Employment	Percent	Employment	Percent
Total All Ownerships	100.0%	512,137	100.0%	295,463	100.0%
Total Private Coverage	88.5%	439,742	85.9%	273,022	92.4%
Natural Resources & Mining	1.0%	1,559	0.3%	3,067	1.0%
Construction	5.6%	24,295	4.7%	16,644	5.6%
Manufacturing	10.7%	35,133	6.9%	51,013	17.3%
Trade, Transportation & Utilities	18.3%	93,442	18.2%	50,599	17.1%
Information	2.2%	11,948	2.3%	7,556	2.6%
Financial Activities	5.4%	29,748	5.8%	14,880	5.0%
Professional & Business Services	16.3%	83,556	16.3%	54,611	18.5%
Education & Health Services	14.3%	79,040	15.4%	36,659	12.4%
Leisure & Hospitality	10.6%	58,562	11.4%	27,414	9.3%
Other Services	4.1%	22,210	4.3%	10,478	3.5%
Unclassified	0.0%	248	0.0%	101	0.0%
Total All Government	11.5%	72,395	14.1%	22,442	7.6%
Total Federal Government	1.4%	12,270	2.4%	814	0.3%
Total State Government	0.8%	4,270	0.8%	2,027	0.7%
Total Local Government	9.2%	55,855	10.9%	19,601	6.6%

Note: (c) = confidential, information not provided by Oregon Employment Department to prevent identifying specific businesses.

Source: Oregon Employment Department. (2019). Quarterly Census of Employment and Wages. Retrieved from Qualityinfo.org

Each supersector faces distinct vulnerabilities to natural hazards. Identifying a region's dominant supersectors and the underlying industries enables communities to target mitigation activities

toward those industries' specific sensitivities. Each of the primary private employment supersectors has sensitivity to natural hazards, as follows.

Trade, Transportation, and Utilities: Retail Trade is the largest employment subsector within this sector. Retail Trade is vulnerable to disruptions in the disposable income of regional residents and to disruptions in the transportation system. Residents' discretionary spending diminishes after natural disasters as spending priorities tend to focus on essential items. Disruption of the transportation system could sever connectivity of people and retail hubs. Retail businesses are concentrated in the larger cities of the region and are most numerous in the Portland Metro area.

Professional and Business Services: This sector is composed of professional service providing industries including scientific and technical, management professionals and administrative and support services (e.g., engineering, law, headquarters, temp help, etc.). In general, this sector has low vulnerability to natural disasters. Vulnerability is increased if suppliers are affected or physical infrastructure such as buildings, roads, telecommunications, or water systems is damaged. Mitigation efforts for this sector should include preparing business continuity and recovery plans.

Leisure and Hospitality: This sector primarily serves regional residents with disposable income and tourists. Following a natural disaster, residents may have less disposable income and tourists may choose not to visit a region with unstable infrastructure.

Education and Health Services: The Health and Social Assistance industries play important roles in emergency response in the event of a disaster. The importance of the health care and social assistance sector is underscored in Region 2 because the region serves as a hub for health care.

Manufacturing: This sector is highly dependent upon transportation networks in order to access supplies and send finished products to outside markets. For these reasons the manufacturing sector may be susceptible to disruptions in transportation infrastructure. However, manufacturers are often less dependent on local markets for sales, which may contribute to the economic resilience of this sector.

Looking at industrial subsectors (three-digit NAICS) provides greater detail about the regional economy while maintaining a level of aggregation useful for analysis. The table below shows the top ten industries by share of employment within the region. In Region 2, the two largest subsectors by share of employment are Food Services and Drinking Places and Educational Services; the former fits into the Leisure and Hospitality supersector and the latter into the Educational and Health Services Supersector. Notably, the region has significant shares of employment in Management of Companies and Computer and Electronic Product Manufacturing, both are featured below as subsectors with high employment concentrations vis-à-vis the nation and higher than average wages.

Table 2-200. Industries with Greatest Share of Employment in Region 2, 2018

Industry	Employment Share	Employment (2018)
Food Services and Drinking Places	9%	102,610
Educational Services	8%	87,951
Administrative and Support Services	7%	82,080
Professional, Scientific, and Technical Services	7%	78,969
Ambulatory Health Care Services	5%	54,795
Specialty Trade Contractors	4%	43,781
Management of Companies and Enterprises	4%	41,522
Social Assistance	3%	35,980
Computer and Electronic Product Manufacturing	3%	33,453
Hospitals	2%	28,780

Source: U.S. Census Bureau (2019), LEHD, Quarterly Workforce Indicators (2010 & 2018); Calculations for employment share and average employment by DLCD

Industry Concentration and Employment Change

A location quotient (LQ) is a metric used to identify a region's area of industrial specialization. It is calculated by comparing an industry's share of regional employment with its share of employment in a reference economy (Quinterno, 2014). If a LQ is higher than 1.0, employment in that industry is more concentrated in that region than in the reference economy. In this case, the reference economy is the United States as a whole. Industries with a high LQ indicate the region might have a competitive advantage and that the industry is potentially—but not always—exporting goods and services. Understanding regional competitiveness and targeting mitigation strategies that make exporting industries less vulnerable can help the region's resiliency. Location quotients, however, require careful interpretation; analysis of employment data should be paired with local knowledge of regional business dynamics.

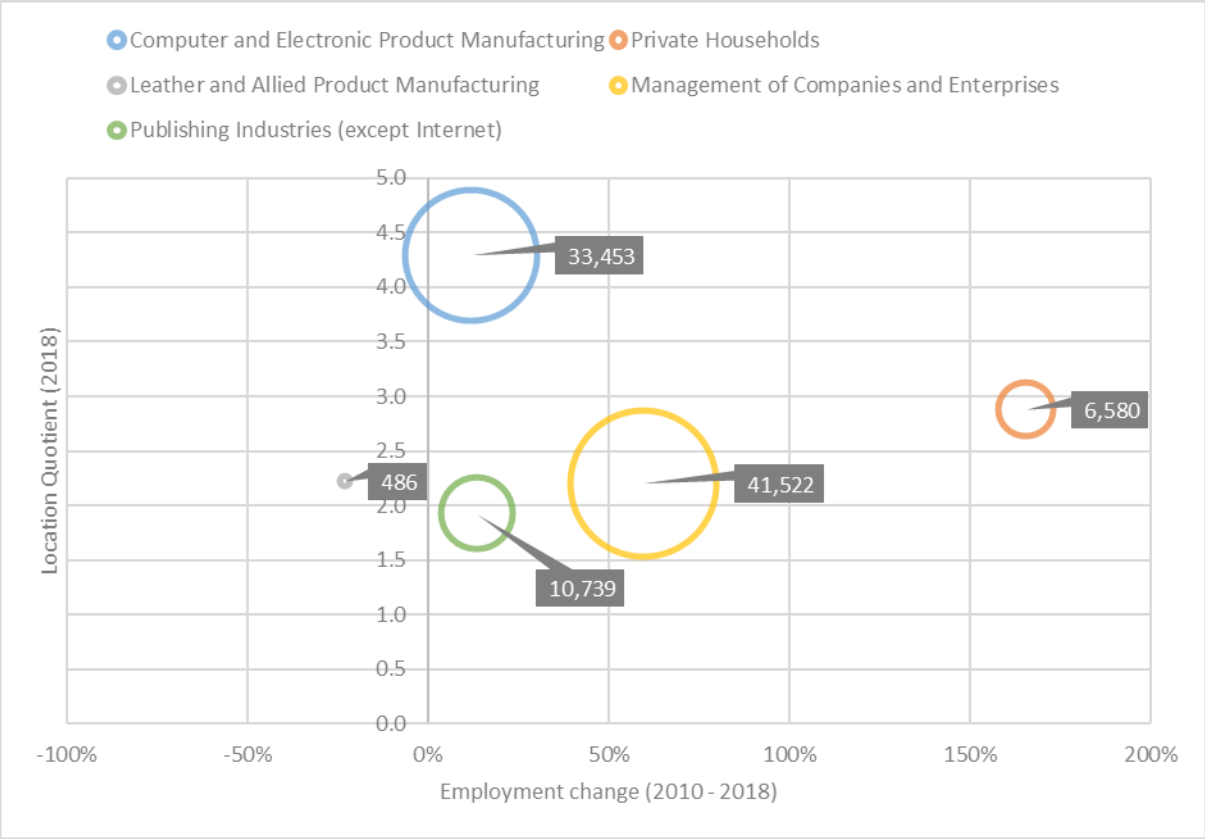
Table 2-201. Most Concentrated Industries and Employment Change in Region 2, 2018

Industry	Location Quotient	Employment (2018)	Employment Change (2010–2018)
Computer and Electronic Product Manufacturing	4.3	33,453	12%
Private Households	2.9	6,580	166%
Leather and Allied Product Manufacturing	2.2	486	−23%
Management of Companies and Enterprises	2.2	41,522	60%
Publishing Industries (except Internet)	1.9	10,739	13%

Source: U.S. Census Bureau (2019), LEHD, Quarterly Workforce Indicators (2010 & 2018), Retrieved from: https://ledextract.ces.census.gov/static/data.html; Calculations for location quotient, average employment, and employment change by DLCD

In addition to an industry's LQ value, it is important to consider the number of jobs and whether the industry is growing or declining. The scatter plot below presents this information for the five industries in Region 2 with the highest LQ values. It shows the percent change in employment over the last eight years, the total number of employees in the industry, and the LQ value.

Figure 2-147. Location Quotients, Employment Change, and Total Employment in Region 2, 2018



Source: U.S. Census Bureau (2019), LEHD, Quarterly Workforce Indicators (2010 & 2018), Retrieved from: https://ledextract.ces.census.gov/static/data.html; Calculations for location quotient, average employment, and employment change by DLCD

Advanced technology manufacturing—namely the production of semiconductors—is a major employer and critical part of Oregon's economy. Employment in the Computer and Electronic Product Manufacturing sector grew modestly during the eight-year period but total employment has dropped since its peak in the early 2000s (Lehner, 2016). Still, the region continues to have a significant employment concentration in the subsector (4.3 LQ) vis-à-vis the nation. The Management of Companies and Enterprises, part of the Professional and Business Services supersector, is also highly concentrated in the region (2.2 LQ). Moreover the subsector has grown significantly since 2010 and employs a significant total number of employees. Wages tend to be high in the subsector, which is comprised largely of company headquarters and bank holding companies (Rooney, 2019). Although the subsector lost employment during the eight-year period and the total number of employees is small, there is an employment concentration in the Leather and Allied Product Manufacturing subsector; this is likely do to the presence of companies like Danner Boots in Portland.

Fastest Growing and Declining Industries

Empirical analysis suggests that natural disasters can accelerate preexisting economic trends (Zhang, Lindell, & Prater, 2009). Therefore, it is important for local planners to understand their region's existing economic context, which industries are growing and which are declining. Between 2010 and 2018, the construction subsector added over 8,500 jobs—driven largely by demographic changes in the metro area. Private Households and Beverage and Tobacco Product Manufacturing industries experienced significant increases in employment within the region. Both, however, comprise a smaller share of employment vis-à-vis the other fastest growing industries.

Lessors of Nonfinancial Intangible Assets experienced the largest percentage decline, but employs a relatively small number of people. Looking at raw numbers, the Wholesale Electronic Markets and Agents and Brokers subsector, which coordinate the sale of goods owned by others, saw the greatest decline—shedding over 4,500 positions from 2010-2018.

Employment change can be caused by internal and external factors. The shift-share analysis helps us understand and separate regional and national influences on a local industry. There are three separate elements to the analysis that attempt to account for local and national forces. The national-growth controls for the broad growth of the national economy; the industry-mix controls for broad national changes within an industry being analyzed; and the regional-shift tries to explain what portion of employment change can be attributed to local factors. The bar chart below depicts a shift-share analysis for Region 2's fastest growing and declining industries.

Table 2-202. Fastest Growing and Declining Industries in Region 2, 2010-2018

Industry	Employment Change	Employment (2010)	Employment (2018)
Fastest Growing			
Private Households	166%	2,477	6,580
Beverage and Tobacco Product Manufacturing	125%	859	1,931
Warehousing and Storage	119%	3,304	7,219
Construction of Buildings	85%	10,227	18,903
Miscellaneous Store Retailers	83%	5,572	10,192
Fastest Declining			
Lessors of Nonfinancial Intangible Assets (except Copyrighted Works)	-64%	240	87
Wholesale Electronic Markets and Agents and Brokers	-42%	10,940	6,349
Leather and Allied Product Manufacturing	-23%	632	486
Printing and Related Support Activities	-22%	4,337	3,401
Electronics and Appliance Stores	-19%	5,543	4,501

U.S. Census Bureau (2019), LEHD, Quarterly Workforce Indicators (2010 & 2018); Calculations for average annual employment, and employment change by DLCD

Growth in the Beverage and Tobacco Product Manufacturing industry is likely driven by Oregon's thriving craft-beer scene, which continues to grow despite increased competition (Lehner, 2020). Indeed, while a portion of new employment in the region can be attributed to the industry-mix—growth in the industry at the national level—regional-growth represented the largest driver of new employment in the shift-share analysis (615 jobs).

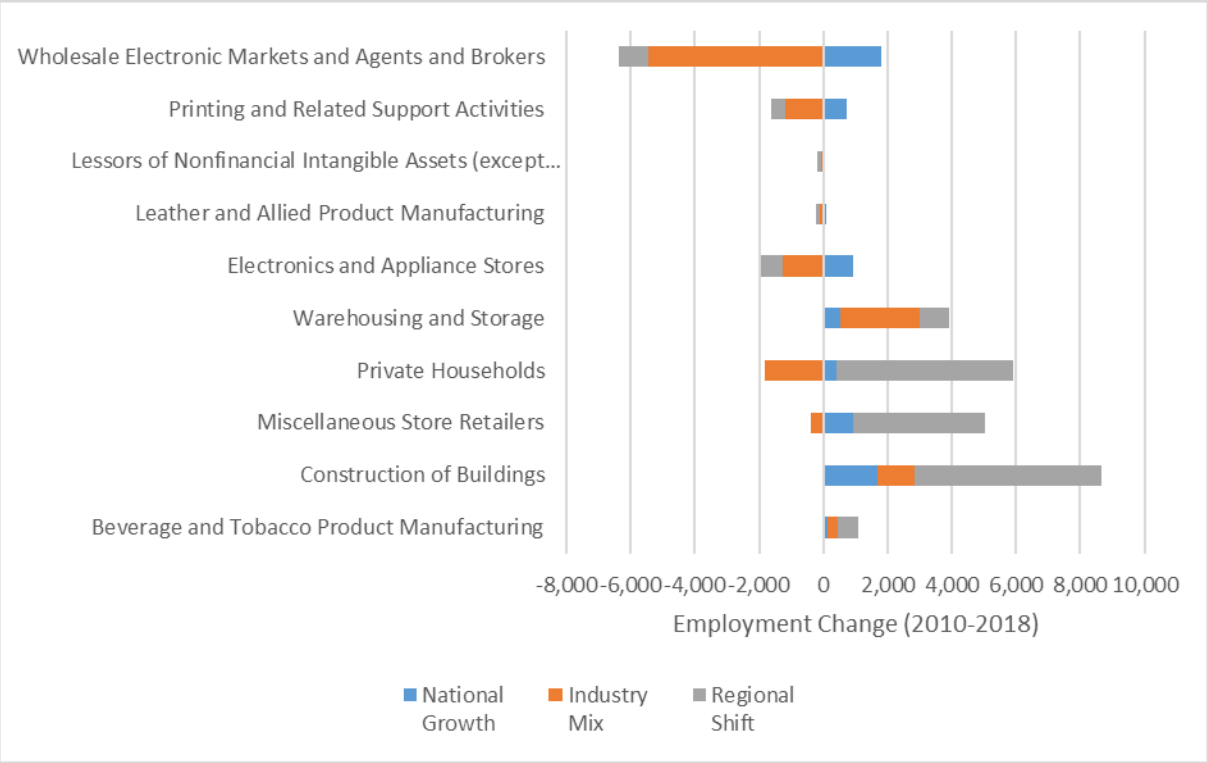
The Private Households industry employs workers "that work on or about the household premises…such as cooks, maids, butlers, gardeners, personal caretakers, and other maintenance workers" (Wallis, 2019). The increase in employment in the Private Households industry mirrors a statewide trend (Wallis, 2019). According to the shift-share analysis, growth in the sector was almost entirely a driven by regional forces.

Employment in the Warehousing and Storage subsector is likely a reflection of the global revolution in retail sales. With an increased share of retail shopping occurring online, growth in transportation, storage, and distribution infrastructure has been increasing nationally. Although the character of work is quite different, new employment in this in the subsector has helped to offset job loss in traditional "Brick and Mortar" retail (Lehner, Oregon's Shifting Retail Landscape, 2017). Growth in the region is driven by access to a relatively large consumer market and strong existing transportation infrastructure—rail, water, and air.

The Portland metro area has experienced considerable economic growth since the last recession; one driver of growth has been the strong in-migration of young college graduates, who are attracted to Portland's urban amenities and high quality of life (Lehner, Portland in Transition, 2017). In-migration has in turn driven demand for new housing, resulting in strong employment growth in the construction subsector. Migration patterns can also help to explain growth in median household income and likely have helped support employment growth in the Establishments in the Miscellaneous Store Retailer subsector. This subsector includes stores with "unique characteristics," such as stationery stores, gift shops, pet and pet supply stores, florists, and used merchandise stores (U.S. Bureau of Labor Statistics, 2020, April 17). The vast majority of growth in this subsector can be attributed to regional factors (4,106 jobs).

As mentioned, the Wholesale Electronic Markets and Agents and Brokers subsector saw the largest total number of jobs lost during the 2010 to 2018 period. The Electronics and Appliance Stores and Printing and Related Support Activities subsectors lost approximately one-thousand jobs each. Job loss in all three subsectors was driven more by the industrial-mix, or changes in the industry at the national level, as opposed to regional factors. For example, employment decline in the Electronics and Appliance Stores was likely the result of aforementioned changes in retail shopping—changes that have resulted in the shuttering of retail giants like Sears.

Figure 2-148. Shift-Share-Analysis of Fastest Growing and Declining Industries in Region 2, 2010-2018



U.S. Census Bureau (2019), LEHD, Quarterly Workforce Indicators (2010 & 2018); Calculations for shift share by DLCD

Table 2-203. Shift-Share-Analysis of Fastest Growing and Declining Industries in Region 2, 2010-2018

Industry	Employment Change	National Growth	Industry Mix	Regional Shift
Fastest Growing				
Beverage and Tobacco Product Manufacturing	1,073	140	317	615
Construction of Buildings	8,676	1,673	1,154	5,848
Miscellaneous Store Retailers	4,620	912	−398	4,106
Private Households	4,103	405	−1,818	5,515
Warehousing and Storage	3,915	540	2,472	902
Fastest Declining				
Electronics and Appliance Stores	−1,043	907	−1,248	−702
Leather and Allied Product Manufacturing	−146	103	−108	−141
Lessors of Nonfinancial Intangible Assets (except Copyrighted Works)	−153	39	−63	−129
Printing and Related Support Activities	−936	709	−1,179	−467
Wholesale Electronic Markets and Agents and Brokers	−4,592	1,790	−5,449	−932

U.S. Census Bureau (2019), LEHD, Quarterly Workforce Indicators (2010 & 2018); Calculations for shift share by DLCD

Economic Trends and Issues

Because a strong and diverse economic base increases the ability of individuals, families, and communities to absorb impacts of a disaster and recover more quickly, current and anticipated financial conditions of a community are strong determinants of community resilience. The economic analysis of the region shows the economy in Region 2 has experienced strong growth in recent years and has a diversity of high paying, traded industries. The following situations increase Region 2's level of vulnerability to natural hazard events:

- Unemployment in Clatsop County is consistently higher than its regional peers and higher than the statewide average
- The Portland metro area is the economic hub for the state. Any disruptions caused by a natural hazard could ripple throughout the other regions.

Supporting the growth of dominant industries and employment sectors, as well as emerging sectors identified in this analysis, can help the region become more resilient to economic downturns that often follow a hazard event (Stahl, et al., 2000).

Infrastructure

Transportation

Roads

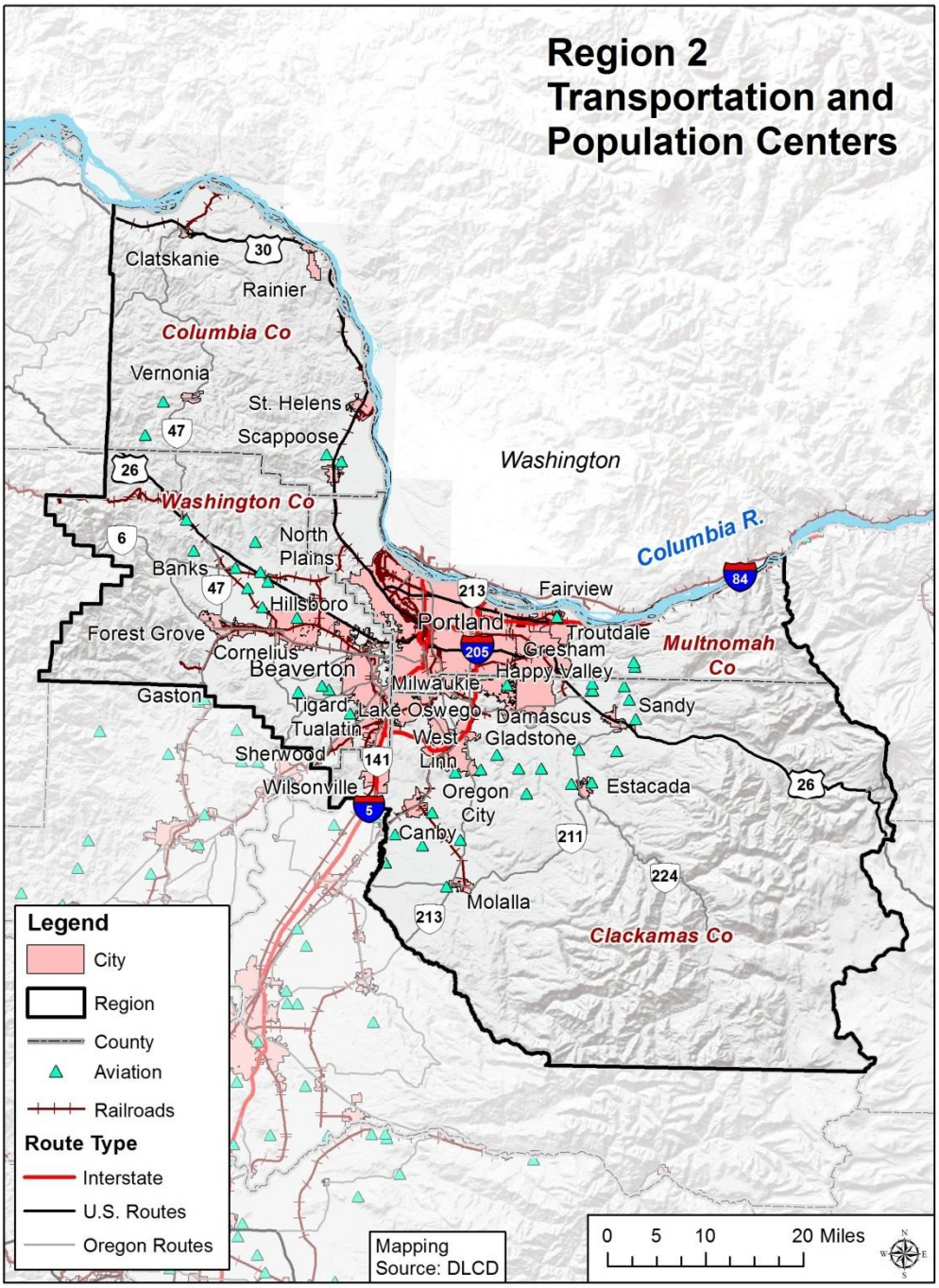
The largest population bases in Region 2 are located along the region's major freeways: I-5, I-205, and I-84. I-5 runs north-south through Region 2 and is the main passage for automobiles and trucks traveling along the West Coast. I-205 is a loop route that serves Portland and Vancouver and provides access through the eastern edge of the Portland area. I-84 runs east-west and is the main passage for automobiles and trucks traveling between Oregon and central and eastern states.

Region 2's growing population centers bring more workers, automobiles and trucks onto roads. Collectively, these create additional stresses on transportation systems through added maintenance, congestion, and oversized loads. Furthermore, a high percentage of workers driving alone to work, coupled with interstate and international freight movement on the interstate corridors, can cause added traffic congestion and accidents.

Natural hazards and emergency events can further disrupt automobile traffic, create gridlock, and shut down local transit systems, making evacuations and other emergency operations difficult. Hazards such as localized flooding can render roads unusable. Likewise, a severe winter storm has the potential to disrupt the daily driving routine of thousands of people.

The region has high exposure to earthquakes, especially a Cascadia Subduction Zone event. Therefore, the seismic vulnerability of the region's lifelines, including roadways and bridges, is an important issue. For information on ODOT's 2012 Seismic Lifelines Report findings for Region 2, see **Seismic Lifelines**.

Figure 2-149. Region 2 Transportation and Population Centers



Source: Oregon Department of Land Conservation and Development, 2014

Bridges

ODOT lists 1,194 bridges in the counties that comprise Region 2.

As mentioned, the region's bridges are highly vulnerable to seismic activity. Non-functional bridges can disrupt emergency operations, sever lifelines, and disrupt local and freight traffic. These disruptions may exacerbate local economic losses if industries are unable to transport goods. The region's bridges are part of the state and interstate highway system that is maintained by the Oregon Department of Transportation (ODOT) or that are part of regional and local systems that are maintained by the region's counties and cities.

Table 2-204 shows the structural condition of bridges in the region. A distressed bridge (Di) is a condition rating used by the Oregon Department of Transportation (ODOT) indicating that a bridge has been identified as having a structural or other deficiency. A deficient bridge (De) is a federal performance measure used for non-ODOT bridges. These ratings do not imply that a bridge is unsafe (ODOT, 2020). A significant improvement in the condition of the region's bridges reduced to 4% (from 30% in 2012 and 2013) the percentage of region's bridges that are distressed or deficient. About 2% (from 28% in 2012 and 2013) of the region's ODOT bridges are distressed.

Table 2-204. Bridge Inventory for Region 2

	State Owned			County Owned			City Owned			Other Owned			Area Total		
	Di	ST	%D*	De	ST	%D	De	ST	%D	De	ST	%D	D	ST	%D
Oregon	42	2,760	2%	258	3,442	7%	30	643	5%	16	121	13%	346	6,966	5%
Region 2	12	549	2%	22	425	5%	5	195	3%	4	25	16%	43	1194	4%
Clackamas	3	118	3%	7	158	4%	1	19	5%	0	0	N/A	11	295	4%
Columbia	1	33	3%	2	81	2%	1	9	11%	0	2	0%	4	125	3%
Multnomah	5	280	2%	4	36	11%	2	129	2%	4	15	27%	15	460	3%
Washington	3	118	3%	9	150	6%	1	38	3%	0	8	0%	13	314	4%

Note: Di = ODOT bridges Identified as distressed with structural or other deficiencies; De = Non-ODOT bridge Identified with a structural deficiency or as functionally obsolete; D = Total od Di and De bridges; ST = Jurisdictional Subtotal; %D = Percent distressed (ODOT) and/or deficient bridges; * = ODOT bridge classifications overlap and total (ST) is not used to calculate percent distressed, calculation for ODOT distressed bridges accounts for this overlap.

Source: ODOT (2020)

Railroads

Railroads that run through Region 2 support cargo and trade flows. The region's major (Class I) freight rail providers are the Union Pacific (UP) and the Burlington Northern-Santa Fe (BNSF) railroads. The Port of Portland is a major marine gateway for rail freight. There are six major rail yards and terminals in the region — all of which are in Portland — operated by UP or BNSF. Oregon's freight rail system is critical to the state's economy, energy, and food systems. Rail systems export lumber and wood products, pulp and paper, and other goods produced in the state, as well as products from other states that are shipped to and through Oregon by rail.

Amtrak provides passenger rail service throughout the region. In addition, the Portland Westside Express Service provides passenger rail options for commuters in Washington County. The area is also serviced by a regional transit system (TriMet) that provides both bus and light rail service through the greater Portland Metropolitan area.

Rails are sensitive to icing from winter storms that can occur in Region 2. Disruptions in the rail system can result in economic losses for the region. The potential for harm from rail accidents can also have serious implications for local communities, especially if hazardous materials are involved.

Airports

The Portland International Airport is the only primary commercial airport in the region and is the busiest airport in Oregon (Federal Aviation Administration [FAA], 2012). The airport is owned, operated, and administered by the Port of Portland. It serves 17 passenger air carriers and seven cargo carriers with approximately 183,000 annual commercial flights, 20,300 cargo flights, and 21,000 military and general aviation annual flights (Portland International Airport, 2014). The Port of Portland also operates two relief airports, Portland-Hillsboro and Portland-Troutdale, that serve the region.

Table 2-205. Public and Private Airports in Region 2

	Number of Airports by FAA Designation				
	Public Airport	**Private Airport**	**Public Heliport**	**Private Heliport**	**Total**
Region 2	12	33	1	24	70
Clackamas	5	19	0	6	30
Columbia	2	2	0	0	4
Multnomah	2	1	1	10	14
Washington	3	11	0	8	22

Source: FAA Airport Master Record (Form 5010) (2014)

In the event of a natural disaster, public and private airports are important staging areas for emergency response activities. Public airport closures will impact the region's tourism industries, as well as the ability for people to leave the region by air. Businesses relying on air freight may also be impacted by airport closures.

Ports

Oregon's ports have historically been used for timber transport and for commercial and recreational fishing. With the decline in the timber industry, ports have evolved to embrace economic development and tourism by offering industrial land and river, rail, road, and air infrastructure. There are two ports within Region 2, the Port of St. Helens and the Port of Portland. The Port of St. Helens includes 93 acres of light industrial and is approximately 30 miles from Portland (Port of St. Helens, http://www.portsh.org/index.php). The Port of Portland is responsible for overseeing the Portland International Airport and other aviation and marine activities in the Portland Metro area. The Port of Portland includes four marine terminals, five industrial parks, and three airports (Port of Portland, http://www.portofportland.com).

Energy

Electricity

The region is served by several investor-owned, public, cooperative, and municipal utilities. Portland General Electric (PGE) is the largest investor-owned utility in the region, serving large areas of Clackamas, Multnomah, and Washington Counties. Pacific Power and Light (Pacific Power) is another investor-owned utility company serving a small portion of Multnomah County. Additionally, the Western Oregon Electric Cooperative, Inc. provides electricity for portions of Region 2. Three municipal utility districts support the region: City of Cascade Locks, City of Forest Grove, and City of Canby. In addition, the Clatskanie People's Utility District and the Columbia River PUD serve portions of the region.

The Northern Willamette Valley / Portland Metro area has eight power-generating facilities: six generate hydroelectric and two generate natural gas. In total, these facilities have the ability to produce up to 1,121 megawatts (MW) of electricity.

Table 2-206. Power Plants in Region 2

	Hydro-electric	Natural Gas	Wind	Coal	Other*	Total
Region 2	6	2	0	0	0	8
Clackamas	6	0	0	0	0	6
Columbia	0	2	0	0	0	2
Multnomah	0	0	0	0	0	0
Washington	0	0	0	0	0	0
Energy Production (MW)	203	918	0	0	0	1,121

*Other includes biomass, geothermal, landfill gas, solar, petroleum, and waste.

Source: Army Corps of Engineers; Biomass Power Association; Calpine Corporation; Eugene Water and Electric Board; Iberdola Renewables; Idaho Power Company; Klamath Energy LLC; Oregon Department of Energy; Owyhee Irrigation District; Form 10K Annual Report (2013), PacifiCorp; Form 10K Annual Report (2013), Portland General Electric; U.S. Geothermal, Inc.

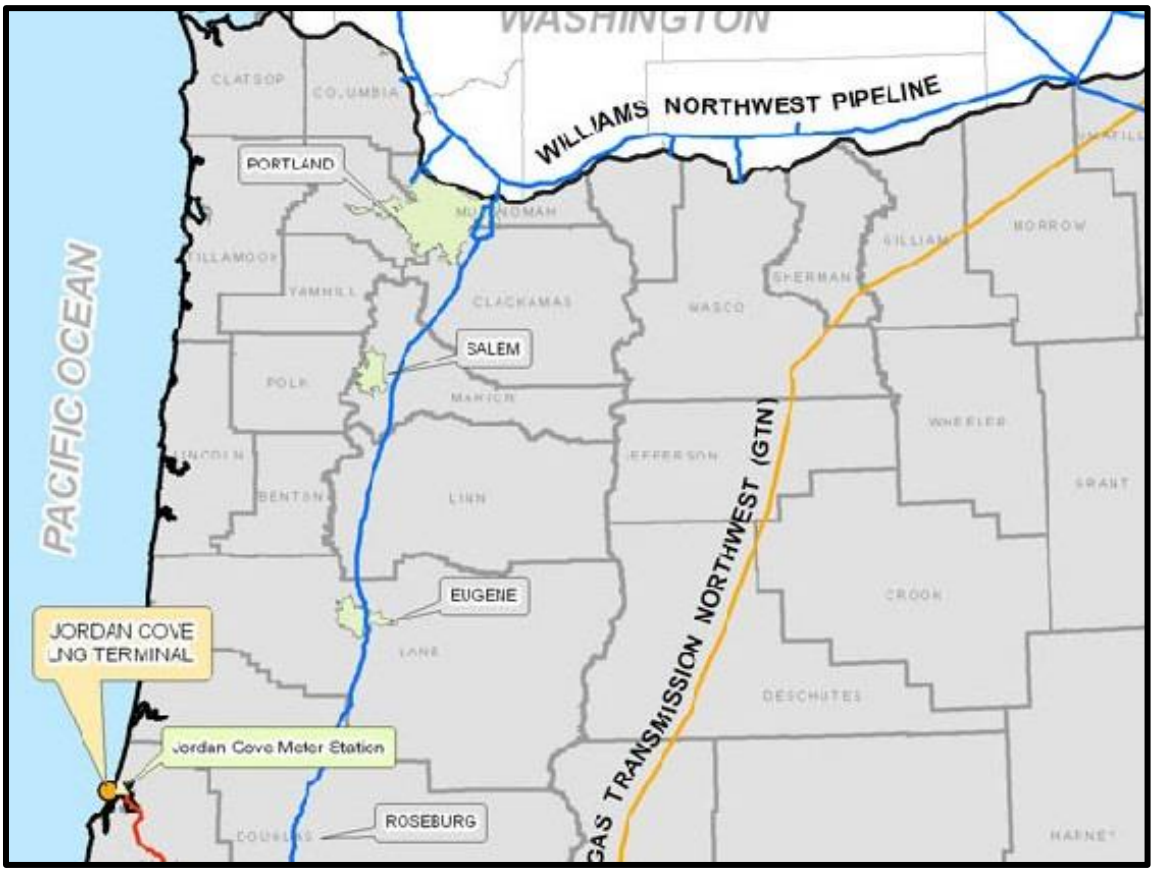
Hydropower

Bonneville Power Administration (BPA) provides hydro-generated electricity to the state's consumer-owned utilities. The Bonneville Dam is BPA's major dam in the region, located on the Columbia River. Other dams in the region are located on the Willamette, Clackamas, and Sandy Rivers.

Natural Gas

Although natural gas does not provide the most energy to the region, it does contribute a significant amount of energy to the region's energy portfolio. Liquefied natural gas (LNG) is transported via pipelines throughout the United States. **Figure 2-150** shows the Williams Northwest Pipeline, which runs through Clackamas and Multnomah Counties (in blue) (Pipelines International, 2009). LNG pipelines, like other buried pipe infrastructure are vulnerable to earthquakes and can cause danger to human life and safety, as well as environmental impacts in the case of a spill.

Figure 2-150. Liquefied Natural Gas Pipelines in Region 2



Source: Retrieved from http://gs-press.com.au/images/news_articles/cache/Pacific_Connector_Gas_Pipeline_Route-0x600.jpg

Oregon's Critical Energy Infrastructure Hub

Oregon's critical energy infrastructure hub (CEI Hub) is located in north Portland on the lower Willamette River between the south tip of Sauvie Island and the Fremont Bridge along US-30. Over 90% of Oregon's refined petroleum is imported to Oregon via the Puget Sound and arrives to Oregon CEI Hub via pipeline or marine vessels (Wang, Bartlett, & Miles, 2013). In addition, much of Oregon's natural gas passes through the CEI Hub and a high voltage electrical transmission corridor crosses, and supplies distribution for, the area. The CEI Hub includes the following energy sector facilities (Pipelines International, 2009):

- All of Oregon's major liquid fuel port terminals,
- Liquid fuel transmission pipelines and transfer stations,
- Natural gas transmission pipelines,
- A liquefied natural gas storage facility,
- High-voltage electric substations and transmission lines, and
- Electrical substations for local distribution.

In 2013, the Oregon Department of Geology and Mineral Industries (DOGAMI) conducted a study of the CEI Hub's earthquake risk entitled Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub (Wang, Bartlett, & Miles, 2013) https://www.oregongeology.org/pubs/ofr/p-O-13-09.htm). The study determined (a) the vast majority of facilities are constructed on soils susceptible to liquefaction and (b) significant seismic risk exists within the various energy sector facilities. The CEI Hub was identified as being highly vulnerable to a Cascadia Subduction Zone (CSZ) event: "western Oregon is likely to face an electrical blackout, extended natural gas service outages, liquid fuel shortage, as well as damage and losses in the tens of billions of dollars" (Pipelines International, 2009). Significant pro-active seismic mitigation projects are recommended to be integrated into the affected energy sector companies' business practices in order to allow Oregon to adequately recover from a CSZ event within a reasonable period of time. For more information see the full report.

Utility Lifelines

The Northern Willamette Valley / Portland Metro region is an important thoroughfare for oil and gas pipelines and electrical transmission lines, connecting Oregon to California and Canada. The infrastructure associated with power generation and transmission plays a critical role in supporting the regional economy. These lines may be vulnerable to severe, but infrequent natural hazards, such as earthquakes. If these lines fail or are disrupted essential functions of the community can become severely impaired.

Region 2 primarily receives oil and gas from Alaska by way of the Puget Sound through pipelines and tankers. Oil and gas are supplied by Northern California from a separate network. The electric, oil, and gas lifelines that run through the region are municipally and privately owned (Loy, Allan, & Patton, 1976).

Portland General Electric and Bonneville Power Administration primarily operate the electrical transmission lines running through Region 2, and these lines produce and distribute power locally (Loy, Allan, & Patton, 1976). Most of the natural gas Oregon uses originates in Alberta, Canada. Avista Utilities owns the main natural gas transmission pipeline (Loy, Allan, & Patton, 1976).

Telecommunications

Telecommunications infrastructure includes television, telephone, broadband internet, radio, and amateur radio (ham radio). Region 2 is part of the Portland Operational Area under The Oregon State Emergency Alert System Plan (Oregon Office of Emergency Management, 2013), which also includes Clark County, Washington. There is a memorandum of understanding between these counties that facilitates the launching of emergency messages. Counties in this area can launch emergency messages by contacting the Oregon Emergency Response System (OERS), which in turn creates emergency messages to communities statewide.

Beyond day-to-day operations, maintaining communications capabilities during disaster events and other emergency situations helps keep citizens safe by keeping them informed of the situation's status, areas to avoid, and other procedural information. Additionally, responders depend on telecommunications infrastructure to be routed to sites where they are needed.

Television

Television serves as a major provider for local, regional, and national news and weather information and can play a vital role in emergency communications. The Oregon State Emergency Alert System Plan does not identify a local primary station for emergency messages.

Telephone and Broadband

Landline telephone, mobile wireless telephone, and broadband service providers serve Region 2. Broadband technology including mobile wireless is provided in the region via five primary technologies: cable, digital subscriber line (DSL), fiber, fixed wireless, and mobile wireless. Internet service is readily available throughout most parts the region with a smaller number of providers and service types available in eastern Multnomah County and a small area of central Columbia County (NTIA, n.d.). Landline telephones are common throughout the region; however, residents in rural areas rely more heavily upon the service since they may not have cellular reception outside of major transportation corridors.

Wireless providers sometimes offer free emergency mobile phones to those impacted by disasters, which can aid in communication when landlines and broadband service are unavailable.

Radio

Radio is readily available to those who live within Region 2 and can be accessed through car radios, emergency radios, and home sound systems. Radio is a major communication tool for weather and emergency messages. Radio transmitters for the Portland Operational Area are (Oregon Office of Emergency Management, 2013):

- KXL-FM, 10.1 MHZ, Portland;
- KGON-FM, 92.3 MHZ, Portland; and
- KOPB-FM, 91.5 MHZ, Portland.

Ham Radio

Amateur radio, or ham radio, is a service provided by licensed amateur radio operators (hams) and is considered to be an alternate means of communicating when normal systems are down or at capacity. Emergency communication is a priority for the Amateur Radio Relay League (ARRL). Region 2 is served by ARES District 1. Radio Amateur Civil Emergency Services (RACES) is

a special phase of amateur radio recognized by FEMA that provides radio communications for civil preparedness purposes including natural disasters (Oregon Office of Emergency Management, n.d.). The official ham emergency station calls for Region 2 include (American Relay Radio League Oregon Chapter, http://www.arrloregon.org):

- Clackamas County: KA7OZO;
- Columbia County: W7OR;
- Multnomah County: N9VCU; and
- Washington County: KE7WKM.

Water

Drinking water, stormwater, and wastewater systems all possess some level of vulnerability to natural hazards that can have repercussions on human health, ecosystems, and industry.

Drinking Water

In Region 2 the majority of the municipal drinking water supply is obtained primarily from surface water sources such as rivers. These surface water sources are often backed up by groundwater that is drawn from an aquifer when surface water levels get low, especially in summer months. For many communities in Regions 2 and 3, the Willamette River is both a source of potable water and a discharge location for wastewater treatment facilities. Cities that draw water from the Willamette River face water rights disputes and issues related to water quality. The Bull Run watershed is the primary drinking source for the City of Portland and its 19 wholesale customers and does not face the same water quality issues as the Willamette River. However, Portland residents have expressed concerns about the well field that is the City's backup water source. Portlanders have complained of the water's unpleasant taste and expressed concern that water quality may be compromised due to the well field's close proximity to industrial facilities.

Rural residents in the region draw water from surface water, groundwater wells, or springs. Areas with sedimentary and volcanic soils may be subject to high levels of arsenic, hydrogen sulfide, and fecal coliform bacteria, which can impact the safety of groundwater sources. In areas where no new live-flow water rights are available, farmers and ranchers are turning to above-ground storage to help supply water for crop irrigation during dry seasons. At times, urban water districts with an abundant supply have sold water to rural areas. The City of Portland has a long history of these transactions and in recent years has faced competition from other sellers.

Surface sources for drinking water are vulnerable to pollutants caused by non-point sources and natural hazards. Non-point source pollution is a major threat to surface water quality, and may include stormwater runoff from roadways, agricultural operations, timber harvest, erosion and sedimentation. DEQ, ODA, and ODF have programs in place to address water quality concerns caused by land management practices that are nonpoint sources of pollution. However, there continue to be on the 303d list and the Pesticide Stewardship Partnerships identified waterbodies that are not meeting water quality standards and pesticide benchmarks. More work is needed to address these. In general ODA's water quality rules and plans and its Confined Animal Feeding Operations (CAFO) program do provide some protection. However, the CAFO program is designed to provide water quality protection for up to a certain design storm, not for a major flood or other natural hazard event. In addition, the data defining the design storm

need to be updated to provide the intended protection. Landslides, flood events, and earthquakes and resulting liquefaction can cause increased erosion and sedimentation in waterways

Underground water supplies and aging or outdated infrastructure such as reservoirs, treatment facilities, and pump stations can be severed during a seismic event. Rigid materials such as cast iron may snap under the pressure of liquefaction. More flexible materials such as polyvinyl chloride (PVC) and ductile iron may pull apart at joints under the same stresses. These types of infrastructure damages could result in a loss of water pressure in municipal water supply systems, thus limiting access to potable water. This can lead to unsanitary conditions that may threaten human health and limit fire suppression. Lack of water can also impact industry, such as the manufacturing sector. Moreover, if transportation infrastructure is impacted by a disaster event, repairs to water infrastructure will be delayed.

Stormwater and Wastewater

In urbanized areas severe precipitation events may cause flooding that leads to stormwater runoff. A non-point source of water pollution, stormwater runoff can adversely impact drinking water quality. It can also lead to environmental issues such as increasing surface water temperatures that can adversely affect habitat health. Furthermore, large volumes of fast-moving stormwater that enter surface waterways can cause erosion issues.

Stormwater can also impact water infrastructure. Leaves and other debris can be carried into storm drains and pipes, which can clog stormwater systems. In areas where stormwater systems are combined with wastewater systems (combined sewers), flooding events can lead to combined sewer overflows (CSOs). CSOs present a heightened health threat as sewage can flood urban areas and waterways. Underground stormwater and wastewater pipes are also vulnerable to damage by seismic events.

In Region 2, most local building codes and stormwater management plans emphasize the use of centralized storm sewer systems to manage stormwater. Requirements for stormwater mitigation vary in Region 2. Low-impact development (LID) mitigation strategies can alleviate or lighten the burden to a jurisdiction's storm sewer system by allowing water to percolate through soil onsite or detaining water so water enters the storm sewer system at lower volumes, lower speeds, and lower temperatures. The City of Portland has been recognized as a national innovator in stormwater management and code because of its progressive LID stormwater mitigation strategies in the City's building code. However, the majority of jurisdictions in the region do not require LID strategies in their building code. Promoting and requiring decentralized LID stormwater management strategies could help reduce the burden of new development on storm sewer systems and increase a community's resilience to many types of hazard events.

Infrastructure Trends and Issues

Physical infrastructure is critical for everyday operations and is essential following a disaster. Lack or poor condition of infrastructure can negatively affect a community's ability to cope with, respond to, and recover from a hazard event. Diversity, redundancy, and consistent maintenance of infrastructure systems help create system resiliency (Meadows, 2008).

Roads, bridges, and rail systems in the region support Oregon's largest population centers and freight moving through the Pacific Northwest. These transportation systems and are vulnerable to a variety of natural hazards that could disrupt transportation of goods, block evacuation routes and sever lifelines. The effects of road, bridge, and rail failures on the economy and health of the region's residents could be devastating. ODOT understands this risk and began seismically upgrading five of the area's key bridges within the Portland Metro area in summer 2014.

In addition, the region has two ports with marine terminals, industrial parks and aviation facilities. The Portland International Airport is the busiest in the state, moving the majority of passengers and freight. These ports, including airports, face potential disruptions in services due to natural hazard events.

The region is an energy hub for the state. There are multiple dams and eight power-generating facilities. The Bonneville Power Administration (BPA) provides hydro-generated electricity to the state's consumer owned utilities. BPA's main dam, the Bonneville Dam, is located on this region on the Columbia River. Liquid Natural Gas is transported through the region via the Williams Northwest Pipeline that runs through Clackamas and Multnomah Counties. Of particular concern is Oregon's critical energy infrastructure hub, located in north Portland, which is highly vulnerable to a Cascadia event.

Decentralization and redundancy in the region's telecommunication systems can help boost the area's ability to communicate before, during, and after a disaster event. It is important to note that broadband and mobile telephone services may not cover rural areas of the region that are distant from Portland, especially central Columbia and eastern Multnomah Counties. This may present a communication challenge in the wake of a hazard event. Encouraging residents to keep AM/FM radios available for emergency situations could help increase the capacity for communicating important messages throughout the region.

Water systems in the region are particularly vulnerable to hazard events because they tend to be centralized and lacking in system redundancies. Furthermore, because most drinking water is sourced from surface water, the region is vulnerable to high levels of pollutants entering waterways during high-water events. The City of Portland has been recognized as a leader in stormwater management best practices because of its decentralized Low Impact Development (LID) stormwater systems.

Built Environment

Settlement and Development Patterns

Balancing growth with hazard mitigation is key to planning resilient communities. Therefore, understanding where development occurs and the vulnerabilities of the region's building stock is integral to developing mitigation efforts that move people and property out of harm's way. Eliminating or limiting development in hazard prone areas can reduce exposure to hazards, and potential losses and damages.

Since 1973, Oregon has maintained a strong statewide program for land use planning. The foundation of Oregon's land use program is 19 land use goals that "help communities and citizens plan for, protect and improve the built and natural systems." These goals are achieved through local comprehensive planning. The intent of Goal 7, Areas Subject to Natural Hazards, is

to protect people and property from natural hazards (DLCD, https://www.oregon.gov/lcd/OP/Pages/Goal-7.aspx).

Urbanization and Population Distribution

The U.S. Census Bureau defines "urban" as either an "urbanized area" of 50,000 or more people or an "urban cluster" of at least 2,500 people (but less than 50,000). Jurisdictions are designated urban or rural after each decennial census. The 2020 Census is currently underway; therefore, the data in **Table 2-207** and **Table 2-208** remain from the 2010 Census.

Washington and Columbia Counties experienced the region's greatest percent urban growth during the decade from 2000 to 2010, roughly 5% and 7% more than the state average respectively. Similar to the state, the region is becoming less rural. However, Columbia County, the least populated county along the coast, is the only county in the region to increase its rural population.

The region's urban housing units grew eight times those in rural areas. Multnomah County was the only county to decrease its share of rural residences, notably by 11%. Columbia County had the largest percent growth in in both urban and rural units 24.1% and 10.8% respectively.

Not surprisingly, populations tend to cluster around major road corridors and waterways. The region's largest population is clustered around the Portland Metro area. The population distribution in Region 2 is presented in **Figure 2-151.**

Table 2-207. Urban and Rural Populations in Region 2, 2010

	Urban			Rural		
	2000	2010	Percent Change	2000	2010	Percent Change
Oregon	2,694,144	3,104,382	15.2%	727,255	726,692	−0.1%
Region 2	1,352,896	1,561,409	15.4%	134,883	128,978	−4.4%
Clackamas	266,367	308,018	15.6%	72,024	67,974	−5.6%
Columbia	22,769	27,828	22.2%	20,791	21,523	3.5%
Multnomah	649,010	725,464	11.8%	11,476	9,870	−14.0%
Washington	414,750	500,099	20.6%	30,592	29,611	−3.2%

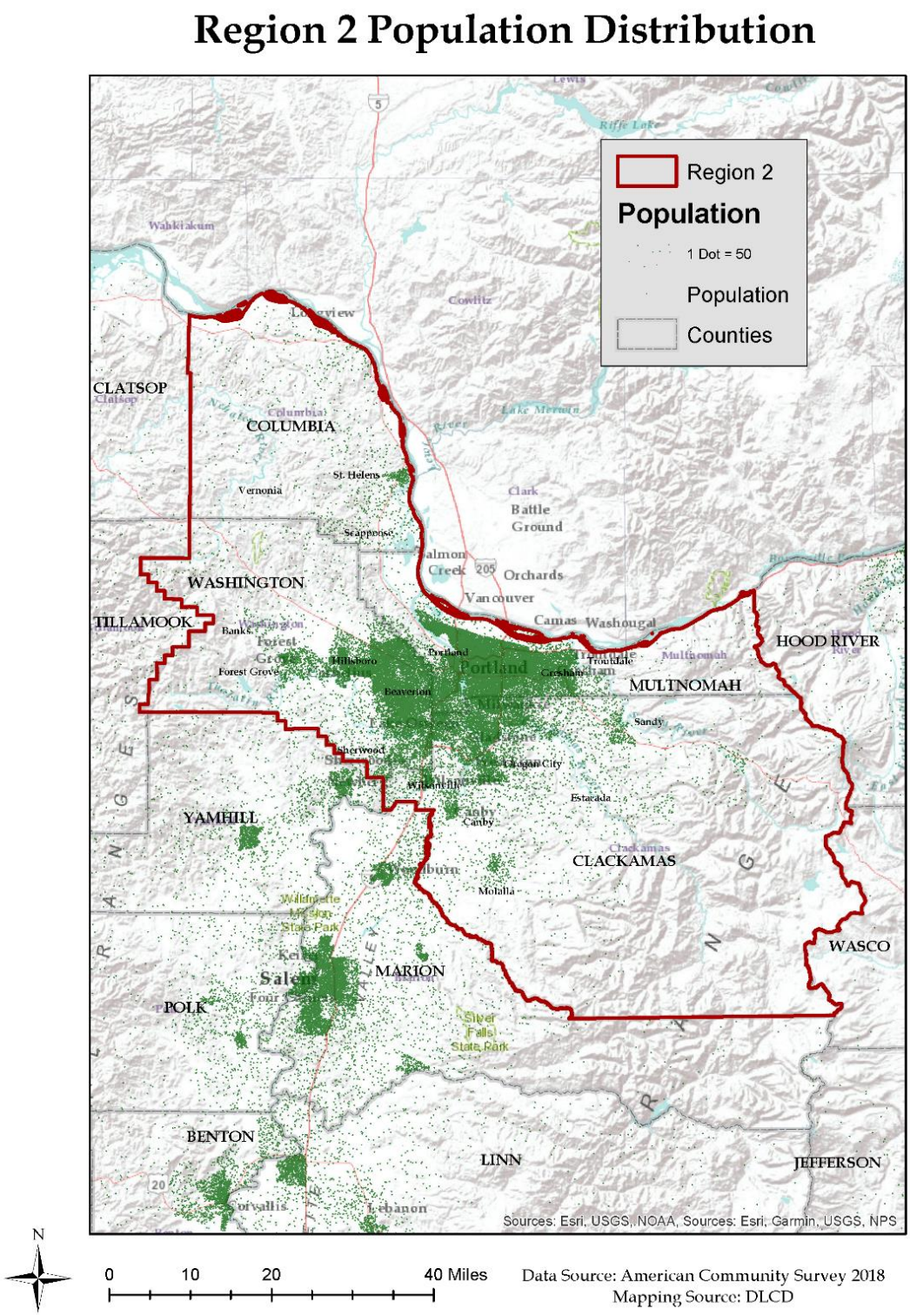
Source: U.S. Census Bureau (n.d.). 2010 Decennial Census, Table P2

Table 2-208. Urban and Rural Housing Units in Region 2, 2010

	Urban			Rural		
	2000	2010	Percent Change	2000	2010	Percent Change
Oregon	1,131,574	1,328,268	17.4%	321,135	347,294	8.1%
Region 2	569,834	661,845	16.1%	52,166	53,080	1.8%
Clackamas	109,047	128,740	18.1%	27,907	28,205	1.1%
Columbia	9,247	11,474	24.1%	8,325	9,224	10.8%
Multnomah	283,957	320,735	13.0%	4,604	4,097	−11.0%
Washington	167,583	200,896	19.9%	11,330	11,554	2.0%

Source: U.S. Census Bureau (n.d.). 2010 Decennial Census, Table H2

Figure 2-151. Region 2 Population Distribution



Source: U.S. Census Bureau, American Community Survey, 2014-2018 5YR

Housing Development

In addition to location, the character of the housing stock can also affect the level of risk a community faces from natural hazards. **Table 2-209** provides a breakdown by county of housing types: single-family, multi-family, and manufactured housing. Note: The total housing units value also includes boats, RVs, vans, etc. that are used as a residence. These homes are not included in the table as a separate category because they represent a small percentage of the overall housing profile. Consequently, adding the percentages horizontally for the state, region, and each county will not equal 100%.

The majority of the region's housing stock is single-family homes. Nearly half of the region's multi-family units are located in Multnomah County, in the Portland area in particular. Manufactured dwellings make up only 3.4% of all housing in the region. Columbia County has the greatest percentage of manufactured homes (14.5 %), and Clackamas County has the highest number of units (10,471). In natural hazard events such as earthquakes and floods, manufactured homes are more likely to shift on their foundations and create hazardous conditions for occupants and their neighbors (California Governor's Office of Emergency Services, 1997).

Table 2-209. Housing Profile for Region 2

	Total Housing Units	Single Family			Multi-Family			Mobile Homes		
		Estimate	CV **	MOE (+/−)	Estimate	CV **	MOE (+/−)	Estimate	CV **	MOE (+/−)
Oregon	1,733,041	68.1%	☑	0.3%	23.5%	☑	0.3%	8.2%	☑	0.1%
Region 2	745,872	65.5%	☑	0.3%	31.0%	☑	0.4%	3.4%	☑	0.1%
Clackamas	163,650	73.1%	☑	0.6%	20.4%	☑	0.8%	6.4%	☑	0.3%
Columbia	21,007	74.2%	☑	2.1%	11.1%	☑	1.6%	14.5%	☑	1.5%
Multnomah	337,821	60.6%	☑	0.5%	37.3%	☑	0.7%	1.9%	☑	0.2%
Washington	223,394	66.5%	☑	0.6%	31.0%	☑	0.8%	2.5%	☑	0.2%

Notes: *Green, orange, and red icons indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with green checkmark icon, medium reliability (CV 15–30% — be careful) is shown with orange dot icon, and low reliability (CV >30% — use with extreme caution) is shown with red "x" icon. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error (MOE) and the need for precision.

Source: U.S. Census Bureau (2018). Table B25024: Units in Structure, 2013-2017 American Community Survey 5-year estimates. Retrieved from https://data.census.gov/cedsci/

Table 2-210. Housing Vacancy in Region 2

	Total Housing Units	Vacant^		
		Estimate	CV **	MOE (+/–)
Oregon	1,733,041	5.6%	☑	0.2%
Region 2	745,872	4.5%	☑	0.2%
Clackamas	163,650	4.0%	☑	0.5%
Columbia	21,007	7.6%	☑	1.5%
Multnomah	337,821	4.8%	☑	0.3%
Washington	223,394	4.1%	☑	0.4%

Notes: ^ Functional vacant units, computed after removing seasonal, recreational, or occasional housing units from vacant housing units.
**Green, orange, and red icons indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with green checkmark icon, medium reliability (CV 15–30% — be careful) is shown with orange dot icon, and low reliability (CV >30% — use with extreme caution) is shown with red "x" icon. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error (MOE) and the need for precision.

Source: U.S. Census Bureau (2018), 2013-2017 American Community Survey 5-Year Estimates. https://data.census.gov/cedsci/. Table B25004: Vacancy Status

Aside from location and type of housing, the year a structure was built (**Table 2-211**) has implications for level of vulnerability to natural hazards. Seismic building standards were codified in Oregon building code starting in 1974. More rigorous building code standards passed in 1993 accounted for the Cascadia earthquake fault (Judson, 2012). Therefore, homes built before 1994 are more vulnerable to seismic events. Moreover, the Judson report did not include manufactured housing in its study, but more recent research concludes that manufactured homes installed prior to 2003 lack adequate anchoring and bracing, and are therefore more vulnerable to damage and loss caused by seismic events (Bauer, et al., 2020).

Also in the 1970s, FEMA began assisting communities with floodplain mapping as part of administering the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. Upon receipt of floodplain maps, communities started to develop floodplain management ordinances to protect people and property from flood loss and damage. Regionally, 36.7% of the housing stock was built prior to 1970, before the implementation of floodplain management ordinances. Notably, over 53% of homes in Multnomah County were constructed before 1970. Regionally, approximately two thirds of the housing stock was built before 1990 and the codification of seismic building standards. Washington County has the highest percentage (46.4%) and largest number (103,575) of units built after 1990. Additionally, as shown in **Table 2-212**, many communities did not adopt their initial FIRM—and therefore did not adopt floodplain management ordinances—until the late 1970s or mid-1980s. This means that some structures built after 1970 could still be at increased risk.

Table 2-211. Age of Housing Stock in Region 2

	Total Housing Units	Pre 1970			1970 to 1989			1990 or Later		
		Estimate	CV **	MOE (+/−)	Estimate	CV **	MOE (+/−)	Estimate	CV **	MOE (+/−)
Oregon	1,733,041	34.6%	☑	0.3%	30.5%	☑	0.3%	34.9%	☑	0.3%
Region 2	745,872	36.7%	☑	0	28.7%	☑	0.4%	34.6%	☑	0.4%
Clackamas	163,650	27.1%	☑	0	34.8%	☑	0.8%	38.1%	☑	0.9%
Columbia	21,007	37.0%	☑	0	26.9%	☑	1.9%	36.1%	☑	2.2%
Multnomah	337,821	53.6%	☑	0	21.4%	☑	0.5%	25.1%	☑	0.6%
Washington	223,394	18.1%	☑	0	35.6%	☑	0.7%	46.4%	☑	0.9%

Notes: *Green, orange, and red icons indicate the reliability of each estimate using the coefficient of variation (CV). This table may not contain all these symbols. The lower the CV, the more reliable the data. High reliability (CV <15%) is shown with green checkmark icon, medium reliability (CV 15–30% — be careful) is shown with orange dot icon, and low reliability (CV >30% — use with extreme caution) is shown with red "x" icon. However, there are no absolute rules for acceptable thresholds of reliability. Users should consider the margin of error (MOE) and the need for precision.

Source: U.S. Census Bureau (2018). Table B25034: Year Structure Built, 2013-2017 American Community Survey 5-Year Estimates. Retrieved from https://data.census.gov/cedsci/

The National Flood Insurance Program's (NFIP's) Flood Insurance Rate Maps (FIRMs) delineate flood-prone areas. They are used to assess flood insurance premiums and to regulate construction so that in the event of a flood, damage is minimized. **Table 2-212** shows the initial and current FIRM effective dates for Region 2 communities. For more information about the flood hazard, NFIP, and FIRMs, please refer to the State Risk Assessment, **Flood** section.

Table 2-212. Community Flood Map History in Region 2

	Initial FIRM	Current FIRM
Clackamas County	Mar. 1, 1978	Jan. 18, 2019
Barlow	May 5, 1981	June 17, 2008
Canby	June 15, 1984	June 17, 2008
Damascus	July 19, 2000	June 17, 2008
Estacada	June 17, 2008	June 17, 2008
Gladstone	Mar. 15, 1977	June 17, 2008
Happy Valley	Dec. 4, 1979	June 17, 2008
Lake Oswego	Aug. 4, 1987	June 17, 2008
Milwaukie	June 18, 1980	June 17, 2008
Molalla	June 17, 2008	June 17, 2008
Oregon City	Dec. 15, 1980	June 17, 2008
Portland	see Multnomah County	see Multnomah County
Rivergrove	Aug. 4, 1987	June 17, 2008
Sandy	Dec. 11, 1979	Jan. 18, 2019
Tualatin	see Washington County	see Washington County
West Linn	Mar. 15, 1977	June 17, 2008
Wilsonville	Jan. 6, 1982	June 17, 2008
Columbia County	Aug. 16, 1986	Nov. 26, 2010
Clatskanie	September 29, 1986	Nov. 26, 2010
Columbia, City	June 5, 1985	Nov. 26, 2010
Prescott	Aug. 16, 1988	Nov. 26, 2010
Rainier	Aug. 16, 1988	Nov. 26, 2010
St. Helens	September 29, 1986	Nov. 26, 2010
Scappoose	Dec. 19, 1975	Nov. 26, 2010
Vernonia	Aug. 16, 1986	Nov. 26, 2010
Multnomah County	June 15, 1982	Feb. 1, 2019
Fairview	Mar. 18, 1986	Feb. 1, 2019
Gresham	July 16, 1979	Feb. 1, 2019
Lake Oswego	see Clackamas County	see Clackamas County
Milwaukie	see Clackamas County	see Clackamas County
Portland	Oct. 15, 1980	Nov. 26, 2010
Troutdale	Sept. 30, 1988	Feb. 1, 2019
Wood Village	Dec. 18, 2009	Dec. 18, 2009
Washington County	Sept. 30, 1982	Oct. 19, 2018
Beaverton	Sept. 28, 1984	Oct. 19, 2018
Cornelius	Jan. 6, 1982	Nov. 4, 2016
Durham	Jan. 6, 1982	Nov. 4, 2016
Forest Grove	Mar. 15, 1982	Oct. 19, 2018
Gaston	July 5, 1982	Nov. 4, 2016
Hillsboro	May 17, 1982	Oct. 19, 2018
King City	Feb. 18, 2005	Oct. 19, 2018
Lake Oswego	see Clackamas County	see Clackamas County
North Plains	April 1, 1982	Oct. 19, 2018
Portland	see Multnomah County	see Multnomah County
Rivergrove	see Clackamas County	see Clackamas County
Sherwood	Jan. 6, 1982	Oct. 19, 2018
Tigard	Mar. 1, 1982	Oct. 19, 2018
Tualatin	May 2, 1978	Oct. 19, 2018
Wilsonville	see Clackamas County	see Clackamas County

Source: Federal Emergency Management Agency, Community Status Book Report (2019), https://www.fema.gov/cis/OR.pdf

State-Owned/Leased and Critical/Essential Facilities

In 2020 the Department of Geology and Mineral Industries updated the 2015 Oregon NHMP inventory and analysis of state-owned and –leased buildings, state-owned and –leased critical facilities, and local critical facilities. Results from this report relative to Region 2 can be found in **Table 2-213**. The region contains roughly one-third of the total value of all local critical facilities and state-owned and –leased critical and non-critical facilities in the state. Cumulatively, these assets are valued at over eleven billion dollars.

Table 2-213. Value of State-Owned/Leased Critical and Essential Facilities in Region 2

	Value of Local and State-Owned/Leased Facilities				
	State Non-Critical	State Critical	Local Critical	State + Local Total	Percent of Total
Oregon	$2,630,306,288	$4,622,433,011	$ 26,285,277,425	$ 33,538,016,724	100%
Region 2	$ 257,430,784	$ 877,465,291	$ 10,224,814,827	$ 11,359,710,902	33.9%
Clackamas	$ 122,919,532	$ 244,339,312	$ 2,627,327,079	$ 2,994,585,923	8.9%
Columbia	$ 9,995,844	$ 5,974,800	$ 319,380,450	$ 335,351,094	1.0%
Multnomah	$ 73,405,014	$ 254,444,106	$ 4,104,558,180	$ 4,432,407,300	13.2%
Washington	$ 51,110,394	$ 372,707,073	$ 3,173,549,118	$ 3,597,366,585	10.7%

Source: DOGAMI, 2020

Land Use Patterns

Approximately 63.3% of the land in Region 2 is in private ownership, while 30.7% is owned by the federal government, and 4% by the state government. The remainder is non-resource lands owned by other public entities. Subtracting the Cascade Mountain area leaves nearly the entire Region 2 in private holdings.

Not surprisingly, between 1974 and 2009, the Portland area, followed by the North Willamette Valley area, demonstrated the greatest rates of change in the state in the conversion of private land in resource land uses to low-density residential and urban uses. Within the Portland area, the highest rate of increase took place in Washington County, followed by Clackamas County. Both counties experienced much higher rates of conversion to low-density residential and urban uses than was the case in highly urbanized Multnomah County (Lettman G. J., 2011).

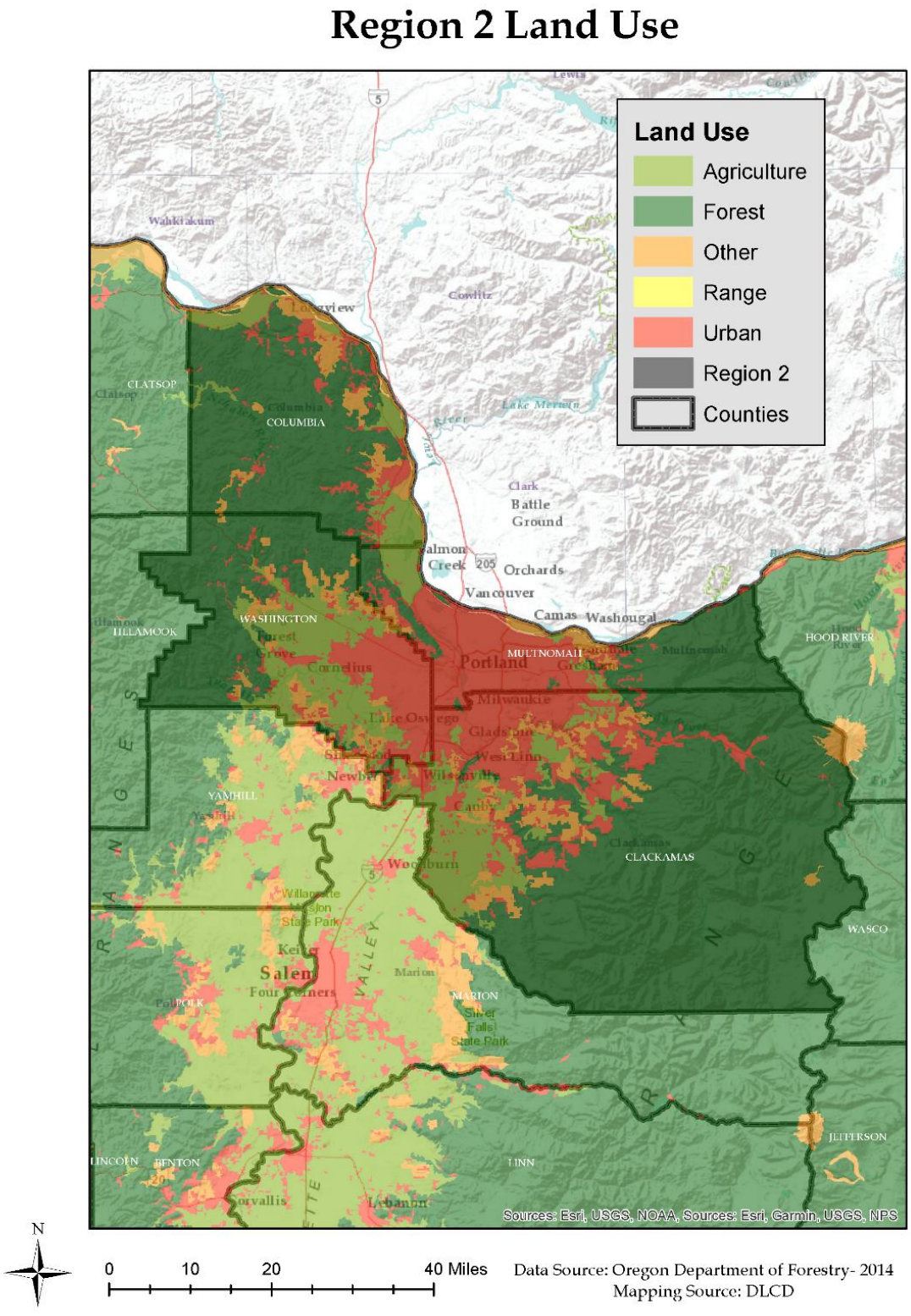
More recently, much of the new residential growth in the Portland area has been either infill or redevelopment. For example, from 2007-2009, 58% of new development in the Portland area fell into one of these two categories (Lettman G. J., 2011). The rest of the residential construction in that time, about 42%, has been on vacant land (Lettman G. J., 2011).

According to the Oregon Department of Forestry's most recent land-use study., "development of resource lands hit a record low between 2009 and 2014...with roughly 3,000 acres per year of Oregon's farms, forests, and rangeland shifted to low-density residential or urban uses" (Lettman G. J., Gray, Hubner, McKay, & Thompson, 2016). In Region 2, approximately 3,693 acres of resource lands were converted to more urban uses during the six-year period. **Table 2-214** shows that during the six-year period, the percentage of resource lands converted in each county in Region 2 was less than one percent of each county's total acreage. Consistent with the longer trends mentioned above, most of the conversion during this period happened in Washington and Clackamas Counties.

Under Oregon law, each of the state's cities and metropolitan areas has created around its perimeter an urban growth boundary (UGB), which is a land use planning line to control urban expansion onto farm and forest lands. The UGB is assessed every 6 years, in a process that involves various levels of government and the public. In 2018, the Metro Council voted to expand the region's urban growth boundary, adding 2,181 acres to the region (Metro, 2020).

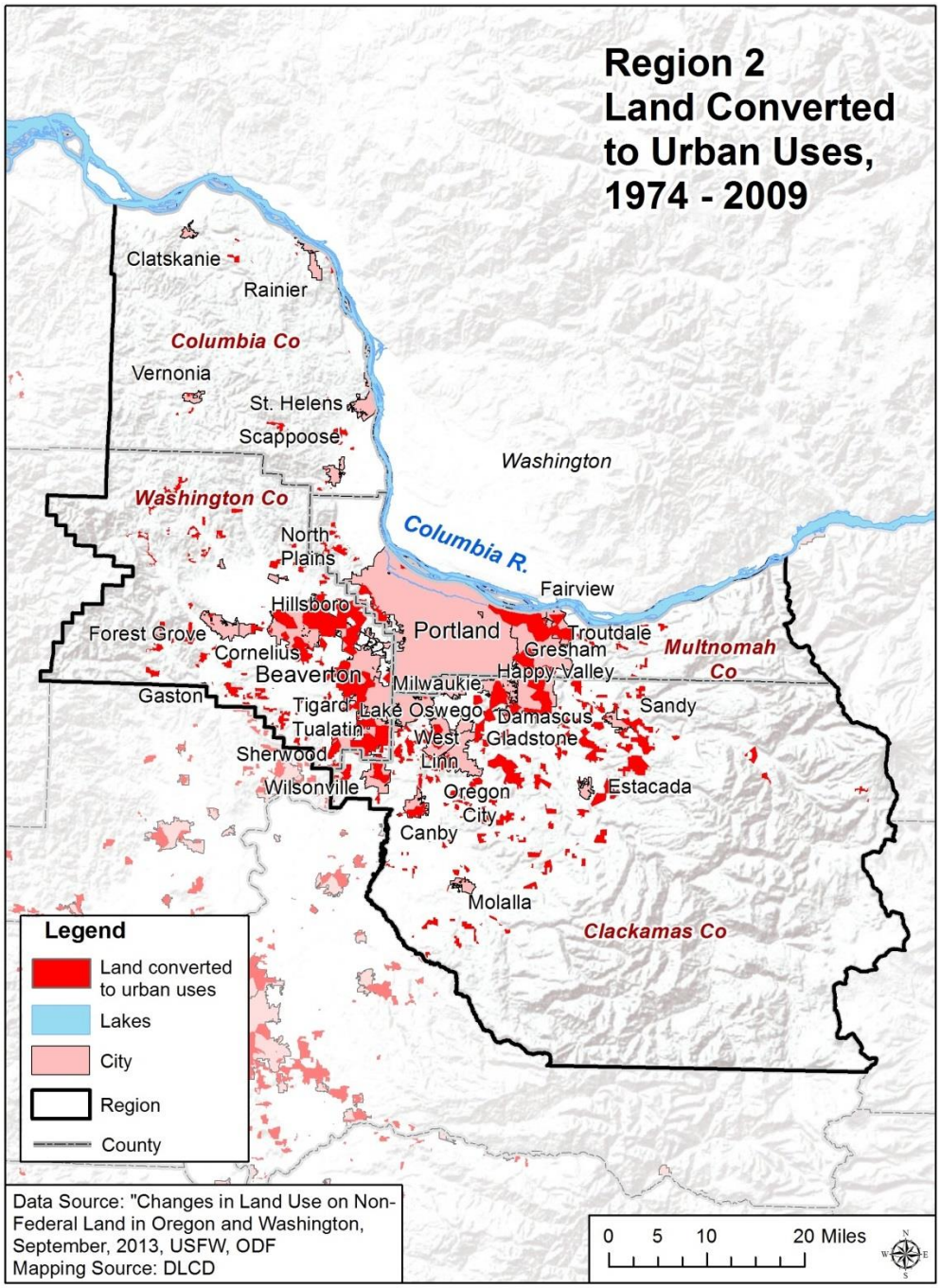
Potential upgrades to the 28 miles of levees that protect the north Portland area from the Columbia River remain a continuing land use issue for the region. As of January 2020, potential costs to the four drainage districts involved were approximately $157 million dollars (U.S. Army Corps of Engineers, 2020). Failure to maintain certification and FEMA accreditation may result in thousands of property owners and businesses subject to federal flood insurance regulations (DLCD, internal communication, 2014).

Figure 2-152. Region 2 Land Use



Source: Oregon Department of Forestry 2014

Figure 2-153. Region 2 Land Converted to Urban Uses, 1974–2009



Source: "Changes in Land Use on Non-Federal Land in Oregon and Washington," September 2013, USFS, ODF

Table 2-214. Region 2 Resource Lands Converted to Urban Uses, 2009-2014

	Lost Resource Lands 2009-2014		
	Total Resource Acres (2009)	Acres Converted to Urban Use	Percent Converted
Region 2	1,200,888	3,693	0.30%
Columbia	377,030	774	0.20%
Washington	354,859	1,277	0.35%
Multnomah	75,266	122	0.16%
Clackamas	393,733	1,520	0.38%

Source: Oregon Department of Forestry, 2014; Oregon Department of Land Conservation and Development, 2020

Built Environment Trends and Issues

The trends within the built environment are critical to understanding the degree to which urban form affects disaster risk. Region 2 is largely an urban county with urban development focused around the Portland Metropolitan area. Between 2010 and 2018, population grew at a rate somewhat faster than the state as a whole. This trend is project to continue over the next ten years. Please refer to the Region 2 Risk Assessment **Demography** section for more information on population trends and forecast. The results of the 2020 U.S. Census will better illustrate what has happened in the region over the last decade in terms of urbanization and population dispersion. In the early part of the last decade, much of the land conversion from natural resource production to urban uses is occurring in Washington and Clackamas Counties.

The region's housing stock is largely single-family homes. However, the region has a slightly higher percentage of multi-family units than the state as a whole; Multnomah County has the highest percentage (37%). Conversely, the region has a lower percentage of manufactured housing compared to the state as a whole, with the exception of Columbia County. Approximately 53% of housing in Multnomah was built prior to 1970, prior to current seismic and floodplain management standards. In contrast, over 46% of housing in Washington County was built after 1990. All of the region's FIRMs have been modernized or updated within the past decade to more accurately depict flood risk in the region.

2.3.2.3 Hazards and Vulnerability

Droughts

Characteristics

Droughts are uncommon in Region 2. In 1992, the Governor declared a drought for all 36 counties in Oregon. Since 1992, no Governor-declared droughts have occurred in Region 2, however, Region 2 counties received federal drought declarations in 2015.

Even though drought may not be declared as often in Western Oregon as in counties east of the Cascades, when drought conditions do develop in the Willamette Valley, the impacts are widespread and severe when both winter snow and spring/summer rain are low. Reasons for broad and significant impact include:

- Higher population density and growing population in the Willamette Valley;
- Dependence on surface water supplies for many municipalities, agriculture and industries from large flood control reservoirs in the Willamette river system;
- Agriculture is a major industry becoming increasingly dependent on irrigation;
- Increased frequency of toxic algal blooms in the Willamette system reservoirs, resulting in restrictions on use of water from reservoirs for drinking (i.e., for human and animals). Affected waters may not be safe for agricultural irrigation, and other uses; necessitating purchasing and transporting water from alternative sources;
- Since drought is typically accompanied by earlier onset of snowmelt (e.g., during flood control or early storage season), little or no snowmelt runoff is stored until later;
- Earlier start to growing season, before the start of the irrigation season, means that crops may not be irrigated until the irrigation season begins;
- Insufficient number of farm workers available because the growing season began before the workers were scheduled to arrive; and
- Responsibilities to recovering anadromous fish.

These are relatively recent and developing concerns, in particular on livestock and some other agricultural operations, and therefore there is no single comprehensive source or other sources for information to assess economic impacts. Impacts of drought on state-owned facilities related to agriculture would include impacts to research conducted in outdoor settings, such as at extension stations and research farms.

Historic Drought Events

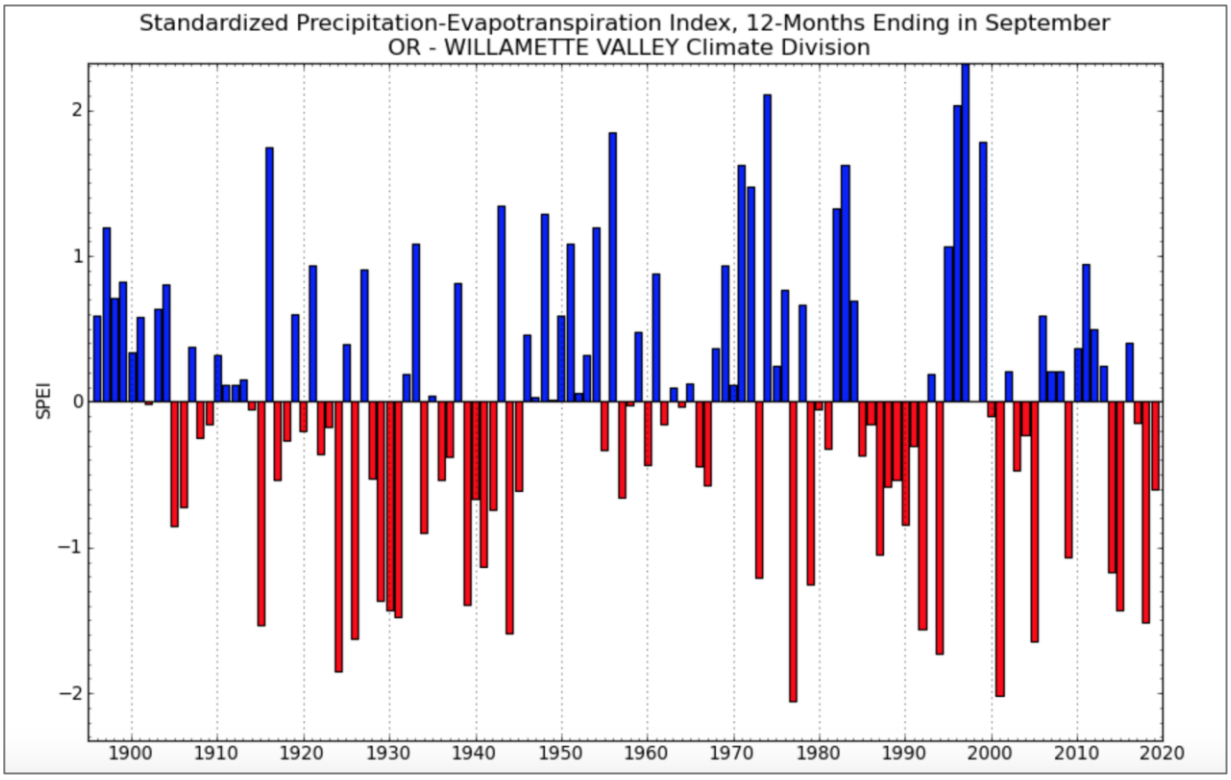
Table 2-215. Historic Droughts in Region 2

Date	Location	Description
1924	statewide	prolonged statewide drought that caused major problems for agriculture
1930	Regions 1–3, 5–7	moderate to severe drought affected much of the state; the worst years in Region 2 were 1928–1930, which kicked off an era of many drier than normal years
1939	statewide	the 1920s and 1930s, known more commonly as the Dust Bowl, were a period of prolonged mostly drier than normal conditions across much of the state and country
1992	statewide, especially Regions 1–4, 8	1992 fell toward the end of a generally dry period, which caused problems throughout the state; the 1992 drought was most intense in eastern Oregon, with severe drought occurring in Region 1
2001	Regions 2–4, 6, 7	the driest water year on record in the Willamette Valley (NOAA Climate Division 2); warmer than normal temperatures combined with dry conditions
2015	statewide	All 36 Oregon counties receive federal drought declarations; No counties in Region 2 received a Governor's declaration.

Sources: Taylor and Hatton (1999); Oregon Secretary of State's Archives Division; NOAA's Climate at a Glance; Western Regional Climate Center's Westwide Drought Tracker http://www.wrcc.dri.edu/wwdt; personal Communication, Kathie Dello, Oregon Climate Service, Oregon State University

Historical drought information can also be obtained from the West Wide Drought Tracker, which provides historical climate data showing wet and dry conditions, using the Standard Precipitation-Evapotranspiration Index (SPEI) that dates back to 1895. **Figure 2-154** shows years where drought or dry conditions affected the Willamette Valley (Climate Division 2). Based on this index, Water Years 1977 and 2001 were extreme drought years for the Willamette Valley. Years with at least moderate drought have occurred 21 times during 1895–2019 (**Table 2-216**).

Figure 2-154. Standard Precipitation-Evapotranspiration Index for Region 2



Drought Severity Scale: -1 to -1.49 = moderate drought; -1.5 to -1.99 = severe drought; -2.0 or less = extreme drought.

Source: West Wide Drought Tracker, https://wrcc.dri.edu/wwdt/time/

Table 2-216. Years with Moderate (<-1), Severe (<1.5), and Extreme (<-2) Drought in Oregon Climate Division 2 according to Standard Precipitation-Evapotranspiration Index

Moderate Drought (SPEI < -1.0)	Severe Drought (SPEI < -1.5)	Extreme Drought (SPEI < -2.0)
1931	1924	1977
1930	1994	2001
2015	2005	
1939	1926	
1929	1944	
1979	1992	
1973	1915	
2014	2018	
1941		
2009		
1987		

Note: Within columns, rankings are from more severe to less severe.

Source: West Wide Drought Tracker, https://wrcc.dri.edu/wwdt/time/

Although not shown here, drought data from Climate Division 4, "the High Cascades," could also be analyzed to show a broader picture of drought impacts in Hazard Regions 2 and 3.

Probability

Table 2-217. Probability of Drought in Region 2

	Columbia	Clackamas	Multnomah	Washington
Probability	VL	VL	VL	VL

Source: OWRD, DLCD

Despite impressive achievements in the science of climatology, estimating drought probability and frequency continues to be difficult. This is because of the many variables that contribute to weather behavior, climate change and the absence of long historic databases.

A comprehensive risk analysis is needed to fully assess the probability and impact of drought to Oregon communities. Such an analysis could be completed statewide to analyze and compare the risk of drought across the state.

A review of Governor drought declarations indicates that Region 2 has received a drought declaration in only 3% of the years since 1992. The probability of drought in Region 2 is therefore very low.

Climate Change

Even though drought is infrequent in the northern Willamette Valley, climate models project warmer, drier summers for Oregon, including Region 2. These summer conditions coupled with projected decreases in mid-to-low elevation mountain snowpack due to warmer winter temperatures increases the likelihood that Region 2 would experience increased frequency of one or more types of drought under future climate change. In Region 2, climate change would result in increased frequency of drought due to low spring snowpack (very likely, >90%), low summer runoff (likely, >66%), and low summer precipitation and low summer soil moisture (more likely than not, >50%). In addition, Region 2, like the rest of Oregon is projected to experience an increase in the frequency of summer drought conditions as summarized by the standard precipitation-evaporation index (SPEI) due largely to projected decreases in summer precipitation and increases in potential evapotranspiration (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

Vulnerability

Table 2-218. Local Assessment of Vulnerability to Drought in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	L	L	—	M

Source: Most recent local hazard vulnerability analyses (Table 2-4)

Table 2-219. State Assessment of Vulnerability to Drought in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	VL	VL	M	VL

Source: OWRD, DLCD

The impacts of drought on agriculture in Region 2 can be severe and widespread. Because these impacts are recent and developing, there is no single comprehensive source or other sources for information to assess economic impacts locally or at the state level or to state assets. Oregon has yet to undertake a comprehensive, statewide analysis to identify which communities are most vulnerable to drought.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

Multnomah County's social vulnerability score is moderate, while those of the other counties are very low. This means that any natural hazard would have a moderate impact on Multnomah County's population and little to no impact on the other counties' populations. None of the Region 2 counties is considered most vulnerable to drought.

State-Owned/Leased Buildings and Critical Facilities and Local Critical Facilities

The value of state-owned and leased buildings and critical facilities in Region 2 is approximately $1,134,896,000 representing the total potential for loss of state assets due to drought. The value of locally owned critical facilities is $10,224,815,000. Because drought, while uncommon in Region 2, could impact the entire region, these figures together represent the maximum potential loss to state assets and local critical facilities due to drought. Because the state is self-insured, FEMA funds are rarely used to cover damage to state assets from natural hazards. According to Department of Administrative Services records, only one loss of over $111,000 to a

state facility was recorded in Region 2 since the beginning of 2015. It was not caused by drought.

Risk

Table 2-220. Risk of Drought in Region 2

	Columbia	Clackamas	Multnomah	Washington
Risk	VL	VL	L	VL

Source: OWRD, DLCD

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life. Based on very low probability of drought and very low vulnerability except in Multnomah County, Region 2 is generally considered to be at very low risk from drought; Multnomah County is at low risk.

Earthquakes

Characteristics

The geographic position of Region 2 makes it susceptible to earthquakes from four sources: (a) the off-shore Cascadia Fault Zone, (b) deep intraplate events within the subducting Juan de Fuca plate, (c) shallow crustal events within the North America Plate, and (d) earthquakes associated with renewed volcanic activity. All have some tie to the subducting or diving of the dense, oceanic Juan de Fuca Plate under the lighter, continental North America Plate. Stresses occur because of this movement and there appears to be a link between the subducting plate and the formation of volcanoes some distance inland from the off-shore fault zone.

Region 2 has had at least seven crustal earthquakes of magnitude 4 or greater since 1877. The region's largest earthquakes were the 1877 M5.3 and the 1962 M5.2. In addition, the region has been shaken historically by crustal and intraplate earthquakes and prehistorically by subduction zone earthquakes centered outside the area. There is good reason to believe that the most devastating future earthquakes would probably originate along shallow crustal faults in the region and along the Cascadia Fault Zone. Deep-seated intraplate events, as occurred near Olympia, Washington in 1949 and 2001, could generate magnitudes as large as M7.5, but none have been identified in the region's historical or prehistoric records.

Earthquakes produced through volcanic activity could possibly reach magnitudes of 5.5. The 1980 Mount St. Helens eruption was preceded by a magnitude 5.1 earthquake. Despite the fact that Cascade volcanoes are some distance away from the major population centers in Region 2, earthquake shaking and secondary earthquake-related hazards such as lahars could cause major damage to these centers.

The City of Portland has been built on three identified crustal faults that stretch the length of Portland: the Oatfield Fault west of the northwest hills; the East Bank Fault, traversing the Willamette into Oregon City and the Portland Hills Fault which runs parallel to Forest Park into downtown Portland. Each of these crustal faults is capable of generating large earthquakes of M6.0–6.8.

Historic Earthquake Events

Table 2-221. Significant Earthquakes Affecting Region 2

Date	Location	Magnitude (M)	Description
Approximate Years: 1400 BCE*, 1050 BCE, 600 BCE, 400, 750, 900	Offshore, Cascadia Subduction Zone (CSZ)	probably 8.0–9.0	these are the mid-points of the age ranges for these six events
Jan. 1700	CSZ	about 9.0	generated a tsunami that struck Oregon, Washington, and Japan; destroyed Native American villages along the coast
Oct, 1877	Portland area, Oregon	5.2	two events in one day; affected area: 41,000 sq km; damage: chimney damage
Feb. 1892	Portland area, Oregon	5.0	no major damage occurred
Dec. 1941	Portland area, Oregon	4.5	felt by most Portland residents; damage: shattered windows and cracked plaster (Hillsboro and Sherwood)
Apr. 1949	Olympia, Washington	7.1	damage: in Washington and NW Oregon
Dec. 1953	Portland area, Oregon	4.5	cracked plaster and caused objects to fall (Portland)
Nov. 1961	Portland area, Oregon	5.0	principal damage: from cracked plaster
Nov. 1962	Portland area, Oregon	5.5	shaking: up to 30 seconds; damage: chimneys cracked, windows broken, furniture moved
Dec. 1963	Portland area, Oregon	4.5	damage: books and pictures fell (Plains)
Mar. 25, 1993	Scotts Mills, Oregon	5.6	FEMA-985-DR-Oregon; center: Mt. Angel-Gales Creek fault; damage: $30 million (including Oregon Capitol Building in Salem)
Feb. 2001	Nisqually, Washington	6.8	felt in the region, no damage reported

Note: No significant earthquakes have affected Region 2 since February 2001.

*BCE: Before Common Area.

Sources: Wong & Bott (1995); Pacific Northwest Seismic Network, https://pnsn.org/

Probability

Table 2-222. Assessment of Earthquake Probability in Region 2

	Columbia	Clackamas	Multnomah	Washington
Vulnerability	H	VH	VH	VH

Source: DOGAMI, 2020

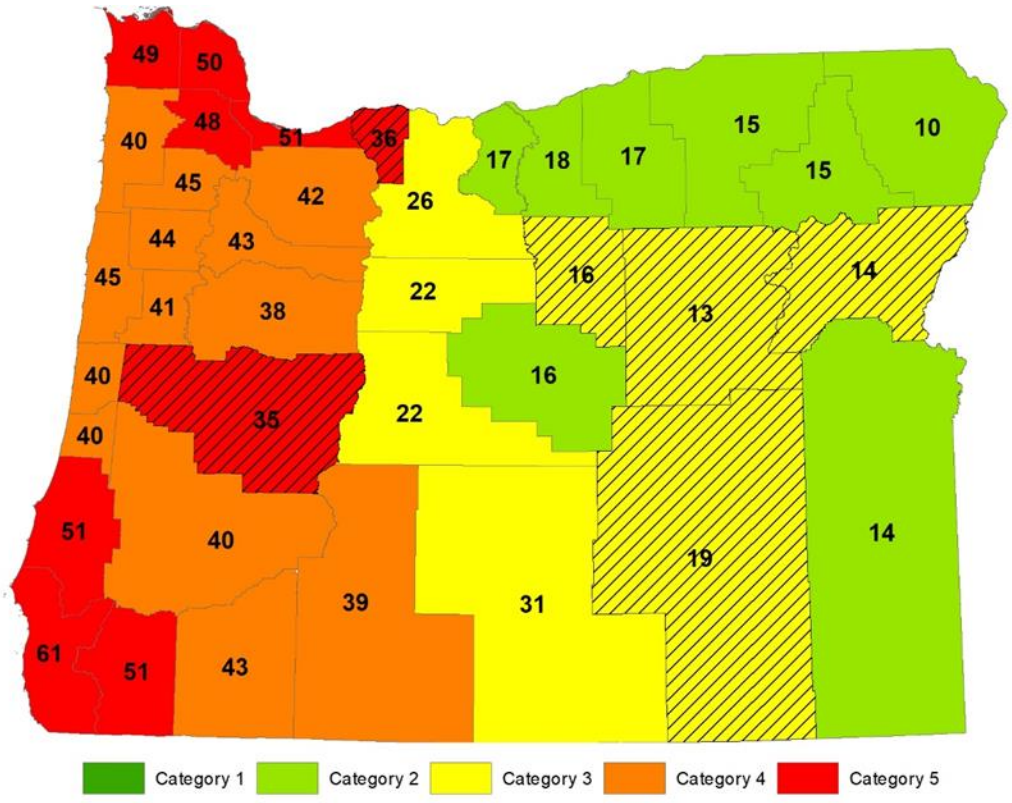
The probability of damaging earthquakes varies widely across the state. In Region 2 the hazard is dominated by Cascadia subduction earthquakes originating from a single fault with a well-understood recurrence history.

DOGAMI has developed a new probability ranking for Oregon counties that is based on the average probability of experiencing damaging shaking during the next 100 years, modified in some cases by the presence of newly discovered faults. If a county had newly discovered faults that were within 10-12 miles of a community, the category defined by the average probability of damaging shaking was increased one step.

- Category 1 100-year probability < 10%
- Category 2 100 year probability 10-20%
- Category 3 100 year probability 21-31%
- Category 4 100 year probability 32-45%
- Category 5 100 year probability > 45%

The probability levels for Baker, Grant, Harney, Hood River, and Wheeler Counties, and the non-coastal portion of Lane County were all increased in this way. The results of this ranking are shown in **Figure 2-155**.

Figure 2-155. 2020 Oregon Earthquake Probability Ranking Based on Mean County Value of the Probability of Damaging Shaking and Presence of Newly Discovered Faults



Note: Counties with hatching had their probability category increased one step due to newly discovered faults.

Source: DOGAMI, 2020

For Oregon west of the crest of the Cascades, the CSZ is responsible for most of the hazard shown in **Figure 2-155**. The paleoseismic record includes 18 magnitude 8.8–9.1 megathrust

earthquakes in the last 10,000 years that affected the entire subduction zone. 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%.

Vulnerability

Table 2-223. Local Assessment of Vulnerability to Earthquakes in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	H	H	H	H

Source: Source: Most recent local hazard vulnerability analyses (Table 2-4)

Table 2-224. State Assessment of Vulnerability to Earthquakes in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	VL	VL	M	L

Source: OWRD, DLCD

Table 2-225 shows the number of school and emergency response buildings surveyed in each county with their respective rankings.

Table 2-225. School and Emergency Response Building Collapse Potential in Region 2

County	Level of Collapse Potential			
	Low (< 1%)	Moderate (>1%)	High (>10%)	Very High (100%)
Clackamas	123	48	40	6
Columbia	19	13	15	3
Multnomah	68	118	116	29
Washington	81	69	80	6

Source: Lewis (2007), available at http://www.oregongeology.org/sub/projects/rvs/default.htm.

The Oregon Department of Geology and Mineral Industries (DOGAMI) developed two earthquake loss models for Oregon based on the two most likely sources of seismic events: (a) the Cascadia Subduction Zone (CSZ), and (b) combined crustal events (500-year model). Both models use Hazus, a software program developed by the Federal Emergency Management Agency (FEMA), as a means of determining potential losses from earthquakes. The CSZ event is based on a potential M8.5 earthquake generated off the Oregon coast. The model does not take into account a tsunami, which probably would develop from such an event. The 500-year crustal model does not look at a single earthquake (as in the CSZ model); it encompasses many faults. Neither model takes unreinforced masonry buildings into consideration.

DOGAMI investigators caution that the models contain a high degree of uncertainty and should be used only for general planning and policy making purposes. Despite their limitations, the

models do provide some approximate estimates of damage and are useful to understand the relative relationships between the counties. Results are found in **Table 2-226**.

Metro (the elected regional government that serves more than 1.3 million residents in Clackamas, Multnomah, and Washington Counties and the 24 cities in the Portland Metro area) has likewise evaluated earthquake potential and losses for its three-county area. The analysis included an inventory of over 50,000 commercial and multi-family dwellings at risk. Single-family dwellings within the Metro boundary were not evaluated because their structural similarity (Metro, 1998).

Other useful resources for planning for earthquakes include the following:

Maps of earthquake hazard areas: DOGAMI has mapped all of the Region 2 counties and has statewide GIS earthquake hazard layers available (Madin & Burns, 2013).

Map of critical facilities vulnerable to hazards: DOGAMI has developed these maps for all Region 2 counties.

Environmental geology maps: DOGAMI has developed these maps for all Region 2 counties.

Nuclear energy/hazardous waste sites inventories: No Region 2 counties have nuclear facilities.

Table 2-226. Projected Dollar Losses in Region 2, Based on an M8.5 Subduction Event and a 500-Year Model

	M8.5 CSZ Event				500-Year Model[1]			
	Multnomah	Washington	Columbia	Clackamas	Multnomah	Washington	Columbia	Clackamas
Injuries	1,521	555	36	128	8,659	2,910	150	1,402
Deaths	28	10	0	2	186	62	3	29
Displaced households	2,803	2,062	94	426	13,777	7,666	326	2,525
Economic losses for buildings[2]	$1.9 b	$931 m	N/A	$316 m	$9.2 b	$3.8 b	$267 m	$2.1 b
Operational "day after" the quake								
Fire Stations	78%	66%	unknown	84%	N/A[3]	*	*	*
Police Stations	76%	64%	45%	84%	N/A	*	*	*
Schools	81%	64%	63%	84%	*	*	*	*
Bridges	94%	79%	82%	90%	*	*	*	*
Economic losses to								
Highways	$21 m	$15 m	$2 m	$6 m	$437 m	$61 m	$10 m	$74 m
Airports	$2 m	$5 m	$2 m	$3 m	$12 m	$23 m	$8 m	$32 m
Communications	$3 m	$752,000	$97,000	$232,000	$31 m	$4 m	$950,000	$4 m
Debris generated (thousands of tons)	1,598	763	57	237	6,745	2,817	184	1,588

Notes: "b" is billion; "m" is million

[1] 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).

[2] "…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 & Clark (1999)

State-Owned/Leased Buildings and Critical Facilities and Local Critical Facilities

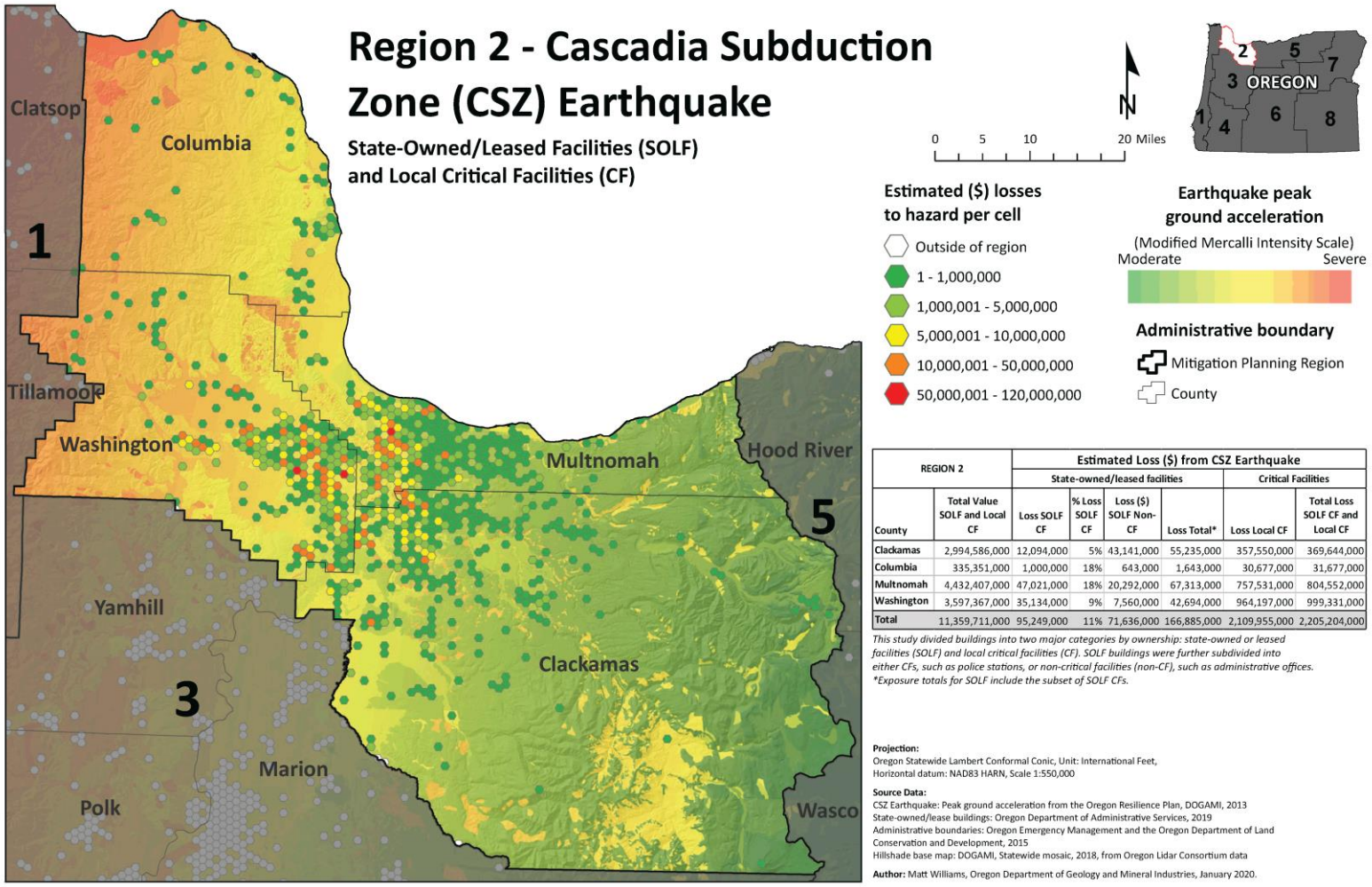
For the 2020 vulnerability assessment, DOGAMI used Hazus-MH to estimate potential loss from a Magnitude 9 Cascadia Subduction Zone (CSZ) event in Region 2. The analysis incorporated information about the earthquake scenario (such as coseismic liquefaction and landslide potential), as well as building characteristics (including the seismic building code and building material). The results of the analyses are provided as a loss estimation (the building damage in dollars) and as a loss ratio (the loss estimation divided by the total value of the building) reported as a percentage at the county level.

DOGAMI used the loss ratio to formulate a separate relative vulnerability score for the state buildings, state critical facilities, and local critical facilities data sets. The percentage of loss for each county was statistically distributed into 5 categories (Very Low, Low, Moderate, High, or Very High).

In Region 2, a CSZ event could cause a potential loss of almost $167M in state building and critical facility assets. Columbia County's potential loss is the least, over $1.6M. The other counties' potential losses range from $42.6M to $67.3M with the greatest potential loss in Multnomah County.

There is a far greater potential loss in local critical facilities: over $2.1B. Washington County stands to lose the most, about 46% of that total, followed by Multnomah County with about 36% and Clackamas County with about 17%. Again Columbia County's potential loss is the least, at 3%. **Figure 2-156** illustrates the potential loss to state buildings and critical facilities and local critical facilities from a CSZ event.

Figure 2-156. State-Owned/Leased Facilities (SOLF) and Local Critical Facilities (CF) in a Cascadia Subduction Zone Earthquake Hazard Zone in Region 2.High-resolution, full-size image linked from Appendix 9.1.26.



REGION 2		Estimated Loss ($) from CSZ Earthquake					
		State-owned/leased facilities				Critical Facilities	
County	Total Value SOLF and Local CF	Loss SOLF CF	% Loss SOLF CF	Loss ($) SOLF Non-CF	Loss Total*	Loss Local CF	Total Loss SOLF CF and Local CF
Clackamas	2,994,586,000	12,094,000	5%	43,141,000	55,235,000	357,550,000	369,644,000
Columbia	335,351,000	1,000,000	18%	643,000	1,643,000	30,677,000	31,677,000
Multnomah	4,432,407,000	47,021,000	18%	20,292,000	67,313,000	757,531,000	804,552,000
Washington	3,597,367,000	35,134,000	9%	7,560,000	42,694,000	964,197,000	999,331,000
Total	11,359,711,000	95,249,000	11%	71,636,000	166,885,000	2,109,955,000	2,205,204,000

This study divided buildings into two major categories by ownership: state-owned or leased facilities (SOLF) and local critical facilities (CF). SOLF buildings were further subdivided into either CFs, such as police stations, or non-critical facilities (non-CF), such as administrative offices.
**Exposure totals for SOLF include the subset of SOLF CFs.*

Projection:
Oregon Statewide Lambert Conformal Conic, Unit: International Feet,
Horizontal datum: NAD83 HARN, Scale 1:550,000

Source Data:
CSZ Earthquake: Peak ground acceleration from the Oregon Resilience Plan, DOGAMI, 2013
State-owned/lease buildings: Oregon Department of Administrative Services, 2019
Administrative boundaries: Oregon Emergency Management and the Oregon Department of Land Conservation and Development, 2015
Hillshade base map: DOGAMI, Statewide mosaic, 2018, from Oregon Lidar Consortium data

Author: Matt Williams, Oregon Department of Geology and Mineral Industries, January 2020.

Source: DOGAMI

Historic Resources

Of the 23,605 historic resources in Region 2, only 335 are in an area of high or very high liquefaction potential. Over half, 53%, are located in Clackamas County. Almost all of the rest, 42%, are located in Washington County. Many more (68%) of Region 2's historic resources are located in areas of high or very high potential for ground shaking amplification. Multnomah County is home to 62% while Clackamas and Washington Counties are home to 20% and 17% respectively.

Archaeological Resources

Nine hundred forty-eight archaeological resources are located in earthquake hazard areas in Region 2. No archaeological resources listed on the National Register of Historic Places and only three eligible for listing are located in areas of high earthquake hazards. Four have been determined not eligible, and 67 have not been evaluated. Two of the three found eligible are in Clackamas County and one is in Columbia County. Overall, most of the archaeological resources in earthquake hazard areas in Region 2 are in Clackamas County followed by Multnomah County.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

For the 2020 vulnerability assessment, DLCD combined the social vulnerability scores with the vulnerability scores for state buildings, state critical facilities, and local critical facilities to calculate an overall vulnerability score for each county. According to this limited assessment, Multnomah County is the most vulnerable in Region 2 with a moderate rating. Washington County has a low rating and Clackamas and Columbia Counties both have a low rating. Washington County's "low" overall vulnerability score is higher than the "very low" scores of Clackamas and Columbia Counties due to greater vulnerability of local critical facilities.

Seismic Lifelines

"Seismic lifelines" are the state highways ODOT has identified as most able to serve response and rescue operations, reaching the most people and best supporting economic recovery. The process, methodology, and criteria used to identify them are described in Section **2.1.6, Seismic Transportation Lifeline Vulnerabilities**, and the full report can be accessed at Appendix **9.1.16**, *Statewide Loss Estimates: Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification* (OSLR). According to that report, seismic lifelines in Region 2 have the following vulnerabilities.

The following geographic zones identified in the OSLR are located within Region 2:

- *Portland Metro Geographic Zone:* In addition to encompassing the largest population concentration in the state, this zone contains extensive facilities (such as transportation, communication, and fuel depots) that are critical to statewide earthquake response and recovery. For these reasons, it has a higher concentration of lifeline routes than the other geographic zones and redundant Tier 1 crossings of the Willamette River.

  The Tier 1 system (highest priority roadway) in the Portland Metro Geographic Zone consists of the following corridors:

  - I-5, excluding the section between the northern and southern I-405 interchanges,
  - I-405,
  - I-205, and
  - OR-99 W from I-5 to OR-217.

  The Tier 2 system (second highest priority roadway) in the Portland Metro Geographic Zone consists of three access corridors:

  - I-84,
  - I-5 between the northern and southern I-405 interchanges, and
  - US-26 from OR-217 to I-405.

  The Tier 3 system in the Portland Metro Geographic Zone consists of the following corridors:

  - OR-217,
  - US-26 from I-5 to I-205, and
  - OR-43.

- *Cascades Geographic Zone:* This region also includes part of the OSLR Cascades Zone. The recommended seismic lifelines for this region include three crossings of the Cascades from western to central Oregon that have areas vulnerable to landslides and may be subject to damage from ground shaking. These routes connect the highly seismically impacted western portion of the state to the less seismically impacted central portion of the state. The Tier 1 system in the Cascades Geographic Zone that serves this region is I-84. The Tier two routes in the Cascades Geographic Zone that serve this region are OR-212 and US-26. There are no corridors designated as Tier 3 in the Cascades Geographic Zone.

REGIONAL IMPACT.

- Ground shaking: In the Northern Willamette Valley / Portland Metro Region, the level of damage from ground shaking levels depends upon its intensity and duration. Unreinforced structures, roadbeds, and bridges will be damaged to varying extents, and it is expected that river crossings and areas with limited surface transportation alternatives will isolate some neighborhoods hindering rescue and recovery activities. There are also several localized faults in the region about which not much is known; it is possible that a major CSZ event could activate local faults.
- Landslides and rockfall: Many roadways in the area are cut into or along landslide prone features. Removal of slide and rockfall material is an ongoing responsibility of

ODOT Maintenance crews in hilly areas and the parts of the Cascades and Coast Regions that fall within Region 2. A major CSZ event may increase landslide and rockfall activities in this region and may reactivate ancient slides that are currently inactive. In the Lower Columbia River basin, ground shaking may change the shipping channel and other features.

- Tsunamis: There may be tsunami impacts in the Lower Columbia area, with variables including the size and force of the tsunami, whether jetties hold up to the tsunami and water levels in the river. Damage to ports, shipping channels, water-dependent uses, and other low lying areas is possible.
- Liquefaction: 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 in this region.

REGIONAL LOSS ESTIMATES. Highway-related losses include disconnection from supplies and replacement inventory, and the loss of tourists and other customers who must travel to do business with affected businesses.

MOST VULNERABLE JURISDICTIONS. Columbia and Multnomah Counties are the most vulnerable to water related effects, particularly liquefaction. The whole region, including Clackamas and Washington Counties, is likely to have significant impacts related to ground shaking. Landslides are likely in some hilly areas. Vulnerabilities with both regional and statewide transportation impacts in Multnomah County, Portland, and the Portland Metro area include 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; and bridge or bridge approach failures across both the Willamette and Columbia Rivers.

Table 2-227. Risk of Earthquake Hazards in Region 2

	Columbia	Clackamas	Multnomah	Washington
Risk	L	M	VH	M

Source: DOGAMI, DLCD

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life. The 2020 risk assessment combined the earthquake probability with the vulnerability assessment to arrive at a composite risk score. According to the 2020 risk assessment, only Multnomah County is at very high risk from earthquakes.

Extreme Heat

Characteristics

Climate conditions in the Willamette Valley are described as Mediterranean, with rainy winters and warm dry summers. Historically, extreme heat and heat waves have not been common, but days above 90°F occur nearly every year. Portland has an average of about 10 days per year above 90°F. The frequency of prolonged periods of high temperatures is expected to increase.

Historic Extreme Heat Events

Table 2-228. Historic Extreme Heat Events in Region 2

Date	Location	Notes
July 26–28, 1998	Region 2	A three-day heat wave brought record high temperatures to western Oregon. The high temperature of 99 degrees at Portland International Airport on the 26th eclipsed the previous record for that date of 98 set in 1988, and the high of 101 on the 28th broke the previous daily record of 99 set in 1973. In Eugene, the high of 102 on the 26th broke the previous daily record of 101 set in 1988, and the 105 degrees on the 27th tied the record high for the month of July. There was one reported death from heat-related illness.
June 24–26, 2006	Region 1–3, 5	A broad upper ridge of unusually high height coupled with a thermally induced surface trough of low pressure lingered over the Pacific Northwest for several days. This pattern resulted in persistent offshore flow, and therefore many days of record-smashing high temperatures. Portland International Airport had 101 degrees on June 26 breaking the old record at 94 degrees in 1987.
July 20-24, 2006	Region 1–3, 5, 7	An unusually strong ridge of high pressure brought several days of record breaking hot and humid weather to NW Oregon. Many cities in Oregon saw record-breaking daily high temperatures for multiple days in a row. On July 21, Portland reported 104°F.
June 28–30, 2008	Region 2, 3, 5, 7	An upper level ridge and thermal trough across the Pacific Northwest produced temperatures above 100 degrees for two consecutive days breaking records in many locations. Two people died of heat-related illness.
Summer 2015	Region 2, 3	A series of heat waves struck western Oregon in the summer of 2015, Oregon's hottest year on record, driven by a strong, persistent upper level ridge over the region. Heat waves occurred June 7–9, June 26–28, July 1–5, July 28–30, and August 18–19. Heat-related illnesses and deaths were markedly greater during these heat wave periods and cooling shelters were opened. High temperatures were 10–20°F above normal and overnight low temperatures were also unseasonably warm. Many locations broke both daytime high temperature records as well as warm overnight low temperature records.
August 11–14, 2016	Region 2	Ridge of high pressure lead to hot temperatures across Northwest Oregon. Temperatures in the upper 80s to mid 90s lead to people seeking relief at local rivers. Two river drownings were reported in the Greater Portland Metro area during this heat event.
August 25-26, 2016	Region 1, 2	Ridge of high pressure and offshore winds brought temperatures along the North Oregon Coast up into the mid 80s to mid 90s on August 25. News reported 8 runners were taken to the hospital with heat-related injuries during the Hood-to-Coast relay through Portland.
May 22-23, 2017	Region 2	Ridge of high pressure brought a couple days of warm weather. Temperatures climbed up into the upper 80s to low 90s in many locations across the area. Early season heat led people to seek relief in local rivers and lakes. While air temperatures were warm, river and lake temperatures were still cold, leading to two drownings across the area.
August 1–4, 2017	Region 2–4, 6	Excessive Heat Event: Strong high pressure brought record breaking heat to many parts of southwest, south central, and northwest Oregon. Region 2–3: The record-breaking heat led people to seek relief at local rivers. Two people drowned while swimming.

Date	Location	Notes
July 12–17, 2018	Region 2, 3, 4	Region 2–3: High pressure over the region led to a stretch of hot day July 12 through July 17th. Hot temperatures led people to cool off in local rivers. There were two drownings recorded on July 16 and July 18. Temperatures on July 16th near the Sandy River in Troutdale got up to 98 degrees

Source: https://www.ncdc.noaa.gov/stormevents

Probability

The relative probability of extreme heat was determined by dividing the counties by quintiles based on historic and projected future frequency of days with heat index above 90°F (as shown in **Figure 2-62**). Counties in the bottom quintile had the lowest frequency of days with heat index above 90°F relative to the rest of the state and were given a score of 1 meaning "very low." Region 2 relative probability rankings are shown in **Table 2-229**.

The probability of extreme heat events in Multnomah County is moderate; in Washington County low; and in Clackamas and Columbia Counties very low. It is important to note that in counties with "very low" probability, extreme heat is rare, yet frequency is expected to increase due to climate change.

Table 2-229. Probability of Extreme Heat in Region 2

	Clackamas	Columbia	Multnomah	Washington
Probability	VL	VL	M	L

Source: Oregon Climate Change Research Institute, https://climatetoolbox.org/

Climate Change

It is *extremely likely* (>95%) that the frequency and severity of extreme heat events will increase over the next several decades across Oregon due to human-induced climate warming (*very high confidence*). Extreme temperatures are relatively rare in Region 2, but are projected to increase under future climate change. **Table 2-230** lists the number of days exceeding the heat index of 90°F in the historical baseline and future mid-21st century period under RCP 8.5 for counties in Region 2.

Table 2-230. Annual Number of Days Exceeding Heat Index ≥ 90°F for Region 2 Counties

County	Historic Baseline	2050s Future
Clackamas	2	15
Columbia	2	16
Multnomah	4	24
Washington	4	21

Note: Numbers represent the multi-model mean from 18 CMIP5 climate models

Source: Oregon Climate Change Research Institute using data from the Northwest Climate Toolbox, https://climatetoolbox.org/.

Vulnerability

Vulnerability of Oregon counties to extreme heat is discussed in Section 2.2.1.3, **Extreme Heat**. Vulnerability is defined as the combination of sensitivity to extreme heat and level of adaptive capacity in response to extreme heat.

For this assessment, sensitivity to extreme heat events was defined using the Center for Disease Control and Prevention (CDC) 2016 Social Vulnerability Index, https://svi.cdc.gov/data-and-tools-download.html.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

Adaptive capacity to extreme heat is defined here as percent of homes with air conditioning; however, the authors note that this measure has its flaws. First, it assumes that people who have access to cooling systems are able to afford to use them. Second, the data only includes single-family homes, which omits populations living in multi-family housing or who are house-less.

Because extreme heat is relatively rare in Region 2 ("low" probability), many people may not be accustomed or prepared when an extreme heat event occurs ("moderate" adaptive capacity). In Cooling Zones 1 and 2, which include Region 2, just over half of single-family homes have air-conditioning (https://neea.org/img/uploads/Residential-Building-Stock-Assessment-II-Single-Family-Homes-Report-2016-2017.pdf).

The relative vulnerability of Oregon counties to extreme heat was determined by adding the rankings for sensitivity (social vulnerability) and adaptive capacity (air conditioning). The sum of the two components ranged from 1 to 10. Rankings were determined as follows: total vulnerability scores of 1-2 earned a ranking of 1 (very low); scores of 3-4 earned a ranking of 2 (low); scores of 5-6 earned a ranking of 3 (moderate); scores of 7-8 earned a ranking of 4 (high); and scores of 9-10 earned a ranking of 5 (very high). Rankings for NHMP regions are averages of the counties within a region and rounded to the nearest whole number.

Table 2-231 displays the vulnerability rankings as well as rankings for sensitivity and adaptive capacity for each county in NHMP Region 2. Table 2-232 provides the summary descriptors of Region 2's vulnerability.

Combining sensitivity and adaptive capacity, Region 2's relative vulnerability to extreme heat is "Low." Only Multnomah County's relative vulnerability is "moderate." None of the Counties in Region 2 is most vulnerable to extreme heat.

Table 2-231. Relative Vulnerability Rankings for Region 2 Counties

County	Sensitivity	Adaptive Capacity	Vulnerability
Region 2	**2**	**3**	**2**
Clackamas	1	3	2
Columbia	1	3	2
Multnomah	3	3	3
Washington	1	3	2

Source: Oregon Climate Change Research Institute

Table 2-232. Vulnerability to Extreme Heat in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	L	L	M	L

Source: Oregon Climate Change Research Institute

Region 1 counties did not rank vulnerability to extreme heat.

Similar to drought, prolonged elevated temperatures pose risks to agriculture, involving health and welfare to farmers, farm workers, crops and livestock. Higher temperatures, crops, livestock and humans require more water. For example, on average, for each degree Fahrenheit increase in temperature, plants use 2.5% - 5% more water. High temperature and insufficient water stunt plant growth and cause areas of crops to wither.

Some livestock, especially dairy cattle, are sensitive to heat. Milk production decreases and susceptibility to death increases during and for some time after a heat wave. Since risks to human health and welfare are also elevated during heat waves, Oregon and the federal government have regulations and guidelines to help prevent injury to those who work on farms.

Similar to drought, impacts of extreme heat on state-owned facilities related to agriculture may include impacts to research conducted in outdoor settings, such as at extension stations and research farms. Since heat waves are more recent to the Willamette Valley, appropriate data have not been collected to assess economic impacts to the state.

State-Owned/Leased Buildings and Critical Facilities and Local Critical Facilities

The value of state-owned and leased buildings and critical facilities in Region 2 is approximately $1,134,896,000 representing the total potential for loss of state assets due to drought. The value of locally owned critical facilities is $10,224,815,000. Because extreme heat, while

relatively uncommon in Region 2, could impact the entire region, these figures together represent the maximum potential loss to state assets and local critical facilities due to extreme heat. Because the state is self-insured, FEMA funds are rarely used to cover damage to state assets from natural hazards. According to Department of Administrative Services records, only one loss of over $111,000 to a state facility was recorded in Region 2 since the beginning of 2015. It was not caused by extreme heat.

Risk

With respect to extreme heat, risk is defined as the combination of the probability of extreme heat events, sensitivity to extreme heat, and level of adaptive capacity in response to extreme heat.

The total relative risk of Oregon counties to extreme heat was determined by adding the rankings for probability and vulnerability (sensitivity and adaptive capacity). The sum of the two components ranged from 1 to 10. Rankings were determined as follows: total risk scores of 1–2 earned a ranking of 1 ("very low"); scores of 3–4 earned a ranking of 2 ("low"); scores of 5–6 earned a ranking of 3 ("moderate"); scores of 7–8 earned a ranking of 4 ("high"); and scores of 9–10 earned a ranking of 5 ("very high"). Rankings for NHMP regions are averages of the counties within a region and rounded to the nearest whole number.

Table 2-233 displays the relative risk ranking as well as rankings for probability and vulnerability for each county in NHMP Region 2. Table 2-234 provides the summary descriptors of Region 2's risk to extreme heat.

Combining probability and vulnerability, Region 2's total relative risk to extreme heat is "Low."

Table 2-233. Risk Rankings for Region 2 Counties

County	Probability	Vulnerability	Risk
Region 2	**2**	**2**	**2**
Clackamas	1	2	2
Columbia	1	2	2
Multnomah	3	3	3
Washington	2	2	2

Source: Oregon Climate Change Research Institute

Table 2-234. Risk of Extreme Heat in Region 2

	Clackamas	Columbia	Multnomah	Washington
Risk	L	L	M	L

Source: Oregon Climate Change Research Institute

Floods

Characteristics

The northern Willamette Valley (including the Portland Metro area) has a lengthy flood history with significant floods occurring about every 7-15 years (**Table 2-235**). The Willamette and Columbia Rivers have produced numerous floods, some of which are shown in **Table 2-235**. Most Willamette River flooding is a winter phenomenon. The common pattern includes the accumulation of heavy wet snow in higher elevations followed by a mild, rainy, weather system. The resulting snowmelt on saturated or frozen ground sometimes produces devastating flood conditions. These conditions would be worse were it not for many dams (used for, among other purposes, flood control) on the upper reaches of the Willamette and some of its tributaries.

Clackamas County is the third most populated county in the state, with nearly all development concentrated in the western half of the county, downstream from significant sources of mountain runoff.

Columbia County, smaller in area and less populated than Clackamas County, receives more annual rainfall and, as a result, has a denser stream network. The City of Vernonia suffered extensive flooding in 2007 resulting in damage to over 300 buildings. Mitigation activities in Vernonia, including relocation of the K–12 school buildings, following the 2007 flood event have significantly reduced damage potential in this small city.

The Columbia River Estuary is the second largest river in the United States and the largest river to flow into the eastern North Pacific. Columbia River floods usually occur in the early summer and are associated with seasonal runoff from melting snow. Although unusually extreme, the Vanport Flood (1948) provides an example of such an event. The 20-day flood was the greatest single disaster in the recorded history of the Columbia River Basin. The toll was 32 dead and 7 missing in the Portland area. Flooding occurred when the Columbia River broke through a dike surrounding the community of Vanport and forced 50,000 people to evacuate their homes. Economic losses reportedly exceeded $100 million. Vanport, a Vancouver-Portland suburban community and the largest public housing project ever built in the United States, was not rebuilt. Prolonged winter rain, debris dams, and breeched dikes have produced flood conditions at several Columbia County locations. Tidal influences are observed on the Columbia River inland to the Bonneville Dam and on the Willamette in Portland.

A common Willamette Valley phenomenon involves tributary stream backup during periods of high water. When tributary streams cannot enter swollen main stem rivers during periods of high water, tributary streams are forced out of their banks. During the February 1996 flood, dams controlled Columbia River flows. This allowed the Willamette River to enter the Columbia, averting flooding in downtown Portland, but other streams produced widespread flooding throughout the region. **Table 2-236** summarizes the sources of flooding for each of the major rivers in the region.

All Region 2 counties have Flood Insurance Rate Maps (FIRMs) depicting the extent of the 1% ("100-year") flood. The FIRM maps were issued as follows:

- Clackamas County, June 7, 2008 with some panels issued November 26, 2010 and January 18, 2019 to correct errors or omissions;

- Multnomah County, November 19, 2004, June 17, 2008 and December 18, 2009 with some panels issued January 18, 2019 and February 1, 2019 to correct errors or omissions;
- Washington County, October 19, 2004, June 17, 2008, November 26, 2010 and November 4, 2016; and
- Columbia County, November 2010.

Historic Flood Events

Table 2-235. Significant Historic Floods in Region 2

Date	Location	Description	Type of Flood
Dec. 1861	coastal rivers	the "Great Flood;" largest flood of known magnitude on the Willamette River; every town on the river was flooded or washed away; widespread damage	rain on snow and snow melt
Dec. 1862	Willamette River Basin	widespread flooding	rain on snow
Jan. 1881	Willamette Basin	Lane, Linn, Benton, Marion, Polk, Yamhill, Clackamas, Multnomah Counties	
Feb. 1890	Willamette Basin	second largest flood of known magnitude; water levels in Portland: 22.3 ft	rain on snow
June 1894	main stem Columbia	largest flood ever observed on the river; current small in Portland; little damage	snow melt
June 1913	Columbia		
Jan. 1923	Willamette and Columbia Rivers	rain and mild weather; widespread damage to roads and railroads	rain on snow
May 1928	Columbia		
Mar. 1931	Umatilla, Sandy, Clackamas, and Santiam		Mar. 1931
Dec. 1937	Willamette Basin	considerable flooding; landslides	rain on snow
Dec. 1945	Willamette Basin / NW Oregon	very warm temperatures; considerable flood damage	rain on snow
Dec. 1946	Willamette, Clackamas, Luckiamute, and Santiam		Dec. 1946
June 1948	main stem of the Columbia	Vanport near Portland completely destroyed	snow melt
Dec. 1955	Columbia River and Willamette Basin	strong winds/flooding; five fatalities	rain on snow
Dec. 1964	entire state	record-breaking December rainfall; widespread damage; warm temperatures	rain on snow
Jan. 1972	Willamette and Sandy Rivers	widespread damage; many fish buildings, etc. destroyed; five fatalities	rain on snow
Jan. 1974	western Oregon	mild storms followed heavy snow and freezing rain; nine counties declared disasters	rain on snow
Jan. 1978	Willamette River and NW Oregon	intense rain/snowmelt; widespread flooding	rain on snow
Feb. 1986	entire state	numerous homes evacuated; intense rain and melting snow	snow melt
Feb. 1987	western Oregon	Willamette and tributaries; mud slides, flooded highways, damaged homes	rain on snow

Date	Location	Description	Type of Flood
Jan. 1990	western Oregon	10 rivers in eight counties flooded; many bridges washed away	rain on snow
Feb. 1996	NW Oregon	warm temperatures / record breaking rains; widespread flooding (FEMA-1099-DR-OR. 1996)	rain on snow
Dec. 1996	western Oregon	mild subtropical moisture led to extensive flooding. 14 county disaster	rain on snow
Sept. 2000	Clackamas County	Heavy rain, estimated at 3 inches in places, plus glacial melt associated with abnormally warm temperatures, acted together to trigger floods and rock and mud slides on the western slopes of Mount Hood.	
Jan. 2006	Washington County	Tualatin River in Dilley and Farmington reached above flood stages	riverine
Nov. 2006	Clackamas County	heavy rain caused the Sandy River and Clackamas River to flood, causing damage in Estacada and Oregon City. Total county-wide damages of $3 million	riverine
Dec. 2007	Washington County	flooding of the Tualatin River following heavy rainfall from a tropical storm; old OR-47 and OR-47 closed temporarily; total of $2.3 million in damages	riverine
Dec. 2007	Columbia County	flooding of the Nehalem River caused widespread damage in Vernonia, flooding numerous homes and causing a total of $36 million in damages for Columbia County	riverine
Jan. 2009	Washington County	severe winter storm/snow event that included snow, high winds, freezing rain, ice, blizzard conditions, mudslides, and landslides	rain on snow
Jan. 2011	Clackamas County	severe winter storm, flooding, mudslides, landslides, and debris flows, DR-1956	
Jan. 2012	Columbia, Hood River, Tillamook, Polk, Marion, Yamhill, Lincoln, Benton, Linn, Lane, Douglas, Coos, and Curry Counties	heavy rain and wind; ice (DR-4055); flooding in the Willamette Valley; 130 homes and seven businesses were damaged in the City of Turner; 21 streets were closed in the City of Salem; the state Motor Pool lost 150 vehicles and thousands of gallons of fuel; Thomas Creek in the City of Scio overtopped, damaging several buildings	
Sep. 2013	Multnomah County	heavy rain resulted in damage to the Legacy Good Samaritan Medical Center and several businesses in northwest Portland	riverine
August 2014	Clackamas County	Heavy rain resulted in the Sandy River to rapidly rise. A foot bridge near Ramona Falls broke loose sending a man into the turbulent waters. The man drowned in the river.	
Dec. 2014	Tillamook, Lincoln, Lane, Polk Clackamas, Benton Coos and Douglas Counties	A slow moving front produced heavy rain over Northwest Oregon which resulted in the flooding of eight rivers. Another impact from the rain were a couple of land/rock slides that both blocked two highways. Heavy rain brought flooding to several rivers in southwest Oregon.	
Dec. 2015	Tillamook, Lincoln, Washington, Clackamas, Multnomah, Lane, Columbia, Hood River, Polk, Coos, Douglas, Jackson and Curry Counties	A moist pacific front produced heavy rainfall across Northwest Oregon which resulted in river flooding, urban flooding, small stream flooding, landslides, and a few sink holes. After a wet week (December 5 through Dec 11), several rivers were near bank full ahead of another front on December 12th. Flooding from the Nehalem River and Rock Creek in Vernonia resulted in evacuation of homes and the implementation of the Vernonia Emergency Command Center. Heavy rain resulted in a land slide that closed OR47 at mile marker 8. More than $15 million dollars in property damage reported in these counties combined.	
Nov. 2016	Columbia, Tillamook, Lincoln, Benton, Washington, Polk, and Yamhill Counties	A moist Pacific front moving slowly across the area produced heavy rainfall, resulting in flooding of several rivers across Northwest Oregon and at least two landslides.	
Feb. 2017	Marion, Polk, Yamhill, Washington, Columbia, Benton, Tillamook, Lane,	High river flows combined with high tide to flood some areas near the southern Oregon coast. Heavy rain combined with snow melt caused flooding along the Coquille River and the Rogue River twice this month in southwest Oregon. Heavy rain combined with snow melt caused flooding	

Date	Location	Description	Type of Flood
	Coos, Curry, Klamath, Wheeler and Malheur Counties	along the Sprague River in south central Oregon. Flows on the John Day river reached flood levels downstream of Monument due to the breaking up of an ice jam.	
May 2017	Multnomah County and Wallowa County	Heavy rain from a strong thunderstorm in addition to a log jam caused the rapid rise of Oneonta Creek in the Oneonta Gorge. Two hikers were injured in the flash flood. In Wallowa County the Imnaha River at Imnaha had minor flooding early on May 6th, due to snow melt.	
Oct. 2017	Tillamook, Benton, and Clackamas Counties	A very potent atmospheric river brought strong winds to the north Oregon Coast and Coast Range on October 21st. What followed was a tremendous amount of rain for some locations along the north Oregon Coast and in the Coast Range, with Lees Camp receiving upwards of 9 inches of rain. All this heavy rain brought the earliest significant Wilson River Flood on record, as well as flooding on several other rivers around the area.	
Feb. 2019	Columbia, Washington and Multnomah Counties	Back-to-back low pressure systems dropping south along the coast of British Columbia and Washington brought cold air south into NW Oregon as well as plenty of moisture. Flooding along Fox Creek in Rainier, 40 county roads in Washington County, and in Multnomah County Northwest Rocky Point Road between U.S. 30 and Skyline Boulevard was closed because of a large crack in the road caused by heavy rains and snowmelt.	
April 2019	Lane, Benton, Marion, Clackamas and Linn Counties	A particularly strong atmospheric river took aim for the south Willamette Valley, sitting over areas south of Salem for two days, producing anywhere from 2.5 to 5 inches of rain over a 48 hour period. Some areas in the Cascades and Cascade Foothills saw 5 to 7 inches of rain over that 48 hour period. Heavy rain combined with snow melt from all the snow from a few weeks prior in this same area caused flooding along most of our rivers in this area as well as along the main-stem Willamette River up to around Oregon City.	

Sources: Taylor and Hatton (1999); National Climatic Data Center; KPTV_KPDX (2013); NOAA Storm Event Database, (http://www.ncdc.noaa.gov/stormevents/), January 2020; Planning for Natural Hazards: Flood TRG (Technical Resource Guide), July 2000, DLCD, Community Planning Workshop

Table 2-236. Principal Riverine Flood Sources in Region 2

Clackamas	Columbia	Multnomah	Washington
Willamette River and tributaries:	Clatskanie River	Columbia and Willamette Rivers and tributaries:	Willamette River and tributaries:
Abernethy Creek	Columbia River	Sandy River	Tualatin River
Clackamas River	Conyers Creek	Multnomah Channel	Fanno Creek
Clear Creek	McNulty Creek	Johnson Creek	Summer Creek
Dear Creek	Milton Creek	Fairview Creek	Ash Creek
Eagle Creek	Multnomah Channel	Columbia Slough	Rock Creek
Johnson Creek	Nehalem Creek	Ponding within Drainage Dist. #1	Cedar Creek
Kellogg Creek	Rock Creek	Beaver Creek	Butternut Creek
Milk Creek	Scappoose Creek	Fairview Creek	Dawson Creek
Molalla River		Kelley Creek	Beaverton Creek
Mt. Scott Creek		Mitchell Creek	Bronson Creek
Nyberg Slough			Willow Creek
Oswego Channel			Cedar Mill Creek
Phillips Creek			Johnson Creek
Pudding River			Dairy Creek
Salmon River			McKay Creek
Sandy River			Council Creek
Still Creek			Gales Creek
Tualatin River			Wapato Creek
Zig Zag River			Nyberg Slough
Tickle Creek			

Sources: FEMA, Clackamas County Flood Insurance Study (FIS), January 18, 2019; FEMA, Columbia County FIS, November 26, 2010, FEMA; Multnomah County FIS, February 1, 2019, FEMA, Washington County FIS, October 19, 2018

Probability, Vulnerability, and Risk

Different methods are used to assess probability and vulnerability at local and state levels. These methods employ history, probability, and vulnerability data to determine probability and vulnerability scores for each hazard. The challenge with these varied methodologies is that access to, interpretation of, and scale of the data are not necessarily the same at local and state levels. As a result, local and state probability and vulnerability scores for a specific hazard in a specific community are not always the same. In some instances, probability and vulnerability scores are even quite different. A description of the "OEM Hazard Analysis Methodology" used by local governments is provided in Section 2.1, **Local Vulnerability Assessments**. The complete "OEM Hazard Analysis Methodology" is located in Appendix **9.1.19**.

The purpose of the probability and vulnerability scores is to identify high-priority areas to which local and state governments can target mitigation actions.

Probability

Local Assessment

Participants in each county's Natural Hazard Mitigation Plan update process used the OEM hazard analysis methodology to analyze the probability that Region 2 will experience flooding. The resulting estimates of probability are shown in **Table 2-237**.

Table 2-237. Local Assessment of Flood Probability in Region 2

	Columbia	Clackamas	Multnomah	Washington
Probability	H	H	M	H

Source: Columbia County NHMP (2020 draft), Clackamas County NHMP (2019), Multnomah County NHMP (2017) – average of all jurisdictions, Washington County NHMP (2016)

State Assessment

Using the methodology described in the **Floods 2.2.5.2, Probability**, the state assessed the probability of flooding in the counties that comprise Region 2. The results are shown in Table **2-238**.

Table 2-238. State Assessment of Flood Probability in Region 2

	Columbia	Clackamas	Multnomah	Washington
Probability	VH	VH	VH	H

Source: DOGAMI

Climate Change

It is very likely (>90%) that Oregon will experience an increase in the frequency of extreme precipitation events and extreme river flows (high confidence). The likelihood of increase in extreme precipitation events is greater east of Cascades than west. Extreme river flow, while affected by extreme precipitation, is also driven by antecedent conditions (soil moisture, water table height), snowmelt, river network morphology, and spatial variability in precipitation and snowmelt. Most projections of extreme river flows show increases in flow magnitude at most locations across Oregon. Along the Willamette River and its tributaries (Regions 2, 3, and 4), the largest increases in extreme river flows are more likely to be upstream (toward Cascades headwaters), and less likely as one travels downstream. Along the Lower Columbia Basin, large increases in extreme flows are least likely. Overall, it is more likely than not (>50%) that increases in extreme river flows will lead to an increase in the incidence and magnitude of damaging floods (low confidence), although this depends on local conditions (site-dependent river channel and floodplain hydraulics). Increases in extreme river flows leading to damaging floods will be less likely where storm water management (urban) and/or reservoir operations (river) have capacity to offset increases in flood peak.

Vulnerability

Table 2-239. Local Assessment of Vulnerability to Flood in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	H	M	M	M

Source: Columbia County NHMP (2020 draft), Clackamas County NHMP (2019), Multnomah County NHMP (2017) – average of all jurisdictions, Washington County NHMP (2016)

Table 2-240. State Assessment of Vulnerability to Flood in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	VL	VL	VH	VL

Source: DOGAMI, DLCD

DOGAMI prepared a Risk Report for the Lower Columbia-Sandy River Watershed Area of Clackamas County. This report referenced in the Clackamas County NHMP determined that within the unincorporated portion of the county within the study area for that report, 74 buildings are expected to be damaged by the 100-year flood event. Channel migration may expose double that number of buildings to flood damage. Within the City of Government Camp, 12 buildings are expected to be damaged by the 100-year flood event with no impact from channel migration. Within the Villages at Mt. Hood 161 buildings are expected to be damaged with 1,307 buildings exposed to damage from channel migration. No critical facilities are among these buildings. Clackamas County performed a GIS analysis for its NHMP and determined that of the 235 critical facilities in the county only two are at risk of damage from the 100-year flood.

In Multnomah County, the most recent NHMP reports analysis by DOGAMI regarding damage from channel migration along the Sandy River. In the Sandy River Channel Migration Zone, the study identifies 186 structures at risk of damage along with 8.4 miles of transportation infrastructure, 6.9 miles of electric transmission lines, 6 bridges and 8 electric transmission towers. These figures are not reflected in Special Flood Hazard Area impacts because channel migration zones are not mapped as such; however, flooding still remains a risk in channel migration zones.

In Washington County There are four county bridges and 19 state-owned bridges that have been identified as seismically vulnerable. Impacts to the transportation system can result in the isolation of vulnerable populations, limit access to critical facilities such as hospitals and adversely impact local commerce, employment and economic activity. There are three “high threat potential” dams located in the county: Kay Lake, Trask River Reservoir, and Scoggins (Hagg Lake).

Repetitive Losses

Table 2-241. Severe/Repetitive Flood Losses and Community Rating System Communities by County in Region 2

County	RL/SRL	# of CRS Communities per County
Clackamas	39	2
Columbia	5	1
Multnomah	2	2
Washington	30	0
Totals:	**76**	**5**

Source: FEMA NFIP Community Information System, https://portal.fema.gov/famsVuWeb/home, accessed February 2020

Communities can reduce the likelihood of damaging floods by employing floodplain management practices that exceed NFIP minimum standards. DLCD encourages communities

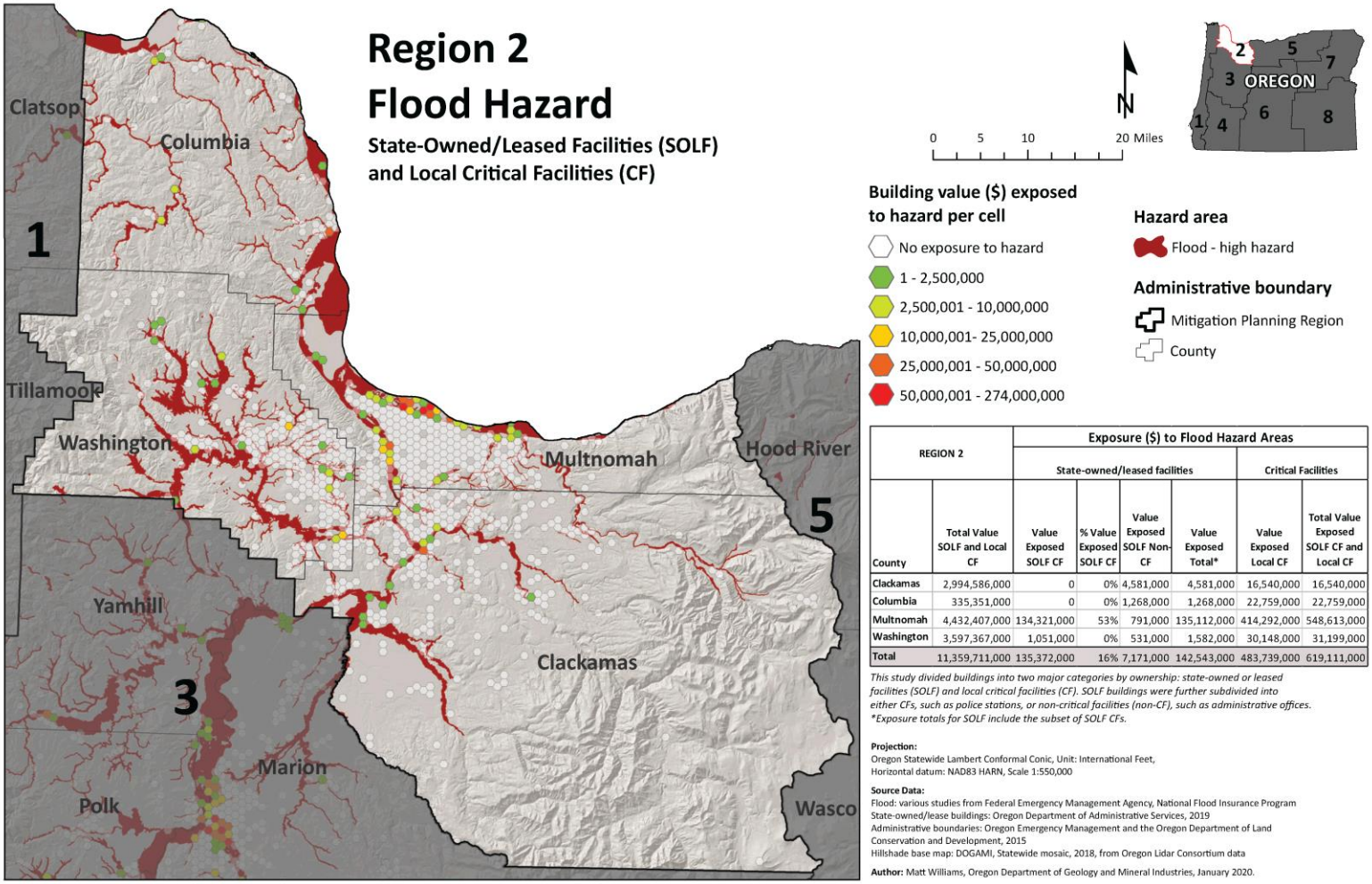
that adopt such standards to participate in FEMA's Community Rating System (CRS), which results in reduced flood insurance costs. Clackamas County participates in CRS, as do the cities of Oregon City, Portland, Scappoose, and Troutdale.

State-Owned/Leased Facilities and Critical/Essential Facilities

For the 2020 Risk Assessment, DOGAMI used a combination of FEMA effective and preliminary flood zone data (FEMA National Flood Hazard Layer, 2019) and FEMA Q3 data (an unpublished digital dataset of paper flood insurance rate maps). All FEMA data that DOGAMI used was current as of 2019. The flood hazard was not divided in to High, Moderate, or Low categories due to the wide variety of flood data, its variable absolute and relative accuracy, and its variable geographic coverage and completeness. Rather, when a building was located within a floodway, 100-year floodplain, or 500-year floodplain, a "High" flood hazard was designated. When there was insufficient information to determine whether a flood hazard exists for a given site, the flood hazard was designated "Other." Sites with "Other" designations could conceivably face relatively high flood hazards or no flood hazard at all.

In Region 2, there is a potential loss from flooding of over $142M in state building and critical facility assets, 95% of it in Multnomah County alone. There is a far greater potential loss due to flood in local critical facilities: close to $484M, almost three-and-a-half times as much. Again the vast majority, 86%, is located in Multnomah County. **Figure 2-157** illustrates the potential loss to state buildings and critical facilities and local critical facilities from flooding.

Figure 2-157. State-Owned/Leased Facilities (SOLF) and Local Critical Facilities (CF) in a Flood Hazard Zone in Region 2.High-resolution, full-size image linked from Appendix 9.1.26.



REGION 2		Exposure ($) to Flood Hazard Areas					
		State-owned/leased facilities				Critical Facilities	
County	Total Value SOLF and Local CF	Value Exposed SOLF CF	% Value Exposed SOLF CF	Value Exposed SOLF Non-CF	Value Exposed Total*	Value Exposed Local CF	Total Value Exposed SOLF CF and Local CF
Clackamas	2,994,586,000	0	0%	4,581,000	4,581,000	16,540,000	16,540,000
Columbia	335,351,000	0	0%	1,268,000	1,268,000	22,759,000	22,759,000
Multnomah	4,432,407,000	134,321,000	53%	791,000	135,112,000	414,292,000	548,613,000
Washington	3,597,367,000	1,051,000	0%	531,000	1,582,000	30,148,000	31,199,000
Total	11,359,711,000	135,372,000	16%	7,171,000	142,543,000	483,739,000	619,111,000

This study divided buildings into two major categories by ownership: state-owned or leased facilities (SOLF) and local critical facilities (CF). SOLF buildings were further subdivided into either CFs, such as police stations, or non-critical facilities (non-CF), such as administrative offices.
**Exposure totals for SOLF include the subset of SOLF CFs.*

Projection:
Oregon Statewide Lambert Conformal Conic, Unit: International Feet,
Horizontal datum: NAD83 HARN, Scale 1:550,000

Source Data:
Flood: various studies from Federal Emergency Management Agency, National Flood Insurance Program
State-owned/lease buildings: Oregon Department of Administrative Services, 2019
Administrative boundaries: Oregon Emergency Management and the Oregon Department of Land Conservation and Development, 2015
Hillshade base map: DOGAMI, Statewide mosaic, 2018, from Oregon Lidar Consortium data

Author: Matt Williams, Oregon Department of Geology and Mineral Industries, January 2020.

Source: DOGAMI, 2020

Historic Resources

Of the 23,605 historic resources in Region 2, eight hundred sixty-nine (4%) are located in an area of high flood hazard. Of those, 393 (45%) and 358 (41%) are located in Multnomah and Clackamas Counties, respectively.

Archaeological Resources

Of the 307 archaeological resources located in high flood hazard areas in Region 2, 50% are located in Multnomah County. Only three are listed on the National Register of Historic Places and 15 are eligible for listing. Twenty-eight have been determined not eligible and 261 have not been evaluated as to their eligibility. The listed resources are located in Clackamas and Multnomah Counties. The eligible resources are spread throughout Region 2.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

For the 2020 vulnerability assessment, DLCD combined the social vulnerability scores with the vulnerability scores for state buildings, state critical facilities, and local critical facilities to calculate an overall vulnerability score for each county. According to this limited assessment, all the counties score very low for vulnerability except Multnomah County which scores very high. Multnomah County's very high score is indicative of the high value of state buildings, state critical facilities, and local critical facilities located in the County as well as its moderate social vulnerability.

Most Vulnerable Jurisdictions

Multnomah County is the county most vulnerable to flood in Region 2.

Risk

Table 2-242. Risk of Flood Hazards in Region 2

	Columbia	Clackamas	Multnomah	Washington
Risk	M	M	VH	VL

Source: DOGAMI, DLCD

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life. The 2020 risk assessment

combined the probability with the vulnerability assessment to arrive at a composite risk score. According to the 2020 risk assessment, only Multnomah County is at a very high risk from flood.

Dam Safety

The Oregon Water Resources Department (OWRD) is the state authority for dam safety with specific authorizing laws and implementing regulations. Oregon's dam safety laws were re-written by HB 2085 which passed through the legislature and was signed by Governor Brown in 2019. This law becomes operative on July 1, 2020, with rules and guidance have been drafted and are currently in the public review and comment period.

OWRD coordinates on but does not directly regulate the safety of dams owned by the United States or most dams used to generate hydropower. OWRD is the Oregon Emergency Response System contact in the event of a major emergency involving a state-regulated dam, or any dam in the State if the regulating agency is unknown. The Program also coordinates with the National Weather Service and the Oregon Office of Emergency Management on severe flood potential that could affect dams and other infrastructure.

Analysis and Characterization

Oregon's statutory size threshold for dams to be regulated by OWRD is at least 10 feet high and storing at least 3 million gallons. Many dams that fall below this threshold have water right permits for storage from OWRD.

Under normal loading conditions dams are generally at very low risk of failure. Specific events are associated with most dam failures. Events that might cause dams to fail include:

- An extreme flood that exceeds spillway capacity and causes an earthen dam to fail;
- Extended high water levels in a dam that has no protection against internal erosion;
- Movement of the dam in an earthquake; and
- A large rapidly moving landslide impacting the dam or reservoir.

Landslides are a significant hazard in many parts of Oregon, and some dams are constructed on landslide deposits. Though not common, a large and rapidly moving landslide or debris flow may generate a wave that can overtop a dam, causing significant flooding, especially if it causes a dam to fail.

Wildfires may increase the risk of debris flows (though wildfire generated debris flows are typically on the smaller size scale). Wildfires and windstorms can also result in large woody debris that can block spillways, also a risk to dam integrity. Oregon will be evaluating both landslide and wildfire risks during its HHPD grant funded risk assessments of dams currently eligible for the program.

Most of the largest dams, especially those owned or regulated by the Federal Government are designed to safely withstand these events and have been analyzed to show that they will. However, there are a number of dams where observations, and sometimes analysis indicates a deficiency that may make those dams susceptible to one or more of the events. The large majority of state regulated dams do not have a current risk assessment or analysis, and safe performance in these events is uncertain.

Failures of some dams can result in loss of life, damage to property, infrastructure, and the natural environment. The impacts of dam failures range from local impacts to waters below the dam and the owner's property to community destruction with mass fatalities. The 1889

Johnston Flood in Pennsylvania was caused by a dam failure, and resulted in over 2000 lives lost. Oregon's first dam safety laws were developed in response to the St. Francis dam failure in California in 1928. That failure was attributed to unsafe design practice, and because of this about 500 persons perished. In modern times (2006) a dam owner filled in the spillway of a dam on the island of Kauai causing dam failure that killed 7 people. This dam had no recent dam safety inspections because the hazard rating was incorrect.

Where a dam's failure is expected to result in loss of life downstream of the dam, an Emergency Action Plan (EAP) must be developed. The EAP contains a map showing the area that would potentially be inundated by floodwaters from the failed dam. These dams are often monitored so that conditions that pose a potential for dam failure are identified to allow for emergency evacuations.

Historic Significant Dam Failures in Region 2

Region 2 has not experienced any historic significant dam failures.

Dam Hazard Ratings

Oregon follows national guidance for assigning hazard ratings to dams and for the contents of Emergency Action Plans, which are now required for all dams rated as "high hazard." Each dam is rated according to the anticipated impacts of its potential failure. The state has adopted these definitions (ORS 540.443–491) for state-regulated dams:

- "High Hazard" means loss of life is expected if the dam fails.
- "Significant Hazard" means loss of life is not expected if the dam fails, but extensive damage to property or public infrastructure is.
- "Low Hazard" is assigned to all other state-regulated dams.
- "Emergency Action Plan" means a plan that assists a dam owner or operator, and local emergency management personnel, to perform actions to ensure human safety in the event of a potential or actual dam failure.

Hazard ratings may change for a number of reasons. For example, a dam's original rating may not have been based on current inundation analysis methodologies, or new development may have changed potential downstream impacts.

There are 20 High Hazard dams and 34 Significant Hazard dams in Region 2.

Table 2-243. Summary: High Hazard and Significant Hazard Dams in Region 2

	Hazard Rating		
	State		Federal
	High	Significant	High
Region 2	10	34	10
Clackamas	2	13	7
Columbia	0	2	0
Multnomah	6	4	2
Washington	2	15	1

Source: Oregon Water Resources Department, 2019

Table 2-244. High Hazard and Significant Hazard Dams in Region 2

County	Name	Rating	Regulator
Clackamas	Bull Run Dam 2 (Lower)	High	Federal
Clackamas	Faraday Diversion Dam	High	Federal
Clackamas	Faraday Forebay	High	Federal
Clackamas	North Fork Dam (Clackamas)	High	Federal
Clackamas	River Mill Dam	High	Federal
Clackamas	Timothy Lake	High	Federal
Clackamas	Willamette Falls	High	Federal
Clackamas	Buche (Clackamas)	High	State
Clackamas	Mompano	High	State
Clackamas	Beyer Reservoir	Significant	State
Clackamas	Cedar Grove Lake	Significant	State
Clackamas	Day Reservoir	Significant	State
Clackamas	Deardorff, Betty Jane	Significant	State
Clackamas	Drescher Reservoir	Significant	State
Clackamas	Haberlach Dam	Significant	State
Clackamas	Oswego Lake Dam	Significant	State
Clackamas	Rogers - Joseph Reservoir	Significant	State
Clackamas	Rose Reservoir	Significant	State
Clackamas	Sandy Farms No. 1-A	Significant	State
Clackamas	Teasel Creek	Significant	State
Clackamas	Veterans Reservoir	Significant	State
Clackamas	Zielinski Farm Reservoir	Significant	State
Columbia	Rainier City Reservoir	Significant	State
Columbia	Salmonberry Reservoir	Significant	State
Multnomah	Bonneville Dam	High	Federal
Multnomah	Bull Run Dam 1 (Upper)	High	Federal
Multnomah	Portland #1 (Mt. Tabor)	High	State
Multnomah	Portland #3 (Washington Park)	High	State
Multnomah	Portland #4 (Washington Park)	High	State
Multnomah	Portland #5 (Mt. Tabor)	High	State
Multnomah	Portland #6 (Mt. Tabor)	High	State
Multnomah	Van Raden	High	State
Multnomah	Binford Dam	Significant	State
Multnomah	Mt. Hood Community College Dam	Significant	State
Multnomah	Peyralans Reservoir	Significant	State
Multnomah	Sester, William H. Reservoir 1	Significant	State
Washington	Scoggins	High	Federal
Washington	Barney	High	State
Washington	Kay Lake	High	State
Washington	Burkhalter #2	Significant	State
Washington	Cook Reservoir (Wash)	Significant	State
Washington	Dierickx	Significant	State

County	Name	Rating	Regulator
Washington	Dober Reservoir	Significant	State
Washington	Ettinger Pond	Significant	State
Washington	Hoefer-Pierson Reservoir	Significant	State
Washington	Jesse Enlargement	Significant	State
Washington	Lind Reservoir	Significant	State
Washington	Maple Headquarters Reservoir	Significant	State
Washington	Paul Chobin Dam	Significant	State
Washington	Pierson-Upper	Significant	State
Washington	Tualatin Park	Significant	State
Washington	Unger-Bill Dam	Significant	State
Washington	Walters, Glenn #1 - Large	Significant	State
Washington	Walters, Glenn #5	Significant	State

Source: Oregon Water Resources Department, 2019

Probability

Engineering risk assessment and analysis of a dam is the best indicator of the probability of failure. Without that, the condition of a dam as determined by OWRD engineering staff is a helpful indicator OWRD has for of the failure potential of a dam.

Dam safety regulators determine the condition of high hazard rated dams, both state- and regulated. A dam's condition is considered public information for state-regulated dams, but the conditions of federally regulated dams are generally not subject to disclosure. State-regulated significant hazard dams do not yet have condition ratings.

Oregon uses FEMA's condition classifications. These classifications are subject to change and revisions are being considered at the national level. Currently, FEMA's condition classifications are:

- "Satisfactory" means no existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria or tolerable risk guidelines.
- "Fair" means no existing dam safety deficiencies are recognized for normal loading conditions. Rare or extreme hydrologic and/or seismic events may result in a dam safety deficiency. Risk may be in the range to take further action.
- "Poor" means a dam safety deficiency is recognized for loading conditions that may realistically occur. Remedial action is necessary. A poor rating may also be used when uncertainties exist as to critical analysis parameters that identify a potential dam safety deficiency. Further investigations and studies are necessary.
- "Unsatisfactory" means a dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution.
- "Not Rated" means the dam has not been inspected, is not under State jurisdiction, or has been inspected but, for whatever reason, has not been rated.

Eight of the ten state-regulated high hazard dams are in satisfactory condition. None are in poor or unsatisfactory condition.

Table 2-245. Summary: Condition of High Hazard State-Regulated Dams in Region 2

	Condition of State-Regulated High Hazard Dams				
	Satisfactory	Fair	Poor	Unsatisfactory	Not Rated
Region 2	8	2	0	0	0
Clackamas	1	1	0	0	0
Columbia	0	0	0	0	0
Multnomah	5	1	0	0	0
Washington	2	0	0	0	0

Source: Oregon Water Resources Department, 2019

Table 2-246. Condition of High Hazard State-Regulated Dams in Region 2

County	Dam Name	Condition
Clackamas	Buche (Clackamas)	Fair
Clackamas	Mompano	Satisfactory
Multnomah	Van Raden	Fair
Multnomah	Portland #1 (Mt. Tabor)	Satisfactory
Multnomah	Portland #3 (Washington Park)	Satisfactory
Multnomah	Portland #4 (Washington Park)	Satisfactory
Multnomah	Portland #5 (Mt. Tabor)	Satisfactory
Multnomah	Portland #6 (Mt. Tabor)	Satisfactory
Washington	Barney	Satisfactory
Washington	Kay Lake	Satisfactory

Source: Oregon Water Resources Department, 2019

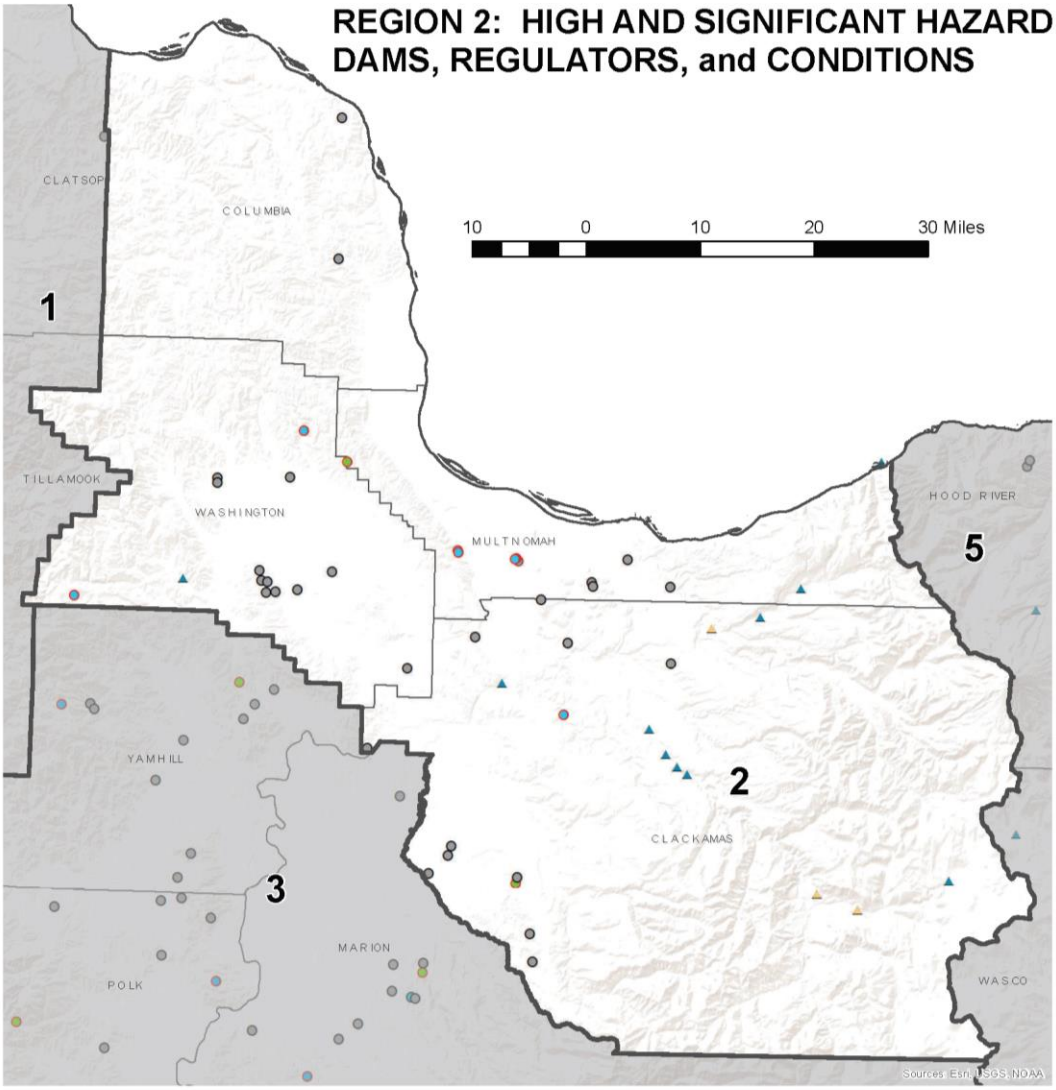
State-Regulated High Hazard Dams not Meeting Safety Standards

There are no state-regulated high hazard dams in Region 2 that are currently assessed to be below accepted safety standards (in Poor or Unsatisfactory Condition). When Oregon's new dam safety laws take effect July 1, 2020, the condition of some dams may be reclassified as unsafe or potentially unsafe.

It is important to note that many state regulated dams have not received a deep level of risk analysis and review, so the number of dams not meeting minimum standards may increase as additional analyses are performed.

Figure 2-158 shows state- and federally regulated high and significant hazard dams as well as the condition of state-regulated dams in Region 2. The table on the map shows the total number of these dams in each of the seven mapped hazard areas.

Figure 2-158. High- and Significant-Hazard Dams, Regulators, and Conditions in Region 2



	Coastal	Earthquake	Flood	Landslide	Volcanic	Tsunami	Wildfire
Region 2	0	29	*	16	0	0	0
Clackamas	0	15	*	6	0	0	0
Columbia	0	0	*	2	0	0	0
Multnomah	0	3	*	4	0	0	0
Washington	0	11	*	4	0	0	0

* - flood risk affected by function and condition of dam, not by presence in mapped flood prone location

Projection:
Oregon Lambert Coordinate Reference System, Unit: International Feet, Horizontal datum: NAD83, EPSG #2992

Source Data:
State regulated dams: Oregon Water Resources Dept., July 2020
Mitigation Planning Regions: Oregon Emergency Management
Counties: U.S. Bureau of Land Management (BLM)
Base map: Esri, World Terrain Base

Author: Robert Harmon, GISP, Oregon Water Resources Dept. (July 2020)

State regulated dams**

Condition assessment

- Poor
- Unsatisfactory
- Fair
- Satisfactory
- No assessment

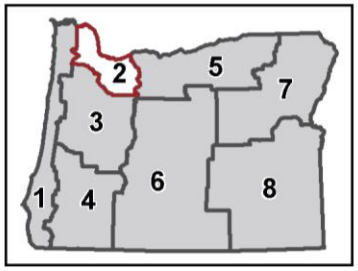
** - Significant hazard dam symbols have a black outline. **High hazard dam symbols have a red outline.**

Federal regulated dams

Hazard

- High
- Significant

Mitigation Planning Regions
Counties



Climate Change

Most climate change models indicate there may be more extreme precipitation due to the increased energy in the oceanic and atmospheric systems. Of main concerns for dams is the potential for larger floods than experienced in the past. Almost half of the historical dam failures around the world have been due the floods that exceed the flow capacity of the spillway and overtop the dam. Another issue for the Pacific coast is the shorter record of precipitation and flood events in the data records. Even without climate change there is uncertainty in the extreme storms that could occur in an extreme atmospheric river event (about which there is much to learn). If the actual flood is larger than the design flood, spillway capacity may be exceeded and the dam may overtop, or the spillway may erode so that it can rapidly empty the reservoir. These scenarios can present real risks to some dams in Oregon, risks that depending on the location may be greater than earthquake related risks.

Vulnerability

State-regulated high hazard dams in Region 2 are currently meeting safety standards.

Dams in in the western and northern portions of Region 2 can have high risks from earthquakes. Some dams in this region may have a moderately increased risk from landslide and wildfire, with some risk of large woody debris from wildfire. State-regulated dams in this region are not close to volcanic hazards; some federally regulated dams are closer.

No dams in Region 2 meet FEMA HHPD eligibility criteria.

Most Vulnerable Jurisdictions

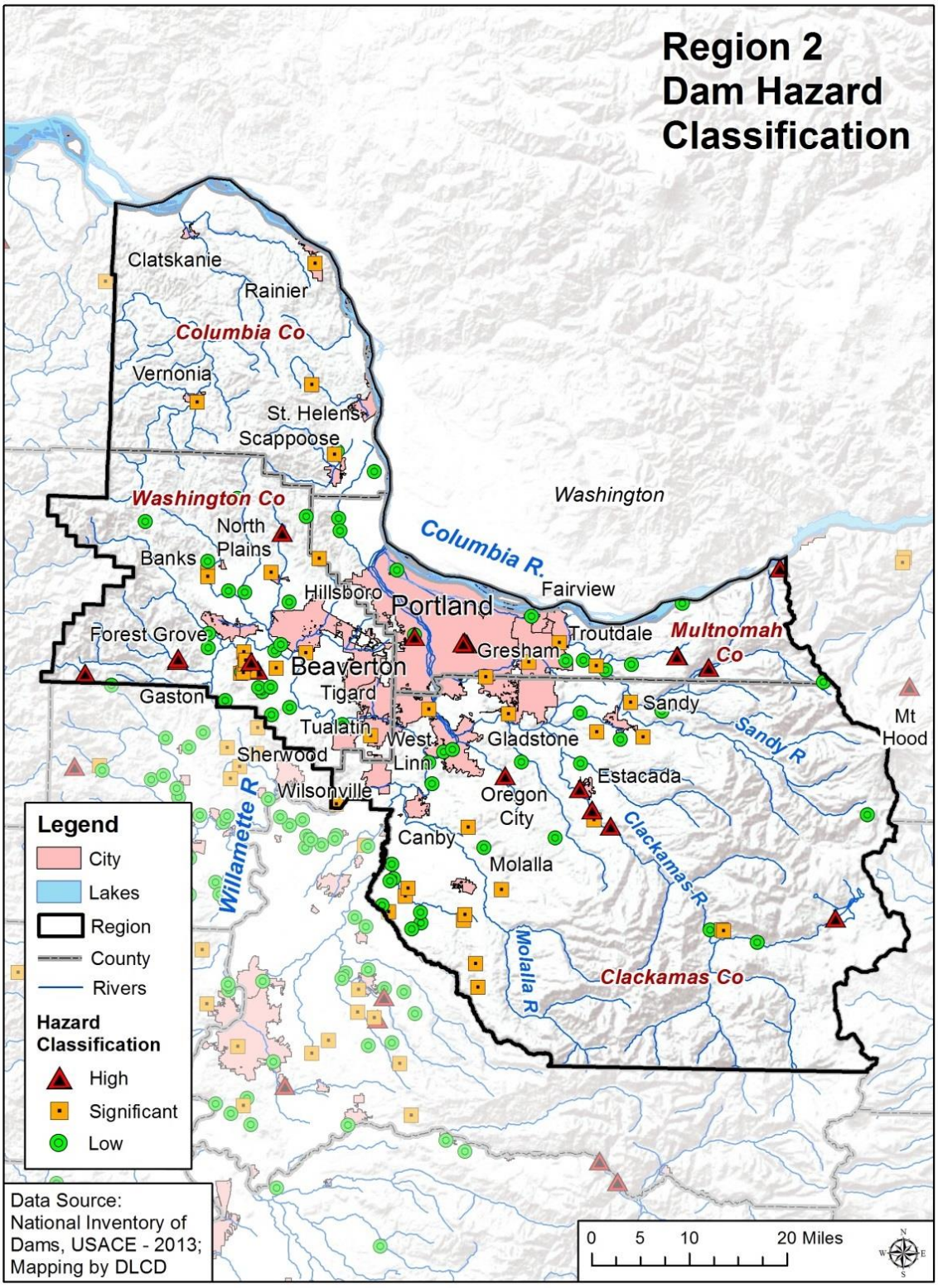
Given the information presented about state-regulated high hazard dams (county and condition; failure expected to result in loss of life) and significant hazard dams (county; failure expected to result in extensive property or infrastructure damage), no Region 2 counties are considered "most vulnerable jurisdictions" because none have high hazard dams in poor or unsatisfactory condition.

As with high hazard dams, whether counties with significant hazard dams are actually "most vulnerable jurisdictions" depends on the conditions of those dams. Since the dams' conditions have not yet been rated, we cannot determine the counties' vulnerability with respect to significant hazard dams. The counties with the most state-regulated significant hazard dams are Washington (15) and Clackamas (13).

Risk

The potential for damage to a dam from extreme floods, lack of protection against internal erosion, earthquakes, or landslides and debris indicates greater potential for failure. Coupled with the potential for loss of life and extensive damage to property and public infrastructure, risk is qualitatively determined.

Figure 2-159. Region 2 Dam Hazard Classification



Source: USACE National Inventory of Dams, 2013

Note: Federally regulated significant hazard dams are not shown.

Landslides

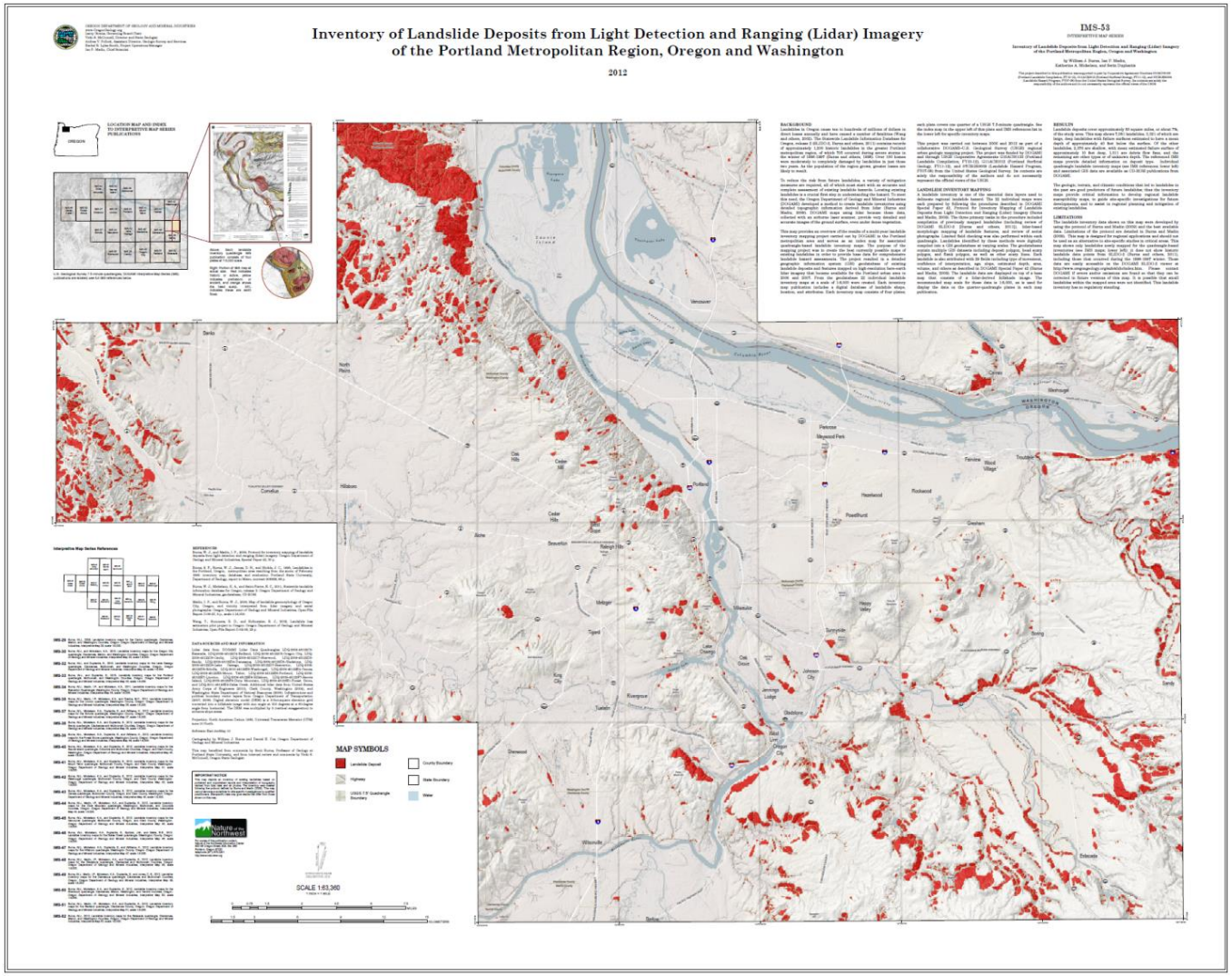
Characteristics

Landslides occur throughout this region of the state, although areas with steeper slopes, weaker geology, and higher annual precipitation tend to have more landslides. In general, the Coast Range and Cascade Mountains have a very high incidence of landslides. On occasion, major landslides sever major transportation routes such as U.S. or state highways and rail lines, causing temporary but significant economic damage to the state.

In Multnomah County (including the city of Portland) landslide activity has been a recurring problem for many years. In February 1996, landslide activity that occurred in Portland and the Dodson-Warrendale area (east Multnomah County) was notable and severely impacted homeowners and transportation routes. In fact, I-84 in the Columbia River Gorge was closed for a number of days by fast moving debris flows that covered the roadway and the east-west railroad tracks.

Lidar-based landslide inventory mapping was completed for most of the Portland Metro area (Burns, Madin, Mickelson, & Duplantis, 2012b). Landslide deposits cover approximately 83 square miles, or about 7%, of the study area. This map shows 7,081 landslides, 3,321 of which are large, deep landslides with failure surfaces estimated to have a mean depth of approximately 40 feet below the surface. Of the other landslides, 2,376 are shallow, with mean estimated failure surface of approximately 10 feet deep; 1,311 are debris flow fans; and the remaining are other types or of unknown depth. The geologic, terrain, and climatic conditions that led to landslides in the past are good predictors of future landslides; thus the inventory maps provide critical information to develop regional landslide susceptibility maps, to guide site-specific investigations for future developments, and to assist in regional planning and mitigation of existing landslides

Figure 2-160. Inventory of Landslide Deposits from Lidar Imagery of the Portland Metro region, Oregon and Washington



Source: Burns, et al. (2012b)

Historic Landslides

In 1996-1997, 700 landslides occurred in the Portland Metro area. Over 100 homes were moderately to completely damaged by landslides in just those two years (Burns, Burns, James, & Hinkle, 1998). As the population of the region grows, greater losses are likely to result.

Table 2-247. Historic Landslides in Region 2

Date	Location	Description
Mar. 1972	near Portland, Oregon	mud and rock slide on I-5; injured: three motorists
Oct. 1984	I-84 near Cascade Locks, Oregon	rockslide; fatalities: two children; cost of stabilizing the slide area: $4 million
Sep. 1990	near Troutdale, Oregon	landslide; injuries: four highway workers
Feb. 1996	Dodson-Warrendale, Portland Metro area, Oregon	FEMA-1099-DR-Oregon; heavy rains and rapidly melting snow contributed to thousands of landslides and debris flows across the state; many occurred on clear cuts that damaged logging roads; I-84 closed at Dodson-Warrendale (700 in the Portland Metro area)
Dec. 2007	Clatsop, Columbia, Tillamook, Washington, and Yamhill Counties, Oregon	landslide due to heavy rains from a strong winter storm; damages: $1.5 million total (Clatsop, Columbia, Tillamook, Washington, and Yamhill Counties); $300,000 (to Columbia County alone)
Dec. 2008	Clackamas, Columbia, Multnomah, Washington	DR-1824; HWY6 closed from landslide.
Jan. 2011	Clackamas	DR-1956; Landslide along bull run watershed water conduit damaged pipe. NW Thompson road closed. Several landslides close areas in the gorge. HWY 26 closed.
Jan. 2012	Columbia	DR-4055; Several landslides in the west hills of Portland.
Dec. 2015	Clackamas, Columbia, Multnomah, Washington	DR-4258; At least 10 roads closed because of landslides in the Portland metro area.
Jan. 2017	Columbia	DR-4328; Several roads closed.

Sources: ODOT Emergency Operations Plan, May, 2002; Interagency Hazard Mitigation Team Report, FEMA-1099-DR-OR, June, 1997; Interagency Hazard Mitigation Team Report, FEMA-1149-DR-OR, March, 1997; Taylor and Hatton, (1999); Hazards and Vulnerability Research Institute (2007). The Spatial Hazard Events and Losses Database for the United States, Version 5.1 [Online Database]. Columbia, SC: University of South Carolina; https://www.fema.gov/disasters

Probability

Table 2-248. Assessment of Landslide Probability in Region 2

	Clackamas	Columbia	Multnomah	Washington
Probability	H	VH	H	H

Source: DOGAMI, 2020

Landslides are found in every county in Oregon. There is a 100% probability of landslides occurring in Oregon in the future. Although we do not know exactly where and when they will occur, they are more likely to happen in the general areas where landslides have occurred in the past. Also, they will likely occur during heavy rainfall events or during a future earthquake.

Climate Change

Landslides are often triggered by heavy rainfall events when the soil becomes saturated. It is *very likely* (>90%) that Oregon will experience an increase in the frequency of extreme precipitation events (*high confidence*). Because landslide risk depends on a variety of site-specific factors, it is *more likely than not* (>50%) that climate change, through increasing frequency of extreme precipitation events, will result in increased frequency of landslides.

Vulnerability

Table 2-249. Local Assessment of Vulnerability to Landslides in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	L	—	M	L

Source: Source: Most recent local hazard vulnerability analyses (Table 2-4)

Table 2-250. State Assessment of Vulnerability to Landslides in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	H	H	H	H

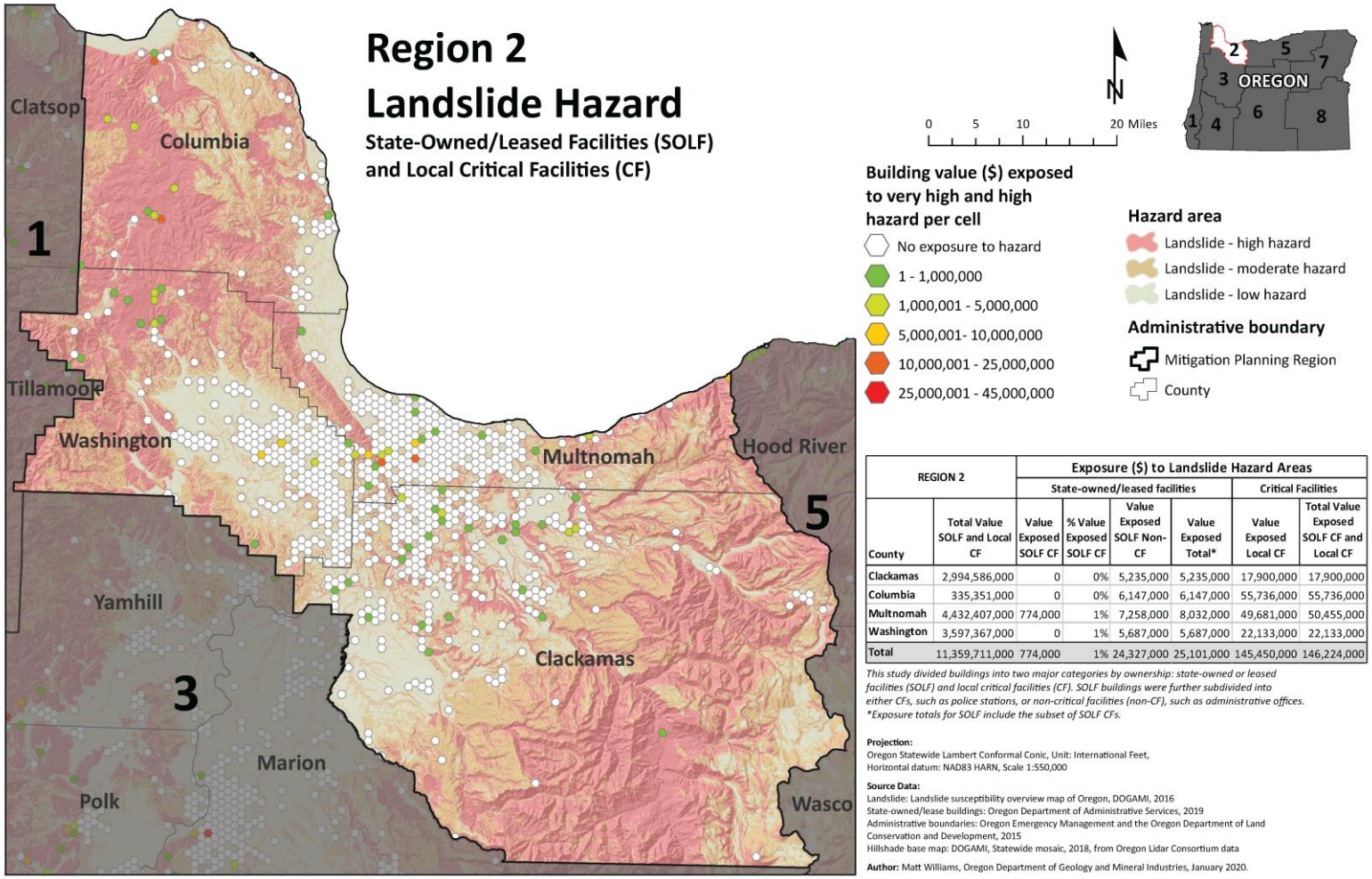
Source: DOGAMI and DLCD, 2020

Many communities in this region are vulnerable to landslides; for example, the Portland Hills and the Oregon City area both have high exposure to landslides. In general, Washington, Multnomah, and Clackamas Counties have relatively high vulnerability.

State-Owned/Leased Facilities and Critical/Essential Facilities

DOGAMI analyzed the potential dollar loss from landslide hazards to state buildings and critical facilities as well as to local critical facilities in Region 2. Over $25M in value of state facilities is exposed to landslide hazards in Region 2, 32% of it in in Multnomah County with the other counties containing between 21% and 24%. However, the potential loss to local critical facilities is much greater at over $145M. Columbia and Multnomah Counties stand to suffer the greatest losses, $55.7M (38%) and $49.7M (34%) respectively. Figure 2-161 illustrates the potential loss to state buildings and critical facilities and local critical facilities from a CSZ event.

Figure 2-161. State-Owned/Leased Facilities (SOLF) and Local Critical Facilities (CF) in a Landslide Hazard Zone in Region 2.High-resolution, full-size image linked from Appendix 9.1.26.



REGION 2		Exposure ($) to Landslide Hazard Areas					
		State-owned/leased facilities				Critical Facilities	
County	Total Value SOLF and Local CF	Value Exposed SOLF CF	% Value Exposed SOLF CF	Value Exposed SOLF Non-CF	Value Exposed Total*	Value Exposed Local CF	Total Value Exposed SOLF CF and Local CF
Clackamas	2,994,586,000	0	0%	5,235,000	5,235,000	17,900,000	17,900,000
Columbia	335,351,000	0	0%	6,147,000	6,147,000	55,736,000	55,736,000
Multnomah	4,432,407,000	774,000	1%	7,258,000	8,032,000	49,681,000	50,455,000
Washington	3,597,367,000	0	1%	5,687,000	5,687,000	22,133,000	22,133,000
Total	11,359,711,000	774,000	1%	24,327,000	25,101,000	145,450,000	146,224,000

This study divided buildings into two major categories by ownership: state-owned or leased facilities (SOLF) and local critical facilities (CF). SOLF buildings were further subdivided into either CFs, such as police stations, or non-critical facilities (non-CF), such as administrative offices.
**Exposure totals for SOLF include the subset of SOLF CFs.*

Projection:
Oregon Statewide Lambert Conformal Conic, Unit: International Feet,
Horizontal datum: NAD83 HARN, Scale 1:550,000

Source Data:
Landslide: Landslide susceptibility overview map of Oregon, DOGAMI, 2016
State-owned/lease buildings: Oregon Department of Administrative Services, 2019
Administrative boundaries: Oregon Emergency Management and the Oregon Department of Land Conservation and Development, 2015
Hillshade base map: DOGAMI, Statewide mosaic, 2018, from Oregon Lidar Consortium data

Author: Matt Williams, Oregon Department of Geology and Mineral Industries, January 2020.

Source: DOGAMI, 2020

Historic Resources

Of the 23,605 historic resources in Region 2, all but seven are exposed to landslide hazards: 1,496 are in an area of very high or high landslide hazard susceptibility; 6,633 in moderate; and 15,469 in low. Of those in areas of very high or high landslide hazards, over half are located in Multnomah County and a third are located in Clackamas County. The greatest number of historic resources exposed to landslide hazards is in Multnomah County.

Archaeological Resources

Of the 570 archaeological resources located in landslide hazard areas in Region 2, four hundred twenty-three (74%) are in high landslide hazard areas. Of those, three are listed on the National Register of Historic Places and 43 are eligible for listing. Fifty-one have been determined not eligible, and 326 have not been evaluated as to their eligibility. Over half the resources in high landslide hazard areas are located in Clackamas County and 94% of the resources in landslide hazard areas in Region 2 overall are also located in Clackamas County. The resources that are listed and eligible for listing are located in Clackamas, Columbia, and Multnomah Counties; none are located in Washington County.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

For the 2020 vulnerability assessment, DLCD combined the social vulnerability scores with the vulnerability scores for state buildings, state critical facilities, and local critical facilities to calculate an overall vulnerability score for each county. According to this limited assessment, Clackamas and Washington Counties have very low vulnerability to landslides and Columbia and Multnomah Counties have low vulnerability.

However, DOGAMI's expert assessment is that each of the four counties is a "most vulnerable community" with a high vulnerability rating. Multnomah County should be prioritized for mitigation actions statewide as it contains the City of Portland, which is the largest city in the state.

A 2018 DOGAMI publication **IMS-57, Landslide hazard and risk study of central and western Multnomah County, Oregon,** (Burns, Calhoun, Franczyk, Lindsey, & Ma, 2018), and **Open-File Report O-17-03, Landslide Inventory of Eastern Multnomah County** (Burns & Lindsey, 2017) provide details about the landslide hazard and risk in Multnomah County. **Open-File Report O-13-08, Landslide hazard and risk study of northwestern Clackamas County, Oregon** (Burns, et al., 2013b) provides details about landslide hazard and risk in Clackamas County. A 2018 DOGAMI publication, **Open-File Report O-18-02, Earthquake regional impact analysis for**

Clackamas, Multnomah, and Washington counties, Oregon, (Bauer, Burns, & Madin, 2018), provides information about potential impacts to Clackamas, Multnomah, and Washington counties from earthquakes, including a magnitude 9 Cascadia Subduction Zone earthquake. By using updated data, current subduction zone science and the latest mapping and modelling techniques, the study greatly improves understanding of potential earthquake impacts for the region. The study's estimates of injuries and fatalities, building damages, and other impacts helps communities, the region, and the state better prepare for, respond to, and recover from major earthquakes (https://www.oregongeology.org/pubs/ofr/p-O-18-02.htm). Major earthquakes will trigger landslides.

Risk

Table 2-251. Assessment of Risk to Landslides in Region 2

	Clackamas	Columbia	Multnomah	Washington
Risk	H	H	H	H

Source: DOGAMI and DLCD, 2020

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life. The 2020 risk assessment methodology combined the probability of landslide hazards occurring with the potential cost of damage to exposed state buildings and state and local critical facilities and with an assessment of the social vulnerability of the local population.

According to the 2020 risk scores and DOGAMI expertise combining the probability of landslides in Region 2 with its vulnerability, risk of landslides in Region 2 is high, and very high in Columbia County. All communities should be prioritized for mitigation actions.

Volcanoes

Characteristics

The eastern boundaries of Clackamas and Multnomah Counties coincide with the crest of the Cascade Mountains. Volcanic activity in the Cascades will continue, but questions regarding how, to what extent, and when remain. Most volcano-associated hazards are local (e.g., explosions, debris, lava, and pyroclastic flows). However, lahars can travel considerable distances through stream valleys, and ashfall can blanket areas many miles from the source.

Historic Volcanic Events

Table 2-252. Historic Volcanic Events in Region 2

Date	Location	Description
about 20,000 to 13,000 YBP	Polallie eruptive episode, Mount Hood	lava dome, pyroclastic flows, lahars, tephra
about 1,500 YBP	Timberline eruptive period, Mount Hood	lava dome, pyroclastic flows, lahars, tephra
1760–1810	Crater Rock/Old Maid Flat on Mount Hood	pyroclastic flows in upper White River; lahars in Old Maid Flat; dome building at Crater Rock
1859/1865	Crater Rock on Mount Hood	steam explosions/tephra falls
1907 (?)	Crater Rock on Mount Hood	steam explosions
1980	Mount St. Helens (Washington)	debris avalanche, ashfall, flooding on Columbia River

Note: YBP is years before present.

Sources: U.S. Geological Survey, Cascades Volcano Observatory: http://volcanoes.usgs.gov/observatories/cvo/; Wolfe and Pierson (1995); Scott, et al. (1997a)

Probability

Table 2-253. Assessment of Vulnerability to Volcanic Hazards in Region 2

	Clackamas	Columbia	Multnomah	Washington
Probability	M	L	M	L

Source: DOGAMI and DLCD, 2020

Region 2 communities are closest to Mount Hood (Clackamas County), a stratovolcano. Stratovolcanoes have wide ranging modes of eruption, making future volcanic activity difficult to predict definitively. Mount Hood's eruptive history can be traced to late Pleistocene times (15,000–30,000 years ago) and will no doubt continue. However, the central question remains: When?

The most recent series of events (1760–1907) consisted of small lahars, debris avalanches, steam explosions, and minor ashfalls. Mount Hood's recent history also includes ashfalls, dome building, lahars, pyroclastic flows, and steam explosions. These occurred approximately 200 years ago. Geoscientists have provided estimates of future activity in the vicinity of Crater Rock, a well-known feature on Mount Hood. They estimate a 1 in 300 chance that some dome activity

will take place in a 30-year period (1996–2026). For comparison, the 30-year probability of a house being damaged by fire in the United States is about 1 in 90 (Scott, et al., 1997a).

The probability of 1 cm or more of ashfall from eruptions throughout the Cascade Range include (Sherrod, Mastin, Scott, & Schilling, 1997):

- Clackamas County: between 1 in 500 and 1 in 1000;
- Multnomah County: between 1 in 500 and 1 in 1,000;
- Washington County: between 1 in 1,000 and 1 in 5,000; and
- Columbia County: between 1 in 5,000 to 1 in 10,000.

Mount St. Helens is less than 50 air miles from some Columbia County communities and is still active. Prevailing wind direction is of paramount importance. Because the prevailing winds are westerly in Columbia County, the risk of ashfall is considerably reduced.

Table 2-254 summarizes the probability of volcano-related hazards for each county. Debris from the 1980 eruption of Mount St. Helens impacted the shipping channel on the Columbia River by reducing water depth to such an extent that dredging was required.

Table 2-254. Probability of Volcano-Related Hazards in Region 2

Volcano Related Hazards	Washington	Multnomah	Clackamas	Columbia	Remarks
Volcanic ash (annual probability of 1cm or more accumulation from eruptions throughout the Cascade Range)	1 in 5,000 to 1 in 10,000	1 in 1,000 to 1 in 5,000	1 in 1,000 to 1 in 5,000	1 in 5,000 to 1 in 10,000	Sherrod, et al. (1997)
Lahar	no risk	Source: Mount Hood	Source: Mount Hood	no risk	Scott, et al. (1997a)
Lava flow	no risk	no risk	Source: Mount Hood	no risk	Scott, et al. (1997a)
Debris flow / avalanche	no risk	Source: Mount Hood	Source: Mount Hood	Mount St. Helens	Scott, et al. (1997a)
Pyroclastic flow	no risk	no risk	Source: Mount Hood	no risk	Scott, et al. (1997a)

Sources: Sherrod, et al. (1997) and Scott, et al. (1997a)

Vulnerability

Table 2-255. Local Assessment of Vulnerability to Volcanic Hazards in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	M	M	M	H

Source: Source: Most recent local hazard vulnerability analyses (Table 2-4)

Table 2-256. State Assessment of Volcanic Hazards Vulnerability in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	L	VL	L	VL

Source: DOGAMI and DLCD, 2020

State-Owned/Leased Buildings and Critical Facilities and Local Critical Facilities

DOGAMI analyzed the potential dollar loss from volcanic hazards to state-owned and –leased buildings and critical facilities as well as to local critical facilities in Region 2 (Figure 2-XX). Over $26M in value is exposed to volcanic hazards in Region 2, all of it in Clackamas County.

Historic Resources

Of the 23,605 historic buildings in Region 2, 197 are exposed to volcanic hazards. In Clackamas County, 111 are in a high hazard area, 50 in a moderate hazard area, and 16 in a low hazard area. In Multnomah County, 20 are in a low hazard area. See Appendix **9.1.12** for details.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

According to the 2020 vulnerability scores, none of the communities identified by DOGAMI as being most vulnerable to volcano hazards are located in Region 2. All communities in Region 2 have either very low (VL) or low (L) vulnerability ratings. While Clackamas County's slightly higher vulnerability score is driven by exposure of state buildings and critical facilities, Multnomah's County's score is driven by social vulnerability.

Risk

Table 2-257. Assessment of Risk to Volcanic Hazards in Region 2

	Clackamas	Columbia	Multnomah	Washington
Risk	M	VL	M	VL

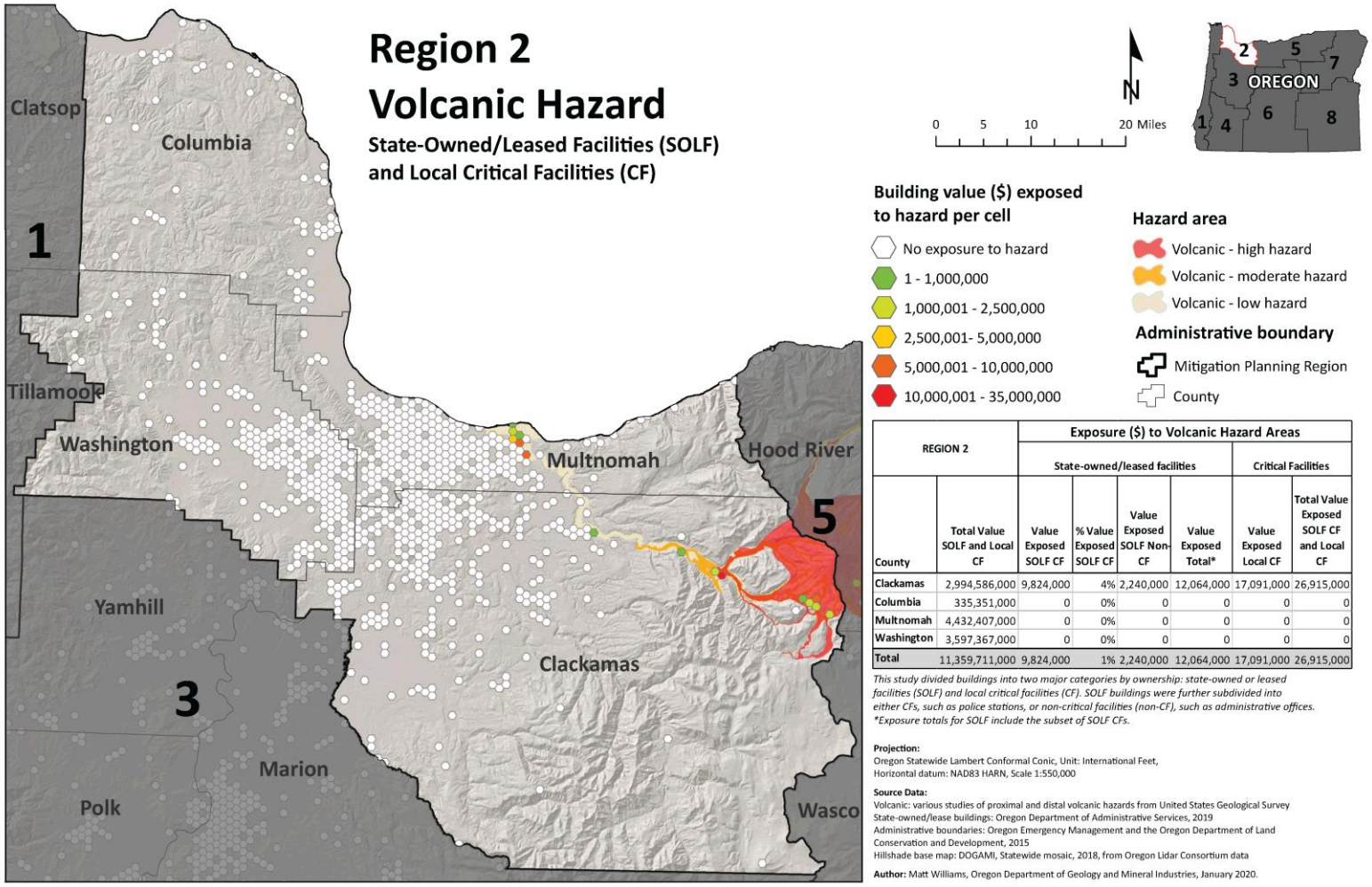
Source: DOGAMI and DLCD, 2020

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life. The probability of the hazard is moderate in both Clackamas and Multnomah Counties. Their vulnerability scores are both low, and they are driven by different variables. Clackamas County's vulnerability is due to the

presence of state and local critical facilities in the hazard area. Multnomah County's is due to social vulnerability.

The U.S. Geological Survey has addressed volcanic hazards at Mount Hood (Scott, et al., 1997a) and Mount St. Helens (Wolfe & Pierson, 1995). These reports include maps depicting the areas at greatest risk. Clackamas and Multnomah Counties, including the Portland Metro area, are at risk and should consider the impact of volcano-related activity on small mountain communities, dams, reservoirs, energy-generating facilities, and highways. These counties also should consider probable impacts on the local economy (e.g., wood products and recreation). The communities of Government Camp, Rhododendron, and Welches merit special attention. There is virtually no risk from volcanoes in Washington County, although normal prevailing winds could shift and carry ash into that area. Debris entering the Columbia River from eruptions at Mount St. Helens or Mount Hood may disrupt shipping operations based in Columbia and Multnomah Counties.

Figure 2-162. State-Owned/Leased Facilities (SOLF) and Local Critical Facilities (CF) in a Volcanic Hazard Zone in Region 2.High-resolution, full-size image linked from Appendix 9.1.26.



REGION 2		Exposure ($) to Volcanic Hazard Areas					
		State-owned/leased facilities				Critical Facilities	
County	Total Value SOLF and Local CF	Value Exposed SOLF CF	% Value Exposed SOLF CF	Value Exposed SOLF Non-CF	Value Exposed Total*	Value Exposed Local CF	Total Value Exposed SOLF CF and Local CF
Clackamas	2,994,586,000	9,824,000	4%	2,240,000	12,064,000	17,091,000	26,915,000
Columbia	335,351,000	0	0%	0	0	0	0
Multnomah	4,432,407,000	0	0%	0	0	0	0
Washington	3,597,367,000	0	0%	0	0	0	0
Total	11,359,711,000	9,824,000	1%	2,240,000	12,064,000	17,091,000	26,915,000

This study divided buildings into two major categories by ownership: state-owned or leased facilities (SOLF) and local critical facilities (CF). SOLF buildings were further subdivided into either CFs, such as police stations, or non-critical facilities (non-CF), such as administrative offices.
**Exposure totals for SOLF include the subset of SOLF CFs.*

Projection:
Oregon Statewide Lambert Conformal Conic, Unit: International Feet,
Horizontal datum: NAD83 HARN, Scale 1:550,000

Source Data:
Volcanic: various studies of proximal and distal volcanic hazards from United States Geological Survey
State-owned/lease buildings: Oregon Department of Administrative Services, 2019
Administrative boundaries: Oregon Emergency Management and the Oregon Department of Land Conservation and Development, 2015
Hillshade base map: DOGAMI, Statewide mosaic, 2018, from Oregon Lidar Consortium data

Author: Matt Williams, Oregon Department of Geology and Mineral Industries, January 2020.

Source: DOGAMI

Wildfires

Characteristics

There is extensive forested land in Columbia, Clackamas, Multnomah, and Washington Counties, both in undeveloped National Forest land and developing wildland-urban interface areas. All of it is at risk, but especially within the interface areas. In recent years, the cost of fire suppression has risen dramatically. A large number of homes has been threatened or burned, more firefighters have been placed at risk, and fire protection in wildland areas has been reduced. These factors have prompted communities and protection agencies to come together and use or create extensive fire prevention/mitigation programs. Community Wildfire Protection Plans lead the way for the development of Firewise Communities and fuel reduction projects throughout the region.

Fire return intervals for these areas is long, but due to the high amounts of vegetation and wind, when a fire does go though, it can be very large and damaging. Areas in this region are also experiencing more risk due to the current trend toward rural home site development. The age of the surrounding timber stands can be a factor in determining whether a non-threatening ground fire will spread to the canopy and become a dangerous crown fire. Clearings and fuel breaks will disrupt a slow moving wildfire enabling successful suppression. Agricultural and ranching activities throughout the area increase the risk of a human-caused wildfire spreading to forested areas. Large expanses of fallow fields or non-annual cash crops provide areas of continuous fuels that have potential to threaten several homes and farmsteads. Under extreme weather conditions, escaped agricultural fires could threaten individual homes or a town site; however, this type of fire is usually quickly controlled. High winds increase the rate of fire spread and intensity of fires.

Table 2-258 shows the single significant fire affecting Region 2.

Historic Wildfire Events

Table 2-258. Historic Wildfires in Region 2

Year	Name of Fire	Counties	Acres Burned
1902	Columbia	Clackamas/Multnomah	170,000
2012	Holloway	Washington	>254,000
2017	Eagle Creek	Tillamook, Washington, Yamhill	48,831

Source: Oregon Department of Forestry

Probability

Table 2-259. Assessment of Wildfire Probability in Region 2

	Columbia	Clackamas	Multnomah	Washington
Probability	L	M	L	L

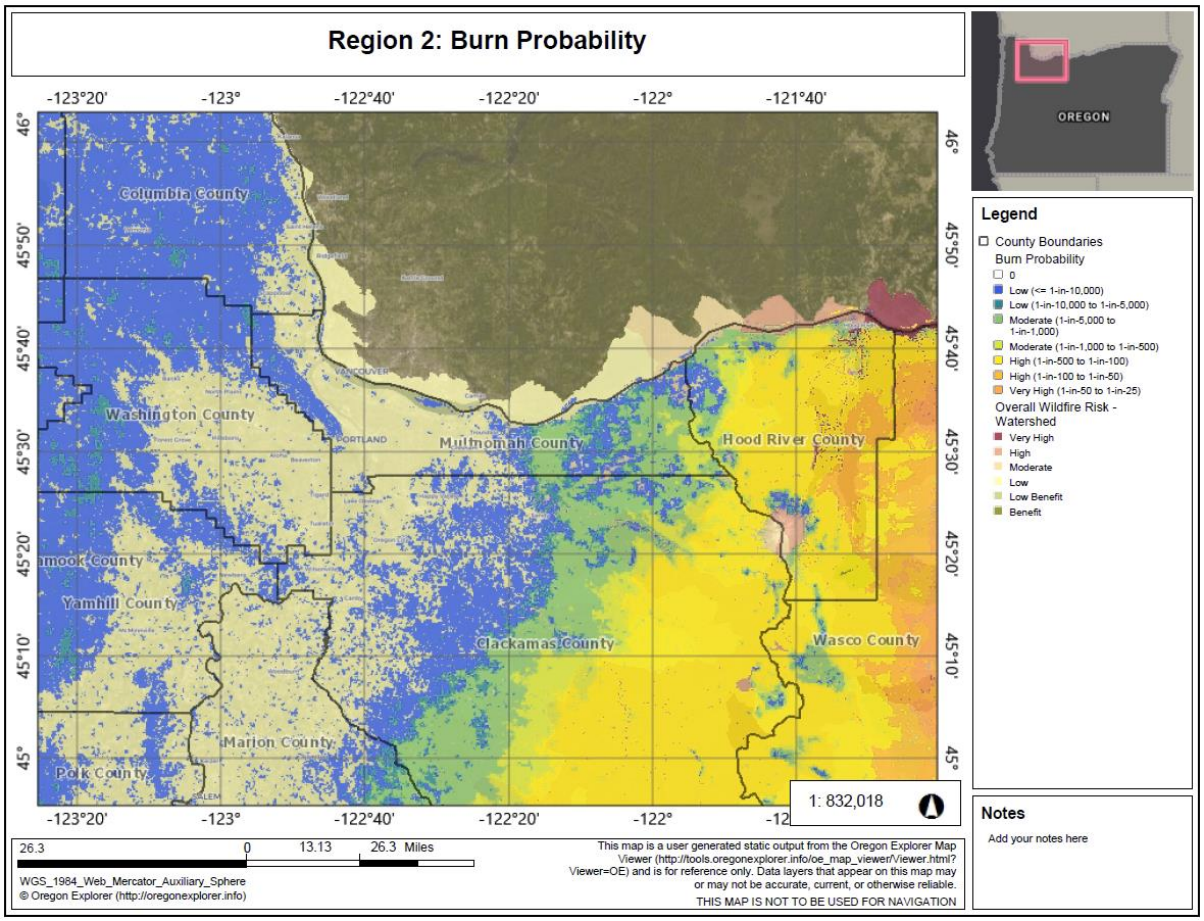
Source: PNW Quantitative Wildfire Risk Assessment and Oregon Explorer, 2020

In the PNW Quantitative Wildfire Risk Assessment, Burn Probability was used to assess the likelihood of a large wildfire (>250 acres occurring). In conjunction with that data, examining the number of fire starts reported by ODF for all acreage sizes, gives a full picture of probability of wildfire.

These scores identify high-priority areas to which local and state governments can target mitigation actions. The challenge with statewide assessments and methodologies is that the scale of the data is not necessarily reflective of the probability at the local and parcel levels, so the fire start data is utilized to help reflect that local level assessment to a certain extent.

Figure 2-163 shows the likelihood of a wildfire >250 acres burning a given location, based on wildfire simulation modeling. This is an annual burn probability, adjusted to be consistent with the historical annual area burned. Be aware that conditions vary widely with local topography, fuels, and weather, especially local winds. In all areas, under warm, dry, windy, and drought conditions, expect higher likelihood of fire starts, higher fire intensities, more ember activity, a wildfire more difficult to control, and more severe fire effects and impacts.

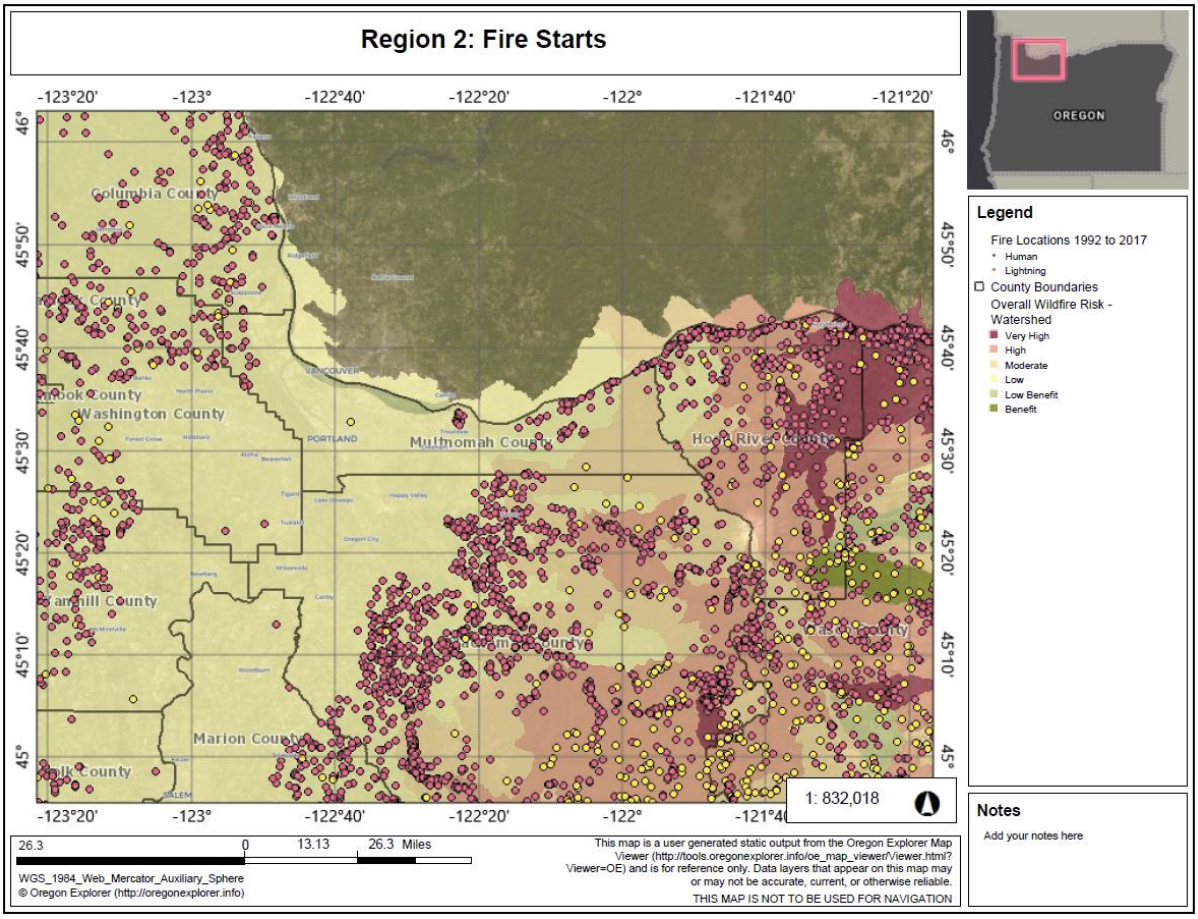
Figure 2-163. Burn Probability



Source: Oregon Wildfire Risk Explorer, March 2020

Wildfire is defined as an uncontrolled burning of forest, brush, or grassland. Wildfires have always been a part of these ecosystems, sometimes with devastating effects. Wildfire may result from natural causes (e.g., lightning strikes), a mechanical failure (Oxbow Fire), or human causes (unattended campfire, debris burning, or arson). Most wildfires can be linked to human carelessness.

Figure 2-164. Human- and Lightning-Caused Wildfires in Region 2, 1992-2017



Source: Oregon Wildfire Risk Explorer, March 2020

Climate Change

Over the last several decades, warmer and drier conditions during the summer months have contributed to an increase in fuel aridity and enabled more frequent large fires, an increase in the total area burned, and a longer fire season across the western United States. Human-cause climate change is partially responsible for these trends, which are expected to continue increasing under continued climate warming (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

In moisture-limited forest systems, such as those in the Coast and Cascade Ranges, warming winters will lead to more fine fuels from greater cold season growth. Hotter and drier conditions will lead to large fuel quantities, which lead to large and severe fires. It is very likely (>90%) that the Coast Range and lower elevations of the Cascade Range in Region 2 will experience

increasing wildfire frequency and intensity under future climate change. Modeled projections of future fire frequency indicate more frequent fires for the Pacific Northwest, particularly west of the Cascade Mountains where fires have been infrequent historically. In coastal areas, fire frequency is projected to change from approximately every 100 years to every 60 years.

One proxy for future change in wildfire risk is a fire danger index called 100-hour fuel moisture (FM100), which is a measure of the amount of moisture in dead vegetation in the 1–3 inch diameter class available to a fire. A majority of climate models project that FM100 would decline across Oregon under future climate scenarios. This drying of vegetation would lead to greater wildfire risk, especially when coupled with projected decreases in summer soil moisture. The number of "very high" fire danger days—in which fuel moisture is below the 10th percentile—is projected to increase across the state and in Region 2 counties (**Table 2-260**).

Table 2-260. Projected Increase in Annual Very High Fire Danger Days in Region 2 Counties by 2050 under RCP 8.5

County	# Additional Days	Percent Change
Clackamas	14	39%
Columbia	13	35%
Multnomah	14	39%
Washington	13	34%

Note: Very High fire danger days are defined as days in which the fuel moisture is below the 10th percentile. By definition, the historical baseline has a 36.5 Very High fire danger days. These numbers represent the multi-model mean change.

Source: Oregon Climate Change Research Institute (OCCRI)

Vulnerability

Table 2-261. Local Assessment of Vulnerability to Wildfire in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	L	L	—	M

Source: Source: Most recent local hazard vulnerability analyses (**Table 2-4**)

Table 2-262. Assessment of Vulnerability to Wildfire in Region 2 – Communities at Risk

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	VL	L	L	VL

Source: ODF Communities at Risk Report, 2020

Table 2-263. Assessment of Vulnerability to Wildfire in Region 2 – 2020 Vulnerability Assessment

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	VL	VL	L	VL

Source: DOGAMI and DLCD, 2020

According to ODF's assessment of Communities at Risk, vulnerability in this region is mild. The Northern Willamette Valley / Portland Metro area is dominated by a highly populated rural interface as well as metropolitan areas. Timber and agriculture land line suburban areas. A cooler climate and reduced fire danger results in fewer wildfires. In addition, response times are typically much quicker in this region due to large populations and several fire agencies nearby.

Each year a significant number of people build homes within or on the edge of the forest (wildland-urban interface), thereby increasing wildfire hazards. These communities have been designated "Wildland-Urban Interface Communities" and include those n **Table 2-264**.

Table 2-264. Wildland-Urban Interface Communities in Region 2

Clackamas	Columbia	Multnomah	Washington
Beaver Creek	Alston	Bonneville	Banks
Boring	Clatskanie	Burlington	Buxton
Bull Run	Columbia City	Corbett	Cedar Mill
Canby	Deep Island	Crystal Spring	Cherry Grove
Cedarhurst Park	Globe	Fairview	Cornelius
Clackamas	Mist Birkenfeld	Gresham	Durham
Colton	Pittsburg	Holbrook	Forest Grove
Damascus	Prescott	Lower Columbia Gorge	Gales Creek
Dickey Prairie	Quincy	Maywood Park	Gaston
Eagle Creek	Rainier	Portland	Glenwood
Estacada	Scappoose	Riverdale	Hillsboro
Fallsview	Spitzenberg	Sauvie Island	Rock Creek
Firgrove	St. Helens	Shelternoon	Shady Brook
Gladstone	Stimson Mill	Skyline	Stimson Mill
Government Camp	Swedetown	Troutdale	Timber
Happy Valley	Vernonia	Warrendale	Tualatin Valley
Hoodland	Yankton		
Lake Grove	Warren		
Lake Oswego			
Maple Grove			
Molalla			
Molino			
Oregon City			
Redland			
Sandy			
Springwater			
Timber Grove			
Timber Park			
West Linn			
Wilsonville			

ODF Communities at Risk Report, 2020

State-Owned/Leased Buildings and Critical Facilities and Local Critical Facilities

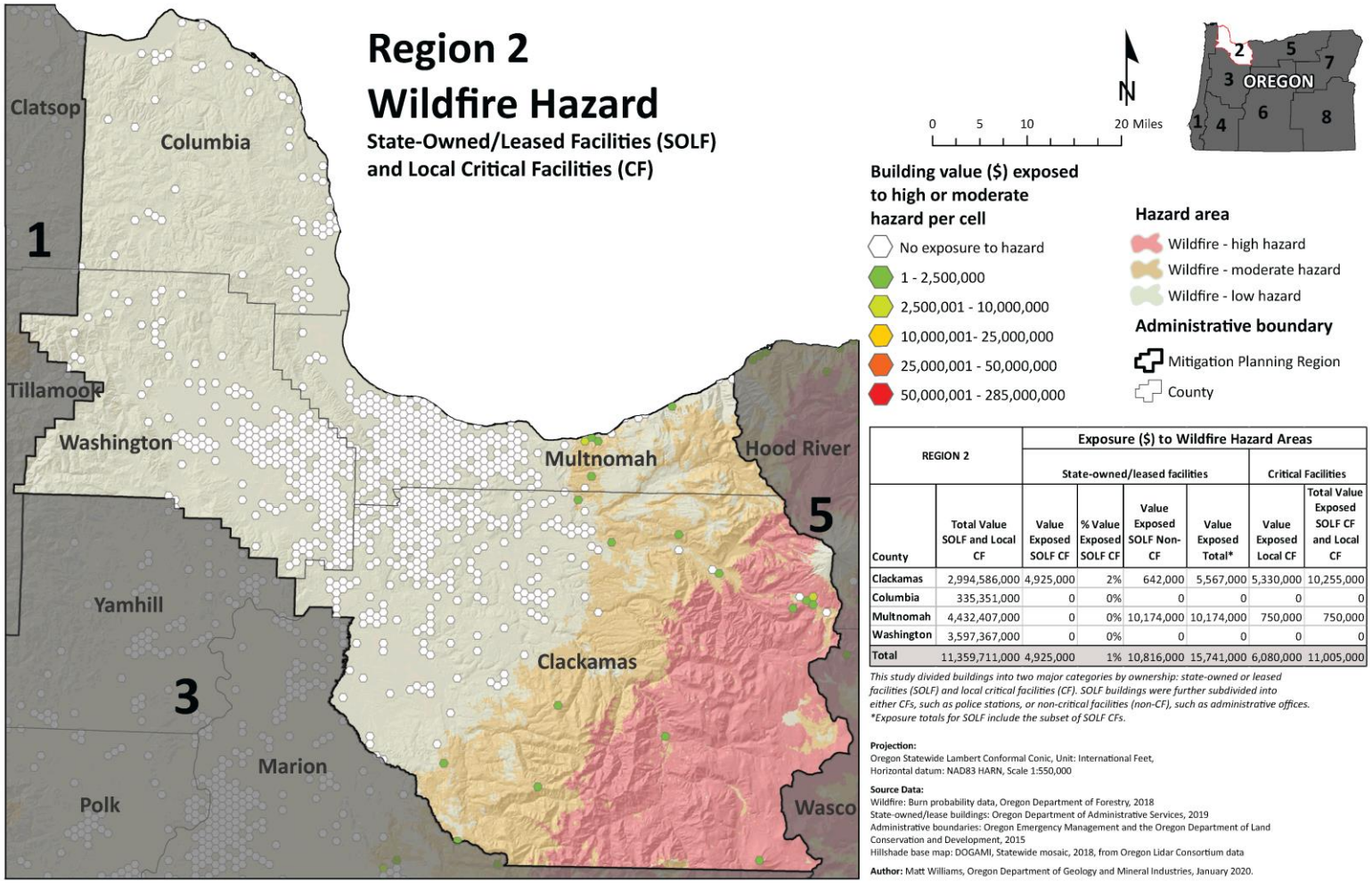
For the 2020 vulnerability assessment, DOGAMI followed ODF guidance and evaluated building exposure to wildfire using the Burn Probability dataset which was classified by ODF in "High,"

"Moderate," and "Low" categories. Urban areas, lake surfaces, and areas bare of vegetation do not have fire risk classifications in the data and are represented here as "Low."

In Region 2, there is a potential loss to wildfire of close to $16M in state building and critical facility assets, about two-thirds of it in Multnomah County and about one-third in Clackamas County. There is a much smaller potential loss in local critical facilities: about $6M, approximately one-third as much. Neither Columbia County nor Washington County has state assets or local critical facilities located in a wildfire hazard area.

Because the state is self-insured, FEMA funds are rarely used to cover damage to state assets from natural hazards. According to Department of Administrative Services records, there has been one reported loss to a state asset caused by a wildfire since the beginning of 2015. It was located in the Columbia River Gorge; whether in Region 2 or Region 5 is not clear. The net claim paid was under $2,000.

Figure 2-165. State-Owned/Leased Facilities (SOLF) and Local Critical Facilities (CF) in a Wildfire Hazard Zone in Region 2.High-resolution, full-size image linked from Appendix 9.1.26.



REGION 2		Exposure ($) to Wildfire Hazard Areas					
		State-owned/leased facilities				Critical Facilities	
County	Total Value SOLF and Local CF	Value Exposed SOLF CF	% Value Exposed SOLF CF	Value Exposed SOLF Non-CF	Value Exposed Total*	Value Exposed Local CF	Total Value Exposed SOLF CF and Local CF
Clackamas	2,994,586,000	4,925,000	2%	642,000	5,567,000	5,330,000	10,255,000
Columbia	335,351,000	0	0%	0	0	0	0
Multnomah	4,432,407,000	0	0%	10,174,000	10,174,000	750,000	750,000
Washington	3,597,367,000	0	0%	0	0	0	0
Total	11,359,711,000	4,925,000	1%	10,816,000	15,741,000	6,080,000	11,005,000

This study divided buildings into two major categories by ownership: state-owned or leased facilities (SOLF) and local critical facilities (CF). SOLF buildings were further subdivided into either CFs, such as police stations, or non-critical facilities (non-CF), such as administrative offices.
**Exposure totals for SOLF include the subset of SOLF CFs.*

Projection:
Oregon Statewide Lambert Conformal Conic, Unit: International Feet,
Horizontal datum: NAD83 HARN, Scale 1:550,000

Source Data:
Wildfire: Burn probability data, Oregon Department of Forestry, 2018
State-owned/lease buildings: Oregon Department of Administrative Services, 2019
Administrative boundaries: Oregon Emergency Management and the Oregon Department of Land Conservation and Development, 2015
Hillshade base map: DOGAMI, Statewide mosaic, 2018, from Oregon Lidar Consortium data

Author: Matt Williams, Oregon Department of Geology and Mineral Industries, January 2020.

Source: DOGAMI,2020

Historic Resources

Of the 23,605 historic resources in Region 2, forty-one are located in an area of high wildfire hazard, all of them in Clackamas County. One hundred forty-four are located in an area of moderate wildfire hazard: one hundred twenty-nine in Clackamas County, and fifteen in Multnomah County.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

For the 2020 vulnerability assessment, DLCD combined the social vulnerability scores with the vulnerability scores for state buildings, state critical facilities, and local critical facilities to calculate an overall vulnerability score for each county. According to this limited assessment, all the counties in Region 2 have very low vulnerability to wildfire except Multnomah County whose low vulnerability is slightly greater. With the exception of Clackamas County (low/very low), the scores based on Communities at Risk and the 2020 vulnerability assessment scores agree.

None of the counties in Region 2 are most vulnerable to wildfire.

Risk

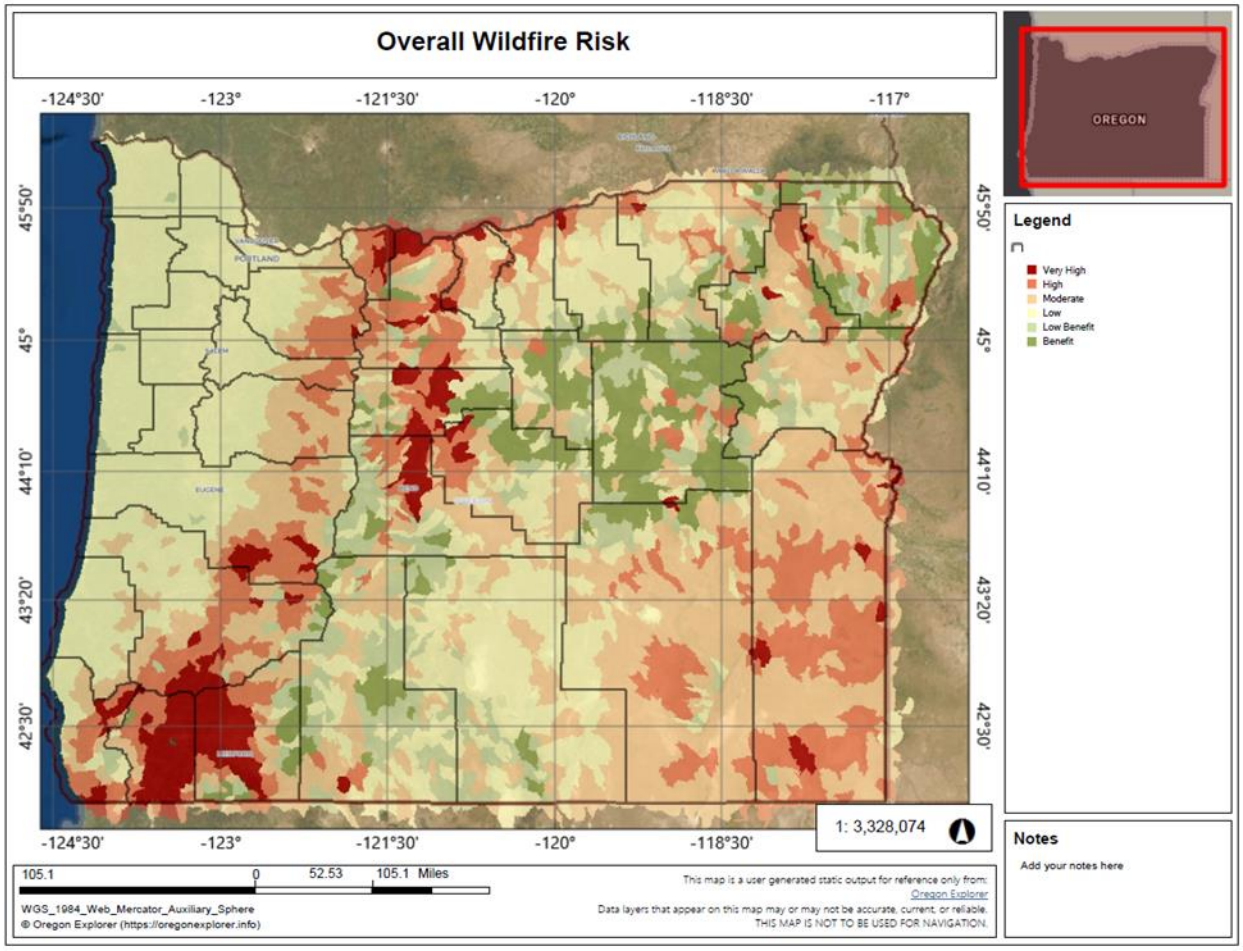
Table 2-265. Risk of Wildfire Hazards in Region 2

	Columbia	Clackamas	Multnomah	Washington
Risk	VL	VL	VL	VL

Source: DOGAMI, DLCD

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life. The 2020 risk assessment combined the wildfire probability with the vulnerability assessment to arrive at a composite risk score. According to the 2020 risk assessment, all of the counties in Region 2 are at very low risk from wildfire. This is consistent with ODF's assessment for the western portion of Region 2, but not the eastern portions of Multnomah and Clackamas Counties. The 2020 risk assessment is not granular enough to account for geographic differences in probability, vulnerability, or risk within a county.

Figure 2-166. Overall Wildfire Risk



Source: Oregon Explorer, 2020

Windstorms

Characteristics

Extreme winds (other than tornadoes) are experienced in all of Oregon's eight regions. The most persistent high winds occur along the Oregon Coast and the Columbia River Gorge; these areas have special building code standards. Tornados and thunderstorms are increasing in frequency in the Willamette Valley. A majority of the destructive surface winds in Region 2 are from the southwest. Under certain conditions, very strong east winds may occur, but these usually are limited to small areas in the vicinity of the Columbia River Gorge or other low mountain passes.

The much more frequent and widespread strong winds from the southwest are associated with storms moving onto the coast from the Pacific Ocean. If the winds are from the west, they may be stronger on the coast than in the interior valleys because of the north-south orientation of the Coast Range and Cascades. These mountain ranges obstruct and slow down the westerly surface winds. The most destructive winds are those which blow from the south, parallel to the major mountain ranges. The Columbus Day Storm of 1962 was a classic example of such a storm, and its effects were so devastating that it has become the benchmark from which other windstorms in Oregon are measured. The storm caused significant damage in Region 2.

Historic Windstorm Events

Table 2-266. Historic Windstorms in Region 2

Date	Location	Description
Apr. 1931	western Oregon	unofficial wind speeds reported at 78 mph; damage to fruit orchards and timber
Nov. 10-11, 1951	statewide	widespread damage; transmission and utility lines; wind speed 40-60 mph; gusts 75–80 mph
Dec. 1951	statewide	wind speed 60 mph in Willamette Valley; 75-mph gusts; damage to buildings and utility lines
Dec.1955	statewide	wind speeds 55–65 mph with 69-mph gusts; considerable damage to buildings and utility lines
Nov. 1958	statewide	wind speeds at 51 mph with 71-mph gusts; every major highway blocked by fallen trees
Oct. 1962	statewide	Columbus Day Storm; Oregon's most destructive storm to date; 116-mph winds in Willamette Valley; estimated 84 houses destroyed, with 5,000 severely damaged; total damage estimated at $170 million
Mar. 1971	most of Oregon	greatest damage in Willamette Valley; homes and power lines destroyed by falling trees; destruction to timber in Lane County
Nov. 1981	most of Oregon	highest winds since Oct. 1962; wind speed 71 mph in Salem; marinas, airports, and bridges severely damaged
Jan. 1990	statewide	heavy rain with winds exceeding 75 mph; significant damage; one fatality
Dec. 1995	statewide	followed path of Columbus Day Storm; wind speeds 62 mph in Willamette Valley; damage to trees (saturated soil a factor) and homes (FEMA-1107-DR-Oregon)
Nov. 1997	western Oregon	wind speed 52 mph in Willamette Valley; trees uprooted; considerable damage to small airports
Feb. 2002	western Oregon	strongest storm to strike western Oregon in several years; many downed power lines (trees); damage to buildings; water supply problems (lack of power); estimated damage costs: $6.14 million (FEMA-1405-DR-Oregon)

Date	Location	Description
June 2004	Washington Count	$100 in property damage from a tornado
Dec. 2004	Clackamas County	$6,250 in property damage *damage estimate includes areas outside of Region 2
June 2005	Multnomah County	lightning causes $50,000 in damage
Dec. 2005	Clackamas, Multnomah, and Washington Counties	$9,000 in property damage
Jan. 2006	Clackamas, Columbia, Washington, and Multnomah Counties	wind storm with winds up to 58 mph caused a total of $500,000 in damages spread out over all four counties and included Yamhill, Marion, and Polk Counties as well
Feb. 2006	Columbia, Multnomah, Clackamas, Washington Counties	strong wind storm caused $167,000 in damage for all four counties; storm also impacted counties in Regions 3 and 1 for a total storm damage of $575,000
May 2007	Clackamas County	windstorm brought wind gusts up to 50 mph and produced extensive hail, causing $5000 in damages
July 2007	Multnomah and Washington Counties	heavy windstorm with 58-mph winds downed several trees, caused $5000 in damage/$1000 in damage in Beaverton
Sep. 2007	Multnomah County	severe storm that produced hail and a tornado, caused $5000 in damages
June 2008	Clackamas County	severe storms produced heavy winds and hail near the Cascades, caused $5000 in damages
Mar. 2009	Columbia County	72-mph winds caused $20,000 in property damage
Nov. 2012	Lincoln County	97-mph winds at Newport cost $1 million in property damage
Dec. 2015	Regions 1-4	FEMA-4258-DR: severe winter storms, straight-line winds, flooding, landslides, and mudslides
Jul. 2018	Portland, Multnomah County	tornado; EF0; damage to trees and homes

Sources: Taylor and Hatton (1999); and FEMA-1405-DR-OR: February 7, 2002, Hazard Mitigation Team Survey Report, Severe Windstorm in Western Oregon; Hazards and Vulnerability Research Institute (2007). The Spatial Hazard Events and Losses Database for the United States, Version 5.1 [Online Database]. Columbia, SC: University of South Carolina. Available from http://www.sheldus.org; National Climatic Data Center, Storm Events, Database http://www.ncdc.noaa.gov/stormevents/; https://www.fema.gov/disaster/; https;//www.weather.gov/pqr/07-01-2019

Probability

Table 2-267. Assessment of Windstorm Probability in Region 2

	Columbia	Clackamas	Multnomah	Washington
Probability	M	M	H	H

Source: Oregon Office of Emergency Management, 2013 County Hazard Analysis Scores

The 100-year storm in Region 2 is considered to be one-minute average winds of 80 mph. A 50-year storm is 72 mph. And a 25-year storm is 65 mph in this region.

Climate Change

There is insufficient research on changes in the likelihood of windstorms in the Pacific Northwest as a result of climate change. While climate change has the potential to alter surface winds through changes in the large-scale free atmospheric circulation and storm systems, there is as yet no consensus on whether or not extratropical storms and associated extreme winds will intensify or become more frequent along the Pacific Northwest coast under a warmer climate.

Vulnerability

Table 2-268. Local Assessment of Vulnerability to Windstorms in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	L	—	M	H

Source: Most recent local hazard vulnerability analyses (Table 2-4)

Table 2-269. State Assessment of Vulnerability to Windstorms in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	L	H	H	H

Source: Oregon Office of Emergency Management, 2013 County Hazard Analysis Scores

Columbia, Multnomah, and Washington Counties are listed as most vulnerable to windstorms, as determined by the staff of the Oregon Public Utilities Commission and OCCRI.

Many buildings, utilities, and transportation systems within Region 2 are vulnerable to wind damage. This is especially true in open areas, such as natural grasslands or farmlands. It also is true in forested areas, along tree-lined roads and electrical transmission lines, and on residential parcels where trees have been planted or left for aesthetic purposes. Structures most vulnerable to high winds include insufficiently anchored manufactured homes and older buildings in need of roof repair.

Fallen trees are especially troublesome. They can block roads and rails for long periods and affect emergency operations. In addition, uprooted or shattered trees can down power and other utility lines and effectively bring local economic activity and other essential facilities to a standstill. Much of the problem may be attributed to a shallow or weakened root system in saturated ground. Many roofs have been destroyed by uprooted ancient trees growing next to a house. In some situations, strategic pruning may be the answer. Prudent counties will work with utility companies to identify problem areas and establish a tree maintenance and removal program.

Additional considerations include ferry systems and bridges, which may be closed during high-wind periods.

Impacts to agriculture related to windstorms, or related to windstorms with heavy and/or freezing precipitation, include crop damage or loss (e.g., grain crops, orchards), and impacts to buildings and infrastructure important for supporting agriculture, for example, Oregon State University Extension and USDA Agricultural Research stations that provide services and support to agricultural communities and conduct valuable research on pest control, irrigation efficiency, soil health, crop research, livestock raising and health, and other topics.

Data have not yet been collected to assess the economic impacts to the state as a consequence of wind-related damage to agriculture and associated infrastructure.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard. The counties with the greatest social vulnerability statewide are Marion, Morrow, Umatilla, Wasco, Jefferson, Klamath, and Malheur.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

Multnomah's County's relatively higher social vulnerability in Region 2 indicates that the effects of windstorms will be felt more intensely by its population than by the populations of the other Region 2 counties and will require more resources for preparation, mitigation, and response. Therefore, Multnomah County is the county most vulnerable to windstorms in Region 2.

State-Owned/Leased Buildings and Critical Facilities and Local Critical Facilities

The value of state-owned and leased buildings and critical facilities in Region 2 is approximately $1,134,896,000 representing the total potential for loss of state assets due to windstorms. The value of locally owned critical facilities is $10,224,815,000. Because windstorms, while primarily impacting the Columbia River Gorge in Region 2, could impact the entire region, these figures together represent the maximum potential loss to state assets and local critical facilities due to windstorms. Because the state is self-insured, FEMA funds are rarely used to cover damage to state assets from natural hazards. According to Department of Administrative Services records, only one loss of over $111,000 to a state facility was recorded in Region 2 since the beginning of 2015. It was not caused by a windstorm.

Risk

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life.

Due to its greater vulnerability, Multnomah County is at greater risk from windstorms than the other counties in Region 2.

Winter Storms

Characteristics

Winter storm events occur annually in Region 2, sometimes becoming severe. Severe winter weather in this region is characterized by extreme cold, snow, ice, and sleet. While most communities are prepared for severe winter weather, some are unprepared financially and otherwise. This is particularly true in the vicinity of Portland, where frigid air sometimes moves westward through the Columbia River Gorge. During these periods, it is not unusual for northern Willamette Valley communities to receive snow or ice storms known as “silver thaws.” Severe weather conditions do not last long in Region 2. Consequently, winter preparedness is a moderate priority.

Historic Winter Storms

Table 2-270. Historic Winter Storms in Region 2

Date	Location	Description
Dec. 1861	statewide	snowfall 1-3 ft; snow in Willamette Valley until late Feb.
1862, 1866, 1884, 1885, 1890, 1892, 1895	Portland area / Northern Willamette Valley	severe winter conditions, especially in the Portland area; record-breaking snowfalls
Jan. 1916	statewide	two snow storms, each totaling 5 inches or more
Dec. 1919	Portland area	third heaviest snowfall on record; Columbia River froze, closing navigation
1927, 1936, 1937, 1943, 1949	Portland area, Western Oregon	heavy snowfalls recorded
Jan. 1950	statewide	heaviest snowfall since 1890; many highway closures; considerable property damage
1956, 1960, 1962	western Oregon	packed snow became ice; automobile accidents throughout the region
Mar. 1960	statewide	snowfall: 3-12 inches, depending on location
Jan. 1969	statewide	record-breaking snowfalls; $3 to $4 million in property damage
Jan. 1980	statewide	a series of storms bringing snow, ice, wind, and freezing rain; six fatalities
Feb. 1985	statewide	western valleys received between 2-4 inches of snow; massive power failures (tree limbs broke power lines)
Dec. 1985	Willamette Valley	heavy snowfall throughout valley
Mar. 1988	statewide	strong winds and heavy snow
Feb. 1989	statewide	heavy snowfall and record low temperatures
Feb. 1990	statewide	average snowfall from one storm about 4 inches (Willamette Valley)
Dec. 1992	western Oregon	heavy snow; interstate highway closed
Feb. 1993	western Oregon	record snowfalls
Winter 1998-1999	statewide	series of storms; one of the snowiest winters in Oregon history
Dec. 2007	Columbia County	resulted in Presidential Disaster Declaration; $180 million in damage in the state; severe flooding in Vernonia; power outages for several days; five fatalities
Dec. 2008	Columbia County	snow and freezing rain in the Portland Metro area; $300,000 in property damage
Dec. 2009	statewide	snow and freezing rain in Salem, and Portland to Hood River; I-84 closed for 22 hours
Nov. 2010	statewide	snow, freezing rain, and ice accumulation in Portland to Hood River
Jan. 2012	Multnomah County	snow and ice east of Troutdale; I- 84 closed for 9 hours
Feb. 6–10, 2014	Columbia, Clackamas, Multnomah, and Washington Counties	DR-4169 Linn, Lane, Benton and Lincoln Counties declared. A strong winter storm system affected the Pacific Northwest during the February 6–10, 2014 time period bringing a mixture of arctic air, strong east winds, significant snowfall and freezing rain to several counties in northwest Oregon; during the 5-day period Feb. 6–10, 2 to10 inches of snow fell in the coastal region of northwest Oregon; freezing rain accumulations generally were 0.25 to 0.75 inches; the snowfall combined with the freezing rain had a tremendous impact on the region

Date	Location	Description
Feb. 11–14, 2014	Clackamas, Multnomah, and Washington Counties	Another weather system moved across northwest Oregon during the February 11–14 time frame; this storm was distinctly different from the storm that produced the snow and ice the week prior and brought abundant moisture and warm air from the sub-tropics into the region; as this storm moved across the area, 2 to 7 inches of rain fell across many counties in western Oregon; the heavy rainfall combined with warm temperatures led to snowmelt and rainfall runoff that produced rapid rises on several rivers, which included flooding on three rivers in northwest Oregon
Nov. 13, 2014	Clackamas, and Multnomah Counties (Western Columbia River Gorge)	An early cold snap hit the Pacific Northwest before moist Pacific air moved in and resulted in one of the earliest snow, sleet, and freezing rain events in northwestern Oregon. Sleet and freezing rain in particular created hazardous commutes for tens of thousands in the western and eastern suburbs of Portland. Snow accumulations was primarily restricted to the Cascade valleys and the central Columbia River Gorge. Spotters reported around 6 to 8 inches of snow for the Cascade Foothills followed by a quarter of an inch of ice. A combination of heavy snow and ice resulted in slick driving conditions for the Western Columbia River Gorge. Areas in the gorge measured a quarter of an inch of ice whereas other areas had 5 to 8 inches of snow.
Dec. 6-23, 2015	Statewide storm events	DR-4258 Clatsop, Columbia, Multnomah, Clackamas, Washington, Tillamook, Yamhill, Polk, Lincoln, Linn, Lane, Douglas, Coos, and Curry Counties declared. Severe winter storms, straight-line winds, flooding, landslides, and mudslides. Several pacific storm systems moved across the region over the Dec 12-13 weekend. Each storm system brought several inches of snow to the mountain areas. At first the snow was limited to higher elevations...but lowered with time to some of the west side valley floors.
Mar. 13, 2016	Clackamas, County (North Oregon Cascades)	A strong low pressure system generated frequent and persistent snow showers over the northern and central Oregon Cascades. Several SNOTEL stations measured 16 to 24 inches of snow over a 24 to 30 hour period above 3500 feet.
Dec. 8, 2016	Multnomah, Clackamas, Washington and Columbia Counties (Greater Portland Area and Western Columbia River Gorge)	A strong frontal system brought strong east winds to the North Willamette Valley and a mix of snow, sleet, and freezing rain down to the Valley Floor. Four to six inches of snow fell along interstate 84 before turning to sleet and freezing rain. One to 1.5 inches of ice accumulation was also reported. The Portland Metro area generally had 1-2 inches of snow, with 0.2 to 0.3 inch of ice accumulation. Ice accumulations were higher in the West Hills and near the Columbia River Gorge, with 0.8 inch of ice accumulation reported at Council Crest in SE Portland. The NWS Office in Parkrose had 0.4 inch of ice accumulation.
Dec. 14-15, 2016	Clackamas County (Northern Cascade foothills)	DR-4296 Lane and Josephine counties declared. Severe winter storm and flooding disaster declared in Lane and Josephine counties. East winds ahead of an approaching low pressure system brought temperatures down below freezing across the area ahead of the approaching precipitation. This lead to a mix of freezing rain, sleet, and snow across the area.
Dec. 26-27, 2016	Clackamas County (North Oregon Cascades)	A frontal system brought high winds to the Central Oregon Coast, heavy snow to the Cascades and a mix of ice and snow in the Columbia River Gorge and Hood River Valley. Estimate the Columbia Gorge had around 0.2 to 0.5 inch of ice accumulation as temperatures in the lower 30s with reports of snow and freezing rain in Hood River.

Date	Location	Description
Jan. 7-8, 2017	Multnomah, Clackamas, Washington, and Columbia Counties (Greater Portland Area)	DR-4328 Columbia, Hood River, Deschutes and Josephine Counties declared. Severe Winter Storms, Flooding, Landslides, And Mudslides. A broad shortwave trough brought multiple rounds of precipitation, including a wintry mix of snow and ice for many locations across Northwest Oregon. Strong easterly pressure gradients generated high winds through the Columbia River Gorge as well on January 8. General snowfall totals of 2-4 inches were reported, with the greatest total being 4.5 inches. Major ice accumulations occurred after the snow, with several locations reporting 0.50-1.00. The combination of snow and ice resulted in significant power outages and closures across the area.
Feb. 3-4, 2017	Multnomah County (Western Columbia River Gorge)	Fronts associated with a low pressure system passing north into the Olympic Peninsula brought heavy snow and ice to the Columbia Gorge.
Dec. 24, 2017	Multnomah County (Western Columbia River Gorge	Low pressure system moving into the Pacific Northwest pulled cold air from the Columbia Basin west into the Willamette Valley, through the Columbia River Gorge. As this system started to bring moisture and precipitation into NW Oregon, temperatures were around or below freezing, allowing for a mix of snow and ice to fall all the way to the Valley Floor around the Portland Metro, in the Columbia River Gorge, and the Hood River Valley.
Jan. 15-16, 2020	Multnomah County (Western Columbia River Gorge)	A 980 mb low located near 45N/130W along with an attendant warm front moved into the southern Oregon Coast and overran a cold air mass originating from the Columbia River Gorge. This resulted in snow that gradually transitioned to freezing rain in the Gorge on Wednesday night into Thursday.

Source: Taylor and Hatton (1999); https://www.fema.gov/disaster; https://www.ncdc.noaa.gov/stormevents

Probability

Table 2-271. Probability Assessment of Winter Storms in Region 2

	Columbia	Clackamas	Multnomah	Washington
Probability	H	H	H	H

Source: Oregon Office of Emergency Management, 2013 County Hazard Analysis Scores

Winter storms occur annually in Region 2. On the basis of historical data, severe winter storms could occur about every 4 years in this region. We can expect to have continued annual storm events in this region. However, there are no solid statistical data available upon which to base these judgments. There is no statewide program to study the past, present, and potential impacts of winter storms in the state of Oregon at this time.

Climate Change

There is no current research available about changes in the incidence of winter storms in Oregon due to changing climate conditions. However, the warming climate will result in less frequent extreme cold events and high-snowfall years.

Vulnerability

Table 2-272. Local Assessment of Vulnerability to Winter Storms in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	M	H	M	H

Source: Most recent local hazard vulnerability analyses (Table 2-4)

Table 2-273. State Assessment of Vulnerability to Winter Storms in Region 2

	Clackamas	Columbia	Multnomah	Washington
Vulnerability	M	H	H	H

Source: Oregon Office of Emergency Management, 2013 County Hazard Analysis Scores

Due to the large population and large truck commodity transport through this region, it is extremely costly when the roads are closed due to severe winter storms.

Social Vulnerability

The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard. The counties with the greatest social vulnerability statewide are Marion, Morrow, Umatilla, Wasco, Jefferson, Klamath, and Malheur.

According to the CDC Social Vulnerability Index, Multnomah County is moderately socially vulnerable and the most vulnerable in Region 2. Multnomah County has the highest percentage of multi-unit housing structures and the highest share of households that lack access to a vehicle. Although vulnerability in Washington and Clackamas Counties is relatively low, both counties are in the 90th percentile for their share of multi-unit housing structures. Washington County is also in the top 10% of counties for its percentage of residents that speak English less than "well" and for its share of minority residents.

Multnomah County's relatively higher social vulnerability in Region 2 indicates that the effects of windstorms will be felt more intensely by its population than by the populations of the other Region 2 counties and will require more resources for preparation, mitigation, and response. Considered in combination with the importance of large truck commodity transport through this region and the costs associated with road closures, Multnomah County is the county most vulnerable to winter storms in Region 2.

State-Owned/Leased Buildings and Critical Facilities and Local Critical Facilities

The value of state-owned and leased buildings and critical facilities in Region 2 is approximately $1,134,896,000 representing the total potential for loss of state assets due to winter storms. The value of locally owned critical facilities is $10,224,815,000. Because winter storms could impact the entire region, these figures together represent the maximum potential loss to state assets and local critical facilities due to winter storms. Because the state is self-insured, FEMA funds are rarely used to cover damage to state assets from natural hazards. According to

Department of Administrative Services records, only one loss of over $111,000 to a state facility was recorded in Region 2 since the beginning of 2015. It was indeed caused by a winter storm.

Risk

With respect to natural hazards, risk can be expressed as the probability of a hazard occurring combined with the potential for property damage and loss of life.

While all the counties in Region 2 are at high risk from winter storms, Multnomah County's elevated vulnerabilities put it at greater risk than the others.