VOLUME II: HAZARD ANNEXES

DROUGHT

Significant Changes since the 2015 Plan

Significant changes to this section include: Maps and data were updated with the most recent information; the section about the Surface Water Supply Index was removed; and information was added to the section on Future Climate Variability.

Causes and Characteristics of the Hazard

Drought can be defined in several ways. The American Heritage Dictionary defines drought as "a long period with no rain, especially during a planting season." Oregon's Legislative Assembly describes drought as a potential state emergency when a lack of water resources threatens the availability of essential services and jeopardizes the peace, health, safety, and welfare of the people of Oregon.[1] Droughts can be characterized by the dominant impact caused by increased demand or decreased supply. Another definition of drought is a deficiency in surface and subsurface water supplies. In socioeconomic terms, drought is present when a physical water shortage begins to affect people, individually and collectively, and the area's economy.

Drought is typically measured in terms of water availability in a defined geographical area. It is common to express drought with a numerical index that ranks severity. The Oregon Drought Severity Index is the most commonly used drought measurement in the state because it incorporates both local conditions and mountain snowpack. The Oregon Drought Severity Index categorizes droughts as mild, moderate, severe, and extreme.

When droughts occur they can be problematic, impacting community water supplies, wildlife refuges, fisheries, and recreation. It reasonable to assume that there is a high probability that Deschutes County will experience drought in the near future.[2]

Precipitation in Oregon follows a distinct spatial and temporal pattern; it tends to fall mostly in the cool season (October–March). The Cascade Mountains block rain-producing weather patterns, creating a very arid and dry environment east of these mountains. Moist air masses originating from the Pacific Ocean cool and condense when they encounter the mountain range, depositing precipitation primarily on the inland valleys and coastal areas.[3]

Water-related challenges are greater than just the temporal and spatial distribution of precipitation in Oregon. A rapidly growing population in the American West has placed a greater demand on this renewable, yet finite resource. The two terms, drought and water scarcity, are not necessarily synonymous; distinctly, water scarcity implies that demand is exceeding the supply. The combined effects of drought and water scarcity are far-reaching and merit special consideration.[4]

[1] Oregon Revised Statute §539.710
[2] State of Oregon NHMP, Region 6. 2020.
[3] Ibid.
[4] Ibid.

Drought is typically measured in terms of water availability in a defined geographic area. It is common to express drought with a numerical index that ranks severity. Most federal agencies use the Palmer Method which incorporates precipitation, runoff, evaporation, and soil moisture. However, the Palmer Method does not incorporate snowpack as a variable. Therefore, it is does not provide a very accurate indication of drought conditions in Deschutes County, although it can be very useful because of its long-term historical record of wet and dry conditions.[5]

With climate change, snow droughts—the type of drought in which snowpack is low, but precipitation is near normal—are expected to occur more often. The 2015 drought in Deschutes County was a "snow drought" and serves as a good example of what future climate projections indicate may become commonplace by mid-21st century.[6] Going forward, drought indices that can account for a changing climate, such as the Standard Precipitation-Evapotranspiration Index (SPEI), may provide a more accurate estimate of future drought risks.

Meteorological or Climatological Droughts

Meteorological droughts are defined in terms of the departure from a normal precipitation pattern and the duration of the event. These droughts are a slow-onset phenomenon that can take at least three months to develop and may last for several seasons or years.

Agricultural Droughts

Agricultural droughts link the various characteristics of meteorological drought to agricultural impacts. The focus is on precipitation shortages and soil-water deficits. Agricultural drought is largely the result of a deficit of soil moisture. A plant's demand for water is dependent on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil.

Hydrological Droughts

Hydrological droughts refer to deficiencies in surface water and subsurface water supplies. It is measured as stream flow, and as lake, reservoir, and groundwater levels. Hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient over an extended period of time, the shortage will be reflected in declining surface and subsurface water levels.

Drought is typically measured in terms of water availability in a defined geographical area. It is common to express drought with a numerical index that ranks severity. The Oregon Drought Severity Index is the most commonly used drought measurement in the state because it incorporates local conditions and mountain snowpack. The Oregon Drought Severity Index categorizes droughts as *mild*, *moderate*, *severe,* and *extreme*.

History of Drought in Deschutes County

Oregon records dating back to the late 1800s, clearly associate drought with a departure from expected rainfall. Concern for mountain snowpack, which feeds the streams and rivers, came

[5] Ibid.
[6] The Third Oregon Climate Assessment Report. 2017. https://pnwcirc.org/sites/pnwcirc.org/files/ocar3_finalweb.pdf

later. When droughts occur they can be problematic, impacting community water supplies, wildlife refuges, fisheries, and recreation. It is reasonable to assume that there is a high probability that Deschutes County will experience drought in the near future.

The following table is, in relevant part, from the State of Oregon 2020 NHMP. Deschutes County is in Region 6; drought declarations not impacting Deschutes have been omitted. It is not clear from the available information if all Region 6 droughts included a drought declaration in Deschutes County:

Table II-1 History of Droughts

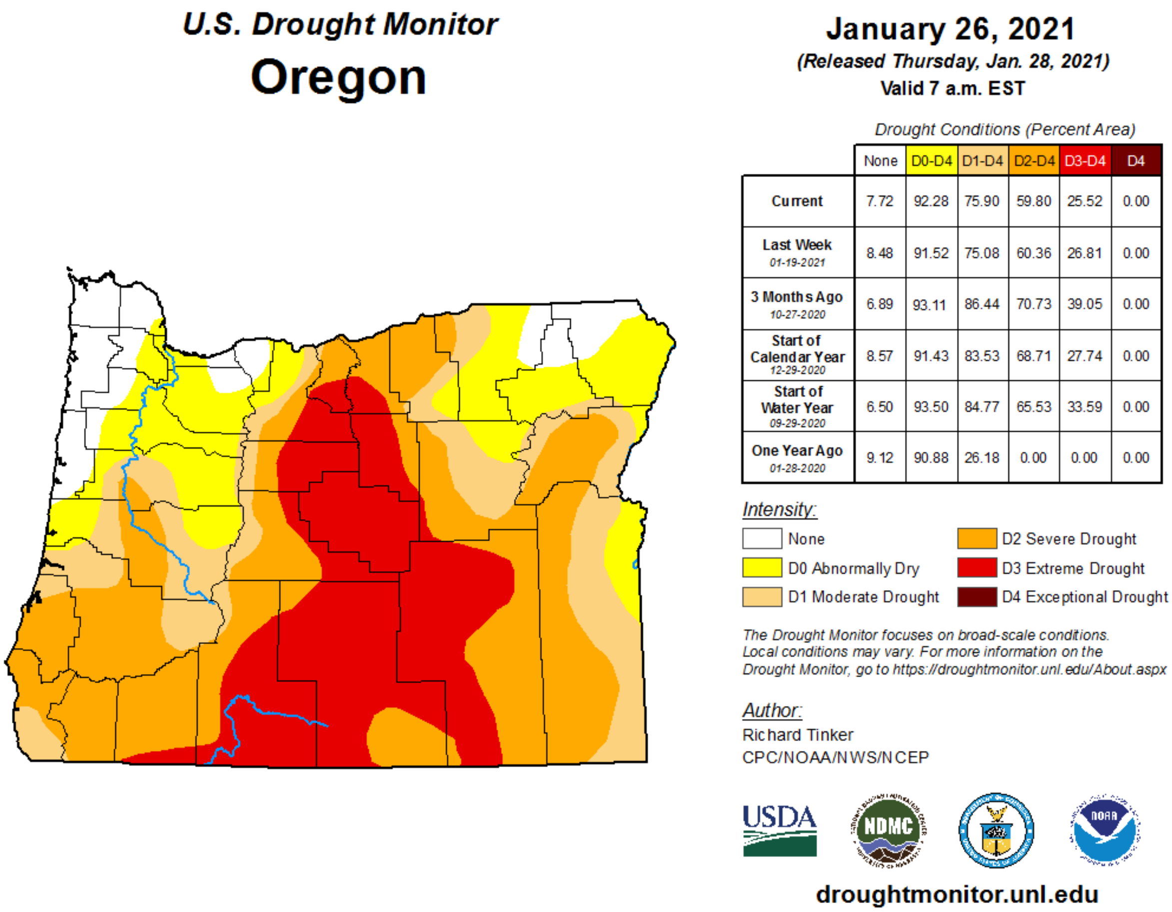
Date	Location	Characteristics
1928-1941	Statewide	A significant drought affected all of Oregon from 1928 to 1941. The prolonged statewide drought created significant problems for the agricultural industry. Punctuated by a three-year intense drought period from 1938-1941.
1985-1994	Statewide	A dry period lasting from 1985 to 1994 caused significant problems statewide. The peak year was 1992, when the state declared a drought emergency; 10 consecutive years of dry conditions caused problems throughout the state, such as fires and insect outbreaks.
2001-2002	Affected all Regions except 2&3	drought declaraction (2001); 23 counties state-declared drought (2002); some of the 2001 and 2002 drought declarations were in effect through June or December 2003.
2005	Regions 5-7	Affected 13 of Oregon's 36 counties
2010	Region 6	Governor declared drought for Klamath and contiguous counties.
2015	Statewide	Governor-declared drought in 25 counties, with federal declarations in all counties. Oregon experienced its warmest year on record (1895–2019) resulting in record low snowpack across the state. All of Oregon was in severe or extreme drought at the peak of the drought in August, according to the U.S. Drought Monitor.
2018	Regions 4-8, 1	Governor declared drought in 11 counties
2020	Southern, Eastern Oregon	Deschutes, Jefferson, Crook, Klamath, Lake and other counties declared drought.

Sources: Oregon State Natural Hazard Mitigation Plan 2020; George and Ray Hatton, *The Oregon Weather Book* (1999); Oregon Secretary of State's Archives Division (Governor's Executive Orders); 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.

The figure below shows the county's current drought conditions monitored according to the National Drought Mitigation Center at the University of Nebraska, Lincoln. The measurement shown displays the percent area of drought severity conditions. It indicates that the majority of Deschutes County is currently registering D2 Severe drought. The possible impacts of a severe drought are: likely crop or pasture losses, water shortages, and imposed water restrictions.[7]

[7] USDM "U.S. Drought Monitor Classification Scheme"

Figure II-1 U.S. Drought Monitor – Oregon



	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	7.72	92.28	75.90	59.80	25.52	0.00
Last Week 01-19-2021	8.48	91.52	75.08	60.36	26.81	0.00
3 Months Ago 10-27-2020	6.89	93.11	86.44	70.73	39.05	0.00
Start of Calendar Year 12-29-2020	8.57	91.43	83.53	68.71	27.74	0.00
Start of Water Year 09-29-2020	6.50	93.50	84.77	65.53	33.59	0.00
One Year Ago 01-28-2020	9.12	90.88	26.18	0.00	0.00	0.00

Source: National Drought Mitigation Center, University of Nebraska, Lincoln. Droughtmonitor.unl.edu, Accessed February 2, 2021.

Hazard Identification

Deschutes County frequently experiences drought conditions, however, due to water availability the cities of Bend, La Pine, Redmond, and Sisters are rarely affected. At the time the plan was developed, no data existed to assist in identifying the location or extent of the drought hazard in Deschutes County. Typically, droughts occur as regional events and often affect more than one county. In severe droughts, environmental and economic consequences can be significant. In recent years, the State has addressed drought emergencies through the Oregon Drought Council. This interagency (state/federal) council meets to discuss climate outlooks, water and soil conditions, and advise the Governor as the need arises.

Droughts are not just a summer-time phenomenon; winter droughts can have a profound impact on the state's agricultural sector, particularly east of the Cascade Mountains. Below-average snowfall in Oregon's higher elevations has a far-reaching effect, especially in terms of irrigation and recreation. There also are environmental consequences. A prolonged drought in

Oregon's forests promotes an increase of insect pests, which in turn, damage trees already weakened by a lack of water. A moisture-deficient forest constitutes a significant fire hazard.

Probability Assessment

Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event. It is a temporary condition and differs from aridity because the latter is restricted to low rainfall regions and is a permanent feature of climate. It is rare for drought not to occur somewhere in North America each year. 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 historic information. Oregon's drought history reveals many short-term and a few long-term events. The average recurrence interval for severe droughts in Oregon is somewhere between 8 and 12 years. Deschutes County's Natural Hazards Mitigation Steering Committee believes that the County's **probability of experiencing a drought is "high,"** meaning one incident is likely within the next 10 – 35 year period. Oregon has yet to undertake a statewide comprehensive risk analysis for drought, to determine probability or vulnerability for a given community. However, based upon available information the Oregon NHMPs Regional Risk Assessment supports this probability rating for Deschutes County.[8]

Vulnerability Assessment

Rural areas are much more dependent on water for irrigation for agricultural production. Landowners in rural or less-populated areas are often reliant on individual, privately owned wells as a drinking water source. Generally speaking, counties east of the Cascades are more prone to drought-related impacts. Deschutes County is less vulnerable to drought impacts than other counties in the Region because its water source is a large aquifer system in the High Cascades which stores precipitation regardless of whether it is rain or snow. However, droughts can still be problematic. Potential impacts to community water supplies are the greatest threat. The aquifer is affected by long-term drought periods (consecutive years) . These extended periods of drought can impact forest conditions and set the stage for potentially destructive wildfires. Additional impacts are described in the Community Hazard Issues section. The Deschutes County Natural Hazards Steering Committee rated Deschutes County as having **a "low" vulnerability to drought hazards**, meaning less than 1% of the region's population or assets would be affected by a major emergency or disaster. Oregon has yet to undertake a statewide comprehensive risk analysis for drought, to determine probability or vulnerability for a given community. However, based upon available information the Oregon NHMPs Regional Risk Assessment rates Deschutes County's vulnerability to drought as high.[9]

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I) shows the county's Hazard Analysis Matrix which scores each hazard

[8] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2021.
[9] Ibid.

and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **drought hazard is rated #4, out of 9 rated hazards, with a total score of 175**.

Future Climate Variability

One of the main aspects of the probability of future occurrences is its reliance on historic climate trends in order to predict future climate trends. Many counties in eastern Oregon are experiencing more frequent and severe droughts than is historically the norm, and many climate predictions see this trend continuing into the future. Temperatures in the Pacific Northwest region increased in the 20th Century by about 2.2 degrees Fahrenheit and are projected to increasingly rise by an average of 5°F by the 2050s and 8.2°F by the 2080s, with the greatest seasonal increases in summer. [10] Precipitation in Oregon is expected to increase in winter and decrease in summer.[11] The predicted increase in winter temperatures will reduce snowpack, which in turn will have effects on spring runoff. In this scenario, the mainstream of the Upper Deschutes River would remain more resilient compared to some of its dominantly snow-fed tributaries such as the Little Deschutes River, Whychus Creek and to a lesser extent Tumalo Creek.[12] These tributaries may respond to the projected climate changes similarly to other Oregon rivers.

With climate change, snow droughts—the type of drought in which snowpack is low, but precipitation is near normal—are expected to occur more often. The 2015 drought in Deschutes County was a “snow drought” and serves as a good example of what future climate projections indicate may become commonplace by mid-21st century.[13] Going forward, drought indices that can account for a changing climate, such as the Standard Precipitation-Evapotranspiration Index (SPEI), may provide a more accurate estimate of future drought risks.

Community Hazard Issues

Drought is frequently an "incremental" hazard, meaning both the onset and end are often difficult to determine. Also, its effects may accumulate slowly over a considerable period of time and may linger for years after the termination of the event.

Droughts are not just a summer-time phenomenon; winter droughts can have a profound impact on agriculture, particularly east of the Cascade Mountains. Also, below average snowfall in higher elevations has far-reaching effects, especially in terms of hydro-electric power, irrigation, recreational opportunities and a variety of industrial uses.

Drought can affect all segments of a jurisdiction’s population, particularly those employed in water-dependent activities (e.g., agriculture, hydroelectric generation, recreation, etc.). Also,

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[10] Dalton, M., and E. Fleishman, editors. 2021. Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://blogs.oregonstate.edu/occri/oregon-climate-assessments/

[11] Ibid.

[12] Gannett, M.W., and Lite, K.E., Jr., 2004, Simulation of regional ground-water flow in the upper Deschutes Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 03–4195, 84 p.

[13] Dalton, M.M., K.D. Dello, L. Hawkins, P.W. Mote, and D.E. Rupp. 2017. The third Oregon climate assessment report. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. https://blogs.oregonstate.edu/occri/oregon-climate-assessments/

domestic water-users may be subject to stringent conservation measures (e.g., rationing) and could be faced with significant increases in electricity rates. In addition, water-borne transportation systems (e.g., ferries, barges, etc.) could be impacted by periods of low water.

There also are environmental consequences. A prolonged drought in forests promotes an increase of insect pests, which in turn, damage trees already weakened by a lack of water. A moisture-deficient forest constitutes a significant fire hazard (see the Wildfire summary). In addition, drought and water scarcity add another dimension of stress to species listed pursuant to the Endangered Species Act (ESA) of 1973.

More information on this hazard can be found in the Regional Risk Assessment for Region 6 of the Oregon NHMP.

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

County and Cities

Deschutes County currently addresses the drought hazard through water conservation measures and water monitoring.

State

Drought Council

The Drought Council is responsible for assessing the impact of drought conditions and making recommendations to the Governor's senior advisors. The Water Availability Committee, a subcommittee of technical people who monitor conditions throughout the state and report these conditions monthly, advises the Drought Council. In this manner the Drought Council keeps up-to-date on water conditions.

Federal

Natural Resources Conservation Service

The United States Department of Agriculture Natural Resources Conservation Service (NRCS) has a regional service center located in Redmond (another is located in Warm Springs). The NRCS is dedicated to three main priorities involving resource preservation. One among them is water quantity and quality. The NRCS incorporates a conservation implementation strategy to preserve natural resources into the future.[14]

[14] NRCS – Deschutes County "Information for Partners and Participants," http://www.or.nrcs.usda.gov

Hazard Mitigation Action Items

There are no identified Drought action items for Deschutes County; however, several of the Multi-Hazard action items affect the Drought hazard. An action item matrix is provided within Volume I, Section 3, while action item forms are provided within Volume IV, Appendix A. To view city actions see the appropriate city addendum within Volume III.

EARTHQUAKE

Significant Changes since the 2015 Plan

There are no significant changes in the potential for earthquakes to occur in Deschutes County since 2015, therefore, there are no significant changes in this section from the 2015 Plan. However, the format of the section and minor content changes has occurred.

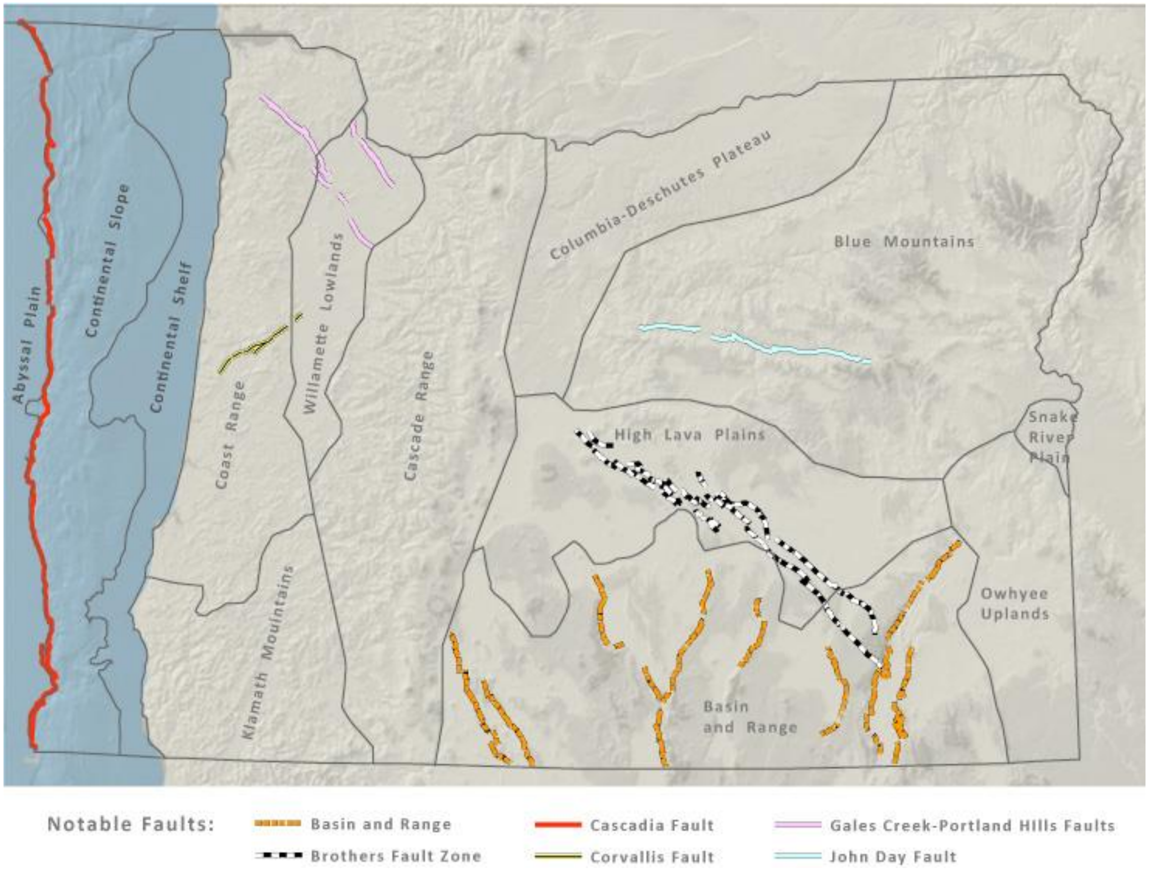
Causes and Characteristics of the Hazard

Seismic events were once thought to pose little or no threat to Oregon communities. However, recent earthquakes and scientific evidence indicate that the risk to people and property is much greater than previously thought. Oregon and the Pacific Northwest in general are susceptible to earthquakes from four sources: 1) the offshore Cascadia Subduction Zone; 2) deep intraplate events within the subducting Juan de Fuca Plate; 3) shallow crustal events within the North American Plate, and 4) earthquakes associated with volcanic activity.

All types of earthquakes in the region have some tie to the subducting, or diving, of the dense, oceanic Juan de Fuca Plate under the lighter, continental North American Plate. There is also a link between the subducting plate and the formation of volcanoes some distance inland from the offshore subduction zone.

Central Oregon includes portions of five physiographic provinces including the High Cascades, Blue Mountains, Basin and Range, High Lava Plains, and Deschutes-Columbia Plateau. Consequently, its geology and earthquake susceptibility varies considerably. There have been several significant historical earthquakes in the region; however all have been located in Klamath and Lake Counties. Additionally, geologically active faults are located in Deschutes, Klamath, and Lake Counties. The region has also been shaken historically by crustal and intraplate earthquakes and prehistorically by subduction zone earthquakes centered outside Central Oregon. All considered, there is good reason to believe that the most devastating future earthquakes would probably originate along shallow crustal faults in the region, or along the offshore Cascadia Subduction Zone.

Figure II-2 Oregon Fault Lines



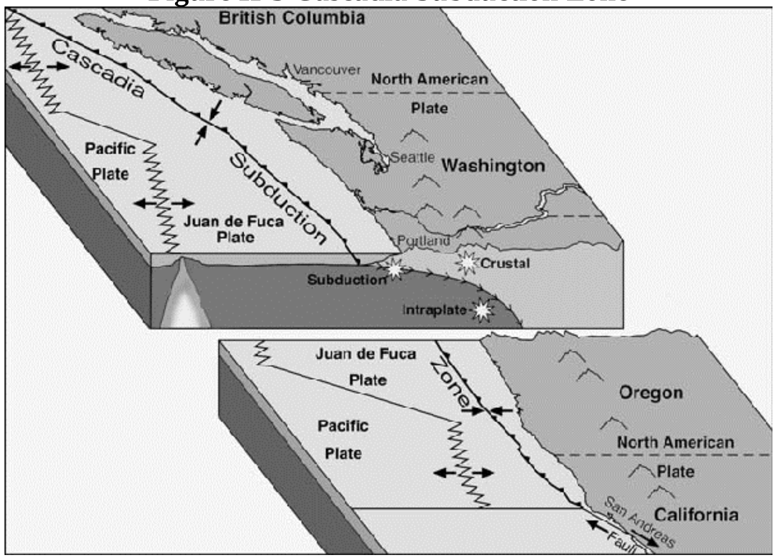
Source: Oregon Department of Geology and Mineral Industries. https://www.oregongeology.org/pubs/ims/ims-028/faults.htm. Accessed March 2021.

Subduction Zone Earthquakes

The Pacific Northwest is located at a convergent plate boundary, called the Cascadia Subduction Zone (CSZ, see Figure II-3), where the Juan de Fuca and North American tectonic plates meet. It extends from British Columbia to northern California. Earthquakes are caused by the abrupt release of slowly accumulated stress. The two plates are converging at a rate of about 1.5 inches per year[1].

[1] Interagency Hazard Mitigation Team. 2020. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

Figure II-3 Cascadia Subduction Zone



Source: Shoreland Solutions. Chronic Coastal Natural Hazards Model Overlay Zone. Salem, OR: Oregon Department of Land Conservation and Development (1998) Technical Guide-3.

Although there have been no large historical earthquakes along the offshore Cascadia Subduction Zone, similar subduction zones worldwide produce large "megathrust" earthquakes with magnitudes of 8 or larger. They occur because the oceanic crust "sticks" as it is being pushed beneath the continent, rather than sliding smoothly. Over hundreds of years, large stresses build up, which are released suddenly in "megathrust" earthquakes. Such earthquakes typically have a minute or more of strong ground shaking, and are quickly followed by numerous large aftershocks.

Historic subduction zone earthquakes include the 1960 Chile earthquake (magnitude 9.5), the 1964 southern Alaska earthquake (magnitude 9.2), the 2004 Indian Ocean earthquake (magnitude 9.0) and the 2011 Tohoku earthquake (magnitude 9.0). Geologic evidence shows that the Cascadia Subduction Zone has generated great earthquakes of similar magnitude, most recently about 320 years ago.[2]

Deep Intraplate Earthquakes

Deep intraplate earthquakes occur at depths of 18 to 60 miles below the earth's surface in the subducting oceanic crust and can reach magnitude 7.5.[3] This type of earthquake is more common in the Puget Sound region; in Oregon these earthquakes occur at lower rates and none have occurred at damaging magnitudes.[4] The February 28, 2001 Nisqually earthquake (magnitude 6.8) in Washington State was a deep intraplate earthquake. It produced a rolling

[2] Interagency Hazard Mitigation Team. 2020. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

[3] Planning for Natural Hazards: Oregon Technical Resource Guide, Community Planning Workshop, (July 2000), p. 8-8.

[4] Interagency Hazard Mitigation Team. 2020. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

motion that was felt from Vancouver, British Columbia to Coos Bay, Oregon and east to Salt Lake City, Utah.[5]

> "Due to the amount of faulting in the area, [the 1993 Klamath Falls earthquake] is just business as usual for such a geologically active region. Historic evidence, combined with geologic evidence for large numbers of earthquakes in the prehistoric past, suggest that one or more earthquakes capable of damage (magnitude 4 – 6) hit south-central Oregon every few decades, so it pays to be prepared."
>
> James Roddey, DOGAMI

Shallow Crustal Earthquakes

These are the most common earthquakes and occur in the North American Plate at relatively shallow depths of 6-12 miles below the surface.[6] When crustal faults slip, they can produce earthquakes of magnitudes up to 7.0. Although most crustal fault earthquakes are smaller than 4.0 and generally create little or no damage, some of them can cause extensive damage. The 1993 Klamath Falls earthquakes (magnitude 6.0 and 5.9) were crustal earthquakes.

Volcanic Earthquakes

Volcanic earthquakes are usually smaller than magnitude 2.5, roughly the threshold for shaking felt by observers close to the event. Swarms of small earthquakes may persist for weeks to months before eruptions, but little or no earthquake damage would occur to buildings in surrounding communities. Some volcanic related swarms may include earthquakes as large as about magnitude 5. For the communities of Bend, La Pine, and Sunriver, shallow earthquakes in the magnitude 4-5 range that are located beneath Newberry Volcano would cause walls to rattle or windows and dishes to vibrate. Both Newberry and the Three Sisters volcanoes routinely experience small magnitude earthquakes that are not felt.

While all four types of earthquakes have the potential to cause major damage, subduction zone earthquakes pose the greatest danger. A major CSZ event could generate an earthquake with a magnitude of 9.0 or greater resulting in devastating damage and loss of life. Such earthquakes may cause great damage to the coastal area of Oregon as well as inland areas in western Oregon; damage to Deschutes County will be less severe, however, it is expected that the impact of such an event will greatly affect eastern Oregon.

The specific hazards associated with earthquakes are explained below:

Ground Shaking

Ground shaking is the motion felt on the earth's surface caused by seismic waves generated by the earthquake. Ground shaking is the primary cause of earthquake damage. The strength of ground shaking depends on the magnitude of the earthquake, the type of fault that is slipping, distance from the epicenter (where the earthquake originates), and local geology. Buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock.

[5] Hill, Richard. "Geo Watch Warning Quake Shook Portland 40 Years Ago." The Oregonian. October 30, 2002.
[6] Madin, Ian P. and Zhenming Wang, Relative Earthquake Hazard Maps Report, DOGAMI, 1999.

Ground Shaking Amplification

Ground shaking amplification refers to the soils and soft sedimentary rocks near the surface that can modify ground shaking from an earthquake. Such factors can increase or decrease the amplification (i.e., strength) as well as the frequency of the shaking. The thickness of the geologic materials and their physical properties determine how much amplification will occur. Ground motion amplification increases the risk for buildings and structures built on soft and unconsolidated soils.

Surface Faulting

Surface faulting are planes or surfaces in Earth materials along which failure occurs. Such faults can be found deep within the earth or on the surface. Earthquakes occurring from deep lying faults usually create only ground shaking.

Liquefaction and Subsidence

Liquefaction occurs when ground shaking causes wet, granular soils to change from a solid state into a liquid state. This results in the loss of soil strength and the soil’s ability to support weight. When the ground can no longer support buildings and structures (subsidence), buildings and their occupants are at risk.

Earthquake-Induced Landslides and Rockfalls

Earthquake-induced landslides are secondary hazards that occur from ground shaking and can destroy roads, buildings, utilities and critical facilities necessary to recovery efforts after an earthquake. Some Deschutes County communities are built in areas with steep slopes. These areas often have a higher risk of landslides and rockfalls triggered by earthquakes.

History of Earthquakes in Deschutes County

A summary of significant earthquake events in the Deschutes County region is found in the table below.

Table II-2 Selected Earthquakes, M 5.0+ (1971-2014)

Date	Location	Magnitude	Comments
Approximate years: 1400 BCE, 1050, BCE 600 BCE 400, 750, 900	Offshore, Cascadia subduction zone	Probably 8.0-9.0	Based on studies of earthquakes and tsunamis in Willapa Bay, WA. These are the midpoints of the age ranges for these six events.
January 1700	Offshore, Cascadia Subduction zone	Approximately 9.0	Generated a tsunami that struck Oregon, Washington and Japan; destroyed Native American villages along the coast.
April 1906	North of Lakeview, OR	5.0	Three felt aftershocks.
April 1920	Crater Lake	5.0	
January 1923	Lakeview, OR	6.0	
March 1958	Southeast of Adel, OR	4.5	Damage unknown
1968	Adel	4.7-5.1	Damage to homes. 20 earthquakes of M4 or greater were recorded between 5/28/68 & 6/24/68.
September 20, 1993	Klamath County	5.9 and 6.0	Two deaths, $10 million damage, including county courthouse; rockfalls induced by ground motion.

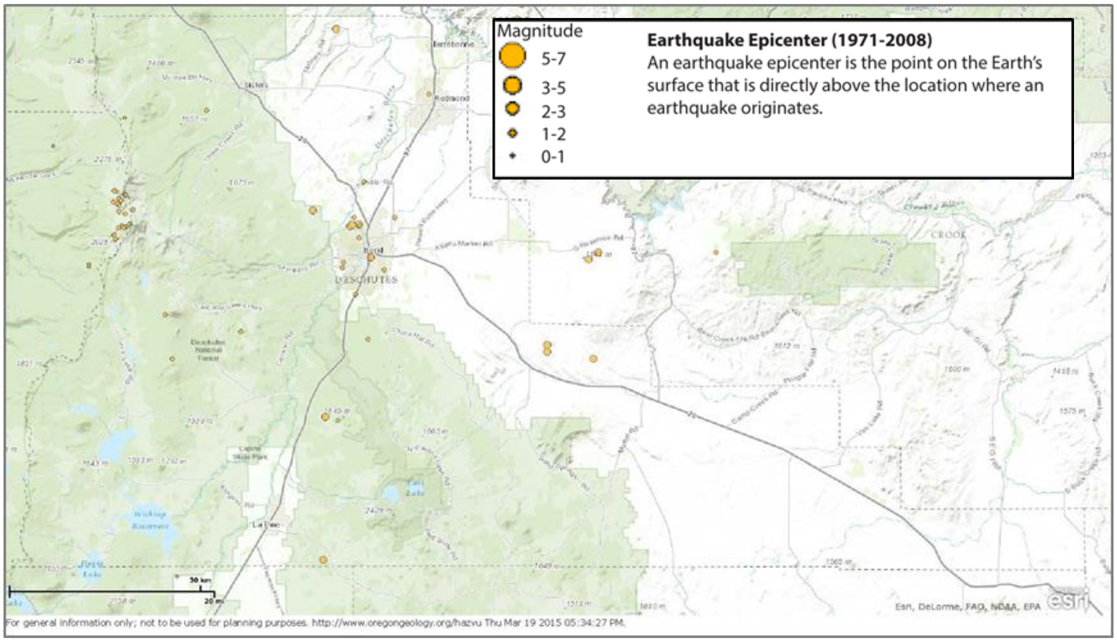
Source: Ivan Wong and others, "A Look Back at Oregon's Earthquake History, 1841-1994," in Oregon Geology, (1995), 125-139; Niewendrop and others, "Map of Selected Earthquakes for Oregon, 1841 through 2002," DOGAMI, (2003).

The Klamath County earthquakes on September 21, 1993, caused two deaths and approximately 7.5 million dollars in damage. One person was killed when a boulder crushed the car he was driving in an earthquake-induced rock fall, and another person died of a heart attack. More than 1,000 homes and commercial buildings were damaged. [7]

Deschutes County routinely has small earthquake events. The earthquakes shown in the figure below are relatively insignificant events below M 5.0. The larger events may have been slightly felt but little to no structural/property damage resulted. There is no historic record of significant crustal earthquakes centered in Deschutes County during the past 150 years, although Oregon has experienced crustal earthquakes that originated outside the county. Recent earthquake events in Deschutes County include a two-day swarm of 100 to 200 small, unfelt earthquakes in the Three Sisters region (shown below on the left side of the map) in April 2004. Additionally, a seismic network on Newberry Volcano has recorded numerous small, unfelt earthquakes since its installation in 2011.

[7] USGS, Earthquake Hazards Program, Earthquake Catalogue.

Figure II-4 Earthquake Epicenters (1971-2008)

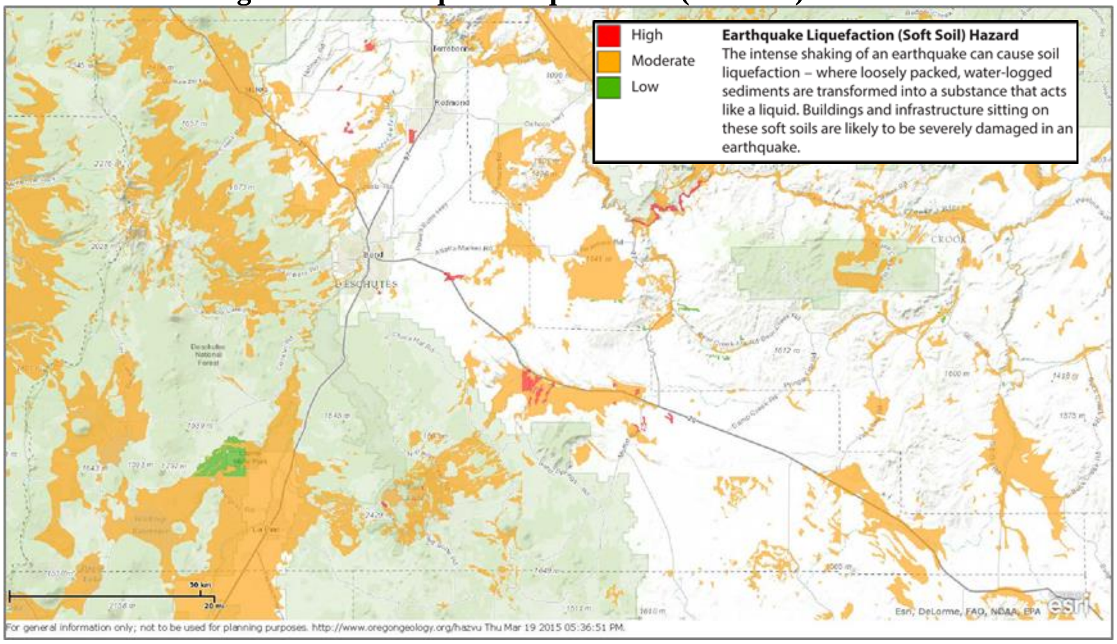


Source: Oregon HazVu: Statewide Geohazards Viewer (HazVu), accessed April 2021.

Hazard Identification

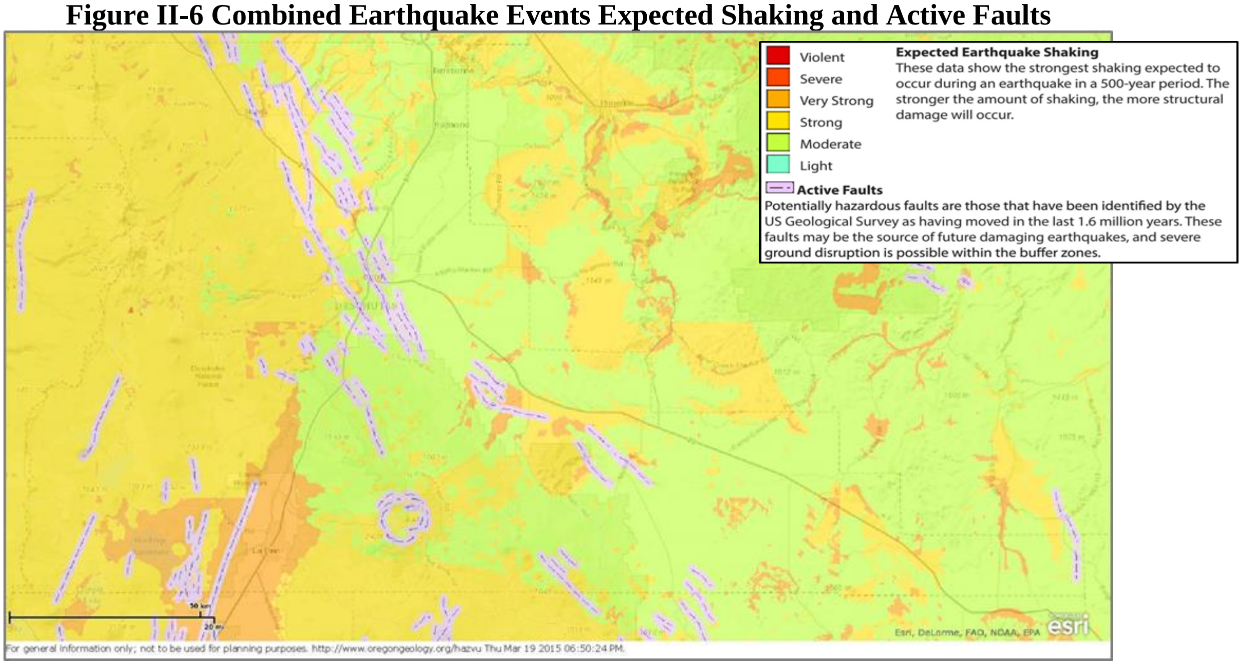
The Oregon Department of Geology and Mineral Industries (DOGAMI), in partnership with other state and federal agencies, has undertaken a rigorous program in Oregon to identify seismic hazards, including active fault identification, bedrock shaking, tsunami inundation zones, ground motion amplification, liquefaction, and earthquake induced landslides. DOGAMI has published a number of seismic hazard maps that are available for Oregon communities to use. The maps show liquefaction, ground motion amplification, landslide susceptibility, and relative earthquake hazards. Steering Committee members used the DOGAMI Statewide Geohazards Viewer to present visual maps of recent earthquake activity (Figure II-4), liquefaction (soft soils, Figure II-5), and expected ground shaking for combined earthquake events (Figure II-6; see vulnerability assessment for more information on the combined events). The severity of an earthquake is dependent upon a number of factors including: 1) the distance from the earthquake's source (or epicenter); 2) the ability of the soil and rock to conduct the earthquake's seismic energy; 3) the degree (i.e., angle) of slope materials; 4) the composition of slope materials; 5) the magnitude of the earthquake; and 6) the type of earthquake.

Figure II-5 Earthquake Liquefaction (Soft Soil) Hazard



Source: Oregon HazVu: Statewide Geohazards Viewer (HazVu), accessed March 2015

Figure II-6 Combined Earthquake Events Expected Shaking and Active Faults



Source: Oregon HazVu: Statewide Geohazards Viewer (HazVu), accessed April 2021

The maps indicate the predominant risks for the county lie in the southwestern portion of the county in the La Pine and Sunriver region; it also shows greater risk in the Sisters region.

Probability Assessment

The Cascadia Subduction Zone (CSZ) generates an earthquake on average every 250-500 years. However, as with any natural processes the average time between events can be misleading.

Some of the earthquakes may have been 150 years apart while some closer to 1,000 years apart.[8] Establishing a probability for crustal earthquakes is difficult given the small number of historic events in the region. Earthquakes generated by volcanic activity in Oregon's Cascade Range are possible, but likewise unpredictable. Mitigation action calls for study of the probability of earthquake events specific to Deschutes County.

It is not feasible at this time to predict when central Oregon or Cascadia will have another moderate to large earthquake. The statistical uncertainty associated with calculating earthquake recurrence intervals are as large as or larger than the calculated recurrence interval. That being said, Deschutes County's Natural Hazards Mitigation Steering Committee hypothesizes that the County's **probability of experiencing a crustal earthquake is "low",** meaning one incident is likely within the next 75 – 100 year period; the committee hypothesizes that the County's **probability of experiencing a Cascadia earthquake is also "low"**. Based upon available information, the Oregon NHMPs Regional Risk Assessment rates Deschutes County's probability of earthquake as moderate.[9]

Vulnerability Assessment

The Oregon Department of Geology and Mineral Industries (DOGAMI) has developed two earthquake loss models for Oregon based on the two most likely sources of seismic events: 1) the CSZ, and 2) combined earthquake events. Both models are based on HAZUS, a computerized program, currently used by the Federal Emergency Management Agency (FEMA) as a means of determining potential losses from earthquakes.

The CSZ event is based on a potential 8.5 earthquake generated off the Oregon coast. The model does not take into account a tsunami, which probably would develop from the event (but not affect Deschutes County). The 500-year crustal model does not look at a single earthquake (as in the CSZ model); it encompasses many faults, each with a 10% chance of producing an earthquake in the next 50 years. The model assumes that each fault will produce a single "average" earthquake during this time. Neither model takes unreinforced masonry building into consideration. DOGAMI investigators caution that the models contain a high degree of uncertainty and should be used only for general planning purposes. Despite their limitations, the models do provide some approximate estimates of damage. Further mention is made of potential for possible flooding in the event of an earthquake in the area of the South Sister uplift. Current research being conducted of this area will determine potential impact and flooding potential.

The Deschutes County Natural Hazards Steering Committee rated Deschutes County as having a **"moderate" vulnerability to the crustal earthquake hazard**, meaning 1-10% of the region's population or assets would be affected by a major emergency or disaster; the committee rated the County as having a **"high" vulnerability to the Cascadia earthquake hazard,** meaning more than 10% of the region's population or assets would be affected by a major emergency or disaster. The Oregon NHMPs Regional Risk Assessment rates Deschutes County's vulnerability to earthquakes as very low.[10]

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[8] Y. Wang & J.L. Clark, Special Paper 29, Earthquake Damage in Oregon: Preliminary Estimates of Future Earthquake Losses. 1999. DOGAMI.
[9] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2021.
[10] Ibid.

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I, Section 2) shows the county's Hazard Analysis Matrix which scores each hazard and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **Cascadia earthquake hazard is rated #6, out of 9 rated hazards, with a total score of 149; while the crustal earthquake hazard is rated #8, out of 9 rated hazards, with a total score of 109**.

Community Hazard Issues

The effects of earthquakes span a large area, and can cause secondary effects such as landslides, fires and flooding. The degree to which earthquakes are felt, however, and the damages associated with them may vary. At risk from earthquake damage are unreinforced masonry buildings, bridges built before earthquake standards were incorporated into building codes, sewer, water, and natural gas pipelines, petroleum pipelines, and other critical facilities and private property located within the county. The areas that are particularly vulnerable to potential earthquakes in the county have been identified as those with soft, alluvial sediments and lands along stream channels. Additionally, the Carver Lake dam has been identified as a hazard risk to the city of Sisters that can be triggered by an earthquake event. For more information on the Carver Lake dam risks, please see the Flood Annex.

Earthquake damage to roads and bridges can be particularly serious by hampering or cutting off the movement of people and goods and disrupting the provision of emergency response services. Such effects in turn can produce serious impacts on the local and regional economy by disconnecting people from work, home, food, school and needed commercial, medical and social services. A major earthquake can separate businesses and other employers from their employees, customers, and suppliers thereby further hurting the economy. Deschutes County is less susceptible to being isolated, unlike other areas of Oregon, due to its location along major highways, which run through multiple locations in the county. Finally, following an earthquake event, the cleanup of debris can be a huge challenge for the community.

Death and Injury

Death and injury can occur both inside and outside of buildings due to falling equipment, furniture, debris, and structural materials. Likewise, downed power lines or broken water and gas lines endanger human life. Death and injury are highest in the afternoon when damage occurs to commercial and residential buildings and during the evening hours in residential settings.[11]

Disruption of Critical Facilities

Critical facilities are police stations, fire stations, hospitals, and shelters. These are facilities that provide services to the community and need to be functional after an earthquake event. The

[11] Planning for Natural Hazards: Oregon Technical Resource Guide, Community Planning Workshop (July 2000).

earthquake effects outlined above can all cause emergency response to be disrupted after a significant event.[12] Tables II-3 and II-4 (below) and tables in the city addenda, display damage and collapse potential for structures including critical and essential facilities.

Economic Loss

Seismic activity can cause great loss to businesses, either a large-scale corporation or a small retail shop. Losses not only result in rebuilding cost, but fragile inventory and equipment can be destroyed. When a company is forced to stop production for just a day, business loss can be tremendous. Residents, businesses, and industry all suffer temporary loss of income when their source of finances are damaged or disrupted.

The potential losses from an earthquake in Deschutes County extend beyond those to human life, homes, property and the landscape. A recent earthquake damage model has not been conducted for Deschutes County, however, based upon data from a 1999 DOGAMI report rough loss estimates are available. The economic base in Deschutes County is estimated at $4,676,000,000 (in 1999 dollars); it is expected that the County will incur total direct losses valuing $5,000,000 (in 1999 dollars) for the Cascadia model and $71,000,000 (in 1999 dollars) for the 500-year model; both amount to a loss ratio of less than one-percent.[13] While the expected losses have increased due to increased development in the County, as well as inflation, the loss ratio and relative damage for the county is expected to be similar. See table on the following page for more information on expected losses.

Local business economies are at substantial risk if an earthquake damages or otherwise necessitates the closure of any of the major transportation routes in Deschutes County. As such, the economic loss to the region can exceed $3.5 million per day in the County.

[12] Y. Wang & J.L. Clark, Special Paper 29, Earthquake Damage in Oregon: Preliminary Estimates of Future Earthquake Losses. 1999. DOGAMI.

[13] Ibid. The loss ratio is determined as a percentage of the expected losses to the county's economic base.

Table II-3 Deschutes County Earthquake Damage Summary

These figures have a high degree of uncertainty and should be used only for general planning purposes. Because of rounding, numbers may not add up to 100%.

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

Deschutes County	8.5 Cascadia subduction zone event	500 year model
Injuries	1	17
Deaths	0	0
Displaced households	0	5
Short term shelter needs	0	3
Economic losses for buildings	$5 million	$71 million
Operating the day after the quake:		
Fire stations	100%	NA
Police stations	99%	NA
Schools	99%	NA
Bridges	100%	NA
Economic losses to:		
Highways	$17,000	$572,000
Airports	$40,000	$2 million
Communication systems:		
Economic losses	$2,000	$1 million
Operating the day of the quake	99%	NA
Debris generated (thousands of tons)	3	47

8.5 Cascadia event	Percentage of buildings in damage categories				
Building type	None	Slight	Moderate	Extensive	Complete
Agriculture	93	1	0	0	0
Commercial	93	1	0	0	0
Education	89	1	0	0	0
Government	98	1	0	0	0
Industrial	93	2	0	0	0
Residential	98	1	0	0	0

500 year model	Percentage of buildings in damage categories				
Building type	None	Slight	Moderate	Extensive	Complete
Agriculture	75	10	7	2	0
Commercial	72	11	9	3	0
Education	71	10	7	2	0
Government	75	12	9	3	1
Industrial	69	12	10	3	1
Residential	83	10	5	1	0

Source: Y. Wang & J.L. Clark, Special Paper 29, Earthquake Damage in Oregon: Preliminary Estimates of Future Earthquake Losses. 1999. DOGAMI.

Bridge Damage

All bridges can sustain damage during earthquakes, leaving them unsafe for use. More rarely, some bridges have failed completely due to strong ground motion. Bridges are a vital transportation link – damage to them can make some areas inaccessible.

Because bridges vary in size, materials, siting, and design, earthquakes will affect each bridge differently. Bridges built before the mid 1970's often do not have proper seismic reinforcements. These bridges have a significantly higher risk of suffering structural damage during a moderate to large earthquake. Bridges built in the 1980's and after are more likely to have the structural components necessary to withstand a large earthquake.[14]

2001 Nisqually Earthquake

A 6.8 magnitude earthquake centered southwest of Seattle struck on February 28, 2001, followed by a mild aftershock the next morning, and caused more than $1 billion worth of damage. Despite this significant loss, the region escaped with relatively little damage for two reasons: the depth of the quake center and preparations by its residents. Washington initiated a retrofitting program in 1990 to strengthen bridges, while regional building codes mandated new structures withstand certain amounts of movement. Likewise, historic buildings have been voluntarily retrofitted with earthquake-protection reinforcements.

Source: "Luck and planning reduced Seattle quake damage", CNN Report, March 1, 2001

Damage to Lifelines

Lifelines are the connections between communities and critical services. They include water and gas lines, transportation systems, electricity, and communication networks. Ground shaking and amplification can cause pipes to break open, power lines to fall, roads and railways to crack or move, and radio or telephone communication to cease. Disruption to transportation makes it especially difficult to bring in supplies or services. All lifelines need to be usable after an earthquake to allow for rescue, recovery, and rebuilding efforts and to relay important information to the public.

Fire

Fire is a common and significant hazard associated with earthquakes. Downed or arcing power lines and broken gas mains can trigger fires. Historically, these hazards, combined with damage to firefighting infrastructure like water systems and fire stations as a result of seismic activity, has resulted in significant loss of buildings and other infrastructure without sufficient preparedness and reinforcement of existing systems and resources.[15]

Debris

After damage occurs to a variety of structures, much time is spent cleaning up brick, glass, wood, steel or concrete building elements, office and home contents, and other materials. More

[14] University of Washington website: www.geophys.washington.edu/SEIS/PNSN/INFO_GENERAL/faq.html#3.
[15] Pacific Northwest Seismic Network, *Earthquake Hazards*. https://pnsn.org/outreach/earthquakehazards/fire

information on this hazard can be found in the [Regional Risk Assessment for Region 6 of the Oregon NHMP](#).

Building and Home Damage

Wood structures tend to withstand earthquakes better than structures made of brick or unreinforced masonry buildings.[16] Building construction and design play a vital role in the survival of a structure during earthquakes. Damage can be quite severe if structures are not designed with seismic reinforcements or if structures are located atop soils that liquefy or amplify shaking. Whole buildings can collapse or be displaced. For an approximation of buildings at risk of collapse by year built see Appendix C.

In 2007, DOGAMI completed a rapid visual screening (RVS) of educational and emergency facilities in communities across Oregon, as directed by the Oregon Legislature in Senate Bill 2 (2005). RVS is a technique used by the Federal Emergency Management Agency (FEMA), known as FEMA 154, to identify, inventory, and rank buildings that are potentially vulnerable to seismic events. DOGAMI surveyed 78 facilities in Deschutes County; of these seven are within county jurisdiction (see City addenda for facilities within city jurisdiction).

DOGAMI scored each building with a 'low,' 'moderate,' 'high,' or 'very high' potential of collapse in the event of an earthquake. It is important to note that these rankings represent a probability of collapse based on limited observed and analytical data and are, therefore approximate rankings.[17] To fully assess a building's potential of collapse, a more detailed engineering study completed by a qualified professional is required, but the RVS study can help to prioritize which buildings to retrofit.

The table below displays the rankings of all facilities within the county's jurisdiction; each "X" represents one building within that ranking category. Of the buildings evaluated by DOGAMI using RVS, none have very high (100% chance) collapse potential, and two buildings have high (greater than 10% chance) collapse potential. The buildings with 'high' or 'very high' collapse potential include multiple public safety and education facilities located throughout the county all of which can play a key role in during disasters events or during long-term recovery. Please see the city addenda for a list of facilities within each jurisdiction (note: some county facilities are located within city jurisdiction, as such they are represented in the applicable addendum table).

It is important to note that the rapid visual survey scores have not been updated since 2007. Therefore, some building changes (movement of facilities and/or new buildings built) have occurred. However, all new buildings can be assumed to be at "low" collapse risk, given updated building codes.

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[16] Wolfe, Myer, et al. Land Use Planning for Earthquake Hazard Mitigation: A Handbook for Planners, Special Publication 14, Natural Hazards Research and Applications Information Center.

[17] State of Oregon Department of Geologic and Mineral Industries, "Implementation of 2005 Senate Bill 2 Relating to Public Safety, Seismic Safety and Seismic Rehabilitation of Public Building", May 22, 2007, Open File Report 0-07-02.

Table II-4 Rapid Visual Survey Scores

	Level of Collapse Potential			
Facility	Low (< 1%)	Moderate (>1%)	High (>10%)	Very High (100%)
Schools				
Three Rivers Elementary School (56900 Enterprise Dr, Sunriver)	X			
Terrebonne Community School (1199 B Ave, Terrebonne)	X		X	
Public Safety				
Cloverdale RFPD (68787 George Cyrus Rd, Cloverdale)	X		X	
Cloverdale RFPD (67433 Cloverdale Rd, Cloverdale)		X		
Sunriver Police Department (57455 Abbot Dr, Sunriver)	X			
Sunriver Fire Department (57475 Abbot Dr, Sunriver)	X			
Deschutes County Sheriff's Office - Terrebonne (8222 Hwy 97, Terrebonne)	X			

Source: DOGAMI 2007. Open File Report 0-07-02. Statewide Seismic Needs Assessment Using Rapid Visual Assessment.

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

County and Cities

At an individual level, preparedness for an earthquake is minimal as perception and awareness of earthquake hazards are low. Strapping down heavy furniture, water heaters and expensive personal property as well as having earthquake insurance are steps toward earthquake mitigation.

City and county building officials enforce building codes for new construction and can coordinate inspection activities in the event of an earthquake. Deschutes County has also mapped critical facilities and major public buildings and inspections of these facilities can be assigned quickly when an earthquake occurs.

State

The Oregon State Building Codes Division adopts statewide standards for building construction that are administered by the state, cities and counties throughout Oregon. The codes apply to new construction and to the alteration of, or addition to, existing structures. Within these standards are six levels of design and engineering specifications for seismic safety that are applied to areas according to the expected degree of ground motion and site conditions. The structural code requires a site-specific seismic hazard report for critical facilities such as hospitals, fire and police stations, emergency response facilities, and special occupancy structures, such as schools and prisons. The seismic hazard report required by the structural code for essential facilities and special occupancy structures considers factors such as the seismic zone, soil characteristics including amplification and liquefaction potential, any known faults, and potential landslides. The findings of the seismic hazard report must be considered in the design of the building. The residential code incorporates prescriptive requirements for foundation reinforcement and framing connections based on the applicable seismic zone for the area.

Retrofitting of existing buildings may be required when such buildings are altered or their occupancy is changed. Requirements vary depending on the type and size of the alteration and whether there is a change in the use of the building that is considered more hazardous.

Hazard Mitigation Action Items

There are three identified Earthquake action items for Deschutes County; in addition, several of the Multi-Hazard action items affect the earthquake hazard. An action item matrix is provided within Volume I, Section 3*,* while action item forms are provided within Volume IV, Appendix A. To view city actions see the appropriate city addendum within Volume III.

FLOOD

Significant Changes since the 2015 Plan

> This section includes one significant change from 2015; updated information on the National Flood Insurance program. In addition, the format of the section and minor content changes have been made.

Causes and Characteristics of the Hazard

Flooding results when rain and snowmelt creates water flow that exceeds the carrying capacity of rivers, streams, channels, ditches, and other watercourses. In Oregon, flooding is most common from October through April when storms from the Pacific Ocean bring intense rainfall. Most of Oregon's destructive natural disasters have been floods.[1] Flooding can be aggravated when rain is accompanied by snowmelt and frozen ground; the spring cycle of melting snow is the most common source of flood in the region.

Anticipating and planning for flood events is an important activity for Deschutes County. Federal programs provide insurance and funding to communities engaging in flood hazard mitigation. The Federal Emergency Management Association (FEMA) manages the National Flood Insurance Program (NFIP) and the Hazard Mitigation Grant Program (HMGP). The NFIP provides flood insurance and pays claims to policyholders who have suffered losses from floods. The HMGP provides grants to help mitigate flood hazards by elevating structures or relocating or removing them from flood hazard areas. These programs provide grant money to owners of properties who have suffered losses from floods, and in some cases, suffered losses from other natural hazard events.

Flood Sources

The principal flood sources in Deschutes County include: Deschutes River, Little Deschutes River, Paulina Creek, Whychus Creek, and Spring River.[2]

Flood Types

The principal types of flood that occur in Deschutes County include:

- Rain-on-Snow (warm winter) flooding
- Spring/Snowmelt flooding
- Ice jams/Frazil ice
- Flash floods
- Dam failure

[1] Taylor, George H. and Chris Hannan. *The Oregon Weather Book*. Corvallis, OR: Oregon State University Press. 1999
[2] FEMA, Deschutes County Flood Insurance Study, revised September 28, 2007.

The most common of these potential flooding events in Deschutes County is a rain-on-snow event.[3]

Rain-on-Snow

The weather pattern that produces these floods occurs during the winter months and has come to be associated with La Nina events, a three to seven year cycle of cool, wet weather. Brief, cool, moist weather conditions are followed by a system of warm, moist air from tropical latitudes. The intense warm rain associated with this system quickly melts foothill and mountain snow. Above-freezing temperatures may occur well above pass levels in the Cascade Mountains (4,000-5,000 feet).[4]

Spring/Snowmelt Flooding

Snowmelt floods occur in the spring and early summer when temperatures rise rapidly, causing rapid melting of accumulated snow. Spring runoff has caused significant riverine flooding in the County, resulting in damage along the Deschutes, Little Deschutes and Spring Rivers, in addition to Paulina and Whychus Creeks, and several smaller rivers and creeks. Most spring flooding has been precipitated by a particular combination of factors: ground saturation followed by a heavy ground freeze, a heavy snowpack in higher elevations, and then spring rains and winds causing sudden snow melt.

Ice Jams

Ice jams on the Deschutes River have created flood conditions in the past and will continue to do so due to local topography. This type of flood is also associated with Frazil Ice, which contributes to jamming (particularly upstream of the former log pond formed by Shevlin Dam). Ice jams commonly happen during the winter and early spring, while the river is still frozen. Sudden warming at higher altitudes can melt waters resulting in increased runoff of water and ice into large reaches of frozen river below. On the way downstream, the ice can “jam” in narrow places on the river or against a road crossing, effectively damming the river, sometimes followed by a sudden breach and release of the water and ice.

Flash Floods

Flash floods usually result from intense storms dropping large amounts of rain within a brief period. They usually occur in the summer during the thunderstorm season, appear with little or no warning and can reach full peak in only a few minutes. They are most common in arid and semi-arid areas of Oregon like Deschutes County where there is often steep topography, little vegetation and intense but short-duration rainfall. This situation would be typified by the eastern part of Deschutes County and areas without permanent streams such as the dry canyon west of Redmond.

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[3] Ibid.

[4] Ibid.

Dam Failure (Natural or man-made)

Major flooding could also result from partial or complete failure of natural dams (mountain streams that begin in glacial lakes behind dams of ice or moraines can occasionally be emptied rapidly and result in flash floods with accompanying mud flows) or man-made structures, constructed to restrict the flow of water on the county's waterways, either impounding reservoirs or diversion dams.

These types of floods are often associated with flash floods. In such situations, waters not only rise rapidly, but also generally move at high velocities and often carry large amounts of debris. In these instances a flash flood may arrive as a fast moving wall of debris, mud, water or ice. Such material can accumulate at a natural or man-made obstruction and restrict the flow of water. Water held back in such a manner can cause flooding both upstream and then later downstream if the obstruction is removed or breaks free.

Manmade dam failures can occur rapidly and with little warning. Fortunately, most failures result in minor damage and pose little or no risk to life safety. However, the potential for severe damage still exists. The Oregon Water Resources Department has inventoried all dams located in Oregon and Deschutes County. There are five dams categorized as high hazard; North Canal Diversion, Crescent Lake, Crane Prairie Dam, Wickiup Dam, and the Sunriver Effluent Lagoon.[5]

Another area of heightened concern focuses on the potential of flooding related to the failure of glacial moraine dams that impound high-altitude lakes around the Three Sisters and Broken Top. In the event of volcanic eruption, earthquake or a large avalanche of rock or ice into the lakes, these dams could release floods of water and debris whose major impact could inundate parts of local areas. A moraine dam impounding a small unnamed lake high on the east side of Broken Top failed in October, 1966, generating a debris flow that traveled down the Soda Creek drainage, across Highway 46 (Cascade Lakes Highway), and spread out over the broad meadow near Sparks Lake. The debris flow buried the road and covered about 250,000 square meters (about 2,700,000 square feet) of the meadow with sand and silt.[6]

Carver Lake is a moraine-dammed lake on the eastern flank of South Sister volcano. The lake sits approximately 20 km upstream from the community of Sisters, Oregon, located in the valley below. The outlet channel of Carver Lake is a small tributary of Whychus Creek, which flows through downtown Sisters. In the 1980s, concern was raised regarding the flooding risk posed to the Sisters community, should a moraine-dam failure lead to an outburst flood from Carver Lake. Modeling conducted at the time suggested that, in the event of complete lake drainage, the flooding hazard could be substantial (Laenen et al., 1987).

There is consensus among geologists and engineers who have visited Carver Lake (e.g., Laenen et al., 1987; O'Connor et al., 2001) that the moraine dam appears stable to spontaneous failure, and that a failure would most likely require overtopping waves generated by a landslide entering the lake. Compared to earlier studies and coarse topography, recent modeling suggests a strikingly different result for our test case involving inundation near Sisters, Oregon. Owing in part to the use of 2-D equations as well as high-resolution lidar topography, recent results

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[5] Source: Oregon water Resources Department, "Dam Inventory Query", http://apps.wrd.state.or.us/apps/misc/dam_inventory/, Accessed January 2021.
[6] O'Connor, J.E., J.H. Hardison and J.E. Costa. 2001. Debris flows from failures of Neoglacial-Age moraine dams in the Three Sisters and Mount Jefferson wilderness areas, Oregon. US Geological Survey Professional Paper 1606.

suggest that flow avulsion and diversion on the alluvial fan surrounding Sisters would lead to a less severe flood hazard to the community.[7] However, model results still suggest widespread shallow flooding in the Sisters Area from moraine-dam failure with depths between 1 to 3 meters along existing and historical drainage channels and in excess of 3 meters in some limited areas, including the City of Sisters wastewater treatment lagoons.[8]

Lesser hazards include several small lakes at the headwaters of Whychus Creek and the basin (currently with no lake) below Collier Glacier at the head of White Branch, and the unnamed lake on the east side of Broken Top which could trigger floods or debris flows in the Soda Creek drainage or the Tumalo Creek drainage.[9]

History of Floods in Deschutes County[10]

Generally, river flooding has not historically been a serious problem in Deschutes County. This is mostly due to the porous nature of the underlying volcanic rock that has a large capacity for water storage, irrigation diversion canals and reservoir retention. Consequently, the discharge rate for the Deschutes River is very low considering the size of its basins. Regular flooding events have occurred however near the headwaters of Tumalo Creek and in the Tumalo community. Along Whychus Creek, the city of Sisters frequently experiences flooding, with the most significant event occurring in 1964.

The flood season on the Deschutes River extends from November through July (larger floods downstream of the Little Deschutes River typically occur in November and December). The flood of record on the Deschutes River upstream of the Little Deschutes River occurred on July 30, 1956 (discharge of 2,280 cfs, approximately a 40-year event); the flood of record on the Deschutes River downstream of the Little Deschutes River occurred on November 27, 1909 (discharge of 5,000 cfs at Benham Falls stream gage). The largest flood since 1958 occurred downstream of the Little Deschutes River in December 1964 (discharge of 3,470 cfs at Benham Falls stream gage, approximately a 175-year event).

The flood season on the Little Deschutes River extends from October through June (majority occur from April to June). Generally there are more days above bankfull stage during the spring (during spring snowmelt floods) than winter. The flood of record occurred in December 1964 (discharge of 3,660 cfs at RM 28.1 north of La Pine, greater than a 500-year event). There are ten bridges within the FIS study area for the Little Deschutes River, of those only the Ranch Bridge (RM 15.1) may be over topped by the 1-percent-annual-chance flood (100-year flood event); however the Vandervert Ranch Bridge (RM 3.1), Lazy River South Ranch Bridge (RM 16.6), Stearns Ranch Bridge (RM 28.1), and the Masten Bridge (RM 39.9) and their approaches may also be over topped by the 0.2-percent-annual-chance flood (500-year flood event).

The flood season on Whychus Creek extends from November through April (larger events occur November and December). The flood of record occurred on December 25, 1980 (discharge of

[7] George et al. Seamless numerical simulation of a hazard cascade in which a landslide triggers a dam-breach flood and consequent debris flow, 7th International Conference on Debris-Flow Hazards Mitigation, 2019.
[8] Ibid.
[9] Hydrologic Hazards Along Whychus Creek From a Hypothetical Failure of the Glacial Moraine Impacting Carver Lake Near Sisters, Oregon—USGS Open File Report 87-41
[10] FEMA, Deschutes County Flood Insurance Study, revised September 28, 2007. Most of the information in this section was obtained from the FIS, additional footnotes are provided as applicable.

2,000 cfs at RM 26.6, approximately an 80-year event). Debris deposition on agricultural land damaging irrigation diversion works, bank erosion, and property damage in Sisters are the principle flood concerns. There are 12 bridges within the FIS study area for Whychus Creek, of those only the ranch bridge (RM 16.3) and the Elm Street Bridge (RM 21.8 in Sisters) may be over topped by the 1-percent-annual-chance flood (100-year flood event); however the ranch bridges at RM 19.3 and RM 19.4 and their approaches may also be over topped by the 0.2-percent-annual-chance flood (500-year flood event).

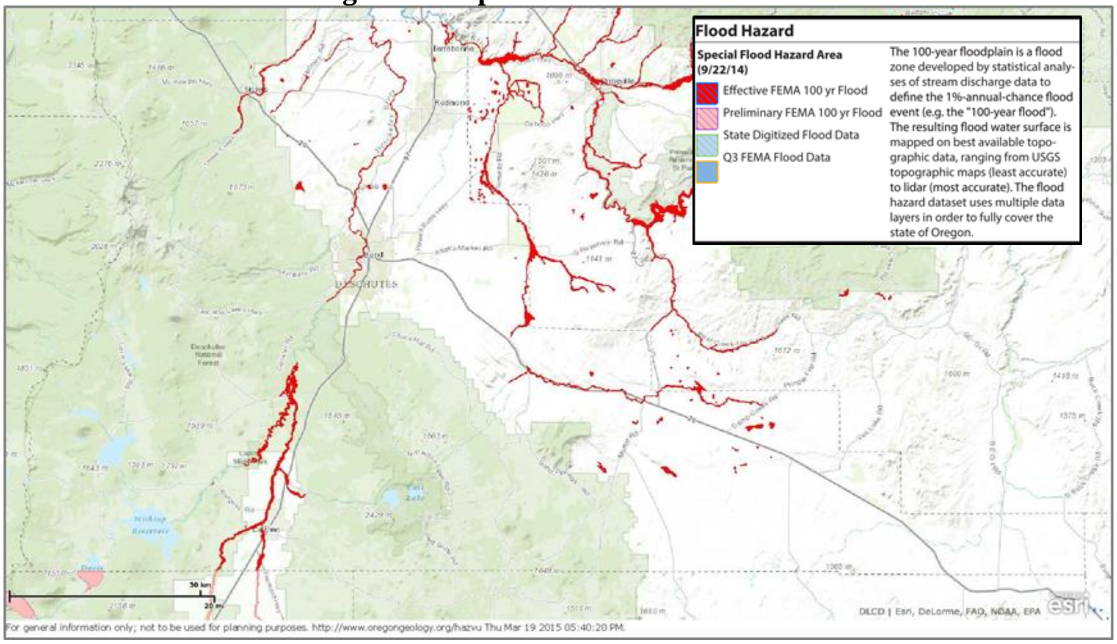
The Whychus Creek stream corridor is particularly vulnerable to obstructions to flood flows due to unconsolidated volcanic deposits that make up the streambed and banks that are prone to erosion. This concern is exacerbated in areas that are at, or below, the elevation of the streambank (see Sisters Addendum for more information). In addition, there is the potential for the moraine dam at Carver Lake to fail during an earthquake, volcanic event, or avalanche/landslide (the lake contains approximately 740 acre feet of water). There have been three observed failures of the dam in the recent past.

More information on the history of the flood hazard can be found in the Regional Risk Assessment for Region 6 of the 2020 Oregon NHMP.

Hazard Identification

FEMA Flood Insurance Rate Maps (FIRMs) and the accompanying Flood Boundary and Floodway maps are the most comprehensive resource for identifying areas subject to flood hazards in Deschutes County. FIRMs and Floodway maps delineate the boundaries of areas subject to inundation by the "base flood." The base flood is defined as an event having a 100-year recurrence interval or a 1% probability of occurring in any year. The maps also provide, in areas of detailed study, projected water surface elevations for the base flood. In general, based on experience with the flood events of the past several decades, Deschutes County's FIRM maps have proven to be fairly accurate in depicting areas subject to riverine flooding. There have been no large flood events since the FIRMs were issued in the mid-1980s so the accuracy of the maps in relation to large flood events is untested. The special flood hazard area is depicted in the map below, for more detailed information visit the Oregon Risk MAP website and click on the "Mapping Tools" tab: http://www.oregonriskmap.com/.

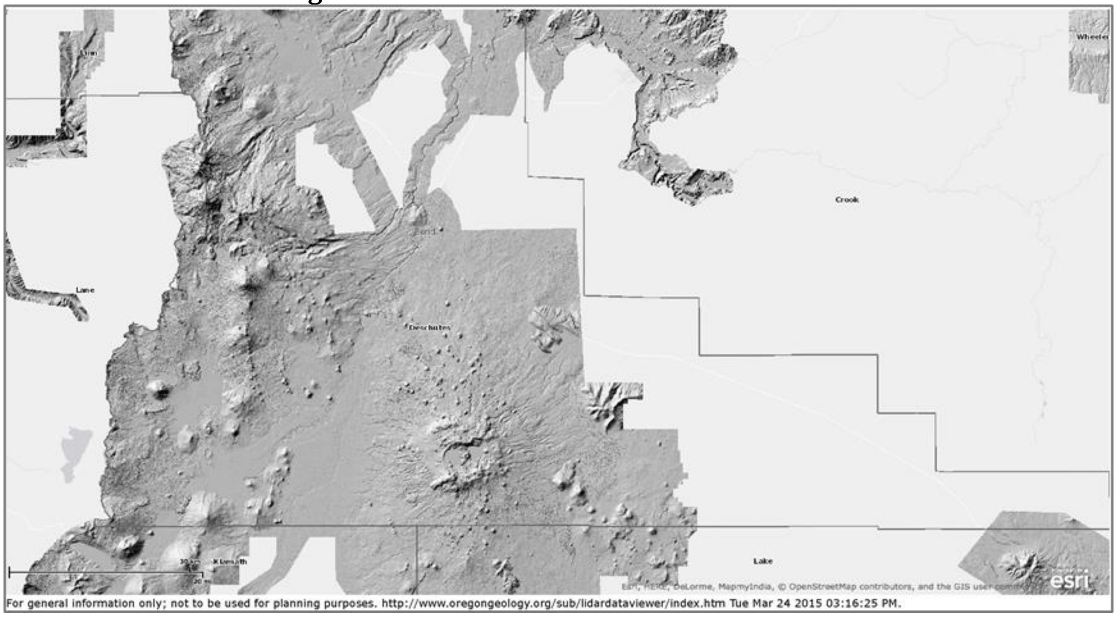
Figure II-7 Special Flood Hazard Area



Source: Oregon HazVu: Statewide Geohazards Viewer (HazVu), accessed March 18, 2015

The county's FIRMs were modernized in 2007, however, there is a concern that sediment accumulation may be occurring within the Deschutes River (and other waterways) that may impact the special flood hazard area. The county has included an action to update the flood insurance study and flood insurance rate maps utilizing existing Lidar. The figure below shows the extent of collected Lidar within Deschutes County, it shows that the areas of the mapped special flood hazard areas are included within the collected Lidar. Although the county is not currently slated to undergo a flood study/mapping project, the existing Lidar data may be useful in conducting future projects.

Figure II-8 Shaded Relief of Collected Lidar



Source: DOGAMI Lidar Data Viewer, accessed March 24, 2015

National Flood Insurance Program (NFIP)

The Deschutes County Flood Insurance Rate Maps (FIRMs) were modernized in September 2007. The table below shows that as of January 2021, Deschutes County (including the incorporated cities) has 267 National Flood Insurance Program (NFIP) policies (90 of these are for properties developed before the initial FIRM) in force and eight total paid claims. The last Community Assistance Visit (CAV) for Deschutes County was on July 22, 1994 (the most recent CAV was in Sisters on April 26, 2004). The county and cities are not members of the Community Rating System (CRS). The table displays the number of policies by building type and shows that the majority of residential structures that have flood insurance policies are single-family homes and that there are 14 non-residential structures with flood insurance policies. According to data from 2021, the proportion of single-family homes (excluding condominiums) within the mapped special flood hazard area (SFHA, floodplain) that have flood insurance (the market penetration rate) for Deschutes County is 12.7%.

The Community Repetitive Loss record for Deschutes County, Bend, La Pine, Redmond, and Sisters identifies zero repetitive loss buildings, zero severe repetitive loss buildings, and zero total repetitive loss claims.

Table II-5 Flood Insurance Detail

Jurisdiction	Current FIRM Date	Initial FIRM Date	Total Policies	Pre-FIRM Policies	Policies by Building Type: Single Family	2 to 4 Family	Other Residential	Non-Residential	Minus Rated A Zone
Deschutes	-	-	218	90	208	3	1	1	14
County*	9/28/2007	9/29/1986	126	66	126	0	0	0	11
Bend	9/28/2007	9/4/1987	60	21	50	3	1	1	1
La Pine	9/28/2007	9/28/2007	1	1	1	0	0	0	0
Redmond	9/28/2007	9/28/2007	0	0	0	0	0	0	0
Sisters	9/28/2007	9/29/1986	31	2	31	0	0	0	2

Jurisdiction	Insurance in Force	Total Paid Claims	Pre-FIRM Claims Paid	Substantial Damage Claims	Repetitive Loss Buildings	Severe Repetitive Loss Buildings	Total Paid Amount	CRS Class Rating	Last CAV
Deschutes County	$67,891,200	8	5	0	1	0	$65,507	-	-
County*	$36,129,300	3	1	0	1	0	$15,115	NP	7/22/1994
Bend	$21,792,700	5	4	0	0	0	$50,392	NP	7/20/1994
La Pine	$280,000	0	0	0	0	0	$0	NP	NA
Redmond	$0	0	0	0	0	0	$0	NP	NA
Sisters	$9,689,200	0	0	0	0	0	$0	NP	4/26/2004

* Portion of entire county under county jurisdiction

NP - Not Participating NA - Information not Available/ Not Applicable

Source: Information compiled by FEMA, January 2021

Probability Assessment

USGS scientists and US Army Corps of Engineers studies indicate the county is at a low level of risk for catastrophic flooding. Potentially, the Little Deschutes and Whychus Creek are most vulnerable; however greater risks are related to future volcanic eruptions (see Volcano annex).

The Federal Emergency Management Agency (FEMA) has mapped the 10, 50, 100, and 500-year floodplains in the Region 6 counties. This corresponds to a 10%, 2%, 1% and 0.2% chance of a certain magnitude flood in any given year. In addition, FEMA has mapped the 100-year floodplain (i.e., 1% flood) in the incorporated cities. The 100-year flood is the benchmark upon which the National Flood Insurance Program (NFIP) is based.

As such, Deschutes County's Natural Hazards Mitigation Steering Committee believes that the County's **probability of experiencing a flood is "high"**, meaning one incident is likely within the next 10 – 35 year period. Based upon available information the Oregon NHMPs Regional Risk Assessment rates Deschutes County's probability of flood as low.[11]

Vulnerability Assessment

Growth rates described in the Community Profile section of this Plan project a continued growth pattern that will place additional development, business and human life at risk.

The Deschutes County Natural Hazards Steering Committee rated Deschutes County as having a **"low" vulnerability to the flood hazard**, meaning less than 1% of the region's population or assets would be affected by a major emergency or disaster. Based upon available information

[11] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2020.

the Oregon NHMPs Regional Risk Assessment rates Deschutes County's vulnerability to flood as very low.[12]

Sisters is particularly vulnerable to economic loss in the event of road closures. According to USGS Open File Report 87-41, locally high velocities, damming, erosion and sediment deposit could cause considerable property damage and possible loss of life. The stream would be especially dangerous at road crossings where bridges may fail or sections could wash away.

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I, Section 2) shows the county's Hazard Analysis Matrix which scores each hazard and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **flood hazard is rated #7, out of 9 rated hazards, with a total score of 114**.

Community Hazard Issues

The extent of the damage and risk to people caused by flood events is primarily dependent on the depth and velocity of floodwaters. Fast moving floodwaters can wash buildings off their foundations and sweep vehicles downstream. Roads, bridges, other infrastructure and lifelines (pipelines, utility, water, sewer, communications systems, etc.) can be seriously damaged when high water combines with flood debris, mud and ice. Extensive flood damage to residences and other structures also results from basement flooding and landslide damage related to soil saturation. Surface water entering into crawl spaces, basements and daylight basements is common during flood events not only in or near flooded areas but also on hillsides and other areas far removed from floodplains. Most damage is caused by water saturating materials susceptible to loss (e.g., wood, insulation, wallboard, fabric, furnishings, floor coverings and appliances.)

If not properly protected from the entry of flood waters, mechanical, electrical and similar equipment can also be damaged or destroyed by flooding.

Older, pre-FIRM manufactured homes are particularly susceptible to flood damage, as many have a lower level of structural stability than "stick-built" (standard wood frame construction) homes. Current regulations require manufactured homes in floodplain zones to be both elevated and anchored to provide structural stability during flood events comparable to site built homes.

Flood events impact businesses by damaging property and interrupting commerce. Flood events can cut off customer access and close businesses for repairs. A quick response to the needs of businesses affected by flood events can help a community maintain economic viability in the face of flood damage.

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[12] Ibid.

Bridges are a major concern during flood events as they provide critical links in road networks by crossing water courses and other significant natural features. However bridges and their supporting structures can also be obstructions in flood-swollen watercourses and can be damaged by debris jams and erosion scour.

More information on this hazard can be found in the Regional Risk Assessment for Region 6 of the Oregon NHMP.

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

County and Cities

Current initiatives to mitigate the effects of potential flooding in Deschutes County are many. These actions are varied from projects initiated by homeowners and neighborhood associations to county policies and procedures aligned with the National Flood Insurance Program.

Home and business owners and neighborhood associations in and around the County's floodplains continue to address mitigation activities for flooding. Riparian zones have been established to reduce erosion, review of building plans/codes and emergency strategies to mitigate damage from floods are being developed.

Regardless of future investigative studies, some early warning, zoning, and planning studies are needed to prevent loss of life and property damage in areas downstream of Carver Lake. In Sisters, the potential breakout of Carver Lake represents several times the magnitude flood for which county and city governments presently plan. The flood could occur with little or no warning.

The city of Sisters is currently engaged in discussions about potential flooding from the Carver Lake scenario described above and other flooding potential. The current belief by city planners is that a rain-on-snow event is more likely to occur than a breach at Carver Lake. Therefore, the City of Sisters will continue to pursue mitigation policies that address local flooding of Whychus Creek.

Deschutes County Comprehensive Plan and Development Code

Deschutes County has enacted a Comprehensive Land Use Plan and is implementing land use regulations in compliance with ORS 197 and the Statewide Planning Goals. The County has enacted and enforces a flood hazard ordinance, which is applied to all areas mapped as subject to inundation by the base flood. The regulations are designed to reduce the risk of flood damage to new and substantially improved structures within known flood hazard areas.

Deschutes County Public Works

Deschutes County annually visually inspects and cleans culverts on county roads. Culverts needing replaced are identified and targeted for replacement. Culverts during past flooding events that could not handle the flow are looked at for replacement with a larger culvert.

Bridges are likewise routinely inspected and during flood events crews keep a visual check on bridges for debris buildup. After a major flood, crews are dispatched to recheck bridges for flood damage.

Federal

National Flood Insurance Program

Deschutes County participates in the National Flood Insurance Program, which enables property and business owners to qualify for federally underwritten flood insurance. Flood insurance policies in effect in the County and the coverage provided by these policies are depicted above. The County's flood ordinance, discussed above, comprises the county's NFIP qualifying floodplain regulation. These standards require all new development to be elevated above the projected level of the base flood, along with a number of other building design and construction standards intended to reduce the risk of flood damage. Strict enforcement of these regulations is required to maintain eligibility for participation in the NFIP; the Community Development Department is charged with this responsibility.

Hazard Mitigation Action Items

There are seven identified Flood action items for Deschutes County; in addition, several of the Multi-Hazard action items affect the Flood hazard. An action item matrix is provided within Volume I, Section 3, while action item forms are provided within Volume IV, Appendix A. To view city actions see the appropriate city addendum within Volume III.

LANDSLIDE

Significant Changes since the 2015 Plan

Significant changes to this section include additions to Community Hazard Issues, additional information on the history of landslides, and an updated Figure II-9.

Causes and Characteristics of the Hazard

Landslides are a major geologic threat in almost every state in the United States. In Oregon, a significant number of locations are at risk from dangerous landslides and debris flows. While not all landslides result in property damage, many landslides do pose serious risk to people and property. Increasing population in Oregon and the resultant growth in home ownership has caused the siting of more development in or near landslide areas. Often these areas are highly desirable to prospective homeowners owing to their location along the coast, rivers and on hillsides.

Landslides are fairly common, naturally occurring events in various parts of Oregon. In simplest terms, a landslide is any detached mass of soil, rock, or debris that falls, slides or flows down a slope or a stream channel. Landslides are classified according to the type and rate of movement and the type of materials that are transported.

In a landslide, two forces are at work: 1) the driving forces that cause the material to move down slope, and 2) the friction forces and strength of materials that act to retard the movement and stabilize the slope. When the driving forces exceed the resisting forces, a landslide occurs.

Landslides can be grouped as “on-site” and “off-site” hazards. An “on-site” slide is one that occurs on or near a development site and is usually relatively slow moving. Slow moving slides cause the most property damage in developed areas. On-site landslide hazards include features called slumps, earthflows and block slides. “Off-site” slides typically are rapidly moving and begin on steep slopes at a distance from homes and development. A 1996 “off-site” slide in southern Oregon began a long distance away from homes and roads, traveled at a high velocity and resulted in five fatalities and a number of injuries, in addition to substantial property damage.

Landslides are classified based on causal factors and conditions and exist in three basic categories.

Falls

This type of landslide involves the movement of rock and soil which detaches from a steep slope or cliff and falls through the air and/or bounces or rolls down the slope. This type of slide is termed a rock fall and is very common along Oregon highways where they have been cut through bedrock in steep canyons and along the coast.

Slides

This type of landslide exists where the slide material moves in contact with the underlying surface. Here the slide moves along a plane and either slumps by moving along a curved surface (called a rotational slide) or along a flat surface (called a translational slide). While slow-moving slides can occur on relatively gentle slopes and are less likely to cause serious injuries or fatalities, they can result in significant property damages.

Flows

Flow landslides are characterized as plastic or liquid in nature where the slide material breaks up and flows during movement. A flow occurs when a landslide moves down slope as a semi-fluid mass scouring or partially scouring rock and soils from the slope along its path. A flow landslide is typically rapidly moving and tends to increase in volume as it moves down slope and scours out its channel.

Rapidly moving flow landslides are often referred to as debris flows. Other terms given to debris flows are mudslides, mudflows, or debris avalanches. Debris flows frequently take place during or following an intense rainfall event on previously saturated soil. Debris flows usually start on steep hillsides as slumps or slides that liquefy, accelerate to speeds as high as 35 miles per hour or more, and travel down slopes and channels onto gentle sloping or flat ground. Most slopes steeper than 70 percent are at risk from debris flows.

The consistency of a debris flow ranges from watery mud to thick, rocky, mud-like, wet cement which is dense enough to carry boulders, trees and cars. Separate debris flows from different starting points sometimes combine in canyons and channels where their destructive energy is greatly increased. Debris flows are difficult for people to outrun or escape from and present the greatest risk to human life. Debris flows have caused most of their damage in rural areas and were responsible for most of the landslide-related deaths and injuries during the 1996 storms in Oregon.

Conditions Affecting Landslides

Natural conditions and human activities can both play a role in causing landslides. Certain geologic formations are more susceptible to landslides than others. Locations with steep slopes are at the greatest risk of slides. However, the incidence of landslides and their impact on people and property can be accelerated by development. Developers who are uninformed about geologic conditions and processes may create conditions that can increase the risk of or even trigger landslides.

There are four principal factors that affect or increase the likelihood of landslides:

1. Natural conditions and processes including the geology of the site, rainfall, wave and water action and seismic tremors, including earthquakes and volcanic activity.
2. Excavation and grading on sloping ground for homes, roads and other structures.

3. Drainage and groundwater alterations that are natural or human-caused can trigger landslides. Human activities that may cause slides include broken or leaking water or sewer lines, water retention facilities, irrigation and stream alterations, ineffective storm water management and excess runoff due to increased impervious surfaces.
4. Change or removal of vegetation on very steep slopes due to timber harvesting, land clearing and wildfire.

History of Landslides in Deschutes County

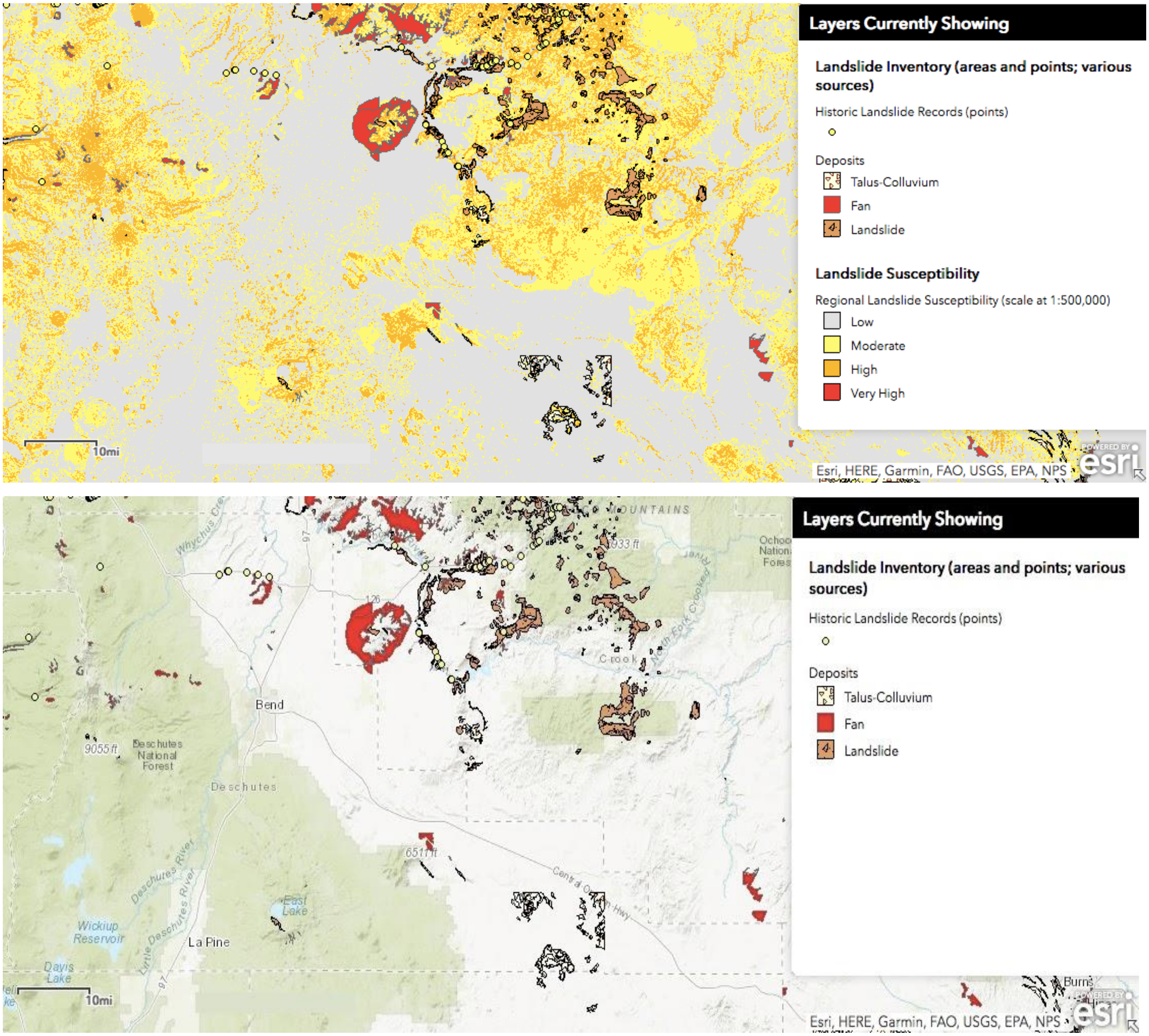
Although most landslides occur in the undeveloped forested areas of the county, landslides may also occur in more developed areas. The fatalities and losses resulting from the 1996 statewide landslide events brought about the passage of Oregon Senate Bill 12, which set site development standards, authorized the mapping of areas subject to rapidly moving landslides and the development of model landslide (steep slope) ordinances.

There is no history of major landslides in Deschutes County within developed areas. At times small debris falls have occurred, however, these have typically not caused major disruptions of normal activity (see figure below). In undeveloped areas the risk of landslides and avalanches is highest within the forested areas and in the Three Sisters Wilderness. There have been recorded landslides that affected the Carver Lake moraine dam and other rural areas; however, this activity has not led to major disruptions of normal activity.

DOGAMI maps the State Landslide Information Layer for Oregon (SLIDO); Figure II-9 relies on the 2012 SLIDO data and shows Deschutes County landslides that have been identified on published maps. The database contains only landslides that have been located on these maps. Many landslides have not yet been located or are not on these maps and therefore are not in this database. This database does not contain information about relative hazards.[1] The map shows that the history of landslide events is sparse, and where they do occur they are in non-populated areas.

[1] DOGAMI. Statewide Landslide Information Database for Oregon (SLIDO-2). http://www.oregongeology.org/sub/slido/index.htm

Figure II-9 Mapped Landslides and Landslide Susceptibility



Source: DOGAMI Statewide Landslide Information Database for Oregon (SLIDO), accessed February 10, 2021.

Hazard Identification

Geologic and geographic factors are important in identifying landslide-prone areas. Stream channels, for example, have major influences on landslides, due to undercutting of slopes by stream erosion and long-term hillside processes.

The Oregon Department of Forestry (ODF) Storm Impacts Study conducted after the 1996-97 landslide events found that the highest probability for the initiation of shallow, rapidly moving landslides was on slopes of 70 to 80 percent steepness. A moderate hazard of shallow rapid landslide initiation can exist on slopes between 50 and 70 percent.[2]

In general, areas at risk to landslides have steep slopes (25 percent or greater,) or a history of nearby landslides. In otherwise gently sloped areas, landslides can occur along steep river and creek banks. At natural slopes under 30 percent, most landslide hazards are related to excavation and drainage practices, or the reactivation of preexisting landslide hazards.[3]

The severity or extent of landslides is typically a function of geology and the landslide triggering mechanism. Rainfall initiated landslides tend to be smaller, and earthquake induced landslides may be very large. Even small slides can cause property damage, result in injuries, or take lives. Geo-engineers with the Oregon Department of Forestry estimate widespread landslide activity about every 20 years.

The Department of Land Conservation and Development (DLCD) requires local governments to address geologically unstable areas as part of their comprehensive plans through Statewide Land Use Planning Goal 7 (Areas Subject to Natural Hazards). In Deschutes County, little planning has been done concerning landslide hazards due to the lack of risk. Goal 7 envisions a process whereby new hazard inventory information generated by federal and state agencies is first reviewed by DLCD. DLCD then notifies the County of the new information, and the County has three years to respond to the information by evaluating the risk, obtaining citizen input, and adopting or amending implementation measures to address the risk. Deschutes County has not received notice of new inventory information concerning landslides.

Probability Assessment

The probability of rapidly moving landslides occurring depends on a number of factors; these include steepness of slope, slope materials, local geology, vegetative cover, human activity, and water. There is a strong correlation between intensive winter rainstorms and the occurrence of rapidly moving landslides (debris flows); consequently, the Oregon Department of Forestry tracks storms during the rainy season, monitors rain gages and snow melt, and issues warnings as conditions warrant. Given the correlation between precipitation / snow melt and rapidly moving landslides, it would be feasible to construct a probability curve. Many slower moving slides present in developed areas have been identified and mapped; however the probability and timing of their movement is difficult to quantify. The installation of slope indicators or the use of more advanced measuring techniques could provide information on these slower moving slides.

[2] Storm Impacts and Landslides of 1996 Final Report. (1999) Oregon Department of Forestry.
[3] Oregon Natural Hazards Mitigation Plan, Landslide Chapter. The Interagency Hazards Mitigation Team, (2012) Oregon Military Department - Office of Emergency Management.

Deschutes County's Natural Hazards Mitigation Steering Committee believes that the County's **probability of experiencing a landslide is "moderate,"** meaning one incident is likely within the next 35-75 year period. Based upon available information the Oregon NHMPs Regional Risk Assessment rates Deschutes County's probability of landslide as low.[4]

Vulnerability Assessment

To a large degree, landslides are very difficult to predict. Both location and extent of landslide hazard are affected by a variety of variables. Many people are unaware of their exposure to landslide risk. Therefore there are a large number of structures, infrastructure, and other community assets within Deschutes County potentially vulnerable to landslides. New private development is subject to regulations which are intended to reduce risk from known landslide hazards. However, there is substantial private development in the county, which pre-dates land use or building code regulations and is therefore subject to increased risk.

The Deschutes County Natural Hazards Steering Committee rated Deschutes County as having a **"low" vulnerability to landslide hazards**; meaning less than 1% of the region's population or assets would be affected by a major emergency or disaster. Based upon available information the Oregon NHMPs Regional Risk Assessment supports this vulnerability rating for Deschutes County ("very low").[5]

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I) shows the county's Hazard Analysis Matrix which scores each hazard and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **landslide hazard is rated #9, out of 9 rated hazards, with a total score of 87**.

Community Hazard Issues

Depending upon the type, location, severity and area affected, severe property damage, injuries and loss of life can be caused by landslide hazards. Landslides can damage or temporarily disrupt utility services, roads and other transportation systems and critical lifeline services such as police, fire, medical, utility and communication systems, and emergency response. In addition to the immediate damage and loss of services, serious disruption of roads, infrastructure and critical facilities and services may also have longer term impacts on the economy of the community and surrounding area. Additionally, the Carver Lake dam has been identified as a hazard risk to the city of Sisters that can be triggered by a landslide event. For more information on the Carver Lake dam risks, please see the Flood Annex.

[4] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2020.
[5] Ibid.

Increasing the risk to people and property from the effects of landslides are the following seven factors:

1. Improper excavation practices, sometimes aggravated by drainage issues, can reduce the stability of otherwise stable slopes.
2. Allowing development on or adjacent to existing landslides or known landslide-prone areas raises the risk of future slides regardless of excavation and drainage practices. Homeowners and developers should understand that in many potential landslide settings that there are no development practices that can completely assure slope stability from future slide events.
3. Building on fairly gentle slopes can still be subject to landslides that begin a long distance away from the development. Sites at greatest risk are those situated against the base of very steep slopes, in confined stream channels (small canyons), and on fans (rises) at the mouth of these confined channels. Home siting practices do not cause these landslides, but rather put residents and property at risk of landslide impacts. In these cases, the simplest way to avoid such potential effects is to locate development out of the impact area, or construct debris flow diversions for the structures that are at risk.
4. Certain forest practices can contribute to increased risk of landslides. Forest practices may alter the physical landscape and its vegetation, which can affect the stability of steep slopes. Physical alterations can include slope steepening, slope-water effects, and changes in soil strength. Of all forest management activities, roads have the greatest effects on slope stability, although changing road construction and maintenance practices are reducing the effects of forest roads on landslides.
5. Deschutes County is susceptible to extreme winter storms and rainfall. High rainfall accumulation in a short period of time increases the probability of landslides.
6. Removal of vegetation from fire significantly increases the risk of landslides, especially as fires become more frequent and more intense due to climate change.
7. Climate change is causing an increase in large, high-intensity fires across the west. Models predict that climate change will result in more extreme winter storms and rainfall in the Pacific Northwest. Climate change is causing glaciers to decrease in size, and, in some locations, to melt completely. As glacial ice is removed from steep mountain slopes the likelihood of rock fall, landslides, and debris flows increases.

More information on this hazard can be found in the Regional Risk Assessment for Region 6 of the Oregon NHMP.

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

State

Oregon Department of Forestry (ODF)

The Oregon Department of Forestry has provided a preliminary indication of debris flows (rapidly moving landslides) in Western Oregon. Their debris flow maps include locations subject to naturally occurring debris flows and include the initiation sites and locations along the paths of potential debris flows (confined stream channels and locations below steep slopes). These maps neither consider the effects of management-related slope alterations (drainage and excavation) that can increase the hazard, nor do they consider very large landslides that could possibly be triggered by volcanic or earthquake activity. Areas identified in these maps are not to be considered "further review areas" as defined by Senate Bill 12 (1999).[6] Information used to develop the ODF Debris Flow maps include:

- Digital elevation models at 30-meter resolution, based on U.S. Geological Survey data, were used to derive slope steepness and then to develop polygons for assigned hazards. Note that actual slopes are steeper than these digitally elevated models.
- Mapped locations of Tyee soil formation and similar sedimentary geologic units.
- Oregon Department of Forestry Storm Impacts and Landslides of 1996 study; debris flow initiation and path location data.
- Stream channel confinement near steep hill slopes based on U.S. Geological Survey Digital Raster Graphics.
- Historical information on debris flow occurrence in western Oregon (from Oregon Dept. of Forestry, U.S. Forest Service, DOGAMI, Bureau of Land Management, and the Oregon Department of Transportation).
- Fan-shaped land formations below long, steep slopes.
- Areas of highest intensity precipitation do not appear to be correlated with known areas of high and extreme debris flow hazard, so precipitation intensity was not used to develop risk (hazard) ratings.[7]

Oregon Department of Geology and Mineral Industries (DOGAMI)

The Oregon Department of Geology and Mineral Industries (DOGAMI) conducted field investigations and consolidated data on Oregon landslides associated with three flood events in 1996 and 1997. They collected evidence of over 9,000 landslide and slope failure locations in the state. The generation of a statewide landslide inventory is intended to provide a means for developing and verifying hazard models as well as to facilitate various local efforts aimed at minimizing risk and damage in future storm events. The database includes a digital Geographic Information System file with landslide locations, a digital database with details on each landslide, and an accompanying report.[8]

In addition to the slope failures report, DOGAMI is identifying and mapping further review areas. The further review areas identify where landslides have occurred and where landslides are likely to occur.[9]

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[6] Western Oregon Debris Flow Hazard Maps: Methodology and Guidance for Map Use. (1999).
[7] Ibid.
[8] Database of Slope Failures in Oregon for Three 1996/1997 Storm Events. Hofmeister, R.J. (2000). Oregon Department of Geology and Mineral Industries – Special Paper 34.
[9] Interagency Hazard Mitigation Team. 2012. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

Debris Flow Warning System

The debris flow warning system was initiated in 1997 and involves collaboration between the Department of Forestry, DOGAMI, the Department of Transportation, local law enforcement, and National Oceanic and Atmospheric Administration (NOAA) Weather Radio and other media.

Since 2008, ODF meteorologists have not issued Debris Flow Warning for Oregon since they do not have sufficient resources. However, information is provided by the National Weather Service (NWS) and broadcast via the NOAA Weather Radio, and on the Law Enforcement Data System. The information provided does not include the Debris Flow Warning system as originally designed since the NWS does not have the geologic and geomorphology expertise. Instead they provide the following language in their flood watches that highlights the potential for landslides and debris flows[10]:

A flood watch means there is a potential for flooding based on current forecasts. Landslides and debris flows are possible during this flood event. People, structures and roads located below steep slopes, in canyons and near the mouths of canyons may be at serious risk from rapidly moving landslides.

DOGAMI provides additional information on debris flows through the media. The Department of Transportation provides warning signs to motorists in landslide prone areas during high-risk periods.[11]

Landslide Brochure

The Department of Geology and Mineral Industries (DOGAMI) developed a landslide public outreach brochure in cooperation with several other state agencies. Forty thousand copies were printed in November 1997 and were distributed widely through building code officials, county planners, local emergency managers, natural resource agency field offices, banks, real estate companies, insurance companies, and other outlets. Landslide brochures are available from DOGAMI, the Office of Emergency Management (OEM), Oregon Department of Forestry (ODF), and the Department of Land Conservation and Development (DLCD).[12]

Oregon State Building Code Standards

The Oregon Building Codes Division adopts statewide standards for building construction that are administered by the state and local municipalities throughout Oregon. The One- and Two-Family Dwelling Code and the Structural Specialty Code contain provisions for lot grading and site preparation for the construction of building foundations.

Both codes contain requirements for cut, fill and sloping of the lot in relationship to the location of the foundation. There are also building setback requirements from the top and bottom of slopes. The codes specify foundation design requirements to accommodate the type of soils, the soil bearing pressure, and the compaction and lateral loads from soil and ground water on sloped lots. The building official has the authority to require a soils analysis for any project

[10] NOAA, NWS. Letter dated December 20, 2010 from Stephen K. Todd, Meteorologist-in-Charge.
[11] Interagency Hazard Mitigation Team. 2012. Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management
[12] Ibid.

where it appears the site conditions do not meet the requirements of the code, or that special design considerations must be taken. ORS 455.447 and the Structural Code require a seismic site hazard report for projects that include essential facilities such as hospitals, fire and police stations and emergency response facilities, and special occupancy structures, such as large schools and prisons. This report includes consideration of any potentially unstable soils and landslides.[13]

Hazard Mitigation Action Items

There are no identified Landslide action items for Deschutes County; however, several of the Multi-Hazard action items affect the Landslide hazard. An action item matrix is provided within Volume I, Section 3*,* while action item forms are provided within Volume IV, Appendix A. To view city actions see the appropriate city addendum within Volume III.

[13] Planning for Natural Hazards: Oregon Technical Resource Guide. Community Planning Workshop. (July 2000). Chapter 5.

VOLCANO

Significant Changes since the 2015 Plan

New information on the hazard and hazard identification was added to this section. As such, some sections utilize modified text from the Central Cascades Volcano Coordination Plan, particularly Appendix B: Volcanic Hazards in the Central Cascades. In addition, the format of the section and minor content changes has occurred.

Causes and Characteristics of Volcanic Eruption

Deschutes County, and the Pacific Northwest, lie within the "ring of fire," an area of very active volcanic activity surrounding the Pacific Basin. Volcanic eruptions occur regularly along the ring of fire, in part because of the movement of the Earth's tectonic plates. The Earth's outermost shell, the lithosphere, is broken into a series of slabs known as tectonic plates. These plates are rigid, but they float on a hotter, softer layer in the Earth's mantle. As the plates move about on the layer beneath them, they spread apart, collide, or slide past each other. Volcanoes occur most frequently at the boundaries of these plates and volcanic eruptions occur when molten material, or magma, rises to the surface.

The primary threat to lives and property from active volcanoes is from violent eruptions that unleash tremendous blast forces, generate landslides and debris flows, or produce flying debris and ash clouds. The immediate danger area in a volcanic eruption generally lies within a 20-mile radius of the volcano. The following section outlines the specific hazards posed by volcanoes.

Volcanoes are commonly, but not always, conical hills or mountains built around a vent that connects with reservoirs of molten rock below the surface of the earth.[1] Volcanoes are built up by an accumulation of their own eruptive products: lava ash flows, debris flows, airborne ash and rocks, and lava domes. When pressure from gases or molten rock becomes strong enough to cause an upsurge, eruptions occur. Gases and rocks are pushed through and ejected from a vent. This intrusion of molten material can weaken volcanoes and trigger large landslides and violent blasts, thrust from a volcano in high eruption plumes, gush from a vent forming lava flows, or ooze from a vent in relatively calm manner and form a lava dome. Collapses of tall eruption plumes or lava domes can generate flows of hot gas, ash, and rock particles that rush down flanks of volcanoes (pyroclastic flows). Debris flows (lahars) can form when snow is melted on volcano flanks, when heavy rains fall on layers of volcanic ashfall, or when dammed lakes along valley margins breach.[2][3]

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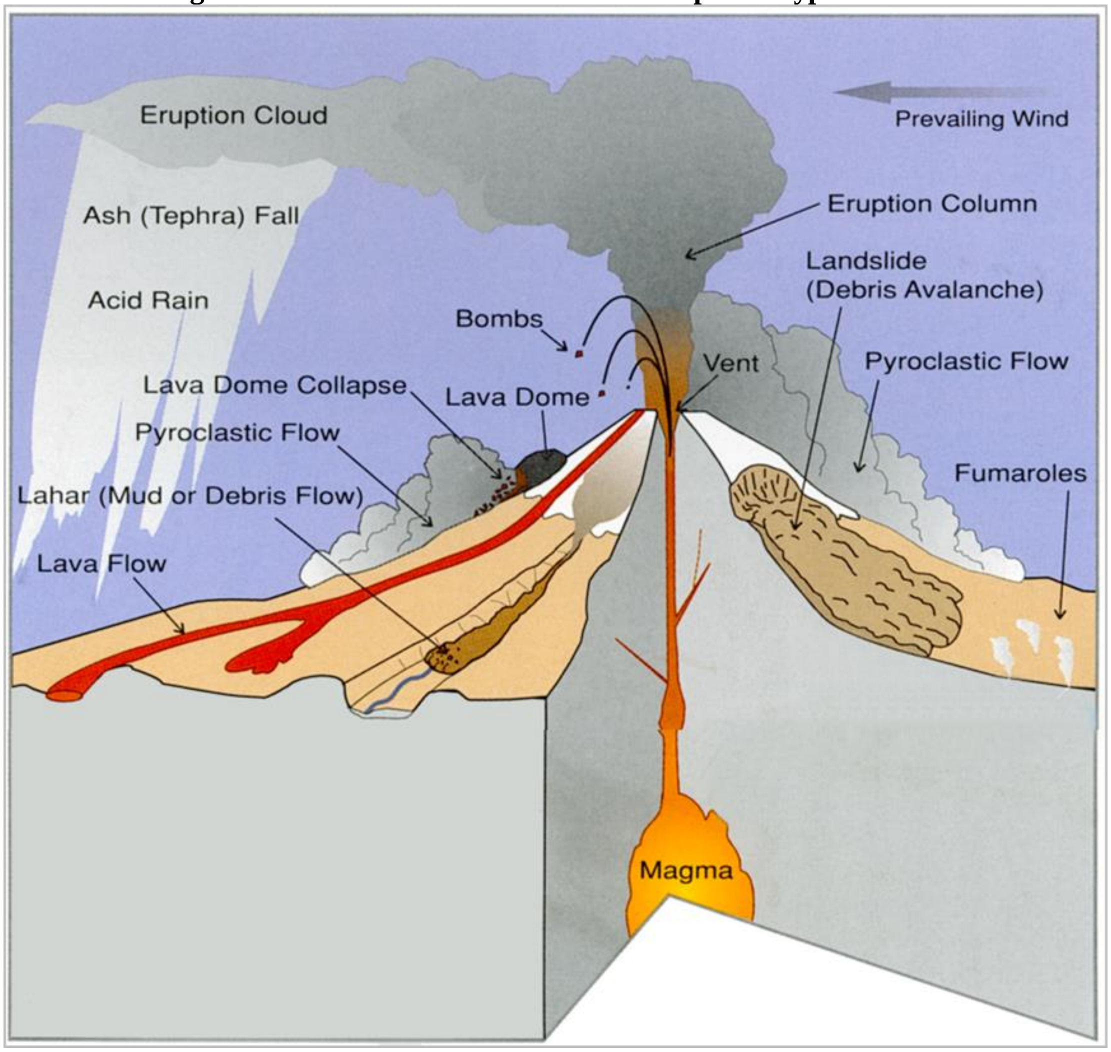
[1] Tilling, Robert I., *Volcanoes*, USGS General Interest Publication, (1985).
[2] Myers, Brantley, Stauffer, and Hendley II., *What are Volcano Hazards?,* USGS Reducing the Risk from Volcano Hazards (Revised 2008). https://pubs.usgs.gov/fs/fs002-97/
[3] Dzurisin, Stauffer, and Hendley II., *Living with Volcanic Risk in the Cascades*, USGS Reducing the Risk from Volcano Hazards (Revised 2008). https://pubs.usgs.gov/fs/1997/fs165-97/

Figure II-10 Volcanic Hazard from a Composite Type Volcano



Source: Walder et al, "Volcano Hazards in the Mount Jefferson Region," 1999; W.E. Scott, R.M. Iverson, S.P. Schilling, and B.J. Fischer, Volcano Hazards in the Three Sisters Region, Oregon: U.S. Geological Survey Open-File Report 99-437, 14p., 200.

Related Hazards

Ash / Tephra

Tephra fall is the rain of fragmented volcanic rock falling to the ground after being ejected from a volcano. It consists of volcanic ash (sand-sized or finer particles) and larger fragments. Larger fragments fall near the volcanic vent while finer (ash) particles drift downwind as part of a volcanic plume. When ash particles fall to the ground, they can form a blanket-like deposit, with finer grains carried further away from the volcano. In general, the thickness of tephra deposits decreases in the downwind direction. Depending on the size and energy of an eruption, tephra fall deposits can be tens of inches thick near volcanoes, and a few to many inches thick tens to hundreds of miles downwind. Tephra hazards include impact of falling fragments, respiratory problems, damage to crops and other vegetation, contamination of drinking water, roof collapse, burial of transportation routes, damage to electrical grids, and mechanical or electrical failure of car and jet engines.

During an eruption that emits tephra, deposition is controlled by the prevailing wind direction. [4] The predominant wind pattern over the Cascades is from the west; the geologic record shows the greatest number and thickest ash fall deposits are east of the volcanoes. [5]

Lava flows

Lava flows are streams of molten rock that erupt relatively non-explosively from a volcano and move downslope, sometimes at velocities of many miles per hour, causing extensive damage or total destruction by burning, crushing, or burying everything in their path. Secondary effects can include forest fires, flooding, and permanent reconfiguration of stream channels. [6]

Pyroclastic flows and surges

Pyroclastic flows are dense mixtures of hot ash, rocks, and gas at temperatures of 600 to 1500 degrees Fahrenheit that flow swiftly away from volcanoes. They typically sweep down the flanks of volcanoes at speeds of up to 150 miles per hour. Pyroclastic surges are a more dilute mixture of gas and ash. They can move even more rapidly than a pyroclastic flow and are more mobile. Both generally follow valleys, but surges sometimes have enough momentum to overtop hills or ridges in their paths. Because of their high speed, pyroclastic flows and surges are difficult or impossible to escape. If it is expected that they will occur, evacuation orders should be issued as soon as possible for the hazardous areas. Objects and structures in the path of a pyroclastic flow are generally destroyed or swept away by the impact of debris or by accompanying hurricane-force winds. Wood and other combustible materials are commonly burned. People and animals may also be burned or killed by inhaling hot ash and gases. The deposit that results from pyroclastic flows is a combination of rock and ash and is termed ignimbrite. If the deposit is sufficiently hot and sufficiently thick, it can consolidate and allow the granular particles to deform and merge together, forming a dense, coherent deposit called a welded tuff. Individual flow deposits can be a few to many feet thick, but multiple flows can form sequences of deposits that can accumulate to hundreds of feet thick and can harden to resistant rock. [7]

Lahars and debris flows

Lahar is an Indonesian term that describes a hot or cold mixture of water and rock fragments flowing down the slopes of a volcano or river valley.[8] Small seasonal events are sometimes referred to as "debris flows", especially in the Cascades. Lahars can form when hot volcanic debris scours and melts snow and ice during eruptions of ice-clad volcanoes like South Sister, Mt. Hood, Mt. Rainier, or Mount Shasta. Heavy rains can also generate lahars by eroding tephra fall from slopes on and near volcanoes even after an eruption stops. Floods and lahars can be generated by the displacement of water from volcanic lakes, which can overtop dams and move

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[4] Oregon State Natural Hazard Mitigation Plan. 2012." Volcanic Hazards Chapter," http://csc.uoregon.edu/opdr/sites/csc.uoregon.edu.opdr/files/docs/ORNHMP/OR-SNHMP_volcano_chapter.pdf
[5] Ibid.
[6] Oregon State Natural Hazard Mitigation Plan. 2012." Volcanic Hazards Chapter," http://csc.uoregon.edu/opdr/sites/csc.uoregon.edu.opdr/files/docs/ORNHMP/OR-SNHMP_volcano_chapter.pdf
[7] Ibid.
[8] USGS website: http://volcanoes.usgs.gov/Hazards/What/Lahars/lahars.html

down outlet streams. Smaller seasonal debris flows can form by processes unassociated with a volcano or an eruption, such as during heavy rains following wildfires.

Some lahars begin as a landslide (debris avalanche) of wet, weakened rock on the steep flanks of volcanoes. These collapses and resultant lahars are natural events during a stratovolcano's life history and can occur long after it stops erupting.[9] They can be triggered by instability at the onset of or during volcanic eruptions, large earthquakes, and intense ground deformation by rising magma and perhaps just long-term exposure to gravity.

Lahars and debris flows react much like flash flood events in that a rapidly moving mass travels downstream. As this flow moves downstream, it can ingest more sediment and debris as it scours out a channel. The flow can also incorporate water from rivers and by scouring snow and ice. By eroding rock debris and incorporating additional water, lahars and debris flows can grow to many times their initial size, but as they move farther away from the volcano they eventually lose sediment load and decrease in size.[10]

Lahars and debris flows often cause serious economic and environmental damage. Because they can transport boulders, logs, and other debris, they can easily crush, abrade, and destroy anything in the flow path. Even if not crushed or carried away by the force of the flow, buildings and valuable land may become partially or completely buried by one or more cement-like layers of rock debris. By destroying bridges and roads, lahars and debris flows can also trap people in areas vulnerable to other volcanic hazards, especially if the debris deposits are too deep, too soft, or too hot to cross.[11]

Volcanic Landslides (debris avalanches)[12]

Landslides and debris avalanches are a rapid downhill movement of rocky material, trees, snow, and (or) ice. Volcanic landslides range in size from small movements of loose debris on the surface of a volcano to massive collapses of large segments of a volcano. Steep volcanoes are susceptible to landslides because they are built up partly of layers of loose volcanic rock fragments. Landslides on volcano slopes are triggered not only by eruptions, but also by heavy rainfall or large earthquakes that can cause materials to break free and move downhill.

Earthquakes

Earthquakes are another potentially hazardous event associated with volcanic eruptions. Volcanic earthquakes are commonly smaller than magnitude 2.5, roughly the threshold for felt shaking by observers close to the event. Swarms of small earthquakes may persist for weeks to months before eruptions, but little or no damage may occur to buildings in surrounding communities. Some swarms of volcanic earthquakes can include earthquakes as large as about magnitude 5. For the communities of Bend, La Pine, and Sunriver, shallow earthquakes in the magnitude 4-5 range that are located beneath Newberry Volcano or in the Three Sisters area would likely cause walls to rattle or windows and dishes to vibrate.

[9] USGS, Volcanic Hazards Program. “Lahars move rapidly down valleys like rivers of concrete”. https://www.usgs.gov/natural-hazards/volcano-hazards/lahars-move-rapidly-down-valleys-rivers-concrete
[10] Ibid.
[11] Ibid.
[12] Wright and Pierson, Living With Volcanoes, USGS Volcano Hazards Program Circular 1973, (1992).

History of Volcanic Events in Deschutes County

No eruptions have occurred in Deschutes County during the past 1,000 years; however the millennium before experienced numerous eruptions, including several at Three Sisters and one at Newberry Volcano. The most devastating effects of these events were restricted to what is now Wilderness or largely undeveloped areas, but tephra fall from these eruptions probably deposited less than one-quarter inch to one-half inch of gritty ash in areas that are now densely populated.

Although there have been no recent volcanic events in the Deschutes County area, it is important to note the area is active and susceptible to eruptive events since the region is a part of the active Cascade Volcanic Range. The figure below displays volcanoes of the western United States.

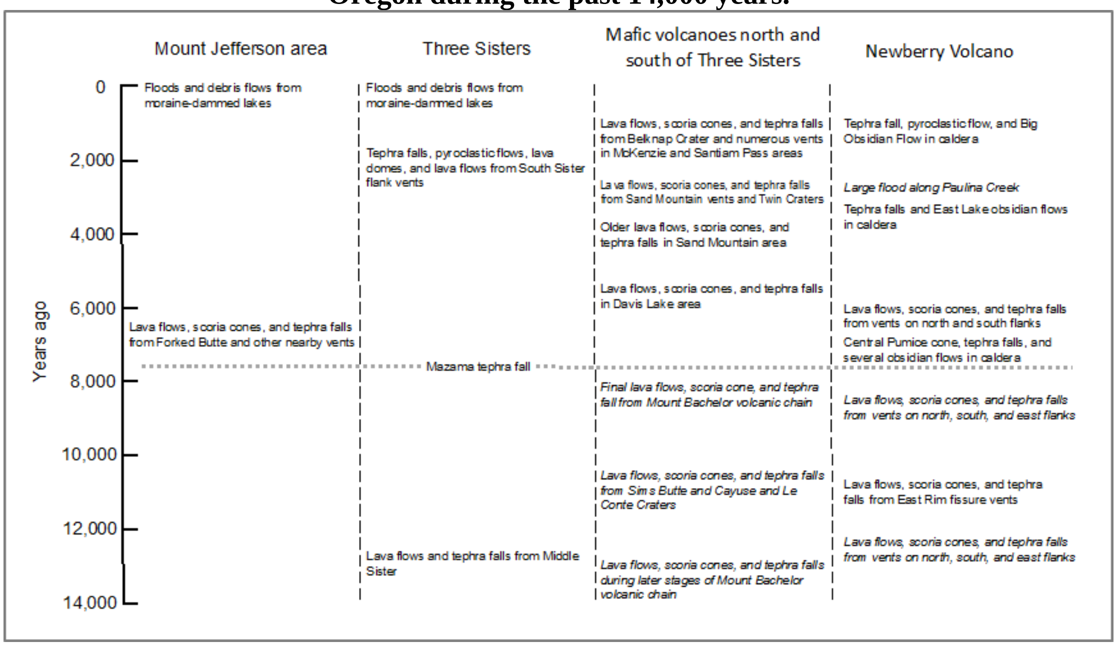
Figure II-11 Potentially Active Volcanoes of the Western United States

Source: USGS. http://www.volcano.si.edu/reports/usgs/maps.cfm#usa

Volcanoes in Central Oregon have been erupting for hundreds of thousands of years. Newberry Volcano, for example, has had many eruptions in the last 15,000 years as shown in the table below. The Three Sisters region has also had eruptions during this time, and the last major eruptive activity at Mt. Mazama occurred approximately 7,700 years ago, forming Crater Lake. Some of the most recent events include tephra and lava from the Big Obsidian Flow eruption at Newberry Volcano, multiple eruptions of tephra and lava from South Sister, and multiple cinder cone eruptions and lava flows in the McKenzie Pass area. All of the Cascade volcanoes are characterized by long periods of quiescence and intermittent activity. These characteristics make predictions, recurrence intervals, and probability of future eruptions very difficult to ascertain.

Much larger eruptions than those of the past few thousand years have occurred in the region in recent geologic time, but, although their hazards are potentially much more widespread and severe, they occur much less frequently than smaller eruptions. Such potential hazards include extensive lava flows from Newberry Volcano that pose a threat to Bend and Redmond, large-scale explosive eruptions of Newberry or the Three Sisters that deposit one foot or more of pumice and ash in developed areas; or eruptions in the Three Sisters region that swiftly melt significant quantities of snow and ice to generate lahars that affect areas such as Whychus Creek and the City of Sisters.

Figure II-12 Eruptive and major debris-flow and flood events in the central Cascades of Oregon during the past 14,000 years.



Source: Central Cascades Volcano Coordination Plan. The events printed in italics are poorly dated, so their ages are less well known than those in normal font. The Mazama tephra fall was produced by the cataclysmic eruption of Mount Mazama that created Crater Lake 7,700 years ago.

Active volcanic areas in the Cascades that have the most potential to impact Deschutes County and the broader region include Mt. Saint Helens, Mt. Hood, Newberry Volcano, Mt. Bachelor, the Three Sisters and Broken Top, and Mt. Mazama/Crater Lake.

Table II-6 Regional Volcanic History

Volcano	Comment
Mount Saint Helens	Mount St. Helens, located in southwestern Washington. It is fifty thousand years old. Over the past 521 years it has produced four major explosive eruptions and dozens of smaller eruptions. On May 18th, 1980, Mount St. Helens exploded violently after two months of intense earthquake activity and intermittent, relatively weak eruptions, causing the worst volcanic disaster in the recorded history of the United States. Mount St. Helens continued to be active, on March 8, 2005, a plume of ash and steam spewed nearly seven miles high into the air. Ten small earthquakes were measured in the area leading up to the eruption. The largest appeared to be a magnitude 2.5, according to the USGS.
Three Sisters & Broken Top	The Three Sisters are located just west of Bend. South Sister had a very small ongoing uplift, which began in 1996 and became undetectable by 2003. This uplift was about one inch a year and likely indicated movement of a small amount of magma. There is no immediate danger of a volcanic eruption or other hazardous activity. The potential exists, however, that further activity could increase danger.
Newberry Volcano	Newberry Volcano is located east of the Cascade Range and about 20 miles south of Bend. It is about 400,000 years old and has had thousands of eruptions both from the central vent area and along its flanks. The most recent eruption was 1,300 years ago. Future eruptions are likely to include lava flows, pyroclastic flows, lahars, and ashfall. Most effects from these activities would be felt within, or up to a few miles beyond, the existing caldera. Ash and lava flows could impact tens of miles from the eruptive center.
Mount Mazama/ Crater Lake	Crater Lake is located in the south-central region of Oregon. About 7,700 years ago, the ancient Mount Mazama erupted with great violence, leaving the caldera that Crater Lake now occupies. The most recent volcanic eruption was about 5,000 years ago and occurred within the caldera. No eruptions have occurred outside the caldera since 10,000 years ago. The probability of another caldera-forming eruption is very low, as is the probability of eruptions occurring outside the caldera.

Source: Oregon Natural Hazards Mitigation Plan (2012); 2018 Update to the U.S. Geological Survey National Volcanic Threat Assessment https://pubs.usgs.gov/sir/2018/5140/sir20185140.pdf

Mount St. Helens Case Study

On May 18, 1980, following two months of earthquakes, deformation of the volcano, and minor eruptions and following a century of dormancy, Mount St. Helens, Washington, exploded in one of the most devastating volcanic eruptions of the 20th century. Approximately 0.67 cubic miles of volume was removed from the volcano in a huge debris avalanche (lowering the mountain summit elevation by 1,314 feet), 57 people died, lahars damaged 27 bridges and nearly 200 homes, 4 billion board feet of timber was blown down, and damage exceeded 1.2 billion dollars.[13] Fortunately, most people in the area had been evacuated before the eruption because the U.S. Geological Survey (USGS) and other scientists had alerted public officials to the danger. As early as 1975, USGS researchers had warned that Mount St. Helens could soon erupt. Coming more than 60 years after the last major eruption in the Cascades (Lassen Peak, 1915), the explosion of St. Helens was a spectacular reminder that the millions of residents of the Pacific Northwest share the region with live volcanoes.[14]

Hazard Identification

Western Deschutes County is on the east slope of the Cascade Range. Volcanic activity in the Cascades will continue, but questions regarding how, to what extent, and when, remain. Many volcano-associated hazards affect local areas within 5 to 10 miles (e.g., explosions, lava flows, pyroclastic flows and debris avalanches). However, lahars, or volcanic mudflows can travel considerable distances down river valleys and wind-borne tephra (ash) can blanket areas many miles from the source.

Deschutes County is therefore at risk from volcanic events and should consider the impact of volcano-related activity on communities, dams that create reservoirs, tourist destinations (e.g., Sunriver, Mt. Bachelor, and Crater Lake), agriculture, public health, highways and railroads. Deschutes County should also consider probable impacts on the local economy should a volcano-related hazard occur.

Two long-lived volcanic centers, Three Sisters to the west and Newberry Volcano to the south, and many tens of smaller volcanoes have hosted numerous eruptions in geologically recent times that range widely in size and character. Some covered sizable, currently developed areas with lava flows or swiftly moving flows of searing ash and pumice. Others only managed to produce small volumes of ash that blew downwind and were barely detectable in the geologic record, or they produced lava flows in areas now protected as Wilderness. Similar eruptions will occur in the future and, depending on their location and scale, will have minor to catastrophic effects on the County. In fact, the Three Sisters and Newberry Volcano are ranked by the USGS as "very high threat" volcanoes and are among the top 20 most hazardous volcanoes in the U.S.[15] In addition, an eruption of any one of the major Cascade volcanoes could affect the county and the region with ashfall if the wind direction is favorable.

Geologic hazard maps have been created for most of the volcanoes in the Cascade Range by the USGS Volcano Hazards Program at the Cascade Volcano Observatory in Vancouver, WA and are available at http://vulcan.wr.usgs.gov/Publications/hazards_reports.html.

[13] Brantley, Steve and Bobbie Myers. Mount St. Helens – From the 1980 Eruption to 2000. USGS Fact Sheet 036-00 Online Version 1.0. http://pubs.usgs.gov/fs/2000/fs036-00/

[14] Dzurisin, Dan, Peter H. Stauffer, and James W. Hendley II, Living With Volcanic Risk in the Cascades, USGS Fact Sheet 165-97, (2000).

[15] 2018 Update to the U.S. Geological Survey National Volcanic Threat Assessment https://pubs.usgs.gov/sir/2018/5140/sir20185140.pdf

Figure II-13 Volcanic Hazards in Central Oregon

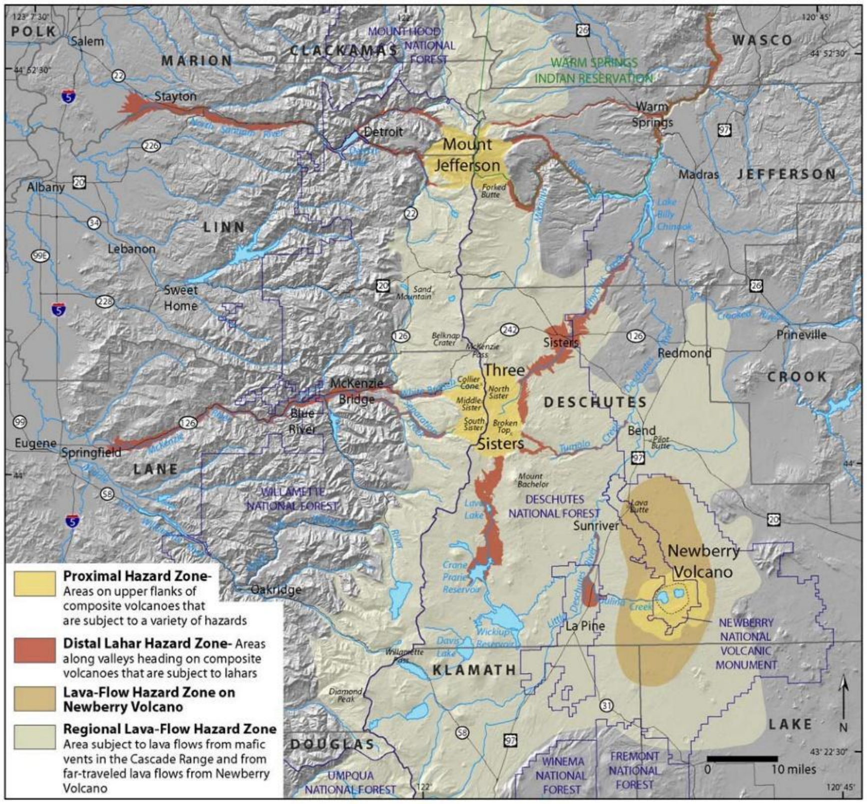


Figure 2. **Volcano hazards in central Oregon.** Hazard zones are modified from the USGS hazard assessments for Mount Jefferson, Three Sisters, and Newberry Volcano listed in references.

Source: Central Cascades Volcano Coordination Plan

Multiple hazards zones affect Deschutes County (Figure 2). Although the hazard map shows sharp boundaries for hazard zones, the degree of hazard does not change abruptly at these boundaries. Rather, the hazard decreases gradually as distance from the volcano increases, and decreases more rapidly as elevation above valley floors increases. Areas immediately beyond outer hazard zones should not be regarded as hazard free, because the boundaries can only be located approximately, especially in areas of low relief. Too many uncertainties exist about the source, size, and mobility of future events to locate the boundaries of zero-hazard zones precisely. Additionally, tephra (ash) hazard zones are not shown on the map, but tephra can impact large areas and the entire map region should be regarded as within the tephra hazard zone.

The **proximal hazard zone** includes areas immediately surrounding the volcanoes. This zone, which extends outward from summits for as little as 2 to as many as 10 kilometers (six miles) depending on local topography, is subject to several types of rapidly moving, devastating flows including pyroclastic flows, debris avalanches, lahars, and dam-break floods. Slower moving lava flows could also affect these zones.[16]

The **distal hazard zone** lies beyond the proximal hazard zone and is concentrated in the surrounding valleys that head on the volcanoes. Debris avalanches and lahars will tend to funnel

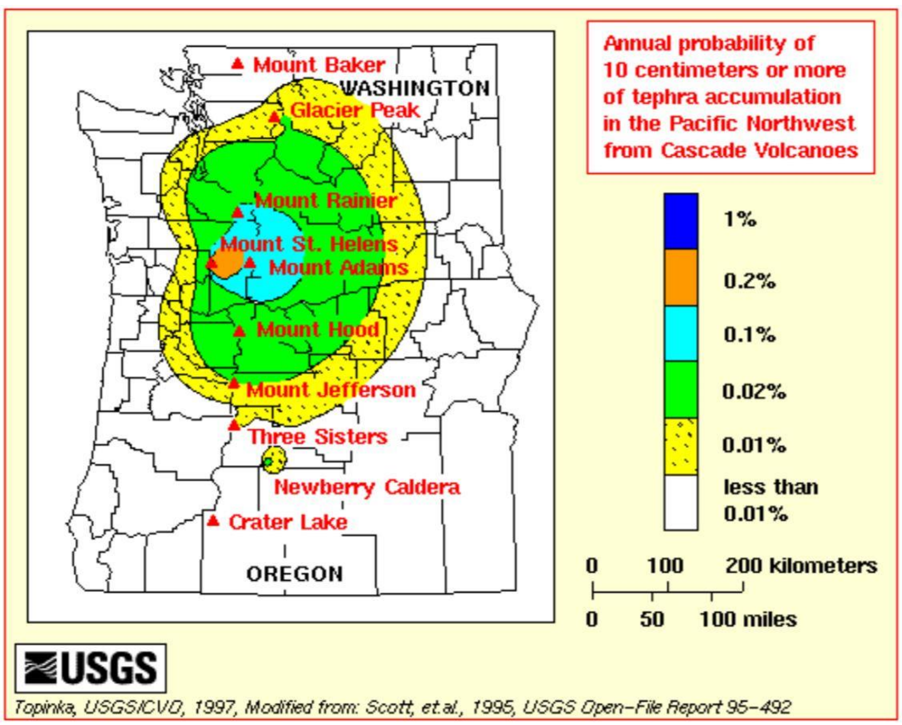
[16] Scott, W.E., Iverson, R.M., Schilling, S.P., and Fisher, B.J., 1999, Volcano hazards in the Three Sisters region, Oregon: U.S. Geological Survey Open-File Report 99-437.

into these valleys as they leave the slopes of the large volcanoes within the proximal hazard zone.

The **regional lava-flow hazard zone** outlines the area of the Three Sisters and Newberry Volcano region subject to lava flows from eruptions of mafic volcanoes. The zone is defined by the distribution of mafic volcanoes that erupted during roughly the past one million years. Hazards from thick tephra fall, ballistic projectiles, and small to medium pyroclastic flows would be restricted to within several kilometers of vents, but lava flows could travel much farther. The hazard zone covers a broad area in Central Oregon, including Bend, Sisters, and areas on the lower flanks of Newberry Volcano in La Pine.

Distributions of volcanic ash fall are affected by wind direction. Scientists also use wind direction to predict areas that might be affected by volcanic ash; during an eruption that emits ash, the ash fall deposition is controlled by the prevailing wind direction. The predominant wind pattern over the Cascades originates from the west, and previous eruptions seen in the geologic record have resulted in most ash fall drifting to the east of the volcanoes. Regional tephra fall shows the annual probability of ten centimeters or more of ash accumulation from Pacific Northwest volcanoes. Figure II-14 depicts the potential and geographical extent of volcanic ash fall in excess of ten centimeters from a large eruption of Mount St. Helens.

Figure II-14 Regional Tephra-fall Maps



Note: The following sections include information that has been modified from the Central Cascades Volcano Coordination Plan, Appendix B: Volcanic Hazards in the Central Cascades.

Three Sisters Volcanoes

Large snow-covered volcanoes of the Three Sisters volcanic center dominate Central Oregon's landscape between Santiam Pass in the north and Willamette Pass in the south. Rapidly developing areas in Deschutes County occupy the eastern border of the region, and westward several small communities dot the McKenzie River valley along its course to the Eugene-Springfield metropolitan area.[17]

The following photograph depicts an aerial view from southeast of the Three Sisters volcanic center (South, Middle, and North Sister left of center; Broken Top right of center). Light colored areas on the south flank of South Sister are 2,000-year-old lava flows.

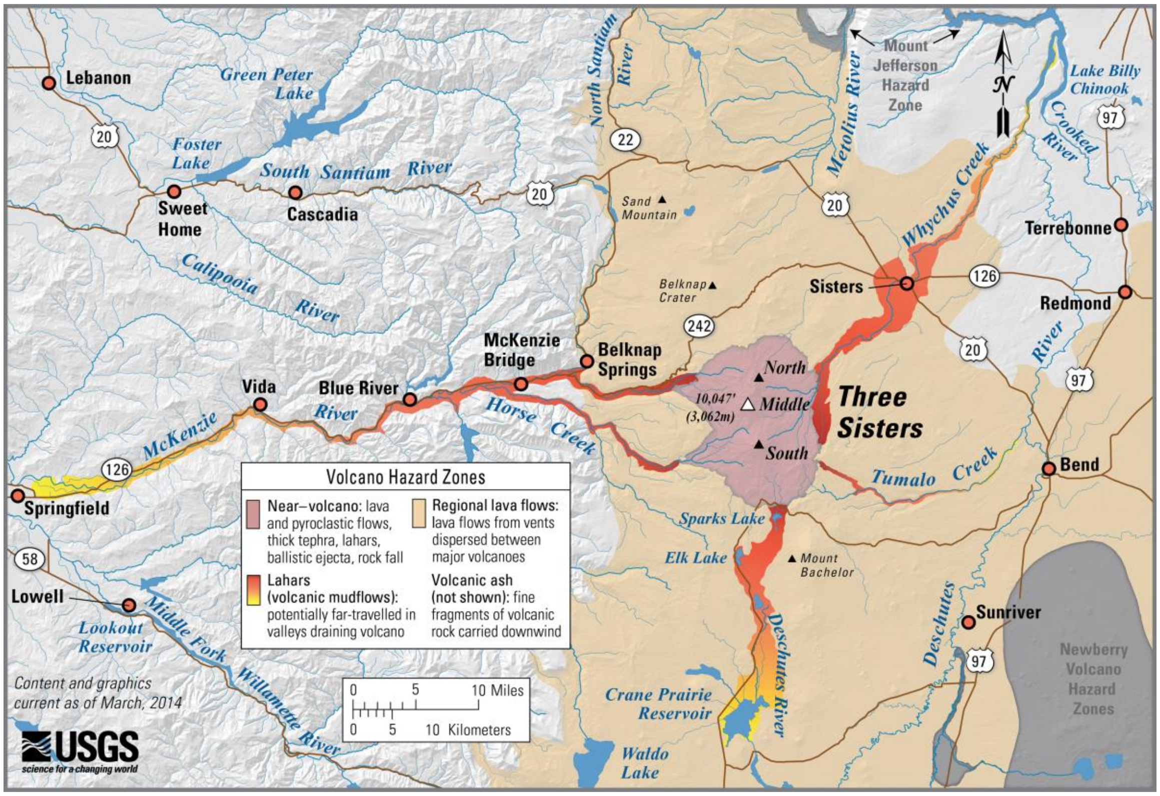
Figure II-15 Three Sisters and Broken Top

Photo by William E. Scott, USGS

Unlike other major Cascade volcanic centers, the Three Sisters center contains two young composite volcanoes, South Sister and Middle Sister, rather than one. The third sister, North Sister, and other nearby conspicuous volcanoes such as Mount Bachelor are large mafic volcanoes. Broken Top is a composite volcano that has not erupted for tens of thousands of years. Eruptions about 2,000 years ago from vents on South Sister produced blocky lava flows, such as Rock Mesa. These eruptions also produced a modest amount of pumice and ash that blanketed downwind areas. Probably no more than 1 or 2 centimeters (less than one inch) of ash fell in the area now occupied by Bend. Similar, but larger, eruptions occurred during the last ice age, which ended about 12,000 years ago, and had more widespread effects. Such eruptions occurred from both Middle Sister and South Sister. Three eruptions during the past one-half million years have been significantly larger and produced pyroclastic flows that swept over present-day Bend and Sisters. Fortunately such eruptions are rare—the last one occurred more than 200,000 years ago—and there is no sign that the Three Sisters system is capable of producing such an eruption during our lifetimes. The figure below demonstrates the volcanic hazards associated with the Three Sisters.

[17] Ibid.

Figure II-16 Volcanic Hazards of the Three Sisters



Source: Central Cascades Volcano Coordination Plan. Hazard zones are simplified from the USGS hazard assessment for the Three Sisters volcanic area. Tephra (ash) hazard zones are not shown, but tephra can impact large areas and the entire map region should be regarded as within the tephra hazard zone.

Owing to the prevailing westerly winds in central Oregon, areas east of the Three Sisters have the greatest probability of being affected by tephra falls from future eruptions. Eruptions that produce higher eruption clouds and greater volumes of tephra will affect progressively larger areas. Although seldom life threatening, ash fall can greatly disrupt life. Darkness and swirling clouds of ash limit visibility and affect transportation. Ash contributes to slippery conditions on wet roads. Ash is also electrically conductive, especially if wet, and abrasive, so it can severely affect electrical and mechanical systems. Ash is also extremely dangerous to aircraft in flight. Very fine ash fall can also affect those with respiratory challenges if inhaled.

Eruptions that disrupt watersheds by removing vegetation and adding large quantities of sediment from tephra fall, pyroclastic flows, debris avalanches, and lahars, typically initiate a period of years to decades during which streams carry increased sediment loads and channels become unstable and migrate. Such effects propagate downstream and can disrupt channels and floodplains far from where direct impacts of eruptions end. The Eugene-Springfield area along the lower McKenzie River and Sunriver and Bend along the Deschutes River below Wickiup Reservoir could be vulnerable to such events in the years following eruptions. Similarly the Tumalo Creek watershed that supplies part of Bend's municipal water, although not likely to be affected directly by volcanic flows, is likely to receive ash fall from any eruption in the Three Sisters area.

South, Middle, and North Sister as well as Broken Top are high, steep-sided peaks that could also produce debris flows and avalanches without volcanic activity. Avalanches of modest volume (less than about 10 million cubic meters) are the most probable and would affect areas primarily within the proximal hazard zone. Nevertheless, even modest-sized avalanches that contain sufficient water could transform into debris flows that travel well into distal hazard zones. Very large avalanches, those involving hundreds of millions of cubic meters of rock debris would likely be preceded by pronounced volcano deformation driven by intrusion of magma. Such activity would be detectable by seismometers and volcano surveys, and thus would elicit advance warning. Drainage systems that originate in the Three Sisters area are all potentially at risk from lahars, debris flows, floods, and avalanches. The location and size of these events will depend on the triggering mechanism and its character.

- Separation Creek and White Branch lead to several small communities in the McKenzie valley, including McKenzie Bridge and Blue River, which could be in the paths of lahars flowing westward. Large-volume lahars could reach communities farther west. Oregon Highway 126 and municipal water and hydroelectric facilities could be affected by lahars and excess sediment in the McKenzie River.
- The Sisters area represents the largest concentration of residents and development in a lahar-hazard zone. The city lies less than 30 kilometers (19 miles) downstream from Middle and South Sisters along Whychus Creek. Below Sisters, Whychus Creek flows into a deep canyon and joins the Deschutes River. Whychus Creek and its tributaries drain the east flanks of North, Middle, and South Sister and the north flank of Broken Top. The broad fan of Whychus Creek around Sisters is of particular concern with regard to potential lahar or debris flow inundation because Whychus Creek drains a large sector of the major volcanoes and the distance to Sisters is relatively short (about 30 kilometers or 20 miles). Typical flow velocities for lahars and debris flows through terrain along Whychus Creek yield travel times to Sisters of as little as 30 minutes to one hour, depending on lahar size and point of origin.
- Tumalo Creek drains the area east of Broken Top and is unlikely to experience large lahars owing to lack of much volcano mass in its headwaters. Nevertheless, small lahars or debris flows might descend Tumalo Creek if rapid sedimentation in Crater Creek diverted debris over a low divide into Tumalo Creek.
- Carver Lake, located 7,800 feet elevation on the east flank of South Sister in the Three Sisters Wilderness, is a glacial moraine-dammed lake. The lake formed when Prouty Glacier retreated from the terminal moraine circa 1930. Lake volume is estimated to be 740 acre-feet with a depth of more than 100 feet. Carver Lake is part of the headwaters of Whychus Creek which flows 20 miles to Sisters, Oregon. Historically, some moraine dams have failed causing a breach and flooding the channel. Failure of the moraine could come from an earthquake, volcanic eruption, or a large wave from the calving of the glacier. Recent two-dimensional (2-D) numerical modeling shows that a displacement and breaching of Carver Lake would produce a flood and debris flow downstream along Whychus Creek. The debris flow and flood were primarily confined to the Whychus Creek drainage for an approximately 15 km reach downstream of Carver Lake, where the creek is deeply incised for much of its path. Several kilometers upstream of the community of Sisters, Whychus Creek opens onto an alluvial fan with low relief and a system of (now dry) distributary channels. When the modeled flow reached this fan after about 1 hour, it immediately overtopped the low banks of the main branch of Whychus Creek, spreading into the distributary channels. The flow

continued to spread widely across the alluvial fan, eventually inundating Sisters. However, due to the spreading, the depth of the flow in the main channel was reduced significantly, presumably lessening the flood risk posed to the more densely populated area of Sisters adjacent to the main channel. These new results contrast with early 1-D simulations performed in the 1980's, which assumed that most of the flow was confined to the channel. These new results suggest that flow avulsion and diversion on the alluvial fan surrounding Sisters would lead to a less severe flood hazard to the community. The probability of Carver Lake moraine dam failing is low. This dam failed in October of 1966, generating a debris flow that traveled down the Soda Creek drainage, across Highway 46 (Cascade Lakes Highway), and spread out over the broad meadow near Sparks Lake. The debris flow buried the road and covered about 250,000 m^2 (about 2,700,000 ft^2) of the meadow with sand and silt.[18][19]

- Broad basins in the upper Deschutes valley, such as those occupied by Sparks, Elk, and Lava lakes, provide traps for lahars and sediment moving south, as do Wickiup and Crane Prairie Reservoirs.

Newberry Volcano

Overview—Newberry Volcano is among the largest and most voluminous of Cascade volcanoes. Although it is not of great height, it is very broad. Newberry lavas extend about 120 kilometers (75 miles) north to south and 43 kilometers (27 miles) east to west. The edifice covers more than 3,000 square kilometers (1,200 square miles), making it by area the largest volcano of the Cascades volcanic chain. Beyond the edifice, Newberry lava flows cover an additional 700 square kilometers (270 square miles), and reach about 25 kilometers (16 miles) north of Redmond. Hundreds of volcanic vents exist on the flanks of Newberry, many arranged in linear arrays, or rift zones, that extend far down the flanks. The youngest rift-zone eruption occurred about 7,000 years ago. At that time, a 32-kilometer long (20-mile long) fissure system opened extending northwest from the caldera. On this Northwest Rift Zone, lava fountains and small explosive eruptions created cinder cones, such as 150-meter high (500-foot high) Lava Butte, and wind spread blankets of cinders and ash downwind, often preceding lava flows. Lava flows from Lava Butte traveled more than 8 kilometers (5 miles) from the vent and temporarily dammed the Deschutes River.

Lava flows—Most of the City of Bend east of the Deschutes River is built on lava flows from Newberry Volcano. Potential future eruptions from rift zones on the north flank of Newberry represent the most credible lava-flow threat to a large settled area in the United States outside of Hawai'i. Lava flows advance relatively slowly compared to rapid flows such as lahars and pyroclastic flows, so they rarely threaten human life. But advancing lava flows ensure almost total destruction from burial and incineration. Lava flows can crush or bury structures, roads, railroads, power lines, gas lines, and other important infrastructure. They can also dam rivers and streams, causing floods and contamination of drinking water, and they can ignite fires. Once

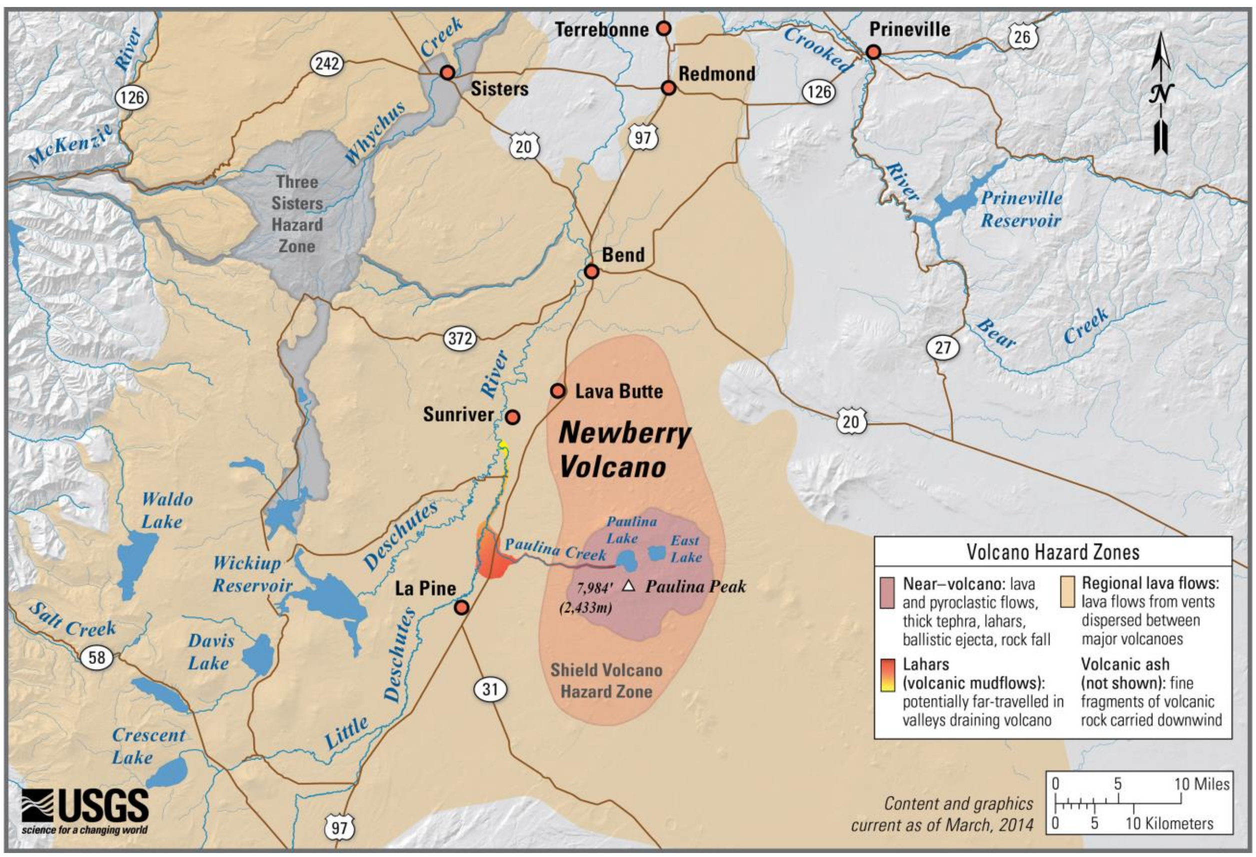
[18] O'Connor, J.E., J.H. Hardison and J.E. Costa. 2001. Debris flows from failures of Neoglacial-Age moraine dams in the Three Sisters and Mount Jefferson wilderness areas, Oregon. US Geological Survey Professional Paper 1606.
[19] Laenen, Antonius, Scott, K M., Costa, J. E., and Orzol, L. L., 1987, HYDROLOGIC HAZARDS ALONG SQUAW CREEK FROM A HYPOTHETICAL FAILURE OF THE GLACIAL MORAINE IMPOUNDING CARVER LAKE NEAR SISTERS, OREGON, Department of Interior, US Geological Survey, Open File Report 87-41

lava begins to flow from a vent, scientists are typically able to forecast which areas down slope are at greatest risk.

Explosive eruptions—Newberry has also produced notable explosive eruptions. Most of these originated from vents located in the broad depression, or caldera, that forms the summit of the volcano. The most recent eruption in the caldera occurred 1,300 years ago. It generated ash clouds that deposited tephra as far east as the Oregon-Idaho border, small pyroclastic flows, and lava of the Big Obsidian Flow. Larger events occurred in the more distant geologic past at Newberry, including some that transported tephra over broad areas of the western United States and sent pyroclastic flows down the volcano's flanks.

During potential future explosive eruptions, cinder cone eruptions on the volcano's flanks could generate modest amounts of tephra that would accumulate near the erupting vent. Explosive eruptions from Newberry caldera could send large amounts of ash several kilometers into the atmosphere where it could be blown by wind to populated regions and become a hazard to aviation. Close to the vents, the ash deposits could be several meters thick, but would typically thin quickly with distance from the vents.

Figure II-17 Volcanic Hazards of Newberry Volcano



Source: Central Cascades Volcano Coordination Plan. Hazard zones are simplified from the USGS hazard assessment for the Three Sisters volcanic area. Tephra (ash) hazard zones are not shown, but tephra can impact large areas and the entire map region should be regarded as within the tephra hazard zone.

Volcanic gases—The presence of the summit caldera and closed basins within it create conditions favorable for accumulation of heavier-than-air volcanic gases, notably carbon dioxide, which could lead to dangerous conditions if increased emission of gas occurs during volcanic unrest or an eruption. Heavier-than-air gases could result in asphyxiation for anyone within the caldera. Other gases released by volcanic activity—such as SO_2 and H_2S—can also produce hazardous air quality in proximal areas.

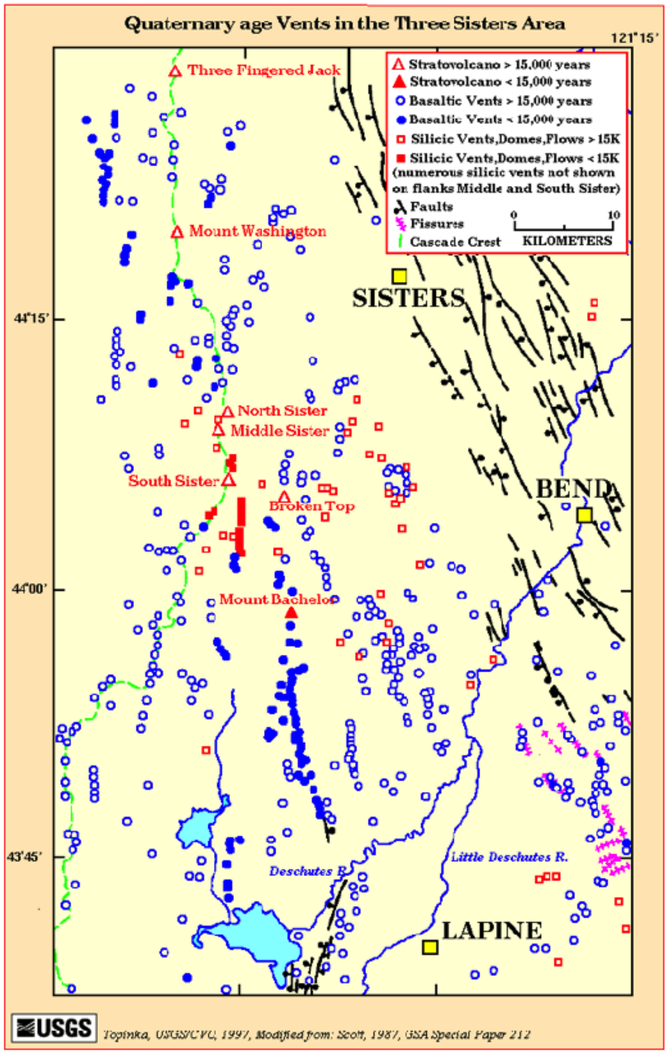
Geothermal—Several lines of evidence indicate that an active magma system exists beneath Newberry Volcano. Currently, both lakes within the caldera, Paulina and East Lake, contain hot springs with temperatures as high as 135 degrees F. A USGS drill hole made in 1981 found temperatures higher than 500-degrees at a depth of 3,000 feet. Several areas on the flanks of Newberry Volcano are being explored as potential sources for geothermal energy. High temperatures encountered now by hot spring users, and by geothermal drillers could become elevated during volcanic reawakening. Additionally, if a volcanic vent opened beneath the caldera lakes or through groundwater, the eruption would almost certainly be highly explosive and would deposit wet, muddy tephra over the immediate area.

Hydrologic hazards—As has happened in the past, rapid release of water from Paulina Lake or from rapid snowmelt could produce lahars, debris flows, or floods that descend Paulina Creek and inundate the Paulina Prairie area north of La Pine.

Fields of Mafic Volcanoes

Hundreds of geologically young volcanoes composed of cinders, ash, and lava flows dot the Central Oregon landscape among the major volcanic centers. Many, such as Collier Cone on the north flank of North Sister, occur on or near larger composite volcanoes; others occur many miles from larger volcanoes. Some of these, such as the Pilot Butte cinder cone in Bend, occur within densely populated areas. Some of these volcanoes are cinder cones (e.g. Collier Cone, Pilot Butte, Lava Butte); others, such as Mount Bachelor, are large shield volcanoes that stand more than 1,000 meters (3,300 feet) above their bases and can be more than 10 kilometers (6 miles) wide. The figure below shows how common these vents are in the Central Oregon landscape.

Figure II-18 Geologically Young Vents in the Three Sisters Area



Source: USGS. Blue circles show fields of mafic vents scattered throughout the Central Oregon Cascades. Solid circles indicate vents younger than 15,000 years, open circles indicate vents older than 15,000 years.

There are many young mafic volcanoes in the region, including Belknap Crater north of McKenzie Pass and Blue Lake Crater, which were active about 1,300 years ago. Geologic evidence suggests that the eruptions forming mafic volcanoes may have lasted for centuries in the case of the largest cones, to weeks to months for smaller ones. In some cases, vents in linear chains more than 10 kilometers (6 miles) were erupting concurrently, or nearly so. Since the last ice age waned, about 12,000 years ago, vents of mafic volcanoes have been concentrated in a narrow zone about 80 kilometers (50 miles) long, extending from south of Mount Bachelor to north of Santiam Junction. A few scattered vents in the area between Davis Lake and Oregon Highway 58 and a few south of Mount Jefferson were also active during this time period.

Future eruptions of mafic volcanoes are possible anywhere in the broad central Cascades region, although eruptions are probably more likely to occur in the greater Three Sisters area and on the flanks of Newberry Volcano, judging from the volcanic history of the past 14,000 years. Tephra from eruptions of mafic volcanoes will affect areas chiefly east of the Cascade crest.

Tephra falls from ongoing eruptions of mafic volcanoes could last months to years, or even longer, would be a chronic nuisance in Deschutes County. Once an eruption begins, the ultimate extent of lava flows will depend on vent location, local topography, and the total volume and rate of lava erupted, but scientists will be able to make forecasts about areas at greatest risk. Future lava-flow eruptions in the central Cascades are more likely to occur away from populated areas and are more likely to impact forests and stream channels, but could also impact major highways and power-line corridors.

Probability Assessment

The annual probability of volcanic activity in or affecting Deschutes County can only be estimated with great uncertainty, but, depending on the type of eruption, ranges from roughly 1 in 1,000 to 1 in 10,000. However, as precursors of volcanic unrest begin the probability of eruption increases greatly. The precursors might include increased seismic activity, temperature and chemical changes in groundwater, ground deformation and release of volcanic gases.

The average annual probability of future mafic eruptions is roughly 1 in 1,500. Because most recent activity has been concentrated in the area between the North Sister and Santiam Pass, future activity is probably more likely there than in other parts of the lava flow hazard zone to the south and east, which includes most of the settled areas in the region. Furthermore, because only a relatively small part of the entire lava flow hazard zone is affected during one eruptive episode, the annual probability of any given point in the hazard zone being affected is considerably less than the average annual probability of 1 in 1,500. The US Geological Survey estimates the range of annual probabilities falls between 1 in 10,000, for some areas near the Cascade Crest around Three Sisters and on the upper flanks of Newberry Volcano, to 1 in 1,000,000 elsewhere. Because ashfall from such eruptions covers much larger areas than lava flows, the probability of ashfall affecting an area is greater.

When a volcano erupts here again, areas close to the erupting vent will be severely affected. For the main Cascades peaks, a proximal hazard zone roughly 20 kilometers (12 miles) in diameter surrounding the volcano could be affected within minutes of the onset of eruption or large landslide. Distal hazard zones that follow river valleys downstream could be inundated by lahars or debris flows generated either by melting of snow and ice during eruption or by large landslides.[20]

On the basis of no prior events in the past 10,000 years, it is estimated that a lahar voluminous enough to inundate the largest of the distal hazard zones in any valley has an annual probability of less than 1 in 10,000. A lahar voluminous enough to inundate the smallest of the distal hazard zones in any valley has a greater annual probability, perhaps from 1 in 1,000 to 1 in 10,000. Still smaller lahars or debris flows that result from phenomena such as moraine-dam failures are much more likely to occur (annual probability greater than 1 in 100 in potentially affected valleys), but are apt to inundate only parts of the smallest distal hazard zones immediately adjacent to streams.

Major drainage systems that head in the Three Sisters area (Separation Creek, White Branch, Whychus Creek, and Tumalo Creek) are all potentially at risk from lahars during future

[20] Ibid.

eruptions, or from debris flows and floods. The location and size of these events will depend on the site of the triggering mechanism and its character.

At least four times in the past 700,000 years, explosive eruptions that were probably sited east of the present location of Broken Top and the Three Sisters produced pyroclastic flows that swept over a broad area from Sisters to south of Bend. Such an event today would be catastrophic for Deschutes County, but fortunately, events of this magnitude are infrequent. Furthermore, there is no evidence that the large volume of magma necessary to drive such an eruption is present in the Three Sisters region today, nor would such a volume likely be generated in the near future.[21]

The annual probability of explosive eruptions at Newberry Volcano affecting the caldera and immediately adjacent areas is about 1 in 3,000 (four eruptive periods, one basaltic and three rhyolitic, in 12,000 years). The probability of such an eruption occurring in a 30-year period, the duration of many home mortgages or a human generation, is roughly 30 times the annual probability or 1 in 100.

The valley of Paulina Creek, which drains from Paulina Lake through the west rim of Newberry Caldera, is the most likely drainage on Newberry to carry damaging lahars and floods. In addition to lahars and floods caused by pyroclastic flows melting snow, a lahar could be generated along Paulina Creek by catastrophic lake overflow. Pyroclastic flows entering the lake or explosive eruptions in the lake itself could displace water into the Paulina Creek drainage. Lahars or floods from Paulina Lake could reach the La Pine valley within 30 minutes.[22]

Where Paulina Creek leaves the confines of its canyon, it diminishes in gradient and forms a broad alluvial fan. Lahars could spread across Paulina Prairie and extend north along the floodplain of Paulina Creek to its confluence with the Little Deschutes River. The 100-year floodplain of the Little Deschutes River downstream from Paulina Creek is also included in the hazard zone for lahars and flooding in the event of volcanically induced surges of water from Paulina Lake.

The U.S. Geological Survey defines two lava flow hazard zones for Newberry on the basis of likelihood of future lava flows within each zone. Lava flow hazard zone LA encompasses the area more likely to be the site of flank vents or to be covered by lava, including the caldera. Zone LB includes two main areas: (1) areas on the lower flanks of Newberry that have relatively few flank vents and are chiefly covered by large lava flows from vents farther upslope and (2) lava flows from vents elsewhere in the Cascade Range or Basin and Range.

The outer boundary of lava flow hazard zone LA is determined by encircling the part of the volcano with greatest density of vents as determined by geologic mapping. As shown on the hazard map, the outline of zone LA broadly defines the elongate shape of Newberry Volcano itself, consistent with the idea that the volcano has grown by the repeated eruption of lava from vents preferentially located on the north and south flanks and in the summit region. The probability that a flank eruption will affect a given area in zone LA can be estimated only approximately because the frequency of such eruptions prior to the last ones about 7,000 years

[21] Central Cascades Volcano Coordination Plan, 2007.
[22] Scott, W.E., Iverson, R.M., Schilling, S.P., and Fisher, B.J., 1999, Volcano hazards in the Three Sisters region, Oregon: U.S. Geological Survey Open-File Report 99-437.

ago are poorly known. The U.S. Geological Survey infers that the annual probability of a flank eruption occurring in zone LA is roughly 1 in 5,000 to 1 in 10,000.

Lava flow hazard zone LB encompasses the entire hazard map area beyond zone LA. Zone LB includes areas on the lower flanks and down slope from Newberry Volcano and elsewhere in the region that have been affected by lava flows less frequently than areas in zone LA. The U.S. Geological Survey estimates that the annual probability of an eruption in this zone or of lava flows invading this zone from vents in zone LA is roughly 1 in 100,000, or less, on the basis of the frequency of lava flow coverage in the past one million years and the few, widely scattered vents in the region.

Deschutes County's Natural Hazards Mitigation Steering Committee believes that the County's **probability of experiencing a volcanic event is "low,"** meaning one incident is likely within the next 75 – 100 year period (or longer). Based upon available information the Oregon NHMPs Regional Risk Assessment rates Deschutes County's probability of a volcano event as "moderate".[23]

Vulnerability Assessment

All of the Pacific Northwest is vulnerable to impacts from volcanic activity. Like the rest of Central Oregon, Deschutes County has some risk of being impacted by volcanic activity in the Cascade Range. Figure II-13 shows the identified hazard zones for volcanic activity.

The Deschutes County Natural Hazards Steering Committee rated Deschutes County as having a **"high" vulnerability to volcanic hazards**; meaning more than 10% of the region's population or assets would be affected by a major emergency or disaster. Based upon available information the Oregon NHMPs Regional Risk Assessment rates Deschutes County's vulnerability to a volcano event as "moderate".[24] However, the communities of Bend, La Pine, and Sisters may be at greater risk since they are located closer to the main volcanoes and are more at risk for inundation by lava and pyroclastic flows, lahars and debris flows, or ash fall.

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I) shows the county's Hazard Analysis Matrix which scores each hazard and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **volcano hazard is rated #5, out of 9 rated hazards, with a total score of 173**.

Community Hazard Issues

Volcanic eruptions can send ash airborne, spreading the ash for hundreds or even thousands of miles. An erupting volcano can also trigger lahars, debris flows, floods, earthquakes, rockfalls,

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[23] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2020.
[24] Ibid.

and avalanches. Volcanic ash can cause respiratory problems, electrical storms, agricultural damage, roof collapse, and can contaminate water supplies and severely disrupt transportation.[25] Lava flows can crush or bury everything in their path, including structures, roads, railroads, power lines, gas lines, and other important infrastructure; lava flows can also dam rivers and streams, causing floods and contamination of drinking water, and they can ignite fires.

Businesses and individuals can make plans to respond to volcano emergencies. Planning is prudent because once an emergency begins, public resources can often be overwhelmed, and citizens may need to provide for themselves and make informed decisions. Knowledge of volcano hazards can help citizens make a plan of action based on the relative safety of areas around home, school, and work.[26]

Building and Infrastructure Damage

Ashfall of 0.4 inches is capable of creating serious although temporary disruptions of transportation, operations, sewage disposal and water systems. The history associated with the Mount St. Helens eruption in 1980 resulted in closed highways, airports and other transportation systems for several days to, in some cases, weeks.

Ash can cause substantial problems for internal-combustion engines and other mechanical and electrical equipment. Additionally, it can contaminate filters, oil systems and scratch surfaces. Fine ash can cause short circuits in electrical transformers, which in turn cause power outages. Specifically in Deschutes County, ash can cause problems for the hi-tech manufacturing industry represented here.

The potential losses in Deschutes County extend beyond those to human life, homes, property and the landscape. Lahars and flooding, resulting from eruptions that melt snow and ice can result in severe damage to roads, bridges, pipelines and buildings. Highway 20 in Sisters, gas pipelines and high-capacity power lines on the flanks of Newberry Volcano are especially vulnerable.

Local business economies are at substantial risk if fallout from a volcanic event necessitates the closure of any of the major transportation routes in Deschutes County. The estimated loss per day is $3.5 million.[27]

Pollution and Visibility

Ash and tephra fallout from an eruption column can blanket areas within a few miles of the vent with a thick layer of pumice and ash. High altitude winds may carry finer ash from tens to hundreds of miles from the volcano, affecting downwind communities and posing a hazard to aircraft. Fine ash in water supplies will cause brief muddiness and chemical contamination. Ash suspended in the atmosphere is especially a concern for airports, where aircraft machinery

[25] Dzurisin, Dan, Peter H. Stauffer, and James W. Hendley II, Living With Volcanic Risk in the Cascades, USGS Fact Sheet 165-97, (2000).
[26] Scott, W.E. et al, Volcano Hazards in the Three Sisters Region, Oregon, USGS Open-File Report 99-437, (2001).
[27] Stutler, J. Informal survey during B & B Complex Fire, 2003.

could be damaged or clogged. Additionally, ashfall decreases visibility and disrupts daily activities.

Economic Impacts

Volcanic eruptions can disrupt the normal flow of commerce and daily human activity without causing severe physical harm or damage. Ash a few millimeters thick can halt traffic, possibly up to one week, and cause rapid wear of machinery, clog air filters, block drains and water intakes, kill or damage agriculture and severely impact tourism and the economy of the region. The interconnectedness of the region's economy can be disturbed after a volcanic eruption.

Losses to agriculture depend greatly on the crop type and the time in the growing season when ashfall occurs. Cook et al. (1981)[28] for example found that flat-leaved crops such as alfalfa suffered greater damage than vertical-stalk plants such as wheat due to the accumulation of ash on their leaves. Ash could not be easily washed off ripe raspberries, resulting in serious crop losses as eruptions occurred near harvest time.

Infrastructure can be impacted, particularly in Sisters which is particularly vulnerable to lahars and flooding. Transportation of goods between Deschutes County and nearby communities and trade centers could be deterred or halted. Subsequent airport closures can disrupt airline schedules for travelers. Fine ash can cause short circuits in electrical transformers, which in turn cause electrical blackouts. Volcanic activity can also force nearby recreation areas to close for safety precautions long before the activity ever culminates into an eruption. The interconnectedness of the region's economy would be disturbed after a volcanic eruption due to the interference of tephra fallout with transportation facilities such as the regional highways.

Death and Injury

Inhalation of volcanic ash can cause respiratory discomfort, damage or result in death for sensitive individuals miles away from the volcano. Likewise, emitted volcanic gases such as fluorine and sulfur dioxide can kill vegetation for livestock or cause a burning discomfort in the lungs. Hazards to human life from debris flows are burial or impact by boulders and other debris.

More information on this hazard can be found in the Regional Risk Assessment for Region 6 of the Oregon NHMP.

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

[28] Cook RJ, Barron JC, Papendick RI, Williams GJ (1981) Impact on Agriculture of the Mount St. Helens Eruptions. Science 211(4477):16-22

State

Central Cascades Volcano Coordination Plan, 2019

The purpose of this plan is to coordinate the actions that various agencies must take to minimize the loss of life and damage to property before, during, and after hazardous geologic events at Central Cascades volcanoes. The most current version of the Plan was completed in July 2019 and can be found here: https://digital.osl.state.or.us/islandora/object/osl:857164

State Natural Hazard Risk Assessment

The state risk assessment chapter on volcanic events provides a useful overview of volcanic risks in Oregon and documents historic volcanic activity. It also recommends a multi-hazard approach, given the uncertainty of most of Oregon being impacted by volcanic hazards in the foreseeable future.

A major existing strategy to address volcanic hazards is to publicize and distribute volcanic hazard maps through DOGAMI and USGS. The volcanoes most likely to constitute a hazard to Oregon communities have been the subject of USGS research. Open-file reports (OFR) address the geologic history of these volcanoes and lesser-known volcanoes in their immediate vicinity. These reports also cover associated hazards and possible mitigation strategies. They are available for volcanoes near Deschutes County including: Mount Saint Helens, Three Sisters, Newberry Volcano, and Crater Lake.

Federal

Volcano Monitoring

USGS and Pacific Northwest Seismic Network at the University of Washington conduct seismic monitoring of major Cascade volcanoes in Washington and Oregon. The USGS serves as the primary dissemination agency for emergency information. As activity changes, USGS scientists provide update advisories and meet with local, state, and federal officials to discuss the hazards and appropriate levels of emergency response.[29]

Techniques for monitoring active or potentially active volcanoes focus on three areas—earthquakes (seismicity), ground deformation, and volcanic gases. Magma intruding a volcanic system breaks rock and causes slippage on faults, thereby creating earthquakes; it adds material at depth and heats and pressurizes ground water, thereby bowing up the ground surface; and it releases volcanic gases, mainly water vapor, carbon dioxide, and sulfur dioxide. Heat and volcanic gases from magma warm and add telltale chemicals to the ground water, which affects the composition of spring water throughout the area.

Some monitoring occurs in real-time or near real-time as data are telemetered from field sites to base stations; other monitoring is done on a periodic basis and requires visits to the field or gathering data from satellites.

[29] Central Cascades Volcano Coordination Plan, 2007.

Earthquakes in central Oregon are detected and located in real-time by the Pacific Northwest Seismic Network (PNSN) at the University of Washington, a cooperative undertaking of the university, USGS, and University of Oregon. Compared to areas that have frequent earthquakes, the station spacing in central Oregon is relatively large, so only earthquakes greater than magnitude (M) 1 or 2 are able to be located routinely. A small network of seismic stations (10) are operated in and around the Three Sisters area. Several of these stations were added after an ongoing uplift was recognized in 2001. The magnitude threshold for locatable earthquakes has now been reduced to about M 0.5 to 1, if all stations are operating. Nine seismometers on or near Newberry Volcano and a couple more at somewhat greater distance have significantly reduced the magnitude threshold for location of earthquakes on Newberry. In addition, a cache of instruments at USGS Cascades Volcano Observatory is available to rapidly augment the existing networks should conditions warrant.

Continuous Global Positioning System (CGPS) receivers are able to track ground deformation in real time for a single point on Earth's surface. At present CGPS receivers at Redmond, Mount Bachelor, and two near South Sister operate in real time. Such a sparse network is of limited use in understanding the complex nature of ground deformation in a volcanic environment. Eight CGPS receivers were installed at Newberry Volcano, along with seismometers, in 2011. This network significantly improved monitoring capabilities at Newberry.

Broader regional coverage is afforded by periodic USGS surveys (typically annual or every few years; more often if conditions warrant) of an array of benchmarks in the Three Sisters and Newberry areas by temporary deployment of GPS instruments. Both areas also have a system of precisely surveyed lines along roads or trails that are used for tilt leveling, a procedure that is capable of measuring slight crustal movements. Another technique called InSAR uses satellite radar data to detect crustal movements over broad areas.

USGS scientists measure output of volcanic gases by airborne surveys. Flights to central Oregon volcanoes are made every few years in order to develop baseline information; additional flights occur as conditions warrant. During times of increased concern, flights could occur as often as atmospheric conditions allow. Annual sampling and chemical and isotopic analysis of spring water from the area permit a broad regional view of how magmatic intrusion is affecting the chemical composition of shallow ground water.

By combining the results of these and other techniques and an understanding of a volcano's past behavior, the goal of volcano monitoring is to issue forecasts as accurately as possible about the state of a volcanic system and the probability for the onset of potentially hazardous conditions. Once an eruption has begun, monitoring information is used to forecast the character and expected outcome of the eruption, as well as its end.[30]

Emergency Coordination

During times of volcanic crisis, USGS scientists will monitor events closely and, together with PNSN and the Oregon Department of Geology and Mineral Industries, issue information statements, alert warnings, updates, and briefings as necessary to keep public officials, the media, and the public aware of potential hazards and other pertinent information. The USGS

[30] USGS-Volcano Hazards Program, http://volcanoes.usgs.gov/observatories/cvo/

and the National Weather Service will work together to provide warnings about lahars, floods, and downwind ash-fall hazards.

Currently, agencies require information on hazards that affect nearby areas much like airlines and the Federal Aviation Administration require information on tephra plumes that can be hazardous to aircraft hundreds of miles from the source. The information required by these two groups is not always the same, and therefore the USGS in cooperation with various agencies, has developed two hierarchies of alert levels; one directed toward emergency response on the ground and the other towards ash hazards to aircraft.

The USGS issues statements of ground-based hazards which are transmitted as appropriate to state and federal agencies including FEMA and the National Weather Service. The counties receive information from Oregon Emergency Management then transmit the notifications as appropriate to local emergency management networks.[31]

Warning Systems

The best warning of a volcanic eruption is one that specifies when and where an eruption is most likely to occur and what type and size eruption should be expected. Such accurate predictions are sometimes possible but still warrant further research. The most accurate warnings are those in which scientists indicate an eruption is probably hours to days away based on significant changes in a volcano's earthquake activity, ground deformation and gas emission. Experience from around the world has shown that most eruptions are preceded by such changes over a period of days to weeks.

A volcano may begin to show signs of unrest several months to a few years before an eruption. In these cases a warning that specifies when it might erupt months to years ahead of time are extremely rare. The strategy that the USGS uses to provide volcano warnings in the Cascade Range volcanoes in Washington and Oregon involves a series of alert levels that correspond generally to increasing levels of volcanic activity. As a volcano becomes increasingly active or as incoming data suggest that a given level of unrest is likely to lead to a significant eruption, the USGS declares a corresponding higher alert level. This alert level ranking thus offers the public and civil authorities a framework they can use to gauge and coordinate their response to a developing volcano emergency.

Education and Outreach

General information on volcano hazards may be found on the USGS Volcano Hazards website: http://volcanoes.usgs.gov.

USGS Open File Reports describe the geographic extent of impacts from volcanic activity originating in the Cascades and can be found on the USGS Cascades Volcano Observatory website: http://volcanoes.usgs.gov/observatories/cvo/. Teaching resources can be found on the USGS Cascades Volcano Observatory website: https://www.usgs.gov/observatories/cascades-volcano-observatory/teaching-resources

[31] Scott, W.E. et al, Volcano Hazards in the Three Sisters Region, Oregon, USGS Open-File Report 99-437, (2001).

Hazard Mitigation Action Items

There is one identified Volcano action item for Deschutes County; in addition, several of the Multi-Hazard action items affect the Volcano hazard. An action item matrix is provided within Volume I, Section 3, while action item forms are provided within Volume IV, Appendix A. To view city actions see the appropriate city addendum within Volume III.

Significant changes since the 2015 Plan

Significant changes to this section include additional information on the 2020 Oregon wildfires. Several tables, figures, and maps were updated as well as the history of wildfires, population growth, and a new fire district in Alfalfa was added. Information on CWPPs was updated and risk information replaced with data from the Oregon Wildfire Risk Explorer (OWRE) where available. Information on air quality and smoke impacts was added.

Causes and Characteristics of the Hazard

Wildfire is a natural and necessary component of ecosystems across the country. Central Oregon is no exception. Historically, wildland fires have shaped the forests and wildlands valued by residents and visitors. These landscapes however, are now significantly altered due to fire prevention efforts, modern suppression activities and a general lack of large-scale treatments, resulting in overgrown forests with dense fuels that burn more intensely than in the past. In addition, the recent explosion in population has led to increased residential development into forested land, in the wildland urban interface (WUI). Assessment of wildfire vulnerability and the identification of mitigation actions is largely dealt with at the community level through each of the County's Community Wildfire Protection Plans; further information on the CWPPs is provided below beginning on page II-80.

The impact on communities from wildfire can be huge. In 1990, Bend's Awbrey Hall Fire destroyed 21 homes, caused $9 million in damage and cost more than $2 million to suppress. The 1996 Skeleton fire in Bend burned over 17,000 acres and damaged or destroyed 30 homes and structures. Statewide that same year, 218,000 acres burned, 600 homes were threatened and 44 homes were lost. These wildfire events provided an impetus for addressing wildland urban interface development and hazardous fuel mitigation statewide.

As development continues in the wildland urban interface, increasing numbers of residents are at risk from wildland fires. The Labor Day fires of 2020 in Western and Southwestern Oregon demonstrated the significant risks many of our community's face. High winds fanned existing fires and caused additional fires throughout Oregon. Eleven lives were lost, over 4000 homes destroyed and a million acres of Oregon burned during the fires. 38% of the homes destroyed were within urbanized cities and demonstrate the risk posed to communities that do not meet the traditional definition of Wildland Urban Interface and quickly turn into an urban conflagration. Current building codes in Deschutes County, and most of Oregon, do not require homes to be built to wildfire resistant standards. This results in homes becoming fuel for wildfires in the wildland urban interface.

Wildfire can be divided into three categories: wildland, interface and urban conflagration. Any of these fires can occur in Deschutes County. Deschutes County experiences interface fires each summer that prompts at least one neighborhood evacuation.

Wildland Fires

A wildland fire's main fuel source is natural vegetation. Often referred to as forest or rangeland fires, these fires occur in national forests and parks, private timberland, and on public and private rangeland. A wildland fire can become an interface fire if it encroaches on developed areas.

Interface Fires

Essentially, an interface fire occurs where wildland and developed areas meet. In these locations, both vegetation and structural development combine to provide fuel. The wildland/urban interface (sometimes called rural interface in small communities or outlying areas) can be divided into three categories.

1. The classic wildland/urban interface exists where well-defined urban and suburban development presses up against open expanses of wildland areas.
2. The mixed wildland/urban interface is more typical of the problems in areas of exurban or rural development: isolated homes, subdivisions, resorts and small communities situated in predominantly wildland settings.
3. The occluded wildland/urban interface where islands of wildland vegetation exist within a largely urbanized area.

Urban Conflagration

Urban conflagrations are a result of fires spreading from wildland fuels into developed areas and moving from structure to structure. These fires burn from structure to structure independent of wildland fuels and are resistant to control.

Structures burn with such extreme intensity that effective suppression is virtually impossible. Wildland fuels are generally not the leading factor of urban conflagration fires. The 2020 Almeda Fire burned through the cities of Talent and Phoenix, Oregon burning 2,800 home in just 3,600 acres is an example of an interface fire that developed into an urban conflagration.

Conditions Contributing to Wildfires

Ignition of a wildfire may occur naturally from lightning or from human causes such as debris burns, arson, smoking, and recreational activities or from an industrial accident. Once started, three main conditions affect the fire's behavior: fuel, topography and weather.

Fuel is the material that feeds a fire. Fuel is classified by volume and type. As a western state, Oregon is prone to wildfires due to its prevalent conifer, brush and rangeland fuel types.

Topography influences the movement of air and directs a fire's course. Slope is a key factor in fire behavior. Unfortunately, hillsides with steep topographic characteristics are also desirable areas for residential development.

Weather is the most variable factor affecting wildfire behavior. High risk areas in Oregon share a hot, dry season in the summer months and early fall with high temperatures and low humidity.

The increase in residential development in interface areas has resulted in greater wildfire risk due to increased values at risk and human activities in our forests. Typically, it is the embers/fire brands that ignite homes rather than the flaming front; as such, defensible space and fire-resistant building materials are often the best mitigation strategies. New residents in remote locations are often surprised to learn that in moving away from built-up urban areas, they have also left behind readily available fire services providing structural protection.

History of Wildfires in Deschutes County

Table II-7 lists the significant large wildland fires in Deschutes County over the last three decades. These fires required a substantial emergency management response from firefighting resources.

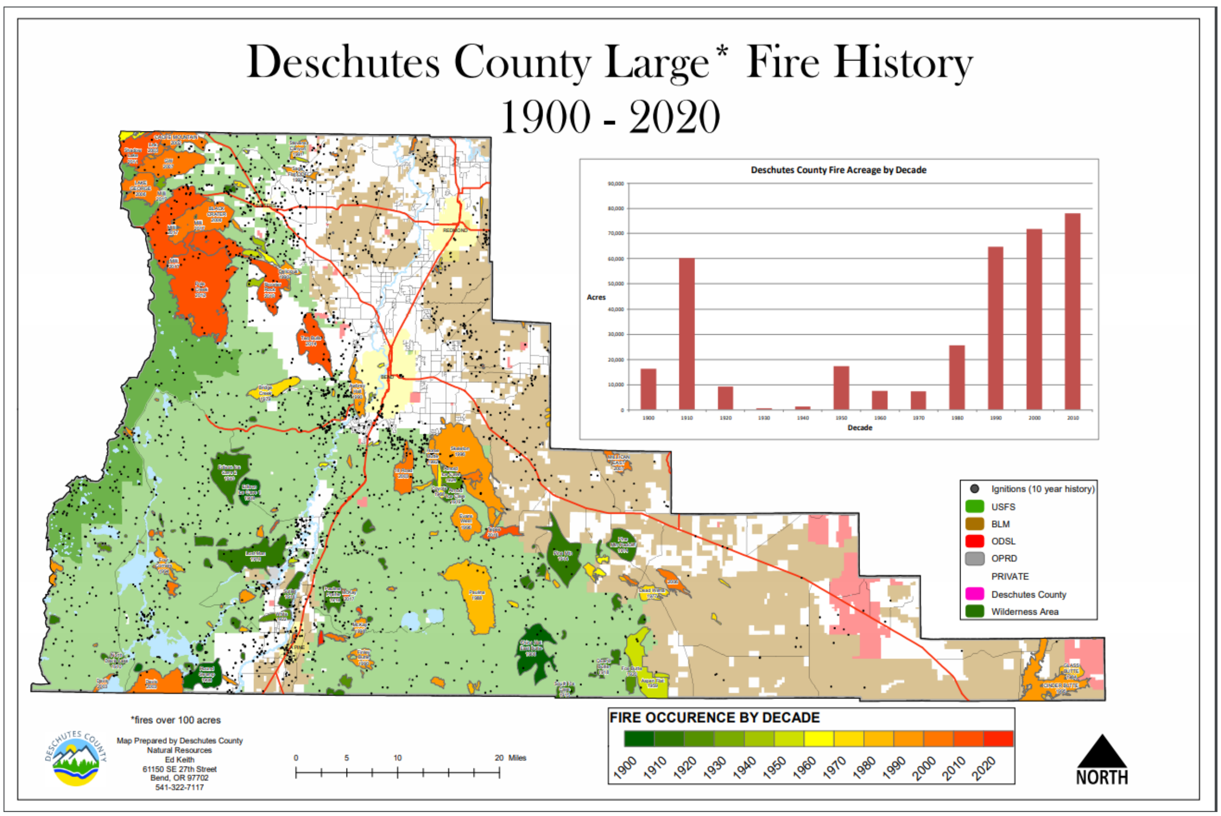
Table II-7 Large Wildfire History (1990 to present)

Date	Fire Name	Acres Burned
2018	Tepee	2,027
2017	Milli	24,000
	McKay	190
2014	Two Bulls	6,908
2013	Burgess Road	168
2012	Pole Creek	26,795
2011	Shadow Lake	10,402
2010	Rooster Rock	6,120
2009	Black Butte II	569
2008	Summit Springs Complex	1,973
2007	GW	8,570
2006	Lake George	5,652
	Black Crater	9,412
2005	Park	139
2003	Davis	21,123
	Link	3,716
	18 Road Fire	3,811
	B & B Complex	90,769
	Cache Mountain	4,451
2001	Crane Complex	713
2000	Hash Rock	18,500
1998	Elk Lake	252
	McKay	1,150
1996	Little Cabin	2,400
	Smith Rock	300
	Skeleton	17,794
	Evans West	4,231
1995	Cinder Butte	11,132
1994	Four Corners	1,524
1992	Sage Flat ODF	1,106
	Horse Butte	1,629
1991	Stevens Canyon	1,080
1990	Awbrey Hall	3,032
	Delicious	2,042
	Finley Butte	1,320

Source: Deschutes County Forestry, 2021.

The local structural and wildland fire organizations have significantly refined the coordinated emergency response system for these types of destructive interface fires. Under the leadership of the Central Oregon Fire Chiefs Association (COFCA), the pre-planned interface fire mutual aid and task force system has effectively integrated the operational response process for structural and wildland firefighting resources from all three counties. This response system is recognized as one of the most effective interagency efforts in the state. As is the case with the regional focus of Table II-7, much of the wildland fire section of this plan is presented with a regional focus on Crook, Deschutes and Jefferson counties. The scope and multi-jurisdictional nature of local wildland fire demand has driven development of a regional approach that addresses pre-incident planning, training, initial and extended response during incidents, and recovery activities. Fire service leadership broadly acknowledges the benefit of this type of coordinated approach as essential to meeting the local wildfire challenge.

Figure II-19 Large Wildfire History



Source: Deschutes County Forester, 2021.

Another measure of the scope and impact of the wildland fire issue, particularly in the wildland-urban interface (WUI) is illustrated by data developed in the Central Oregon Fire Atlas. The Nature Conservancy produced the Fire Atlas as a part of their Fire Learning Network initiative. The Fire Atlas focuses on 2.05 million acres in Klamath, Deschutes and Jefferson counties and was used by stakeholders and community members to visualize wildfire risk in relation to regional landscapes and vegetation regimes, their location in relation to communities, and the history of past wildfires.[1]

The tables below illustrate not only the escalating size of large wildland fires in Deschutes County, but also the increasing impact on the citizens, values-at-risk and infrastructure of the county.

Table II-8 Acres Burned by Decade

Decade	Acres Burned
1900 - 1909	16,200
1910 - 1919	60,400
1920 - 1929	9,200
1930 - 1939	600
1940 - 1949	1,400
1950 - 1959	17,400
1960 - 1969	7,400
1970 - 1979	7,400
1980 - 1989	25,600
1990 - 1999	64,700
2000 - 2009	71,900
2010-2019	98,600
Summary	
1900-1999	210,300
2000-present	170,500

Source: Deschutes County Forestry (2014) and Oregon Wildfire Risk Explorer (2021)

The significant story here is that Deschutes County has experienced high intensity wildland fires on 45% more acreage in the last 19 years than in the previous 100 years combined. The following table details the structures lost since 1981. The table shows that the majority of structures lost occurred during events in 1990 and 1996; since 2019 there have been no structures lost in the county due to wildland fire.

[1] See more at: https://www.conservationgateway.org/News/Pages/deschutes-fln-helps-commu.aspx#sthash.0k6rrEmA.dpuf

Table II-9 Structures Lost to Wildland Fire

Year	Structures Lost
2019	1
2018	3
2003	1
2002	20
2001	5
1996	30
1990	22
1981	5
Total	87

Source: Central Oregon Interagency Dispatch Records, 2021

The escalating size and intensity of these interface fires is the subject of continuing research in several scientific disciplines. These include the arenas of forest health, hazardous fuels treatment and community infrastructure protection; as well as studies of the impacts of climate change. These issues are likewise the subject of significant public discourse. Over the last two decades, community awareness and participation has developed substantially regarding the interface fire threat. Participation hazardous in fuel reduction and wildfire preparedness activities within neighborhoods in Deschutes County increases with each passing fire season.

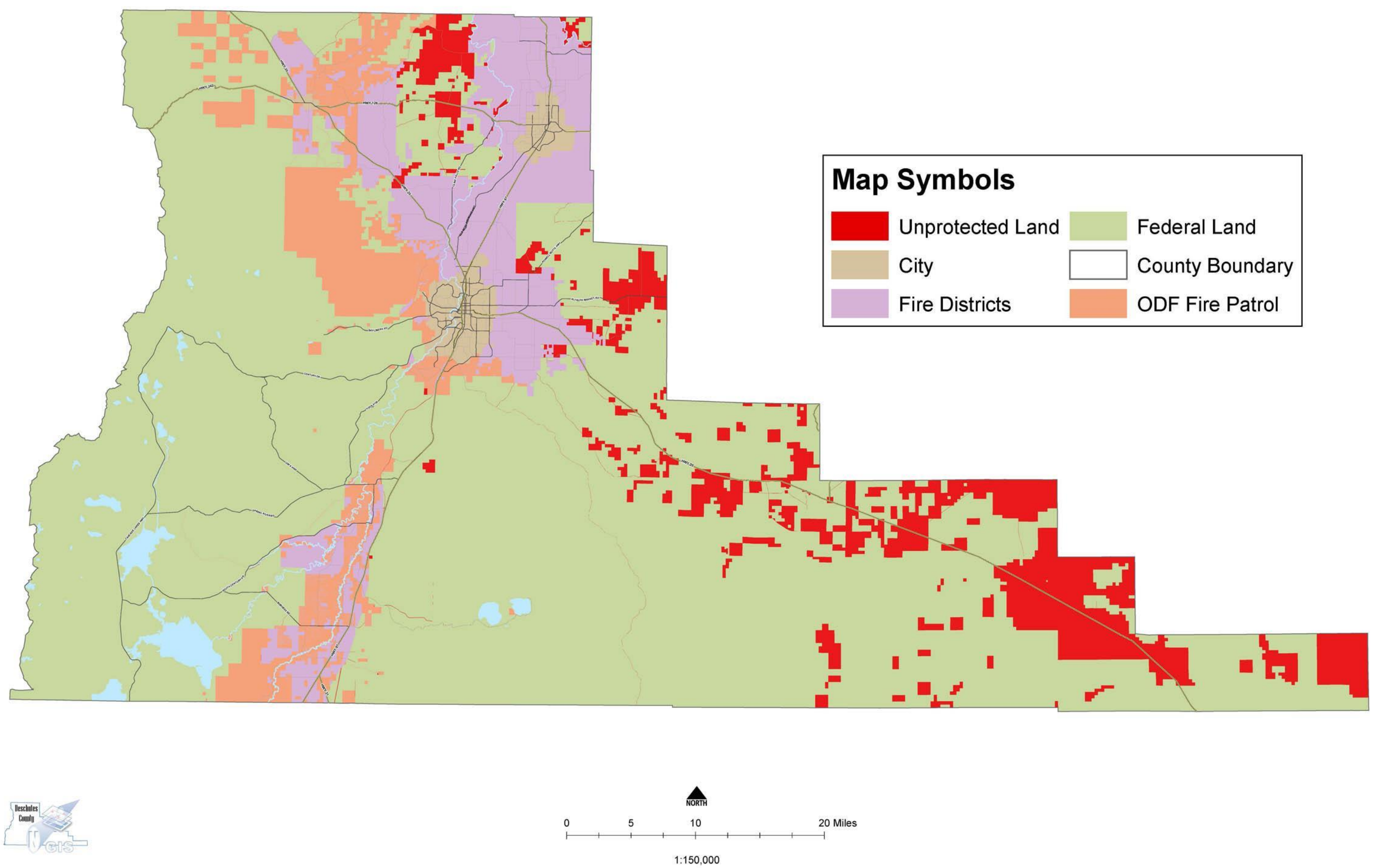
Central Oregon population growth has become a companion issue. In 1980, Deschutes County population was estimated to be 62,500. In 20 years, by 2000, it had nearly doubled to 115,367 and by July 1st 2020 it had increased another 71% to 197,015. The 2004 Coordinated Population Forecast for Deschutes County (updated in 2018) estimates the 2043 county population to increase by another 114,000 over the next 25 years to 311,015. This trend of rapid population growth will have significant impacts on citizen exposure, infrastructure vulnerability, and economic losses to the effects of wildland fire.

Deschutes County includes approximately 175,400 acres of unprotected lands (see Figure II-21 for a map of the protected and unprotected lands within Deschutes County). Throughout eastern Oregon approximately eight million acres of unprotected, privately owned wildland areas exist. In Deschutes County there are several examples of residential development that are under protected from fire These include the Lower Bridge area east of Sisters, and the Brothers and Hampton areas along Highway 20 on the eastern edge of the county. In addition, there are approximately 100,000 acres of privately-owned rangeland east of Bend that do not have structural fire protection and receive some wildland fire protection from Rangeland Fire Protection Associations. Alfalfa, a community located east of Bend, passed a bond measure in 2014 to fund a fire district that currently provides fire protection to its residents, signifying the only expansion in protected lands since the last NHMP update in 2015.

Because these types of areas have limited fire protection and because of the light, flashy nature of the fuel types present in some areas, wildland fires have the potential to get quite large, often spreading to the point where they become a threat to protected areas. In Deschutes County, county code 8.21 has been developed that outlines a system for landowners to respond to the wildland fire threat with defensible space and fire breaks on private property in the unprotected areas.

There are likewise substantial resource commitments and fiscal costs associated with emergency response to wildland fire incidents. This impact on local organizations was demonstrated by the multiple agency organizational response each fire season. Notable recent incidents that exemplify the impact on local organizations are Pole Creek (2012), Burgess Road (2013), Two Bulls (2014) and Milli (2017). The costs associated with multiple day mobilization of law enforcement, search and rescue, structural fire assets and state fire resources can quickly deplete local and state agency budgets. Residential evacuation triggers American Red Cross mobilization and when major transportation routes are impacted, Oregon Department of Transportation and County Road Department personnel are also mobilized. Depending on the scope and specifics of an individual fire, additional agency and non-governmental support organizations may also be mobilized to help mitigate the impact on citizens and community infrastructure.

Figure II-21 Deschutes County Fire Protection



Source: Deschutes County Forester, 2021

The rapid rates of spread and higher fire intensity observed in the recent past have raised the awareness level of the public and local public safety officials. Public safety and structural mobilization, at some level, occurs shortly after the initial smoke report for every wildland fire with wildland urban interface threat potential in Deschutes County

Much of the public policy discussion associated with the wildland urban interface at federal, state and local levels have been focused on resources and public safety issues. While that will continue to be an important component of future initiatives, these examples of rapidly moving, high intensity fires with long-range spotting demonstrate the need for coordinated fuels treatment strategies and public education efforts that address fire behavior and preparedness issues for several miles beyond private and public land boundaries.

Hazard Identification

Deschutes County is generally considered within two vegetative ecosystems:

- The "high desert" dominated by Western juniper, sagebrush and a variety of grass species to the east, and
- To the west, a transition from dry-site ponderosa and lodgepole pine to mixed conifer to a sub-alpine mix of tree species near the crest of the Cascades.

The boundary between these two general eco-types is driven for the most part by elevation, precipitation and soil moisture-holding capacity.

Central Oregon Fire Adapted Ecosystems

Most central Oregon ecosystems, particularly those at low and mid elevations adjacent to most community and residential development, are described as fire adapted. Vegetative species in these areas have evolved in and are dependent on relatively short fire return intervals. Over the last 100+ years, fire suppression and forest management activities have altered this natural fire return interval. This has created species shifts and increases in stand density and forest fuels. This change has increased susceptibility of the forest to insects, diseases and to wildland fire.[2] Inventory and analysis of this shift by the Central Oregon Fire Management Service (COFMS) stratifies the national forest and adjacent lands into one of three Condition Classes based on the number of "missed" fire cycles.[3]

Vegetative Mapping for Fire Regime and Condition Class

The Deschutes National Forest, Ochoco National Forest and the Prineville District of the Bureau of Land Management, working together as Central Oregon Fire Management Services (COFMS) review, and edit if necessary, the Central Oregon Fire Management Plan on an annual basis. Included in that plan is an extensive Fire Regime and Condition Class analysis of the condition of the vegetation on the public lands managed by the agencies.

[2] Fitzgerald, S., OSU Extension Wildland Forest Specialist, interview March 2004.
[3] Central Oregon Fire Management Plan, Central Oregon Fire Management Service.

Because of the wide variability in vegetative types in central Oregon, the Fire Regime – Condition Class approach was selected as the best method to describe the range of conditions present on the ground.

Fire Regime - Condition Class considers the type of vegetation and the departure from its natural fire behavior return interval. Five natural (historical) fire regimes are classified based on the average number of years between fires (fire frequency) combined with the severity of the fire on dominant overstory vegetation. Western juniper, for example has a fire return interval of approximately 30 years with high potential for stand replacement fires. Therefore, it falls within Fire Regime II.

Table II-10 Fire Regimes

Fire Regime Group	Fire Frequency	Fire Severity	Plant Association Group
I	0 - 35 years	Low severity	Ponderosa pine, manzanita, bitterbrush
II	0 - 35 years	Stand replacement	Western juniper
III	35 - 100+ years	Mixed severity	Mixed conifer dry
IV	35 - 100+ years	Stand replacement	Lodgepole pine
V	> 200 years	Stand replacement	Western hemlock, mixed conifer wet

Source: Deschutes County CWPPs

Condition Class categorizes a departure from the natural fire frequency based on ecosystem attributes. In Condition Class 1, the historical ecosystem attributes are largely intact and functioning as defined by the historical natural fire regime. In other words, the stand has not missed a fire cycle. In Condition Class 2, the historical ecosystem attributes have been moderately altered. Generally, at least one fire cycle has been missed. In Condition Class 3, historical ecosystem attributes have been significantly altered. Multiple fire cycles have been missed. The risk of losing key ecosystem components (e.g. native species, large trees, soil) is low for Class 1, moderate for Class 2, and high for Class 3.

Table II-11 Condition Class

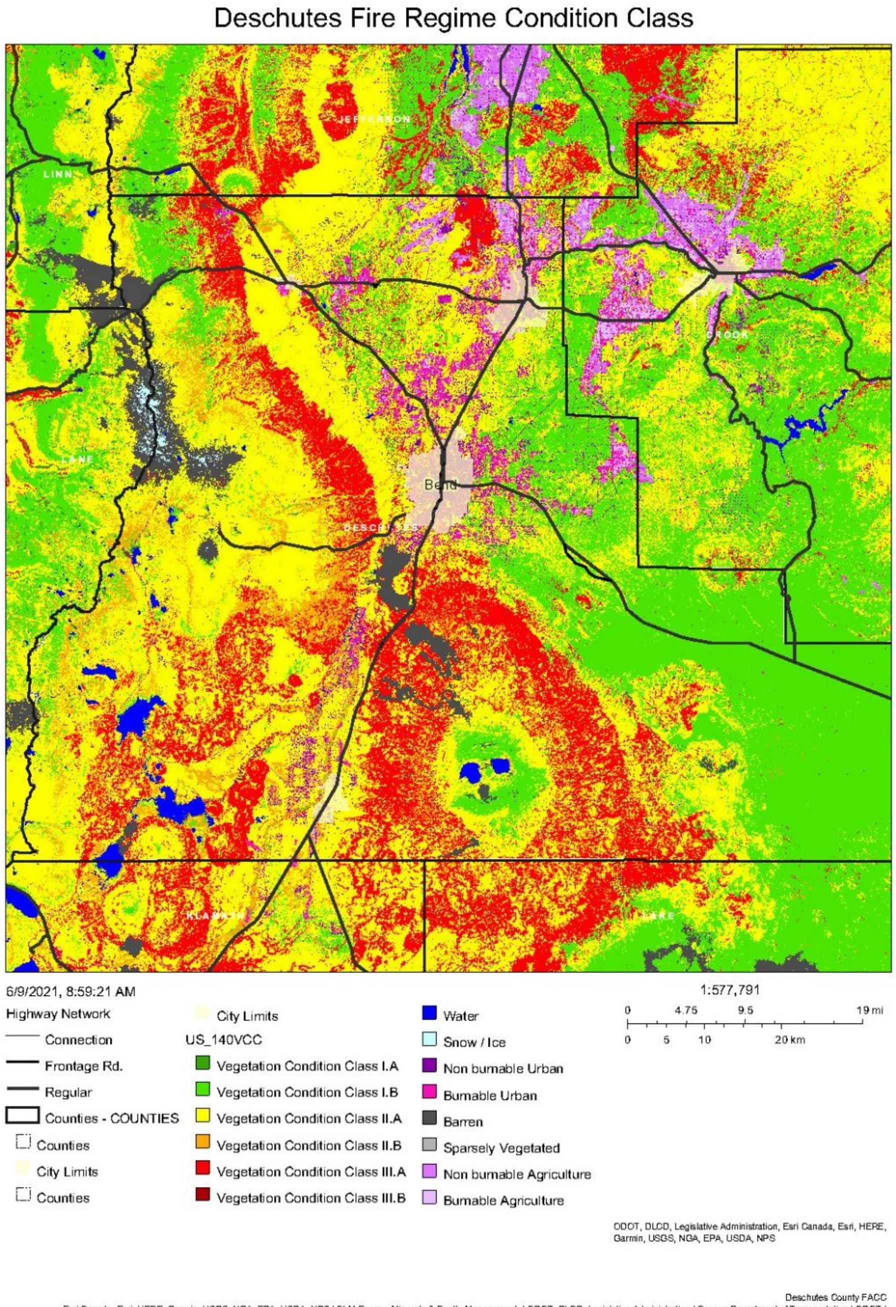
Condition Class	Attributes
Condition Class 1	*Fire regimes are within or near an historical range. *The risk of losing key ecosystem components is low. *Fire frequencies have departed from historical frequencies (either increased or decreased) by no more than one return interval. *Vegetation attributes are intact and functioning within an historical range.
Condition Class 2	*Fire regimes have been moderately altered from their historical range. *The risk of losing key ecosystem components has increased to moderate. *Fire frequencies have departed (either increased or decreased) from historical frequencies by more than one return interval. This change results in moderate changes to one or more of the following: fire size, frequency, intensity, severity or landscape patterns. *Vegetation attributes have been moderately altered from their historic ranges.
Condition Class 3	*Fire regimes have been significantly altered from their historical range. *The risk of losing key ecosystem components is high. *Fire frequencies have departed (either increased or decreased) by multiple return intervals. This change results in dramatic changes to one or more of the following: fire size, frequency, intensity, severity, or landscape patterns. *Vegetation attributes have been significantly altered from their historic ranges.

Source: Deschutes County CWPPs

While each of the fire regimes described exist in Deschutes County, Fire Regime I and Fire Regime II generally describe the forest condition that is present at the lower elevations adjacent to the more densely populated, wildland urban interface (WUI) areas of the county. The forest vegetative species shift cited above however is causing a greater presence of Fire Regime III at lower elevations with an increasing dominance of non-native species and increased fuels loading in those sites. This results in higher levels of fire intensity, crowning and spotting potential.

In Deschutes County, the majority of public lands are in Condition Class 2 or 3, having missed one or two (or more) fire return intervals. Ground vegetation and tree saplings have grown unchecked by natural fire contributing significantly to the potential for extreme fire behavior including crowning, torching and spotting.

Figure II-22 Deschutes Fire Regime Condition Class



Source: Deschutes County FACC

Fire Behavior

Wildland fire behavior is comprised of three components: fuels, topography and weather. While these three parameters individually define fire behavior, their interactive dynamics offer insight for effective mitigation approaches. The fire behavior triangle helps demonstrate the relationship between these three parameters.

The **fuels** aspect of fire behavior takes into consideration loading, size and shape, compactness, horizontal and vertical continuity and chemical composition. Each of these parameters offers opportunities for effective hazardous fuels treatment mitigation actions. Due to the dry nature of most areas of Deschutes County, many of the brush species contain a significant amount of volatile, highly flammable oils and resins (e.g. bitterbrush). These relatively low profile fuels can generate very intense, high flame length fire behavior. This is similar to fires observed in the chaparral fires in southern California.

Topography takes into account elevation and slope position and steepness, aspect and shape of the country. Deschutes County's west boundary lies at the crest of the Cascade Mountains generally about 6,000 to 7,000 feet. The elevation falls off to the east, transitioning through the lower slopes and foothills of the Cascades, crossing the Deschutes River and progressing down to about 3,000 feet in the high desert. This generally gives the area an east and south aspect, which provides strong solar exposure throughout most of the day. The Cascades also act as a barrier to the prevailing westerly winds. This creates a rain shadow effect that limits precipitation on the east side of the mountains and contributes to gusty, turbulent, dry cold front passages that have historically contributed to high intensity fires with rapid rates of fire spread and medium to long range spotting.

As mentioned above and described in Appendix C, Central Oregon weather is strongly affected by the Cascade Mountains. The relatively low precipitation, particularly at lower elevations adjacent to areas of community development, strong solar radiation and gusty wind patterns combine to generate a fairly dry environment.

There are some opportunities to compensate for the wildland interface fire exposure effects of local dry climatic conditions and weather patterns by consideration of topographic features during home construction and development planning. Overall, however, the greatest potential to impact fire behavior lies with hazardous fuels management, varying in scope from defensible space around individual homes and structures to well planned, landscape scale treatments to mimic the effects of periodic low intensity fire.

In Central Oregon, forests ecologically within the historical norm are also more fire tolerant and are less susceptible to high intensity, stand replacement fires. Ultimately, fire behavior is related to the structure of the forest fuels. Hazardous fuels treatment strategies are the subject of ongoing research efforts.[4]

The Wildland Urban Interface of Deschutes County

Over the last twenty years, public recognition of the term "wildland urban interface" (WUI) has become greater with increased incidences of wildland fires, loss of residences, and highly visible smoke columns. The term "wildland urban interface" describes the boundary and intermixture of structural development adjacent to and within areas dominated by wildland fire vegetation. Fire suppression tactics in interface areas, both structural and wildland, are continually adapting to provide better safety for firefighters and the public.

[4] Science Basis for Changing Forest Structure to Modify Wildfire Behavior and Severity by Russell T. Graham, Sarah McCaffrey, and Theresa B. Jain. RMRS-GTR-120, USDA Forest Service, 2004.

Probability Assessment

In Oregon, wildfires are inevitable. Although usually thought of as being a summer occurrence, wildland fires can occur during any month of the year. The vast majority of wildfires burn during the June to October time period. Dry spells during the winter months, especially when combined with winds and dead fuels, may result in fires that burn with intensity and a rate of spread that cause difficulty for local resources that typically don't have their full staffing in the winter season. Wildfire risk to human welfare and economic and ecological values is more serious today than in the past because of the buildup of flashy fuels, changes in vegetation composition over time, construction of houses in proximity to forests and rangelands, increased outdoor recreation, and a lack of public appreciation of wildfire.[5]

The natural ignition of forest fires is largely a function of weather and fuel; human-caused fires add another dimension to the probability. Dry and diseased forests can be mapped accurately and some statement can be made about the probability of lightning strikes. Each forest is different and consequently has different probability and recurrence estimates. Wildfire has always been a part of these ecosystems and sometimes with devastating effects. The intensity and behavior of wildfire depends on a number of factors including fuel, topography, weather, and density of development. There are a number of often-discussed strategies to reduce the negative impacts of these phenomena. They include land-use regulations, management techniques, site standards, and building codes. All of these have a bearing on a community's ability to prevent, withstand, and recover from a wildfire event.

Deschutes County's Natural Hazards Mitigation Steering Committee believes that the County's **probability of experiencing a wildfire event is "high,"** meaning at least one incident is likely within the next 10 – 35 year period (as the history of wildfires indicates, it is likely that Deschutes County will experience a wildfire on an annual basis). Based upon available information the Oregon NHMPs Regional Risk Assessment supports this probability rating for Deschutes County.[6]

Future Climate Variability

One of the main aspects of the probability of future occurrences is its reliance on historic climate trends in order to predict future climate trends. Counties east of the Cascade Mountain Range in Oregon are experiencing more frequent and severe wildfires than is historically the norm, and many climate predictions see this trend continuing into the future. Temperature increases will occur throughout all seasons, with the greatest variation occurring during summer months. Hotter temperatures mean more combustible vegetation. This information was considered while developing the probability of wildfire occurrence for the county.

Vulnerability Assessment

Wildfires are a natural part of forest and grassland ecosystems. Past forest practices included the suppression of all forest and grassland fires. This practice, coupled with hundreds of acres of dry brush or trees weakened or killed through insect infestation, has fostered a dangerous

[5] Ibid
[6] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2020.

situation. Present state and national forest practices include the reduction of understory vegetation through thinning, mastication and prescribed (controlled) burning.

Each year a significant number of people build homes within or on the edge of the urban/wildland interface, thereby increasing wildfire hazards. Many Oregon communities (incorporated and unincorporated) are within or near areas subject to serious wildfire hazards, complicating firefighting efforts and significantly increasing the cost of fire suppression.

Each Community Wildfire Protection Plan (CWPP) utilized a variety of hazard assessment tools depending on the vegetation ecotypes of the Communities at Risk within each CWPP. CWPPs that have been updated within the last 2 years use the new Oregon Wildfire Risk Explorer tool (OWRE) to conduct the risk assessment. The OWRE Advanced Report provides wildfire risk information for a customized area of interest to support Community Wildfire Protection Plans (CWPPs), Natural Hazard Mitigation Plans (NHMPs), and fuels reduction and restoration treatments in wildfire-prone areas in Oregon. The assessment uses the most current data and state-of-the art fire modeling techniques, and is the most up-to-date wildfire risk assessment for Oregon. Moving forward, all CWPPs will use the OWRE to assess risk.

Over the last five years, collaborative groups in each of seven CWPP areas met to conduct these assessments and determine priorities for fuels reduction activities on public and private lands. Each CWPP and year of update (and next expected revision) is listed below:

- Greater Bend CWPP (2016, expected revision 2021)
- Greater La Pine CWPP (2020, expected revision 2025)
- Greater Redmond CWPP (2018, expected revision 2023)
- Greater Sisters Country CWPP (2019, expected revision 2024)
- Sunriver CWPP (2020, expected revision 2025)
- East and West Deschutes County CWPP (2018, expected revision 2023)
- Upper Deschutes River Coalition CWPP (2018, expected revision 2023)

While the formatting changes some between the CWPPs, the priorities and goals are the same across all the CWPPs. These following table details these shared priorities. To view in detail the CWPPs above, visit https://www.projectwildfire.org/cwpps/

Table II-12 Summary of CWPP Priorities

Communities at Risk - Priorities
Reduce hazardous fuels on public lands
Reduce hazardous fuels on private lands (both vacant and occupied)
Reduce structural vulnerability
Increase education and awareness of wildland fire threat
Identify, improve and protect critical transportation routes

Source: Deschutes County CWPPs

Notes: While the formatting changes between the CWPPs, the priorities and goals are the same across all the CWPPs; more information can be found in each community's Community Wildfire Protection Plan.

The Deschutes County CWPPs utilized the Oregon Department of Forestry Assessment of Risk methodology to determine community risk. The assessment used a scoring matrix with six factors: likelihood of fire occurring (Risk), hazard (based on weather, topography, and fuel), protection capability, values protected, and structural vulnerability.[7] The hazard assessment information was used to develop a scoring matrix that would provide results that was used for prioritizing the WUI areas.

The Deschutes County Natural Hazards Steering Committee rated Deschutes County as having a **"high" vulnerability to wildfire hazards**; meaning more than 10% of the region's population or assets would be affected by a major emergency or disaster. Based upon available information the Oregon NHMPs Regional Risk Assessment supports this vulnerability rating for Deschutes County.[8]

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I) shows the county's Hazard Analysis Matrix which scores each hazard and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **wildfire hazard is rated #2, out of 9 rated hazards, with a total score of 220**.

Community Hazard Issues

Threat to Life and Property

The interface between urban and suburban areas and these resource lands are producing increased exposure to life and property from wildfire. In many cases, existing fire protection services cannot adequately protect new development. Wildfires that also involve structures present complex and dangerous situations to firefighters.

Personal Choices

Many interface areas, found at lower elevations and drier sites, are also desirable real estate. More people in Oregon are becoming vulnerable to wildfire by choosing to live in wildfire-prone areas.[9]

A community at risk is a geographic area within and surrounding permanent dwellings (at least one home per 40 acres) with basic infrastructure and services, under a common fire protection jurisdiction, government, or tribal trust or allotment, for which there is a significant threat due to wildfire.

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[7] Deschutes County CWPPs. https://www.projectwildfire.org/cwpps/
[8] Ibid.
[9] National Wildland/Urban Interface Fire Protection, Fire protection in the Wildland/Urban Interface: Everyone's responsibility, Washington D.C., (1998).

Private Lands

Private development located outside of rural fire districts where structural fire protection is not provided is at risk. In certain areas fire trucks cannot negotiate steep grades, poor road surfaces, narrow roads, flammable or inadequately designed bridges, or traffic attempting to evacuate the area. Little water during the fire season, and severe fuel loading problems add to the problem. In some areas, current protection resources are stretched thin, thus both property in the interface and traditionally protected property in the forests and cities are at greater risk from fire. While the Firewise program has increased knowledge of the fire risk and preparedness for fire season however, many property owners in the interface are not aware of the problems and threats that they face, and owners in some areas have done little to manage or offset fire hazards or risks on their own property.

Drought

Recent concerns about the effects of climate change, particularly drought, are contributing to concerns about wildfire vulnerability. Unusually dry winters and hot summers increase the likelihood of a wildfire event, and place importance on mitigating the impacts of wildfire before an event takes place.

More information on this hazard can be found in the Regional Risk Assessment for Region 6 of the Oregon NHMP.

Wildfire Smoke

History

Deschutes County and some of the cities in the County have had a history of some elevated particulate matter concentrations from the 1980s when air quality measurements were first taken. Woodstoves, open burning, and burn barrels were the initial issue causing elevated winter time levels of PM10, or particulate matter with approximately 10 µg diameter. The first standards for the more modern day air quality began with PM10, and it was thought that Bend was close to exceeding the standard due to winter time smoke. The air in Bend, and later in Sisters, was monitoring for PM10 concentrations. As more homes were built in all communities, and natural gas mostly available other than in outlying communities, and population density caused rethinking of ordinances such as allowing winter time burning and burn barrels, the winter time PM10 levels were reasonably controlled. Since the late 90's, a standard for finer and more impactful particulate, PM2.5, were promulgated, and revised downward in 2006 to more protective levels for human health.

Current Air Quality Monitoring

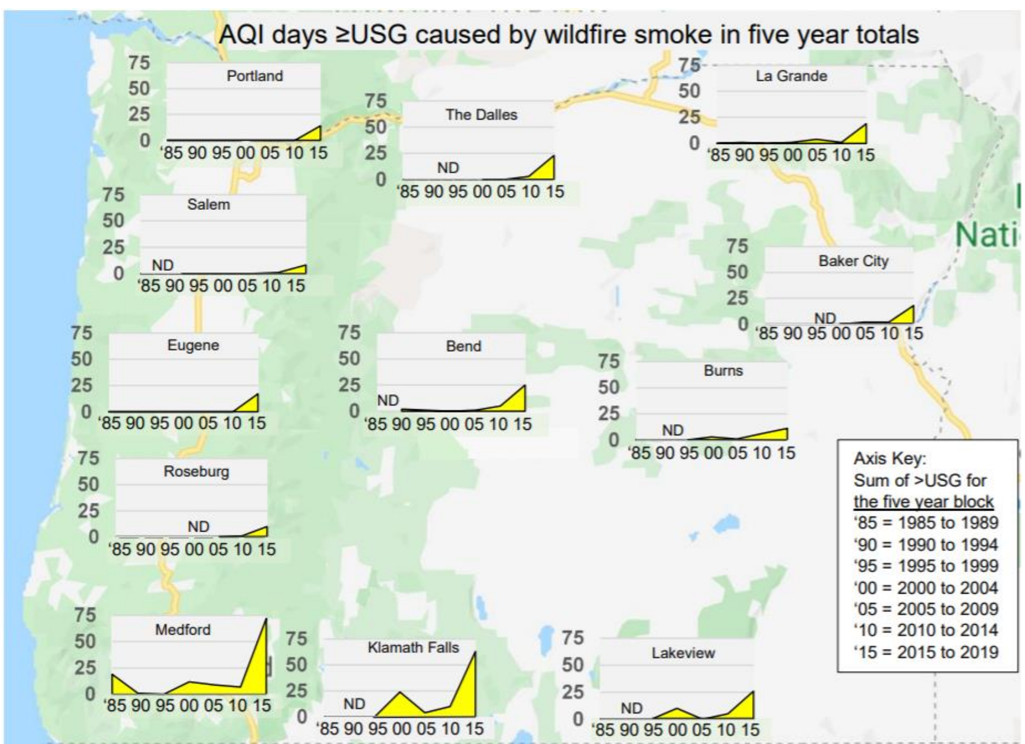
PM2.5 levels were first monitored in Bend, then in Sisters, and finally in 2019 in Redmond and in 2020 in La Pine. Other air quality monitoring networks have also appeared, from low cost home systems such as the Purple Air monitors and the e::space network throughout Central Oregon. The former are not calibrated and prone to higher readings of wood smoke (1.5 or higher times in value than a calibrated unit), giving people a false sense of alarm. The e::space network does undergo a calibration and correlation routine to be more reliable than the simple air quality monitors. The DEQ monitoring network must meet rigorous quality control and quality assurance routines accepted by the U.S. Environmental Protection Agency and included into national monitoring network. The current more widespread monitoring in the County, from all different AQ monitors, allows for the evaluation of where the PM2.5 levels are high and gives us trends or an indication of concentration of PM2.5 throughout the county.

While PM2.5 is under control for the most part during non-wildfire episodes, the current National Ambient Air Quality Standard for PM2.5 is subject to change and may be revised downward in the future from 35 ug/m3 in a 24 hour period to something lower which may initially be difficult for areas in the County to meet. Wildfire smoke, not being caused by regular human activity, is not counted against the communities in the critical evaluation of compliance with the NAAQS, but air quality is recognized as still degrading to levels that otherwise exceed the air quality standards and is not healthy for the residents during episodes of smoke.

Wildfire Smoke

Wildfire smoke is an emerging periodic health challenge to residents of Deschutes County. Besides the increasing trend of local fires, there is also an increasing trend of severe smoke impacts from other areas in Oregon, the Pacific Northwest, California, or even from British Columbia. This smoke has a trend of being more concentrated and having a longer duration, causing harm to the residents of the County.

Figure II-23 Map of Wildfire Air Quality Index trends across Oregon



Source: Barnack, A. (2020). (rep.). *Wildfire Smoke Trends and the Air Quality Index*. Portland, OR: Oregon Department of Environmental Quality

Health Impacts

Wildfire smoke contains many toxic gases, including polycyclic aromatic hydrocarbons (PAHs), and particulate matter. The particulate matter can be comprised of many smaller molecules joined together, and/or organic carbon molecules as a base. Wildfire smoke also contains high amounts of carbon monoxide which can be lethal when inhaled over a period of time or have other deleterious side effects. Carbon monoxide is mainly a concern to wildland fire fighters and those on the front line or very close to large fires.[10]

The particulate matter can be transported long distances or be present from nearby fires and is a focus of concern to health authorities (Oregon Health Authority, Department of Environmental Quality). Concentrations of fine particulate matter (PM2.5) from wildfires readily exceed the National Ambient Health Standard of 35 μg/m^3 for a 24-hour period. When exceeded for multiple days in a row, the regional health can be compromised unless prompt, effective, and continuous mitigation measures are employed.[11]

Vulnerable populations are especially prone to having adverse impacts quickly from wildfire smoke. As defined in the Oregon Department of Forestry Rules, OAR 629-048: **"***Vulnerable populations" means people with specific sensitivities including, but not limited to, those with heart diseases, coronary artery disease, congestive heart failure, or those with lung and respiratory diseases, such as chronic obstructive pulmonary disease (COPD), and those with asthma, older adults, pregnant women, and children.*

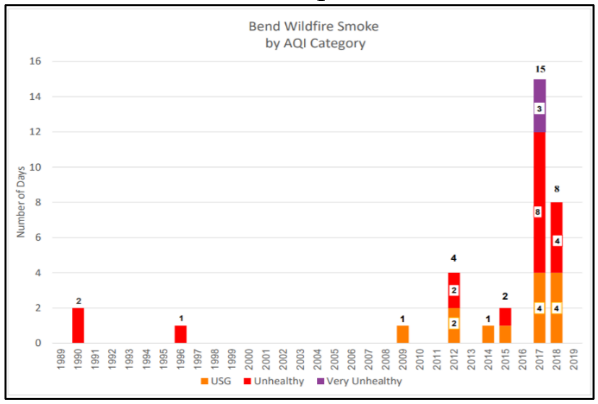
Such populations can be impacted by smoke from just an hour or more of elevated concentrations (such as above 25 μg/m^3, 1 hour basis). This is because fine particulate matter enters and impacts the lungs but also the small particulates can enter the bloodstream through the lungs. The former is more of the immediate issue for people with breathing problems and respiratory conditions, but the latter can impact everyone over time and have carcinogenic impacts. The relationship between increases in smoke concentration and rates of morbidity is increasingly a topic of research due to concern over the health impacts of wildfire smoke.[12]

[10] Oregon Health Authority, *Wildfires and Smoke.* https://www.oregon.gov/oha/PH/Preparedness/Prepare/Pages/PrepareForWildfire.aspx#health

[11] Central Oregon Fire Info, *Smoke & Your Health*. https://www.centraloregonfire.org/wildfire-smoke-your-health/

[12] Oregon Department of Environmental Quality, *Air Quality Monitoring*. https://www.oregon.gov/deq/aq/Pages/Air-Quality-Monitoring.aspx

Figure II-24 Bend ≥ USG AQI Wildfire Smoke Trends



Source: Barnack, A. (2020). (rep.). *Wildfire Smoke Trends and the Air Quality Index*. Portland, OR: Oregon Department of Environmental Quality

At times, all of Deschutes County can be blanketed in smoke. This is mostly when the smoke is coming from other areas and plumes are widespread. Local heavy impacts can occur from nearby fires, such as from the Pole Creek fire when Sisters what inundated with smoke, but Bend and further south was mostly not. Smoke from local fires tends to mostly impact down drainage sites or area in the predominant wind flow patterns, and can often not be as heavy for many hours in the day then degrade to unhealthy or worse conditions.[13]

Probability

The probability of wildfire smoke impacts are very difficult to predict, but Deschutes County and Central Oregon overall will likely experience widespread wildfire smoke in the near future. Some years there may be no smoke impacts, others with a few days, and others with smoke impacts for a week or longer in duration. Due to the number of forested areas in and around Deschutes County, and in the heavily forested Pacific Northwest and up into British Columbia, smoke from distant wildfires can impact this region.[14]

Mitigation

Mitigating impacts of smoke can vary from shorter-term impacts to longer duration incidents. For shorter term elevated concentrations, people are advised to stay inside or be outside only as necessary and for as little time as possible. Indoors, people are recommended to keep windows and doors closed, operate the air system on recirculation and use a HEPA filter if they have one, or operate an indoor air purifier with a HEPA filter.

For long term exposures, or when it is known the smoke will persevere for a few days or longer, there are a few options:

- Shelter in place and use HEPA level filters;
- Operate HVAC on recirculation mode;

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[13] Deschutes County NHMP Steering Committee members, 2021.
[14] Ibid.

- Keep all windows and doors closed, possibly applying tape to leakier door frames or windows to keep air infiltration down;
- Use a draft block at the base of doors (a towel or draft snake as they can be called);
- Properly wear an N95 mask if one needs to go outside (people who should not wear N95's include children and people with certain medical conditions that may be exacerbated by mask-wearing);
- Limit any time spent outdoors to the minimum;
- Consider leaving the area for a location with clean air or not impacted by wildfire smoke. Sometimes this is out of state and many states distant.
- Operate multiple air purifiers in the home, possibly including Do-it-yourself air filtration systems using 20"x20" box fans with 1" filters of MERV 13 level as possible but even MERV 11 or 12 will help some.

Current tips and recommendations can be found on the Oregon Health Authority's (OHA) webpages for Wildfire Smoke.

Deschutes County Public Health has obtained some HEPA portable air filters and placed them in some of the public places where vulnerable people meet. Recommendations have been made to conduct surveys of air filtrations systems in places such as the school systems, County buildings, Senior Centers, Libraries and so forth to first know how each area is equipped to handle long term and short-term smoke events and where improvements need to be made. The goal is to make the County much more resilient to wildfire smoke and truly be a Smoke Ready Community. All citizens are being educated on the value of obtaining their own HEPA systems and having spare filters on hand to be able to endure a wildfire smoke event such as the one in September 2020.[15]

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

Local fire prevention and hazardous fuels treatment efforts have been an integral component of the local interagency coordination picture since the early 1980's. The challenge of an expanding wildland urban interface was recognized in Deschutes County two decades ago. The local fire service response system reflects that long period of interface fire experience and the recognized value of pre-incident mitigation activities.

County and Cities

Project Impact

Deschutes County was designated an Oregon Project Impact community in 1999. At the time, this national-level program was established "to reduce the human and economic costs of disasters through prevention, preparation and mitigation." Deschutes County was one of only a

[15] Deschutes County Public Health, https://www.deschutes.org/health/page/health-tips-wildfire-smoke. Accessed May 2021.

few areas across the nation identified to focus on wildland fire related mitigation activities. A steering committee was established by the Deschutes County Board of Commissioners to provide oversight and accountability for use of the funds. The original $300,000 grant allowed Project Impact to construct an additional escape route out of an at-risk community and fund additional activities for the next three years.

In 2002, a consultant and a sub-group of the steering committee began to explore development of a business plan for a follow-on organization to Project Impact. Project Wildfire was established. Based on the foundation of the Project Impact experience and as stated previously, Project Wildfire continues to provide coordination of a variety of wildland fire mitigation activities including the FireFree program, the facilitation of the 7 Community Wildfire Protection Plans, serves as a source of wildfire mitigation and preparedness information for local groups, and secures grant funding to support fuel mitigation activities in local at risk communities.

FireFree

The FireFree program is a nationally recognized model for homeowner education and mitigation programs in the wildland urban interface. Created in 1997 following the devastating Skeleton Fire in Bend, FireFree creates awareness and educates residents about the risks of wildland fire to homes and property and the ten simple steps they can take to reduce those risks. FireFree encourages homeowners to take responsibility for risk mitigation by creating defensible space around their property and disposing of debris. To find the ten FireFree steps, the FireFree program has an established website www.firefree.org.

FireFree is the local grass root, call-to-action program in Deschutes County for residents to prepare their property for wildfire. The FireFree events culminate every spring and fall with FireFree community clean up days where residents can dispose of their yard debris created by maintaining or creating defensible space, for free at surrounding disposal sites. FireFree is coordinated by Project Wildfire as a collaborative effort among local fire agencies, forestry departments, private businesses and the insurance industry.

Project Wildfire

Project Wildfire is the result of a Deschutes County effort to create long-term wildfire mitigation strategies and provide for a disaster-resistant community. Its mission is to prevent deaths, injuries, property loss and environmental damage resulting from wildfires in Deschutes County. Created by Deschutes County Ordinance 8.24.010, Project Wildfire is the community organization that facilitates, educates, disseminates and maximizes community efforts toward effective fire planning and mitigation. Project Wildfire is governed by a 27-member steering committee that is defined by County Ordinance 8.24.020 as a 50-50 balanced mix between fire agency representatives, private residents, elected officials, Deschutes County 911, Deschutes County Emergency Management, Insurance, and many other at large community members.

Project Wildfire has established a web site (www.projectwildfire.org) to help showcase the wide variety of hazardous fuels treatment, prevention projects, and public information and educational opportunities.

Wildland and Structural Fire Services Program Coordination

Both wildland and structural fire agencies provide a range of services including:

- educational and prevention services;
- pre-season planning and incident response consistent with statutory, jurisdictional and regulatory responsibility; and
- fire response on private and public lands within Deschutes County.

Fire agencies in central Oregon have responded to expanding community development, increasing population and increasing wildland urban interface fire load (risk) by developing a well-coordinated structural and wildland response system.

A formal Central Oregon Cooperative Wildland Fire Agreement exists among wildland and structural fire agencies. While wildland fire agencies are funded to address wildland fire issues there are statutory and agency-specific limitations to expending dedicated firefighting funds for "all risk" incidents. During a Declaration of Emergency, wildland fire agencies can be partially reimbursed through the federal response framework.

Central Oregon Fire Chiefs Association

The Central Oregon Fire Chiefs Association (COFCA) provides a formal forum for fire chiefs in Crook, Deschutes, Bureau of Indian Affairs (BIA), and Jefferson counties to integrate any refinements to the interface fire response system for their individual structural and wildland agencies. COFCA also provides the leadership umbrella for a variety of local interagency prevention, investigation and training groups.

Wildland Fire Prevention

Central Oregon wildland and structural fire services have a long tradition of effective organization-specific and cooperative programs. In dry, fire-prone regions such as central Oregon, fire prevention programs address two facets of preventing destructive wildfires: 1) ignition prevention, and 2) large, catastrophic fire prevention.

An example of a cooperative ignition prevention effort is the Central Oregon Fire Prevention Cooperative (COFPC). This effort was organized in 1978 to provide a forum for coordination of common fire prevention needs between the state and federal wildland fire agencies and structural fire service agencies in Crook, Deschutes, Bureau of Indian Affairs (BIA) and Jefferson counties. COFPC provides a mechanism to maximize effective use of staffing and fiscal resources from all of the cooperating agencies. Its purpose is to conduct a wide variety of ignition prevention, youth education, public service and public education initiatives. COFPC remains active today and has received state, regional and national recognition for its efforts.

The second category includes activities intended to mitigate the impact of large fires. Examples focus on broad hazardous fuels treatment strategies to keep fires at more manageable levels and the development of defensible space around individual homes. There are a variety of local programs currently active and several more in the developmental stage throughout the county.

In Deschutes County, Project Wildfire is a successful example of a collaborative approach to large wildland fire mitigation. A national leader and model for wildland fire mitigation; Project

Wildfire takes advantage of public and private partnerships and collective resources to prevent deaths, injuries, property loss and environmental damage from wildland fire.

In recent years, Project Wildfire has become the facilitator and "caretaker" of seven Community Wildfire Protection Plans and the coordinator of the FireFree Program. Project Wildfire succeeds where an individual or one agency cannot. Project Wildfire is also committed to developing wildland fire prevention and education strategies and implementing hazardous fuels reduction programs across the County.

Community Wildfire Protection Plans

Through the CWPP process, the overwhelmingly clear answer to the wildland fire mitigation question is to reduce the potential for extreme fire behavior by reducing the amount of hazardous fuels in high risk areas on both public and private lands. Since the inception of CWPPs, Deschutes County has secured approximately $6 million in funding under the National Fire Plan, Western States and FEMA grant programs to educate communities and treat hazardous fuels in and around communities at risk.

The wildland fire mitigation efforts in Deschutes County span a variety of agencies and groups. The County has facilitated treatment on over 2,000 acres of hazardous vegetation on private lands each year since 2005. While this number does not sound significant on the surface, it is rather formidable when one considers that these fuels treatments were achieved on private properties ¼ to ½ acres at a time. Since Project Wildfire's establishment in 1999, over 110,000 acres have been treated within and around communities. Complimentary Federal Land projects more than double this figure.

The CWPPs identified priority Communities at Risk and the US Forest Service has responded by treating national forest land in the WUIs since 2005.

These successful projects; however, are also due in part to the level of collaboration experienced in Deschutes County. As stated earlier, Project Wildfire and the CWPP Committees and other groups such as the Nature Conservancy's Fire Learning Network and Central Oregon Intergovernmental Council routinely engage community members from all areas concerned about wildland fire. This includes representatives from the timber industry as well as environmental groups. It is not uncommon to see Timber Industry Consultants at the same planning table as Sierra Club members. This collaborative approach to fuels management on public lands includes all interested parties from the beginning. The results we continue to see in central Oregon are broadly accepted fuels treatment projects that proceed without litigation and protest.

Deschutes County is also home to one of the first ten funded Collaborative Forest Landscape Restoration projects, which is restoring the federal forest to a more resilient condition while improving the fuel conditions in the WUI. Called the Deschutes Collaborative Forest Project (DCFP).

The CWPPs for Deschutes County can be found at www.projectwildfire.org

Emergency Operations Plans

The county and cities have Emergency Operations Plans (EOPs). The EOPs describe how the jurisdictions will organize and respond to emergencies and disasters. The plans include specific information related to wildfires.

Rangeland Fire Protection Associations

Rangeland Fire Protection Associations (RFPAs) provide wildfire protection of private land within Deschutes County. RFPAs (formed under ORS 477.315) protect over 3.2 million acres of private land in eastern Oregon with support from the Oregon Department of Forestry (ODF). RFPAs operate as independent associations of landowners that provide their own protection with the support of the ODF (chiefly technical support for grants, grant writing, procurement of equipment and firefighting training).[16] The ODF provides a small source of funding for the RFPAs, however, the majority of funds come from federal grants (primarily Volunteer Fire Assistance and Rural Fire Assistance). Additional fees are collected from voluntary membership dues. The RFPA has a responsibility to protect private lands of members and non-members alike per the agreement formed with ODF when the RFPA is formed.

The following two RFPAs are active within Deschutes County:

- Brothers-Hampton RFPA (established 2006)
- Post-Paulina RFPA (established 2006)

State

In part because of Deschutes County's 1990 Awbrey Hall Fire, the 1993 State Legislature initiated a process to identify wildfire hazard and declare wildfire hazard zones. The legislation provided a mechanism for counties to supersede local provisions requiring the use of flammable roofing materials such as wood shake. A second provision requires that addresses of structures be clearly identified. This process is complete in Deschutes County with the implementation of provisions in the Deschutes County Building Code. This is of particular significance because a combustible roof is the most vulnerable structure component to ember attack in interface wildfire situations. By Deschutes County Ordinance, installation of combustible roofing materials is no longer allowed on new structures or replacement roof systems.

The Oregon Forestland-Urban Interface Fire Protection Act of 1997 (Senate Bill 360)

Administered by the Oregon Department of Forestry (ODF), Senate Bill 360 enlists the aid of property owners toward the goal of turning wildland urban interface properties into less volatile zones where homes can survive and firefighters may more safely and effectively defend them against wildland fire. Senate Bill 360 applies only to interface areas on private land within the boundary of an Oregon State Department of Forestry District.

[16] Foster, Gordon. Oregon Department of Forestry. "Status of Rangeland Fire Protection Associations". 2011. http://www.oregon.gov/odf/fire/fpfc/rfawhite.pdf. Accessed March 2013.

The law requires property owners in identified areas to reduce excess vegetation around structures and along driveways. In some cases, depending on the rating classification of the property, it is also necessary to create additional fuel breaks along property lines and roadsides.

The process of identifying wildland urban interface areas follows steps and definitions described in Oregon Administrative Rules. Briefly, the identification criteria include:

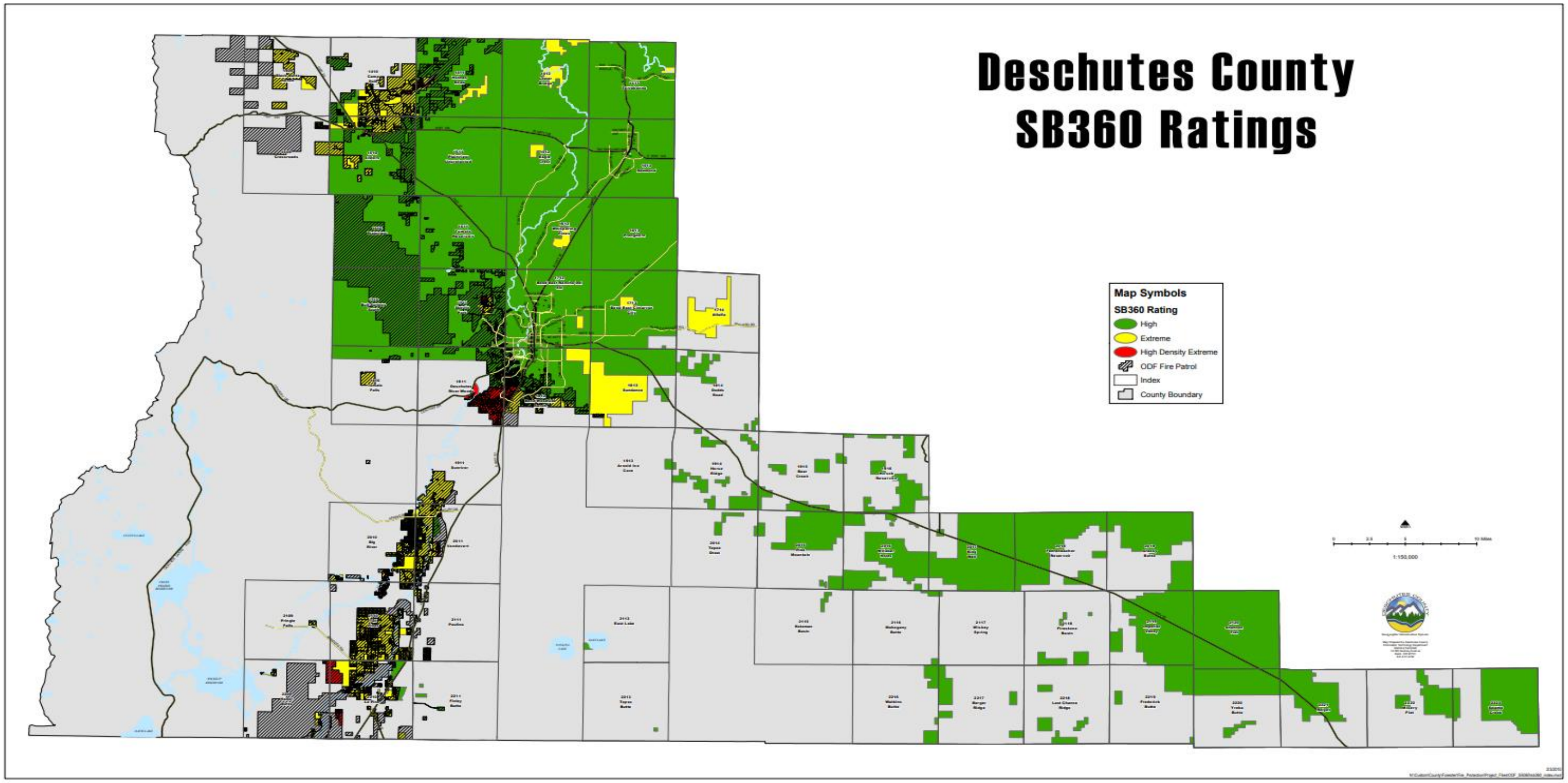
- Lands within the county that are also inside an Oregon Department of Forestry protection district.
- Lands that meet the state’s definition of “forestland.”
- Lands that meet the definition of “suburban” or “urban”; in some cases, “rural” lands may be included within a wildland urban interface area for the purpose of maintaining meaningful, contiguous boundaries.
- Lots that are developed, 10 acres in size or smaller, and which are grouped with other lots with similar characteristics in a minimum density of four structures per 40 acres.

A classification committee identified wildland urban interface areas in each county where Senate Bill 360 is applied. Once areas are identified, a committee applies fire risk classifications to the areas. The classifications range from “low” to “high density extreme," and the classification is used by a property owner to determine the size of a fuel break that needs to be established around a structure. The classification committee reconvenes every five years to review and recommend any changes to the classifications.

The Oregon Department of Forestry is the agency steward of this program. It supplies information about the act’s fuel reduction standards to property owners. ODF also mails each of these property owners a certification card, which may be signed and returned to ODF after the fuel reduction standards have been met. Certification relieves a property owner from the act’s fire cost recovery liability. This takes effect on properties that are within a wildland urban interface area and for which a certification card has not been received by the Department of Forestry. In these situations, the state of Oregon may seek to recover certain fire suppression costs from a property owner if a fire originates on the owner's property, the fuel reduction standards have not been met, and ODF incurs extraordinary suppression costs. The cost-recovery liability under the Oregon Forestland- Urban Interface Fire Protection Act is capped at $100,000.

In Deschutes County, Senate Bill 360 Ratings fall into High, Extreme and High-Density Extreme categories (see Figure II-22 below). The provisions of Senate Bill 360 also contain Optional Standards to accommodate a variety of circumstances and landowner preferences. Additional fuel breaks along property lines and roadsides are required for those properties that fall under the Extreme and High Density Extreme ratings.

Figure II-25 Deschutes County SB 360 Ratings



Source: Deschutes County Forester, 2021

Each of the Community Wildfire Protection Plans incorporates Senate Bill 360 ratings where appropriate to provide additional risk assessment information. It also incorporates the Senate Bill 360 standards when listing recommendations for defensible space and fuel breaks on private property:

- A minimum 30-foot primary fuel break around structures for properties rated High. Up to an additional 70 feet of fuel breaks are required depending on rating and roof composition. A fuel break consists of: Removal of dead/dry/flammable brush around home, roof, chimney, decks and under nearby trees; removal of low hanging branches on trees; and reposition of wood piles at least 20 feet away from home during fire season.
- A minimum fuel break of 12 feet wide and 13.5 feet tall along driveways are also required if they are over 150 feet long.

Federal

In 2002, President George Bush established the Healthy Forests Initiative (HFI) to improve regulatory processes to ensure more timely decisions, greater efficiency and better results in reducing the risk of high intensity wildfire. This initiative allowed forest management agencies for the first time, to expedite the environmental compliance process for the purpose of reducing hazardous fuels on public lands.

In 2003, the US Congress passed historical bi-partisan legislation: the Healthy Forests Restoration Act (HFRA). This legislation expands the initial effort under the Healthy Forests Initiative and directs federal agencies to collaborate with communities in developing a Community Wildfire Protection Plan (CWPP), which includes the identification and prioritization of areas needing hazardous fuels treatment. It further provides authorities to expedite the National Environmental Policy Act (NEPA) process for fuels reduction projects on federal lands. The act also requires that 50% of funding allocated to fuels projects be used in the wildland urban interface.[17]

At the time of compiling data, resources and information for the 2005 Natural Hazard Mitigation Plan, HFRA was new on the scene and the complete impact of its legislative reach was unknown.

As a result of the authorities under HFRA, communities in Deschutes County now have the opportunity to participate in advising where federal agencies place their fuels reduction efforts. With a Community Wildfire Protection Plan in place, community groups can apply for federal grants to treat hazardous fuels and address special concerns to reduce the risk of catastrophic loss as a result of wildland fire.

Although some of the authorities under the Healthy Forests Initiative have been subsequently challenged in federal courts, all have been successfully appealed and the original intent and authorities under each remain the same.

As the Deschutes County CWPPs are revised, the plans now include specific language regarding the National Cohesive Fire Management Strategy. In 2009, Congress passed the Federal Land Assistance, Management, and Enhancement (FLAME) Act and called for a National Cohesive

[17] "Healthy Forests Restoration Act of 2003" (H.R. 1904); One Hundred Eighth Congress; Administrative implementation information available at www.fireplan.gov.

Wildland Fire Management Strategy to address wildland fire related issues across the nation in a collaborative, cohesive manner. The Cohesive Strategy was finalized in 2014 and represents the evolution of national fire policy:

> "*To safely and effectively extinguish fire, when needed; use fire where allowable; manage our natural resources; and as a Nation, live with wildland fire.*"

The primary, national goals identified as necessary to achieving the vision are:

Resilient landscapes: Landscapes across all jurisdictions are resilient to fire-related disturbances in accordance with management objectives.

Fire-adapted communities: Human populations and infrastructure can withstand a wildfire without loss of life and property.

Wildfire response: All jurisdictions participate in making and implementing safe, effective, efficient risk-based wildfire management decisions.

Hazard Mitigation Action Items

There are four identified wildfire action items for Deschutes County; in addition, several of the Multi-Hazard action items affect the wildfire hazard. An action item matrix is provided within Volume I, Section 3, while action item forms are provided within Volume IV, Appendix A. To view city actions, see the appropriate city addendum within Volume III.

WINDSTORM

Significant Changes since the 2015 Plan

> Significant changes to this section include an updated definition of a windstorm and history of significant windstorms in 2020, a new section on Future Climate Variability, updated wind speed category, new information on wind conditions in relation to fire and damage, and additions to Causes & Characteristics. Tables II-13 and 14 were updated as well.

Causes and Characteristics of the Hazard

Extreme winds occur throughout Oregon. The most persistent high winds take place along the Oregon Coast and in the Columbia River Gorge. High winds in the Columbia Gorge are well documented. The Gorge is the most significant east-west gap in the Cascade Mountains between California and Canada. Wind conditions in central Oregon are not as dramatic as those along the coast or in the Gorge yet can cause dust storms or be associated with severe winter conditions such as blizzards. A majority of the destructive surface winds striking Oregon are from the southwest. Some winds blow from the east but most often do not carry the same destructive force as those from the Pacific Ocean. East winds can, however, create unusually volatile fire weather environments, especially through the Cascades. Additionally, if winds are fairly strong from the east/ northeast, the unusual wind direction can topple trees and other vegetation that is not used to/rooted for such winds.

Winds associated with thunderstorms are short-lived, but strong winds not associated with thunderstorms can last several hours. Although windstorms can affect the entirety of Deschutes County, they are especially dangerous in developed areas with significant tree stands and major infrastructure, especially above ground utility lines. A windstorm will frequently knock down trees and power lines, damage homes, businesses, public facilities, and create tons of storm related debris.

Though tornadoes are not common in Oregon, these events do occasionally occur and sometimes produce significant property damage and even injury. Tornadoes are the most concentrated and violent storms produced by earth's atmosphere, and can produce winds in excess of 300 mph. They have been reported in most of the counties throughout the state since 1887. Most of them are caused by intense local thunderstorms common between April and October. While tornadoes can result in much more severe damage than straight line winds, the damage is usually confined to a narrow path of a quarter mile or less. Damaging straight line winds pose a greater risk as they occur more frequently and over a broader area.

History of Windstorms in Deschutes County

The Columbus Day storm in 1962 was the most destructive windstorm ever recorded in Oregon in terms of both loss of life and property. Damage from this event was the greatest in the Willamette Valley, where the storm killed 38 people and left over $200 million in damage. Windstorms occur yearly; more destructive storms occur once or twice per decade. The following table shows windstorms that have affected Deschutes County between 1951 and 2020.

Table II-13 Partial History of Significant Windstorms (1951 to 2020)

Date	Affected Area	Comments
Nov., 1951	Statewide	Widespread damage, transmission and utility lines, wind speeds 40-60 mph, gust 75-80 mph
Dec., 1951	Statewide	Wind Speed up to 60 mph in Willamette Valley, 75 mph gusts; damage to building and utility lines.
Dec., 1955	Statewide	Wind speeds 55-65mph, with 69 mph gusts. Considerable damage to buildings and utility lines.
Nov., 1958	Statewide	Wind speeds up to 51 mph, with 71 mph gusts. Major highways blocked by fallen trees.
Oct., 1962	Almost all of Oregon	Oregon's most famous and most destructive windstorm, the Columbus Day Storm, produced a barometric pressure low of 960 mb
Mar., 1971	Most of Oregon	Storm center moved into NW Washington, bringing cold front heading east and damaging winds on March 26.
Nov., 1981	Pacific Northwest	Back-to-back storms on the 13th and 15th of November
Jan., 1990	Statewide	Severe windstorm
Dec., 1991	NE and Central Oregon	Severe windstorm
Dec., 1995	Statewide	Strongest windstorm since Nov. 1981; barometric pressure of 966.1 mb at Astoria, and an Oregon record low 953 mb off the coast; major disaster declaration FEMA-1107-DR-OR
Apr., 2003	Deschutes County	$10,000 in property damage
Nov., 2003	Deschutes County	$2,000 in property damage
Oct., 2005	Central Oregon	A strong wind gust blew a Ponderosa Pine tree over onto a home in southeast Bend. The property damage from this event is estimated at $50,000
Nov., 2005	Central Oregon	A strong wind gust blew over a Ponderosa Pine Tree which fell on two mobile homes causing extensive damage at Sisters Mobile Home Park. The property damage from this event is estimated at $40,000.
Jun., 2006	Jefferson, Deschutes, Crook Counties	Strong winds and hail caused $7 million in insurance claims for damage to automobiles and homes
Oct., 2007	Central Oregon	A cold front brought strong winds with gusts 40-50 mph which knocked down trees and power lines in Sisters. One tree fell onto a house.
Jan. 1, 2009	Central Oregon	A downslope windstorm generated high winds with gusts between 65 and 70 mph in and around Bend and other Central Oregon locations.
Mar. 31, 2009	Central Oregon	A strong low pressure system brough high winds to areas east of the Cascades. Wind gusts of 70-75 mph occurred north of Sisters with damage to trees, power lines, and blowing dust.
May 3, 2010	Central Oregon	Damaging winds toppled trees and power lines in the Bend area.
Nov. 22, 2011	Central Oregon	A strong storm system brought damaging winds that toppled trees and power lines in the Bend and Sisters area, and forced the closure of Shevlin Park.
Nov. 19, 2012	Central Oregon	Widespread strong winds toppled several trees in the Bend area, knocking down several trees and power lines.
May 4, 2013	Deschutes County	Strong winds brought down numerous trees and some power lines, resulting in a fast moving grass fire that burned 160 acres.
Jan. 11, 2014	Deschutes County	High winds with a strong cold front resulted in downed trees and power lines with outages affecting over 10,000 people. Wind gusts were measured around 60 mph.
Dec. 11, 2014	Central Oregon	A powerful storm system generated downslope winds of 60 mph, resulting in downed trees and power lines around the Bend and Redmond areas.
Feb. 6-9, 2015	Central Oregon	Two wind events occurred back to back, one associated with a warm front on the 6th, and another on the 9th associated with a downslope wind storm off the Cascades. In both instances, wind gusts of 55-60 mph occurred across parts of Deschutes County, damaging trees and power lines.
Nov. 17, 2015	Central Oregon	A strong low pressure system brought wind gusts of 60 to 65 mph to the region.
Dec. 7, 21, 2015	Central Oregon	A downslope wind event onthe 7th brought 60 mph winds, downing several trees and causing power interruptions. On the 21st, winds of 60-65 mph were felt in Deschutes county with a measured gust to 64 mph at the Redmond Airport. Tree damage was also reported at Tumalo.

Table II-13 Partial History of Significant Windstorms (1951 to 2020) cont.

Date	Affected Area	Comments
Dec. 19, 2017	Deschutes County	A strong cold front brought damaging wind guststs to Deschutes County. Numerous trees and power lines were affected in and around Bend, resulting in power loss to around 2000 people.
Feb. 17, 2018	Deschutes County	A powerful storm system brought damaging wind gusts to portions of Deschutes County. A wind gust of 66 mph was recorded 1 mile NNE of Sisters with at least one large tree blown down.
Aug. 9, 2019	Deschutes County	Thunderstorms produced quarter sized hail and wind gusts to 60 mph, leading to minor roof damage on the west side of Redmond.
Feb. 23, 2020	Deschutes County	A strong cold front brought intense winds to much of Central Oregon. Winds of 45 to 55 mph were common with the stronger gusts around 60 mph affecting Bend. Downed trees and lines resulted in power outages and some minor damage to homes and vehicles.
May 30, 2020	Deschutes County	A significant severe thunderstorm moved from south to north on the west side of highway 97. The storm brought hail to the size of golfballs to baseballs and damaging straight line winds of 70 to 90 mph. The winds downed numerous trees and power lines, resulting in some structural damage as well.

Sources: Oregon State Natural Hazard Mitigation Plan 2020; Taylor, G.H. and Hatton, R.R., 1999; The Oregon Weather Book, A State of Extremes: Corvallis, Oregon, Oregon State University Press; NOAA Storm Events Database http://www.ncdc.noaa.gov/stormevents/. Accessed April 2021.

Future Climate Change Variability

Research into current links between climate change and wind are ongoing, but results and/or data into these studies may still be a few years out.

Hazard Identification

Windstorms can affect developed areas of the county with significant tree stands and major infrastructure, especially above ground utility lines. The lower wind speeds typical of eastern Deschutes County can still be high enough to knock down trees and power lines, and cause other property damage.

As of the 2014 Oregon Residential Specialty Code, Oregon Basic Wind Speeds for 50 Year Mean Recurrence Interval, Deschutes County is listed within the lowest wind speed category as an area impacted by 65 mph area wind speeds.

For winter weather events (including high winds,) the National Weather Service monitors gauging stations and provides public warnings for storms and high winds.

Windstorms in Deschutes County usually occur from October to March, and their extent is determined by their track, intensity (the air pressure gradient they generate), and local terrain.[1] The National Weather Service uses weather forecast models and local and regional observations

[1] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2020.

to predict oncoming windstorms, while monitoring storms with weather stations in protected valley locations throughout Oregon.[2]

Extreme weather events are experienced in all regions of Oregon. The regions that experience the highest wind speeds are in the Central and North Coast of Region 1. The table below shows the wind speed probability intervals that structures 33 feet above the ground would expect to be exposed to within a 25, 50 and 100 year period. The table shows that structures in Deschutes County, within Region 6, can expect to be exposed to lower wind speeds than most regions within the state.

Table II-14 Probability of Severe Wind Events by NHMP Region

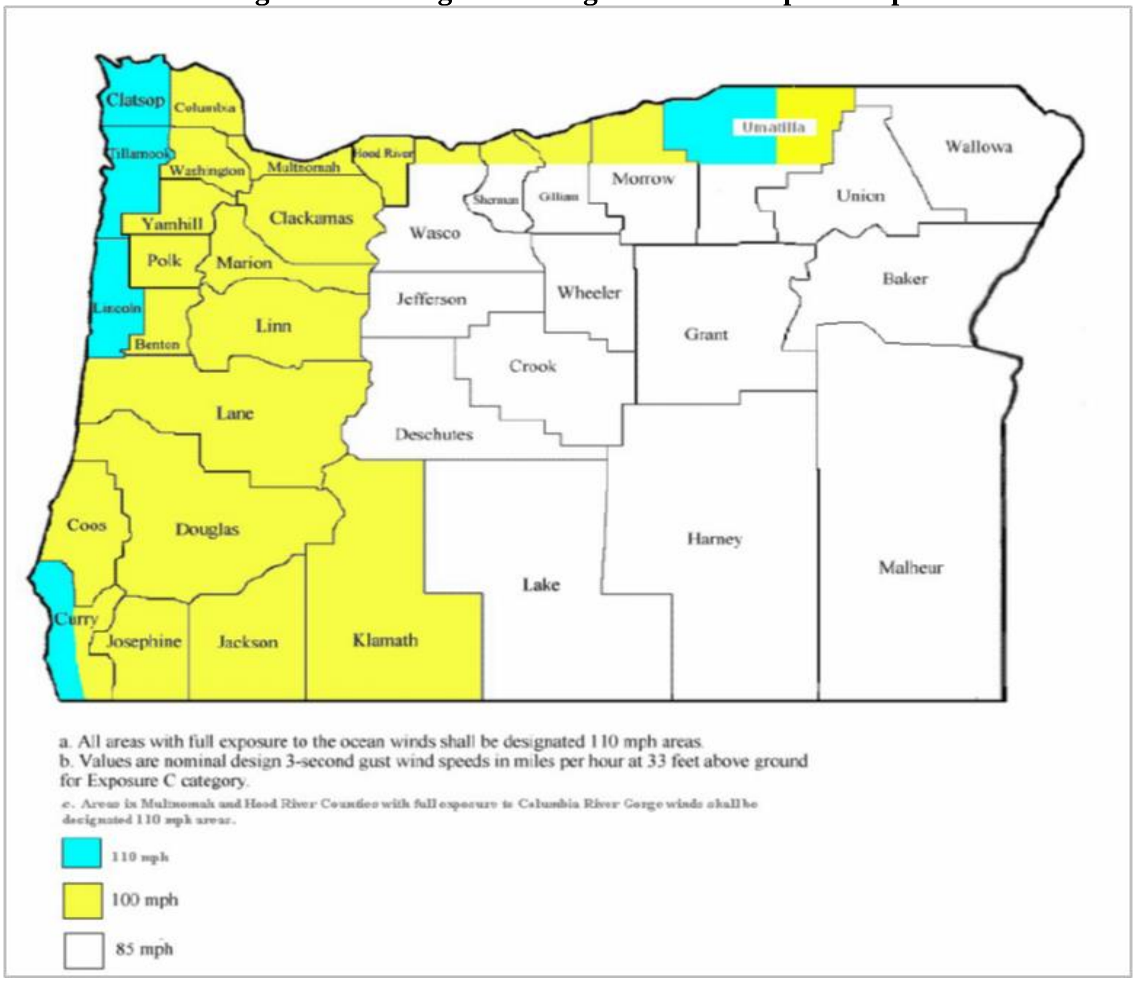
	25-Year Event (4% annual probability)	50-Year Event (2% annual probability)	100-Year Event (1% annual probability)
Region 1: Oregon Coast	75 mph	80 mph	90 mph
Region 2: North Willamette Valley	65 mph	72 mph	80 mph
Region 3: Mid/Southern Willamette Valley	60 mph	68 mph	75 mph
Region 4: Southwest Oregon	60 mph	70 mph	80 mph
Region 5: Mid-Columbia	75 mph	80 mph	90 mph
Region 6: Central Oregon	60 mph	65 mph	75 mph
Region 7: Northeast Oregon	70 mph	80 mph	90 mph
Region 8: Southeast Oregon	55 mph	65 mph	75 mph

Source: Oregon State Natural Hazard Mitigation Plan, 2020

Figure II-23 visualizes the maximum wind speed that structures 33 feet above the ground would expect to be exposed to; for Deschutes County that expected wind speed is less than most of the state at 85 mph.

[2] "Some of the Area's Windstorms." National Weather Service, Portland. https://www.wrh.noaa.gov/pqr/paststorms/wind.php

Figure II-26 Oregon Building Codes Wind Speed Map



Source: Oregon Residential Specialty Code, 2014.

Probability Assessment

Windstorms affect Deschutes County on nearly a yearly basis. More destructive storms occur once or twice per decade. According to the State NHMP Region 6 – Central Oregon where Deschutes County is located is likely to experience windstorms of 60 mph during a 25-year cycle. It should be noted that some of the report incidents are localized events that do not affect large areas of the county or cities.

Deschutes County's Natural Hazards Mitigation Steering Committee believes that the County's **probability of experiencing a windstorm event is "high,"** meaning one incident is likely within the next 10 – 35 year period. Based upon available information, the Oregon NHMPs Regional Risk Assessment supports this probability rating for Deschutes County.[3]

[3] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2020.

Vulnerability Assessment

Many buildings, utilities, and transportation systems within Deschutes County are vulnerable to wind damage. This is especially true in open areas, such as natural grasslands or farmlands. It is also 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 of time, impacting emergency operations. In addition, up-rooted or shattered trees can down power and/or 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. In Deschutes County, trees are more likely to blow over during the winter (wet season). Also, irrigation wheel lines frequently get tangled in windstorms, and ultimately affect the agriculture economy.

The Deschutes County Natural Hazards Steering Committee rated Deschutes County as having a **"moderate" vulnerability to windstorm hazards**; meaning between one and ten-percent of the region's population or assets would be affected by a major emergency or disaster (particularly if utility lines are damaged). Based upon available information the Oregon NHMPs Regional Risk Assessment rates Deschutes County's vulnerability to windstorms as "low".[4]

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I) shows the county's Hazard Analysis Matrix which scores each hazard and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **windstorm hazard is rated #3, out of 9 rated hazards, with a total score of 210**.

Community Hazard Issues

The damaging effects of windstorms may extend for distances of 100 to 300 miles from the center of storm activity. Positive wind pressure is a direct and frontal assault on a structure, pushing walls, doors, and windows inward.

Negative pressure also affects the sides and roof: passing currents create lift and suction forces that act to pull building components and surfaces outward. The effects of winds are magnified in the upper levels of multi-story structures. As positive and negative forces impact and remove the building protective envelope (doors, windows, and walls), internal pressures rise and result in roof or leeward building component failures and considerable structural damage.

[4] Ibid.

Windstorms can result in collapsed or damaged buildings, damaged or blocked roads and bridges, damaged traffic signals, streetlights, and parks, among others. Roads blocked by fallen trees during a windstorm may have severe consequences to people who need access to emergency services. Emergency response operations can be complicated when roads are blocked or when power supplies are interrupted.

Historically, falling trees have been the major cause of power outages in Deschutes County. Overhead power lines can be damaged even in relatively minor windstorm events.

Industry and commerce can suffer losses from interruptions in electric service and from extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from windstorms related to both physical damages and interrupted services.

Windstorms can be particularly damaging to manufactured homes and other non-permanent housing structures, which, in 2012, accounted for 9.1% of the housing units in Deschutes County, special attention should be given to securing these types of structures.

More information on this hazard can be found in the Regional Risk Assessment for Region 6 of the Oregon NHMP.

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

County and Cities

The county, cities, and utility districts routinely maintain hazard trees to keep utility lines and other infrastructure safe from damage in wind events.

State

The Oregon Building Code (both residential and other codes) sets standards for structures to withstand 80 mph winds. It is based on the International Residential Code and the International Building code.

Existing strategies and programs at the state level are usually performed by Public Utility Commission (OPUC), Building Code Division (BCD), Oregon Department of Forestry (ODF), Oregon Emergency Management (OEM), Oregon Department of Transportation (ODOT), and the Oregon Emergency Response System (OERS), who all have vital roles in providing windstorm warnings statewide.

The Public Utility Commission ensures the operators manage, construct and maintain their utility lines and equipment in a safe and reliable manner. These standards are listed on the following website: http://www.puc.state.or.us/PUC/safety/index.shtml

The OPUC promotes public education and requires utilities to maintain adequate tree and vegetation clearances from high voltage utility lines and equipment.

Oregon Emergency Management strives to reduce any damage and impacts caused by windstorms by working in partnership with PUC, ODOT, and the NWS. ODF promotes mitigation strategies and programs that reduce tree-caused damage to utility systems and highway corridors.

Federal

FEMA has recommended having a safe room in homes or small businesses to prevent residents and workers from "dangerous forces" of extreme winds to avoid injury or death. This recommendation is provided through FEMA's resource manual: *Taking Shelter from the Storm*.[5]

Hazard Mitigation Action Items

There are no Windstorm action items for Deschutes County as of 2021; however, several of the Multi-Hazard action items affect the Windstorm hazard. An action item matrix is provided within Volume I, Section 3, while action item forms are provided within Volume IV, Appendix A. To view city actions, see the appropriate city addendum within Volume III.

[5] http://www.fema.gov/safe-room-resources/fema-p-320-taking-shelter-storm-building-safe-room-your-home-or-small-business

WINTER STORM

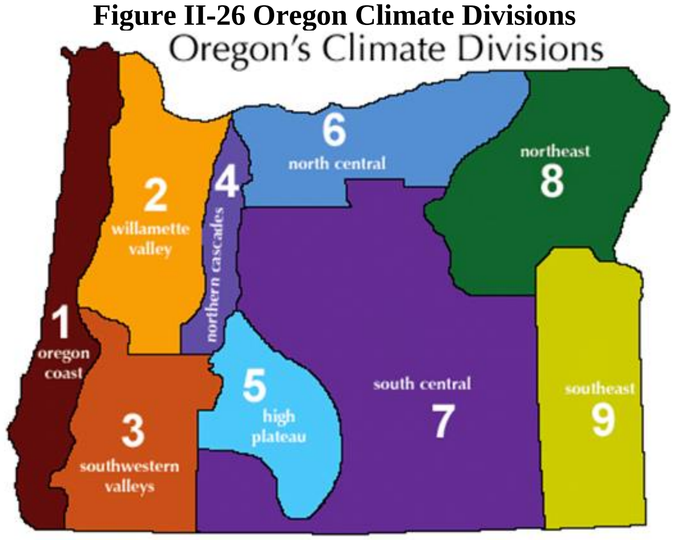
Significant Changes since the 2015 Plan

Partners with the National Weather Service provided updated information for table II-15, history of winter storms. Additionally, minor formatting changes occurred.

Causes and Characteristics of Winter Storms

The National Climatic Data Center has established climate zones in the United States for areas that have similar temperature and precipitation characteristics. Oregon's latitude, topography, and proximity to the Pacific Ocean give the state diversified climates. Deschutes County is primarily located within Zone 7: South Central Area, south and western portions of the county are located within Zone 5: High Plateau. The climate in Zone 7 generally consists of wet winters and dry summers.[1] These wet winters result in potentially destructive winter storms that produce heavy snow, ice, rain and freezing rain, and high winds. Severe storms affecting Oregon with snow and ice typically originate in the Gulf of Alaska or in the central Pacific Ocean. Winter storms occur over eastern Oregon regularly during November through February.[2] Cold arctic air sinks south along the Columbia River basin, filling the valleys with cold air.[3]

Figure II-26 Oregon Climate Divisions



Source: Oregon Climate Service

The principal types of winter storms that occur in Deschutes County include:

[1] Oregon Climate Service, "Climate of Deschutes County,"
[2] Oregon State Natural Hazards Mitigation Plan "Winter Storms Chapter", 2020
[3] Ibid

Snow Storm

Snowstorms require three ingredients: cold air, moisture, and an upper or lower level storm system. The result is snow, small ice particles that fall from the sky. In Oregon, the further inland and north one moves, or the higher in elevation, the more snowfall can be expected. Blizzards are included in this category.

Ice Storms

Ice storms are a type of winter storm that forms when a layer of warm air is sandwiched by two layers of cold air. Frozen precipitation melts when it hits the warm layer, and refreezes when hitting the cold layer below the inversion. Ice storms can include sleet (when the rain refreezes before hitting the ground) or freezing rain (when the rain freezes once hitting the ground).

Extreme Cold

Dangerously low temperatures accompany many winter storms. This is particularly dangerous because snow and ice storms can cause power outages, leaving many people without adequate heating.

History of Winter Storms in Deschutes County

Destructive storms producing heavy snow, ice and cold temperatures occurred throughout the County's history, most notably in 1916, 1920, 1937, 1950, 1985, 1986, 1988, 1990, 1992-93 and the winter of 1998-99. More recently, the winters of 2010-11, 2013-14, 2016-17, and 2019 were especially active with numerous winter storm occurrences. All of these active storm years were marked by drifting snow and cold temperatures. Records also indicate people and communities were generally prepared and equipped to cope with the extreme weather conditions.

The severe winter storm of 1950 impacted the entire state of Oregon. While many places experienced high winds, cold weather and snow, the impact in Deschutes County was high snowfall and drifts. Transportation of supplies imported to the Deschutes Basin was limited. In general, Deschutes County and the region are well prepared for severe winter storms thus reducing the impact of inclement weather.[4] The most significant storms which have affected Deschutes County and neighboring counties are listed below:

[4] Taylor, George H. and Hannan, Chris, The Oregon Weather Book, (1999) Oregon State University Press.

Table II-15 Significant Winter Storm History for Deschutes and Nearby Counties

Date	Location	Event	Comments
Dec. 22, 1861	Pacific Northwest	Snowstorm Cold Weather	Very snowy winter; temperatures ranged from 0°F to -30° F. Over ten thousand cattle in eastern Oregon and Washington starved to death. Storm produced between 1 and 3 feet of snow.
Jan. 11-15, 1916	Entire State	Snowstorm	Two storms. Heavy snowfall, especially in mountaneous areas; coldest winter on record since record keeping began.
Dec. 15-16, 1924	Entire State	Cold Weather	Coldest December on record at the time; Drewsey and Riverside set a state record for lowest temperature at -53° F
Jan. 20-25, 1927	Entire State	Cold Weather	Harney Experiment Station reached -36° F
Feb. 1933	All of Oregon	Cold Weather	Coldest February to date for eastern Oregon. Seneca and Ukiah reached -54°F, all time records for Oregon.
Jan. 31 - Feb. 4, 1937	Statewide	Snowstorm	Heavy snows throughtout state.
mid Jan.- Feb., 1950	Across the State	Ice/Snowstorm Cold Weather	Extremely low temperatures for nearly two months; heaviest snowfalls since 1890; blizzard conditions from Jan. 9 to 18. Halted all traffic for three days and people were moved to safety by railway.
Mar. 1-2, 1960	Entire State	Snowstorm	Heavy snow throughout state. Four known injuries, but no fatalities. Major traffic jams.
Jan. 25-30, 1969	Entire State	Snowstorm	Heavy snow throughout state
Jan. 9-11, 1980	Entire State	Snowstorm	Series of string storms across state. Many injuries and power outages.
Feb. 7-8, 1985	Entire State	Snowstorm	Heavy snow throughout state
Feb. 1986	Central/Eastern Oregon	Snowstorm	Heavy snow. Traffic accidents; broken power lines
Mar. 23, 1988	Entire state	Snowstorm	Strong winds; heavy snow.
Feb. 1-8, 1989	Entire State	Snowstorm Cold Weather	Heavy snow and cold temperatures throughout state.
Feb. 11-16, 1990	Entire State	Snowstorm Strong Winds	Heavy snow throughout state
Jan. 6-7, 1991	All of eastern Oregon	Snowstorm	The higher lands of eastern Oregon accumulated between 1 and 6 inches of new snow. Two traffic related fatalities.
Nov. 1993	Cascade Mountains	Snowstorm	Heavy snow throughout region
Feb. 10, 1994	Southeastern Oregon	Snowstorm	Heavy snow throughout the region.
Jan. 16-18, 1996	Columbia Gorge, Willamette Valley	Ice/Snowstorm Cold Weather	Cold air funneling through the Columbia River Gorge with overruning moisture created freezing rain with heavy accumulations of glaze ice. Scattered power outages and minor traffic accidents.
Feb. 2-4, 1996	Columbia Gorge, Willamette Valley	Ice Storm	A warm front overrunning cold air produced an ice storm that caused widespread disruptions of traffic and power outages. Numerous traffic accidents and one fatality.
Winter 1998-99	Entire State	Snowstorm	One of the snowiest winters in Oregon history (Snowfall at Crater Lake: 586 inches)
Jan. 10, 2000	Central Oregon	Heavy Snow	11 inches of new snow fell in La Pine at an elevation of 4,200 ft. This storm led to a fatality when icy roads caused a collision between a car and a logging truck on Highway 26 at the Ochoco Resevoir east of Prineville.
May 6, 2002	Central Oregon	Extreme Cold Wind Chill	Area low temperatures dipped into the mid teens and 20s across central and north central Oregon.
Oct. 30-31, 2002	Central Oregon	Extreme Cold Wind Chill	An artic front moved through the region bringing much colder temperatures. Many locations broke all time records for the month of October. Madras saw a low of -2 degrees Fahrenheit.
Dec. 2003- Jan 2004	Most of Oregon	Snowstorm	Preliminary damage assessments from this event estimated almost $16 million dollars in impacts to state and local agencies across most of Oregon
Nov. 2005	Jefferson County	Snowstorm Cold Weather	Snow fall and dropping temperatures halted road extension projects on J Street.

Table II-15 Significant Winter Storm History for Deschutes and Nearby Counties (cont.)

Date	Location	Event	Comments
Nov. 2006	Jefferson County	Snowstorm	Heavy snow caused sport cancellations.
Jan. 2008	Statewide	Snowstorm Cold Weather	Heavy snow and single digit weather.
Jan. 4-5, 2004	Central Oregon	Cold Wind Chill	An artic air mass moved south out of British Columbia, setting daily record low temperatures for january 5th. Meacham broke an all time recorn low temperature on the morning of January 5th, with a low temperature of -31 degrees Fahrenheit.Madras saw a record low of -4. The corld temperatures and slick roadways resulted in several school closures and cancellations.
Apr. 17, 2006	Central Oregon	Heavy Snow	Heavy snow hit the south and east parts of Bend with 8 to 11 inches of snow.
Dec. 18-24, 2008	Central Oregon	Heavy Snow	Moist Pacific air over running Artic air at the surface led to heavy snowfall.
Dec. 31, 2009	Central Oregon	Heavy Snow	A surge of moist Pacific air brought heavy snowfall. Camp Sherman saw 5 inches.
Jan. 24, 2010	Central Oregon	Heavy Snow	A moist Pacific disturbance brought heavy snowfall to northcentral and central Oregon. Snowfall amounts in inches include: Camp Sherman (7).
Apr. 2, 2010	Central Oregon	Heavy Snow	A strong cold front and associated upper level trough brought late season heavy snow.
Nov. 21-24, 2010	Central Oregon	Heavy Snow and Cold Temperatures	A powerful arctic front brought widespread heavy snow to much of Central Oregon. Snow totals ranged from 7 to 10+ inches in many areas including Bend and La Pine. Camp Sherman saw nearly a foot. In the wake of the heavy snow, bitter cold settled in with sub-zero low temperatures on Nov 24.
Dec. 17-18, 2010	Central Oregon	Heavy Snow	Abundant Pacific moisture combined with very cold temperatures to bring heavy snow to northern and central Oregon. Snow totals ranged from 6 to 10 inches with 8 inches near Redmond, just under 7 inches in Madras, and 9 inches at Camp Sherman.
Dec. 14-15, 2011	Central Oregon	Heavy Snow	A Pacific storm system and slow moving Arctic front brought a prolonged period of snow to the region. Snow totals of 6 to 10 inches were observed in many areas including Bend, Redmond, Tumalo, and Camp Sherman.
Jan. 17-18, 2012	Northern and Central Oregon	Heavy Snow	A series of storm systems interacted with an Arctic front to bring several waves of moderate to heavy snow to the region. Snow totals ranged from 8 to 15+ inches. Camp Sherman recorded 16 inches with totals ranging from 6 to 10 inches in many other areas including Bend, Black Butte Ranch, and La Pine.
Feb. 24-25, 2012	Central Oregon	Heavy Snow	A winter storm system brought a bout of heavy snow to some areas. 6 to 10 inches of snow fell from Sunriver to Camp Sherman.
Mar. 20-21, 2012	Central Oregon	Heavy Snow	A late season winter storm pummeled portions of Central Oregon. Snow totals ranged from 8 to 12 inches in many areas including Camp Sherman (12 inches), Culver (7.5 inches), and Black Butte Ranch (10 inches).
Feb. 6-8, 2014	Central Oregon	Heavy Snow	A series of storm systems brought several waves of moderate to heavy snow to the region with snow totals of 10 to 20+ inches. Select observations include Camp Sherman (22 inches), in and around Bend (16-18 inches), and Warm Springs (14 inches).
Nov. 12-14, 2014	Northern and Central Oregon	Ice and Heavy Snow	A warm frontal system and abundant moisture interacted with a shallow Arctic airmass, bringing a mixed mode of freezing rain and snow. Freezing rain eventually transitioned to heavy snow with hefty accumulations in many areas. Ice accumulations ranged from 0.5 to 1 inch, with nearly an inch observed in Bend. Snow totals include 20 inches near Redmond, 21 inches in Sisters, and 19 inches east of Prineville.

Table II-15 Significant Winter Storm History for Deschutes and Nearby Counties (cont.)

Date	Location	Event	Comments
Dec. 14-15, 2016	Entire State	Heavy Snow	A powerful Pacific storm system brough abundant moisture into the region. With cold air in place, many areas of northern and central Oregon saw moderate to heavy snow.
Jan. 3-4, 2017	Central Oregon	Heavy Snow	A strong winter storm system brought bouts of heavy snow to much of central and east-central Oregon.
Feb 7-9, 2017	Northern and Central Oregon	Heavy Snow, Sleet, and Freezing Rain	A slow moving winter storm brought widespread wintry precipitation to the Inland Northwest, including Oregon. Substantial snow accumulations occurred in many areas, including Central Oregon.
Nov. 10-11, 2017	Northern and Central Oregon	Heavy Snow	A strong upper storm system moved across southern Oregon, resulting in heavy snow banding across much of northern and central Oregon. This resulted in widespread heavy snow accumulations.
Mar. 1-2, 2018	Northern and Central Oregon	Heavy Snow	A late season winter storm brough snow to much of Oregon with moderate to heavy accumulations in Central and northern Oregon.
Feb. 3-4, 2019	Northern and Central Oregon	Heavy Snow	A series of winter storm systems brought hefty snow accumulations to the higher elevations of the Cascades and Blue Mountains and their adjacent slopes. This included moderate to heavy accumulations in and around Central Oregon.
Feb. 9-10, 2019	Northern and Central Oregon	Heavy Snow	A powerful Pacific storm collided with Arctic air to bring moderate to heavy snow to many areas. Snow totals of 6 to 12 inches were recorded in many areas of Central Oregon.
Feb. 23-25, 2019	Northern and Central Oregon	Heavy Snow	southwesterly flow continued to bring moisture into an unseasonably frigid airmass east of the Cascades. This resulted in multi-day snow totals of 1 to 3 feet in some areas including Sisters (40 inches), Bend (33 inches), Redmond (30 inches), and Prineville (22 inches). The heavy snow resulted in at least a couple roof failures in the Bend area.
Nov. 26-27, 2019	Central Oregon	Heavy Snow	An early season winter storm brought snow totals of 6 to 10 inches to many areas of Central Oregon.
Feb. 12-16, 2021	Northern and Central Oregon	Heavy Snow	Several storm systems moved into the Inland Northwest in the wake of an unusually cold Arctic intrusion. This resulted in several rounds of moderate to heavy snows across much of northern, central, and eastern Oregon. Heavy snow fell in many areas with total accumulations up to 10 to 24 inches.

Sources: Oregon Weather Book, NOAA Storm Events Database, http://www.ncdc.noaa.gov/stormevents/, Accessed April 30, 2021.

In recent years, the challenge facing the region is the significant increase in population and growth in tourism as a local industry. Both of these shifts have generally brought new populations to the area, particularly with little or no experience with living and working in severe winter weather. This condition impacts shelter, access to medical services, transportation, utilities, fuel sources and telecommunication systems. In severe winter storm conditions, travelers must seek accommodations, sometimes in communities where lodging is limited or overextended. A significant amount of supplies including food and fuel are transported into the Deschutes Basin and in severe winter conditions, these necessities are often limited when road conditions are unfavorable. Likewise, unfavorable road conditions make emergency response operations more difficult for a more fragile population.

Recent shifts in climate patterns beginning in the 1960's have resulted in snowfall and cold weather shifts. While there have been record snowfalls, they are less frequent. The number of severe cold days has been fewer and less frequent. Fluctuating temperatures within storm events also creates the likelihood of ice dams, which can result in an increased flood threat as snows melt.

Hazard Identification

Winter storms occur in all parts of the county. The extent depends upon air temperatures, the level of moisture in the atmosphere, and elevation.

A severe winter storm is generally a prolonged event involving snow and cold temperatures. The characteristics of severe winter storms are determined by the amount and extent of snow, air temperature, and event duration. Severe storms have various impacts in different parts of the county. There may be a 20 degree temperature difference from Terrebonne in the north part of the county and La Pine in the south part of the county. The National Weather Service Pendleton office monitors the stations and provides public warnings on storm, snow and cold temperature events as appropriate.

Probability Assessment

The recurrence interval for significant winter storms throughout Oregon is about every 13 years; however, there can be many localized storms between these periods. Winter storms do occur in eastern Oregon regularly from November through February. Deschutes County experiences winter storms a couple times every year, to every other year.

Deschutes County's Natural Hazards Mitigation Steering Committee believes that the County's **probability of experiencing a winter storm event is "high",** meaning one incident is likely within the next 10 – 35 year period. Based upon available information the Oregon NHMPs Regional Risk Assessment supports this probability rating for Deschutes County.[5]

Vulnerability Assessment

Perhaps the most advantageous aspect of Central Oregon's cold and snowy winters is the fact that the region is typically prepared, and those visiting the region usually come prepared. As can be expected, however, there are occasions when preparation cannot meet the challenge. In Deschutes County, extreme cold and heavy snow can disrupt farming practices. Likewise, schools have trouble heating their buildings. The constant freezing and melting of snow around manholes often lead to potholes, and power outages can be frequent in adverse weather. Finally, extreme cold can cause breaks in water pipelines when temperatures drop below 10 F. Specific estimates of property and infrastructural damages for winter storm events are not available at this time.

The Deschutes County Natural Hazards Steering Committee rated Deschutes County **as having a "high" vulnerability to winter storm hazards**; meaning that more than 10% of the region's population or assets would be affected by a major emergency or disaster. Based upon available information the Oregon NHMPs Regional Risk Assessment supports this vulnerability rating for Deschutes County.[6]

[5] *2020 Oregon Natural Hazard Mitigation Plan*. Department of Land Conservation and Development, 2020.
[6] Ibid.

Risk Analysis

The risk analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period of time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section), and (2) the likelihood or probability of the harm occurring. Table 2-6 of the Risk Assessment (Volume I) shows the county's Hazard Analysis Matrix which scores each hazard and provides the jurisdiction with a sense of hazard priorities, but does not predict the occurrence of a particular hazard. Based on the matrix the **winter storm hazard is rated #1, out of 9 rated hazards, with a total score of 230**.

Community Hazard Issues

Life and Property

Severe winter storms contribute to threats on life and property. Injury and death are often associated with traffic accidents on snow and/or ice covered roads, physical exertion linked to shoveling snow and other activities involved in traveling through snow, and hypothermia from prolonged exposure to the cold. When streets and roads are affected by severe snow and ice, emergency vehicles including police, fire and medical may experience difficulty in reaching targeted destinations.

Roads

County, state, city and many private roads are routinely monitored for snow and ice. Jurisdictions and many private landowners in the rural-urban interface plow snow on a regular basis. Extreme snowfall and ice conditions usually place more demand on local jurisdictions, staff and budgets. Impassable roads hamper emergency response operations.

Power Lines

Extreme cold temperatures have caused power outages that interrupt services and damage property. Many outlying ranches and farms have generators and are generally self- sufficient in these events. However as the general population becomes more urban, fewer numbers of people have resources such as wood stoves, a traditional backup source for heat. Rising population growth and new infrastructure, particularly tourism related, create higher probability for damage to occur from severe winter storms as more life and property are exposed to risk.

Water Lines

The most frequent water system problems related to extreme cold weather are breaks in water mainlines. Breaks occur during severe cold events impacting residents and business. Inadequate insulated potable water and fire sprinkler pipes can rupture and cause extensive damage to property. Aligned with the extreme population growth, Deschutes County has a significant number of new residential and commercial structures which have been built under current codes that recognize severe cold weather conditions.

Creek flooding within a single storm event, or between events and fluctuating temperatures may lead to the buildup of ice dams in creeks. In the winter of 2003, an ice dam release on Whychus Creek caused ice and debris to build up and recede on the creek as it passed through Sisters. This release caused the creek level to rise to its high water mark, but broke loose before flooding homes.

More information on this hazard can be found in the Regional Risk Assessment for Region 6 of the Oregon NHMP.

Existing Authorities, Policies, Programs, and Resources

Existing authorities, policies, programs, and resources include current mitigation programs and activities that are being implemented by city, county, regional, state or federal agencies and/or organizations.

County and Cities

County and municipal Public Works and Road Departments have plans in place to mitigate and respond to severe winter storms. The plans are updated annually and routinely implemented. Utility companies have existing restoration plans that include routine upgrade and repair, emergency restoration, and public education. Additionally, schools and employers of large scale businesses and agencies have "snow-day" plans. These schedules routinely plan a minimum of five to eight "snow-days" per year.

State

Studded tires can be used in Oregon from November 1 to April 1. They are defined under Oregon Law as a type of traction tire. Research shows that studded tires are more effective than all-weather tires on icy roads, but can be less effective in most other conditions.

Highway maintenance operations are guided by local level of service (LOS) requirements. In general, classifications of highways receive more attention. Routes on the National Highway System network, primary interstate expressways and primary roads, will be cleared more quickly and completely. In Deschutes County, this includes Highway 97 and Highway 26. Critical areas like mountain passes will have snow-chain requirements for vehicles, and many local streets are "snow emergency routes" that will be cleared of parked cars. Parking lot and sidewalk snow removal is mostly the responsibility of property owners, sometimes by local ordinance.

Oregon Department of Transportation (ODOT) spends about $16 million per year on snow and ice removal from the state highway system though winter maintenance practices. These practices include: snow plowing, sanding roadways for ice, and using anti-icing chemicals.

Through the educational collaboration between the Oregon Department of Forestry and the Pacific Northwest Chapter, International Society of Arboriculture (ISA) the *How to Recognize and Prevent Tree Hazards* activity brochure was created.

TripCheck provides traffic incident, weather, and highway condition reports, as well as useful links to bus, rail, airport, and truck information. The website provides road condition images from approximately 140 road cameras, including over 40 in rural areas such as mountain passes where knowing road conditions can be crucial to safety: http://www.TripCheck.com/.

Federal

The National Weather Service issues winter storm watches and warnings when appropriate to alert government agencies and the public of possible or impending weather events. The watches and warnings are broadcast over NOAA weather radio and are forwarded to the local media for retransmission using the Emergency Alert System. They also work closely with county and local officials to identify mitigation and risk management strategies, and provide briefings and support leading up to and during such events.

Hazard Mitigation Action Items

There are three identified winter storm action items for Deschutes County; in addition, several of the multi-hazard action items affect the winter storm hazard. An action item matrix is provided within Volume I, Section 3, while action item forms are provided within Volume IV, Appendix A. To view city actions see the appropriate city addendum within Volume III.