Volume II: Hazard Annexes

List of Figures

List of Tables

WILDFIRE HAZARD ANNEX

Causes and Characteristics of Wildfire

Countywide exposure

- Number of buildings: **2,692**
- Exposure Value: **$588,264,000**
- Ratio of Exposure Value: **29%**
- Critical facilities exposed: **5**
- Potentially Displaced Population: **1,446**

The majority of wildfires primarily occur in Eastern and Southern Oregon. Fire is an essential part of Oregon's ecosystem, but it is also a serious threat to life and property particularly in the state's growing rural communities. Wildfire is defined as am uncontrollable burning of forest, brush, or rangeland. Fire has always been a part of high desert ecosystems and can have both beneficial and devastating effects.[1]

Wildfires threaten valued forest and agricultural lands and individual home sites. State or federal firefighters provide the only formal wildfire suppression service in some areas, and they do not protect structures as a matter of policy. As a result, many rural dwellings have no form of fire protection. Once a fire has started, homes and development in wildland settings complicate firefighting activities and stretch available human and equipment resources. The loss of property and life, however, can be minimized through cooperation, preparedness, and mitigation activities.

Wildfire ranked first in the risk score in the local risk assessment Hazard Vulnerability Analysis (HVA) for the *2020 Grant County Multi-Jurisdictional NHMP* out of the eight natural hazards that the Grant County NHMP Steering Committee identified.

Grant County has a lengthy history (see Table 2 Significant Historic Wildfires) of wildfire in both wildlands and in wildland-urban interface (WUI) areas.

WUI areas are where the human developed areas meet the undeveloped areas; it is a transition area. Figure 1 illustrates the WUI area in Grant County. If population in this region grows, development in the WUI may increase. Concern is warranted when development patterns increase the threat of wildfire to life and property. Nearly 3,700 sq. mi. or 2.4 million acres are considered WUI areas in Oregon, which is about 3.8% of the state. Of the nearly 1.7 million total homes in Oregon, over 603,000 or 36%, are in the WUI.[2]

Wildfires threaten the limited but valued and valuable forest resources, agricultural land, rangelands, and individual home sites. State and federal wildland firefighters protect state and federal lands. While they fight to protect structures, they do not fight fires once they become structural and equipment fires.

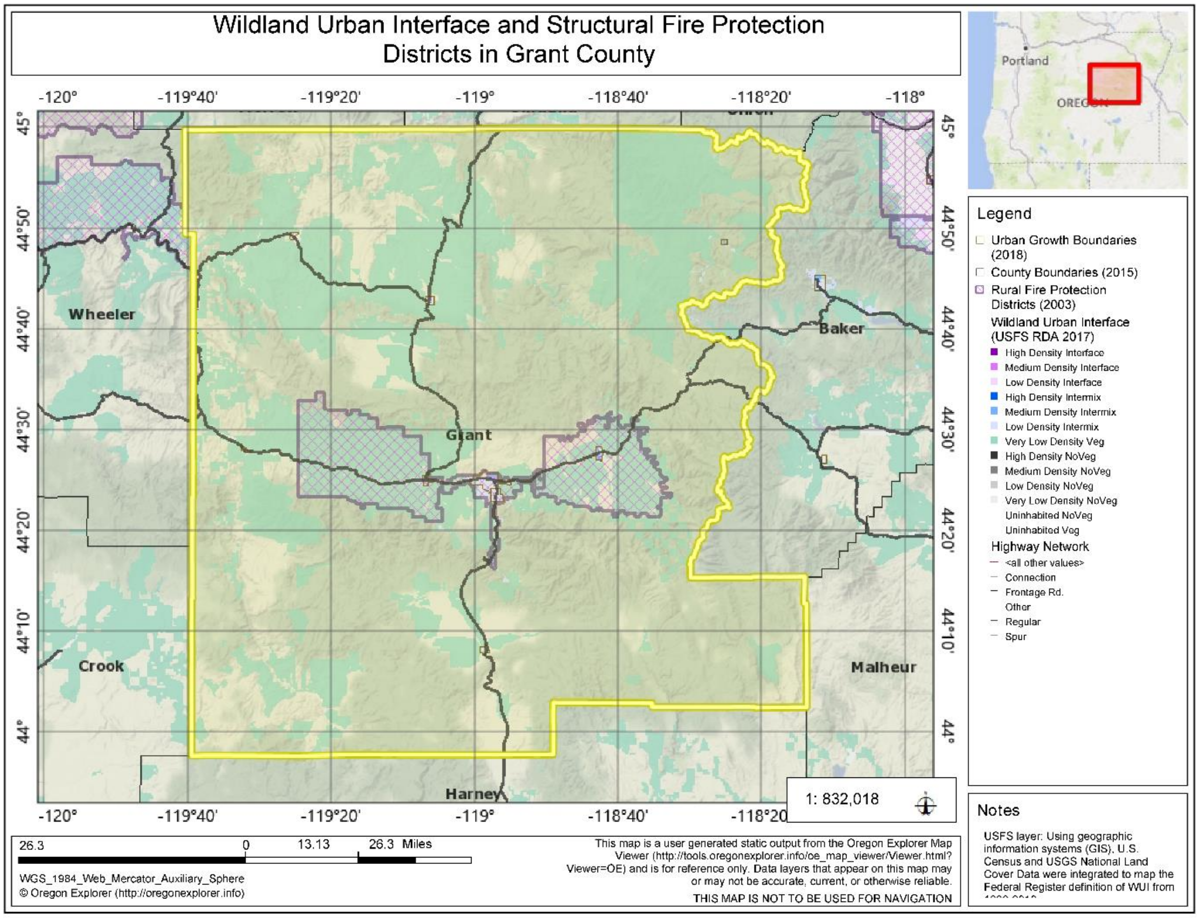
---

[1] Fire Ecology, Pacific Biodiversity Institute http://www.pacificbio.org/initiatives/fire/fire_ecology.html and Evaluating the ecological benefits of wildfire by integrating fire and ecosystem simulation models, USDA, Treesearch, https://www.fs.usda.gov/treesearch/pubs/34994

[2] Oregon Wildfire Risk Explorer, December 2019.

Notably, once a fire has started, homes and development in wildland and WUI settings complicate firefighting activities and stretch available human and equipment resources.

Figure 1. WUI areas and Structural Protection Districts in Grant County



Source: Oregon Explorer, State of Oregon, DLCD Katherine Daniel, April 2020

State and federal wildland firefighters can provide wildfire suppression service on non-state and non-federal areas through formal agreements. Currently, fire suppression authorities include the rural/city fire protection districts/departments for John Day, Mt. Vernon, Prairie City, Canyon City, Dayville, Long Creek, Granite, and Monument; the Oregon Department of Forestry (ODF) Central Oregon Forest Protection District; the USFS; and the BLM. Mutual Aid Agreements exist among the fire authorities for mutual aid and support in the event of a wildfire incident; however, each fire authority operates under regulations that dictate their area of responsibility and specify limitations.

To reduce the impact of wildfire, Grant County adopted the *Grant County Community Fire Protection Plan* in 2005. This plan provided the means to identify wildfire risk, prioritize mitigation projects, improve public awareness, and improve fire authority coordination to better manage wildfire. The most recent revision to that plan is the 2013 *Grant County Community Wildfire Protection Plan*. An update to that version is poised to get underway at this writing.

The references to wildfire risk and mitigation in the *2020 Grant County NHMP* are based on the 2013 *Grant County CWPP* as the primary source of wildfire information and mitigation actions for the county. The 2020 Grant County NHMP also draws on the Oregon State NHMP and the ongoing update for statewide analysis of wildfire risk and mitigation strategies.

The 2013 *Grant County CWPP* provides detailed information on the vulnerability and history of wildfire in the County, and provides mitigation actions the County can implement to reduce the impact of wildfire. The focus of the 2013 *Grant County CWPP* is on a sub-watershed basis with emphasis on "zones" defined by watersheds and centered around the communities of Long Creek and Monument, Ritter and Dale, Granite, the Upper Middle Fork of the John Day River, Prairie City, John Day and Canyon City, Mt. Vernon, Dayville, and the Seneca area including the Lower Middle Fork area

The impact on communities from wildfire can be huge. Reporting by the Oregonian stated that in 2017, more than 1.1 million acres were scorched by wildfire in Oregon and Washington. 2018 was even worse, with 1.3 million acres of forest and fields going up in flame. That's an area close to the size of Delaware up in smoke each year. Fighting wildfires cost Oregon and Washington more than a $1 billion in 2017 and 2018 combined, according to the Northwest Interagency Coordination Center.

The fire season in 2019 was a much different story: Just over 200,000 acres were scorched across both states, a nearly 84 percent drop from the two previous years. In 2019, both states spent less than $100 million, a 92 percent drop in costs. Much of the quiet season can be attributed to weather. The relatively cool temperatures kept fuels in forests and grasslands from drying into the tinderboxes they were in recent years. [3]

The History of Wildfires in Grant County section in this Wildfire Hazard Annex includes a description of documented wildfires as reported in the 2020 Oregon State NHMP; it is likely that not all the wildfires that have occurred are included on this list.

Wildfire can be divided into four categories: interface fires, wildland fires, firestorms, and prescribed fires.[4] These descriptions are provided for a brief but comprehensive understanding of wildfire.

Interface Fires

An interface fire occurs where wildland and developed areas come together with both vegetation and structural development combining to provide fuel. The wildland/urban interface (sometimes abbreviated to WUI or called rural interface in small communities or outlying areas) can be divided into categories.

- The **classic wildland-urban interface** exists where well-defined urban and suburban development presses up against open expanses of wildland areas.

[3]Portland Oregonian, Oregonlive.com https://www.oregonlive.com/environment/2019/10/summer-2019-the-oregon-wildfire-season-that-wasnt.html

[4] Federal Emergency Management Agency, *Multi-hazard, Identification and Risk Assessment Report*, 1997, Washington, D.C., https://www.fema.gov/media-library/assets/documents/7251.

- 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 in wildland settings.

- The **occluded wildland-urban interface** where islands of wildland vegetation exist within a largely urbanized area.[5]

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.

Firestorms and Mega-Fires

A firestorm is a very intense and destructive fire usually accompanied by high winds; it may be a large fire that is difficult to impossible to control. [6] Firestorms are events of such extreme intensity that effective suppression is virtually impossible. Firestorms often occur during dry, windy weather and generally burn until conditions change or the available fuel is consumed.

In 1987, widespread dry lightning in late August ignited fires throughout northern California and southwest Oregon. Two of these were over 10,000 acres, and according to the Oregon Department of Forestry, this series of events fits the definition of a firestorm. Resources were brought in from other states and Canada to fight them.[7] Another term used is mega-fire which is a fire that is more than 100,000 acres in size. Only the 2015 Canyon Creek complex fire rises to that level in Grant County.

Prescribed Fires

Prescribed fires are intentionally set or are select natural fires that are allowed to burn for beneficial purposes. Before humans suppressed forest fires, small, low intensity fires cleaned the underbrush and fallen plant material from the forest floor while allowing the larger plants and trees to live through the blaze. These fires were only a few inches to two feet tall and burned slowly. Forest managers now realize that a hundred years of prevention has contributed to the unnatural buildup of plant material that can flare up into tall, fast moving wildfires. These can be impossible to control and can leave a homeowner little time to react.

Conditions Contributing to Wildfires

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

---

[5] Ibid.

[6] Definition of firestorm, Merriam-Webster Dictionary, https://www.merriam-webster.com/dictionary/firestorm and Cambridge Dictionary, https://dictionary.cambridge.org/us/dictionary/english/firestorm.

[7] Wolf, Jim, ODF, personal communication, May 8, 2001.

Fuel

Fuel is the material that feeds a fire. Fuel is classified by volume and type. Forested lands provide a larger fuel source to wildfires than other vegetated lands due to the presence of large amounts of timber and other dense vegetation in these areas. Grassland are included in the rangeland areas Grasslands, which naturally cover much of the region, are highly susceptible to wildfire. According to BLM staff, there is an increasing amount of invasive grasses in the grasslands; these invasive grasses are more susceptible to burn. The variability of the fire likelihood is great, as the factors of soil moisture, soil temperature, and amount of and nature of grass there varies. Vegetation such as agricultural lands and rangelands also provides fuel for wildfires.

Topography

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

In this region, much of the topography is hilly or mountainous which can exacerbate wildfire hazards. These areas can cause a wildfire to spread rapidly and burn larger areas in a shorter period of time, especially, if the fire starts at the bottom of a slope and migrates uphill as it burns. Wildfires tend to burn more slowly on flatter lying areas, but this does not mean these areas are exempt from a rapidly spreading fire. Hazards that can affect these areas after the fire has been extinguished include landslides (debris flows), floods, and erosion.

Weather

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

The natural ignition of wildfires is largely a function of weather and fuel; human caused fires add another dimension to the probability. Lightning strikes in areas of forest or rangeland combined with any type of vegetative fuel source will always remain as a source for wildfire. Thousands of lightning strikes occur each year throughout much of the region. Fortunately, not every lightning strike causes a wildfire, though they are a major contributor.

Future Climate Projections

Oregon's Department of Land Conservation and Development (DLCD) contracted with the Oregon Climate Change Research Institute (OCCRI) of Oregon State University to perform and provide analysis of the influence of climate change on natural hazards for Grant County. The report referenced here presents future climate projections for Grant County relevant to specific natural hazards for the 2020s (2010–2039 average) and 2050s (2040–2069 average) as compared to the 1971–2000 average historical baseline. [8]

Over the last several decades, warmer and drier conditions during the summer months have contributed to an increase in fuel aridity and enabled more frequent large fires, an increase in the total area burned, and a longer fire season across the western United States, particularly in forested ecosystems. The

[8] Future Climate Projections Grant County (Dalton, February 2020)

lengthening of the fire season is largely due to declining mountain snowpack and earlier spring snowmelt. As a proxy for wildfire risk, the OCCRI report considers a fire danger index called 100---hour fuel moisture (FM100), which is a measure of the amount of moisture in dead vegetation in the 1–3 inch diameter class available to a fire. It is expressed as a percent of the dry weight of that specific fuel. The OCCRI report defines a "very high" fire danger day to be a day in which FM100 is lower (i.e., drier) than the historical baseline 10th percentile value. By definition, the historical baseline has 36.5 very high fire danger days annually. The future change in wildfire risk is expressed as the average annual number of additional "very high" fire danger days for two future periods under two emissions scenarios compared with the historical baseline.

The key conclusions of the analysis by OCCRI are as follows:

- Wildfire risk, as expressed through the frequency of very high fire danger days, is projected to increase under future climate change in Grant County.
- In Grant County, the frequency of very high fire danger days per year is projected to increase on average by about 14 days (with a range of ---4 to +36 days) by the 2050s under the higher emissions scenario compared to the historical baseline.
- In Grant County, the frequency of very high fire danger days per year is projected to increase on average by about 39% (with a range of ---10 to +98%) by the 2050s under the higher emissions scenario compared to the historical baseline.

Development

The increase in residential development in interface areas has resulted in greater wildfire risk. Fire has historically been a natural wildland element and can sweep through vegetation that is adjacent to a combustible home. New residents in remote locations are often surprised to learn that in moving away from urban areas, they have left behind readily available fire services providing structural protection. Rural locations may be more difficult to access and or simply take more time for fire protection services to get there.

History of Wildfire in Grant County

Southeastern Oregon contains large tracts of ponderosa pine forests, primarily in the northern part of Harney County. These areas are highly vulnerable to wildfire because of natural aridity and the frequency of lightning strikes. Grasslands, which naturally cover much of the region, also are problematic. The ecosystems of most forest and wildlands depend upon fire to maintain functions.

The effects of fire on ecosystem resources can include damages, benefits, or some combination of both. The benefits can include, depending upon location and other circumstances, reduced fuel load, disposal of slash and thinned tree stands, increased forage plant production, and improved wildlife habitats, hydrological processes, and aesthetic environments. Despite the benefits, fire has historically been suppressed for years because of its effects on rangelands, grasslands, recreation areas, agricultural operations, and the significant threat to property and human life.

Knowing the fire history of a place is important to understand the fire environment of the area. Knowing where and why fires start is one of the first steps in prevention and mitigation efforts. Understanding the burn probability, the hazard to potential structures, the fire intensity and flame length, and the sub-watershed level for context, provides comprehensive information for decision-making about wildfire prevention and mitigation.

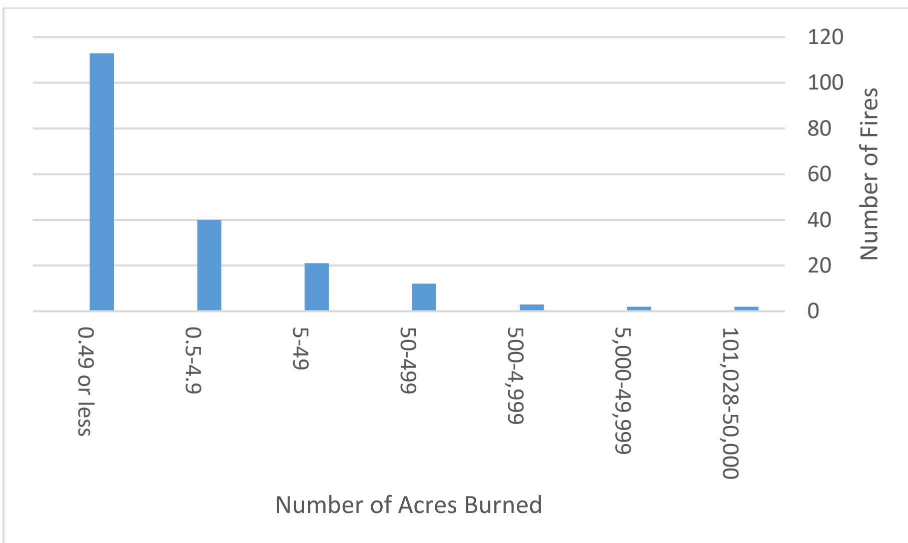
During the period from January 2014 through January 2020 a total of 193 fires were reported in Grant County. The majority of those fires consumed less than half an acre of land. The largest fires were few in number but caused the greatest amount of damage.

Table 1. Size distribution of fires in Grant County from 1/2014 through 1/2020

Number of fires	Acres burned
2	101,028-50,000
2	5,000-49,999
3	500-4,999
12	50-499
21	5-49
40	0.5-4.9
113	0.49 or less

Source: data from Oregon Department of Forestry Fire Database, consulted January 2020

Figure 2. Fire Incidents in Grant County 2014-2020



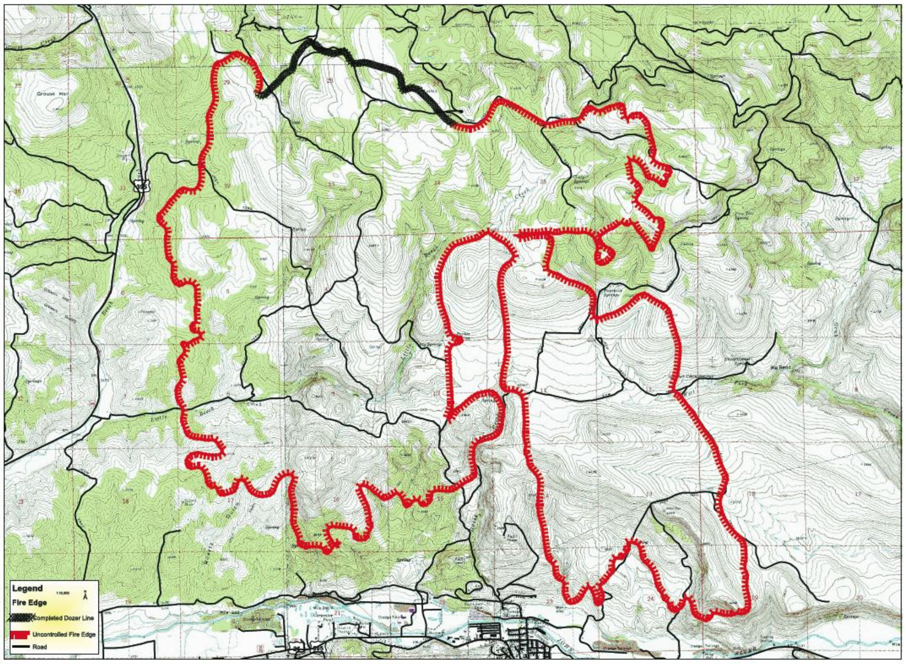
Source: data from Oregon Department of Forestry Fire Database, consulted January 2020, graphed by author

Table 2. Significant Historic Wildfires exceeding 1,000 acres in Grant County (partial list)

Fire Year	Report Date	Name of Fire	Acres Burned	Remarks
1986		Clear	6,000	Lightning caused
1988		Turner	8,000	
1996	07/26/1996	Wildcat	10,303	52 structures threatened near Pairie City; Conflagration mobilization cost: $176,107
1996	08/08/1996	Sloan’s Ridge	10,556	
1996	08/20/1996	Summit Fire	37,842	Lightning caused
1996	08/26/1996	Tower Fire	50,815	Lightning caused
1999		Cummings Creek, 11 miles west of Mt. Vernon		Executive Order No. EO-00-27; 50 structures threatened, one structure lost; Conflagration costs: $52,296
2000		Carrol Creek	3,197	
2001	08/13/2001	Monument Complex	32,352	Lightning caused; Executive Order No. EO-01-21; 28 structures threatened; Conflagration mobilization costs: $229,717; federal funding: $229,717
2002	July	Malheur Complex/Flagtail	21,641	Lightning caused; Executive Order No. EO-02-09; Threatened large portions of Grant County near Austin Junction and Seneca; Two structures lost; Conflagration mobilization costs: $188,697; federal funding: $188,697
2002	07/12/2002	Roberts Creek	13,480	Lightning caused
2006	08/22/2006	Shake Table	14,453	Lightning caused
2007	07/14/2007	Monument Complex-Lovelett Ck	53,556	Lightning caused
2009	08/01/2009	North Fork Complex	14,000	Lightning caused
2013	August	GC Complex Fire (Grouse Mountain and Starvation Fires)	12,076	Threatened John Day including 400 residences and 11 structures, one structure lost; Conflagration mobilization costs (as of 9-12-13): $17,084
2014	07/14/2014	Sunflower	7,175	Lightning caused
2014	08/01/2014	Murderers Creek South	66,174	Lightning caused
2014	08/29/2014	Lost Hubcap	2,712	Equipment use
2015	08/12/2015	Berry Creek (part of Canyon Creek Complex fire)	101,028	Lightning caused Suppression costs: $31,000,000
2015	08/12/2015	Mason Spring (part of Canyon Creek Complex fire	9,211	Lightning caused

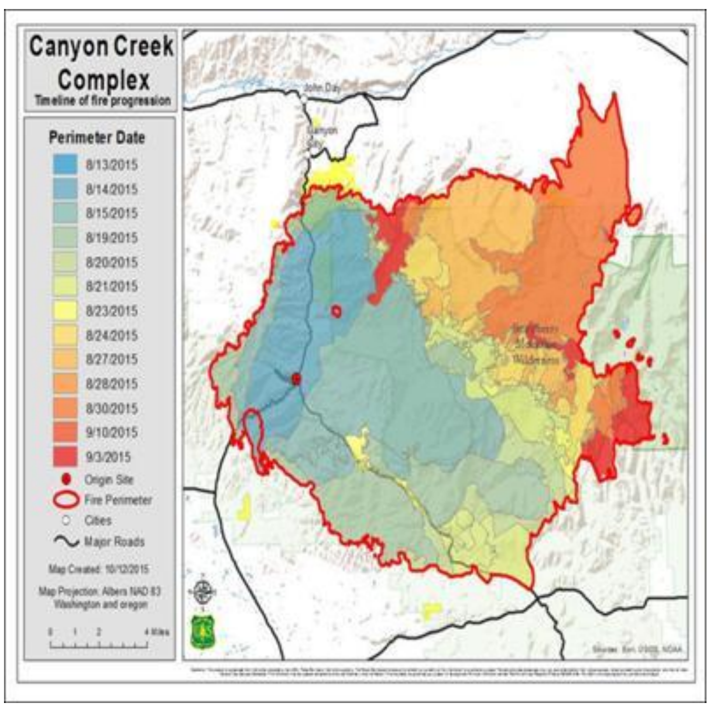
Source: 2015 Oregon State NHMP; Grant County CWPP 2013; Oregon Department of Forestry; Governor’s List of Executive Orders: http://www.oregon.gov/gov/Pages/exec_orders.aspx; Oregon Governor-Declared Conflagrations http://www.oregon.gov/osp/SFM/docs/ConflagrationHistory.pdf

Figure 3. Grouse Mountain Fire Boundaries (John Day city at bottom edge of map)



Source: Inciweb: Incident Information System

Figure 4. Canyon Creek Complex, Timeline of Fire Progression



Source: US Forest Service Canyon Creek Complex, Malheur National Forest, Overview and Frequently Asked Questions https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd503421.pdf, consulted January 2020

Community Wildfire Protection Plan[9]

The Healthy Forests Restoration Act of 2003 (HFRA) provides the impetus for wildfire risk assessment and planning at the county and community level. The HFRA refers to this level of planning as Community Wildfire Protection Plans (CWPP). The minimum requirements for a CWPP as described in the HFRA are:

- Collaboration: A CWPP must be collaboratively developed by local and state government representatives, in consultation with federal agencies and other interested parties. Prioritized Fuel Reduction: A CWPP must identify and prioritize areas for hazardous fuel reduction treatments and recommend the types and methods of treatment that will protect one or more at-risk communities and essential infrastructure.
- Treatment of Structural Ignitability: A CWPP must recommend measures that homeowners and communities can take to reduce the ignitability of structures throughout the area addressed by the plan.

Grant County developed and adopted one of the earliest CWPPs completed in Oregon dated July 6, 2005. The 2013 revision included a detailed wildfire hazard assessment (*Communities At Risk* or CAR) that ranked risk using a range of factors (prior occurence, slope, aspect, elevation, vegetation, crown fire potential, home density, infrastructure, fire response and community preparedness), a county-wide community base map prepared by Grant Soil and Water Conservation District, and a discussion of the county's wildfire suppression situation. This plan is now ready to be updated. The Community Wildfire Coordinator, Irene Jerome, will be engaging the communities of Grant County to update the plan during the course of 2020.

The CWPP allows a community to evaluate its current situation with regards to wildfire risk and plan ways to reduce risk for protection of human welfare and other important economic, social or ecological values. The CWPP may address issues such as community wildfire risk, structure flammability, hazardous fuels and non-fuels mitigation, community preparedness, and emergency procedures. The CWPP should be tailored to meet the needs of the community.

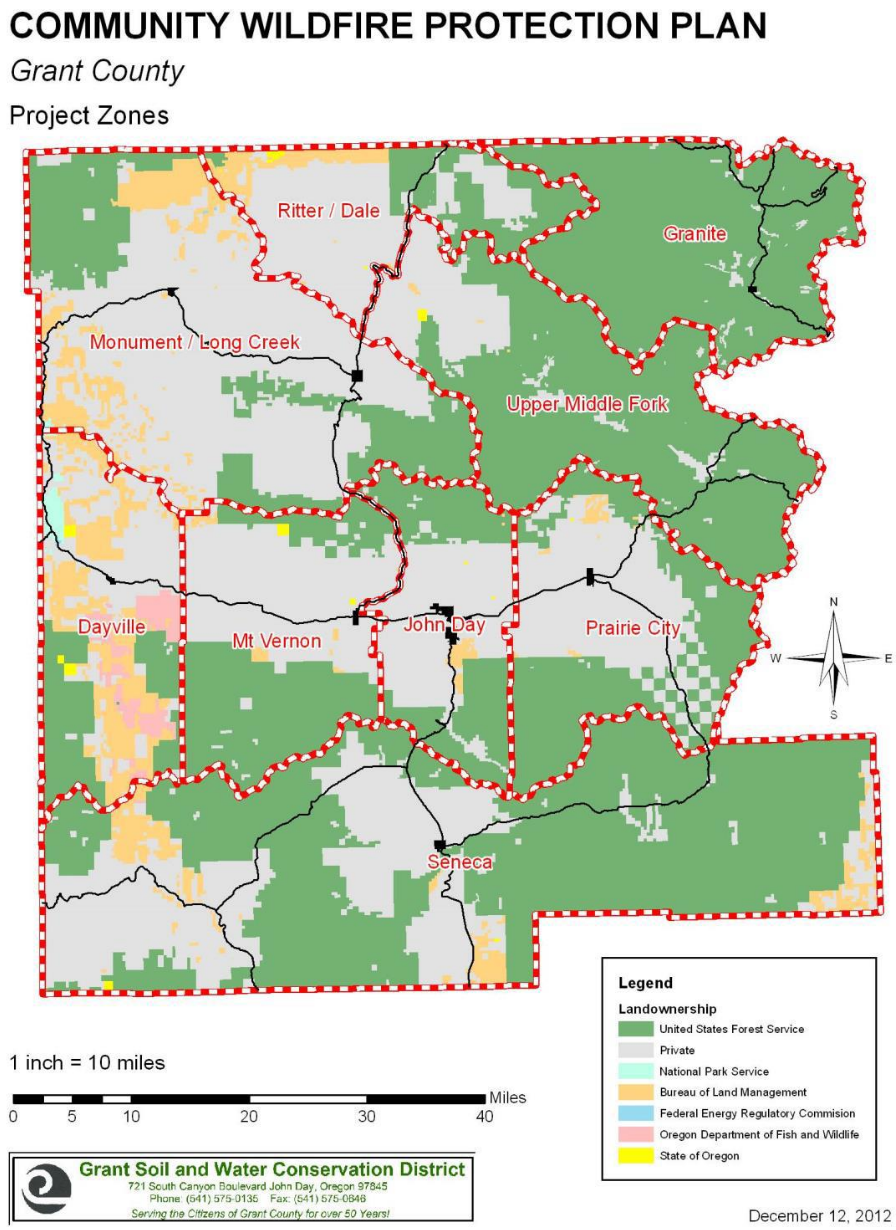
The 2013 Grant County CWPP was developed on a sub-watershed basis with emphasis on "zones" defined by watersheds and centered on the communities of Long Creek and Monument, Ritter and Dale, Granite, the Upper Middle Fork of the John Day River, Prairie City, John Day and Canyon City, Mt. Vernon, Dayville, and the Seneca area including the Lower Middle Fork area (Figure 6). The CWPP describes the broader conditions and history of the county as well as providing detail on the personnel, capabilities and equipment of each Fire District in the county. There is a thorough description of the roles and responsibilities of a range of federal, state and local agencies and departments that must work together to implement the CWPP. The CWPP describes the linkages with the County Emergency Operations Plan and the cooperative agreements with Harney County.

The CWPP contains a section devoted to the legislation, policies and programs that form the regulatory environment for wildfire mitigation. The CWPP discusses Oregon Senate Bill 360, the Oregon Forestland-Urban Interface Fire Protection Act of 1997 which was the Oregon legislature's response to several escalating wildland fire problems. As firefighting capacity may be limited SB-360 enlisted the aid of the only people who can make fuel reduction changes to residential property: the landowners themselves. It discusses the Emergency Conflagration Act, which once invoked, authorizes the Governor

[9] This section excerpts the 2013 Grant Community Wildfire Protection Plan http://www.grantcountycwpp.com/

to use the resources of any county, city, or district fire suppression organization to assist fire-fighting efforts anywhere in the state. It discusses both federal and Oregon state laws that govern fire management including the National Fire Plan, the Healthy Forest Restoration Act (HFRA), FEMA Presidential Disaster Relief Fund, the FLAME Act to fund fire suppression costs, the National Cohesive Wildland Fire Management Strategy, the Oregon Statewide Land Use Planning Goals, Fire Adapted Communities, and Firewise Communities USA, a program of the National Fire Protection Association.

Figure 5. CWPP Project Zones and Land Ownership



Source: 2013 Grant County Community Wildfire Protection Plan

The 2013 CWPP also assesses the risk of wildfire in each of the zones using a framework developed by the Oregon Department of Forestry for application statewide called *Communities at Risk (CAR).* The CAR assessment was used to develop a statewide fuels strategy and to help set large-scale priorities across geographic areas (watersheds, multi-county coordination areas, etc). The CAR methodology is applicable at a national scale and must be applied consistently statewide for relative comparisons. The 2013 Grant CWPP applied this methodology and found that all of the cities in Grant County are Moderate (Dayville, Monument) or High Risk (Canyon City, Granite, John Day, Mt. Vernon, Prairie City and Seneca). The application of the CAR methodology of wildfire risk assessment yielded the conclusion that all of the zones in Grant County are at High Risk of wildfire.

The final section of the 2013 CWPP entitled Wildfire Mitigation Strategy covers prioritization of the wildland urban interface areas of the county and the application of nine strategies. These strategies have been incorporated into the 2020 Grant County Multi-Jurisdictional Natural Hazard Mitigation Plan as noted in Table 4 of Volume I: Basic Plan.

FLOOD HAZARD ANNEX

Flooding results when rain and snowmelt creates water flow that exceed 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 most destructive natural disasters have been floods. 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.

Countywide exposure to 100-year flood:

- Number of buildings damaged: **488**
- Loss Estimate: **$20,261,000**
- Loss Ratio: **1.0%**
- Damaged critical facilities: **7**
- Potentially Displaced Population: **799**

Causes and Characteristics of Flooding

The most damaging floods have occurred during the winter months, when warm rains from tropical latitudes melt mountain snow packs. Such conditions were especially noteworthy in February 1957, February 1963, December 1964 and January 1965. Somewhat lesser flooding has been associated with ice jams, normal spring run-off, and summer thunderstorms. Heavily vegetated stream banks, low stream gradients (e.g. Grande Ronde Valley), and breeched dikes have contributed to past flooding at considerable economic cost. Northeast Oregon counties also have experienced flooding associated with low bridge clearances, over-topped irrigation ditches, and natural stream constrictions

The Oregon Climate Change Research Institute prepared an analysis of the potential future impact of changing climate on the natural hazards experienced in Grant County. With respect to flooding the report summarizes the likely effects as follows:

- The intensity of extreme precipitation events is expected to increase slightly in the future as the atmosphere warms and is able to hold more water vapor.
- Although the frequency of days with at least ¾" of precipitation is not projected to change substantially, the magnitude of precipitation on the wettest day and wettest consecutive five days per year is projected to increase on average by about 16% (with a range of 7% to 25%) and 12% (with a range of ---3%to 24%), respectively, by the 2050s under the higher emissions scenario relative to the historical baselines. Rainfall events are expected result in more rain.
- In Grant County, the frequency of days exceeding a threshold for landslide risk, based on 3---day and 15---day precipitation accumulation, is not projected to change substantially. However, landslide risk depends on a variety of factors and this metric may not reflect all aspects of the hazard.

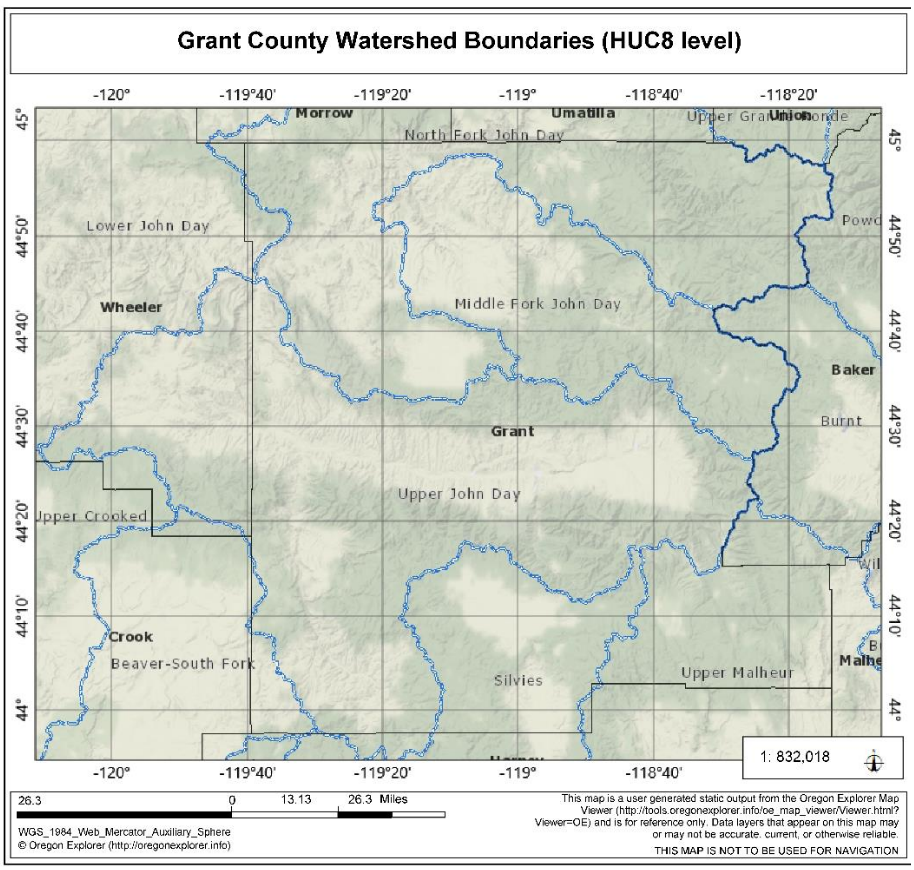
The report makes particular note of the effect of warming temperatures on low to mid-level elevations where winter precipitation may fall more frequently as rain rather than snow thereby exacerbating spring rain on snow flooding events[10].

The principal types of floods that occur in Grant County include:

Riverine Flooding

Riverine floods occur when water levels in rivers and streams overflow their banks. Most communities located along such water bodies have the potential to experience this type of flooding after spring rains, heavy thunderstorms or rapid runoff from snow melt. Riverine floods can be slow or fast-rising, but usually develop over a period of days. The danger of riverine flooding occurs mainly during the winter months, with the onset of persistent, heavy rainfall, and during the spring, with melting of snow. Figure 6 below shows the river HUC 8 level sub-basins in Grant County that are the sources of riverine flooding.

Figure 6. Grant County Watershed Boundaries



Source: Oregon Explorer map prepared by K. Daniel, April 2020

[10] Future Climate Projections Grant County, Oregon Climate Change Research Institute, Oregon State University, February 2020

Snow-melt Flooding

Flooding throughout the region is most commonly linked to the spring cycle of melting 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. In brief, cool, moist weather conditions are followed by a system of warm, moist air from tropical latitudes. The intense warm air associated with this system quickly melts foothill and mountain snow. Above-freezing temperatures may occur well above pass levels (4,000-5,000 feet). Such conditions were especially noteworthy with low bridge clearances which have particularly damaged Northeast Oregon areas as seen in the 2010 flooding of the Grant-Union High School. The 2011 flooding in Pine Valley was also the result of snow-melt flooding.

Figure 7. Flooding near John Day/Canyon City damaged the Grant-Union High School in 2010

Source: 2014 NE OR Multi-Jurisdictional Natural Hazard Mitigation Plan

Flash Floods

Flash floods usually result from intense storms dropping large amounts of rain within a brief period. Flash floods usually occur in the summer during thunderstorm season, appear with little or no warning and can reach full peak in a few minutes. They are most common in the arid and semi-arid central and eastern areas of the state where there is steep topography, little vegetation and intense but short duration rainfall. Flash floods can occur in both urban and rural settings, often along smaller rivers and drainage ways. In flash flood 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 up stream and then later downstream if the obstruction is removed or breaks free.

Terms related to Flooding

Floodplain

A floodplain is land adjacent to a river, stream, lake, estuary or other water body that is subject to flooding. These areas, if left undisturbed, act to store excess floodwater. The floodplain is made up of two areas: the flood fringe and the floodway:

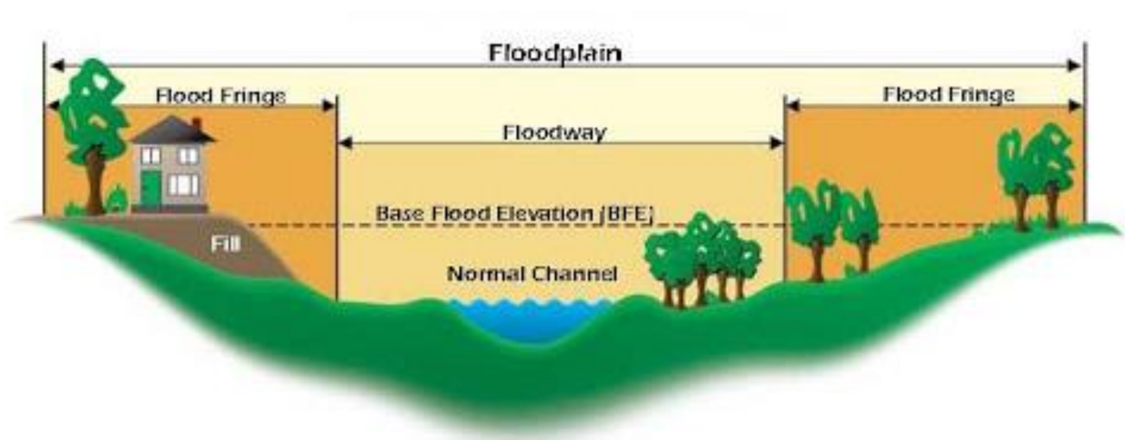
Floodway

The floodway is the portion of the floodplain that is closer to the river or stream. For National Flood Insurance Program (NFIP) and regulatory purposes, floodways are defined as the channel of a river or stream, and the over-bank areas adjacent to the channel. Unlike floodplains, floodways do not reflect a recognizable geologic feature. The floodway carries the bulk of the floodwater downstream and is usually the area where water velocities and forces are the greatest. NFIP regulations require that the floodway be kept open and free from development or other structures, so that flood flows are not obstructed or diverted onto other properties. The NFIP floodway definition is "the channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot (See Figures FL-3 and FL-4)." Floodways are not mapped for all rivers and streams but are typically mapped in developed areas.

The Flood Fringe

The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward. This is the area where development is most likely to occur, and where precautions to protect life and property need to be taken (See Figure FL-3).

Figure 8. Characteristics of a Floodplain



Source: Oregon Department of Geology and Mineral Industries

Base Flood Elevation

Base Flood Elevation (BFE) means the water surface elevation during the base flood in relation to a specified datum or benchmark. The Base Flood Elevation (BFE) is depicted on the FEMA Flood Insurance

Rate Map (FIRM) to the nearest foot and in the Flood Insurance Study to the nearest 0.1 foot. The Base Flood Elevation is a baseline pulled together from historic weather data, local topography, and the best science available at the time. It's a reasonable standard to insure against, but it is not a guarantee that it will flood only 1 time every 100 years.

Factors that Affect Flooding in Grant County

Precipitation

In Oregon, observed precipitation is characterized by high year--to--year variability and future precipitation trends are expected to continue to be dominated by this large natural variability. On average, summers in Oregon are projected to become drier and other seasons to become wetter resulting in a slight increase in annual precipitation by the 2050's.[11] Locations surrounded by mountains receive barely 10 inches per year, a portion of which falls as snow. This is in sharp contrast to the 37 to 50 inches normally seen in other parts of the Pacific Northwest. Low levels of precipitation are due in part by the rain shadow effect caused by the Cascade Mountains. Summer precipitation is very low, increasing the risk of wildfire and requiring irrigation for crops.

Projections for future changes in climate suggest that there is greater uncertainty in future projections of precipitation-related metrics than temperature-related metrics. Future streamflow magnitude and timing in the Pacific Northwest is projected to shift toward higher winter runoff, lower summer and fall runoff, and an earlier peak runoff, particularly in snow-dominated regions. These changes are expected to result from warmer temperatures causing precipitation to fall more as rain and less as snow, in turn causing snow to melt earlier in the spring; and in combination with increasing winter precipitation and decreasing summer precipitation.

Warming temperatures and increased winter precipitation are expected to increase flood risk for many basins in the Pacific Northwest, particularly mid--- to low---elevation mixed rain---snow basins with near freezing winter temperatures. The greatest changes in peak streamflow magnitudes are projected to occur at intermediate elevations in the Cascade Range and the Blue Mountains.[12]

Surface Permeability

In urbanized areas, increased pavement leads to an increase in volume and velocity of runoff after a rainfall event, exacerbating potential flood hazards. Storm water systems collect and concentrate rainwater and then rapidly deliver it into the local waterway. Traditional storm water systems are a benefit to urban areas, by quickly removing captured rainwater. However, they can be detrimental to areas downstream because they cause increased stream flows due to the rapid influx of captured storm water into the waterway. It is very important to evaluate storm water systems in conjunction with development in the floodplain to prevent unnecessary flooding to downstream properties. Frozen ground and burn scars are other contributors to rapid runoff in the urban and rural environment.

The principle rivers in Grant County include the North Fork, the South Fork and the Middle Fork of the John Day River, Canyon Creek and the Silvies River.

---

[11] Future Climate Projections Grant County, Dalton, February 2020, p. 17
[12] Ibid p. 21

Location of Development

When development is located in the floodplain, it may cause floodwaters to rise higher than before the development was located in the hazard areas. This is particularly true if the development is located within the floodway. When structures or fill are placed in the floodplain, water is displaced. Development raises the base-flood elevation by forcing the river to compensate for the flow space obstructed by the inserted structures. Over time, when structures or materials are added to the floodplain and no fill is removed to compensate, serious problems can arise.

Displacement of a few inches of water can mean the difference between no structural damage occurring in a given flood event and the inundation of many homes, businesses, and other facilities. Careful attention must be paid to development that occurs within the floodplain and floodway of a river system to ensure that structures are prepared to withstand base flood events.

How is Flooding Hazard Identified?

Flood hazard in some areas of Grant County are identified through FEMA issued Flood Insurance Rate Maps (FIRM), in conjunction with their Flood Insurance Studies (FIS). Flood records in areas without FIRMs are often not well documented, particularly in unincorporated areas because their floodplains are sparsely developed and risk to life and property are low. The Grant County's Flood Insurance Rate Maps (FIRMs), like much of eastern Oregon are not modernized. New floodplain mapping of the Silvies River and Bear Creek in Seneca and adjacent Grant County has been completed and is currently in the 90 day appeal period. Pending adjudication of any appeals these maps will become effective May 26, 2020. Additional lidar will be prepared to cover the area of the confluence of the Silvies River and Bear Creek in the future. Lidar for the Upper John Day watershed has been funded and will be carried out as a first step to updating the FEMA floodplain maps for most of the John Day River in Grant Count.

The table below shows that as of April 2020, Grant County (including the cities of Canyon City, John Day, Mount Vernon and Prairie City) has 61 National Flood Insurance Program (NFIP) policies in force, 11 total paid claims and one repetitive loss building. The repetitive flood loss claims in John Day resulted in $16,643 in payments over two losses. The tables below display the number of policies by building type and show that the majority of residential structures that have flood insurance policies are single-family homes and that there are 11 non-residential structures with flood insurance policies. The county has not received a Community Assistance Visit in the past 15 years, however, the City of John Day participated in a recent Community Assistance Visits in the April 2019. The county is not a member of the Community Rating System (CRS) and neither are any of the incorporated cities within Grant County.

The Community Repetitive Loss record for Grant County identifies one repetitive loss building and two total repetitive loss claims totaling $16,644. The repetitive loss building is located within the City of John Day. There are no other repetitive loss buildings within any other city in the county. The one identified repetitive flood loss property is a single-family residential building located in Flood Zone A03 of the existing FIRM. The property is located on NW Bridge Street, between NW 7th Avenue and NW 5th Avenue.

Repetitive flood loss properties (those which have experienced multiple flood insurance claims) have been identified as high priority hazard projects by the NFIP. Nationwide, 40% of all flood insurance claims are paid on just two-percent of insured properties. In Oregon, repetitive loss properties represent about one-percent of all insured properties, and account for about 14% of all claims paid (19% of the dollar amounts paid).[13]

Table 3. Grant County Flood Insurance Policy Detail

Jurisdiction	Current FIRM effective date	Policies	Pre-FIRM	Policies by Building Type			
				Single Family	2 to 4 Family	Other Residential	Non-Residential
Grant County	5/18/1982	17	11	15	-	-	2
Canyon City	9/18/1987	2	2	2	-	-	
John Day	2/23/1982, revised by LOMR effective 10/17/2019	34	24	25	-	-	9
Mount Vernon	9/18/1987	7	5	6	1	-	-
Prairie City	2/17/1988	1	1	1	-	-	-
Totals		61	43	49	1		11

Table 4. Grant County Flood Insurance Claim and Substantial Damage Detail

Jurisdiction	Insurance in Force	Total Paid Claims	Substantial Damage Claims	Repetitive Loss Buildings	Total Paid Amount	Last CAV	Last CAC
Grant County	$3,203,500	0	0	0	0	6/29/1994	5/09/2019
Canyon City	$315,000	0	0	0	0	7/1/1989	5/28/2019
John Day	$6,810,800	10	1	1	$51,094	4/26/2019	none
Mount Vernon	$879,900	1	0	0	0	6/14/1993	none
Prairie City	$175,000	0	0	0	0	7/1/1989	none
Totals	$11,384,200	11	1	1	$51,094		

Source: Information compiled by Department of Land Conservation and Development, FEMA Community Information System consulted April 2020.

[13] State Natural Hazards Mitigation Plan 3-FL-9

There are no NFIP policies in the cities of Dayville, Long Creek, Monument, or Seneca. The FIRMs for these communities each became effective on 9/24/1984.

History of Flooding in Grant County

Table 5 below shows the history of major flood events within Grant County. Staff at the Oregon Department of Land Conservation and Development (DLCD) compiled a list of all recorded floods in Oregon across 146 years of available data, as part of a 2020 update to the 2015 State NHMP table of flooding events. Data for this list had two sources: the Table 1 in the DLCD "Flood Technical Resource Guide" (Andre and others, 2001)[14] which was used to record events that occurred prior to 2000 and the NOAA Storm Event Database [15] which captured events from 2000 to the present.

There are limitations to this listing in that information from the DLCD Flood Technical Resource Guide's represents a list of 'Historic Flooding' which typically records only at most 12 events in a single region across a decade. In comparison, the NOAA database records storm-driven flooding events that result in damage, injury, loss of life or events that have unusual conditions that may generate media attention. This shows as many as 45 events occurring in one region within a decade. By compiling data from two different sources, neither of which have a quantitative metric for defining a flood, has resulted in a list that is inconsistent and likely incomplete. This table differs somewhat from the list of historic floods in the 2014 NHMP because this plan relates to only a portion of the area covered in the 2014 NHMP.

[14] https://oregonexplorer.info/data_files/OE_topic/hazards/documents/04_flood.pdf
[15] https://www.ncdc.noaa.gov/stormevents/

Table 5. History of flooding in Grant County

Date	Location	Description
June 1884	John Day	
Feb. 1907	western Oregon and John Day	
March 1932	Malheur, Grande Ronde, John Day, and Umpqua	
Dec. 1964–Jan. 1965	Pacific Northwest	rain on snow; record flood on many rivers
June 2001	Grant County	The Oregon Dept of Transportation reported flash flooding on State Highway 26
May – June 2011	Union and Grant Counties	melting heavy snowpack caused riverine and playa flooding
March 2014	Union, Umatilla, and Grant Counties	Heavy rain fell across much of the northern Blue Mountains and Wallowa County throughout the first week of March. March 9th received very heavy rain with snow levels around 6000ft. This allowed for a significant increase in runoff, which lead to a quick rise in rivers for the period
May 2018	Grant and Wallowa Counties	Heavy rain from slow moving thunderstorms caused rock slides and water on roadways within an area that includes Mount Vernon, John Day and Canyon City
April 2019	Union, Grant, Umatilla, Wallowa and Wheeler Counties Note: DR-4452 declared 7/9/19 in Grant, Umatilla and Wheeler Counties	Snow water equivalents near 200% of normal in the Blue Mountains coupled with warm temperatures and near record rainfall totals for April produced significant river flooding across eastern Oregon.

Sources: DLCD "Flood Technical Resource Guide" (Andre and others, 2001) and National Climate Data Center Storm events Database http://www.ncdc.noaa.gov/stormevents

DROUGHT HAZARD ANNEX

Risk Score: **219** of 240

Risk Level: **High**

Drought is a hazard of nature. We can't see it ignite, like a fire, or predict where it is likely to touch down, as we do a tornado. Like its natural hazard cousins, however, drought can leave a trail of destruction that may even include loss of life.

And while we might refer to a fire's crackle or the roar of a tornado, a drought hazard does not announce its arrival. In fact, those familiar with drought call it a "creeping phenomenon," because what may first appear to be merely a dry spell can only be discerned in hindsight as the early days of a drought.

Drought's stealthy reputation is also based on the way its effects vary from region to region. A week without rain might be considered a drought in a tropical climate like Bali, while a gap of only seven days between rains might be unusual in Libya, a desert area where annual rainfall is less than seven inches(180 millimeters). Drought can even co-exist with record rainfall!

In the most general sense, drought is defined as a deficiency of precipitation over an extended period of time(usually a season or more), resulting in a water shortage. The effects of this deficiency are often called drought impacts. Natural impacts of drought can be made even worse by the demand that humans place on a water supply. [16]

Causes and Characteristics of Drought

Droughts can generally be characterized by an increased demand or decreased supply of water. Drought is commonly understood to be a period of drier than normal conditions that results in water-related problems.[17] In the most general sense, drought is defined as a deficiency of precipitation over an extended period of time (usually a season or more), resulting in a water shortage. In the early 1980s, researchers with the National Drought Mitigation Center (NDMC) and the National Center for Atmospheric Research located more than 150 published definitions of drought. In order to simplify analysis, the NDMC now provides four different ways in which drought can be defined based on the impacts of the drought. They are as follows: meteorological, agricultural, hydrological, and socioeconomic.

Drought is a temporary condition – it is seen in an interval of time, generally months or years, when moisture is consistently below normal. It differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate. [18] The Oregon Climate Change Research Institute conducted a

[16] University of Nebraska-Lincoln, National Drought Mitigation Center website https://drought.unl.edu/Education/DroughtBasics.aspx

[17] Moreland, A. USGS, *Drought. Open File Report 93-642*, 1993, https://pubs.er.usgs.gov/publication/ofr93642.

[18] National Drought Mitigation Center, *Types of Drought*, https://drought.unl.edu/Education/DroughtIn-depth/TypesofDrought.aspx, accessed April, 2020.

study of potential future climate impacts in Grant County and predicts that what has been “normal” is likely to change[19].

The National Drought Mitigation Center (NDMC) categories of drought impacts are mirrored in the Oregon’s *Emergency Operations Plan (*EOP*)* in the *Incident Annex for Drought.* The 2016 Oregon EOP Incident Annex for Drought adopted these characterizations of drought except for drought that has ecological impacts. The *2015 Oregon Natural Hazards Mitigation Plan* (*2015 Oregon NHMP*) also includes all the classifications of drought identified by the NDMC except ecological drought.

Wilhite and Glantz[20] cited by NDMC categorized the definitions in terms of four basic approaches to measuring drought: *meteorological*, *hydrological*, *agricultural*, and *socioeconomic*. The first three approaches deal with ways to measure drought as a physical phenomenon. The last deals with drought in terms of supply and demand, tracking the effects of water shortfall as it ripples through socioeconomic systems.

Meteorological Droughts

Meteorological droughts are defined in terms of the departure from a normal precipitation pattern and the duration of the event. These are region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region. This drought type may relate specific precipitation departures to average amounts on a monthly, seasonal, or yearly basis.

Agricultural Droughts

Agricultural drought links various characteristics of meteorological or hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced groundwater or reservoir levels. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought accounts for the variable susceptibility of crops during different stages of crop development, from emergence to maturity.

Hydrological Droughts

Hydrological droughts refer to deficiencies in surface water and sub-surface water supplies. It is measured as stream flow, and as lake, reservoir, and ground water levels. When precipitation is reduced or deficient over an extended period of time, the shortage will be reflected in declining surface and sub-surface water levels. Hydrological droughts are usually out of phase with the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and groundwater and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. Also, water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., flood control, irrigation, recreation, navigation, hydropower, and wildlife habitat), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.

[19] Future Climate Projections Grant County, Dalton, February 2020
[20] https://www.tandfonline.com/doi/abs/10.1080/02508068508686328

Socioeconomic Droughts

Socioeconomic definitions of drought associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on weather. Because of the natural variability of climate, water supply is ample in some years but unable to meet human and environmental needs in other years. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

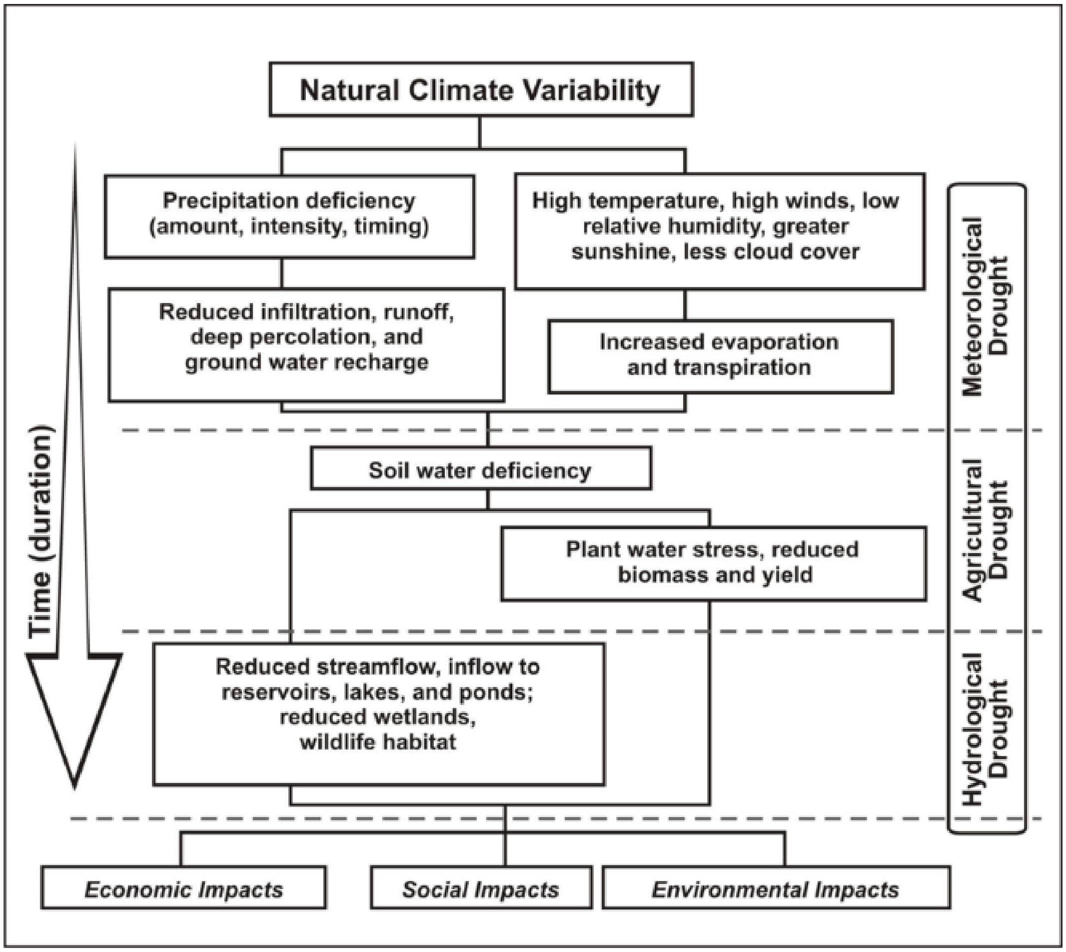
In most instances, the demand for economic goods is increasing as a result of increasing population and per capita consumption. Supply may also increase because of improved production efficiency, technology, or the construction of reservoirs that increase surface water storage capacity. If both supply and demand are increasing, the critical factor is the relative rate of change. Is demand increasing more rapidly than supply? If so, vulnerability and the incidence of drought may increase in the future as supply and demand trends converge.

Ecological Droughts

A more recent effort by conservationists focuses on defining drought in ecological terms. The Science for Nature and People Partnership (SNAPP) is a first-of-its-kind collaboration between three partners: The Nature Conservancy (TNC), the Wildlife Conservation Society (WCS), and the National Center for Ecological Analysis and Synthesis (NCEAS) at the University of California, Santa Barbara. They define ecological drought as "a prolonged and widespread deficit in naturally available water supplies — including changes in natural and managed hydrology — that create multiple stresses across ecosystems."[21]

[21] https://snappartnership.net/teams/ecological-drought/

Figure 9. Types of Drought and Impacts



Sequence of drought occurrence and impacts for commonly accepted drought types. All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impacts cascade from this deficiency. (Source: NDMC)

Oregon's Drought Planning and Monitoring

Oregon Revised Statute (ORS) Chapter 536 identifies authorities available during a drought. "To trigger specific actions from the Water Resources Commission and the Governor, a "severe and continuing drought" must exist or be likely to exist. Oregon relies upon two inter-agency groups to evaluate water supply conditions, and to help assess and communicate potential drought-related impacts. The Water Supply Availability Committee (WSAC) is a technical committee chaired by the Water Resources Department. The other group—the Drought Readiness Council—is a coordinating body of state agencies co-chaired by the Water Resources Department and the Office of Emergency Management."[22]

[22] State of Oregon, *Emergency Operations Plan*, *Incident Annex for Drought*, April 2016, https://www.oregon.gov/oem/Documents/2015_OR_EOP_IA_01_drought.pdf.

An example of a tool used to estimate drought conditions is the Surface Water Supply Index (SWSI).[23] The SWSI is an index of current water conditions throughout a state that the Natural Resources Conservation Service (NRCS) calculates to predict the surface water available in a basin compared to historic supply. The index utilizes parameters derived from snow, precipitation, reservoir and streamflow data.

Another tool produced by NRCS is the Water Supply Outlook report[24]. The Water Supply Outlook is a report containing forecasts of runoff and snowmelt runoff. It also contains a summary of current snowpack, precipitation, river flow volumes, reservoir storage and soil moisture, and data for these is published in the Maps and Data Summaries section. Runoff from the mountains is important for the major rivers in the province where reservoirs store water supplies for irrigation, hydroelectricity and community & municipal purposes. Plains area runoff is important for replenishing soil moisture and water storage in local storage facilities.

Another drought index used by most federal agencies is 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 Oregon and the Pacific Northwest, although it can be very useful because of its a long-term historical record of wet and dry conditions.

The Water Supply Availability Committee consists of state and federal agencies that meet early and often throughout the year to evaluate the potential for drought conditions. If drought development is likely, monthly meetings occur shortly after release of NRCS Water Supply Outlook reports for that year (second week of the month beginning as early as January) to assess conditions. The following are indicators used by the WSAC for evaluating drought conditions:

- Snowpack
- Precipitation
- Temperature anomalies
- Long range temperature outlook
- Long range precipitation outlook
- Current stream flows and behavior
- Spring and summer streamflow forecasts
- Ocean surface temperature anomalies (El Nino, La Nina)
- Storage in key reservoirs
- Soil and fuel moisture conditions
- NRCS Surface Water Supply Index.[25]

In the *2015 Oregon Natural Hazards Mitigation Plan* (*2015 Oregon NHMP*), it states "Oregon has not undertaken a comprehensive statewide analysis to identify which communities are most vulnerable to drought. Mitigation actions specified in this plan including developing an improved methodology for

[23] Natural Resource Conservation Service, Surface Water Supply Index
[24] Natural Resource Conservation Service, Water Supply Outlook reports https://www.wcc.nrcs.usda.gov/state_outlook_reports.htm
[25] State of Oregon, *Emergency Operations Plan*, *Incident Annex for Drought*, April 2016, https://www.oregon.gov/oem/Documents/2015_OR_EOP_IA_01_drought.pdf.

gathering data and identifying the communities most vulnerable to drought and related impacts, and implementing this methodology continue to require adequate staffing and priority for funding.

Ranching, farming, and other agricultural activities contribute significantly to Grant County's economy. Drought can have a significant impact on the agricultural community and associated businesses that rely on this industry. Besides the economy, the *2015 Oregon NHMP* also describes impacts of droughts on the environment, population, infrastructure, critical/essential facilities, and state-owned and operated facilities.

Factors that Affect Drought in Grant County

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. Dust storms are a common occurrence during simultaneous high wind events and drought periods.

Droughts are not just a summer-time phenomenon; winter droughts can have a profound impact on agriculture. Below average snowfall in higher elevations has a far-reaching effect, 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 such as ranching, agriculture, hydroelectric generation, and recreation. Aquifer capacity may be a notable concern under drought conditions. Domestic water-users within the cities may be subject to stringent conservation measures such as water rationing and could be faced with significant increases in electricity rates.

Grant County has been impacted numerous times by precipitation shortfalls/drought conditions. Seasonal irrigation water from mountain snow packs tails off towards the end of August. It is common to find municipal water systems imposing some type of water rationing during dry years. Location of reservoirs helps mitigate the impact of a drought -- water availability is not always correlated to the amount of precipitation.

Facilities affected by drought conditions include communications facilities, hospitals, and correctional facilities that are subject to power failures. Storage systems for potable water, sewage treatment facilities, water storage for firefighting, and hydroelectric generating plants may be vulnerable to drought. Low water also means reduced hydroelectric production especially as the habitat benefits of water compete with other beneficial uses.

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). Discussions with community members during the hazard identification process indicate that while drought may limit the growth of fuel for wildfires, it does provide ideal conditions for wildfires to occur. Drought significantly increases the probability for lightning-caused wildfires to occur, and provides ideal conditions for the rapid spread of wildfire. In addition, drought and water scarcity add another dimension of stress to species listed pursuant to the Endangered Species Act (ESA) of 1973.

History of Drought in Grant County and Oregon

Quantifying drought requires an objective criterion for defining the beginning and end of a drought period. The Palmer Drought Severity Index is most effective in determining long-term drought — e.g. several months — and is not as good with short-term forecasts, e.g. a matter of weeks.

The Palmer Method or Palmer Drought Severity Index (PDSI) indicates the prolonged and abnormal moisture deficiency or excess. It indicates general conditions and not local conditions caused by isolated rain. The PSDI is an important climatological tool for evaluating the scope, severity, and frequency of prolonged period of abnormally dry or wet weather. It can be used to delineate disaster areas and indicate the availability of irrigation water supplies, reservoir levels, range conditions, amount of stock water, and potential intensity of forest fires.

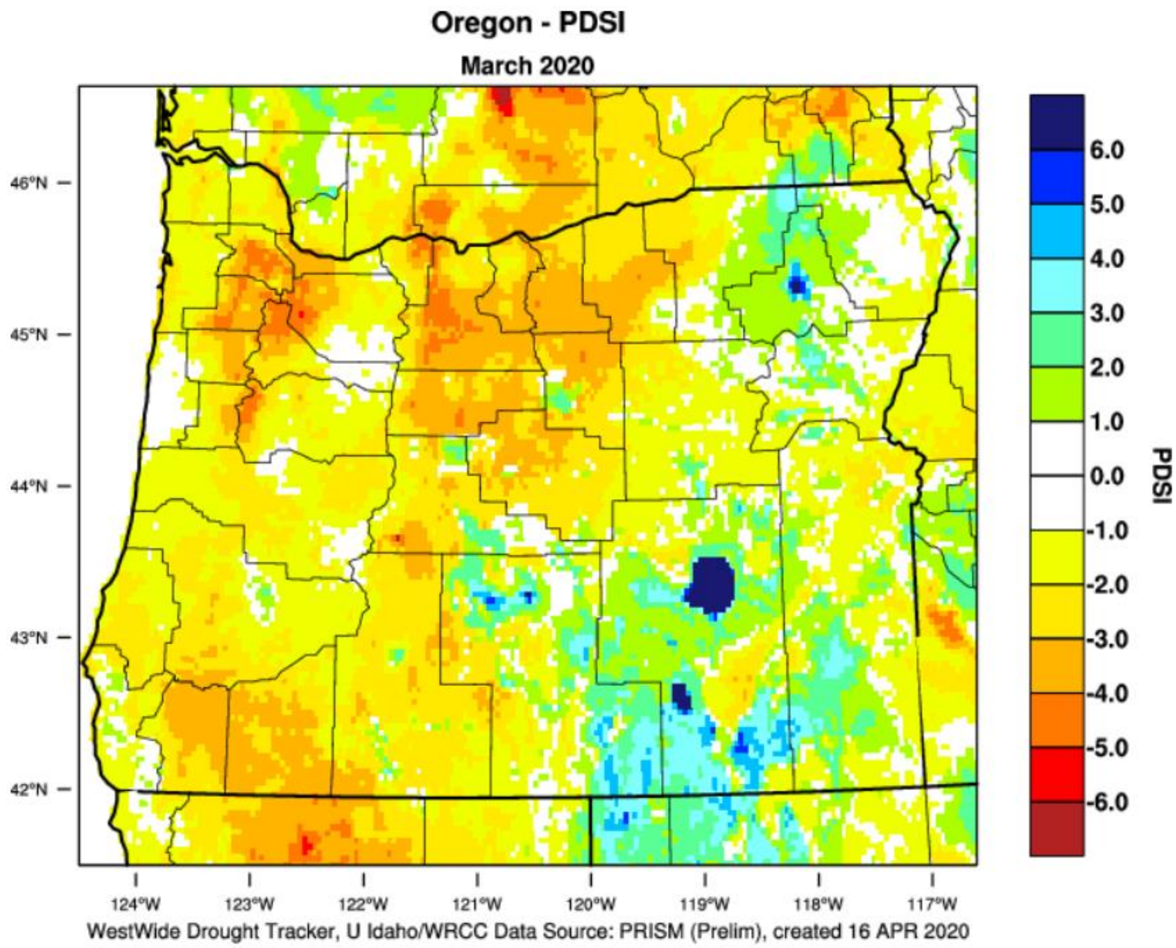
The PDSI uses readily available temperature and precipitation data to estimate relative dryness. It is a standardized index that spans -10 (dry) to +10 (wet). As it uses temperature data and a physical water balance model, it can capture the basic effect of global warming on drought through changes in potential evapotranspiration. Monthly PDSI values do not capture droughts on time scales less than about 12 months. The PDSI uses a zero (0) as normal, and drought is shown in terms of negative numbers; for example, negative two (-2.00) is moderate drought, negative three (-3.00) is severe drought, and negative four (-4.00) is extreme drought.[26] See Figure 1.

Some Oregon droughts were especially significant during the period of 1928 to 1994. The period from 1928 to 1941 was a prolonged drought that caused major problems for agriculture. The only area spared was the northern coast, which received abundant rains in 1930-33. The three Tillamook burns (1933, 1939, and 1945) were the most significant results of this very dry period.

During 1959-1962 stream flows were low throughout Eastern Oregon, but areas west of the Cascades had few problems. The driest period in Western Oregon was the summer following the benchmark 1964 flood. Low stream flows prevailed in Western Oregon during the period from 1976-81, but the worst year, by far, was 1976-77, the single driest year of the century. The Portland airport received only 7.19 inches of precipitation between Oct. 1976 and Feb. 1977, only 31% of the average 23.16 inches for that period. The 1985-94 drought was not as severe as the 1976-77 drought in any single year, but the cumulative effect of ten consecutive years with mostly dry conditions caused statewide problems. The peak year of the drought was 1992, when a drought emergency was declared for all of Oregon. Forests throughout the state suffered from a lack of moisture. Fires were common and insect pests, which attacked the trees, flourished. In 2001 and 2002 Oregon experienced drought conditions.

[26] https://climatedataguide.ucar.edu/climate-data/palmer-drought-severity-index-pdsi

Figure 10. Oregon Counties Palmer Drought Severity Index Map for March 2020



Source: West Wide Drought Tracker, Oregon – PDSI, https://wrcc.dri.edu/wwdt/index.php?region=or

During the 2005 drought the Governor issued declarations for eight counties, all east of the Cascades, and the USDA issued three drought declarations, overlapping two of the Governor's. State declarations were made for Baker, Crook, Gilliam, Hood River, Klamath, Morrow, Sherman, and Umatilla counties. Federal declarations were made in Coos, Klamath, and Umatilla counties. Wheeler County made a county declaration. The USDA declarations provided access to emergency loans for crop losses.

Table 6. History of Drought in Grant County

Year	Location	Description
1938-1939	statewide	the 1920s and 1930s, known more commonly as the Dust Bowl, were a period of prolonged mostly drier than normal conditions across much of the state and country
1977	N & S central Oregon; eastern Oregon	a severe drought for northeast Oregon
1999	Baker, Grant, Union and Wallowa	Baker, Grant, Union and Wallowa Counties were declared disaster areas by the Department of Agriculture due to drought. Approximately one-third of the wheat crop in those areas was lost due to weather.
1994	Regions 4–8	in 1994, Governor's drought declaration covered 11 counties located within regions 4, 5, 6, 7, and 8
2002	southern and eastern Oregon	2001 drought declarations remain in effect for all counties, including Region 7's Baker, Union, and Wallowa Counties; Governor adds Grant County in 2002, along with five additional counties, bringing statewide total to 23 counties under a drought emergency.
2003	southern and eastern Oregon	Grant County 2002 declaration remains in effect through June 2003; Governor issues new declarations for Baker, Union, and Wallowa Counties, which are in effect through December 2003
2007	Regions 6–8	Grant, Baker, and Union Counties receive a Governor drought declaration; three other counties affected in neighboring regions
2014	Regions 4, 6–8	Grant and Baker County receive drought declarations, including eight other counties in other regions
2015	statewide	36 Oregon Counties across the state receive federal drought declarations, including 25 under Governor's drought declaration
2018	Regions 1, 4-8	Baker and Grant County receive Governor's drought declarations, including 9 other counties in 5 other regions

Source: 2015 Oregon State Hazard Mitigation Plan update; 2014 NE Oregon Multi-Jurisdictional NHMP

LANDSLIDE HAZARD ANNEX

Countywide exposure:
- Number of buildings: **1,035**
- Exposure Value: **$205,629,000**
- Ratio of Exposure Value: **10%**
- Critical facilities exposed: **2** (Blue Mountain Hospital and Dayville School)
- Potentially Displaced Population: **1,080**

Landslides are a chronic problem in our state, affecting both infrastructure and private property. Approximately 13,048 documented landslides have occurred in Oregon in the last 150 years (Burns, 20172). The combination of geology, precipitation, topography, and seismic activity makes portions of Oregon especially prone to landslides[27].

Landslides are a geologic hazard in almost every state in America. Nationally, landslides cause 25 to 50 deaths each year.[28] In Oregon, economic losses due to landslides for a typical year are estimated to be over $10 million.[29] In years with heavy storms, such as in 1996, losses can be an order of magnitude higher and exceed $100 million.[30]

While not all landslides result in private property damage, many landslides impact transportation corridors, fuel and energy conduits, and communication facilities. They can also pose a serious threat to human life. 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 owing to their location along the coast, rivers, and on hillsides. Local example

Although landslides are propelled by gravity, they can be triggered by other natural geologic events or human activity. Volcanic eruptions and earthquakes can initiate earth movement on a grand scale. Although earthquakes can initiate debris flows, the major causes of landslides in the northwest are continuous rains that saturate soils.

---

[27] Landslide Guide

[28] Mileti, Dennis. 1999. Disasters by Design: A Reassessment of Natural Hazards in the United States. Washington D.C.: Joseph Henry Press.

[29] Wang, Yumei, Renee D. Summers, R. Jon Hofmeister, and Oregon Department of Geology and Mineral Industries. 2002. “Open-File Report O-02-05: Landslide Loss Estimation Pilot Project in Oregon.” http://www.oregon.gov/LCD/docs/rulemaking/012308/item_1_Kehoe_att_b.pdf, accessed February 14, 2010

[30] Ibid.

Landslides can also be the direct consequence of human activity. Seemingly insignificant modifications of surface flow and drainage may induce landslides. In an urban setting, improper drainage is most often the factor when a landslide occurs.

Many unstable, landslide prone areas can be recognized. Tip-offs include scarps, tilted and bent ("gun-stocked") trees, wetlands and standing water, irregular and hummocky ground topography, and over steepened slopes with a thick soil cover. The technology of spotting landslides by use of aerial photography and new laser based terrain mapping called lidar is helping DOGAMI develop much more accurate and detailed maps of areas with existing landslides and they are now able to create landslide susceptibility maps, that is, maps that that show where staff geologists estimate that different types of landslides may occur in the future.[31]

All landslides can be classified into one of the following six types of movements: (1) slides, (2) flows, (3) spreads, (4) topples, (5) falls, or (6) complex. In addition, landslides may be broken down into the following two categories: (1) rapidly moving; and (2) slow moving. Rapidly moving landslides are typically "off-site" (debris flows and earth flows) and present the greatest risk to human life. Rapidly moving landslides have caused most of the recent landslide-related injuries and deaths in Oregon, including eight deaths in 1996 following La Niña storms. Slow moving landslides tend to be "on-site" (slumps, earthflows, and block slides) and can cause significant property damage, but are less likely to result in serious human injuries.

Landslides vary greatly in the volumes of rock and soil involved, the length, width, and depth of the area affected, frequency of occurrence, and speed of movement. Some characteristics that determine the type of landslide are slope of the hillside, moisture content, and the nature of the underlying materials.

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, and along ocean bluff faces. At natural slopes under 30 percent, most landslide hazards are related to excavation and drainage practices, or the reactivation of preexisting landslide hazards.[32]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. Natural conditions and human activities can both play a role in causing landslides. The incidence of landslides and their impact on people and property can be accelerated by development.[33]

Causes and Characteristics of Landslides

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.

[31] Ibid

[32] Interagency Hazard Mitigation Team.2012- Oregon Natural Hazards Mitigation Plan. Salem, OR: Oregon Military Department – Office of Emergency Management

[33] DLCD, CPW, Planning for Natural Hazards: Oregon Technical Resource Guide, 1999

In understanding 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 broken down into two categories: (1) rapidly moving; and (2) slow moving, in addition to "on-site" or "off-site" hazards. Rapidly moving landslides are typically "off-site" (debris flows and earth flows) and present the greatest risk to human life, and persons living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious injury. Rapidly moving landslides have also caused most of the recent landslide-related injuries and deaths in Oregon. Slow moving landslides tend to be "on-site" (slumps, earthflows, and block slides) and can cause significant property damage, but are less likely to result in serious human injuries.

The staff from Oregon Department of Geology and Mineral Industries teamed up with staff from Oregon Department of Land Conservation and Development to develop an updated guide on land use issues for landslide hazards. This Landslide Guide both describes landslides and the methods used to map them more accurately using LiDAR (Light Detection and Ranging) methods, as well as the types of site specific reporting and the professionals qualified to produce them, mitigation planning topics and the implementation of mitigation actions including a guide to examples of landslide codes for local planners. This document is excerpted below and a reference to the full document is available through the following link:
https://www.oregon.gov/lcd/Publications/Landslide_Hazards_Land_Use_Guide_2019.pdf

Types of Landslides

All landslides can be classified into six types of movement: 1) falls, 2) topples, 3) slides, 4) spreads, 5) flows, and 6) complex (**Figure 2-1**). Most slope failures are complex combinations of these six distinct types, but the generalized groupings provide a useful means for framing discussion of the type of hazard and potential mitigation actions. Movement type should be combined with other landslide characteristics such as type of material, rate of movement, depth of failure, and water content to understand more fully the landslide behavior. For a more complete description of the different types of landslides, see *U.S. Transportation Research Board Special Report 247, Landslides: Investigation and Mitigation* (Turner & Schuster, 199610), which has an extensive chapter on landslide types and processes.

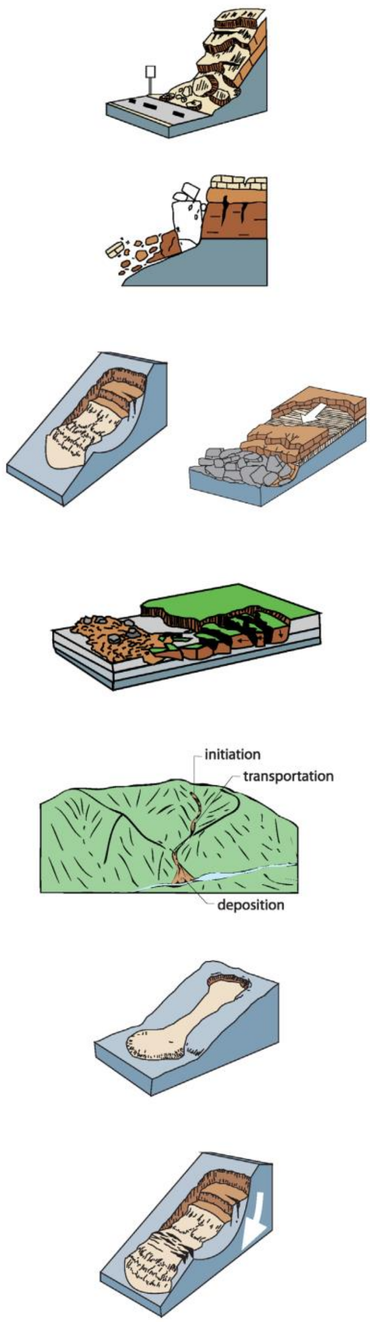
One type of landslide that is commonly life threatening is channelized debris flow, sometimes referred to as a *rapidly moving landslide* or RML. They are more prevalent and impactful than most people recognize. Channelized debris flows normally initiate on a steep slope, move into a steep channel (or drainage), increase in volume by incorporating channel materials, and then deposit material, usually at the mouth of the channel on existing fans. Debris flows can be mobilized by other types of landslides that occur on slopes near a channel. Debris flows can also initiate within channels from accelerated erosion during heavy rainfall or snowmelt. These debris flows move fast enough that they are difficult to outrun. Slopes that have failed in the past often remain in a weakened state, and many of these areas tend to fail repeatedly over time. For example, a channel with a debris flow fan at its mouth indicates a history of debris flows in that channel. The formation of talus slopes indicates that numerous rock falls have occurred above the slope. Talus is "[a]n outward sloping and accumulated heap or mass of rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope, and formed chiefly by gravitational falling, rolling, or sliding" (USGS11).

The tendency for failures to reoccur is true for all types of landslide movements and over periods much longer than human recorded history. Large landslide complexes may have moved dozens of times over thousands of years, with long periods of stability punctuated by episodes of movement. In some cases, areas that have previously failed have subtle topographic morphology now, making them difficult to identify. However, technological advances such as lidar have greatly helped in the process of identifying and mapping older landslides. Identifying and mapping both historical and ancient landslide areas – many of which will move again – is of great importance for mitigating the risk these natural hazards pose.

Potential slope instability is not limited to past landslide sites. Areas near previous landslides and of similar geology and topography are also at higher risk for slope failure. This makes it even more important to locate previous landslides and study them: Mapping landslide locations can identify nearby or similar areas susceptible to slope instability.[34]

[34] Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities (October 2019)

Figure 11. Types of Common Landslides in Oregon



Falls are near-vertical, rapid movements of masses of materials, such as rocks or boulders. The rock debris sometimes accumulates as talus at the base of a cliff.

Topples are distinguished by forward rotation about some pivotal point, below or low in the mass.

Slides are downslope movement of soil or rock on a surface of rupture (failure plane or shear-zone).

- **Rotational** slides move along a surface of rupture that is curved and concave.
- **Translational** slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.

Spreads are commonly triggered by earthquakes, which can cause liquefaction of an underlying layer and extension and subsidence of commonly cohesive materials overlying liquefied layers.

Channelized Debris Flows commonly start on a steep, concave slope as a small slide or earth flow into a channel. As this mixture of landslide debris and water flows down the channel, it pick ups more debris, water, and speed, and deposits in a fan at the outlet of the channel.

Earth Flows commonly have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head.

Complex landslides are combinations of two or more types. A common complex landslide is a slump-earth flow, which usually exhibit slump features in the upper region and earth flow features near the toe.

Source: Preparing for Landslide Hazards: A Land Use Guide for Oregon Communities (October 2019)

Conditions Affecting Landslides

Depending upon the type, location, severity and area affected, severe property damage, injuries and loss of life can be caused by landslides. 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.

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.

The following are principal factors that affect or increase the likelihood of landslides:

- Natural conditions and processes including the geology of the site, rainfall, wave and water action, seismic tremors and earthquakes and volcanic activity.
- Excavation and grading on sloping ground for homes, roads and other structures. Improper excavation practices, sometimes aggravated by drainage issues, can reduce the stability of otherwise stable slopes.
- 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.
- High rainfall accumulation in a short period of time increases the probability of landslide. An extreme winter storm can produce inches of rainfall in a 24 hour period; if the storm occurs well into the winter season, when the ground is already saturated, the hydraulic overload effect is heightened.
- Change or removal of vegetation on very steep slopes due to timber harvesting, land clearing and wildfire.

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 there are no development practices that can completely assure slope stability from future slide events.

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.

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.

History of Landslides in Grant County and Oregon

In recent events, particularly noteworthy landslides accompanied storms in 1964, 1982, 1966, 1996, and 2005. Most of Oregon's landslide damage has been associated with severe winter storms where landslide losses can exceed $100 million in direct damage such as the February 1996 event. More winter storm induced landslides occurred in Oregon during November 1996. Intense rainfall on recently past logged land as well as previously unlogged areas triggered over 9,500 landslides and debris flows that resulted directly or indirectly in eight fatalities Highways were closed and a number of homes were lost. The fatalities and losses resulting from the 1996 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.

Annual average maintenance and repair costs for landslides in Oregon are over $10 million.[35]Heavier than normal rains caused thousands of landslides throughout Oregon of which roughly 9,500 were identified and added to a database. Some of these slides were the reactivation of ancient and historically active landslides and some were new failures.

Recent landslide history in Grant County

Preparing for Landslide Hazards: A Land Use Guide for Oregon

DOGAMI and DLCD prepared a comprehensive guide on landslide hazard reduction entitled *Preparing for Landslide Hazards: A Land Use Guide for Oregon* (referred to as the Landslide Guide) that addresses what landslides are and the nature of the risk that they pose to people and property along with specific details on the methodology for mapping landslide susceptibility. The Landslide Guide goes beyond the identification of the hazard and description of the risk to mitigation actions that local jurisdictions can to reduce risk from landslides. The Landslide Guide contents will be summarized here and will serve as a key reference to consult when considering mitigation of the risk of landslides in Oregon communities.

The Landslide Guide identifies planning tools and mitigation strategies to reducing landslide hazard risk. Improved mapping is the first step in better identifying areas where landslides have occurred in the past, a landslide inventory map., and susceptible to landslides. This improved mapping based on lidar (Light Detection and Ranging) technology has significantly improved DOGAMI's ability to identify and map landslide features. Lidar is a relatively new technology that allows mappers to see the earth's surface beneath vegetation and trees, as if the earth had been stripped bare. Lidar gives geologists the ability to identify and map landslide features that may have previously been unrecognized or overlooked. DOGAMI has published the landslide inventory maps in a database called SLIDO. Currently SLIDO is at release 3.4 and has been updated to contain 13,048 historic landslide points and 44,929 landslide polygons. So far, 2,986 square miles of Oregon have been mapped. Oregon is 95,988 square miles.[36]

---

[35] Wang and Chaker, 2004. Geological Hazards Study for the Columbia River Transportation Corridor. Oregon Department of Geology and Mineral Industries Open File Report OFR 0-4-08

[36] https://www.indexmundi.com/facts/united-states/quick-facts/oregon/land-area#map

Further analysis that combines geologic information with the landslide inventory can be used to develop landslide susceptibility maps. Once a landslide feature has been recognized and mapped using lidar, several attributes about the slide, such as type of movement and material, depth of failure, direction of movement, volume of material, and initial slope angle are recorded to aid in the creation of landslide susceptibility maps for the local area. The estimated depth of failure or landslide thickness is used to classify some of the landslides as shallow (less than 15 feet depth) or deep (greater than 15 feet depth). The deep and shallow susceptibility maps are produced using the landslide inventory data combined with models and highlight the relative risk of a landslide occurring at any given point within the mapped area. These susceptibility maps work in conjunction with landslide inventory maps to provide jurisdictional staff, community leaders, and residents information necessary to reduce the risk of landslides impacting people, property, and the environment.

The Landslide Guide answers questions local planners and property owners may have regarding the type of professionals who are qualified to perform engineering geologic reports or geotechnical engineering reports. Engineering geologic reports and geotechnical engineering reports refer to different but related services performed by geoprofessionals with different professional certifications. Engineering geologic reports focus on how the earth (e.g., landforms, water table, soil, and bedrock) and earth processes (e.g., landslides and earthquakes) impact structures or potential structures and describe the degree of risk, while geotechnical engineering reports focus on the design of building products (e.g., structures, retaining walls, pavements) that can withstand or mitigate for subsurface and geologic conditions.

The primary purpose of the Landslide Guide is to provide a range of tools and strategies for using the information provided by landslide inventory and susceptibility maps and the information in geotechnical engineering or engineering geologic reports.

The Landslide Guide addresses how landslide hazard can be incorporated into comprehensive plans. In Oregon the required components of a comprehensive plan are: an inventory of existing conditions (factual base); goals and objectives; plan policies; and implementation measures and ordinances. The inventory of existing conditions (factual base) provides the basis and justification for plan policies. The plan policies provide general guidance in review of land use proposals. The implementing measures and ordinances provide the specific standards and criteria against which development proposals are reviewed. The Cities of Medford, Astoria and Portland provide examples of incorporation of landslide hazard mapping into comprehensive planning.

The Landslide Guide goes further to address the implementation of comprehensive plans through zoning codes. Zoning for natural hazards is often accomplished through zoning overlays, with other related maps, and with corresponding text in the zoning code. A better understanding of the causes and characteristics of landslides, as well as recognizing the locations, types, and extents of landslides leads to more effective plans, policies, and implementing measures. Identifying hazard areas and evaluating proposed development in these areas reduces risk and better protects a community. Zoning ordinances can be a powerful tool for protecting community and private assets against landslides and other hazards.

Finally the Landslide Guide reviews the codes of thirty-four Oregon communities with respect to landslide hazard and summarizes what makes a strong regulatory framework for reducing hazards from landslide. The Landslide Guide summarizes key ways that communities can reduce risk from landslide as follows:

• **Identify the hazard** – Know what the hazard is, where it is located, what causes it, what are its characteristics, when and where has it occurred historically, and when and where might it happen again.

• **Assess the vulnerabilities** – Inventory and analyze the existing and planned property and populations exposed to a hazard, and estimate how they will be affected by the hazard.

• **Assess the level of risk** – Risk is the expression of the potential magnitude of a disaster's impact. A natural hazards risk assessment involves *Landslide Hazards Land Use Guide for Oregon Communities* characterizing the natural hazards, assessing the vulnerabilities, and describing the risk either quantitatively or qualitatively or both.

• **Avoid the hazard** – Stay away from the hazard area if possible.

• **Reduce the level of risk** - Minimize development, reduce density, and implement mitigation measures. Manage the water on the site. Coordinate land use planning efforts with other planning efforts such as emergency operations plans, transportation plans, economic development plans, stormwater management plans, and so forth.

• **Evaluate development in landslide-prone areas** – Use technical information such as maps and reports, including site specific studies as well as broader scale information.

• **Require geotechnical investigations** – When development is proposed for locations that have landslide hazards, require site specific reports by a certified engineering geologist engineer (geotechnical assessment) or a certified engineering geologist and a geotechnical engineer (geotechnical report).

• **Adopt land use policies and enact regulations** – Regulatory tools such as overlay zones, incentive zoning, grading and erosion control provisions, stormwater management, restrictions on the types of uses and development in landslide-prone areas, size and weight of structures, management of vegetation, and other means can reduce risk of landslides. Incentive zoning requires developers to exceed limitations imposed upon them by regulations, in exchange for specific concessions. For example, if the developer avoids building on a landslide-prone area of the property then they could build on another portion of the land at a higher density than is allowed by the zoning.

• **Consider non-regulatory strategies** – Sharing information, incentives, and purchasing high hazard lands to keep them as open space are examples of strategies that can reduce risk.

• **Provide public outreach and education** – Information about the landslide hazards should be available to all inhabitants of the jurisdiction. Post it on the website, have handouts, and raise awareness of the hazard with the public at large.