City of Salem

NATURAL HAZARDS MITIGATION PLAN

2023 Update is underway, and your input is needed!

DRAFT 1: RISK ASSESSMENT is now available.

Please provide comments to
BCARRARA@CITYOFSALEM.NET
by May 5, 2023.

Questions?

CITY OF Salem AT YOUR SERVICE

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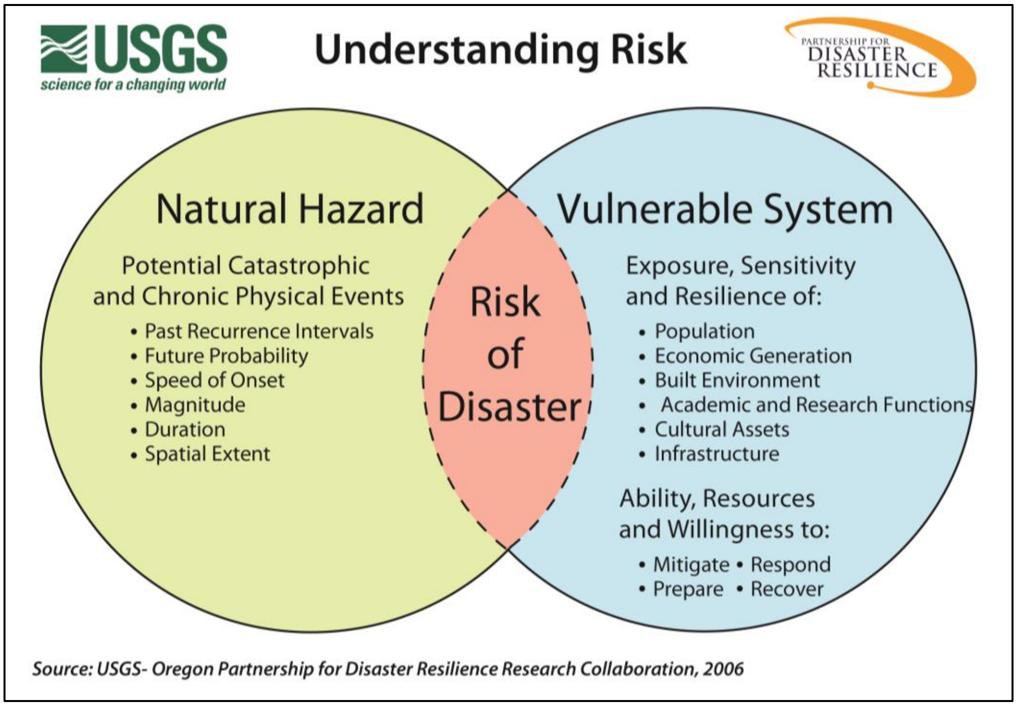
SECTION 2: RISK ASSESSMENT

This section serves as the factual basis for City of Salem to address Oregon Statewide Planning Goal 7 – Areas Subject to Natural Hazards. In addition, this section of the NHMP addresses 44 CFR 201.6(b)(2) - Risk Assessment. Assessing natural hazards risk has three primary phases:

- **Phase 1:** Identify hazards that can impact the jurisdiction. This includes an evaluation of potential hazard impacts – type, location, extent, etc.
- **Phase 2:** Identify important community assets and system vulnerabilities. Example vulnerabilities include people, businesses, homes, roads, historic places, and drinking water sources.
- **Phase 3:** Evaluate the extent to which the identified hazards overlap with, or have an impact on, the important assets identified by the community.

This section provides information on the natural hazard risk assessment process. It is general in scope and provides information on what a risk assessment entails, describes the sources of information and risk assessment exercise used to assess risk of natural hazard events in the City of Salem, and some of the related hazard vulnerability maps that are included in the natural hazard sections. The OEM Hazard Vulnerability Assessment exercise allowed the steering committee to identify and evaluate the natural hazards that pose the greatest risk to the City of Salem and to evaluate the risk of each of those based on four factors (history, probability, vulnerability, and maximum threat).

The information presented below, along with hazard specific information presented with each Hazard and community characteristics presented in the Community Profile (Volume II: Appendix A) will be used as the local level rationale for the risk reduction actions identified in the Mitigation Strategy (Volume I: Section 3). The risk assessment process is graphically depicted in



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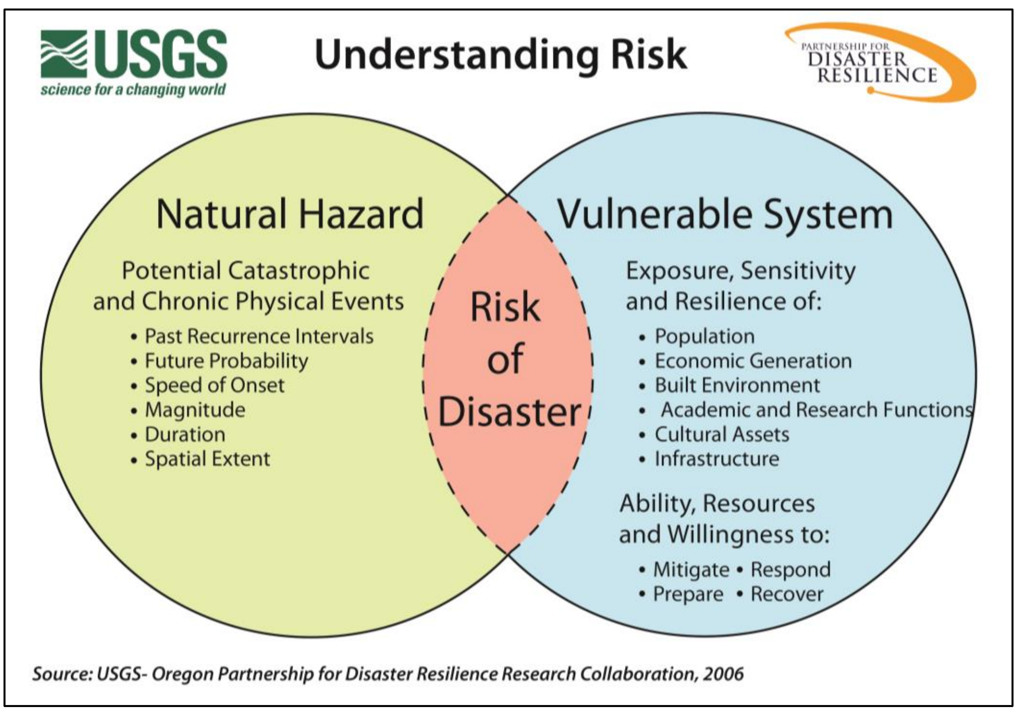
Ultimately, the goal of hazard mitigation is to reduce the area where hazards and vulnerable systems overlap.

Figure 2-1 Understanding Risk

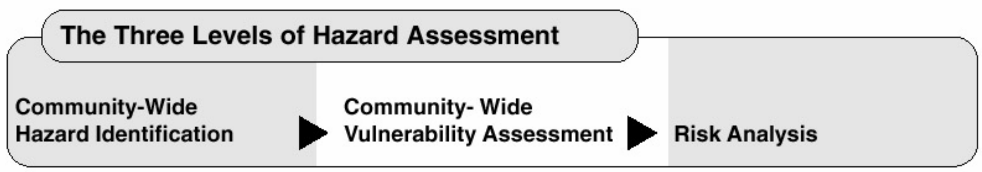


Source: Institute for Policy Research and Engagement in the School of Planning, Public Policy and Management. (n.d.) Oregon Partnership for Disaster Resilience. University of Oregon. Retrieved from https://opdr.uoregon.edu/. .

Risk Assessment Approach

According to the FEMA Local Mitigation Planning Handbook, risk assessment is a product or process that collects information and assigns values to risks for the purpose of informing priorities, developing, or comparing courses of action, and informing decision making. Conducting a risk assessment can provide information on the location of hazards, the value of existing land and property in hazard locations, and an analysis of risk to life, property, and the environment that may result from natural hazard events. A risk assessment consists of three primary levels: hazard identification, vulnerability assessment, and risk analysis. The Salem NHMP identifies a fourth level that includes consideration of how development trends affect risk assessments.

Figure 2-2 Three Levels of a Risk Assessment



Source: Oregon DLCD. (2000, July). *Planning for Natural Hazards: Key elements of a Comprehensive Plan in Oregon's Statewide Land Use Planning Program.* Retrieved from https://www.oregon.gov/LCD/NH/Documents/PlanningForNaturalHazards-KeyElements_2000.pdf.

This three-phase approach to developing a risk assessment should be conducted sequentially because each phase builds upon data from prior phases. However, gathering data for a risk assessment need not occur sequentially. These three levels, together with the fourth component Salem added, are described below.

Hazard Identification

Hazard identification involves the identification of the geographic extent of a hazard, its intensity, and its probability of occurrence. This level of assessment typically involves producing a map. The outputs from this phase can also be used for land use planning, management, and regulation; public awareness; defining areas for further study; and identifying properties or structures appropriate for acquisition or relocation (Burby, 1998).

The hazard identification includes a profiling of hazard events, which describes the causes and characteristics of each natural hazard, how each has affected Salem in the past, and what part of Salem's population, infrastructure, and environment has historically been vulnerable to each specific hazard. A full profile of each hazard discussed in this plan is provided in hazard section, including a full description of the history of hazard-specific events.

In the *2017 Salem NHMP*, the City of Salem identified 10 major hazards that consistently affect this geographic area: drought, earthquake, extreme heat, flood, hazardous materials incident, landslide, volcano, wildfire, windstorm, and winter storm. During the NHMP update process in 2022, the steering committee members identified two additional natural hazards, Air Quality and Water Quality.

Another change made to the list of natural hazards addressed in the plan was the reconsideration of the impact of Climate Change. The steering committee agreed that the impact of climate change is experienced in the increased severity and frequency of natural hazard events and will be addressed throughout the NHMP.

Vulnerability Assessment

The vulnerability assessment combines the information from the hazard identification with an inventory of the existing (or planned) property and population exposed to a hazard and attempts to predict how different types of property and population groups will be affected by the hazard. This step can also assist in justifying changes to building codes or development regulations, property acquisition programs, policies concerning critical and public facilities, taxation strategies for mitigating risk, and informational programs for members of the public who are at risk. (Burby, 1998)

The critical facilities have been identified, listed in a table at the end of this section and noted, where applicable, in each identified hazard.

Risk Assessment/Analysis

The risk assessment/analysis involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over a period. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment, and (2) the likelihood or probability of the harm occurring.

The following risk analysis draws upon four sources: 2017 Salem Natural Hazard Mitigation Plan, Hazard Vulnerability Assessment exercise conducted with Salem NHMP Steering Committee using the method developed by FEMA Region X and Oregon Department of Emergency Management (OEM), and the list of Local Essential and State-owned and Leased Properties for Marion and Polk Counties contained within the 2020 Oregon Natural Hazard Mitigation Plan. This list was evaluated and revised by the Salem Steering Committee to develop the list provided in Table 2-23 of critical and essential facilities. The value and area of these structures comprises the data used to estimate potential losses.

The fourth source of information for the risk analysis is the DOGAMI Multi-Hazard Risk Report that utilizes HAZUS-MH analysis and geospatial analysis for Marion County and the western portion of Salem that is in Polk County. HAZUS-MH stands for Hazards U.S. – Multi-Hazard and it is a software program that joins current scientific and engineering knowledge with the latest geographic information systems (GIS) technology to produce estimates of hazard-related damage before, or after a disaster occurs. The geospatial analysis includes both loss estimates (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using FEMA Hazus®-MH methodology, and (2) calculated number of buildings, their value, and associated populations exposed to earthquake, and flood scenarios, or susceptible to varying levels of hazard from landslides and wildfire (Williams & Madin, 2022).

Development Trends

Assessing vulnerability and analyzing development trends provides a general description of land uses and development trends within the community so that mitigation options can be considered in land-use planning and future land-use decisions. This plan provides a comprehensive description of the character of the Salem community in Appendix A: Community Profile. This description includes the geography and environment, population and demographics, land use and development, housing and community development, employment and industry, and transportation and commuting patterns. Analyzing these components of the Salem community can help in identifying potential problem areas and can serve as a guide for incorporating goals and ideas contained in this mitigation plan into other community development plans.

Hazard assessments are subject to the availability of hazard-specific data. Gathering data for a hazard assessment requires a commitment of resources on the part of participating organizations and agencies. Each hazard-specific section of the plan includes a section on hazard identification using data and information from city, county, or state agency sources.

Regardless of the data available for hazard assessments, there are numerous strategies the City of Salem can take to reduce risk. These strategies are described in the action items detailed in Section 3 of this plan. Mitigation strategies can further reduce disruption of critical services, reduce the risk to human life, and alleviate damage to personal and public property and infrastructure. Action items provide recommendations to collect further data to map hazard locations and conduct hazard assessments.

NHMP Planning Area

44 CFR 201.6(c)(2)(iii) – Multi-jurisdictional Risk Assessment: The Risk Assessment must assess each jurisdiction's risks where they vary from the risks facing the entire planning area . . .

This is not a multi-jurisdictional NHMP; the only plan holder for this NHMP is City of Salem. A plan holder is a partner that is a jurisdiction that signs the IGA with DLCD for the work on the NHMP. The planning area for the *2023 Salem NHMP* is the City of Salem. There are other partners that participated on the *2023 Salem NHMP,* but they did not sign an IGA with DLCD. All partners are listed in the Special Thanks and Acknowledgements section of the *2023 Salem NHMP*. There are maps throughout the NHMP that illustrate the location of Salem with reference to Marion County or Polk County and Oregon. In addition, there are maps of Salem in detail.

Hazard Identification and Assessment

Salem identifies 11 natural hazards that could impact the city. These hazards include air quality, drought, earthquake, extreme heat, flood, landslide, volcanic event, water quality, wildfire, windstorm, and winter storm. At the Salem NHMP Steering Committee meeting on November 15, 2022 and December 14, 2022, the DLCD Natural Hazards Planner led the group in an exercise called the Hazard Vulnerability Analysis or Assessment (HVA). At the January 26, 2023 steering committee meeting, the HVA was reviewed and revised. The results are discussed in more detail later in this Risk Assessment.

Table 2-1 categorizes the hazards identified by Sweet Home and compares it to the regional hazards identified in the *2020 Oregon Natural Hazard Mitigation Plan* for the Mid/Southern Willamette Valley Region (Region 3). Region 3 includes Linn, Lane (non-coastal), Marion, Polk, and Yamhill Counties.

Table 2-1 Salem Hazard Identification Comparison

Salem	Marion County	Oregon NHMP Region 3: Mid/Southern Willamette Valley
Natural Hazards		
Air Quality	N/A	N/A
Drought	Drought	Drought
Earthquake	Earthquake	Earthquake
Extreme Heat	Extreme Heat/ High Temperature	Extreme Heat
Flood	Flood	Flood
Landslide	Landslide	Landslide
Water Quality	N/A	N/A
Wildfire	Wildland Interface Fire	Wildfire
Windstorm	N/A	Windstorm
Winter Storm	Severe Weather/Storm (winter)	Winter Storm
N/A	Avalanche	N/A
N/A	N/A	Volcano
Other Hazards		
Hazardous Materials Incident	Hazardous Materials*	

Source: Salem NHMP Steering Committee (2022), Marion County NHMP (2022), and State of Oregon NHMP (2020).
*Note: Marion County 2022 NHMP identified multiple non-natural hazards including hazardous materials.

This Hazard Identification section includes descriptions for each natural hazard in the following ways: significant changes since the *2017 Salem NHMP*, characteristics, and the location/extent. The hazard identification also includes profiling of hazard events, which describes the causes and characteristics of each natural hazard, how each has affected Salem in the past, and what part of Salem's population, infrastructure, and environment has historically been vulnerable to each specific hazard. For additional details on the history of events for each hazard, the relationship with climate projections, and maps of the hazards, see below under Hazard Characterization.

As part of the NHMP update process, there is a requirement to examine changes in development. Climate change and climate resilience are important parts of this discussion. The climate is changing and the impacts becoming more evident in both quantitative and qualitative information. According to the UN Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2014: Mitigation of Climate Change*, resilience is defined as "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (Arctic Council, 2013)." (Allwood et al., 2014).

The Hazard Vulnerability Assessment and the analysis of risk are included within and after the Hazard Identification section of this Risk Assessment. This analysis covers all the identified natural hazards in a relatively brief manner. Other hazards such as hazardous materials incident was not reviewed. Note that Table 2-23 Critical and Essential Facilities for the City of Salem, identifies the critical facilities, critical infrastructure, and vulnerable population centers of Salem.

Of the *2020 Oregon Natural Hazards Mitigation Plan*, Region 3 includes Linn, Lane (non-coastal), Marion, Polk, and Yamhill Counties. As described in the Risk Assessment for Region 3, Climate Change section:

> The hazards faced by Region 3 that are projected to be influenced by climate change include drought, wildfire, flooding, landslides, and extreme heat.
>
> Climate models project warmer, drier summers for Oregon. Coupled with projected decreases in mountain snowpack due to warmer winter temperatures, Region 3 is expected to be affected by an increased incidence of drought and wildfire. In Region 3, climate change would result in increased frequency of drought due to low spring snowpack (very likely, >90%), low summer runoff (likely, >66%), and low summer precipitation and low summer soil moisture (more likely than not, >50%). It is very likely (>90%) that Region 3 will experience increasing wildfire frequency and intensity due to warmer, drier summers coupled with warmer winters that facilitate greater cold-season growth.
>
> It is extremely likely (>95%) that the frequency and severity of extreme heat events will increase over the next several decades across Oregon due to human-induced climate warming (very high confidence).
>
> Furthermore, flooding and landslides are projected to occur more frequently throughout western Oregon. It is very likely (>90%) that Oregon will experience an increase in the frequency of extreme precipitation events and extreme river flows (high confidence) that is more likely than not (>50%) to lead to an increase in the incidence and magnitude of damaging floods (low confidence). Because landslide risk depends on a variety of site-specific factors, it is more likely than not (>50%) that climate change, through increasing frequency of extreme precipitation events, will result in increased frequency of landslides.
>
> While winter storms and windstorms affect Region 3, there is little research on how climate change influences these hazards in the Pacific Northwest. For more information on climate drivers and the projected impacts of climate change in Oregon, see Section 2.2.1.2.

Federal Disaster and Emergency Declarations

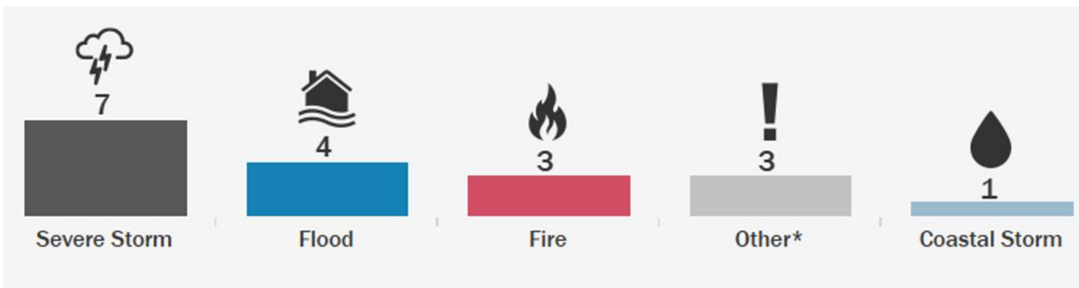
Reviewing past events that have occurred in Salem and Marion and Polk Counties can provide a general sense of the hazards that have caused significant damage in the city and surrounding area. Where trends emerge, disaster declarations can help inform hazard mitigation project priorities.

President Dwight D. Eisenhower approved the first federal disaster declaration in May 1953 following a tornado in Georgia. Since then, federally declared disasters have been approved within every state as a result of natural hazard related events. When governors ask for presidential declarations of major disaster or emergency, they stipulate which counties in their state they want included in the declaration.

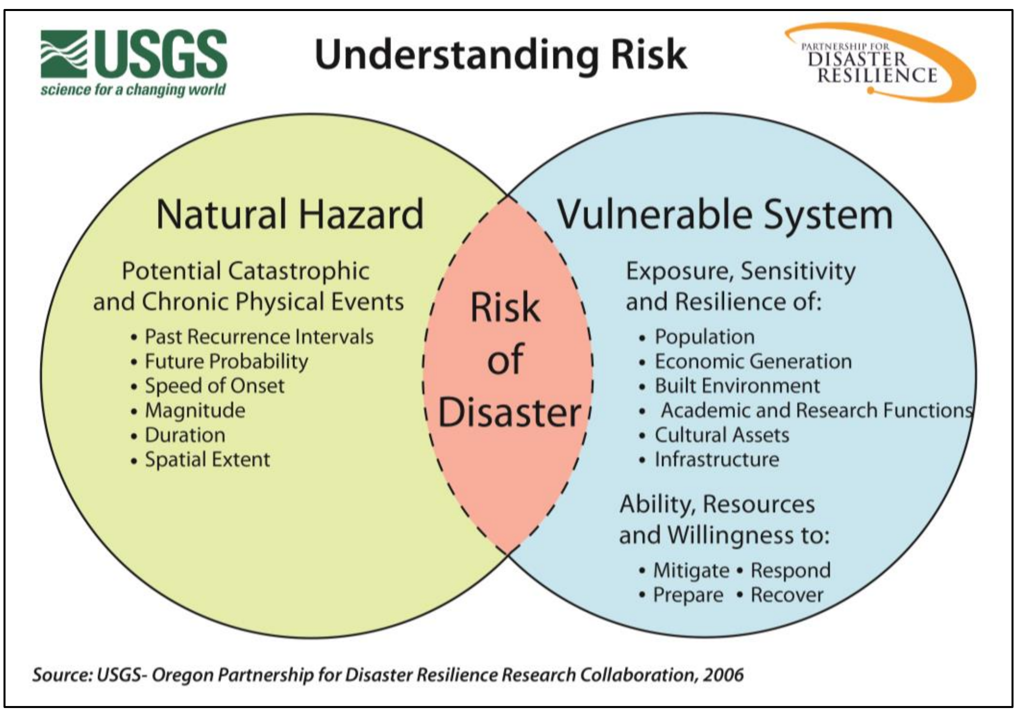
A Major Disaster Declaration provides a wide range of federal assistance programs for individuals and public infrastructure, including funds for both emergency and permanent work. An Emergency Declaration is more limited in scope and without the long-term federal recovery programs of a Major Disaster Declaration. Generally, federal assistance and funding are provided to meet a specific emergency need or to help prevent a major disaster from occurring. Fire Management Assistance is provided after a State submits a request for assistance to the FEMA Regional Director at the time a "threat of major disaster" exists.

According to FEMA's Disaster Declarations for States and Counties, FEMA has approved a total of 39 federal major disaster (DR) declarations in Oregon, as of February 2023. In addition, there have been 4 emergency (EM) declarations and 99 fire management assistance (FM) declarations in Oregon as of February 2023. There are also 36 Fire Suppression Authorizations (FSA) on record for Oregon. Counting primary types of disaster declarations (DR, EM, and FM), the total number of disasters in Oregon is 142.

Figure 2-3 Marion and Polk County Disasters by Incident Category



Source: FEMA. (February 25, 2021). Disaster Declarations for States and Counties. Retrieved February 15, 2023, from https://www.fema.gov/data-visualization/disaster-declarations-states-and-counties.



Understanding Risk 3, shown above, uses FEMA's historical disaster data information as a visual for the disaster declarations in Marion and Polk Counites. Salem is in Marion County and Polk County. Of the 142 Oregon declarations, Marion and Polk Counties are associated with 18 of those declarations, which include 14 DR, 3 EM, and 1 FM declarations. Table 2-2 summarizes the FEMA disaster declarations declared in Oregon that have directly affected Marion and Polk Counties since 1953; this table uses the FEMA disaster declarations information as noted in the source listed under the table.

Table 2-2 FEMA Major Disaster, and Emergency, and Fire Management Assistance Declarations for Marion and Polk Counties

Declaration Number	Declaration Date	Incident Period		Incident	Individual Assistance	Public Assistance Categories
		From	To			
DR-184	12/24/1964	12/24/1964	12/24/1964	Heavy rains and flooding	Yes	A, B, C, D, E, F, G
DR-413	1/25/1974	1/25/1974	1/25/1974	Severe Storms, Snowmelt, Flooding	Yes	A, B, C, D, E, F, G
DR-985^	4/26/1993	3/25/1993	3/25/1993	Earthquake	Yes	A, B, C, D, E, F, G
DR-1099	2/9/1996	2/4/1996	2/21/1996	Severe Storms/Flooding	Yes	A, B, C, D, E, F, G
DR-1510	2/19/2004	12/26/2003	1/14/2004	Severe Winter Storm	None	A, B, C, D, E, F, G
EM-3228	9/7/2005	8/29/2005	10/1/2005	Hurricane Katrina Evacuation	None	B
DR-1632*	3/20/2006	12/18/2005	1/21/2006	Severe Storms, Flooding, Landslides, and Mudslides	None	A, B, C, D, E, F, G
DR-1683*	2/22/2007	12/14/2006	12/15/2006	Severe Winter Storm and Flooding	None	A, B, C, D, E, F, G
DR-1733*	12/8/2007	12/1/2007	12/17/2007	Severe Storms, Flooding, Landslides, and Mudslides	None	A, B, C, D, E, F, G
DR-1824	3/2/2009	12/13/2008	12/26/2008	Severe Winter Storm, Record and Near Record Snow, Landslides, and Mudslides	None	A, B, C, D, E, F, G
DR-4055	3/2/2012	1/17/2012	1/21/2012	Severe Winter Storm, Flooding, Landslides, and Mudslides	None	A, B, C, D, E, F, G
DR-4258*	2/17/2016	12/6/2015	12/23/2015	Oregon Severe Winter Storms, Straight-line Winds, Flooding, Landslides, and Mudslides	None	A, B, C, D, E, F, G
EM-3429	3/13/2020	1/20/2020	Ongoing	Oregon Covid-19	None	B

Declaration Number	Declaration Date	Incident Period		Incident	Individual Assistance	Public Assistance Categories
		From	To			
DR-4499	3/28/2020	1/20/2020	Ongoing	Oregon Covid-19 Pandemic	Yes	B
FM-5356^	9/8/202	9/7/2020	10/15/2020	Oregon Beachie Creek Lionshead Complex	None	B, H
EM-3542^	9/10/2020	9/8/2020	9/15/2020	Oregon Wildfires	None	B
DR-4562^	9/15/2020	9/7/2020	11/3/2020	Oregon Wildfires, Straight-line Winds	Yes	A, B, C, D, E, F, G
DR-4599	5/4/2021	2/11/2021	2/15/2021	Oregon Severe Winter Storms	None	A, B, C, D, E, F, G

Source: FEMA. (2021, February 25). *Disaster Declarations for States and Counties*. Reports and Data. Retrieved February 15, 2023, from https://www.fema.gov/data-visualization/disaster-declarations-states-and-counties.
Note: ^-Declared for Marion County Only, *-Declared for Polk County Only

Air Quality

Significant Changes Since Previous Plan:

The Air Quality Hazard is new to Salem's NHMP.

Causes and Characteristics

Communities across Oregon have begun to recognize the impacts of inversion layers trapping particulates in smoke from wood stove, prescribed fire, wildfire, and field burning as a natural hazard. In addition, Salem has begun to recognize the impacts of reduced outdoor air quality with warmer temperatures and increase in the number and size of wildfires in the region.

The nature of air movement or stagnation in a valley causes inversion layers to form. At the valley floor daytime temperatures heat the air. In the evening, air further up the slope of the mountains cools faster than the air lower down the slope. Because cool air is slightly heavier than warm air, the cool air sinks into the valley which displaces the warm air above it to form a "lid." If the weather creates stagnant conditions this inversion "lid" may persist trapping air pollutant discharges to create poor air quality.

The Oregon Climate Change Research Institute's *Future Climate Projections Marion County, Oregon* report (June 2022) discusses how fire seasons have increased in length over the past several decades. The fires have also increased in intensity and severity. Wildfires that have occurred in the western United States have created extensive plumes of smoke, which travel at high altitudes over long distances. This can affect air quality near and far from a wildfire site. The report states, "This trend is expected to continue as a result of complex factors including traditional forest management practices, increasing population density in fire risk zones, and climate change (Sheehan et al., 2015)." (Dalton, Fleishman, & Bachelet, 2022)

Air quality can be affected by several types of pollutants including ozone, particulate matter, air toxics (such as benzene), greenhouse gases (such as carbon dioxide), and products of combustion (such as carbon monoxide, sulfur dioxide and NOx). Among these, particulate matter with particles 2.5 microns or smaller (PM2.5) is the pollutant of highest concern in Salem.

Wildfires[1] tend to provide a wide-ranging source of smoke that can blanket large areas and be detrimental to the health of people, animals, and plants. Wood burning stoves tend to be a more concentrated, point source type of pollution that decreases air quality. Field burning is an agricultural technique that can contribute to air quality issues. Diesel emissions, often from vehicles on roads, also contribute to lower air quality. If a volcano[2] were to erupt,

[1] See the Wildfire Hazard for more information about wildfire impacts.

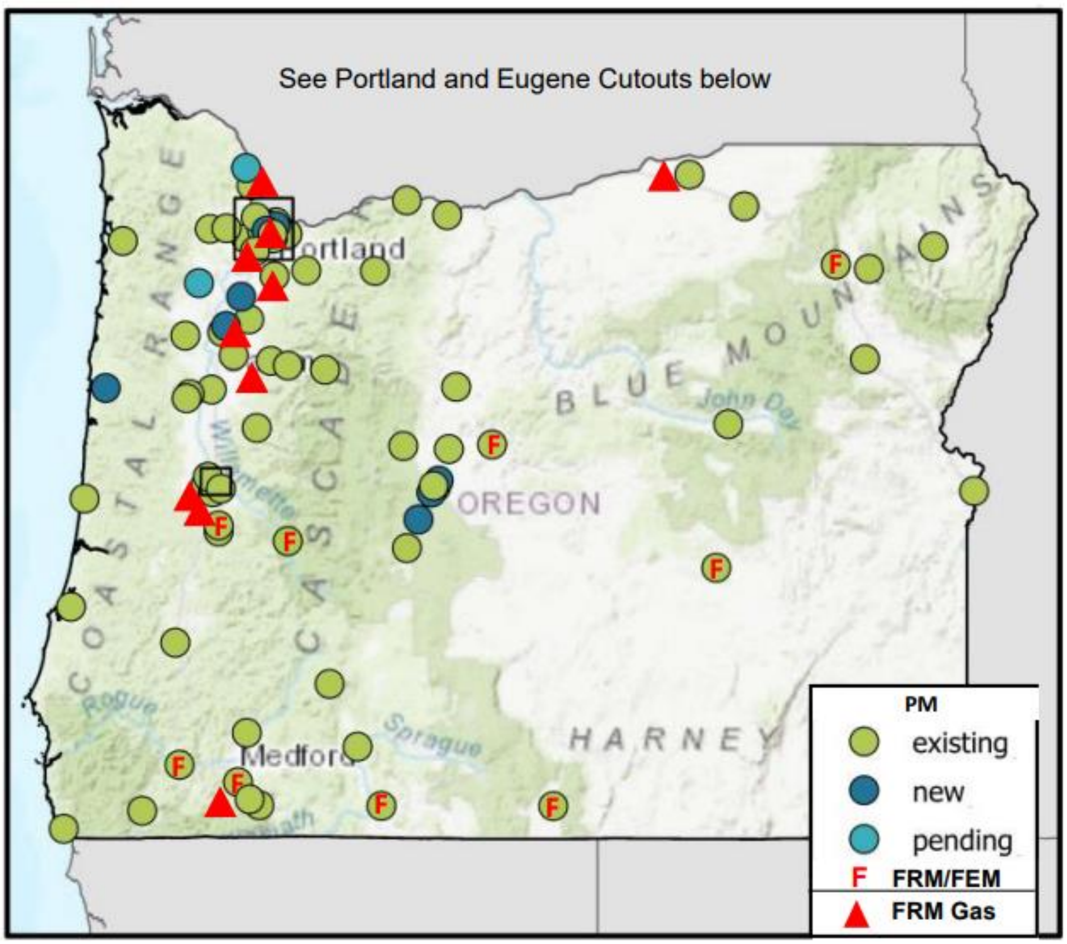
[2] See the Volcano hazard for more information about volcano impacts.

ashfall could inundate the areas sufficiently to impact transportation and cause widespread health concerns.

Location and Extent

According to the *2022 Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan* issued by DEQ, air quality pollutants are currently monitored at various locations in the Salem area including at the Salem State Hospital, Chemeketa Community College's Salem campus, and Cascade Junior High School in Turner. Poor Air Quality has seasonality in that inversion layers tend to form from November to February. Once air temperatures warm the inversion layer conditions dissipate. During the summer months from June through August high pressure weather systems can remain in place for an extended period resulting in the accumulation of airborne particles in the lower levels of the atmosphere affecting the air quality. In addition, smoke from surrounding fires could impact Salem and affect the air quality prompting Air Stagnation Advisories (Dalton, Fleishman, & Bachelet, 2022). Figure 2-4 shows the 2022 Ambient Air Monitoring Network sites in Oregon. In addition, Figure 2-8 shows the types of air quality monitoring station in and around Salem.

Figure 2-4 Oregon 2022 Ambient Air Monitoring Network (DEQ and LRAPA sites)



Source: Oregon DEQ. (2022) *Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan*. Retrieved December 2022, from https://www.oregon.gov/deq/aq/Documents/AnnualACPAMNPlan.pdf.
Note: Portland metro and Eugene metro cutouts are not shown here.

Air Quality Pollutants

Oregon DEQ monitors air quality pollutants. DEQ operates the ambient monitoring network for the entire state, except Lane County, which is operated by the Lane Regional Air Protection Authority (LRAPA). These air quality monitoring networks measure ambient concentrations of the criteria pollutants – ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. Air quality pollutants are currently monitored at various locations in the Salem area, according to DEQ's *2022 Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan,* including at the Salem State Hospital, Chemeketa Community College's Salem campus, and Cascade Junior High School in Turner.

Ozone

DEQ's *Oregon Air Quality Monitoring Annual Report: 2020 (2021)* describes the following:

> Ozone is a secondary pollutant formed when there are elevated levels of nitrogen dioxide and volatile organic compounds that undergo chemical reactions in high temperatures, and sunlight. In Oregon, elevated ozone occurs in the summer and can be formed by human-caused pollution from fossil fuel combustion and also by naturally caused pollution from wildfire smoke, which contains NO2 and VOCs. In 2017 and 2018, most of the state experienced elevated ozone because the wildfire smoke introduced natural precursors on top of the human-caused emissions.

Data with wildfire contributions are included because it is very difficult to determine if the ozone would have exceeded the NAAQS without the smoke from wildfires.

The *Oregon Air Quality Monitoring Annual Report: 2020* continues, "Data with wildfire contributions are included because it is very difficult to determine if the ozone would have exceeded the NAAQS without the smoke from wildfires." Additionally, it is noted that the wildfire smoke in 2018 and 2020 contributed to the elevated ozone levels, which likely caused Portland and Medford to violate the NAAQS. However, it is very difficult to determine what the ozone level would have been since high levels typically occur in the summer months, "precisely when wildfire smoke impacts occur."

The *2022 Oregon Annual Ambient Criteria Pollutant Air Monitoring Network Plan* describes the 10 DEQ and LRAPA monitoring sites for ozone. There are two of these monitoring sites in or near Salem at the Salem State Hospital and Cascade Junior High School in Turner.

$PM_{2.5}$

Fine particulate matter ($PM_{2.5}$) is a concern due to smoke impacts from woodstoves, fireplaces and other wood burning appliances besides wildfire smoke in the summer. Other sources of $PM_{2.5}$ include open burning, prescribed burning, wildfires, smoke from industrial stacks, and some road dust from vehicle travel.

The Future Climate Projections report issued in June 2022 for Marion County's NHMP update stated that with the increasing wildfires and $PM_{2.5}$ levels, there is a greater risk of wildfire smoke exposure through increasing frequency, length, and intensity of "smoke wave" days. "Smoke wave" days are two or more consecutive days with high levels of $PM_{2.5}$ from wildfires (Dalton, Fleishman, & Bachelet, 2022).

DEQ notes that it is useful to understand how much wildfire smoke contributed to particulate levels above the NAAQS standard, because this shows the effectiveness of local air quality improvement in communities with particulate reduction plans to promote such actions as wood stove efficiency programs.

There are harmful effects from breathing particles measuring less than 10 microns in diameter (PM_{10}). Fine particle matter $PM_{2.5}$ may be responsible for the most significant health effects, like premature mortality, hospital admissions, and respiratory illness. These particles can be inhaled deeply into the lungs where they enter the bloodstream or can remain for years. The health effects of particulate matter vary with the size, concentration, and chemical composition of the particle, according to the EPA.

PM_{10}

In the *Oregon Air Quality Monitoring Annual Report: 2020* (2021), the PM_{10} trend chart shows the values in the city with the highest concentration, the average, concentration, and the lowest concentration. All cities are well below the standard, but EPA requires DEQ to continue monitoring in PM_{10} maintenance areas and in cities over 500,000 people.

Carbon Monoxide, Sulfur Dioxide, Nitrogen Dioxide

Carbon monoxide was above the standard in the Portland Metro area for three days during the wildfire impacts. Otherwise, for the rest of the year carbon monoxide, sulfur dioxide, and nitrogen dioxide [met] federal health standards. These pollutants, according to the *Oregon Air Quality Monitoring Annual Report: 2020* (2021), have been trending mostly downward for most locations over the last ten years.

Air Toxics

DEQ and LRAPA began sampling for air toxics in Oregon in 1999. This section of the *Oregon Air Quality Monitoring Annual Report: 2020* (2021) describes data for the toxics, or hazardous air pollutants, of concern: benzene, tetrachloroethylene, acetaldehyde, formaldehyde, naphthalene, arsenic, cadmium, chromium, lead, manganese, and nickel. According to the annual report, the values are compared to the Oregon ambient concentration health benchmarks. These benchmarks are the levels where people exposed for a lifetime have an additional one in a million risk of cancer or of experiencing non-cancer health effects. The information provided in the report is for neighborhood monitoring only and does not include monitoring next to industrial facilities. Information regarding monitoring next to industrial facilities is presented in separate reports issued by the Oregon Health Authority, specific to the monitoring project and facility.

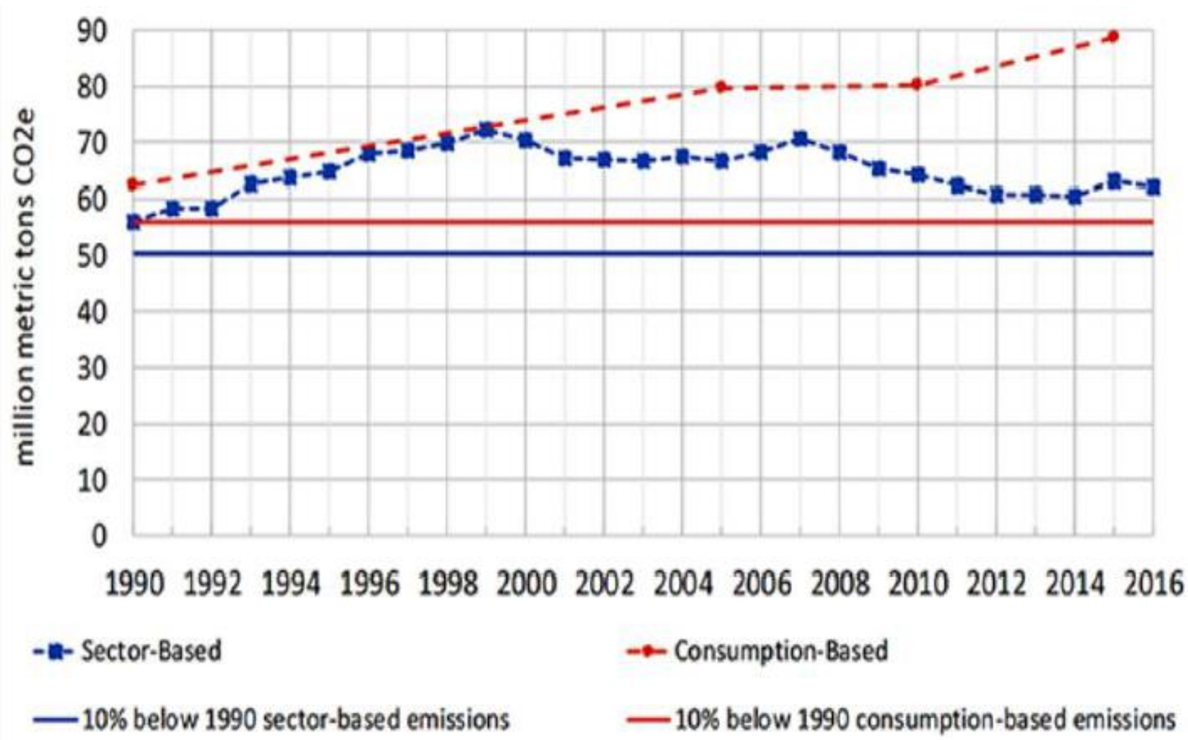
Greenhouse Gases

Greenhouse gas emissions are produced directly from activities such as driving cars and heating homes. Indirectly, greenhouse gas emissions are indirectly contributed to when electricity, goods or food is purchased or manufactured in other states or countries. Oregon DEQ divides statewide greenhouse gas emissions into two categories: sector-based and consumption-based.

According to the *Oregon Air Quality Monitoring Annual Report: 2020* (2021), sector-based emissions are “produced in Oregon from transportation, residential, commercial, industrial, and agriculture sectors, including electricity produced elsewhere but used in state” while consumption-based emissions are "produced around the world due to Oregon's consumption of energy, goods, and services." Additional information about greenhouse gas emissions in Oregon are presented on DEQ's website at https://www.oregon.gov/deq/ghgp/Pages/GHG.aspx.

Figure 2-5 is excerpted from the *Oregon Air Quality Monitoring Annual Report: 2020* (2021) report and shows Oregon's greenhouse gas emissions from 1990 through 2016 by sector. Emissions from transportation and electricity use are Oregon's largest sources of greenhouse gas emissions, as shown in Figure 2-5 by the *Oregon Greenhouse Gas Sector-Based Inventory Data* (n.d.).

Figure 2-5 Oregon total greenhouse gas emissions by sector 1990-2016



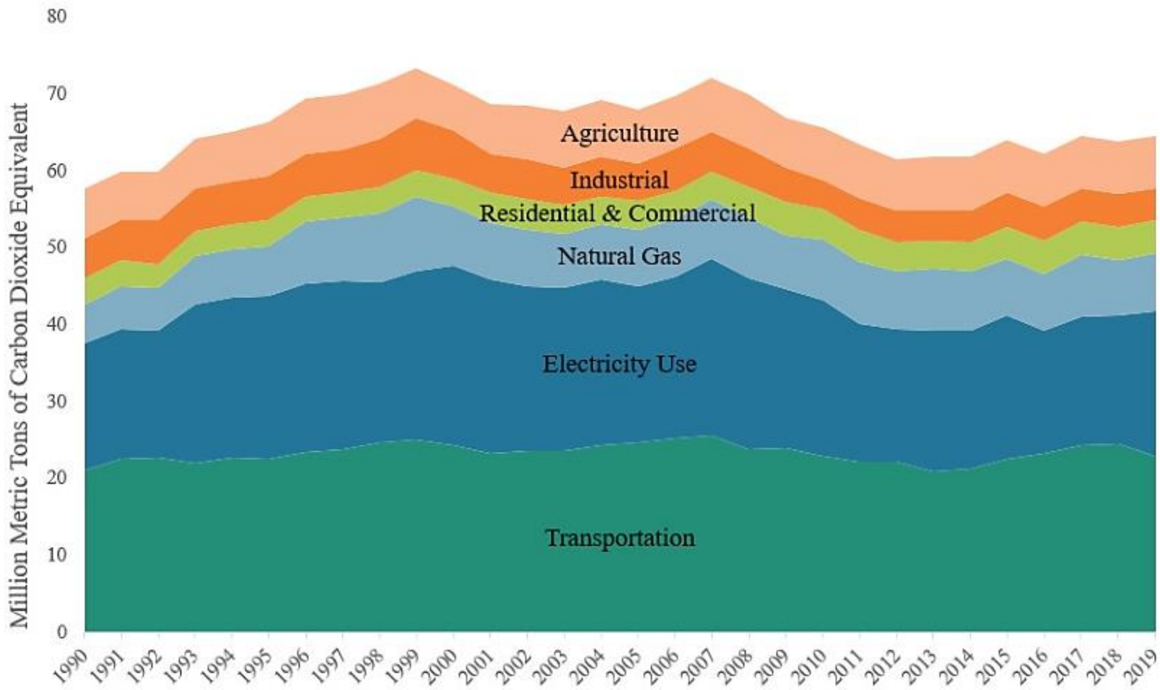
Source: Oregon DEQ. (2021, December) *Oregon Air Quality Monitoring Annual Report: 2020*. Retrieved December 2022, from https://www.oregon.gov/deq/aq/Documents/2020AQMonitoringReport.pdf.

Identifying Poor Air Quality

Both specific measures of components of poor air quality and a general Air Quality Index are methods for determining the quality of the air.

Standards for air quality as determined by the EPA have changed over time. In 1987 particulate matter was measured using the national PM_{10} levels as 24-hour concentrations and as average annual concentrations. The Clean Air Act, which was last amended in 1990, requires EPA to set National Ambient Air Quality Standards. In 1996 the impact of 2.5-micron particles was recognized and the national $PM_{2.5}$ 24-hour National Ambient Air Quality Standard (NAAQS) was established at 65 ug/m^3, and the annual average NAAQS set at 15 ug/m^3. In 2006 the national $PM_{2.5}$ 24-hour standard was reduced to 35 ug/m^3. In 2012 the national $PM_{2.5}$ annual average NAAQS was further reduced to 12 ug/m^3. The PM_{10} annual average was revoked.

Figure 2-6 Greenhouse gas emissions from 1990-2019



Source: Oregon DEQ. (n.d.). *Oregon Greenhouse Gas Sector-Based Inventory Data*. Retrieved December 2022, from https://www.oregon.gov/deq/ghgp/Pages/GHG-Inventory.aspx.

The Air Quality Index (AQI) is a daily index of air quality that reports how clean the air is and provides information on potential health risks. Oregon's index is based on three pollutants regulated by the federal Clean Air Act: ground-level ozone, particle pollution, and nitrogen dioxide. The highest of the AQI values for the individual pollutants becomes the AQI value for that day. For example, if values are 90 for ozone and 88 for nitrogen dioxide, the AQI reported would be 90 for the pollutant ozone on that day. A rating of good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous are designated for the AQI providing a daily air quality rating (

Air Quality Rating	Air Quality Index (AQI)	$PM_{2.5}$ 24-hour Average ($\mu g/m^3$)	Ozone 8-hour Average (ppm)
GOOD	0 - 50	0.0 - 12.0	0.000 - 0.054
MODERATE	51 - 100	12.1 - 35.4	0.055 - 0.070
UNHEALTHY FOR SENSITIVE GROUPS	101 - 150	35.5 - 55.4	0.071 - 0.085
UNHEALTHY	151 - 200	55.5 - 150.4	0.086 - 0.105
VERY UNHEALTHY	201 - 300	150.5 - 250.4	0.106 - 0.200
HAZARDOUS	>300	>250.5	>0.200

). The EPA provides all states with the AQI equation for national uniformity. DEQ and LRAPA report the AQI for cities in Oregon. The *Oregon Air Quality Monitoring Annual Report: 2020* provides a review of the health levels over the past year.

Table 2-3 Air Quality Index Ranges and Episode States for PM2.5 and ozone.

Air Quality Rating	Air Quality Index (AQI)	$PM_{2.5}$ 24-hour Average ($\mu g/m^3$)	Ozone 8-hour Average (ppm)
GOOD	0 - 50	0.0 - 12.0	0.000 - 0.054
MODERATE	51 - 100	12.1 - 35.4	0.055 - 0.070
UNHEALTHY FOR SENSITIVE GROUPS	101 - 150	35.5 - 55.4	0.071 - 0.085
UNHEALTHY	151 - 200	55.5 - 150.4	0.086 - 0.105
VERY UNHEALTHY	201 - 300	150.5 - 250.4	0.106 - 0.200
HAZARDOUS	>300	>250.5	>0.200

Source: Oregon DEQ. (2021, December) *Oregon Air Quality Monitoring Annual Report: 2020*. Retrieved December 2022, from https://www.oregon.gov/deq/aq/Documents/2020AQMonitoringReport.pdf.

According to *Oregon Air Quality Monitoring Annual Report: 2020* (2021), the air pollutants of greatest concern in Oregon were the following:

- Fine particulate matter (mostly from combustion sources) known as $PM_{2.5}$
- Air Toxics - pollutants that cause or may cause cancer or other serious health effects.
- Ground-level ozone, a component of smog.
- Greenhouse gas (GHG) emissions and global climate change are also concerns in Oregon. Oregon state agencies track GHG emissions from a wide variety of products, services, utilities, and fuel providers. These emissions data are available on DEQ's web site under Air Quality/ AQ Programs / Greenhouse Gas Reporting Home. This is an overall issue across all of Oregon but more considered in the higher population density areas.

According to the *2022 Salem Area Comprehensive Plan*, the first *Greenhouse Gas Inventory Report* was completed in 2019. The report informed the development of their first *Salem Climate Action Plan 2021* and the 2022 update to Salem's comprehensive plan.

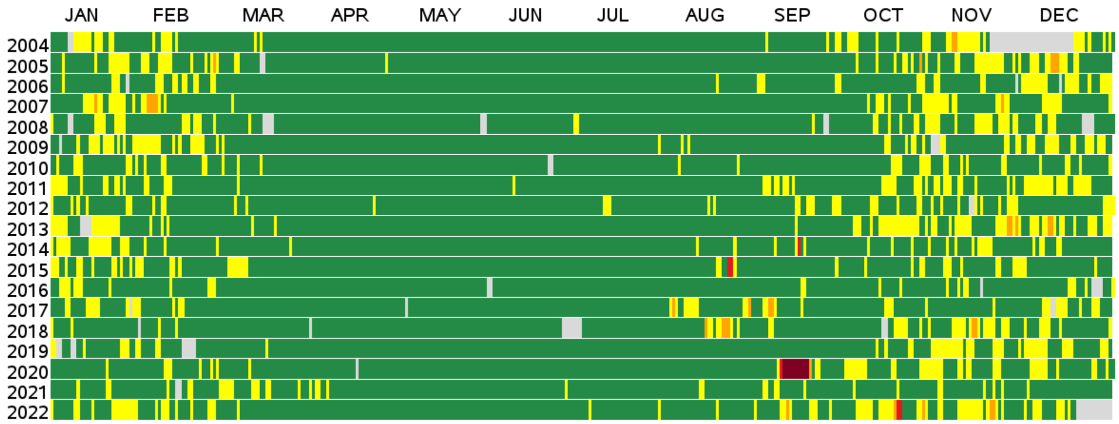
The Salem *Greenhouse Gas Inventory Report* spans six emissions source categories including: mobile emissions, stationary combustion, water and wastewater, electricity generation, agriculture/urban forestry, and waste generation. The *2022 Salem Comprehensive Plan* provides this summary.

> The sector-based inventory determined that Salem's residents, businesses, employees, and visitors produced over 1.5 million metric tons of carbon dioxide equivalent (CO2e) in 2016. Of the six emissions source categories surveyed, mobile emissions – transportation – made up more than half (53%) of the CO2e produced. Electricity generation comprised over one quarter of all emissions, while residential and commercial stationary combustion (e.g., propane and natural gas) was the third largest contributor at 16 percent.

History

The data available to track poor air quality conditions in Salem are limited to three permanent monitoring stations measuring $PM_{2.5}$. Figure 2-7 below shows a pattern of periods of the year where the likelihood of high levels of particulate matter of this diameter (2.5 microns) have been present at that station. One example is during the September 2020 wildfires in the region and as depicted in dark red in Figure 2-7, Salem experienced extremely poor air quality.

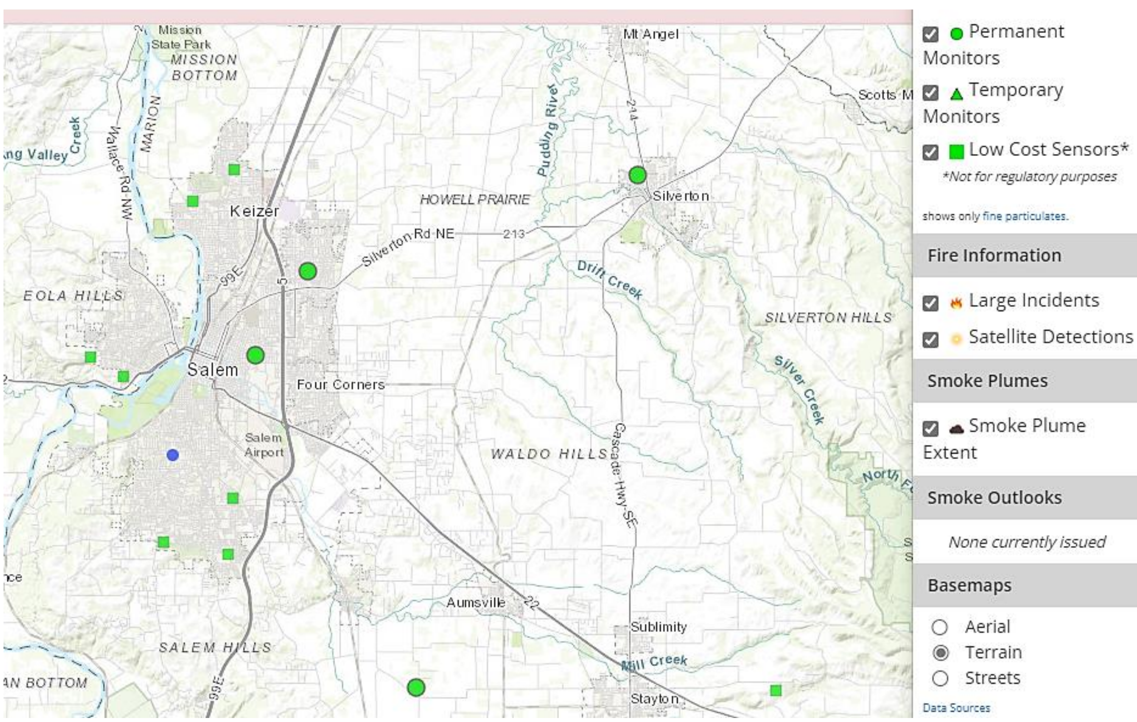
Figure 2-7 $PM_{2.5}$ Daily AQI Values, 2004 to 2022 for Salem, OR



Source: U.S. EPA. (2023, February). *Outdoor Air Quality Data, Air Data – Multiyear Tile Plot*. Retrieved December 2022, from https://www.epa.gov/outdoor-air-quality-data/air-data-multiyear-tile-plot.

The EPA AirNow website maintains a real time Fire and Smoke Map for monitoring air quality and provides a tool for NHMP plan holders to use when using the plan. The figure below shows locations of both regulatory and low cost sensors not valid for regulatory purposes, but represented on the map in the interest of public health.

Figure 2-8 Air Quality Monitoring Station Types



Source: U.S. EPA. (2023, February). *AirNow Fire and Smoke Map v3.*1. Retrieved February 2023, from https://fire.airnow.gov/?lat=44.9025&lng=-123.0518&zoom=10.

The determination of the severity of poor air quality and collecting data demonstrating the problem may provide support for mitigation actions aimed at managing prescribed burning, reduction of the risk of high intensity wildfire, and support for mitigation actions aimed at providing relief for vulnerable people during poor air quality conditions. The EPA Ambient Monitoring Technology Information Center (AMTIC) provides information on monitoring programs and methods, quality assurance and control procedures, and federal regulations.

Future Climate Variability

The OCCRI *Future Climate Projections Marion County, Oregon* (2022) indicates that future climate projections are for reduced outdoor air quality. Warmer temperatures may increase ground-level ozone concentrations. Increases in the number and size of wildfires may increase concentrations of smoke and particulate matter. In Marion County, the number of "smoke wave" days is projected to increase by 18% and the intensity of those days is projected to increase by 91%.

In addition, OCCRI's report indicates that plants are responding to changes in climate and atmospheric concentrations of carbon dioxide by producing more pollen, and producing pollen earlier in spring, for longer periods of time. In the conterminous United States, pollen seasons increased by about 20 days and pollen concentration increased by 21% from 1990 through 2018. Such poor air quality is expected to exacerbate allergy and asthma conditions and increase the incidence of respiratory and cardiovascular illnesses and death.

As noted previously, Salem completed their first *Greenhouse Gas Inventory Report* in 2019, which informed the development of their first *Salem Climate Action Plan 2021* and the 2022 update to Salem's comprehensive plan. According to city's Comprehensive Plan, the *Salem Climate Action Plan 2021* "sets the course for the City to reduce its greenhouse gas emissions and increase its resilience to climate change." The *Salem Climate Action Plan 2021* includes numerous strategies to address a variety of climate-related challenges facing the city including poor air quality as stated here,

> Salem residents will notice several changes in the climate in coming decades. The shifts in climate are projected to occur in three main areas: warming temperatures, changing precipitation patterns, and increased risk of wildfire. Some of the most significant projected climate impacts are the following:
>
> - The number of days with a heat index over 90°F will increase from a historic average of 7 per year to 33 per year by mid-century.
> - Hotter and drier conditions are likely to cause more frequent droughts.
> - More intense rainfall and rain-on-snow events could also lead to flood events in areas outside of historical high-risk zones.
> - Wildfire is a significantly increasing risk across the state of Oregon. The number of extreme fire danger days in Salem will double by mid-century, increasing from a historic average of 10 per year to 20 per year. Extremely large, intense fires will become more likely under hotter and drier climate scenarios.
> - Poor to hazardous air quality resulting from wildfires could greatly impact unsheltered populations and people with underlying health issues such as asthma, diabetes and obesity.

Probability Assessment

As previously noted, communities across Oregon have begun to recognize the impacts of inversion layers trapping particulates in smoke from wood stove, prescribed fire, wildfire, and field burning as a natural hazard. In addition, Salem has begun to recognize the impacts of reduced outdoor air quality with warmer temperatures and increase in the number and size of wildfires in the region.

Depending upon climate conditions, air stagnations can be infrequent or numerous in any given year, which can have a potential impact to air quality levels for both $PM_{2.5}$ and ozone in the area. Prevailing wind direction and strength can influence the location and extent of the air quality impacts. The probability of air quality at one level or another varies, as air quality is a range based on multiple factors such as those measured for carbon monoxide, particulate matter (PM_{10} and $PM_{2.5}$), ozone, and others described above.

The sources of air pollution in the region include wood stove, prescribed fire, wildfire, and field burning, industrial, and motor vehicle emissions. Industry and residential wood stoves emit particulate matter and carbon monoxide. Concerns for air quality arise when smoke from regional wildfires either blows through the Willamette Valley or becomes trapped during inversions. See the Wildfire Hazard for more information about wildfire impacts. In addition, climate change has a relationship with natural hazards, as noted above.

Several key points from the OCCRI *Future Climate Projections Marion County, Oregon* report are shared here:

- Wildfire risk, expressed as the average number of days per year on which fire danger is very high, is projected to increase under future climate change in Marion County.
- The average number of days per year on which vapor pressure deficit is extreme is projected to increase by 27 days (range 9–43) by the 2050s, compared to the historical baseline, under the higher emissions scenario.
- With air quality, under future climate change, the risk of wildfire smoke exposure is projected to increase in Lake County.
- In Marion County, the number of “smoke wave” days is projected to increase by 18% by 2046-2051 under a medium emissions scenario compared with 2004-2009.

Warmer temperatures may increase ground-level ozone concentrations. Increases in the number and size of wildfires may increase concentrations of smoke and particulate matter. Although usually thought of as being a summer occurrence, wildfires can occur during any month of the year. Many wildfires burn during June to October time, but over the years there have been more and larger fires, extending the season beyond the past years’ typical timeframes.

As noted previously, plants also are responding to changes in climate and atmospheric concentrations of carbon dioxide by producing more pollen earlier in the spring and for longer periods of time. Lastly, the wood stove, industrial, and motor vehicle emissions can occur during any month of the year.

Based on the available data and research for Salem, the NHMP Steering Committee assessed the **probability of experiencing a locally poor air quality as “high,”** meaning one incident is likely within a 10 to 35-year period.

Vulnerability Assessment

A climate-related driver of health is air quality, including pollen, wildfire smoke, smog, and ozone. Poor air quality puts the health of all persons at risk. However, people experience the impacts differently. According to OCCRI, *Fifth Oregon Climate Assessment* (2021), inequities and unequal investments in social determinants of health are contributing stress factors and include housing, education, income, wealth, transportation access, food security, income security, access to health care. The effects of poor air quality are long-term, chronic, and often difficult to trace. Those persons most at risk tend to be the elderly, very young children, and people with pre-existing respiratory problems. The OCCRI *Fifth Oregon Climate Assessment* (2021) report states,

> The health effects of climate change are strongly affected by the baseline status of individuals and communities, especially people's living conditions and pre-existing health conditions. These factors differ significantly by race, historical levels of economic investment, and level of pollution exposure. Among the individuals most susceptible are those with existing chronic conditions, older adults, pregnant women, and children (Liu et al. 2017, Hutchinson et al. 2018). People of color, people with low incomes, unhoused populations, agricultural workers, first responders, and rescue workers are those most susceptible to wildfire smoke exposure (Rudolph et al. 2018). Asthma hospitalizations in Oregon disproportionately affect Black, Pacific Islander, and Indigenous people as compared to other racial or ethnic groups (OHA 2018a). Exposure to smoke compounds this existing disparity.

The Salem NHMP steering committee is especially concerned about the increase in regional wildfire smoke and the impact it has on the community. According to NASA's *Increased Fire Comes with Increased Health Risks*, it states, "Researchers believe recent fire seasons give a taste of the more active wildfires of the future. Such fires are likely to increase air pollution, even as emissions from industry and motor vehicles have fallen in recent decades." Furthermore, "The U.S. has really made great strides in reducing man-made particles," said study co-author Loretta Mickley of Harvard University. Mickley continues, however, "wildfires dominate poor air quality in the West." The study identifies that wildfires contribute roughly 18 percent of the total particulate emissions in the U.S.

That same study noted,

> Globally, fine particles have been linked to more than 3.3 million premature deaths…. Particulate pollution, one of the results of burning matter, can cause a slew of health problems, including chronic obstructive pulmonary disease, acute lower respiratory illness, asthma, ischemic heart disease, and lung cancer.
>
> …
>
> Using atmospheric and climate models, the research team found that more than 82 million people are likely to experience an increase in the frequency and duration of smoke waves. Northern California, western Oregon, and the Great Plains are among areas that researchers estimate will be hit hardest by particulate matter (PM2.5) in the atmosphere.

> "Wildfires are difficult to predict because they're variable one day to the next and one year to the next," said Jason West, a professor of environmental science at the University of North Carolina. The new research is valuable, he said, because it places the fires into a health context.
>
> "What's interesting [about the study] is that it shows that climate change can have a direct impact on public health," said Mickley. "We're used to thinking of climate change as affecting temperatures and rising sea levels. This is something different that requires a lot of resources to control, affects millions of people, and it has been overlooked."

According to the EPA's *Carbon Monoxide (CO) Pollution in Outdoor Air*, carbon monoxide can cause harmful health effects by reducing oxygen delivery to the body's organs, especially the heart, brain, and tissues. At extremely high levels, CO can cause death. Exposure to CO can reduce the oxygen-carrying capacity of the blood. People with several types of heart disease already have a reduced capacity for pumping oxygenated blood to the heart, which can cause them to experience myocardial ischemia (reduced oxygen to the heart), often accompanied by chest pain (angina), when exercising or under increased stress. For these people, short-term CO exposure further affects their body's already compromised ability to respond to the increased oxygen demands of exercise or exertion.

Ozone reacts with molecules in the lining of our airways. Chemical bonds break and reform in different ways with the addition of oxygen atoms (the process of oxidation) from ozone, and this causes acute inflammation. The lining of our airways loses some of its ability to serve as a protective barrier to microbes, toxic chemicals, and allergens. Our airways respond by covering the affected areas with fluid and by contracting muscles. Breathing becomes more difficult.

Shortness of breath, dry cough or pain when taking a deep breath, tightness of the chest, wheezing, and nausea are common responses to ozone, according to NASA's *The Ozone we Breathe*. Ozone also triggers asthma and may aggravate other respiratory illnesses such as pneumonia and bronchitis. Ozone concentrations can make the small bands of muscles that help control breathing more sensitive to dry air, cold or dust, so ozone exposure may increase allergic responses in susceptible people.

While the effects of acute, short-term episodes of ozone exposure are reversible, the human body's response to long-term exposure may not be reversible. Exposure to ozone at levels we commonly encounter in our own communities permanently scars the lungs of experimental animals, causing long-term impairment of lung capacity, or the volume of air that can be expelled from fully inflated lungs. Ozone may have similar effects on human lungs. Studies in animals suggest ozone may reduce the human immune system's ability to fight bacterial infections in the respiratory system.

Ozone damage to people can occur without any noticeable signs. Even when initial symptoms appear, they can disappear while ozone continues to cause harm. Otherwise, healthy people can expect to experience acute but reversible effects if they exercise regularly outdoors when ozone levels are high. The National Institute of Environmental Health Sciences (NIEHS) considers such people to be especially susceptible as a group (NASA Earth Observatory, 2022).

Particulate matter is also known as particular pollution; it is a complex mixture of extremely small particles and liquid droplets that get into the air. Once inhaled, these particles can affect the heart and lungs, and cause serious health effects, according to EPA. The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into lungs and the bloodstream. Exposure to such particles can affect both the lungs and heart. As noted by the EPA, People with heart or lung diseases, children, and older adults are the most likely to be affected by particle pollution exposure.

Numerous scientific studies, according to the EPA's *Particulate Matter (PM) Pollution*, have linked particle pollution exposure to problems, including:

- premature death in people with heart or lung disease,
- nonfatal heart attacks,
- irregular heartbeat,
- aggravated asthma,
- decreased lung function, and
- increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing.

EPA also notes that fine particles (PM2.5) are the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas. Particles can be carried over long distances by wind and then settle on ground or water. Depending on their chemical composition, the effects of this settling may include:

- making lakes and streams acidic,
- changing the nutrient balance in coastal waters and large river basins,
- depleting the nutrients in soil,
- damaging sensitive forests and farm crops,
- affecting the diversity of ecosystems, and
- contributing to acid rain effects.

Particulate Matter can stain and damage stone and other materials, including culturally important objects such as statues and monuments. Some of these effects are related to acid rain effects on materials, according to the EPA.

Salem Climate Action Plan 2021

The *Salem Climate Action Plan 2021* outlines the following potential vulnerabilities and consequences of various projected climate changes as it relates to air quality.

Projected Wildfire Risk

Increased temperatures and drier conditions will lead to increased fire risk in forested areas outside of Salem. However, those impacts to Salem include health risks due to poor air quality, increased emergency operations and evacuations, and reductions in revenue and employment in the tourism industry.

- Poor to hazardous air quality resulting from wildfires would greatly impact vulnerable populations—for example, people who are unsheltered, people who work outdoors, and people who live with chronic medical conditions such as asthma.

The Salem NHMP Steering Committee rated the city as having **a "high" vulnerability to air quality hazards**, meaning over 10% of the city's population or property would be affected by a major air quality emergency or disaster.

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

The Clean Air Act of 1970 and the U.S. Environmental Protection Agency established health-based National Ambient Air Quality Standards (NAAQS) for six air pollutants: carbon monoxide (CO), particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and lead (Pb). The areas that fail to meet the standards are designated "nonattainment" and are required to develop plans to come into compliance with the standards. Once compliance with the standard is achieved, a maintenance plan is developed to ensure that air quality will not be compromised in the future. According to DEQ's *Maintenance Areas in Oregon* data, Salem, together with neighboring city of Keizer are together an Air Quality Maintenance Area (AQMA) referred to as the Salem-Keizer area, which involves the following plans: *Portland-Vancouver Air Quality Maintenance Area (Oregon Portion)* and *Salem-Keizer Area Ozone Maintenance Plan and Salem-Keizer Area Carbon Monoxide Limited Maintenance Plan*.

According to EPA's *Process of Reviewing the National Ambient Air Quality Standards* website, the Clean Air Act established two types of national air quality standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings. The Clean Air Act requires periodic review of the science upon which the level of the standards is based and determine if changes to the level of the standards are warranted.

State Resources

Department of Environmental Quality

DEQ is a regulatory agency with the responsibility to protect and enhance the quality of Oregon's environment. DEQ is "responsible for providing accurate scientific data concerning the State of Oregon's air quality to ensure that the state meets the National Ambient Air Quality Standards as required by the Federal Clean Air Act."

Department of Energy

The Oregon Department of Energy (ODOE) partners with other Oregon state agencies to develop policy options to reduce greenhouse gas emissions. The agency also provides technical assistance for greenhouse gas planning and mitigation programs in other state agencies, cities, and counties.

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to coastal hazards, floods, and other natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of natural hazards including the Hazard Mitigation Grant Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, OEM notifies local public safety agencies and keeps them informed of potential and actual hazard events so prevention and mitigation actions can be taken.

Local Resources

Salem Climate Action Plan 2021 and Community Greenhouse Gas Inventory

Salem is taking action to respond to climate change with the *Salem Climate Action Plan 2021* that outlines strategies and actions to reduce Greenhouse Gas emissions and increase climate resiliency in our community. Through the development of the CAP, it was determined that Salem's projected climate impacts will include three main categories: warming temperatures, changes in precipitation patterns, and increased risk of wildfires. Many of the strategies in the CAP are designed to help the community adapt to impacts and build resiliency for the future. The strategies seek to do the following:

- Expand the urban tree canopy and access to green spaces
- Create a climate related education and outreach program
- Create a network of indoor gathering places that can serve as community centers during times of need
- Engage underserved populations in co-creating resilient solutions
- Strengthen the local economy

Drought

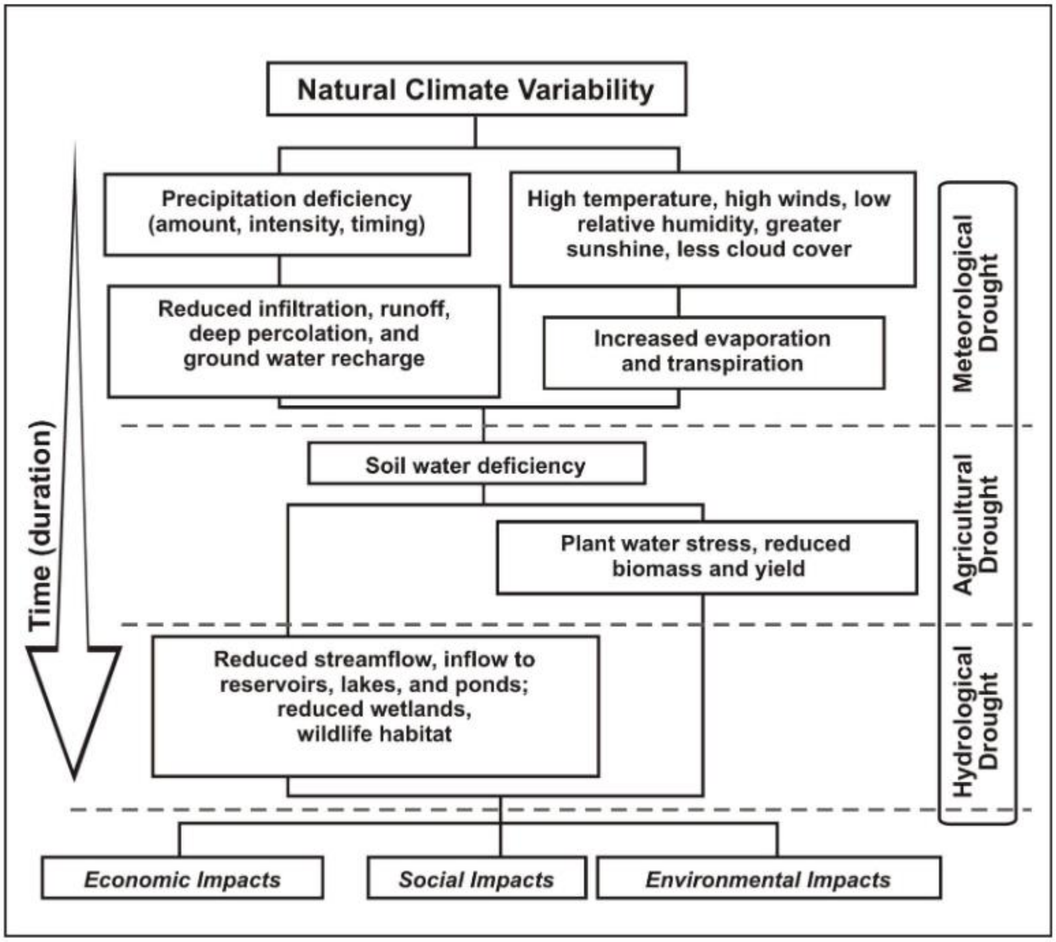
Significant Changes Since Previous Plan:

The Drought hazard section has been updated to include new history.

Causes and Characteristics

Drought is a normal, recurrent feature of the climate. It occurs almost everywhere, although it features vary from region to region. According to the National Drought Mitigation Center (University of Nebraska), defining drought is, therefore, difficult; it depends on differences in regions, needs, and disciplinary perspectives. In the most general sense, drought is defined as a deficiency of precipitation over an extended period (usually a season or more), resulting in a water shortage. A drought is a period of drier than normal conditions. Drought occurs in virtually every climatic zone, but its characteristics vary significantly from one region to another. Drought is a temporary condition; it differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate. The extent of drought events depends upon the degree of moisture deficiency, and the duration and size of the affected area. Typically, droughts occur as regional events and often affect more than one city or county.

In the early 1980s, researchers with the National Drought Mitigation Center and the National Center for Atmospheric Research (NCAR) located more than 150 published definitions of drought. To simplify analysis, the NDMC now provides four primary ways in which drought can be defined based on the impacts of the drought. They are as follows: meteorological, agricultural, hydrological, 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.



below illustrates the interrelationship of these types of droughts.

Types of Drought

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. Hydrological measurements are not the earliest indicators of drought. When precipitation is reduced or deficient over an extended period, 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.

Socioeconomic Drought

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 other three types of droughts 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 because of a weather-related shortfall in water supply.

In most instances, the demand for economic goods is increasing because 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.

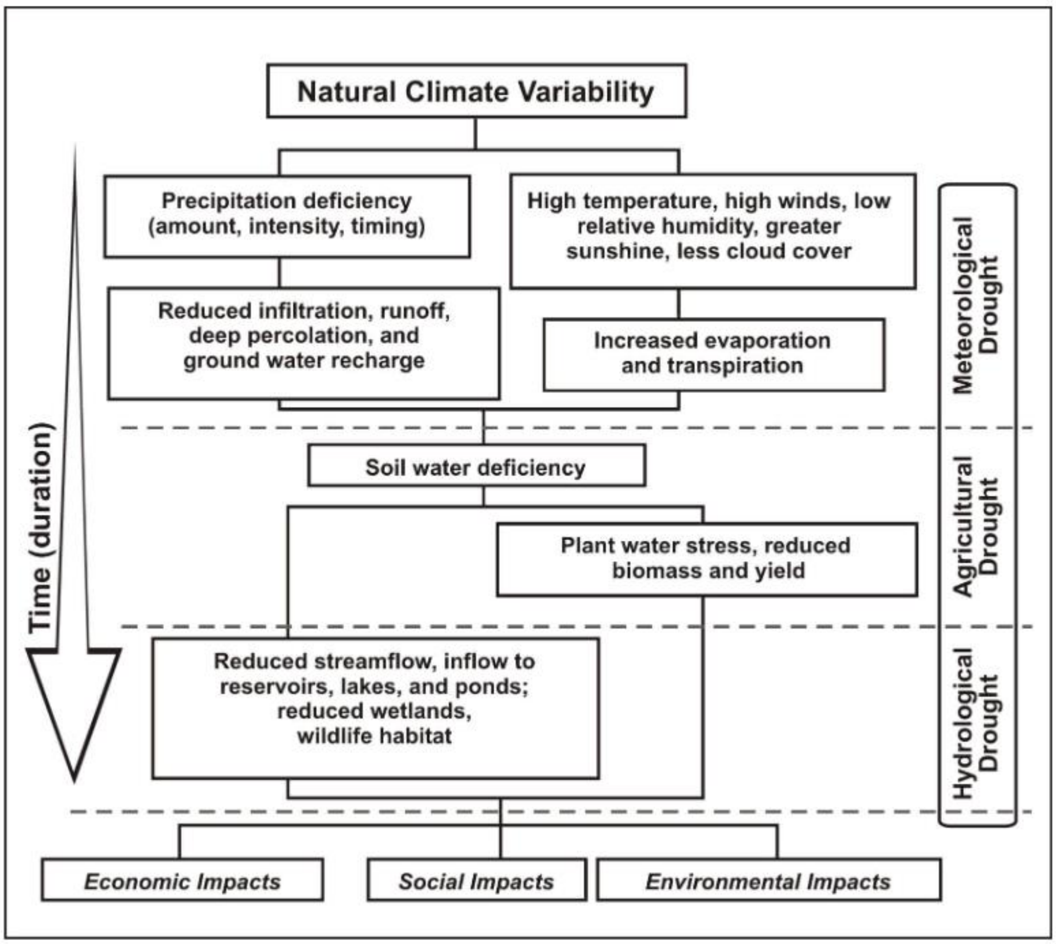
Ecological, Flash, and Snow Drought

In addition to these primary drought designations, three other drought designations—ecological, flash, and snow—were, according to OCCRI's *Fifth Oregon Climate Assessment* (2021), proposed more recently to reflect more-specific drivers and impacts of drought. Ecological drought is defined as "[a]n episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems." Like agricultural drought, ecological drought usually is caused by meteorological and hydrological drought. Vegetation and soil types affect likelihood of ecological drought.

Flash drought refers to relatively short periods of warm surface temperatures, low relative humidity and precipitation deficits, and rapidly declining soil moisture. According to the *Fifth Oregon Climate Assessment* (2021), these droughts tend to develop and intensify rapidly within a few weeks and may be generated or magnified by prolonged heat waves.

Snow droughts are defined when snowpack—or snow water equivalent (SWE)—is below average for a given point in the water year, traditionally April 1. Years with low SWE on April 1 often are followed by summers with low river and stream flows. The low flows sometimes lead to or exacerbate water supply deficiencies, especially in snowmelt-dominated basins. Although the idea of snow drought has existed for many years, it was further developed in Oregon and the Northwest following the 2015 water year, in which below-average snowpack counterintuitively corresponded with above-average precipitation. The *Fifth Oregon Climate Assessment* (2021) indicates that this type of snow drought is classified as warm snow drought. Dry snow drought is classified based on below-average snowpack and precipitation.

Figure 2-9 Types of Droughts and Impacts



Source: National Drought Mitigation Center, University of Nebraska-Lincoln. (n.d.). *Drought In-depth*. Retrieved December 2022, from http://drought.unl.edu/index.htm.

Location and Extent

Droughts occur in every climate zone and can vary from region to region. Drought may occur throughout Salem and may have profound effects on the economy. The extent of drought events depends upon the degree of moisture deficiency, and the duration and size of the affected area. Typically, droughts occur as regional events and often affect more than one city and county. The *2020 Oregon Natural Hazards Mitigation Plan*, Mid/ Southern Willamette Valley (Region 3) Risk Assessment states,

> Even though drought may not be declared as often in Western Oregon as in counties east of the Cascades, when drought conditions do develop in the Willamette Valley, the impacts are widespread and severe. Reasons for broad and significant impact include insufficient water for crop irrigation; lack of farmworkers when the growing season begins early; and increased frequency of toxic algal blooms in the Willamette system reservoirs, among other reasons.

The U.S. Drought Monitor (USDM) is the current primary tool used to identify and categorize drought conditions in Oregon (https://droughtmonitor.unl.edu/) and is discussed in the subsequent section. In addition, the Natural Resources Conservation Service (NRCS) SWSI index is of current water conditions throughout the state and further discussed below.

Since the last NHMP update, City of Salem participated in the development of the *North Santiam Watershed Drought Contingency Plan* (NSDCP). The NSDCP was developed by the North Santiam Watershed Task Force to foster a collaborative and non-regulatory approach to drought planning, monitoring, and response within the watershed. The goal of the NSDCP is to build long-term resiliency to drought to minimize impacts to the communities, local economies, and the critical natural resources within the watershed. The NSDCP addresses the entire North Santiam watershed, in addition to, users outside the basin, such as City of Salem. Additional information related to NSDCP planning efforts is discussed later in this section.

Identifying Drought

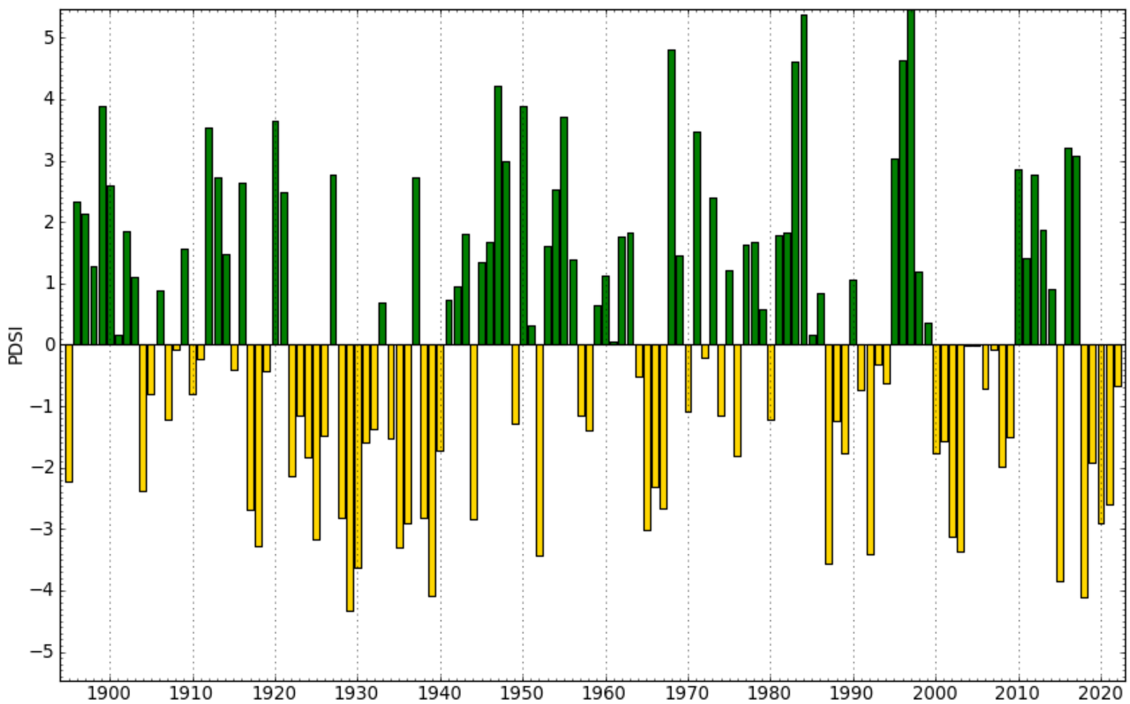
The USDM is the current primary tool used to identify and categorize drought conditions in Oregon. The USDM is not a statistical model, although numeric inputs include the following: Palmer Drought Severity Index, Standardized Precipitation Index, and other climatological inputs; the Keech-Byram Drought Index for fire, satellite-based assessments of vegetation health, and various indicators of soil moisture; and hydrologic data, particularly in the West, such as the Surface Water Supply Index and snowpack. Three of these inputs are discussed below.

An example of a tool used to estimate drought conditions is the *State Water Supply Outlook Report* (WSOR) produced by the NRCS. The State 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, community, and municipal purposes. Current WSOR are available for Oregon.

Palmer Drought Severity Index

According to NCAR, quantifying drought requires an objective criterion for defining the beginning and end of a drought period. Most federal agencies use the Palmer Drought Severity Index (PDSI). The index incorporates precipitation, runoff, evaporation, and soil moisture as variables. However, the PDSI 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 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. Figure 2-10 illustrates the PDSI for Marion County between 1895 – 2022.

Figure 2-10 Palmer Drought Severity Index, Marion County, Oregon 1895-2002

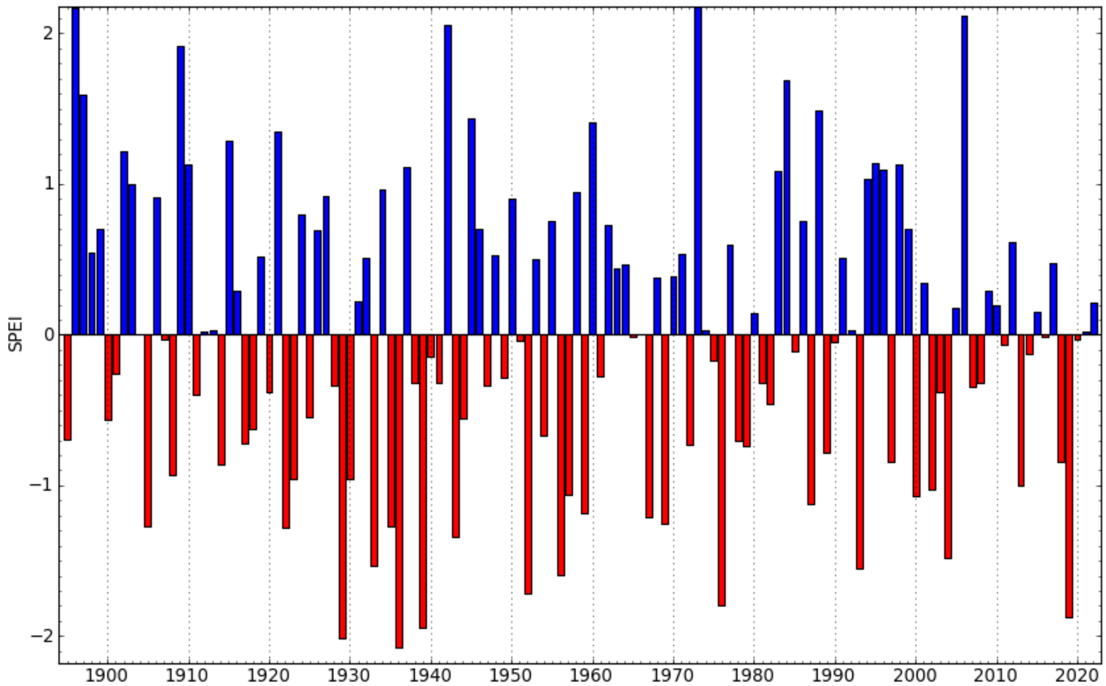


Source: Western Regional Climate Center. (n.d.) West Wide Drought Tracker. Retrieved December 2022, from https://wrcc.dri.edu/wwdt/time/.

Standardized Precipitation Evapotranspiration Index

The Standardized Precipitation Evapotranspiration Index (SPEI) is another method for analyzing drought conditions. It is an extension of the widely used Standardized Precipitation Index (SPI) and is designed to consider both precipitation and potential evapotranspiration in determining drought. According to *Fifth Oregon Climate Assessment* (2021), it is a key quantitative metric for assessing the occurrence and severity of meteorological and hydrological drought by comparing the net water balance between precipitation and potential evapotranspiration between a recent period and a historical period. The SPEI also allows for comparison of drought severity in different locations and times and for identification of different drought types, including consideration of the role of temperature in drought assessment. The *Fifth Oregon Climate Assessment*, (2021) indicates a 12-month SPEI is a reliable predictor of annual streamflow in the Northwest and water levels in lakes and reservoirs. The SPEI employs a Drought Severity Scale where 0 represents normal and drought is represented by negative numbers (-1 to -1.49 = moderate drought; -1.5 to -1.99 = severe drought; -2.0 or less = extreme drought).

Figure 2-11 Standardized Precipitation-Evapotranspiration Index (SPEI), Marion County, Oregon 1895-2020

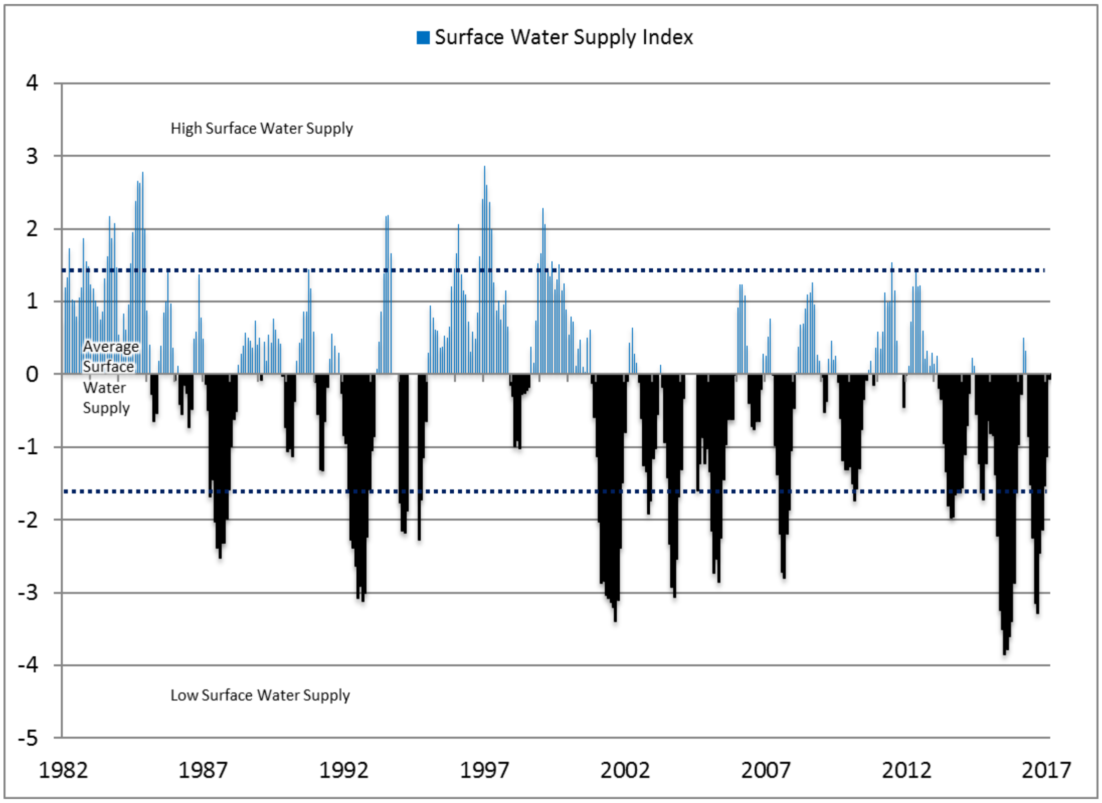


Source: Western Regional Climate Center. (n.d.) West Wide Drought Tracker. Retrieved December 2022, from https://wrcc.dri.edu/wwdt/time/.

Surface Water Supply Index

The SWSI index is of current water conditions throughout the state. The index utilizes parameters derived from snow, precipitation, reservoir and stream flow data. The data is gathered each month from key stations in each basin. The lowest SWSI value, -4.2, indicates extreme drought conditions (Low Surface Water Supply ranges from -1.6 to -4.2). The highest SWSI value, +4.2, indicates extreme wet conditions (High Surface Water Supply ranges from +1.6 to +4.2). The mid-point is 0.0, which indicates an average water supply (Average Water Supply ranges from +1.5 to -1.5). Moderate droughts are classified at SWSI values between -2.0 and -4.0, while severe drought is classified at SWSI values of -4.0 and below. **Error! Reference source not found.** below shows the monthly history of SWSI values from February 1982 to March 2017 for the Willamette Basin which includes Salem.

Figure 2-12 SWSI Values for the Willamette Basin (1982-2017)



Source: U.S. Natural Resources Conservation Service. (n.d.). Surface Water Supply Index (SWSI). Retrieved May 2017, from www.or.nrcs.usda.gov.

Research shows that the periods of drought have fluctuated; recent moderate drought periods occurred in 1987, 1992, 1994, 2001, 2003, 2005, 2015, and 2016. According to the OWRD Public Declaration Status Report, the governor signed a drought declaration for Marion County covering the period from September 18 – December 31, 2015; a period which came close to reaching the severe drought SWSI classification. In addition, there were no drought declarations between 2017 and 2022 for Marion and Polk Counties.

History

Although Salem is spared from most droughts because of its location east of the ocean and west of the Cascades, it has been affected by droughts in the past. The broader region surrounding Salem experiences dry conditions annually during the summer months from June to September. The Drought Monitor (National Weather Service Climate Prediction Center) shows episodes of drought within the past five years occurring during the summer through the fall. Periodically, this region experiences more significant drought conditions that affect the region or the state. Table 2-4 identifies historic drought events that impacted Salem.

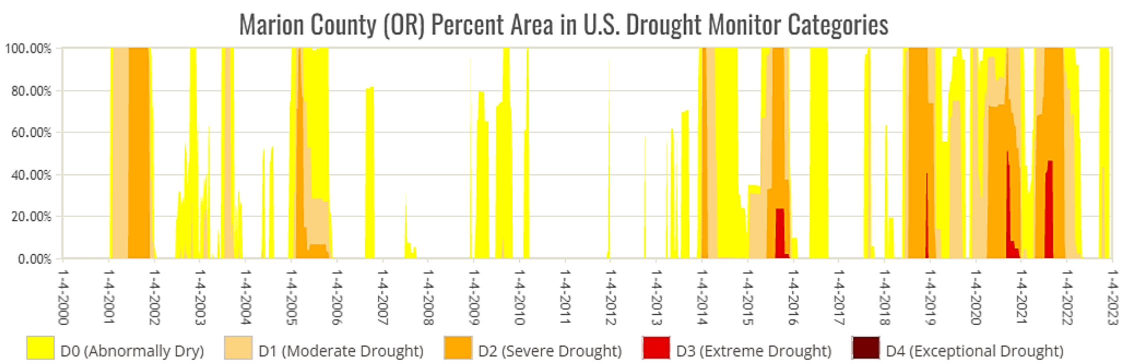
Table 2-4 Historic Drought Events

Time Period	Drought Description
1928-1941	Statewide drought
1976-1981	Low stream flows prevailed in western Oregon
1976-1977	Driest year of the century
1985-1994	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.
1992	The peak year of the drought when a drought emergency was declared for all of Oregon.
2015-2016	Two drought events
2017-2022	No drought declarations

Source: Taylor, G. H. and Hannan, C. (1999). *The Oregon Weather Book*. Corvallis, OR. Oregon State University Press and Oregon Water Resources Department. (n.d.). *Public Declaration Status Report*. Retrieved from http://apps.wrd.state.or.us/apps/wr/wr_drought/declaration_status_report.aspx.

For additional historical drought events for the Mid/ Southern Willamette Valley refer to the *2020 Oregon Natural Hazards Mitigation Plan*, Mid/ Southern Willamette Valley (Region 3) Risk Assessment.

Figure 2-13 Marion County Percent Area in U.S. Drought Monitor Categories (2000-2022)



Source: National Drought Mitigation Center, University of Nebraska-Lincoln. (n.d.) *U.S. Drought Monitor*. Retrieved December 2022, from https://droughtmonitor.unl.edu/DmData/TimeSeries.aspx.

El Niño

El Niño Southern Oscillation (ENSO) weather patterns can increase the frequency and severity of drought. During El Niño periods, alterations in atmospheric pressure in equatorial regions yield an increase in the surface temperature off the west coast of North America. This gradual warming sets off a chain reaction affecting major air and water currents throughout the Pacific Ocean. In the North Pacific, the Jet Stream is pushed north, carrying moisture laden air up and away from its normal landfall along the Pacific Northwest coast. In

Oregon, this shift results in reduced precipitation and warmer temperatures, normally experienced several months after the initial onset of the El Niño. These periods tend to last nine to twelve months, after which surface temperatures begin to trend back towards the long-term average. El Niño periods tend to develop between March and June, and peak from December to April. ENSO generally follows a two to seven-year cycle, with El Niño or La Niña periods occurring every three to five years. However, the cycle is highly irregular, and no set pattern exists. The last major El Niño was during 1997-1998. After that event, four El Niño events occurred but each were weaker and had shorter effects than the 1997–98 event.

Future Climate Variability

Even though drought is infrequent in the Willamette Valley where Salem is located, climate models project warmer, drier summers for Oregon according to the OCCRI *Fifth Oregon Climate Assessment* (2021). The *2020 Oregon Natural Hazards Mitigation Plan* indicates that for the Mid/Southern Willamette Valley (Region 3), these summer conditions coupled with projected decreases in mid-to-low elevation mountain snowpack due to warmer winter temperatures increases the likelihood that Salem would experience increased frequency of one or more types of drought under future climate change. In the Salem area, climate change would result in increased frequency of drought due to low spring snowpack, low summer runoff, and low summer precipitation and low summer soil moisture. In addition, the Mid/Southern Willamette Valley, like the rest of Oregon is projected to experience an increase in the frequency of summer drought conditions as summarized by the SPEI due largely to projected decreases in summer precipitation and increases in potential evapotranspiration.

The *Salem Climate Action Plan 2021*, includes numerous strategies to address a variety of climate-related challenges facing the city including drought. The plan acknowledges significant projected climate impacts including the following:

- The number of days with a heat index over 90°F will increase from a historic average of 7 per year to 33 per year by mid-century.
- Hotter and drier conditions are likely to cause more frequent droughts.
- Wildfire is a significantly increasing risk across the state of Oregon. The number of extreme fire danger days in Salem will double by mid-century, increasing from a historic average of 10 per year to 20 per year. Extremely large, intense fires will become more likely under hotter and drier climate scenarios.

Probability Assessment

Droughts are not uncommon in the State of Oregon, nor are they just an "east of the mountains" phenomenon. They occur in all parts of the state, in both summer and winter. Oregon's drought history reveals many short-term and a few long-term events. The average recurrence interval for severe droughts in Oregon is somewhere between 8 and 12 years. The 2020 Oregon NHMP states the following regarding the probability for the drought hazard in Mid/ Southern Willamette Valley (Region 3),

> Despite impressive achievements in the science of climatology, estimating drought probability and frequency continues to be difficult. This is because of the many

variables that contribute to weather behavior, climate change and the absence of long historic databases.

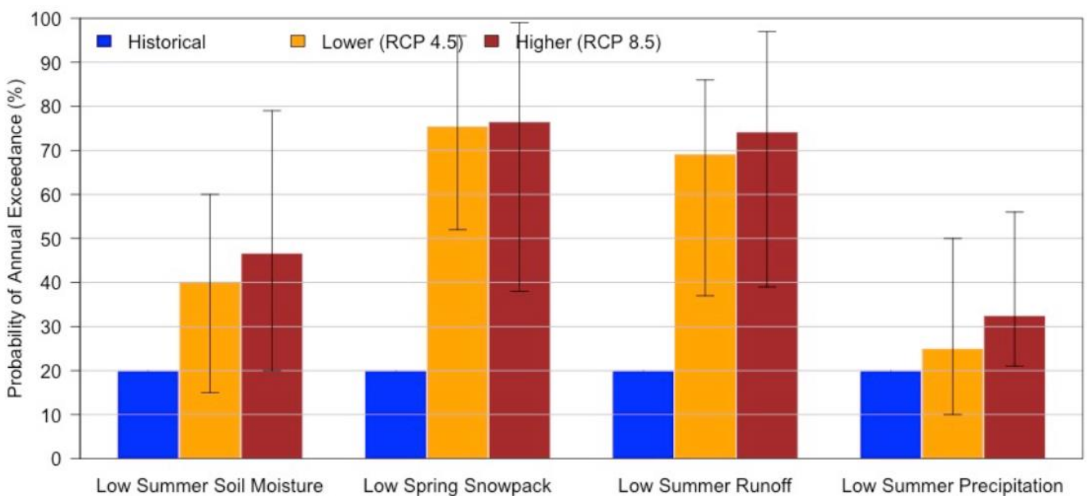
A comprehensive risk analysis is needed to fully assess the probability and impact of drought to Oregon communities. Such an analysis could be completed statewide to analyze and compare the risk of drought across the state.

Benton, Polk, and Yamhill Counties have received drought declarations in only 3% of the years since 1992, Marion and Linn in 7%, and Lane in 10%. This accounts for their very low and low probability, respectively, of experiencing drought.

Based on the available data and research for Salem the NHMP Steering Committee assessed the **probability of experiencing a locally severe drought as "high,"** meaning one incident is likely within a 10 to 35-year period.

Figure 2-14 shows the projected probability of exceeding the magnitude of seasonal drought conditions for which the historical annual probability of exceedance was 20%.

Figure 2-14 Projected Future Drought in Marion County



Source: Dalton M., Fleishman E., and Bachelet D. (2022, June), *Future Climate Projections Marion County, Oregon.* Oregon Climate Change Research Institute, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, Oregon. Retrieved from https://oregonstate.app.box.com/s/me7ih3b6vvlffrm6ndwmt8a5ag6zs6xw.
Note: Projections are for the 2050s (2040–2069), relative to the historical baseline (1971–2000), under two emissions scenarios. Seasonal drought conditions include low summer soil moisture (average from June through August), low spring snowpack (April 1 snow water equivalent), low summer runoff (total from June through August), and low summer precipitation (total from June through August). The bars and whiskers represent the mean and range across ten global climate models.

Vulnerability Assessment

Droughts in the past have caused no personal injury or death. The potential for future injuries or deaths is anticipated to increase compared to historic events. Salem estimates that greater than 10% of the city's population or property is likely to be affected by drought conditions. The following summary is reflected in the 2020 Oregon NHMP, regarding the Mid/ Southern Willamette Valley (Region 3) vulnerability of drought to the region,

> Although long-term drought conditions are uncommon in the mid-Willamette Valley, a dry winter or spring could affect many communities and water users throughout the Basin. Recreation, particularly at the reservoirs owned and operated by the U.S. Army Corps of Engineers, contributes greatly to the valley's economy. Communities, such as Detroit in Marion County, can be economically impacted by low reservoir levels. The Willamette Valley is also home to one of the most productive and diverse agricultural regions in the United States. Drought, especially a long drought, could significantly impact agricultural production.
>
> Impacts of drought on state-owned facilities related to agriculture would include impacts to research conducted in outdoor settings, such as at extension stations and research farms.
>
> Because drought impacts are relatively recent in Region 3, there is no single comprehensive source or other sources for information to assess economic impacts.
>
> Oregon has yet to undertake a comprehensive, statewide analysis to identify which communities are most vulnerable to drought.

The 2020 Oregon NHMP continues by addressing social vulnerability,

> The Centers for Disease Control and Prevention (CDC) has calculated a social vulnerability index to assess community resilience to externalities such as natural hazard events. It employs fifteen social vulnerability factors and uses data from the US Census Bureau's American Community Survey. The index is reported in quintiles (1–5). Social vulnerability scores do not vary by hazard.
>
> According to the CDC Social Vulnerability Index, social vulnerability in the region is highest in Marion County, followed by Linn and Yamhill Counties. Marion County ranks in the 90th percentile for its share of persons aged 17 or younger, percentage of single-parent households, and percentage of occupied housing units with more people than rooms. The county is also the 90th percentile for its share of residents that speak English less than "well." …
>
> Marion County's social vulnerability score is very high, Linn and Yamhill Counties' high. Lane and Polk Counties' social vulnerability score is moderate, Benton County's low. The social vulnerability score indicates the extent of impact of any natural hazard, including drought, on a county's population. Marion, Linn, and Yamhill are the communities most vulnerable to drought in Region 3.

Facilities throughout the city anticipate little or no damage due to a drought, estimated at less than $1 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely less than 10% of businesses located in the city and surrounding area could experience commerce interruption for a period of days. The agricultural sector could suffer the greatest impact from a drought in comparison to other types of business. Lastly, drought would likely have moderate impacts on more than 75% of the city's ecological systems, including, clean water, wildlife habitat, and parks. Also, domestic water-users may be subject to stringent conservation measures (e.g., rationing) as per the city's water conservation plan.

Salem Climate Action Plan

The *Salem Climate Action Plan 2021* outlines the following potential vulnerabilities and consequences of various projected climate changes as it relates to drought and extreme heat events.

Projected Temperature Increases

While higher summer temperatures may lead to health impacts for vulnerable populations, the temperature increase is not projected to be extreme and may be offset by people's ability to naturally acclimate to changing temperatures over time.

- Increased risk of heat-related illnesses to small children, the elderly, people with chronic illnesses, residents living at or near the poverty line, and people who work outside (e.g., farmworkers and construction workers), and people who are unsheltered.
- Increased risk of respiratory problems.
- Salem's population is expected to grow 28% by 2035. Combined with warming temperatures, increases in population mean more people will likely use air conditioning on the warmest days, which may lead to an increased demand for electricity.
- Warming temperatures may allow for new pests to infiltrate the area. New pests may have the ability to negatively impact Salem's ecosystems, for example by harming the Salem's tree canopy and spreading disease.
- Decreased water levels in the reservoirs on the North Santiam River which provide all of Salem's water.

Projected Precipitation Patterns

Though overall precipitation amounts are expected to remain consistent, increased temperatures noted above will lead to a water deficit.

- Increased risk of drought, especially when combined with warmer temperatures.
- Water use restrictions and food insecurity in periods of drought.

North Santiam Watershed Drought Contingency Plan

The goal of *North Santiam Watershed Drought Contingency Plan*, as noted previously, is to build long-term resiliency to drought to minimize impacts to the communities, local economies, and the critical natural resources within the watershed. The NSDCP assessed vulnerabilities through inventory of watershed assets and other resources at risk in the event of water shortage. The plan reviews the extent to which the assets are vulnerable now and into the future, and the underlying causes of the vulnerability was examined.

The following list includes the NSDCP prioritized grouped assets at risk because of drought. Those assets in bold are the most vulnerable assets under current conditions.

- **Municipal water users: Detroit, Idanha, Lyons-Mehama, Gates, Stayton, and Salem**
- **In-stream natural resources (e.g., endangered species, water quality, and wetlands)**
- **Commercial crop irrigation**

- **Municipal-supplied commercial/industrial use**
- Fire suppression
- Individual domestic water
- **Water oriented recreation**
- Non-commercial irrigation
- Hydropower
- Upland natural resources
- Other irrigation/watering

The NHMP Steering Committee rated the city as having **a "high" vulnerability to drought hazards**, meaning greater than 10% of the city's population or property would be affected by a major drought emergency or disaster.

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

NOAA National Integrated Drought Information System

The National Integrated Drought Information System (NIDIS) program was authorized by Congress in 2006 (Public Law 109-430) and reauthorized in 2014 and 2019 with an interagency mandate to coordinate and integrate drought research, building upon existing federal, tribal, state, and local partnerships in support of creating a national drought early warning information system to make climate and drought science accessible and useful for decision makers and stakeholders.

State Resources

Water Supply Availability Committee and Drought Readiness Council

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 interagency groups to evaluate water supply conditions, and to help assess and communicate potential drought related impacts, the Water Supply Availability Committee and the Drought Readiness Council.

The Water Supply Availability Committee (WSAC) is a technical committee chaired by the Oregon Water Resources Department (OWRD). The WSAC provides the scientific foundation that decision-makers need to identify and respond appropriately to drought. The Committee consists of state and federal science and emergency preparedness agencies.

The WSAC meets 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 as identified in the OEM *Comprehensive Emergency Management Plan, Incident Annex 01 Drought*:

- 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

The other group that Oregon relies upon to evaluate water conditions is the Drought Readiness Council (DRC), which is co-chaired by the OWRD and OEM. The council consists of state agencies with natural resources management, public health, or emergency management expertise. The role of the DRC is to review local requests for assistance and make recommendations to the Governor regarding the need for state drought declarations.

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to coastal hazards, floods, and other natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of natural hazards including the Hazard Mitigation Grant Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, OEM notifies local public safety agencies and keeps them informed of potential and actual hazard events so prevention and mitigation actions can be taken.

Local Resources

North Santiam Watershed Drought Contingency Plan

Since the last NHMP update, Salem participated in the development of the North Santiam Watershed Drought Contingency Plan (NSDCP). The NSDCP was developed by the North Santiam Watershed Task Force to foster a collaborative and non-regulatory approach to drought planning, monitoring, and response within the watershed. The goal of the NSDCP is to build long-term resiliency to drought to minimize impacts to the communities, local economies, and the critical natural resources within the watershed. The NSDCP addresses the entire North Santiam watershed, in addition to, users outside the basin, such as City of Salem. The NSDCP was accepted in April 2018 by the Bureau of Reclamation.

Salem and Santiam Water Control District are sponsoring partners for the Bureau of Reclamation 2022 WaterSMART Drought Contingency Planning grant, which has funded an update to the NSDCP. The NSDCP update is aimed at continuing to build long-term resiliency to drought in the North Santiam Watershed. This update process began in November 2022 and is anticipated to be completed sometime in 2024.

Santiam Water Control District, Council of Water Leaders

The Council of Water Leaders (CWL) was created in 2022 to help address urgent water resource challenges in the North Santiam Watershed and provide a forum for increasing communication and coordination amongst decision-makers and other leaders on important issues in the North Santiam Watershed. CWL holds quarterly meetings and an annual symposium.

The CWL uses available science to develop long-term solutions to water management issues, such as the following:

- Emergency planning
- Post-fire recovery
- Drought contingency planning
- Water quantity (flow restoration and flow management)
- Water quality (source water protection and Willamette River mercury total maximum daily load (TMDL))
- Riparian and aquatic habitat restoration

Salem Climate Action Plan 2021 and Community Greenhouse Gas Inventory

Since the last NHMP update, Salem developed the *Salem Climate Action Plan 2021* that outlines strategies and actions to reduce Greenhouse Gas emissions and increase climate resiliency in our community. Through the development of the *Salem Climate Action Plan 2021*, it was determined that Salem's projected climate impacts will include three main categories: warming temperatures, changes in precipitation patterns, and increased risk of wildfires. Many of the strategies in the CAP are designed to help the community adapt to impacts and build resiliency for the future. The strategies seek to do the following:

- Expand the urban tree canopy and access to green spaces
- Create a climate related education and outreach program
- Create a network of indoor gathering places that can serve as community centers during times of need
- Engage underserved populations in co-creating resilient solutions
- Strengthen the local economy

Earthquake

Significant Changes Since Previous Plan:

The Earthquake Hazard section was reformatted and expanded with additional information since the previous plan.

Causes and Characteristics

Earthquakes occur in Oregon every day; every few years an earthquake is large enough for people to feel; and every few decades there is an earthquake that causes damage. Each year, the Pacific Northwest Seismic Network locates more than 1,000 earthquakes greater than magnitude 1.0 in Washington and Oregon. Of these, approximately two dozen are large enough to feel. These noticeable events offer a subtle reminder that the Pacific Northwest is an earthquake-prone region.

Seismic hazards pose a real and serious threat to many communities in Oregon, including Salem, requiring local governments, planners, and engineers to consider their community's safety. Currently, no reliable scientific means exists to predict earthquakes. Identifying seismic-prone locations, adopting strong policies and implementing measures, and using other mitigation techniques are essential to reducing risk from seismic hazards in the Willamette Valley, which includes Salem.

Types of Earthquakes

Oregon and the Pacific Northwest in general are susceptible to earthquakes from four sources: 1) shallow crustal fault – slippage events within the North American Plate; 2) deep intra-plate events within the subducting Juan de Fuca Plate; 3) the off-shore Cascadian Subduction Zone (CSZ); and 4) earthquakes associated with renewed volcanic activity. The first three identified are discussed below under Identifying Earthquakes. Marion County, which Salem is included, is primarily susceptible to crustal and subduction zone earthquakes.

While all three types of earthquakes have the potential to cause major damage, subduction zone earthquakes pose the greatest danger. A major CSZ event could generate an earthquake with a magnitude 9.0 or greater resulting in devastating damage and loss of life. Such earthquakes may cause great damage to the coastal area of Oregon as well as inland areas in western Oregon. It is estimated that shaking from a large subduction zone earthquake could last up to five minutes.

Characteristics of Earthquakes

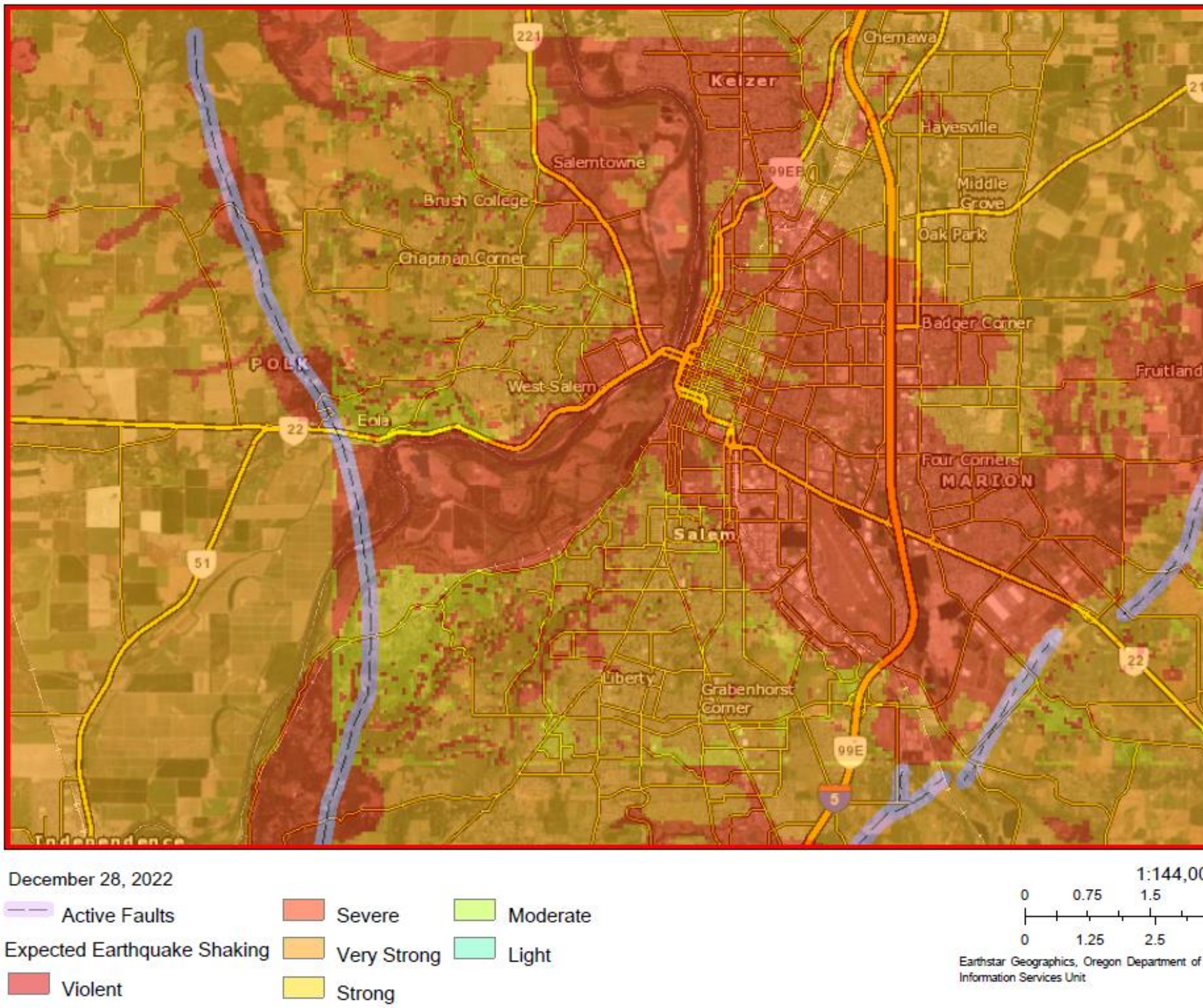
The following are earthquake-induced hazards:

Ground Shaking

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

Buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock. The amount of damage sustained by a building during a strong earthquake is difficult to predict and depends on the size, type and location of the earthquake, the characteristics of the soils at the building site, and the characteristics of the building itself, according to DOGAMI's Earthquakes in Oregon site.

Figure 2-15 Cascadia Subduction Zone Expected Shaking Map of City of Salem



shows the expected shaking/damage potential for Salem resulting from a Cascadia Subduction Zone event. The figure shows that the city will experience "very strong" to "severe shaking" that will last two to four minutes. The strong shaking will be extremely damaging to lifeline transportation routes including Interstate 5.

The figure shows that the city will experience "very strong" to "severe shaking" that will last two to four minutes. The strong shaking will be extremely damaging to lifeline transportation routes including Interstate-5. For more information on expected losses due to a CSZ event see *The Oregon Resilience Plan* (2013).

DOGAMI's *Multi-Hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022) includes Figure 2-16, below, which shows anticipated shaking due to a magnitude 6.6 earthquake on the Mt. Angel fault. The City of Salem Expected Shaking related to Cascadia Subduction Zone is shown in Figure 2-15.

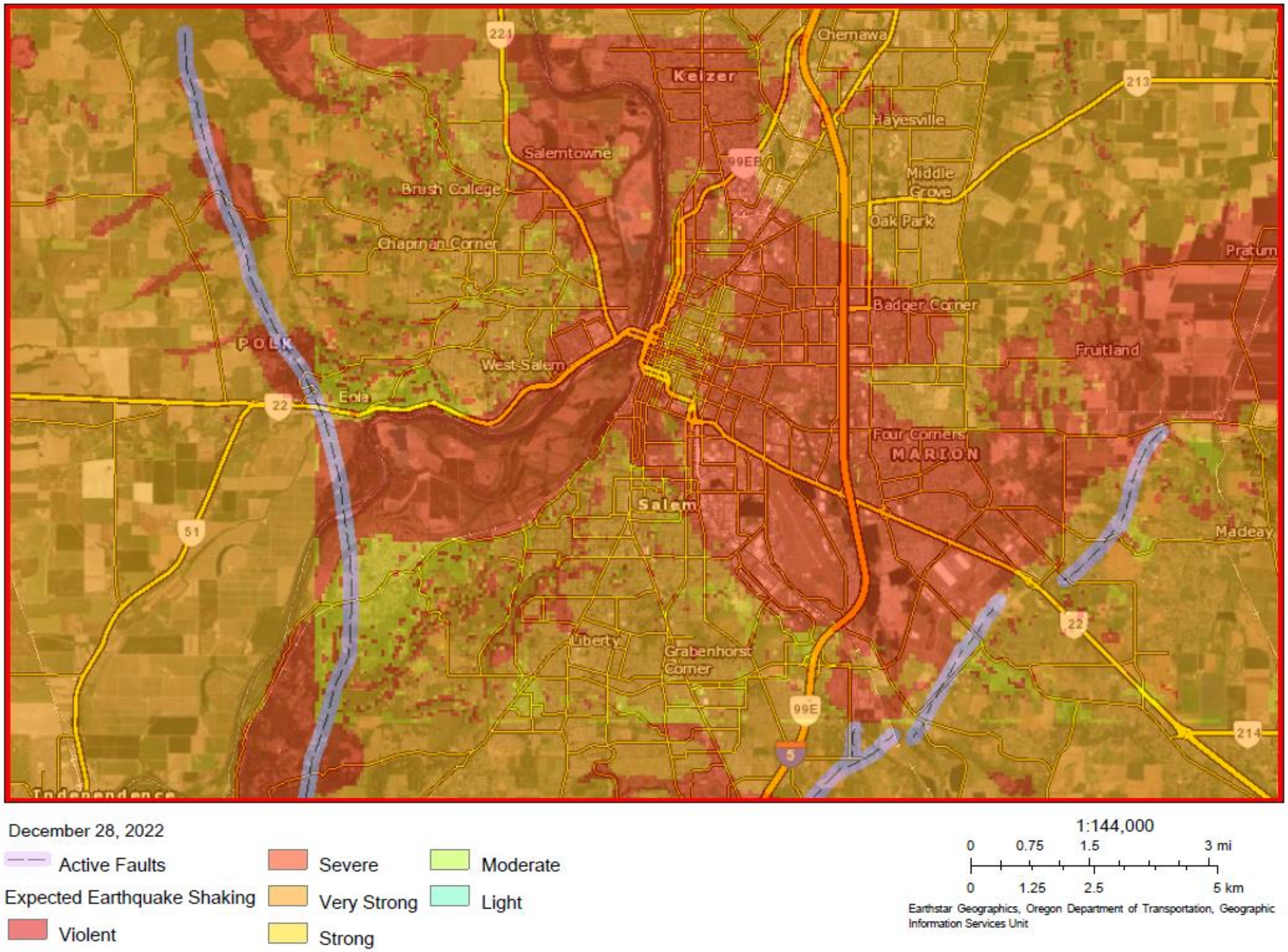
Ground Shaking Amplification

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

Surface Faulting

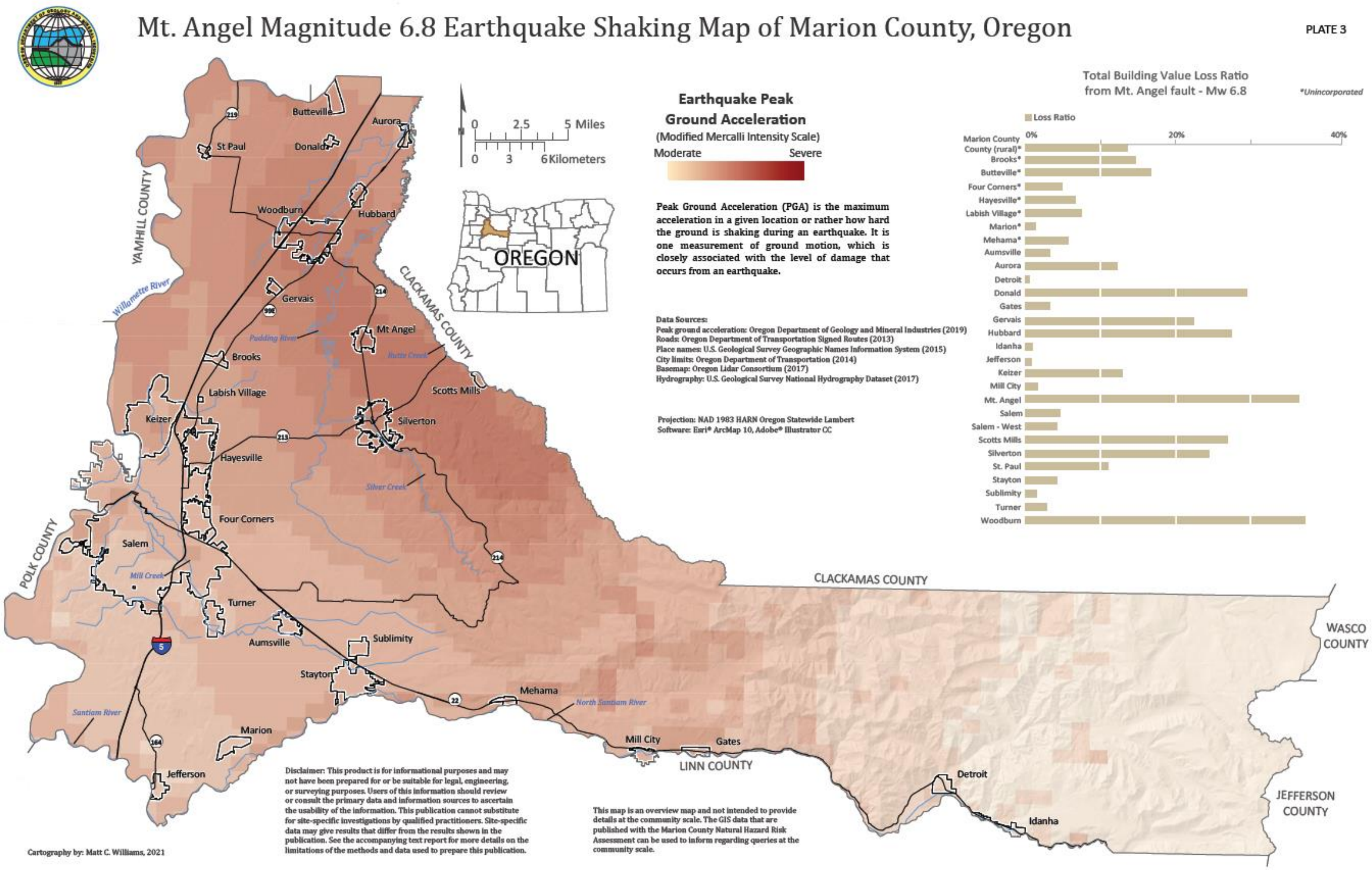
Surface faulting are planes or surfaces in Earth materials along which failure occurs. Such faults can be found deep within the earth or on the surface. Earthquakes occurring from deep lying faults usually create only ground shaking.

Figure 2-15 Cascadia Subduction Zone Expected Shaking Map of City of Salem



Source: Williams, M. C. & Madin, I. P. (2022). Open-file Report O-22-05 Multi-Hazard Risk Report for Marion County, Oregon. Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/O-22-05/p-O-22-05.htm.

Figure 2-16 Mt. Angel Magnitude 6.8 Earthquake Shaking Map of Marion County, Oregon



Source: Williams, M. C. & Madin, I. P. (2022). *Open-file Report O-22-05 Multi-Hazard Risk Report for Marion County, Oregon.* Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/O-22-05/p-O-22-05.htm.

Liquefaction and Subsidence

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

Earthquake-Induced Landslides and Rockfalls

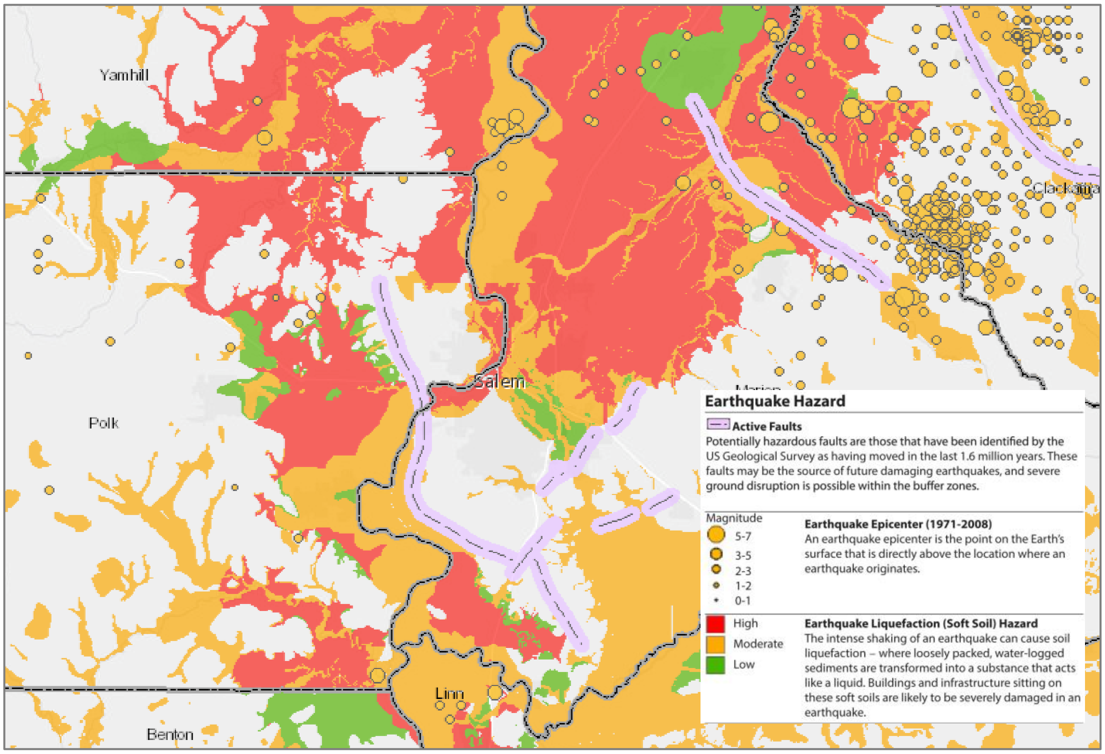
Earthquake-induced landslides are secondary hazards that occur from ground shaking and can destroy roads, buildings, utilities and critical facilities necessary to recovery efforts after an earthquake. These areas often have a higher risk of landslides and rockfalls triggered by earthquakes.

The severity of an earthquake is dependent upon several factors including: 1) the distance from the earthquake's source (or epicenter); 2) the ability of the soil and rock to conduct the earthquake's seismic energy; 3) the degree (i.e., angle) of slope materials; 4) the composition of slope materials; 5) the magnitude of the earthquake; and 6) the type of earthquake.

Location and Extent

Figure 2-17 shows a generalized geologic map of Salem and includes the Mount Angel, Canby-Mollala, and Newberg faults. Within the Salem Urban Growth Boundary (UGB), the area south of the Willamette River and west of River Road has the highest risk of earthquakes. Other small areas with high earthquake risk exist to the east of the city. According to DOGAMI's *Geologic Hazards, Earthquake and Landslide Hazard Maps, and Future Earthquake Damage Estimates for Six Counties in the Mid/Southern Willamette Valley* (Burns, Hofmeister, & Wang, 2008), the areas that are most susceptible to ground amplification and liquefaction have young, soft alluvial sediments, found in most of the Willamette Valley and are along stream channels. The extent of the damage to structures and injury and death to people will depend upon the type of earthquake, proximity to the epicenter and the magnitude and duration of the event.

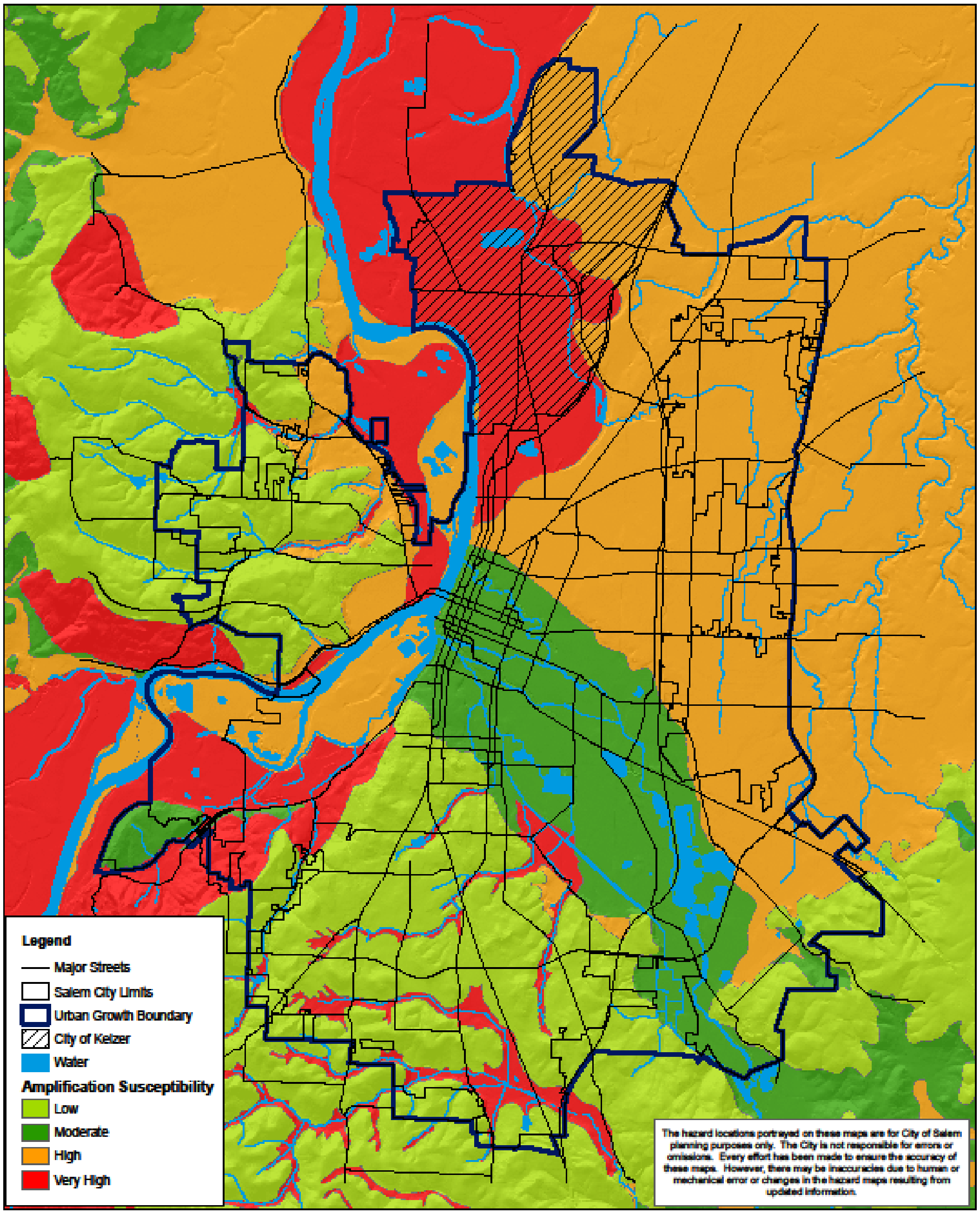
Figure 2-17 Earthquake Epicenters (1971-2008), Active Faults, and Soft Soils



Source: Oregon HazVu: Statewide Geohazards Viewer, Retrieved from https://gis.dogami.oregon.gov/maps/hazvu/

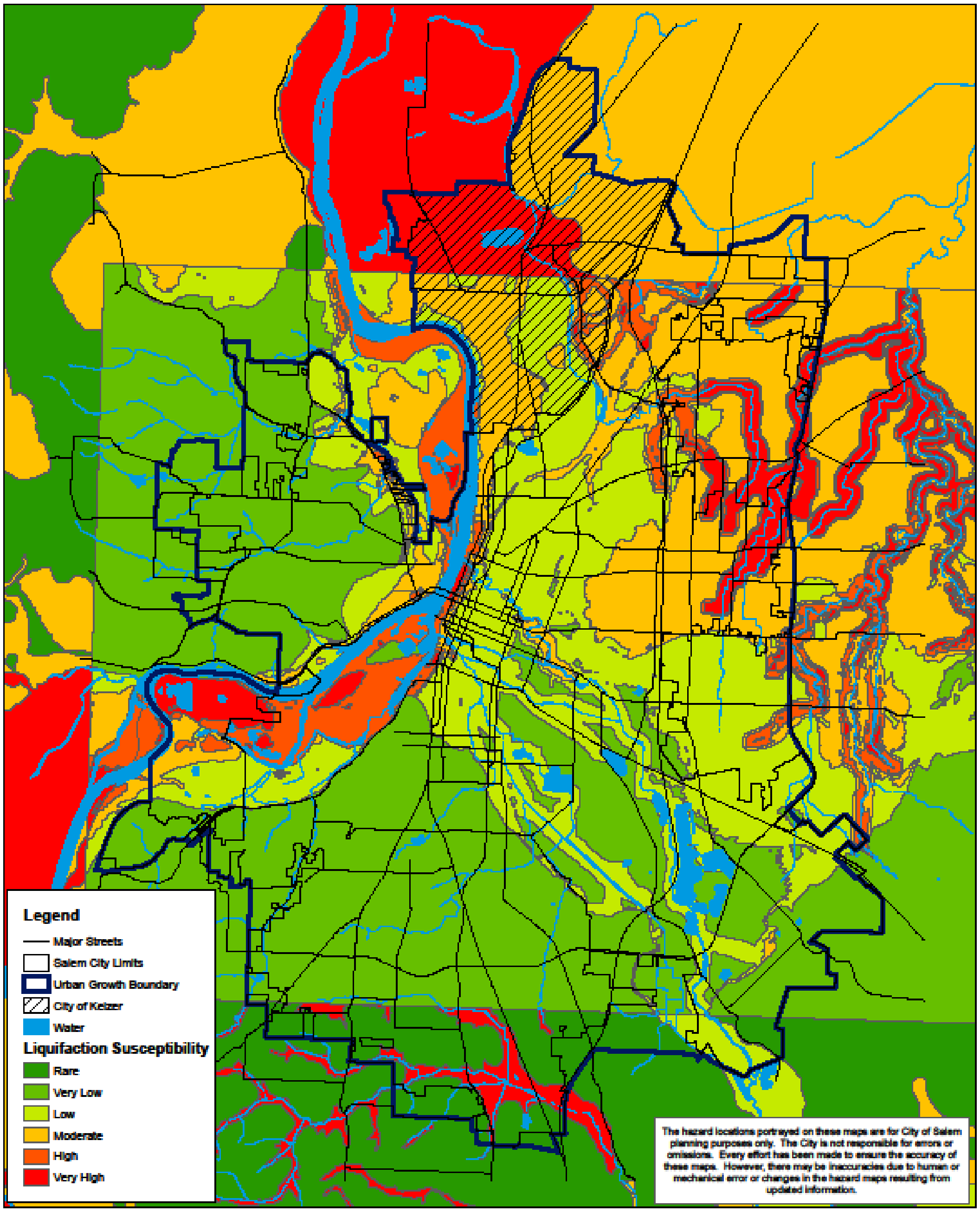
DOGAMI, in partnership with other state and federal agencies, has undertaken a rigorous program in Oregon to identify seismic hazards, including active fault identification, bedrock shaking, tsunami inundation zones, ground motion amplification, liquefaction, and earthquake induced landslides. Several seismic hazard maps have been published and are available for communities to use. The maps show ground motion amplification (Figure 2-18), liquefaction (Figure 2-19), landslide susceptibility, and relative earthquake hazards. The DOGAMI Statewide Geohazards Viewer was used to present a visual map of recent earthquake activity, active faults, and liquefaction; ground shaking is generally expected to be higher in the areas marked by soft soils in the map above. The severity of an earthquake is dependent upon several factors including the distance from the earthquake's source (or epicenter), the ability of the soil and rock to conduct the earthquake's seismic energy, the degree (i.e., angle) of slope materials, the composition of slope materials, the magnitude of the earthquake, and the type of earthquake.

Figure 2-18 Earthquake Amplification Susceptibility



Source: City of Salem, DOGAMI

Figure 2-19 Earthquake Liquefaction Susceptibility



Source: City of Salem, DOGAMI

For more information, see the following reports:

Interpretive Map Series: IMS-6, Water-induced landslide hazards, western portion of the Salem Hills, Marion County, Oregon by Andrew F. Harvey and Gary L. Peterson, 1998, 13 p., 1:24,000

Interpretive Map Series: IMS-8, Relative earthquake hazard maps for selected urban areas in western Oregon: Canby-Barlow-Aurora, Lebanon, Silverton-Mount Angel, Stayton-Sublimity-Aumsville, Sweet Home, Woodburn-Hubbard

Interpretive Map Series: IMS-17, Earthquake-induced slope instability; relative hazard map, western portion of the Salem Hills, Marion County, Oregon by R. Jon Hofmeister, Yumei Wang, and David K. Keefer, 2000, 1:24,000

Interpretive Map Series: IMS-24, Geologic hazards, earthquake and landslide hazard maps, and future earthquake damage estimates for six counties in the Mid/Southern Willamette Valley including Yamhill, Marion, Polk, Benton, Linn, and Lane Counties, and the City of Albany, Oregon

Geologic Map Series: GMS-105, Relative earthquake hazard maps of the Salem East and Salem West quadrangles, Marion and Polk Counties, Oregon by Yumei Wang and William J. Leonard, 1996, 10 p., 1:24,000

Open-File Report: O-2003-02, Map of Selected earthquakes for Oregon (1841-2002), 2003

Open-File Report: O-2007-02, Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings, 2007

Open-File Report: O-2013-22, Cascadia Subduction Zone earthquakes: A magnitude 9.0 earthquake scenario, 2013

Special Papers: SP-29, Earthquake damage in Oregon Preliminary estimates of future earthquake losses (1999)

Additional reports are available via DOGAMI's Publications Center website: https://www.oregongeology.org/pubs/

Oregon Seismic Safety Policy Advisory Commission Reports: *The Oregon Resilience Plan* (2013)

Identifying Earthquakes

Oregon Department of Geology and Mineral Industries, in partnership with other state and federal agencies, has undertaken a rigorous program in Oregon to identify seismic hazards, including active fault identification, bedrock shaking, tsunami inundation zones, ground motion amplification, liquefaction, and earthquake induced landslides.

Most large earthquakes in the Pacific Northwest are shallow crustal, deep intraplate, or subduction zone earthquakes. These earthquakes can have great impact on Oregon communities. The extent of the damage to structures and injury and death to people will depend upon the type of earthquake, proximity to the epicenter and the magnitude and duration of the event.

Crustal Fault Earthquakes

according to OEM's *Cascadia Playbook* (2018). Crustal fault earthquakes are the most common and occur at relatively shallow depths of 6-12 miles below the surface. While most crustal fault earthquakes are smaller than magnitude 4.0 and generally create little or no damage, some can produce earthquakes of magnitude 7.0 and higher and cause extensive damage. Crustal earthquakes within the North American plate are possible on faults mapped as active or potentially active as well as on unmapped (unknown) faults.

Deep Intraplate Earthquakes

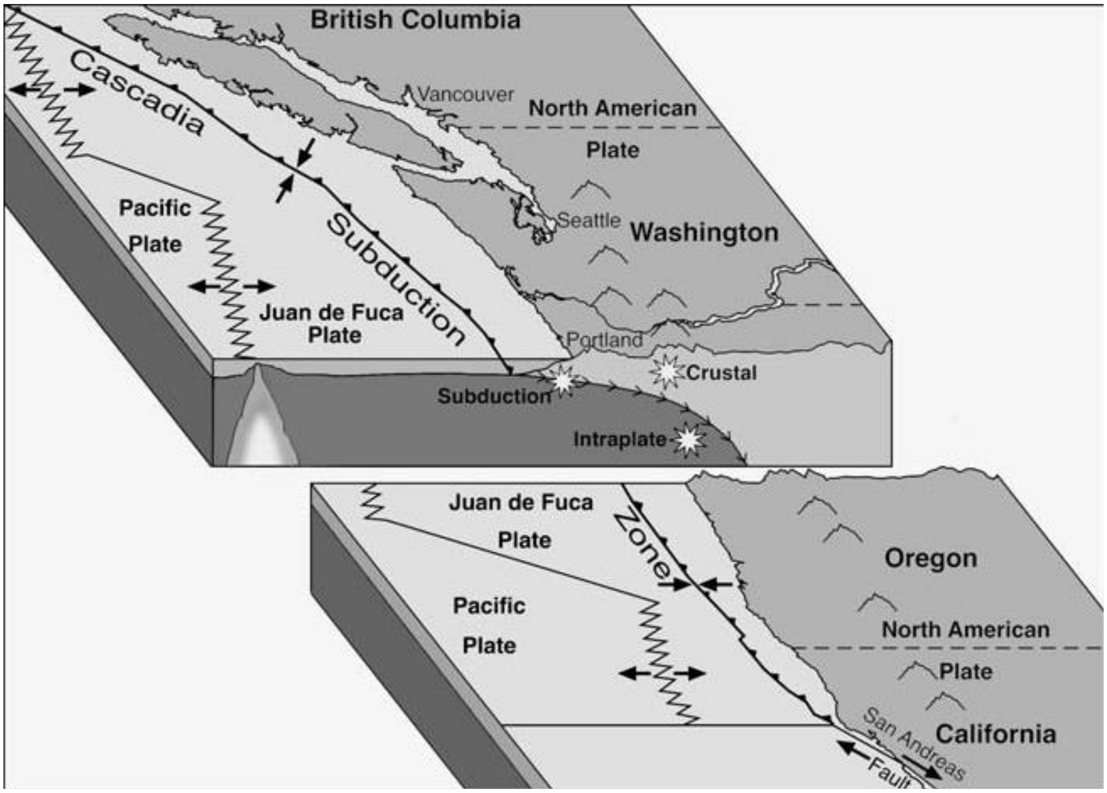
Occurring at depths from approximately 30 – 37 miles below the earth's surface in the subducting oceanic crust, deep intraplate earthquakes can reach magnitude 7.5, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. This type of earthquake is more common in the Puget Sound of Washington. In Oregon these earthquakes occur at lower rates, and none have occurred at a damaging magnitude, according to the 2020 Oregon NHMP. The February 28, 2001, earthquake in Washington State was a deep intraplate earthquake. It produced a rolling motion that was felt from Vancouver, British Columbia to Coos Bay, Oregon and east to Salt Lake City, Utah (Hill, 2002). A 1965 magnitude 6.5 intraplate earthquake centered south of the Seattle-Tacoma International Airport caused seven deaths (Hill, 2002).

Subduction Zone Earthquakes

The Pacific Northwest is located at a convergent plate boundary where the Juan de Fuca and North American tectonic plates meet. The two plates are converging at a rate of about 1.5 inches per year. This boundary is called the Cascadia Subduction Zone (CSZ) and is illustrated in Figure 2-20. The CSZ extends from British Columbia to northern California. Subduction zone earthquakes are caused by the abrupt release of slowly accumulated stress. Subduction zones like the Cascadia Subduction Zone have produced earthquakes with magnitudes 8.0 or greater. Historic subduction zone earthquakes include the 1960 Chile (magnitude 9.5) and the 1964 southern Alaska (magnitude 9.2) earthquakes. Geologic evidence shows that the Cascadia Subduction Zone has generated great earthquakes, most recently about 300 years ago. The largest is generally accepted to have been magnitude 9.0 or greater. The average recurrence interval of these great Cascadia earthquakes is approximately 500 years, with gaps between events as small as 200 years and as large as 1,000 years. Such earthquakes may cause great damage to the coastal area of Oregon as well as inland areas in western Oregon. It is estimated that shaking from a large subduction zone earthquake could last up to five minutes.

While all three types of earthquakes have the potential to cause major damage, subduction zone earthquakes pose the greatest danger. A major CSZ event could generate an earthquake with a magnitude of 9.0 or greater resulting in devastating damage and loss of life. Such earthquakes may cause great damage to the coastal area of Oregon as well as inland areas in western Oregon.

Figure 2-20 Cascadia Subduction Zone

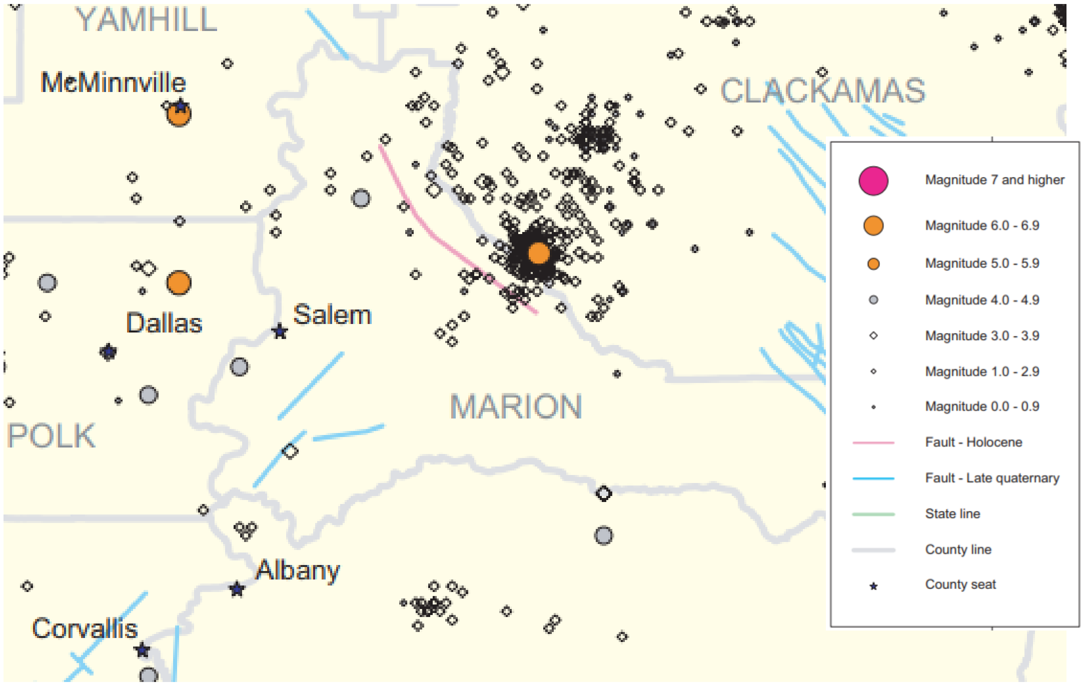


Source: Oregon DLCD. (1998). *Shoreland Solutions. Chronic Coastal Natural Hazards Model Overlay Zone. Salem, Ore*. Technical Guide-3.

History

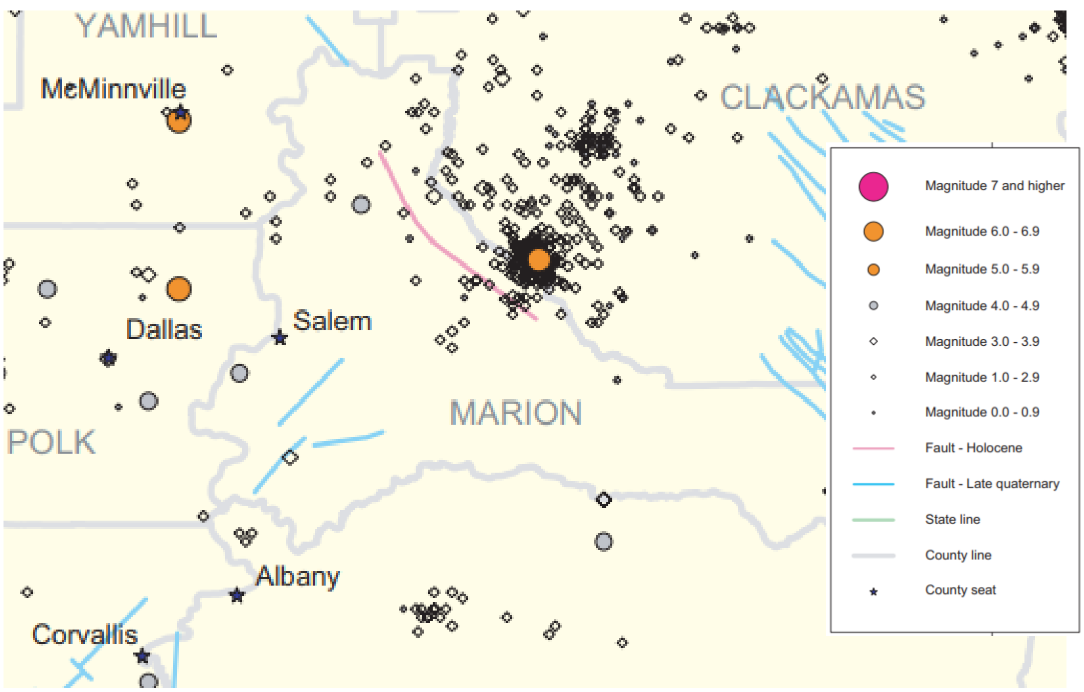
The region has been shaken historically by crustal and intraplate earthquakes and prehistorically by subduction zone earthquakes centered off the Oregon coast. There have been multiple moderate earthquakes in Marion County in the past 100 years. Earthquakes with magnitudes of 5.0 and 4.6 occurred in Salem in 1957 and 1963 respectively. Minor damage was reported following both events. In the greater Marion County region, the most significant event in the region occurred near Scotts Mills in March of 1993. This magnitude 5.7 event resulted in damage throughout Marion County including cracking the rotunda of the state Capitol cracked, and the nearly rocking the Golden Pioneer statue off its base (Elliott, 1993). In Mount Angel, authorities closed the historic St. Mary Catholic Church for fear its 200-foot bell tower could collapse. Chunks of plaster fell from the walls at the Queen of Angels Monastery. Woodburn felt the strongest effects of the quake. Officials shut down four century-old brick and mortar buildings that began to crumble. At a Walmart store, fumes overcame several employees when pesticides, paints and car batteries mixed (Elliott, 1993).

Historically observed crustal earthquakes in Oregon from 1841 to 2002 are shown in DOGAMI Open-File Report O-2003-02.



below shows only part of this map, focused on Salem and nearby counties. During this period, several small earthquakes occurred in Marion and Polk County. Larger earthquakes in nearby counties are also shown.

Figure 2-21 Map of Selected Earthquakes for Oregon, 1841 through 2002



Source: Niewendorp, C. A. and Neuhaus, M. E. (2003). Open-file Report O-2003-02 Map of Selected Earthquakes for Oregon, 1841 through 2002. Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/O-03-02.pdf.

Salem has not experienced any major earthquake events in recent history. Seismic events do, however, pose a significant threat. Specifically, a CSZ event could produce catastrophic damage and loss of life in Salem. Table 2-5 has a list of the significant earthquakes that have affected the Mid/Southern Willamette Valley, which Salem is located.

Table 2-5 Significant Earthquakes Affecting Mid/Southern Willamette Valley

Date	Location	Magnitude	Comments
Approximate Years: 1400 BCE*, 1050 BCE, 600 BCE, 400, 750, 900	Offshore, Cascadia Subduction Zone	Probably 8-9	Mid-points of the age ranges for these six events
Jan. 1700	Offshore, Cascadia Subduction Zone	Approximately 9.0	Generated a tsunami that struck Oregon, Washington, and Japan; destroyed Native American villages along the coast
Apr. 1896	McMinnville, Oregon	4	Also felt in Portland
July 1930	Perrydale, Oregon	4	Cracked plaster
Apr. 1949	Olympia, Washington	7.1	Intraplate event. Damage: significant (Washington); minor (NW Oregon)
Aug. 1961	Albany, Oregon	4.5	Damage: minor (Albany)
Nov. 1962	Portland area, Oregon	5.5	Shaking up to 30 seconds. Damage: chimneys cracked; windows broken; furniture moved.
Mar. 1963	Salem, Oregon	4.6	Damage: minor (Salem)
Mar. 1993	Scotts Mills, Oregon	5.6	FEMA-985-DR-Oregon; center: Mt. Angel-Gales Creek fault. Damage: $30 million (including Oregon State Capitol in Salem)
Feb. 2001	Nisqually, Washington	6.8	Felt in the region. Damage: none reported
Jul. 4, 2015	East of Springfield, OR	4.0	

Sources: 2020 Oregon NHMP, Wong and Bolt (1995)
*BCE: Before Common Era.

Future Climate Variability

Future climate variability does not affect the community's earthquake risk.

Probability Assessment

Based on the historical seismicity in western Oregon and on analogies to other geologically similar areas, small to moderate earthquakes up to magnitude 5.0 or 5.5 are possible almost any place in western Oregon, including almost any place in Marion County, including Salem. Such earthquakes would mostly be much smaller than the 1993 Scotts Mills earthquake, which had a magnitude 5.7. The possibility of larger crustal earthquakes in the magnitude 6.0 or greater cannot be ruled out. However, the probability of such events is likely to be very low. For more information see DOGAMI reports linked above.

Because the probability of large crustal earthquakes (magnitude 6.0 or greater) affecting Salem is low and because any damage in smaller crustal earthquakes is likely to be minor and very localized, crustal earthquakes are not considered significant for hazard mitigation planning purposes. Therefore, our analysis focuses on the larger, much more damaging earthquakes arising from the CSZ.

The 2020 Oregon NHMP Risk Assessment for Region 3 concluded that the probability of damaging earthquakes varies widely across the state. In Region 3, the hazard is dominated by Cascadia subduction earthquakes originating from a single fault with a well-understood recurrence history. DOGAMI has developed a new probability ranking for Oregon counties that is based on the average probability of experiencing damaging shaking during the next 100 years, modified in some cases by the presence of newly discovered lidar faults. In this ranking Marion and Polk County, which Salem resides, is estimated to have a 32-45% chance of experiencing damaging shaking during the next 100 year.

According to the 2020 Oregon NHMP, the return period for the largest of the CSZ earthquakes (magnitude 9.0 or greater) is 530 years with the last CSZ event occurring 314 years ago in January of 1700. The probability of a magnitude 9.0 or greater CSZ event occurring in the next 50 years ranges from 7 - 12%. Notably, an additional 10 - 20 smaller, magnitude 8.3 - 8.5, earthquakes occurred over the past 10,000 years that primarily affected the southern half of Oregon and northern California. The average return period for these events is roughly 240 years. The combined probability of any CSZ earthquake occurring in the next 50 years is 37 - 43%.

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing an earthquake is "high,"** meaning one incident is likely within the next 35-year period.

Vulnerability Assessment

The effects of earthquakes span a large area. The degree to which earthquakes are felt, however, and the damages associated with them may vary. Earthquake damage occurs because humans have built structures that cannot withstand severe shaking. Buildings, airports, schools, and lifelines (highways, phone lines, gas, water, etc.) suffer damage in earthquakes and can ultimately result in death or injury to humans.

Based on the combination of local faults in the region, Salem's proximity to the CSZ, potential slope instability, and prevalence of certain soils subject to liquefaction and amplification give the city a high-risk profile. Due to the expected pattern of damage resulting from a CSZ event, *The Oregon Resilience Plan* (2013) divides the State into four distinct zones and places Salem predominately within the "Willamette Valley Zone" (Valley Zone, from the summit of the Coast Range to the summit of the Cascades). Within the Valley Zone damage and shaking is expected to be widespread but moderate, an event will be disruptive to daily life and commerce, and the main priority is expected to be restoring services to business and residents.

Death and Injury

Earthquakes in the past caused no injuries regarding the health and safety of residents. However, the potential for injuries or deaths from past events or from similar events in other communities could escalate resulting in multiple deaths and major injuries. Death and injury can occur both inside and outside of buildings due to falling equipment, furniture, debris, and structural materials. Likewise, downed power lines or broken water and gas lines endanger human life. Death and injury are highest in the afternoon when damage occurs to commercial and residential buildings and during the evening hours in residential settings (LeDuc et al, 2000). It is estimated that 50-75% of the city's population would be physically displaced by an earthquake, accounting for the number of homes that would be damaged from seismic activity, and there would be extensive impact on community social networks.

Building Damage

Wood structures tend to withstand earthquakes better than structures made of brick or unreinforced masonry buildings (Wolfe et al., 1986). Building construction and design play a vital role in the survival of a structure during earthquakes. Damage can be quite severe if structures are not designed with seismic reinforcements or if structures are located atop soils that liquefy or amplify shaking. Whole buildings can collapse or be displaced. Most facilities throughout the city anticipate extensive damage due to an earthquake, estimated at more than $1 billion for hazard response, structural repairs and equipment replacement.

The DOGAMI *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022) indicates that during a Mt. Angel Mw-6.8 deterministic[3] scenario, there is the potential to have 2,682 (4.2% population) displaced residents, 4,171 damaged buildings, 6 of which are critical facilities. The loss estimate is $ 1,176,844,018 (loss ratio of 8.7%).

Bridge Damage

Earthquake damage to roads and bridges can be particularly serious by hampering or cutting off the movement of people and goods and disrupting the provision of emergency response services. All bridges can sustain damage during earthquakes, leaving them unsafe for use. More rarely, some bridges have failed completely due to strong ground motion. Bridges are a vital transportation link – damage to them can make some areas inaccessible.

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[3] A deterministic scenario is based on a specific seismic event, such as a Cascadia Subduction Zone magnitude (Mw)-9.0 event. DOGAMI used the deterministic scenario method for this study along with the user-defined facility (UDF) database so that loss estimates could be calculated on a building-by-building basis. The Mt. Angel Fault deterministic scenario was selected as the most appropriate for communicating earthquake risk for Marion County (Williams & Madin, 2022).

Because bridges vary in size, materials, siting, and design, earthquakes will affect each bridge differently. Bridges built before the mid 1970's often do not have proper seismic reinforcements. These bridges have a significantly higher risk of suffering structural damage during a moderate to large earthquake. Bridges built in the 1980’s and after are more likely to have the structural components necessary to withstand a large earthquake (LeDuc et al., 2000).

Damage to Lifelines

Lifelines are the connections between communities and critical services. They include water and sewer lines, food suppliers, electricity and gas lines, communications, and transportation systems. Ground shaking and amplification can cause pipes to break open, power lines to fall, roads and railways to crack or move, and radio or telephone communication to cease. Disruption to transportation makes it especially difficult to bring in supplies or services. All lifelines need to be usable after an earthquake to allow for rescue, recovery, and rebuilding efforts and to relay important information to the public (LeDuc et al., 2000).

Disruption of Critical Facilities

Critical facilities, also considered community lifelines, are police stations, fire stations, hospitals, other medical and social services, food and water suppliers, and shelters. These are facilities that provide services to the community and need to be functional after an earthquake event. The earthquake effects outlined above can all cause emergency response to be disrupted after a significant event (Wang & Clark, 1999).

As noted previously, the DOGAMI *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022) indicates that during a Mt. Angel Mw-6.8 deterministic scenario, there is the potential to have 4,171 damaged buildings, 6 of which are critical facilities. The loss estimate is $ 1,176,844,018 (loss ratio of 8.7%).

Economic Loss

Seismic activity can cause great loss to businesses, either a large-scale corporation or a small retail shop. Losses not only result in rebuilding cost, but fragile inventory and equipment can be destroyed. When a company is forced to stop production for just a day, business loss can be tremendous. Residents, businesses, and industry all suffer temporary loss of income when their source of finances is damaged or disrupted. A major earthquake can separate businesses and other employers from their employees, customers, and suppliers thereby further hurting the economy. It is likely more than 75% of businesses located in the city and surrounding area would experience commerce interruption for a period of a year or longer.

Fire

The community energy and communication lifelines, such as power lines, gas lines, and telecommunication facilities can be damaged by an earthquake. Downed power lines or broken gas mains can trigger fires. When fire stations suffer building or lifeline damage, quick response to quench fires is less likely.

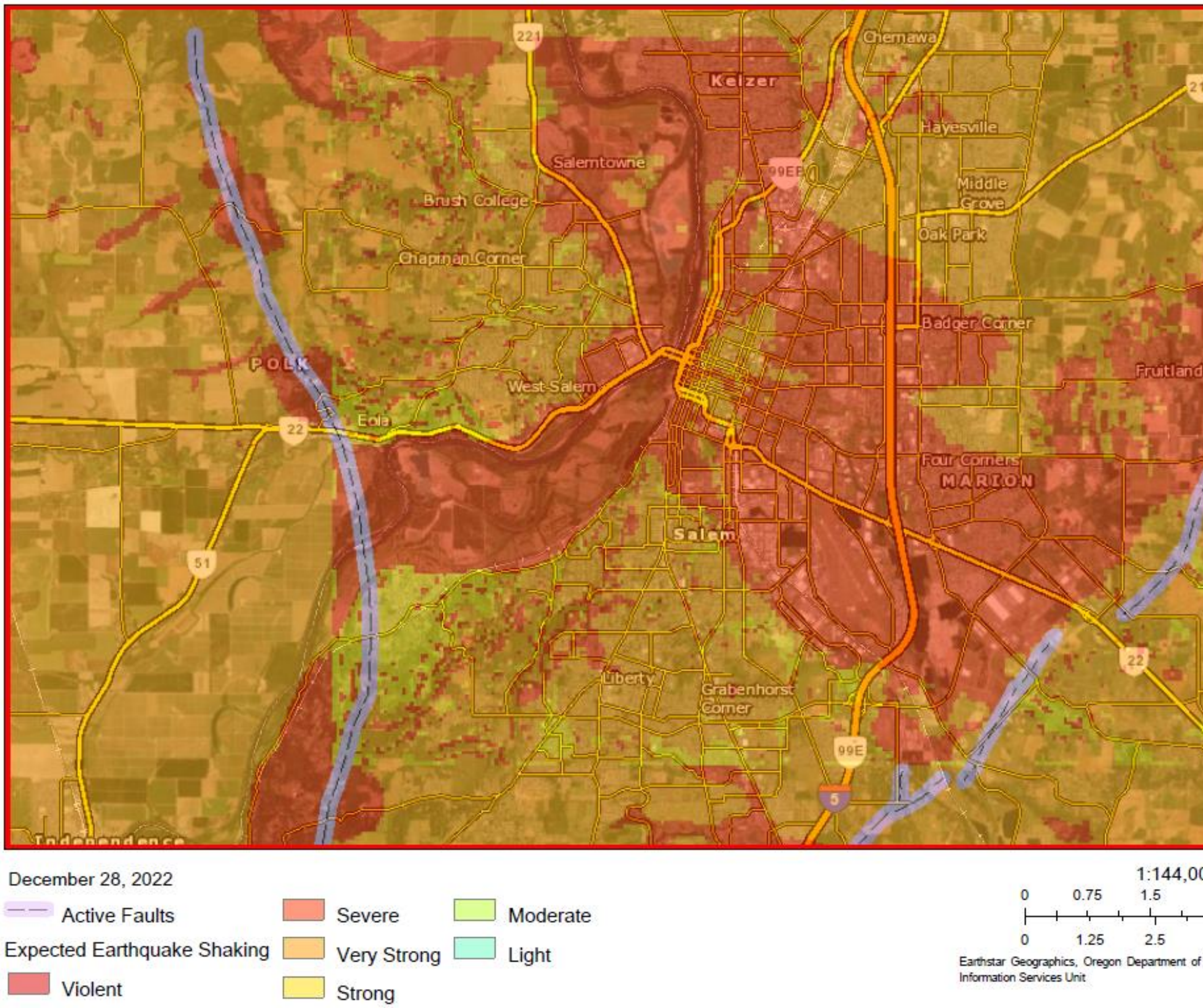
Natural Resources

Earthquakes would likely have extensive impacts on more than 75% of the city's ecological systems, including, clean water, wildlife habitat, and parks.

Debris

After damage occurs to a variety of structures, much time is spent cleaning up brick, glass, wood, steel or concrete building elements, office and home contents, and other materials. Following an earthquake event, the cleanup of debris can be a challenge for the community.

Figure 2-15 Cascadia Subduction Zone Expected Shaking Map of City of Salem



above shows the expected shaking/damage potential for Salem resulting from a CSZ earthquake event. The figure shows that the city will experience "very strong" to "severe shaking" that will last two to four minutes. The strong shaking will be extremely damaging to lifeline transportation routes including Interstate-5. For more information on expected losses due to a CSZ event see *The Oregon Resilience Plan* (2013).

The NHMP Steering Committee rated the city as having a **"high" vulnerability to an earthquake hazard**, meaning that more than 10% of the city's population or assets would be affected by a major earthquake emergency.

2007 Rapid Visual Survey

In 2007, DOGAMI completed a rapid visual screening (RVS) of educational and emergency facilities in communities across Oregon, as directed by the Oregon Legislature in Senate Bill 2 (2005). Rapid Visual Survey is a technique used by FEMA, known as FEMA 154, to identify, inventory, and rank buildings that are potentially vulnerable to seismic events. DOGAMI ranked each building surveyed with a 'low,' 'moderate,' 'high,' or 'very high' potential for collapse in the event of an earthquake. It is important to note that these rankings represent a probability of collapse based on limited observed and analytical data and are therefore approximate rankings. To fully assess a building's potential for collapse, a more detailed engineering study completed by a qualified professional is required, but the RVS study can help to prioritize which buildings to survey.

DOGAMI surveyed 78 buildings in Salem. Buildings with a 'high' or 'very high' potential for collapse are listed in Table 2-6.

Table 2-6 City of Salem Building Collapse Potential

Level of Collapse Potential			
Low (<1%)	Moderate (1-10%)	High (>10%)	Very High (100%)
29	9	33	7

Source: Lewis, D. (2007). *Open-File Report O-07-02 Statewide seismic needs assessment: Implementation of Oregon 2005 Senate Bill 2 relating to public safety, earthquakes, and seismic rehabilitation of public buildings*. Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/p-O-07-02.htm.

Of the facilities evaluated by DOGAMI using RVS, in Salem it included seven schools, seven government buildings and emergency services facilities (including the State Capital, Salem City Hall, and Oregon State Police), and 11 Chemeketa Community College buildings have a high collapse potential. The seven buildings with very high collapse potential are all School District 24-J buildings.

For reference, the DOGAMI *Multi-Hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022) identified the following critical facilities that would experience moderate to complete damage (>50% probability) from a Mt. Angel magnitude 6.8 earthquake. Overall, the potential includes 4.2% of residents displaced and 4,171 buildings damaged, including six critical facilities.

- Bush Elementary School
- Chemawa Indian School
- Englewood Elementary School
- Hammond Elementary School
- Marion County Community Corrections
- Brush College Elementary School

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

USGS National Earthquake Information Center

The USGS National Earthquake Information Center (NEIC) has the following three main missions aimed at efforts to mitigate the risks of earthquakes to mankind.

1. NEIC determines, as rapidly and as accurately as possible, the location and size of all significant earthquakes that occur worldwide. NEIC disseminates this information immediately to concerned national and international agencies, scientists, critical facilities, and the general public.
2. NEIC collects and provides to scientists and to the public an extensive seismic database that serves as a solid foundation for scientific research, principally through the operation of modern digital national and global seismograph networks and through cooperative international agreements. The NEIC is the national data center and archive for earthquake information.
3. NEIC pursues an active research program to improve its ability to locate earthquakes and to understand the earthquake mechanism.

The NEIC operates a 24-hour-a-day service to determine the location and magnitude of significant earthquakes in the United States and around the world as rapidly and accurately as possible. This information is communicated to federal and state government agencies who are responsible for emergency response, to government public information channels, to national and international news media, to scientific groups (including groups planning aftershock studies), and to private citizens who request information. The NEIC issues rapid reports for those earthquakes with magnitudes at least 3.0 in the eastern United States and 3.0 in the western United States.

In addition, the USGS ShakeAlert Earthquake Early Warning System detects earthquakes quickly so alerts can be delivered to people before they feel shaking. ShakeAlert is a warning system for the west coast of the United States and can be directly integrated into healthcare facility communication and control systems, such as intercoms, to warn people and protect patients and staff. ShakeAlert does not predict earthquakes, rather it detects an earthquake moments after it begins, so that alerts can be sent to people in the affected area. Because information travels faster than earthquake waves, alerts can reach people quickly, even before they begin to feel shaking. ShakeAlert can be enabled on most cell phones.

National Earthquake Hazards Reduction Program

The National Earthquake Hazards Reduction Program (NEHRP) leads the federal government's efforts to reduce the fatalities, injuries and property losses caused by earthquakes. The U.S. Congress established NEHRP in 1977, directing four federal agencies, noted below, to coordinate their complementary activities to implement and maintain the program. These agencies are:

- Federal Emergency Management Agency (FEMA)
- National Institute of Standards and Technology (NIST)
- National Science Foundation (NSF)
- U.S. Geological Survey (USGS)

NEHRP also partners with state and local governments, universities, research centers, professional societies and trade associations and businesses.

Federal Emergency Management Agency

FEMA administers several grant programs intended to reduce the risks to people and property posed by earthquakes. Although FEMA's programs are not dedicated exclusively to earthquakes, they can be valuable sources of funding for risk reduction efforts targeting earthquakes or earthquakes and other hazards at state or local levels.

FEMA's National Earthquake Hazards Reduction Program (NEHRP) Earthquake State Assistance Grant Program was created to increase and enhance the effective implementation of earthquake risk reduction at the local level. NEHRP has two separate funding opportunities: Individual State Earthquake Assistance and Multi-State and National Earthquake Assistance funding opportunities, both of which are designed to increase and enhance the effective implementation of earthquake risk reduction at the national, state and local level.

State Resources

Business Oregon, Infrastructure Finance Authority

Business Oregon's Infrastructure Finance Authority supports the Seismic Rehabilitation Grant Program (SRGP). This program is a State of Oregon competitive grant program that provides funding for the seismic rehabilitation of critical public buildings, particularly public schools and emergency services facilities. Public K-12 school districts, community colleges, and education service districts are eligible for the grant program. For emergency services facilities, the emphasis is on first responder buildings. This includes hospital buildings with acute inpatient care facilities, fire stations, police stations, sheriff's offices, 9-1-1 centers, and Emergency Operations Centers (EOCs).

Oregon Statewide Building Code

The Oregon's Building Codes Division adopts statewide standards for building construction that are administered by the state, cities and counties throughout Oregon. The codes apply to new construction and to the alteration of, or addition to, existing structures. Within these standards are six levels of design and engineering specifications that are applied to areas according to the expected degree of ground motion and site conditions that a given area could experience during an earthquake. The Structural Code requires a site-specific seismic hazard report for projects including critical facilities such as hospitals, fire and police stations, emergency response facilities, and special occupancy structures, such as large schools and prisons.

The seismic hazard report required by the Structural Code for essential facilities and special occupancy structures considers factors such as the seismic zone, soil characteristics including amplification and liquefaction potential, any known faults, and potential landslides. The findings of the seismic hazard report must be considered in the design of the building. The Dwelling Code incorporates prescriptive requirements for foundation reinforcement and framing connections based on the applicable seismic zone for the area. The cost of these requirements is rarely more than a small percentage of the overall cost for a new building.

Requirements for existing buildings vary depending on the type and size of the alteration and whether there is a change in the use of the building that is considered more hazardous. Oregon State Building Codes recognize the difficulty of meeting new construction standards in existing buildings and allow some exception to the general seismic standards. Upgrading existing buildings to resist earthquake forces is more expensive than meeting code requirements for new construction. The state code only requires seismic upgrades when there is significant structural alteration to the building or where there is a change in use that puts building occupants and the community at greater risk.

Local building officials are responsible for enforcing these codes. Although there is no statewide building code for substandard structures, local communities have the option of adopting a local building code to mitigate hazards in existing buildings. Oregon Revised Statutes allow municipalities to create local programs to require seismic retrofitting of existing buildings within their communities. The building codes do not regulate public utilities or facilities constructed in public right-of-way, such as bridges.

Oregon Department of Emergency Management

September is National Preparedness Month, a time to raise awareness about preparing for disasters and emergencies before they happen. In addition, The Great Oregon ShakeOut occurs in October. OEM coordinates activities such as earthquake drills related to Great Oregon ShakeOut and encourages individuals to prepare for earthquakes by strapping down computers, heavy furniture and bookshelves in homes and offices.

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to coastal hazards, floods, and other natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of natural hazards including the Hazard Mitigation Grant Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, OEM notifies local public safety agencies and keeps them informed of potential and actual hazard events so prevention and mitigation actions can be taken.

Local Resources

City of Salem

An individual's level of preparedness for an earthquake is minimal as perception and awareness of earthquakes are low. To help community members, Salem's Emergencies & Disaster Preparedness website provides resources that will aid in individual's preparing for a natural hazard event, including earthquakes. Strapping down heavy furniture, water heaters and expensive personal property as well as having earthquake insurance, is a step towards earthquake mitigation.

Salem-Keizer Public Schools

Salem-Keizer Public Schools conduct earthquake drills regularly throughout Oregon and teach students how to respond when an earthquake event occurs.

The Salem and City of Keizer voters approved a 2018 bond measure that, in part, approved improvements safety and security in the Salem-Keizer School District. Included in this bond measure included:

Seismic Renovations - $67M

- Address areas rated very high-risk for earthquake collapse
- Design additions constructed under the bond to re-occupancy standard, which means the structure could be used as a community shelter

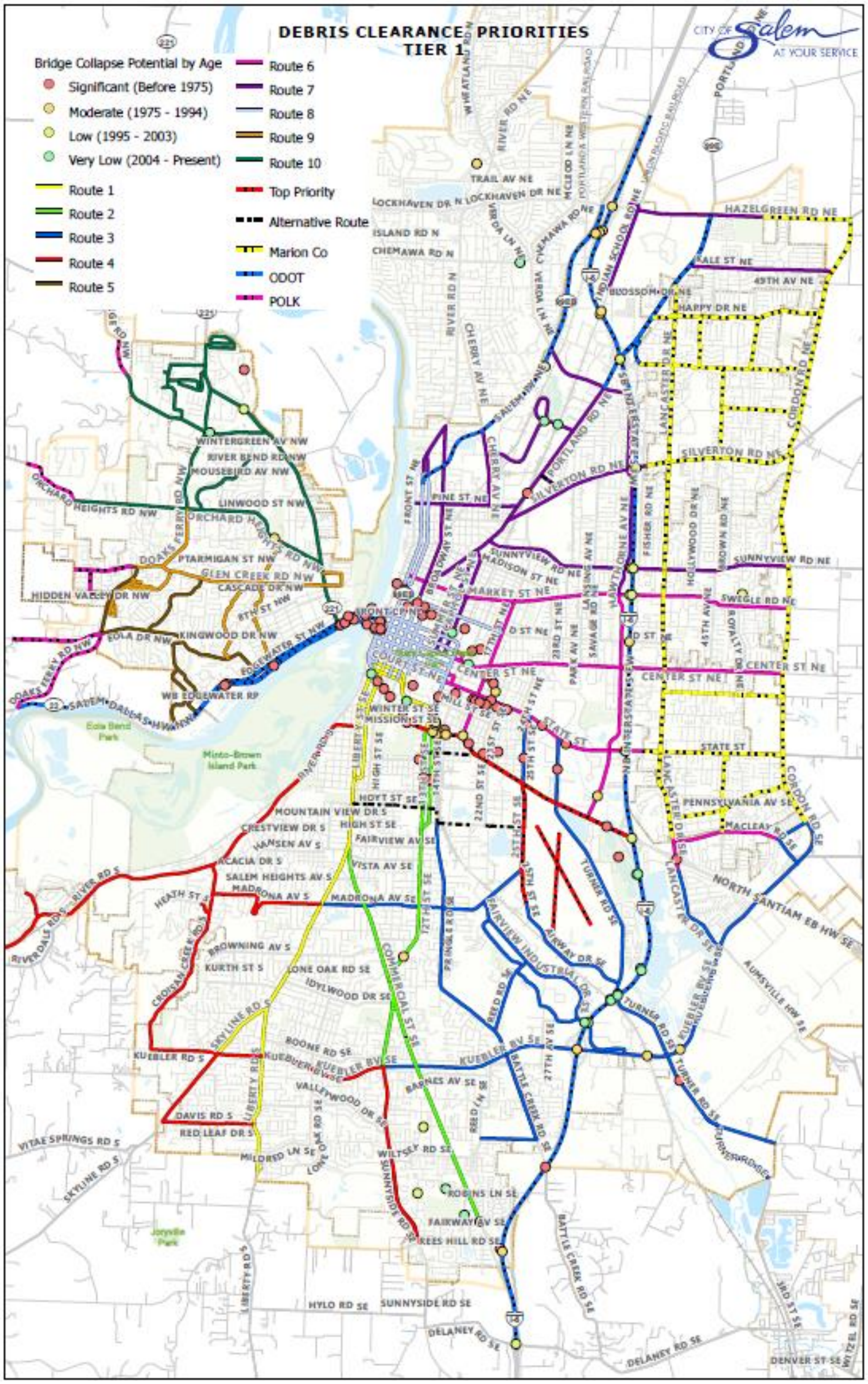
The school district's bond implementation plan notes that 24 school district buildings have received seismic upgrades since the 2018 bond was approved. For more information, the Salem-Keizer Public Schools Bond Project website provides a construction and improvement overview by year and school.

As noted in the *2017 Salem NHMP*, seismic retrofit grant awards per Oregon's Seismic Rehabilitation Grant Program were funded to retrofit these Salem-Keizer Public Schools: Richmond Elementary and Four Corner Elementary.

Salem Public Works – Transportation Routes

Since the 2017 Salem NHMP, the city has identified and designated priority transportation routes through a 2020 amendment to their Transportation System Plan. In addition, a bridge prioritization inventory based on major lifeline routes including state highways, routes, and major road arteries was also established. Salem's priorities focus on routes between Interstate I-5, Salem Health Hospital, and Salem Municipal Airport. The following map shows priority routes and bridge locations. Salem prioritizes improvement needs based on sufficiency rating (an overall score assigned to each bridge during their routine inspections – every 2 years) as well as average daily trip calculations.

Figure 2-22 Salem Disaster Priority Routes and Bridge Locations



Source: City of Salem Public Works

Extreme Heat

Significant Changes Since Previous Plan:

The Extreme Heat Hazard section was reformatted and expanded with additional information since the previous plan.

Causes and Characteristics

North American summers are hot; most summers see heat waves in one or more parts of the United States. East of the Rockies, they tend to combine both high temperature and high humidity; although some of the worst heat waves have been catastrophically dry, according to NOAA's *Heat Wave: A Major Summer Killer*.

Climate conditions in the Willamette Valley, which Salem is located, are described as Mediterranean, with rainy winters and warm dry summers. Extreme temperatures aren't as common in western Oregon compared to other parts of the state. However, the Willamette Valley experiences days above 90°F nearly every year. The frequency of prolonged periods of high temperatures is expected to increase.

The definition of extreme heat varies by region; however, in general a heat wave is a prolonged period of extreme heat for several days to several weeks. High temperatures are also often combined with excessive humidity, according to FEMA's *Are You Ready? 2.6 Extreme Heat*. Heat is considered the silent killer, affecting the lives and health of people across the country. According to the Centers for Disease Control and Prevention, an average of 702 heat-related deaths occur each year in the U.S (NOAA, Excessive heat, a 'silent killer', 2014). Heat is the number one weather-related killer in the United States, resulting in hundreds of fatalities each year. In fact, on average, excessive heat claims more lives each year than floods, lightning, tornadoes and hurricanes combined (NOAA, *Heat Wave: A Major Summer Killer*).

According to NOAA's Heat Index, heat waves form when high pressure aloft (approximately 10,000 to 25,000 feet above the earth surface), strengthens and remains over a region for several days up to several weeks. This is common in summer. Weather patterns in the summer are slower to change, generally, compared to winter, and thus the mid-level high pressure also moves slowly. Under high pressure, the air subsides or sinks toward the earth surface. This sinking air acts as a dome capping the atmosphere. This cap then traps heat instead of allowing it to lift, which doesn't allow for much convection. The result is a continual build-up of heat at the earther's surface.

Location and Extent

The most severe impact of extreme heat affects peoples' health directly. Most heat disorders occur because the victim has been overexposed to heat or has over-exercised for his or her age and physical condition. Older adults, young children, and those who are sick or overweight are more likely to succumb to extreme heat (FEMA, *Are You Ready? 2.6 Extreme Heat)*.

According to the FEMA, "[C]onditions that can induce heat-related illnesses include stagnant atmospheric conditions and poor air quality. Consequently, people living in urban areas may be at greater risk from the effects of a prolonged heat wave than those living in rural areas. Also, asphalt and concrete store heat longer and gradually release heat at night, which can produce higher nighttime temperatures known as the "urban heat island effect" (FEMA, *Are You Ready? 2.6 Extreme Heat)*.

With respect to extreme heat, the *Fifth Oregon Climate Assessment* (2021) by OCCRI states,

> The frequency and magnitude of days that are warmer than 90°F is increasing across Oregon. During summer, relative increases in nighttime minimum temperatures have been greater than those in daytime maximum temperatures. The frequency, duration, and intensity of extreme heat events is expected to increase throughout the state during the twenty-first century.

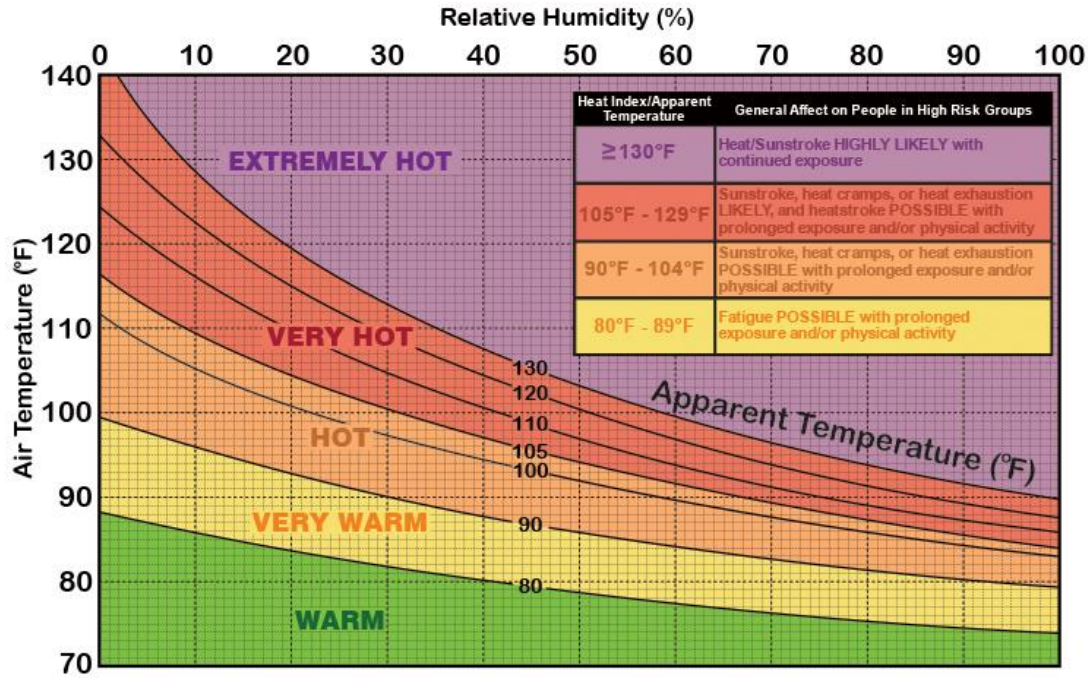
Identifying Excessive Heat

NOAA's heat alert procedures are based mainly on Heat Index Values. The Heat Index, sometimes referred to as the apparent temperature, is given in degrees Fahrenheit. The Heat Index is a measure of how hot it really feels when relative humidity is factored with the actual air temperature.

To find the NOAA Heat Index temperature, look at the Heat Index chart below. These values are for shady locations only. Exposure to full sunshine can increase heat index values by up to 15°F (8°C). Also, strong winds, particularly with very hot, dry air, can be extremely hazardous as the wind adds heat to the body. As an example, if the air temperature is 96°F and the relative humidity is 65%, the heat index--how hot it feels--is 121°F. The National Weather Service will initiate alert procedures when the Heat Index is expected to exceed 105˚-110˚F (depending on local climate) for at least two consecutive days (NOAA, *Heat Wave: A Major Summer Killer)*.

NOAA issues outlooks for excessive heat 8-14 days, as well as 3-7 days in advance and provides hourly forecasts, advisories, watches and warnings when dangerous heat becomes likely or imminent.

Figure 2-23 Heat Index



Source: NOAA. (2023, February 15). *Heat Index*. Retrieved from https://www.noaa.gov/jetstream/global/heat-index.

History

In June 2021, a high-pressure heat dome over the region led to a 3-day stretch of extreme heat from June 26 - 29. Heat advisories were issued across the Pacific Northwest with record highs warming over 100 degrees Fahrenheit with a record-breaking temperature up to 117 degrees recorded in Salem. A total of 123 heat related deaths were reported since many were without air-conditioning and an increase in the number of drownings. Widespread closures and postponements of businesses and events also occurred. Heat continued into August 2021, with temperatures peaking at 105 degrees, according to NOAA Storm Event Database for Oregon. Oregon Governor issued an Emergency Declaration due to forecasted heat across the State affecting 23 counties.

Prior to this event, in July 2009 heat advisories were issued across the Pacific Northwest, with record highs of 107 degrees Fahrenheit in Salem, 106 degrees in Portland and over 100 degrees in Seattle. Extreme heat also affected Salem in June 2015. Additional minor occurrences of extreme heat occur annually. Table 2-7 provides heat and excessive heat events reported from 2017-2022.

In some of these cases, the heat wave lasted several days, which is unusual for the region. Many homes and buildings throughout Northern Oregon and Washington do not have air-conditioning, because temperatures are generally moderate in this region. Cooling centers were open in cities and communities throughout the Pacific Northwest.

Table 2-7 Heat and Excessive Heat Events in Marion and Polk Counties 2017-2022

Zone	Begin Date	Begin Time	Event Type	Deaths
NORTH OREGON CASCADES (ZONE)	5/22/2017	1200	Heat	0
CENTRAL WILLAMETTE VALLEY (ZONE)	8/1/2017	1200	Excessive Heat	0
CENTRAL WILLAMETTE VALLEY (ZONE)	7/18/2018	700	Heat	0
CENTRAL WILLAMETTE VALLEY (ZONE)	8/16/2020	700	Heat	0
CENTRAL WILLAMETTE VALLEY (ZONE)	8/17/2020	800	Heat	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	6/26/2021	1000	Excessive Heat	2
CENTRAL WILLAMETTE VALLEY (ZONE)	6/26/2021	1200	Excessive Heat	16
CENTRAL WILLAMETTE VALLEY (ZONE)	7/29/2021	1400	Heat	0
CENTRAL WILLAMETTE VALLEY (ZONE)	8/11/2021	1400	Excessive Heat	0
NORTH OREGON CASCADES (ZONE)	8/11/2021	1400	Excessive Heat	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	8/11/2021	1400	Excessive Heat	0

Source: NOAA. (n.d.). Storm Event Database. Retrieved October 2022 from, https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=41%2COREGON.

Future Climate Projections

It is extremely likely (>95%) that the frequency and severity of extreme heat events will increase over the next several decades across Oregon due to human-induced climate warming (very high confidence). Extreme temperatures are relatively rare in the region but are projected to increase under future climate change.

As noted previously, in Marion County, the number of extremely hot days (days on which the temperature is 90°F or higher) and the temperature on the hottest day of the year are projected to increase by the 2020s and 2050s under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios. In particular, the number of days per year with temperatures 90°F or higher is projected to increase by an average of 16 days (range 5–27 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario. In addition, the temperature on the hottest day of the year is projected to increase by an average of about 7°F (range 2–10°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

The *Salem Climate Action Plan 2021*, includes numerous strategies to address a variety of climate-related challenges facing the city including heat and extreme heat. The plan acknowledges significant projected climate impacts including the following:

- The number of days with a heat index over 90°F will increase from a historic average of 7 per year to 33 per year by mid-century.
- Hotter and drier conditions are likely to cause more frequent droughts.

Probability Assessment

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing an extreme heat event is "high,"** meaning one incident is likely within the next 35-year period

Vulnerability Assessment

Extreme heat requires the body to work extra hard to maintain a normal temperature, which can lead to death. Extreme heat is responsible for the highest number of annual deaths among all weather-related hazards. Older adults, children and sick or overweight individuals are at greater risk from extreme heat, according to FEMA.

Extreme heat events in the past caused few minor injuries to the health and safety of Salem residents. However, the potential for injuries or deaths from past events or from similar events in other communities could escalate resulting in multiple major injuries or possible death. During the June 2021 extreme heat event, a total of 123 heat related deaths in the Pacific Northwest were reported since many were without air-conditioning and an increase in the number of drownings, when residents sought relieve in bodies of water. Widespread closures and postponements of businesses and events also occurred. It is estimated that approximately 10% of the city's population would be physically displaced by an extreme heat, likely accounting for those individuals who seek refuge in a cooling center, and there would be mild impact on community social networks.

According to the Agency for Toxic Substances and Disease Registry (in collaboration with the Center for Disease Control and Prevention) 2020 Social Vulnerability Index (SVI), social vulnerability in the region is highest in Marion County, followed by Linn and Yamhill Counties. Polk County, which includes the western area of Salem, has a low-medium SVI. Marion County ranks in about the 90th percentile for its share of persons aged 17 or younger, percentage of single-parent households, and percentage of occupied housing units with more people than rooms. The county is also the 90th percentile for its share of residents that speak English less than "well."

Facilities throughout the city are anticipated to reflect little to no damage due to extreme heat, estimated at less than $1 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely 10-30% of businesses located in the City and surrounding area would experience commerce interruption for a period of at least a few days. Extreme heat has the potential to overload the electric grid and result in widespread power outages. Lastly, extreme heat would likely have mild impacts on 10-25% of the city's ecological systems, including, clean water, wildlife habitat, and parks.

Salem Climate Action Plan 2021

The *Salem Climate Action Plan 2021* outlines the following potential vulnerabilities and consequences of various projected climate changes as it relates to extreme heat events.

Projected Temperature Increases

While higher summer temperatures may lead to health impacts for vulnerable populations, the temperature increase is not projected to be extreme and may be offset by people's ability to naturally acclimate to changing temperatures over time.

- Increased risk of heat-related illnesses to small children, the elderly, people with chronic illnesses, residents living at or near the poverty line, and people who work outside (e.g., farmworkers and construction workers), and people who are unsheltered.
- Increased risk of respiratory problems.
- Salem's population is expected to grow 28% by 2035. Combined with warming temperatures, increases in population mean more people will likely use air conditioning on the warmest days, which may lead to an increased demand for electricity.
- Warming temperatures may allow for new pests to infiltrate the area. New pests may have the ability to negatively impact Salem's ecosystems, for example by harming the Salem's tree canopy and spreading disease.

Projected Precipitation Patterns

Though overall precipitation amounts are expected to remain consistent, increased temperatures noted above will lead to a water deficit.

- Increased risk of drought, especially when combined with warmer temperatures.
- Water use restrictions and food insecurity in periods of drought.

As such, the NHMP Steering Committee rated the city as having a **"high" vulnerability to extreme heat hazards**, meaning that more than 10% of the city's population or property would be affected by a major disaster.

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

Federal Emergency Management Agency

FEMA recommends preparing the home and the person for extreme heat events. For the home, cover windows and/or use window reflectors, weather-strip doors and windows, add insulation to keep the heat out, use an attic ventilator or fan, and install window air conditioners. The Low Income Home Energy Assistance Program through Benefits.gov can assist if someone is unable to afford these energy-related home repairs and weatherization, and cooling costs. It will also be helpful to identify cooling centers in the community if air conditioning is unavailable elsewhere. To be safe during an event, FEMA recommends not leaving people or pets in a closed car; take cool showers or baths; use the cook oven less; wear lose, lightweight and light-colored clothing; drink plenty of fluids; avoid high-energy activities or working outdoors; and wear a hat and seek shade if outside. Furthermore, know the signs of heat-related illnesses and ways to respond. (https://www.ready.gov/heat)

National Oceanic and Atmospheric Administration

As part of the interagency National Integrated Heat Health Information System, NOAA launched Heat.gov in 2022, which is a website that provides clear, timely, and science-based information to understand and reduce the health risks of extreme heat. Heat.gov is intended for the public, decision-makers, and news media. This website provides real time updates regarding the percentage of the country is under extreme heat advisories, watches, and warnings. The information provided on the website includes heat forecasts from NOAA's National Weather Service, Department of Health and Human Services monthly Climate and Health Outlook, and CDC's Heat and Health Tracker.

Regarding heat monitoring and forecasting, NOAA issues outlooks for excessive heat 8-14 days, as well as 3-7 days in advance and provides hourly forecasts, advisories, watches and warnings when dangerous heat becomes likely or imminent.

State Resources

Oregon Health Authority

Heat-related deaths and illness are preventable, yet annually many people succumb to extreme heat. The Oregon Health Authority (OHA) website provides accessible resources for members of the public, local health departments, and other organizations to assist ongoing outreach efforts to those most vulnerable to extreme heat events.

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Local Resources

Salem Climate Action Plan 2021 and Community Greenhouse Gas Inventory

Salem is taking action to respond to climate change with a *Salem Climate Action Plan 2021* that outlines strategies and actions to reduce Greenhouse Gas emissions and increase climate resiliency in our community. Through the development of the CAP, it was determined that Salem's projected climate impacts will include three main categories: warming temperatures, changes in precipitation patterns, and increased risk of wildfires. Many of the strategies in the CAP are designed to help the community adapt to impacts and build resiliency for the future. The strategies seek to do the following:

- Expand the urban tree canopy and access to green spaces
- Create a climate related education and outreach program
- Create a network of indoor gathering places that can serve as community centers during times of need
- Engage underserved populations in co-creating resilient solutions
- Strengthen the local economy

Flood

> **Significant Changes Since Previous Plan:**
>
> The Flood Hazard section was reformatted and expanded with additional information since the previous plan.

Causes and Characteristics

Flooding results when climate or weather patterns (e.g., rain and snowmelt) combined with geology and hydrology creating water flows that exceed the carrying capacity of rivers, streams, channels, ditches, and other watercourses. These factors, combined with ongoing development can create seasonal flooding conditions. In Oregon, flooding is most common from October through April when storms from the Pacific Ocean bring intense rainfall. Most of Oregon's destructive natural disasters have been floods (Taylor & Hannan, 1999). According to the Salem *Floodplain Management Plan* (2018), Salem receives approximately 38 inches of rain on average each year.

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. Statewide, the most damaging floods have occurred during the winter months, when warm rains from tropical latitudes melt mountain snowpacks. Somewhat lesser flooding has been associated with ice jams, normal spring run-off, and summer thunderstorms. Heavily vegetated stream banks, low stream gradients, and breeched dikes have contributed to past flooding at considerable economic cost.

Types of Floods

The principal types of floods that occur in Salem include riverine floods, shallow area floods, and urban floods.

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.

As noted in the Salem *Floodplain Management Plan* (2018), the City of Salem features the Willamette River, smaller tributaries, and streams that are susceptible to annual flooding events that pose threats to life and safety and cause significant property damage. The streams include Battle Creek, Cinnamon Creek, Claggett Creek, Clark Creek, Croisan Creek, Davidson Creek, Gibson Creek, Glenn Creek, Golf Creek, Jory Creek, Laurel Creek, Little Pudding, Mill Creek, Mill Race, Pettijohn Creek, Powell Creek, Pringle Creek, Scotch Creek, Shelton Ditch, Waln Creek, and Winslow Creek. Salem's flood events often occur when warm weather and heavy rains melt snow at higher elevations which flood local streams.

Shallow Area Floods

These floods are a special type of riverine flooding. FEMA defines a shallow area flood hazard as an area that is inundated by a 100-year flood with a flood depth between one to three feet. Such areas are generally flooded by low velocity sheet flows of water.

Urban Floods

Urban floods occur when there is an inundation of land in a built environment, particularly in densely populated areas. It happens when rainfall overwhelms the capacity of drainage systems. According to the Center for Neighborhood Technology's *The Prevalence and Cost of Urban Flooding* (2014), although sometimes triggered by events such as flash flooding or snowmelt, urban flooding is a condition, characterized by its repetitive and systemic impacts on communities, which can happen regardless of whether the affected community is located within designated floodplains or near any body of water.

Other Flood Hazards

Flood is one of the identified climate change metrics in OCCRI's analysis that is included in the 2020 Oregon NHMP for the Mid/Southern Willamette Valley (Region 3). Region 3 includes Linn, Lane (non-coastal), Marion, Polk, and Yamhill Counties.

Furthermore, flooding and landslides are projected to occur more frequently throughout western Oregon. According to the 2020 Oregon NHMP for Region 3, it is very likely (>90%) that Oregon will experience an increase in the frequency of extreme precipitation events and extreme river flows (high confidence) that is more likely (>50%) to lead to an increase in the incidence and magnitude of damaging floods (low confidence). Because landslide risk depends on a variety of site-specific factors, it is more likely (>50%) that climate change, through increasing frequency of extreme precipitation events, will result in increased frequency of landslides.

The Salem *Floodplain Management Plan* (2018) identifies levees and dams as other flood hazards. Dam failure, together with High Hazard Potential Dams (HHPD) that could impact Salem, is addressed below in the Dam Failure section of the Flood Hazard. Otherwise, the *Floodplain Management Plan* (2018) states the following about levees,

> **Inventory of Levees**
>
> The Keizer River Wall protects the City of Keizer from Willamette River flooding. This wall was inspected by the US Army Corps of Engineers in 2010, as described in an inspection report titled *Keizer River Wall, Flood Damage Reduction Project, Periodic Inspection No. 1.* Because this flood wall is located sufficiently downstream of Salem to prevent backwater effects, this flood protection measure does not appear to affect the flood hazards within the city limits of Salem.
>
> The FIS describes that an earthen berm protects the Sun Retirement Center along West Fork Pringle Creek at 12th Street SE. This berm appears to restrict localized flooding for one property along 12th Street Cutoff SE.

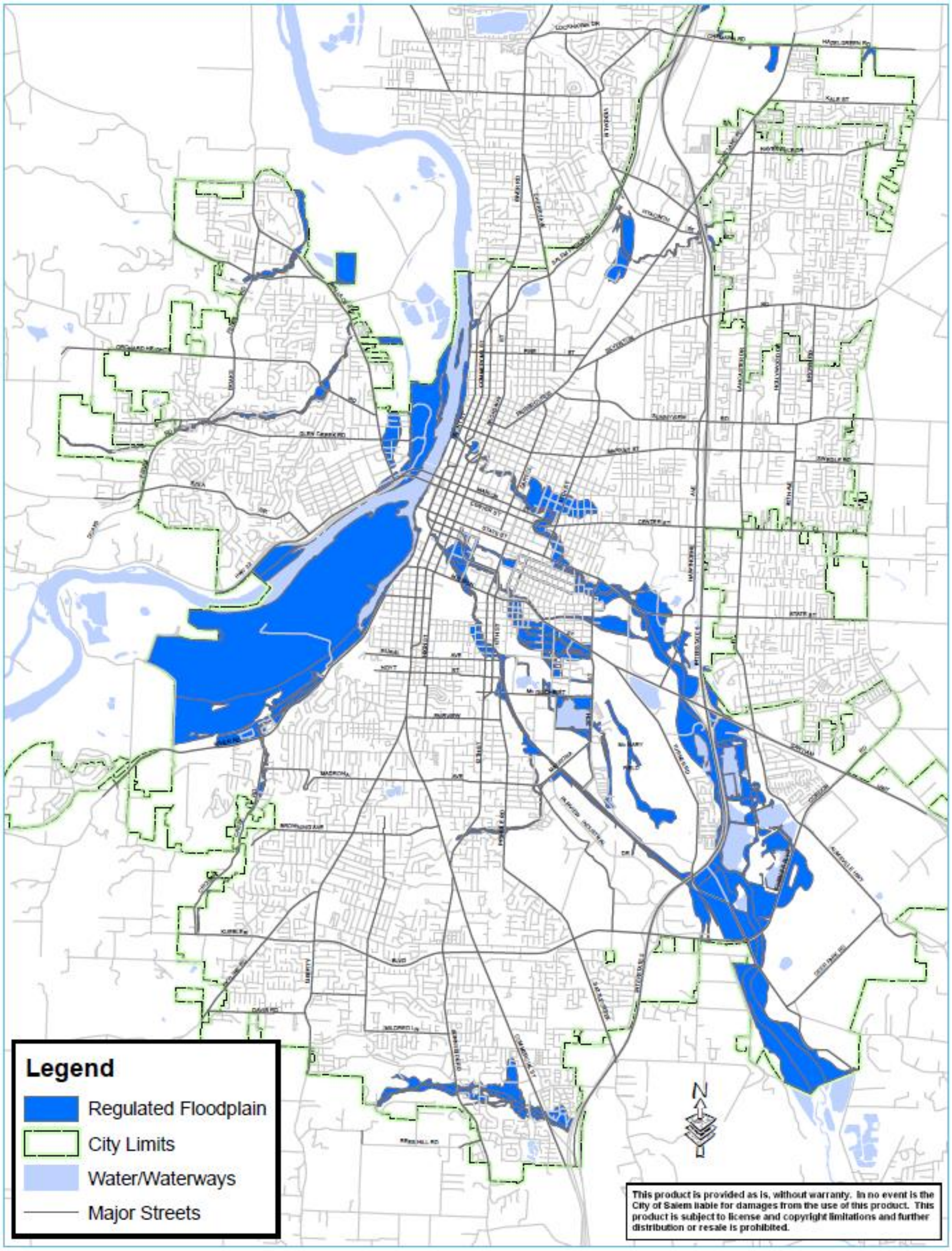
Location and Extent

Floods are described in terms of their extent (including the horizontal area affected and the vertical depth of floodwaters) and the related probability of occurrence. Flood studies often use historical records, such as streamflow gages, to determine the probability of occurrence for floods of different magnitudes. The probability of occurrence is expressed in percentages as the chance of a flood of a specific extent occurring in any given year.

The magnitude of flood used as the standard for floodplain management in the United States is a flood having a probability of occurrence of 1 percent in any given year. This flood is also known as the 100-year flood or base flood. The most readily available source of information regarding the 100-year flood is the system of Flood Insurance Rate Maps (FIRM) prepared by FEMA. These maps are used to support the National Flood Insurance Program (NFIP). The FIRMs show 100-year floodplain boundaries for identified flood hazards. These areas are also referred to as Special Flood Hazard Areas (SFHAs) and are the basis for flood insurance and floodplain management requirements.

According to the Salem *Floodplain Management Plan* (2018), the city has more than 4,000 acres of floodplain and approximately 3,000 individual parcels that are partially or entirely located within the floodplain. The most significant of the FEMA-determined floodplains and floodways either surround the southern side of the Willamette River west of Salem or are within the greater Mill Creek/Pringle Creek watershed.

Properties in and near the floodplains in the City of Salem are subject to frequent flooding events. Since flooding is such a pervasive problem throughout the city, many residents have purchased flood insurance to help recover from losses incurred from flooding events.


Legend
Regulated Floodplain
City Limits
Water/Waterways
Major Streets
N
This product is provided as is, without warranty. In no event is the City of Salem liable for damages from the use of this product. This product is subject to license and copyright limitations and further distribution or resale is prohibited.

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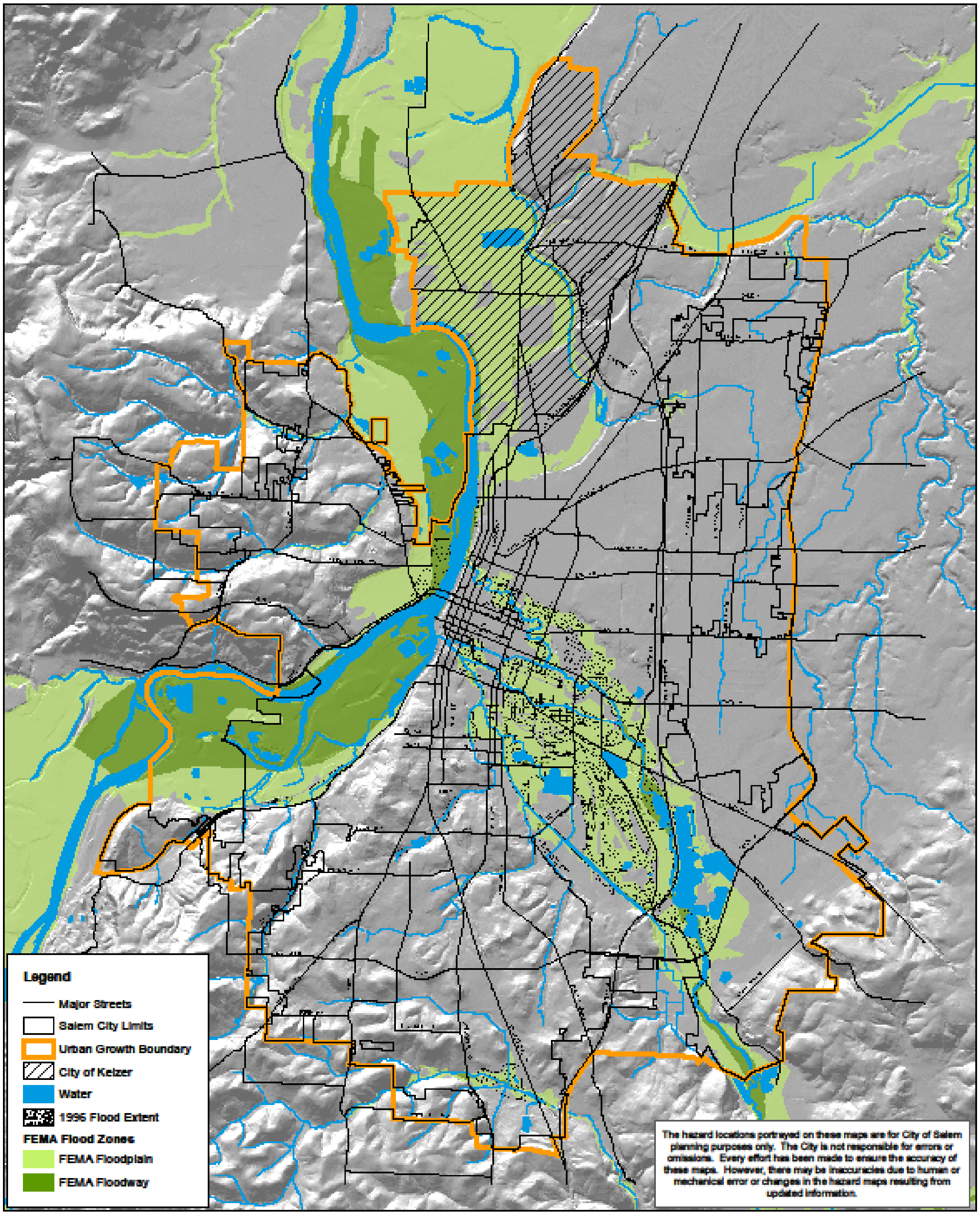
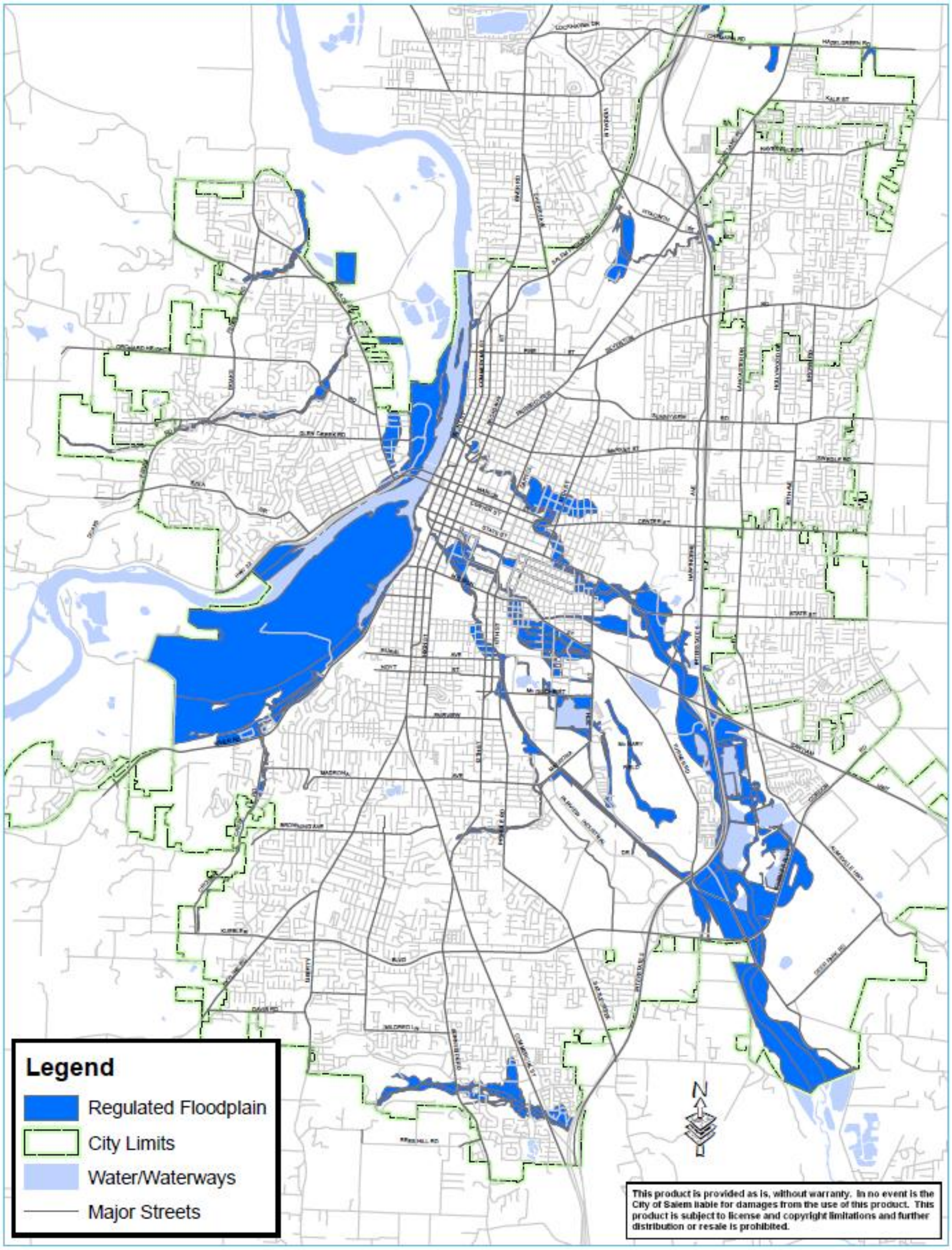


illustrate the regulate floodplain and special flood hazard areas.

Monitoring stream levels and rainfall in near real-time, which is done from several sites across Salem and throughout the Mill Creek Watershed. The Willamette River has a river gauge is located at the base of the Center Street Bridge and can be electronically read on the National Weather Service website. Similarly, the gauges are also on Mill Creek, Battle Creek, Clark Creek, Waln Creek, Pringle Creek, Shelton Ditch, and Glenn Creek. The electronic read provides for seven days of actual river or stream depth and flow history and seven days of future forecast as reported by the National Weather Service. The gauges also have the action stage, flood stage, moderate flood stage, and major flood stage on the chart so an individual can see immediately where the river is in reference to potential flooding. This gauge provides the city with up-to-date river levels that it can use to determine the immediate impact to the community. Using the seven-day forecast portion of the gauge provides the city the opportunity to plan for future impacts that flooding may have on specific portions of the city depending on river flood stages and city elevations.

Figure 2-24 Salem Regulated Floodplain



Source: City of Salem. (2018, April). *Floodplain Management Plan*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/1228/637789751589700000.

Dam Failure

The Oregon Water Resources Department is the state authority for dam safety with specific authorizing laws and implementing regulations. Oregon's dam safety laws were rewritten by HB 2085 which passed through the legislature and was signed by Governor Brown in 2019. This law became operative on July 1, 2020.

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

The OWRD has been striving to inspect the over 900 dams under its jurisdiction with recommendations sent to dam owners. At times, urgent dam safety notices are needed, and for uncooperative dam owners' failure to maintain the dam may lead to an administrative hearing and formal order. The program meets the minimum FEMA standard for Emergency Action Plans and sometimes exceeds FEMA guidance for dam safety inspections on schedule and for condition classification.

Causes and Characteristics of Dam Failure

Oregon's statutory size threshold for dams to be regulated by OWRD is at least 10 feet high and storing at least 3 million gallons. An additional 12,000 or so dams that fall below that threshold have water right permits for storage from OWRD. As of December 2019, there were 945 state-regulated dams and another 252 federally regulated dams that met Oregon's statutory size threshold for regulation by OWRD. The largest dams are under federal ownership or regulation.

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

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

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

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

Most of the largest dams, especially those owned or regulated by the Federal Government are designed to safely withstand these events and have been analyzed to confirm such design.

However, there are several dams where observations, and sometimes analysis indicates a deficiency that may make those dams susceptible to one or more of the events. Most of the state regulated dams do not have a current risk assessment or analysis, and safe performance in these events is uncertain.

Failures of some dams can result in loss of life, damage to property, infrastructure, and the natural environment. The impacts of dam failures range from local impacts to the dam owner's property and waters below the dam to community destruction with mass fatalities. The 1889 Johnston Flood in Pennsylvania was caused by a dam failure and resulted in over 2000 lives lost. Oregon's first dam safety laws were developed in response to the St. Francis dam failure in California in 1928. That failure was attributed to unsafe design practice, and because of this about 500 persons perished. In modern times (2006) a dam owner filled in the spillway of a dam on the island of Kauai causing dam failure that killed 7 people. This dam had no recent dam safety inspections because the hazard rating was incorrect.

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

According to the 2020 Oregon NHMP, the state has records of at least 55 dam failures in the State. Many of these failures had very little or no impacts on people, structures, or properties. Of these, 21 dams had more serious to tragic effects (Table 2-53, 2020 Oregon NHMP) and included 16 east of the Cascade Range, 3 in southern and coastal Oregon (Jackson and Coos County), and 2 in the Willamette Valley region (Linn County and Marion County).

Regarding dam hazard ratings, Oregon's new dam safety laws were developed considering the joint Association of State Dam Safety Officials and FEMA's Model State Dam Safety Program. Oregon follows national guidance for assigning hazard ratings to dams and for the contents of EAPs, which are now required for all dams rated as "high hazard." Each dam is rated according to the anticipated impacts of its potential failure. The state has adopted these definitions (ORS 540.443–491) for state-regulated dams:

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

OWRD conducts hazard rating reviews as its limited resources permit. Correction of hazard ratings is the Dam Safety Program priority; therefore, hazard ratings can and do change.

Ratings may change for several reasons. For example, a dam's original rating may not have been based on current inundation analysis methodologies, or new development may have changed potential downstream impacts. Since 2013, OWRD has formally reviewed the hazard ratings of over 25 state-regulated dams, resulting in the ratings of about 16 being elevated to high hazard status. Federal agencies conduct similar analyses to determine hazard ratings of federally regulated dams.

Salem Dam Safety Issues

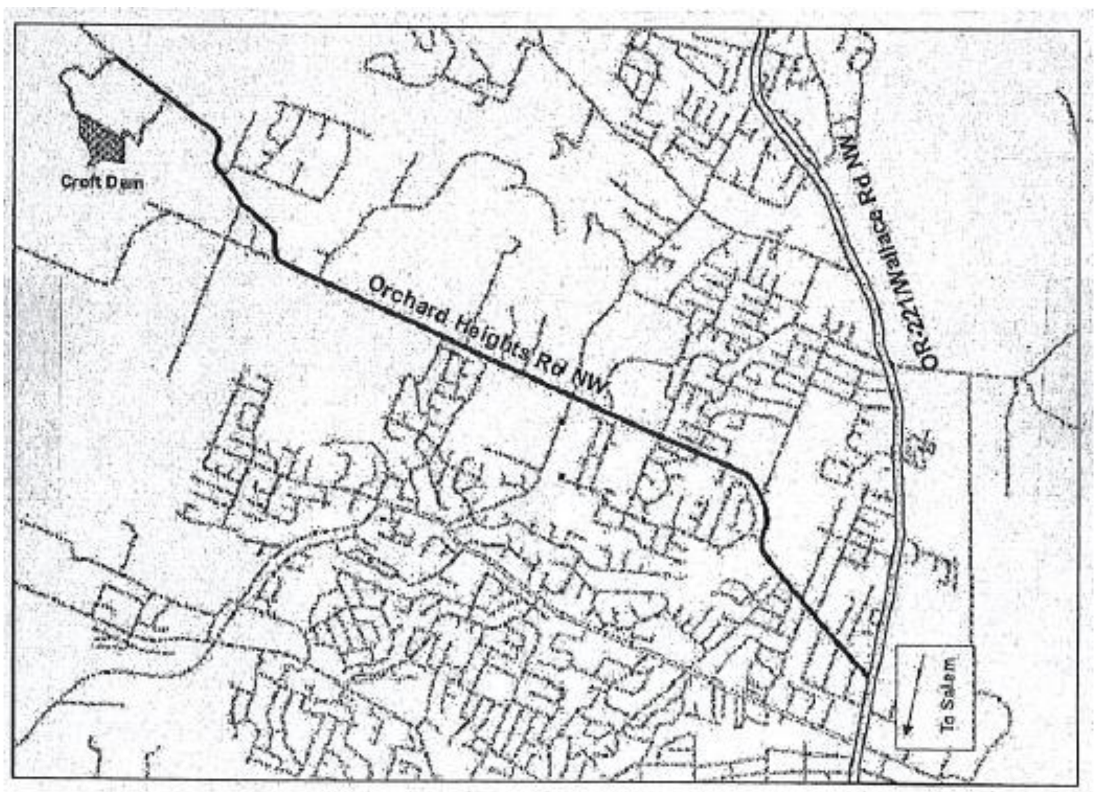
There are two High Hazard Potential Dams – Croft and Franzen – regulated by Oregon that, if they were to fail, could impact to Salem. These two dams, either within or close proximity of city limits, are assigned a hazard rating based on downstream hazard to people and property, not on the condition of the dam. The following is a brief description of the two dams.

Croft Dam

Croft dam is located within city limits, west of the Willamette River in Polk County. Croft Reservoir Dam is approximately 43 feet in height and in satisfactory condition. The OWRD Dam Safety Program has an Emergency Action Plan (EAP) for Croft, which includes an inundation map. According to the Croft EAP, "Croft Dam has been well maintained and it has a high maintenance and construction history."

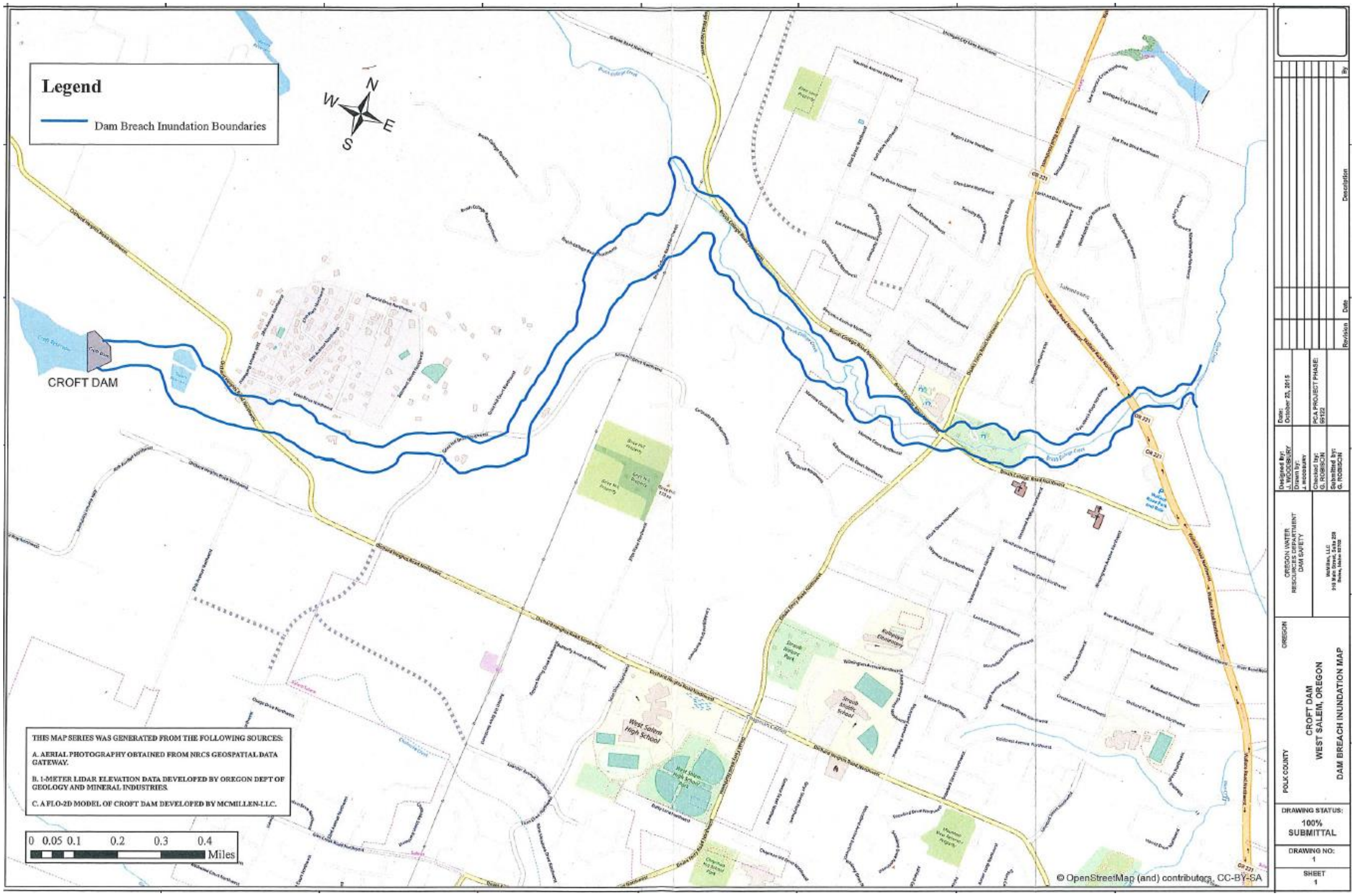
The following includes the Croft dam location and inundation maps.

Figure 2-25 Croft Dam Location



Source: City of Salem. (2018, December 1). *Emergency Action Plan for Croft Reservoir Dam.*

Figure 2-26 Croft Dam Inundation Map



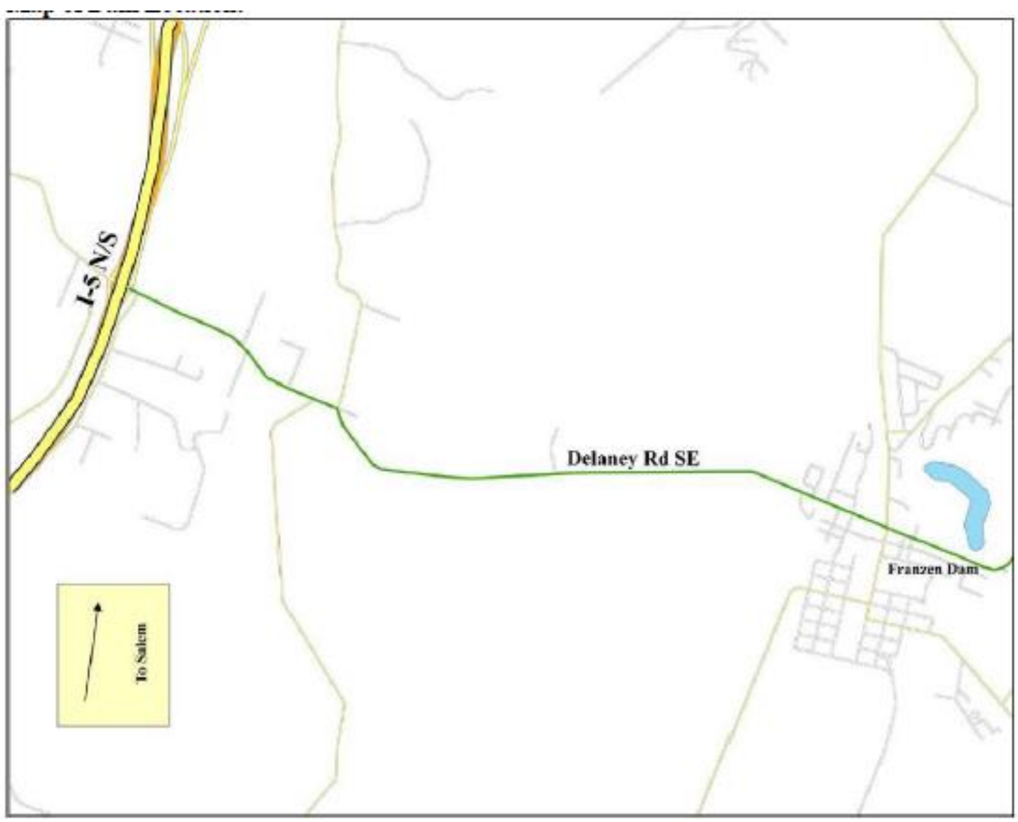
Source: City of Salem. (2018, December 1). *Emergency Action Plan for Croft Reservoir Dam*.

Franzen Dam

Franzen dam is located outside city limits near the City of Turner and is used for water supply. Franzen dam is in satisfactory condition. Although Franzen dam is out the city limits of Salem, and its loss would not inundate within Salem's city limits[4] but would affect or possibly eliminate water supply for Salem. The OWRD Dam Safety Program has an EAP for Franzen, which includes an inundation map.

The following two maps show the Franzen dam location and inundation map.

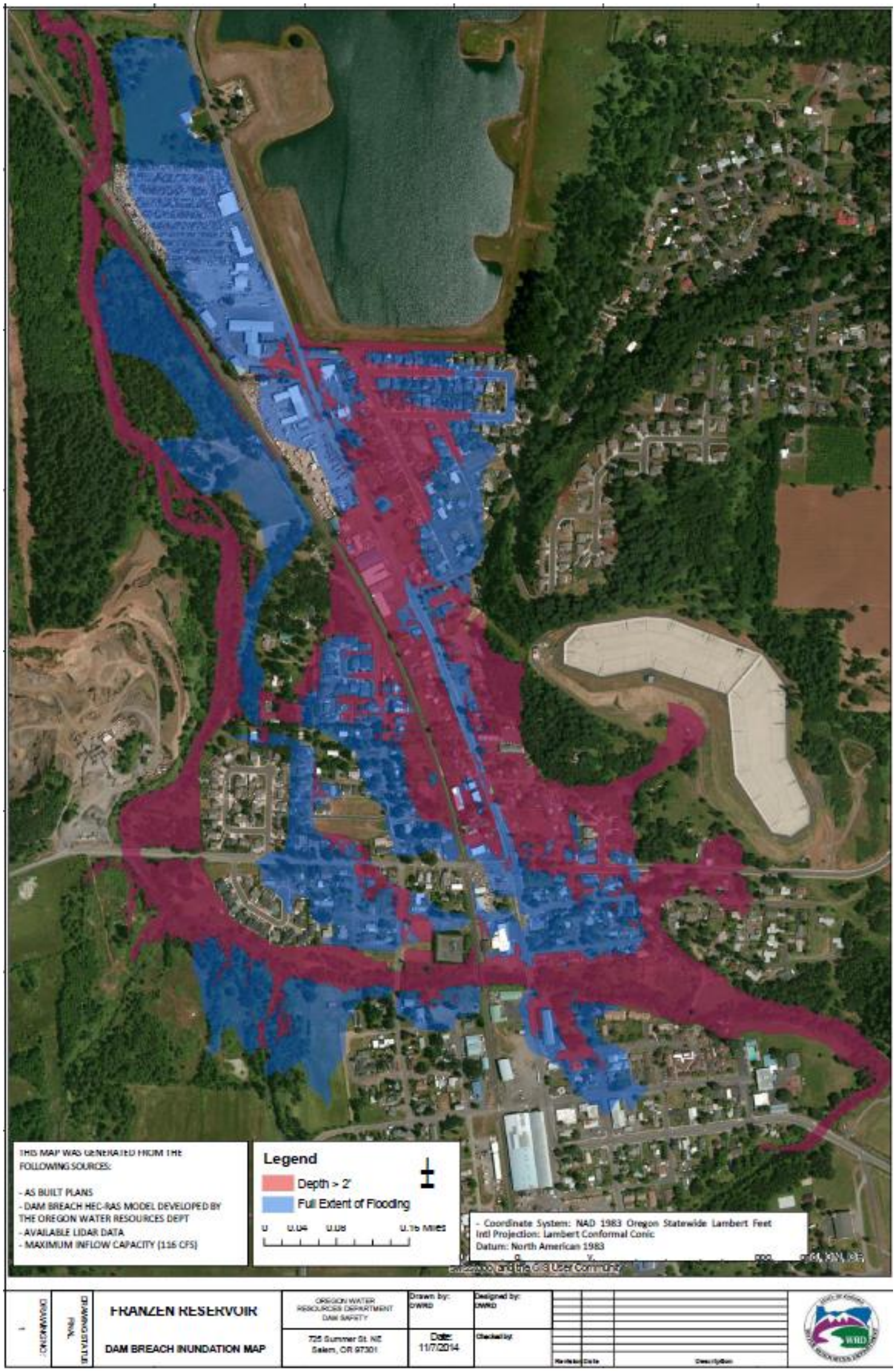
Figure 2-27 Franzen Dam Location



Source: City of Salem. (2019, February 7). *Emergency Action Plan for Franzen Dam*.

[4] According to the Franzen EAP, "Dam failure may inundate numerous areas of subdivisions north of Delaney Road east of Turner Road, and homes between the reservoir and Mill Creek."

Figure 2-28 Franzen Dam Inundation Map



Source: City of Salem. (2019, February 7). *Emergency Action Plan for Franzen Dam*.

The Salem *Floodplain Management Plan* (2018) identifies two other HHPDs that could impact Salem. Big Cliff Dam is federally regulated and produces hydropower. Detroit dam is also a HHPD but is identified in the National Inventory of Dams as being in Linn County. The plan states,

> **Inventory of Dams**
>
> The *Marion County, Oregon, Multi-Jurisdictional Natural Hazard Mitigation Plan* identifies two dams with high hazard potential—Big Cliff Dam and Detroit Dam—that are located on the North Santiam River, which ultimately discharges into the Willamette River upstream of Salem.
>
> > *Dams play a crucial role in power generation and water control mechanisms for the region. Dam failures can occur rapidly and with little warning. Fortunately most failures result in minor damage and pose little or no risk to life safety. However, the potential for severe damage still exists. The Oregon Water and Resources Department has inventoried all dams located across Marion County and Salem. The "hazard level" estimates the amount of damage that could occur in the event of dam failure.*
> >
> > *Marion County has over 56 dams, and two are ranked at a high hazard level: Detroit Dam and Big Cliff Dam. Detroit and Big Cliff are hydroelectric dams that control the flow of water on the Santiam River, providing a major boating and recreational area. However, both dams are considered a major hazard for the large population downstream that would be at risk in the event of a dam failure, including populations in Salem. Besides the Detroit and Big Cliff dams, other major dams surrounding the Salem area include Waconda and Silverton* (Salem Natural Hazard Mitigation Plan, 2017, p. C-32).

Flood Terminology

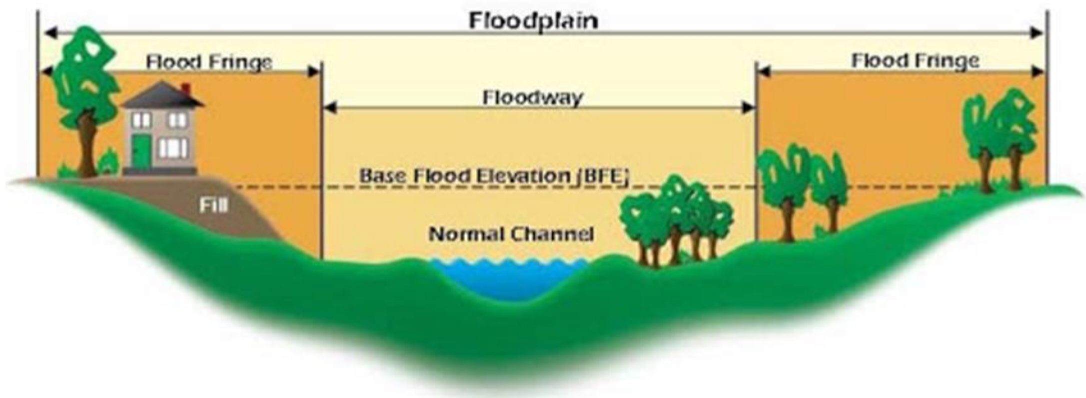
Floodplain

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 the 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. The 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…." Floodways are not mapped for all rivers and streams but are typically mapped in developed areas.

Figure 2-29 Special Flood Hazard Area Schematic



Source: DOGAMI

Flood Fringe

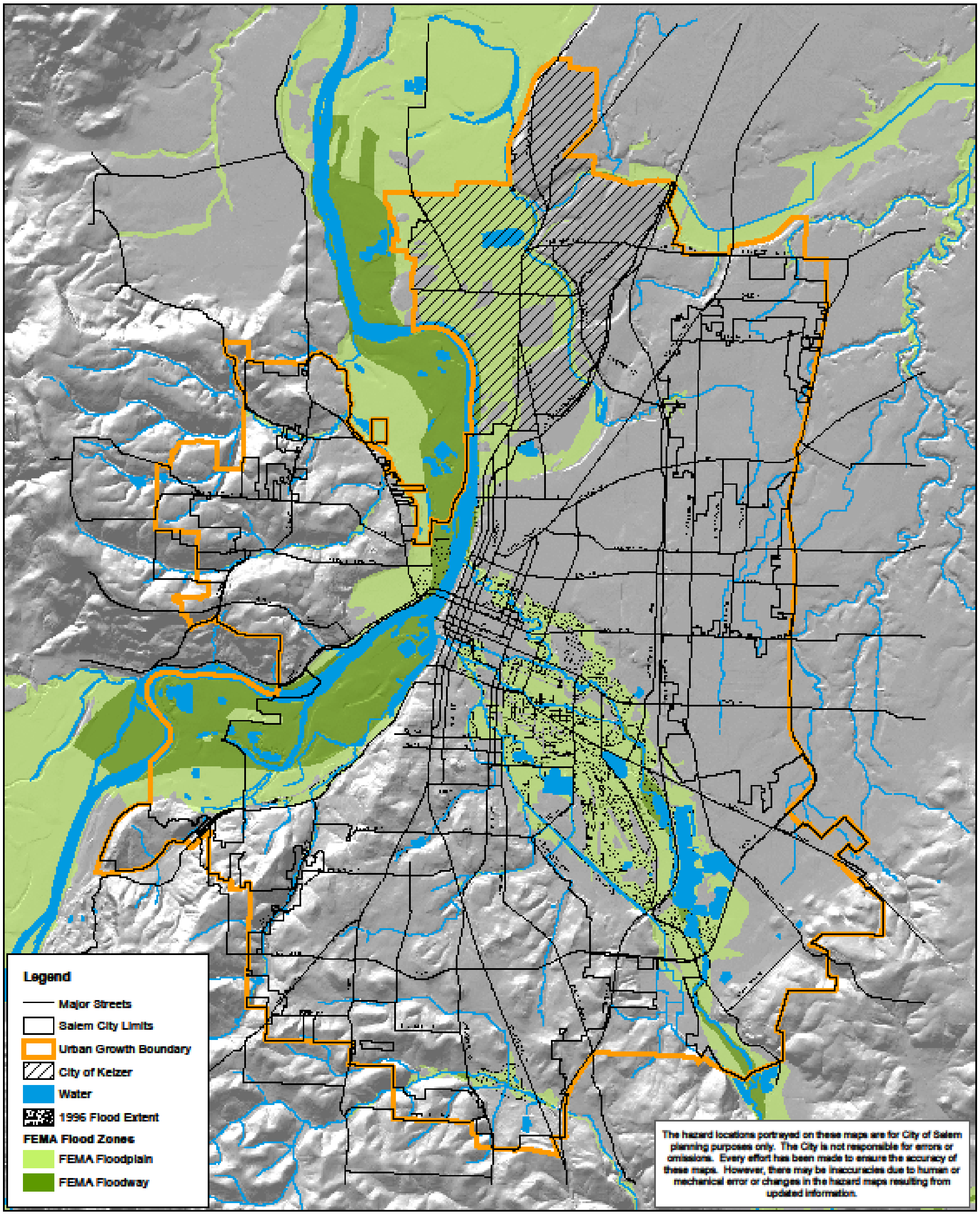
The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward. This is the area where development is most likely to occur, and where precautions to protect life and property need to be taken.

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 BFE is depicted on the FEMA Flood Insurance Rate Map to the nearest foot and in the Flood Insurance Study to the nearest 0.1 foot. The BFE 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 one time every 100 years.

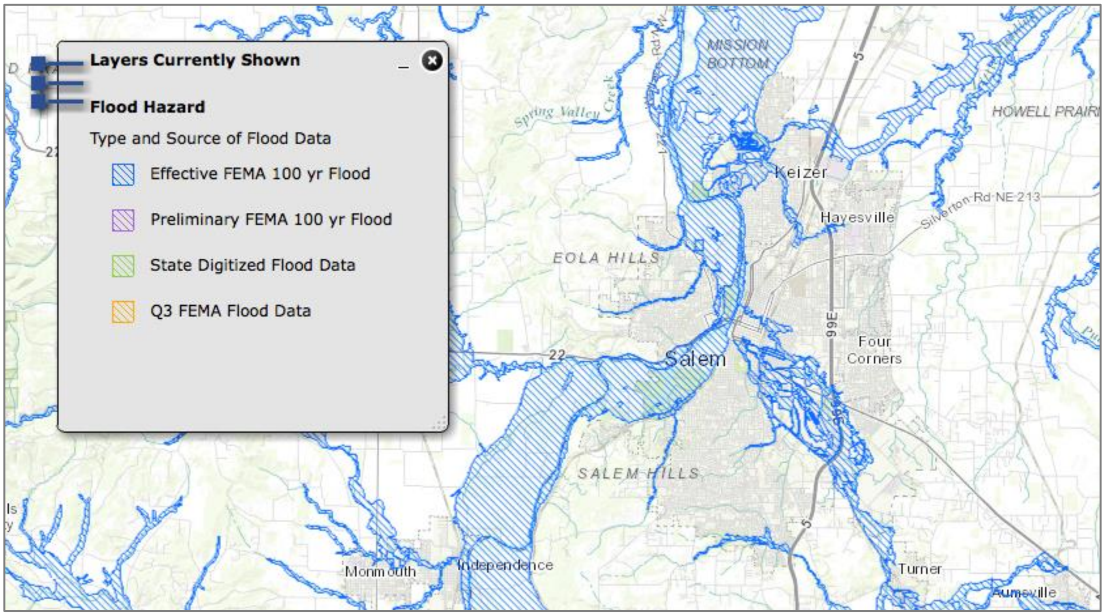
The special flood hazard that identifies the location and extent of the flood hazard is included below in Figure 2-30 and Figure 2-31.

Figure 2-30 Salem Special Flood Hazard Areas



Source: City of Salem

Figure 2-31 Special Flood Hazard Area



Source: Oregon HazVu: Statewide Geohazards Viewer (HazVu)

History

Salem has more than 4,000 acres of floodplain and approximately 3,000 individual parcels that are partially or entirely located within the floodplain. In Salem, flooding generally occurs when: (1) unusually warm weather mixed with heavy rain melts snow in the higher elevations and flood local streams, and/or (2) ongoing development within the City continues to displace natural areas that have historically functional as flood storage.

According to the 2020 Oregon NHMP and the NOAA Storm Event Database, following is a table of significant historic floods affecting the Mid/Southern Willamette Valley. Many of the listed events impacted Salem.

Table 2-8 Significant Historic Floods Affecting Mid/Southern Willamette Valley

Date	Location	Characteristics	Type of Flood
Dec. 1861	Willamette Basin and coastal rivers	Preceded by two weeks of heavy rain; every town on the Willamette was flooded or washed away; 635,000 cfs at Portland	Rain on snow; snow melt
Jan. 1881	Willamette Basin	Lane, Linn, Benton, Marion, Polk, Yamhill, Clackamas, Multnomah Counties	
Feb. 1890	Willamette Basin and coastal rivers	Second largest known flood in the Willamette Basin; almost every large bridge washed downstream	Rain on snow
Dec. 1937	Western Oregon	Flooding followed heavy rains; considerable highway flooding; landslides	Rain on snow
Jan. 1953	Western Oregon	Widespread flooding in western Oregon accompanied by windstorm	Rain on snow

Date	Location	Characteristics	Type of Flood
Dec. 1964 – Jan. 1965	Willamette Basin	Record flooding throughout Willamette Basin; two intense storms; near-record early season snow depths; largest flood in Oregon since dam construction on upper Willamette (1940s–50s; $34 million in damages	Rain on snow
Jan. 1974	Western Oregon	Flooding followed heavy wet snow and freezing rain; nine counties received Disaster Declaration	Rain on snow
Dec. 1978	Western Oregon	Intense heavy rain, snowmelt, saturated ground; one fatality in Region 3 (Benton County)	Rain on snow
Feb. 1986	Statewide	Severe statewide flooding; rain and melting snow; numerous homes flooded and highways closed	Snow melt
Feb. 1987	Western Oregon	Willamette River and tributaries; mudslides; damaged highways and homes	Rain on snow
Feb. 1996	Statewide	Deep snowpack, warm temperatures, record-breaking rains; flooding, landslides, power-outages (FEMA-1099-DR-Oregon)	Rain on snow
Nov. 1996	Statewide	Record-breaking precipitation; local flooding/landslides (FEMA-1149-DR-Oregon)	Rain on snow
Dec. 2005	Polk, Marion, Linn, Lane and Benton Counties	Heavy rains causing rivers to crest above flood stage in Polk, Marion, Linn, Lane, and Benton Counties, as well as other counties in the Willamette Valley	Riverine
Jan. 2006	Willamette Valley	Heavy rains caused many rivers to crest above flood stage in the Willamette Valley, causing road closures and damage to agricultural lands	Riverine
Dec. 2007	Yamhill County	South Yamhill River flooded near McMinnville, causing damage to roads and bridges, 120 homes in Sheridan along with a few businesses and churches, and causing minor damage in Willamina; total county-wide damage estimates at $9.6 million	Riverine
Dec. 2007	Polk County	Major flooding in Suver and other areas in Polk County; total losses equal $1 million for entire county	Riverine
Jan. 2012	Polk, Marion, Yamhill, Lincoln, Benton, Linn and Lane Counties	Heavy rain and wind; ice; flooding in the Willamette Valley; 130 homes and seven businesses were damaged in the City of Turner; 29 streets were closed in the City of Salem; the state motor pool lost 150 vehicles and thousands of gallons of fuel; Thomas Creek in the City of Scio overtopped, damaging several buildings. (FEMA-4055-DR-Oregon)	Riverine
Nov. 2012	Curry, Josephine and Lane Counties	Heavy precipitation; the Curry Coastal Pilot reported over 2 million dollars in infrastructure damage in Brookings and another 2 million in Curry County due to recent heavy rains; sinkholes and overflowing sewage facilities were also reported; according to KVAL news, Eugene Public Works has opened its emergency command center to deal with numerous flooding incidents, including two flooded intersections	Riverine
Feb. 2014	Lane, Coos, Marion and Tillamook and Counties	A series of fronts resulted in a prolonged period of rain for Northwest Oregon, and minor flooding of several of the area's rivers from February 12–17. Heavy rains caused the Coquille River at Coquille to flood. The flood was categorized as a moderate flood. The Nehalem River near Foss in Tillamook County exceeded flood stage on February 18th, 2014. Floods occurred in Salem which impacted roads and other city infrastructure. (FEMA-4169-DR-Oregon)	Riverine and urban flooding

Date	Location	Characteristics	Type of Flood
Dec. 2014	Tillamook, Lincoln, Lane, Polk, Clackamas, Benton Coos and Douglas Counties	A slow moving front produced heavy rain over Northwest Oregon which resulted in the flooding of eight rivers. Another impact from the rain were a couple of land/rock slides that both blocked two highways. Heavy rain brought flooding to several rivers in southwest Oregon.	Riverine
Dec. 2015	Tillamook, Lincoln, Washington, Clackamas, Multnomah, Lane, Columbia, Hood River, Polk, Coos, Douglas, Jackson and Curry Counties	A moist pacific front produced heavy rainfall across Northwest Oregon which resulted in river flooding, urban flooding, small stream flooding, landslides, and a few sink holes. After a wet week (December 5-11), several rivers were near bank full ahead of another front on December 12th. Flooding from the Nehalem River and Rock Creek in Vernonia resulted in evacuation of homes and the implementation of the Vernonia Emergency Command Center. Heavy rain resulted in a land slide that closed OR47 at mile marker 8. More than $15 million dollars in property damage reported in these counties combined. Floods occurred in Salem which impacted roads and other city infrastructure. (FEMA-4258-DR-OR)	Riverine, coastal, and urban flooding
Nov. 2016	Columbia, Tillamook, Lincoln, Benton, Washington, Polk and Yamhill Counties	A moist Pacific front moving slowly across the area produced heavy rainfall, resulting in flooding of several rivers across Northwest Oregon and at least two landslides.	Riverine
Feb. 2017	Marion, Polk, Yamhill, Washington, Columbia, Benton, Tillamook, Lane, Coos, Curry, Klamath, Wheeler and Malheur Counties	High river flows combined with high tide to flood some areas near the southern Oregon coast. Heavy rain combined with snow melt caused flooding along the Coquille River and the Rogue River twice this month in southwest Oregon. Heavy rain combined with snow melt caused flooding along the Sprague River in south central Oregon. Flows on the John Day River reached flood levels downstream of Monument due to the breaking up of an ice jam.	Riverine and coastal flooding
Oct. 2017	Tillamook, Benton and Clackamas Counties	A very potent atmospheric river brought strong winds to the north Oregon Coast and Coast Range on October 21. What followed was a tremendous amount of rain for some locations along the north Oregon Coast and in the Coast Range, with Lees Camp receiving upwards of 9 inches of rain. All this heavy rain brought the earliest significant Wilson River Flood on record, as well as flooding on several other rivers around the area.	Riverine
June 2018	Lane County	In Lane County an upper-level trough moved across the area from the southwest, generating strong thunderstorms which produced locally heavy rainfall, lightning, hail, and gusty winds.	
April 2019	Statewide	The event occurred April 6-21, 2019. Counties that were part of the disaster declaration: Linn, Douglas, Curry, Wheeler, Grant, and Umatilla. Individual and Public Assistance money was approved. (FEMA-4452-DR-Oregon)	Riverine, coastal, and urban flooding

Date	Location	Characteristics	Type of Flood
Sept. 2020	Northwestern Oregon	An eastward-moving upper-level trough and associated area of surface low pressure moved across northwest Oregon and southwest Washington Sept. 17-18, resulting in widespread showers and thunderstorms. One severe thunderstorm developed southeast of Salem and moved northward across the eastern Willamette Valley and Cascade Foothills before weakening over northeast sections of the Portland metro area. This storm produced hail to near 1 inch in diameter, wind damage, and locally heavy rain with minor street flooding. Other thunderstorms developed over southwest Washington producing heavy rainfall and local flooding.	Riverine and urban flooding
Dec. 2020	Western Oregon	A series of strong Pacific fronts moved across the region bringing high winds to the coast with heavy rain across much of the area. The heavy rains resulted in flooding of some coastal rivers as well as small stream flooding and a debris flow.	Riverine and coastal flooding
Jan. 2021	Willamette Basin	A series of slow-moving fronts brought periods of heavy rain along with strong winds. This resulted in high surf; coastal, river and urban flooding; landslides; and debris flows. As the front moved inland early on the Jan. 13, a debris flow resulted in a fatality in the Columbia River Gorge. The front brought a burst of 35-50 mph winds to the Willamette Valley and southwest Washington interior resulting in over 100K customers without power across southwest Washington and northwest Oregon.	Riverine, coastal, and urban flooding

Source: Taylor and Hannon (1999); NOAA. (n.d.). Storm Event Database. Retrieved October 2022 from, https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=41%2COREGON.

Future Climate Variability

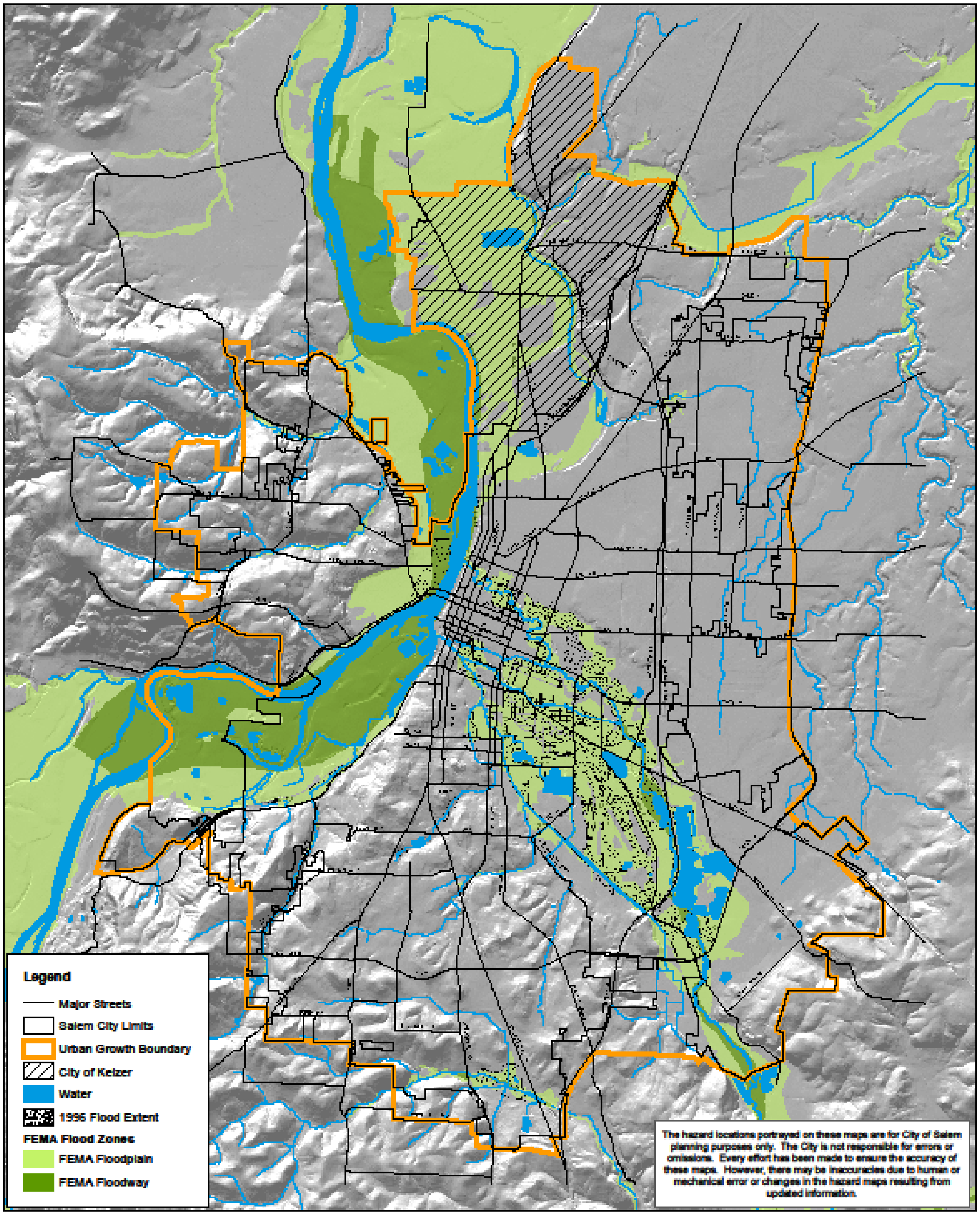
According to the *Fifth Oregon Climate Assessment* (2021), flood magnitudes are likely to increase in Oregon. It is very likely (>90%) that Oregon will experience an increase in the frequency of extreme precipitation events and extreme river flows (high confidence), which is also driven by antecedent conditions (soil moisture, water table height), snowmelt, river network morphology, and spatial variability in precipitation and snowmelt Moreover, heavy precipitation events are expected to become more intense because a warmer atmosphere can carry more moisture and the relatively contribution to floods of rainfall will be greater than that of snowmelt. The report continues by indicating that the wet season precipitation is projected to increase and thus winter flood magnitude will also likely increase. According to the 2020 Oregon NHMP for the Mid/Southern Willamette Valley (Region 3), along the Willamette River and its tributaries, the largest increases in extreme river flows are more likely to be upstream (toward the Cascade Range headwaters), and less likely downstream. Overall, it is more likely (>50%) that increases in extreme river flows will lead to an increase in the incidence and magnitude of damaging floods (low confidence), although this depends on local conditions (site-dependent river channel and floodplain hydraulics). Increases in extreme river flows leading to damaging floods will be less likely where storm water management (urban) and/or reservoir operations (river) have capacity to offset increases in flood peak.

The *Salem Climate Action Plan 2021*, includes numerous strategies to address a variety of climate-related challenges facing the city including flooding. The plan acknowledges significant projected climate impacts including the following:

- More intense rainfall and rain-on-snow events could also lead to flood events in areas outside of historical high-risk zones. *Department of State Lands, Wetlands Functions and Assessment* (May 2001)

Probability Assessment

The Federal Emergency Management Agency has mapped the 10, 50, 100, and 500-year floodplains in portions of Salem (see



and Figure 2-31 and referenced FIS for more information). This corresponds to a 10%, 2%, 1% and 0.2% chance of a certain magnitude flood in any given year. The 100-year flood is the benchmark upon which the NFIP is based.

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing a flood is "high,"** meaning one incident is likely within the next 10-year period.

Vulnerability Assessment

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

Public Health

Protection of human life is of primary importance. This is paramount and is tied to several other community issues. Keeping homes safe from floodwaters will also help protect human life.

The Centers for Disease Control and Prevention warn that floodwaters pose a variety of health risks, including exposure to infectious diseases, chemical hazards, and injuries. Floodwaters can become contaminated with bacteria and hazardous chemicals which present the risk of disease through physical contact, ingestion, or open wounds. There is risk of physical injury from floating objects and damaged electrical power lines from floodwaters. The rapidly moving floodwaters also pose risk of drowning. Floodwaters can also cause indirect health risks. Animals can be displaced during flooding and give rise to a public health risk. Standing water during and after a flood can increase insect populations, creating additional risk of insect-borne diseases. If clean-up efforts are delayed after flood events, water-damaged buildings can collect mold, which is a significant health concern to building occupants. Many of these indirect public health concerns can be reduced after flood events by expediting repair of water-damaged buildings and other clean-up efforts.

When it comes to notifying the public in the event of a natural hazard event, through its *Emergency Management Plan*, Salem has put in place a preparedness team made up of various city departments including Fire, Police, Public Works, Community Development, Administrative Services, Human Resources, Information Technology, Emergency Management, School District, and the Public Information Officer. Preparedness support also includes Marion and Polk Counties, various state and federal agencies, and local colleges, utilities, medical centers, transportation, and amateur radio emergency services. Dissemination of information to the public is done through Marion Polk Alert system for a variety of safety situations including evacuations, flooding, hazardous materials release, police activity requesting resident action. The Marion Polk Alert is managed by Marion and Polk Counties, in partnership with Salem’s emergency personnel. In addition, information for the public is provided on City’s website, Twitter, and Facebook. In very extreme cases, door-to-door notification to evacuate is used.

Floods in the past caused multiple major injuries or death. The potential for future injuries or deaths is anticipated to remain similar to historic events. It is estimated that 10-25% of the city's population would be physically displaced by a flood, accounting for the number of homes located in or near floodplains, and there would be moderate impact on community social networks.

Residential Building Damage

Homes in frequently flooded areas can experience blocked sewer lines and damage to septic systems and drainfields. This is particularly the case of residences in rural flood prone areas who commonly utilize private individual sewage treatment systems. Inundation of these systems can result in the leakage of wastewater into surrounding areas creating the risk of serious water pollution and public health threats. This kind of damage can render homes unlivable.

Many older manufactured home parks may be in floodplain areas. Manufactured homes have a lower level of structural stability compared to traditional lumber-built homes. Manufactured homes in floodplain zones should be anchored to provide additional structural stability during flood events.

Approximately 3,190 buildings are located within the City's regulatory floodplain, according to Salem's *Floodplain Management Plan* (2018). See Table 2-9 below regarding the zoning designation and number of structures in the regulatory floodplain. Those buildings zoned residential comprise approximately 70 percent of buildings in the floodplain. In addition to structural and life-safety impacts, flooding in residential areas can also result in the need for temporary shelters to house displaced residents.

The DOGAMI *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022) indicates that there is the potential to have 2,932 (3.1% population) displaced residents and 1,588 damaged buildings during a 100-year flood scenario (1% annual chance). The loss estimate is $82,571,000 (loss ratio of 0.7%).

Development Change

Changes to development patterns have the potential to incur increased risk of flooding. However, city development regulations restrict, but do not prohibit, new development in areas identified as floodplain. This reduces the impact of flooding on future buildings. As new land has been brought into the Salem UGB the applicable development codes have been written to prevent the siting of new structures in flood prone areas.

Critical Facilities, Critical Infrastructure, and Vulnerable Population Centers

Of particular importance during flood events are critical facilities located in flood hazard areas. A critical facility is defined as a facility that needs to be operable during a flood, or for which even a slight chance of flooding might pose an unacceptable risk to health and safety. Critical facilities include schools, nursing homes, hospitals, police, fire, and other emergency responders, and installations that produce, use, or store hazardous materials. The Salem *Floodplain Management Plan* (2018) states,

> Fourteen critical facilities are located within the regulatory floodplain, totaling approximately $930 million in improvement value. Salem Hospital is a critical facility

that can be substantially impacted during flood events, since vehicular access to the facility can be limited by street closures surrounding the hospital. Salem has also identified approximately 200 essential facilities (i.e., schools, residential care facilities, daycares, record retention facilities, hazardous waste storage, etc.) in the regulatory floodplain. City staff coordinates contact and flood response planning efforts with both critical and essential facilities. A critical and essential facilities database is maintained in the Salem Emergency Operations Center Situational Awareness Framework for Events (SAFE) system.

In the January 2012 flood event, City public infrastructure damage was estimated at approximately $10 million. Most of the damage, $7.5 million, was to vehicular bridges; other damage included City-owned parks, buildings, streets, and water, wastewater, and stormwater facilities. The January 2012 event was somewhat localized to the Battle Creek and Mill Creek basins; however, the potential damage to critical facilities and infrastructure city-wide is significant.

The DOGAMI *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022) indicates that during a 100-year flood scenario (1% annual chance), there is the potential to have 2,932 (3.1% population) displaced residents, 1,588 damaged buildings, 8 of which are critical facilities. The loss estimate is $82,571,000 (loss ratio of 0.7%).

The DOGAMI report for Marion County identifies the following eight critical facilities that are on property located entirely or partially in the floodplain.

1. Battle Creek Elementary (1640 Waln Drive SE)
2. North Salem High School (765 14th Street NE)
3. McNary Army Aviation Hangars (1921 Turner Road SE)
4. Salem Municipal Airport/McNary Field (2990 25th Street SE)
5. Oregon Dept of Transportation (various locations including 885 Airport Road SE)
6. Oregon State Police (3565 Trelstad Avenue SE)
7. Salem Hospital (890 Oak Street SE)
8. Salem Public Works (555 Liberty Street SE)

The DOGAMI report for Marion County also identified areas of significant risk. These locations are within the study area and are comparatively at greater risk from flood hazard. The following two are in or near Salem:

- The very large floodplain of Mill Creek (near Salem) and its tributaries from the city of Turner to Salem correspond to high levels of urban development. This area is at high risk from flood hazard.
- Buildings within the Willamette River floodplain, particularly in the city of Salem, including West Salem, are at risk from flood hazard.

Business and Industry

Flood events impact businesses by damaging property and by interrupting business. Flood events can cut off customer access to a business as well as close a business for repairs. The economic losses due to business closures often total more than the initial property losses that result from floods. Direct damages from flooding are the most common impacts, but indirect damages, such as diminished clientele, can be just as debilitating to a business. Floods can cut off customer vehicular and pedestrian access and close businesses for repairs. A quick response to the needs of businesses affected by flood events can help a community maintain economic viability in the face of flood damage. Responses to business damages can include funding to assist owners in elevating or relocating flood-prone business structures.

Multiple facilities throughout the city anticipate severe damage due to a flood, estimated between $10 million and $100 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely 10-30% of businesses located in the city and surrounding area would experience commerce interruption for a period of a months. Floods have the potential to inflict widespread damage to not only buildings but also the transportation network that may inhibit access to businesses. Lastly, floods would likely have extensive impacts on more than 75% of the city's ecological systems, including, clean water, wildlife habitat, and parks.

The Salem *Floodplain Management Plan* (2018) states the following regarding employers and economy,

> A number of employment centers are located within the regulatory floodplain. The Pringle Creek floodplain area includes industrial employment areas in the vicinity of McGilchrist Street SE and Salem Memorial Hospital, one of Salem's largest employers. Mill Creek can overflow into Salem Airport, which would potentially restrict air traffic, and the overflow can continue through industrial employment areas west of 25th Street SE, including the City Operations Complex. In West Salem, the Willamette River causes flooding in commercial areas along Wallace Road NW and Edgewater Street NW.
>
> Transportation impacts during flood events can cause significant economic impacts. Major transportation corridors can be closed by high water, restricting commercial traffic. The most significant transportation impacts involve the potential closure of arterial streets, including the Wallace/Edgewater intersection, Mission Street SE, Center Street NE/SE, State Street, and River Road S.

As noted previously, Salem's *Floodplain Management Plan* (2018) approximates 3,190 buildings that are located within the city's regulatory floodplain. Moreover, the DOGAMI *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022) indicates that there is the potential to have 1,588 damaged buildings during a 100-year flood scenario (1% annual chance) with a loss estimate of $82,571,000 (loss ratio of 0.7%). Table 2-9 shows the number of structures in the floodplain by zoning designation.

Table 2-9 Number of Buildings in the Floodplain by Zoning Designation

Number of Buildings in the Floodplain by Zoning Designation	
Zoning Designation	**Number of Buildings**
Critical Facilities (All Zones)	14
Commercial	274
Industrial	364
Public	120
Residential	2,417
Mixed Use	1
TOTAL	**3,190**

Source: City of Salem. (2018, April). *Floodplain Management Plan*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/1228/637789751589700000.

Public Infrastructure (General)

Publicly owned facilities are a key component of daily life for all residents of Salem. Damage to public water and sewer systems, transportation networks, flood control facilities, emergency facilities, and offices can hinder the ability of the government to deliver services. Moreover, public buildings such as libraries, schools and government buildings are of concern to the city due to their potential utility in the event of a flood. These buildings can be used as temporary locations for medical and emergency housing services. Some public infrastructures noted here are provided in more detail below.

Roads

Road systems are important to the local economy, and during hazard events, resilient road connections are critical for providing essential and emergency services. Emergency vehicles can be delayed because of restricted mobility in flooded areas. Roads are maintained by multiple jurisdictions. Federal, state, county, and city governments all have a stake in protecting roads from flood damage. Some roads in Salem cross floodplain areas.

Salem's *Floodplain Management Plan* (2018) identifies critical transportation corridors throughout Salem. Major streets that may likely be closed during flood events include those indicated in Table 2-10.

Table 2-10 Critical Transportation Corridors Affected by Flooding

Classification	Street Names
Parkway	Mission Street SE
Major Arterial	Center Street NE State Street Capitol Street NE/SE 12th Street NE/SE Hawthorne Avenue NE/SE Summer Street NE Madrona Avenue SE 25th Street SE McGilchrist Avenue SE River Road
Minor Arterial	17th Street NE/SE Airport Road SE Broadway Street NE Glen Creek Road NW Orchard Heights Road NW Fairview Industrial Drive SE Turner Road SE
Collector	Airway Drive SE Croisan Creek Road S D Street NE Fairway Avenue SE Oxford Street SE Hines Street SE 22nd Street NE/SE Rural Street SE Cross Street SE

Source: City of Salem. (2018, April). *Floodplain Management Plan*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/1228/637789751589700000.

Bridges

Bridges are key points of concern during flood events for two primary reasons:

1. Bridges are often important links in road networks, crossing watercourses or other significant natural features.
2. Bridges can be obstructions in the floodway, collecting debris and inhibiting the flow of water during flood events. This can cause water to back up and inundate areas upstream from the bridge that would not otherwise be affected. Also, this build-up of water can suddenly release, causing a flash flood of larger magnitude downstream.

Wastewater Treatment Facility

Floods significantly impact drinking water and wastewater systems. When sewer systems are inundated with floodwaters, raw sewage can be flushed into the waterways, posing a significant health hazard. Additionally, drinking water supplies can be contaminated with flushed wastewater or high levels of solids (eroded soil for example), and made unsafe for consumption. Both water and sewage systems often require significant repair and maintenance work following a flood.

In Salem, wastewater is pumped to the Willow Lake Wastewater Pollution Control Facility, which is partially located within the floodplain. Because of this location, the facility is prone to some flooding. The City of Salem's wastewater system serves more than 60 square miles through over 800 miles of pipe and includes the cities of Turner and Keizer. When needed, the city has a back-up facility at River Road Park, which is not located in the floodplain. Once at Willow Lake Wastewater Pollution Control Facility, the wastewater is treated to clean it so that it is safe to be released to the Willamette River for downstream communities to re-use. According to Salem's Wastewater website, during the wet weather months or when there is a storm event expected that could overload the sanitary sewer system, crews carefully and continuously monitor the wastewater collection system, including 30 sewer pump stations around Salem, so releasing untreated wastewater into the Willamette River can be avoided.

Salem's Demonstration Project, also known as Natural Reclamation System, will determine whether technology should be used more extensively in the watershed. The demonstration project that uses the "natural systems as a sustainable method of improving water quality, provide reclaimed water supply and management, and to determine whether this technology is appropriate within the Willamette River watershed." For more information on this demonstration project, visit the following site: https://www.cityofsalem.net/community/household/water-utilities/wastewater/natural-reclamation-system-project.

Stormwater Systems

Stormwater systems collect and concentrate rainwater and rapidly deliver it into the local waterway. This infusion of water causes increased flows downstream. During large rainstorms and floods, these systems are pushed past their capacity and stormwater begins flowing over-ground, causing other infrastructure damage. Traditional stormwater systems are a benefit to urban areas by quickly removing captured rainwater, however, they can be detrimental to areas downstream.

Other problems often develop where open ditches enter culverts or go underground into stormwater systems. An obstruction at these intersections causes overland water flow. The filling of ditches and swales near buildings can inhibit or prevent the flow of water can compound these problems. Inadequate maintenance, especially following leaf accumulation in the fall, can also contribute to the flood hazard in urban areas.

Salem's stormwater system is considered by the state as separated from the wastewater treatment system. Salem provides its residents with a variety of stormwater services, including flooding response. The stormwater collection system that must be maintained consists of ditches, streams, pipe, detention basins, and storm drainage structures in and around the city. This system collects water to slow or divert the stormwater to areas where it can be filtered by natural environment or Salem's stormwater utility services and thus help keep excessive rain runoff and pollution from enter the local streams and rivers (City of Salem, *Stormwater*).

According to *Salem's Local Floodplain (Map)* website, the following streams are prone to flooding in the Salem area:

- Battle Creek
- Claggett Creek
- Croisan Creek
- Gibson Creek
- Glenn Creek
- Mill Creek
- Mill Race
- Powell Creek
- Pringle Creek
- Shelton Ditch

All water from this system will ultimately end up in the Willamette River. The higher the river, the more difficult it is for stormwater run-off to make it to the river. During significant rain events, the city typically experiences localized flooding first followed by river flooding after the rain event has passed. During heavy rains not necessarily associated with high river levels, sections of the storm system can become inundated and result in localized flooding. In general, these events do not cause damage to the City's storm water system and subside relatively quickly.

The City of Salem updated their *Stormwater Master Plan* in 2020. Under Policy 3.12, Flood Risks and Capital Project Criteria, the following risk reducing projects shall be considered in addition to increasing the capacity and construction of detention facilities:

> (1) Opportunity to retrofit structures, including elevating or relocating buildings, and applying of floodproofing techniques such as shields, membranes, waterproofing, venting, and other practices;
>
> (2) Evaluation of cost impacts based on damage assessment data contained in the Natural Hazard Mitigation Plan (City of Salem 2017);
>
> (3) Ability to implement green stormwater infrastructure to reduce runoff volumes and peak flows;
>
> (4) Ability to conduct floodplain and stream enhancement projects to increase flow attenuation and stream capacity; and (5) Suitability of purchasing flood-prone properties

Additional information on Salem's *Stormwater Master Plan* (2020) can be found at the following site:
https://www.cityofsalem.net/home/showpublisheddocument/5168/637798392359400000

Water Management and Water Quality

Floods significantly impact drinking water and long-term water quality monitoring is conducted by DEQ. Salem is located within the Willamette Basin. DEQ's North Santiam and South Santiam Subbasin Water Quality Overview indicates that bacteria, mercury, and temperature are significant concerns in this watershed. People can become sick if they ingest water that is contaminated with bacteria when they are swimming or otherwise in contact with the water. Both urban and rural/agricultural sources are major contributors to the high bacteria levels found in many of the rivers in the Willamette Basin. DEQ has set a goal to reduce bacterial loads by addressing direct discharges and runoff of bacterial sources. The Willamette River has fish consumption advisories due to elevated levels of mercury found in some fish species. The DEQ TMDL implementation program aims for a reduction in the load of total mercury from point sources and non-point erosion. Reductions in stream temperature can be achieved by reducing solar radiation loading by planting vegetation to increase streamside shading and by improving base flows.

As discussed in Salem's *Water Management and Conservation Plan* (WMCP), the city has a various means of obtaining drinking water including surface water, groundwater, and aquifer storage and recovery. Salem's primary water source is surface water from the North Santiam River. Water is diverted from the north channel of the river at approximately river mile 20 and is treated at the adjacent Geren Island Water Treatment Facility (Geren Island). Salem also holds water rights to appropriate water from the Willamette River.

Salem also appropriates and treats groundwater at Geren Island through a collector well facility. In addition, a limited amount of groundwater is available from wells within Salem's water service area. These groundwater sources are a supplemental during emergencies, water quality events, and peak demand periods.

Salem's Aquifer Storage and Recovery (ASR) system provides a supplemental water supply during periods of peak demand, high turbidity events, or emergencies. The city has four active ASR wells and may develop two more. With an ASR system, treated drinking water from the North Santiam River is injected into the Columbia River basalt aquifer via the ASR wells. The injected water is stored in the aquifer for later recovery.

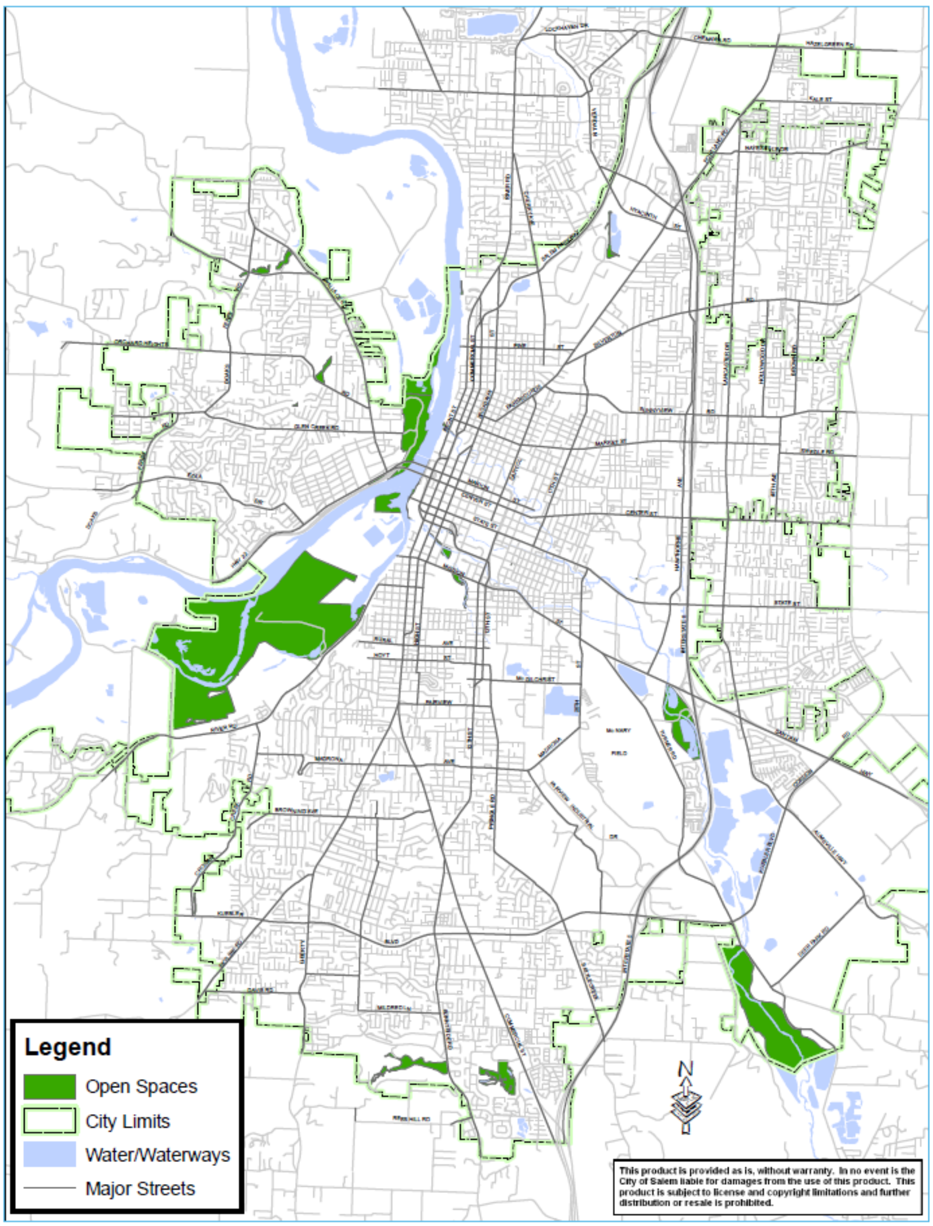
The City of Salem's WMCP describes the efforts to strengthen water supply reliability for its water customers. Salem recognizes that effective water management and conservation is critical. Included in this plan is a water curtailment plan that outlines proactive measures to reduce demand and to find alternative supplies during short-term water supply shortages. The intent is to minimize the impacts of water supply shortages, which may result from incidents including prolonged drought, mechanical or electrical equipment failure in the system, unanticipated catastrophic events (flooding, landslides, earthquakes and contamination), or events not under control of the water supplier.

Additional discussion regarding water management can be found under the Water Emergencies Hazard.

Parks, Open Space, and Natural Environments

The capacity of the natural environment is essential in sustaining all forms of life including human life, yet it often plays an underrepresented role in community resiliency to natural hazards such as floods. The natural environment includes land, air, water, and other natural resources that support and provide space to live, work and recreate. Natural capital such as wetlands and forested hill slopes play significant roles in protecting communities and the environment from weather-related hazards, such as flooding and landslides. When natural systems are impacted or depleted by human activities, those activities can adversely affect community resilience to natural hazard events.

Figure 2-32 Salem Open Spaces in Floodplain



Source: City of Salem. (2018, April). *Floodplain Management Plan*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/1228/637789751589700000.

Public parks and publicly owned open space and natural systems can provide a buffer between flood hazards and private property. Maintaining and restoring natural systems helps mitigate the impact of flood events on the built environment. Flooding changes the natural environment and hydrology of an affected area. High water can be beneficial to the natural processes within a floodplain and can benefit riparian areas. Wetlands in public ownership can reduce flood impacts by absorbing floodwaters and buffering water level fluctuations.

Riparian areas are important transitional area that link water and land ecosystems. Vegetation in riparian areas is dependent upon stream processes such as flooding and often is composed of plants such as willow and cottonwood trees that require large amounts of water. Healthy vegetation in riparian buffers can reduce streamside erosion. During flood events, high water can cause significant erosion. Well-managed riparian areas can reduce the amount of erosion and help to protect water quality during flooding events.

Many floodplain and stream-associated wetlands absorb and store storm water flows, which reduces flood velocities and stream bank erosion. Preserving these wetlands reduces flood damage and the need for expensive flood control devices such as levees. According to Oregon Department of State Lands (DSL), when the storms are over, many wetlands augment summer stream flows by slowly releasing the stored water back to the stream system. Wetlands are highly effective at removing nitrogen, phosphorous, heavy metals, and other pollutants from water. For this reason, artificial wetlands are often constructed for cleaning storm water runoff and for tertiary treatment (polishing) of wastewater. Wetlands bordering streams and rivers and those that intercept runoff from fields and roads provide this valuable service free of charge.

According to Salem's *Comprehensive Park System Master Plan Update* (2013), there are approximately 1,928 acres of park land within the city; 1,328 acres are developed, and 600 acres are undeveloped. Parks in Salem range from the smallest neighborhood park, Gracemont Park (0.34 acres) to the expansive natural landscape of Minto-Brown Island Park. At 899 acres, Minto-Brown Island Park accounts for almost half of the city's total park acreage. Salem's parks include neighborhood, community and urban parks, linear parks, natural areas, historic areas and special use facilities. Salem's 600 acres of undeveloped park land include sites identified as neighborhood, community, and urban parks, and natural areas. These sites are dispersed throughout the city and range in size from less than an acre to over 50 acres. The natural areas that are primarily undeveloped lands left in a natural state for conservation are identified in Table 2-11.

Table 2-11 Natural Area Acreage, Salem, Oregon

Park	Developed Acres	Undeveloped Acres	Total Acres
Carson Springs	-	0.32	0.32
Chandler Nature Park	-	7.88	7.88
Claggett Creek Natural Area	-	41.87	41.87
Cunningham Lane	-	4.63	4.63
Eola Boaters Tract	-	2.00	2.00
Glen Creek Property	-	1.50	1.50
Minto-Brown Island Park	654.05	244.81	898.86
Mouth of Mill Creek	-	1.44	1.44
Skyline Natural Area[A]	-	35.26	35.26
Straub Nature Park	10.00	-	10.00
Wallace Natural Area[A]	-	57.66	57.66
Natural Area Total	**664.05**	**397.37**	**1,061.42**

[A] Park classification changed since 1999 plan.

Source: City of Salem. (2013, May). *Comprehensive Park System Master Plan Update*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/5050/637798374462430000.

The *Comprehensive Park System Master Plan Update* states,

> These parks are designed to protect and manage unique or significant natural features, such as rivers, streams, wetlands, steep hillsides, environmentally sensitive areas, rare or endangered species, heritage trees, tree groves, forested areas, and wildlife habitat. Some natural areas may have limited access due to resource conservation needs. Natural areas provide a number of ecological benefits, including providing habitat, filtering stormwater, and controlling erosion. Protected sensitive areas should be the majority of the acreage in a natural area. Natural areas may support passive recreation, such as trail-related uses, bird and wildlife viewing, environmental interpretation and education, and nature photography. A developed natural area does not have the same high level of development or use as other park classes.

The Salem Area Comprehensive Plan is the primary guiding document for all planning and development efforts in the city, which includes a goal addressing acquisition and development of adequate parks and recreation facilities. It outlines several policies to guide Salem's park planning efforts that include park acquisition and development, priority acquisition, school and parks coordination, recreation, open space, heritage trees, and riparian areas. Policies related to parks and open spaces are also incorporated in numerous related sections, including stormwater, transportation, school location and development, Willamette River Greenway, scenic and historic areas, natural resources and hazards, and urban renewal. Some of Salem's waterway basin plans provide studies of natural areas. The Salem *Pringle Creek Basin Plan* (2019), provides the following analysis summary,

> Wetlands and Floodplains – Riparian areas, adjacent wetlands and local floodplains are important drainage features in a watershed because they decrease flood volumes and rates of flow. Well-vegetated riparian areas may also store

floodwaters, thereby reducing associated flood damage downstream. Furthermore, the natural capacity of a watershed to manage flood events is reduced when channelization occurs, impervious surfaces increase and wetlands are filled in.

For information on studies and analysis of natural areas incorporated into Salem's Stormwater Drainage Basin Plans, refer to the following:

Battle Creek Basin Plan, September 2019

Mill Creek Basin Plan, September 2019

Pringle Creek Basin Plan, September 2019

Power Supply

Flooding can also significantly impact electrical supply systems. Floodwaters short-out electrical lines and cause transformers to fail. Additionally, debris transported by floodwaters has the potential to knock down power poles and put live, high-voltage lines in the water, posing an electrocution hazard to people.

Communications/Phone Lines

Telephone and cable lines are similarly susceptible to floodwaters and floating debris. Underground lines are more resistant to flood damage, but often are exposed and damaged by swift currents.

Salem Climate Action Plan 2021

The *Salem Climate Action Plan 2021* outlines the following potential vulnerabilities and consequences of various projected climate changes as it relates to flooding.

Projected Precipitation Patterns

Though overall precipitation amounts are expected to remain consistent, increased temperatures noted above will lead to a water deficit. Precipitation patterns may change, leading to increased frequency of heavy downpour events and flooding.

- Flood conditions could be exacerbated in areas outside the historical high-risk floodplain and where new development is occurring. Risks to unsheltered people living near waterways could increase.
- Risk of water damage to homes and businesses from flooding.
- Water intrusion in homes can create mold issues, respiratory issues, and psychological stress.
- Potential harm to railroads, bridges, and overpasses from flooding.

As such, the NHMP Steering Committee rated the city as having a **"medium" vulnerability to flood hazards**, meaning that 1% to 10% of the city's population or property would be affected by a major flood event.

Mitigation Activities and Resources

There are numerous programs currently under way in Salem as well as Marion and Polk Counties that are designed to mitigate the impacts of flooding. These programs range from federally funded national programs to individual projects by landowners and projects by watershed councils and special districts.

National Flood Insurance Program

The NFIP is a federal program administered by FEMA. The function of the NFIP is to provide flood insurance to homes and businesses located in floodplains at a reasonable cost, and to encourage the location of new development away from the floodplain. The program maps flood risk areas, and requires local implementation to reduce the risk, primarily through restricting new development in floodplains. The City of Salem participates in the National Flood Insurance Program.

Flood insurance covers only the improved land, or the actual building structure. It is important to note that property located outside the SFHA may still be subject to severe flooding. FEMA reports that 25% to 30% of all flood insurance claims are from owners of property located in low to moderate-risk areas located outside of the SFHA.

Repetitive Loss structures are defined as a NFIP-insured structure that has had at least two paid flood losses of more than $1,000 each in any 10-year period since 1978. Repetitive Loss structures are concerning because they continue to expose lives and property to the flooding hazard. Local governments as well as the federal agencies, such as FEMA, attempt to address losses by encouraging and requiring floodplain insurance and funding projects such as acquiring land and improvements, relocating homes, or elevating structures. Continued repetitive loss claims from flood events lead to an increased amount of damage caused by floods, higher insurance rates, and contribute to the rising cost of taxpayer funded disaster relief for flood victims.

FEMA modernized the Salem Flood Insurance Rate Maps in January 2003. Table 2-12 shows that as of December 2022, Salem has 640 National Flood Insurance Program (NFIP) policies in force. The last Community Assistance Visit (CAV) for Salem was on March 22, 2017. Salem is a member of the Community Rating System (CRS) and has a Class 4 rating.

Table 2-12 Flood Insurance Detail

	City of Salem
Effective FIRM and FIS	1/2/2003
Initial FIRM Date	6/15/1979
Total Policies	640
Total Claims Since 1978	204
Insurance in Force	$185,240,100
Total Paid Claims Since 1978	$3,472,820
Substantial Damage Claims	33
Repetitive/Severe Repetitive Loss Properties	48
CRS Class Rating	4
Last Community Assistance Visit	3/22/2017

Source: Information compiled by Department of Land Conservation and Development, December 2022
Note: City of Salem resides in both Marion and Polk Counties. Depending on what part of the city, FIRM panels were issued January 19, 2000, January 2, 2003, or October 18, 2019.

Flood Insurance Rate Maps

The FIRM floodplain maps are the basis for implementing floodplain regulations and for delineating flood insurance purchase requirements. A FIRM is the official map produced by FEMA, which delineates special flood hazard areas or floodplains where NFIP regulations apply.

The City of Salem uses the FIRM to advise prospective homeowners of flood hazards, locate zoning boundaries that separate developable land from open space, make decisions for new development in floodplains, and administer the terms of the NFIP during the issuance of building permits. The maps are also used by insurance agents and mortgage lenders to determine if flood insurance is required.

City of Salem resides in both Marion and Polk Counties. Depending on what part of the city, FIRM panels were issued January 19, 2000, January 2, 2003, or October 18, 2019.

Flood Insurance Study

For mapped floodplain areas, the flood hazard data included in the Flood Insurance Study (FIS) allow quantitative calculation of the frequency and severity of flooding for any property within the floodplain. Such calculations are very important for mitigation planning because they allow the level of flood risk for any structure to be evaluated quantitatively.

Standard hydrologic and hydraulic study methods were used to determine the flood hazard data contained in the FIS. Flood events of a magnitude expected to occur once on average every 10-, 50-, 100-, and 500-year period were studied for each of Salem's rivers and creeks.

Quantitative flood hazard data are very important for mitigation planning purposes because they allow quantitative determination of the frequency and severity (i.e., depth) of flooding for any building or other facility (e.g., road or water treatment plant) for which elevation data exist. Such quantitative flood hazard data also facilitate detailed economic analysis (e.g., benefit-cost analysis) of mitigation projects to reduce the level of flood risk for a particular building or other facility.

Community Rating System

The NFIP CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. The CRS program recognizes a community's efforts to reduce flood risk, facilitate accurate insurance ratings, and promote the awareness of flood insurance.

For CRS communities, flood insurance premium rates are discounted in increments of 5%; i.e., a Class 1 community would receive a 45% premium discount, while a Class 9 community would receive a 5% discount. **Error! Reference source not found.**illustrates how the CRS point system is broken down.

Table 2-13 Summary of Points and Insurance Rate Discounts Under CRS

Credit Points	Class	Premium Reductions
0-499	10	0%
500-999	9	5%
1000-1499	8	10%
1500-1999	7	15%
2000-2499	6	20%
2500-2999	5	25%
3000-3499	4	30%
3500-3999	3	35%
4000-4599	2	40%
4500+	1	45%

Source: FEMA. (2022, March 9). *Flood Insurance*. Retrieved from https://www.fema.gov/flood-insurance.

Salem originally joined the CRS in 2008 and has continued to upgrade its rating through improvements to its floodplain management program. Some of the floodplain management and damage mitigation activities used by Salem include providing one-on-one advice to residents regarding property protection, implementing higher regulatory standards, maintaining open space, managing stormwater runoff, and developing a flood warning and response program. In late 2021, FEMA upgraded Salem from Class 5 to Class 4 CRS program. Unprecedented for any Oregon community, Salem becomes one of approximately 25 cities in the United States to achieve a Class 4 or better rating out of the 22,000 communities that participate nationwide in the NFIP. Participation in the program acknowledges Salem's efforts that help save lives and reduce property damage in the event of a flood. Salem continues to make improvement in the CRS program and strives to improve the rating within any given year.

According to Salem's Flood Insurance website, the following are a few examples of Salem's involvement in credited activities include:

- Conduct outreach efforts to increase awareness of flood issues in Salem and provide information about protecting yourself, your family and your property from flooding;
- Maintain staff that are trained as Certified Floodplain Managers and able to assist the community with floodplain and flood insurance related inquiries;
- Improve flood map information and accessibility;
- Provide detailed review by floodplain management staff of all development proposals in the floodplain to ensure areas prone to flooding are not affected by the development activity;
- Require safe building practices to reduce future flood damage;
- Operate a drainage system maintenance program that includes annual inspections and regular maintenance of creeks, streams and ditches in Salem to reduce the risk of flooding; and
- Conduct flood response exercises and encourage community engagement in early warning and response efforts in the event of a flood.

Federal Resources

In addition to the National Flood Insurance Program, together with the FIRM, FIS, and CRS, discussed above, the following are flood-related federal resources.

National Weather Service

The Portland Office of the National Weather Service issues severe winter storm watches and warnings when appropriate to alert government agencies and the public of possible or impending weather events. The watches and warnings are broadcast over NOAA weather radio and are forwarded to the local news media for retransmission using the Emergency Alert System.

National Resources Conservation Service

The NRCS provides a suite of federal programs designed to assist state and local governments and landowners in mitigating the impacts of flood events. The Watershed Surveys and Planning Program and the Small Watershed Program provide technical and financial assistance to help participants solve natural resource and related economic problems on a watershed basis. The Wetlands Reserve Program and the Flood Risk Reduction Program provide financial incentives to landowners to put aside land that is either a wetland resource or that experiences frequent flooding. The Emergency Watershed Protection Program (EWP) provides technical and financial assistance to clearing debris from clogged waterways, restoring vegetation, and stabilizing riverbanks. The measures taken under EWP must be environmentally and economically sound and generally benefit more than one property.

Federal Emergency Management Agency Programs

FEMA resulted from the consolidation of five federal agencies that dealt with different types of emergencies. Many states and local jurisdictions have accepted the same approach and changed the names of their organizations to include the words “emergency management.” FEMA provides maps of flood hazard areas, various publications related to flood mitigation, funding for flood mitigation projects, and technical assistance.

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (USACE) plays a major role in a coordinated and complex system to reduce flood risks and provide water for hydropower generation, fish and wildlife enhancement, navigation, recreation, and other uses. Portland District’s primary water management mission is to save lives and reduce property damage by reducing flood risks with measures both structural (such as dams) and non- structural (such as improving the natural function of floodplains).

State Resources

State Natural Hazard Risk Assessment: Flood

The risk assessment in the 2020 Oregon NHMP provides an overview of flood risk in Oregon and identifies the most significant floods in Oregon’s recorded history. It has overall state and regional information and includes flood related mitigation actions for the entire state. https://www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to coastal hazards, floods, and other natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of flooding including the Hazard Mitigation Grant Program, the Flood Mitigation Assistance Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, OEM notifies local public safety agencies and keeps them informed of potential and actual flood conditions so prevention and mitigation actions can be taken.

Oregon Water Resources Department

The OWRD is the state authority for dam safety with specific authorizing laws and implementing regulations. OWRD coordinates on but does not directly regulate the safety of dams owned by the United States or most dams used to generate hydropower. The OWRD has been striving to inspect the over 900 dams under its jurisdiction. The Dam Safety Program meets the minimum FEMA standard for Emergency Action Plans and sometimes exceeds FEMA guidance for dam safety inspections on schedule and for condition classification.

OWRD is the Oregon Emergency Response System contact in the event of a major emergency involving a state-regulated dam, or any dam in the State if the regulating agency is unknown. The Dam Safety Program also coordinates with the National Weather Service and the OEM on severe flood potential that could affect dams and other infrastructure.

State of Oregon Removal/Fill Law

The Oregon Removal/Fill Law, which is administered by the Oregon Department of State Lands (DSL), requires a permit for activities that would remove or fill 50 cubic yards or more of material in waters of the state (e.g., streams, lakes, wetlands). The City of Salem is a cooperating partner with DSL by maintaining waterway and wetlands maps for public use, referring affected owners to DSL, and coordinating permit activities.

Oregon's Wetlands Protection Program

Oregon's Wetlands Protection Program was created in 1989 to integrate federal and state rules concerning wetlands protection with the Oregon Land Use Planning Program. The Wetlands Program has a mandate to work closely with local governments and DSL to improve land use planning approaches to wetlands conservation. A local wetlands inventory is one component of that program. DSL also develops technical manuals, conducts wetlands workshops for planners, provides grant funds for wetlands planning, and works directly with local governments on wetlands planning tasks. Salem has compiled a local wetlands inventory for lands where development is likely to occur and identified those wetlands that provide the greatest benefit to the community. These significant wetlands are commonly found in flood-prone areas.

Oregon Department of Transportation

Oregon Department of Transportation (ODOT) travel information site, TripCheck, provides road conditions, weather information, and travel information. This website also provides information to help the public detour away from hazard areas during times of emergency. The TripCheck link also has road camera images to inform the public of road conditions prior to making a trip. https://tripcheck.com/

Silver Jackets

The Silver Jackets program is a joint state-federal-local flood mitigation subcommittee, which is tied to a national USACE initiative. In Oregon, Silver Jackets provides a forum where DLCD, DOGAMI, OEM, USACE, FEMA, U.S. Geological Survey (USGS), and additional federal, state and sometimes local and Tribal agencies can come together to collaboratively plan and implement flood mitigation, optimizing multi-agency utilization of federal assistance by leveraging state/ local/ Tribal resources, including data/ information, talent and funding, and preventing duplication among agencies.

Oregon established Silver Jackets as a subcommittee to the Interagency Hazard Mitigation Team (IHMT), with the primary intents of strengthening interagency relationships and cooperation, optimizing resources, and improving risk communication and messaging.

The Oregon Silver Jackets act as a catalyst in developing comprehensive and sustainable solutions to state flood hazard challenges. Objectives of this IHMT subcommittee include:

- Facilitate strategic life-cycle flood risk reduction,
- Create or supplement a continuous mechanism to collaboratively solve state-prioritized issues and implement or recommend those solutions,
- Improve processes, identifying and resolving gaps and counteractive programs,
- Leverage and optimize resources,
- Improve and increase flood risk communication and present a unified interagency message, and
- Establish close relationships to facilitate integrated post-disaster recovery solutions.

For more information regarding the Oregon Silver Jackets, refer to https://www.iwr.usace.army.mil/Silver-Jackets/State-Teams/Oregon/.

Local Resources

Zoning Ordinance – Floodplain Standards

Community participation in the NFIP requires the adoption and enforcement of a local floodplain management ordinance that controls development in the floodplain. Communities participating in the NFIP may adopt regulations that are more stringent than those contained in 44 CFR 60.3, but not less stringent.

Held within the City of Salem's Code of Ordinances (which includes zoning and other provisions) is Chapter 601, Floodplain Overlay Zone.

Salem has a *Floodplain Management Plan* (2018), which is referenced throughout this plan. The *Floodplain Management Plan* identifies flood hazards, establishes a program of activities to mitigate the hazards, and coordinates mitigation activities to prevent conflicts with other community needs. Additional information on Salem's *Floodplain Management Plan* can be found at the following site: https://www.cityofsalem.net/home/showpublisheddocument/1228/637789751589700000.

Flood Management Plan

Resulting from the *2017 Salem NHMP* mitigation strategy, the City of Salem created this floodplain management plan. The Salem *Floodplain Management Plan* (2018) identifies flood-related hazards and establishes an action plan for how to mitigate those hazards. Goals of the Flood Management Plan include: 1) develop and implement mitigation activities to protect human life; 2) protect existing buildings and infrastructure as well as future development from the impacts of natural hazards; 3) strengthen communication and coordination of public and private partnerships and emergency services among local, county, and regional governments and the private sector; and 4) enhance economic resilience to reduce the impact on the local economy.

Goal 5: Preserve and rehabilitate natural systems to serve natural hazard mitigation functions and protect natural resources.

Salem Area Comprehensive Plan

The *Salem Area Comprehensive Plan* (2022), is the long-range plan for guiding development in the Salem-Keizer urban area for the next 20 years. The Natural Resource goal of the Salem Area Comprehensive Plan is "To conserve open space, protect natural, historic, cultural and scenic resources, and to protect life and property from natural disasters and hazards." Regarding flood hazards, the plan specifies:

> Development in the floodplain shall be regulated to preserve and maintain the capability of the floodplain to convey the flood water discharges and to minimize danger to life and property.

Stormwater Master Plan

The Salem *Stormwater Master Plan* (2020), is a detailed part of the Salem Area Comprehensive Plan. The plan includes three major elements: (1) descriptions of the drainage basin for each major creek system; (2) a Drainage System Improvement Plan; and (3) a Stormwater Management Program Plan

As the *Stormwater Master Plan* (2020) indicates, several of Salem's major creek systems are in multiple jurisdictions. The drainage basins for most creek systems within Salem originate in rural areas outside the UGB including Battle, Croisan, Glenn-Gibson, Little Pudding, Mill, and Pettijohn-Laurel. Although most Salem creeks discharge into the Willamette River within the UGB, there are a few creek systems that can affect downstream communities that are not located along the Willamette River. These include Battle Creek discharges into Mill Creek near the City of Turner; Claggett Creek discharges near the City of Keizer; and Little Pudding River discharges into the Willamette River near Canby.

Salem is currently undergoing a process to update its *Stormwater Master Plan* (2020). One key issue affecting the plan's policies relates to how flood inundation data may be used for floodplain management.

For information on Stormwater Drainage Basin Plans, refer to the following:

Battle Creek Basin Plan, September 2019

Mill Creek Basin Plan, September 2019

Pringle Creek Basin Plan, September 2019

Salem Transportation System Plan (TSP)

The Salem *Transportation System Plan* (2020) provides a framework of goals, objectives, and policies that guides Salem's transportation system and recommends how Salem invest its resources in future transportation programs and infrastructure to meet anticipated travel demands. The TSP includes the following paragraph related to critical routes:

The City's arterial street system connects people to critical facilities as well as providing emergency response and evacuation routes in the event of natural hazards. Planning for and maintaining a robust network of critical routes supports the health and safety of the community. Identification of transportation improvement projects for both existing and new facilities should take into consideration the function of the street as a critical route for emergency management purposes. Data available to support this analysis includes identification of street segments that are prone to flooding and information gained through ridge inspection reports. Future transportation projects should consider opportunities to reduce the potential for critical routes to be blocked during major floods or other hazards.

Elevation Certificate Maintenance

Elevation certificates are administered by Salem's Public Works Department. The certificates are required for buildings constructed in the floodplain to demonstrate that the building is elevated adequately to protect it from flooding. The elevation certificate is an important administrative tool of the NFIP. It is used to determine the proper flood insurance premium rate; it can be used to document elevation information necessary to ensure compliance with community floodplain management regulations; and it may be used to support a request for a Letter of Map Amendment (LOMA), or Letter of Map Revision based on fill (LOMR-F). City of Salem has elevation certificates on file for many developed properties.

NOAA NWS and Salem Emergency Management

The National Weather Service (NOAA NWS) can predict severe weather events that may trigger prolonged or flash flood events. NOAA NWS can issue notices to response agencies and to the public via television, radio, internet and Weather Radios (formerly Tone Alert Radios) when the potential for flooding is likely. Salem Emergency Management, Salem Police, and the Salem Fire and Ambulance District coordinate with NOAA NWS when notices may be required to inform response agencies and the general public of potential flooding events.

This description is excerpted from the *Salem Emergency Management Plan* (2014).

> This Emergency Management Plan is an all-hazard plan that describes how the City of Salem will organize and respond to emergencies and disasters in the community. It is based on, and is compatible with, Federal, State of Oregon, and other applicable laws, regulations, plans, and policies, including Presidential Policy Directive 8, the National Response Framework, Oregon Office of Emergency Management Plan, and both Marion and Polk County Emergency Operations Plans.
>
> Response to emergency or disaster conditions in order to maximize the safety of the public and to minimize property damage is a primary responsibility of government. It is the goal of the City of Salem that responses to such conditions are conducted in the most organized, efficient, and effective manner possible. To aid in accomplishing this goal, the City of Salem has, in addition to promulgating this plan, formally adopted the principles of the National Incident Management System, including the Incident Command System and the National Response Framework.
>
> Consisting of a Basic Plan, Functional Annexes aligned with both Marion and Polk County Emergency Support Functions, and Incident Annexes, this Salem Emergency Management Plan provides a framework for coordinated response and recovery activities during a large-scale emergency. The plan describes how various agencies and organizations in the City of Salem will coordinate resources and activities with other Federal, State, local, tribal, and private-sector partners.

Hazardous Materials Incident

Significant Changes Since Previous Plan:

There have not been significant changes to this hazard since the previous plan, however, this section has been reformatted.

Causes and Characteristics

For the purposes of mitigation planning, hazardous materials releases are considered a secondary hazard derived from the impact of a natural hazard event (i.e., flooding in a chemical storage area could result in toxic levels of chemicals in water or air). Hazardous materials may be defined simply as any materials that may have negative impacts on human health. That is, exposure to hazardous materials may result in injury, sickness, or death. They may also include materials that may cause negative impacts on the environment or on animal or plant species.

Hazardous chemicals are widely used in heavy industry, manufacturing, agriculture, mining, the oil and gas industry, forestry, and transportation as well as in medical facilities and commercial, public, and residential buildings. There are literally hundreds of thousands of chemicals that may be hazardous to human health, at least to some extent. A typical single-family home may contain dozens of potentially hazardous materials including fuels, paints, solvents, cleaning chemicals, pesticides, herbicides, medicines and others. However, for mitigation planning purposes, small quantities of slightly or moderately hazardous materials being used by end users are rarely the focus of interest. Rather, interest is focused primarily on larger quantities of hazardous materials in industrial use and on hazardous materials being transported, where the potential for accidental spills is high. Situations involving extremely hazardous materials or large quantities of hazardous materials in locations where accidents or malevolent actions (terrorism or sabotage) may result in significant public health risk are of special concern for planning purposes.

The severity of any hazardous material release incident for an affected community depends on several factors, including the toxicity, quantity, and dispersal characteristics of the hazardous material; local conditions such as wind direction, topography, soil and ground water characteristics; proximity to drinking water resources and populations.

There are three principal modes of human exposure to hazardous materials, **inhalation** of gaseous or particulate materials via the respiratory (breathing) process; **ingestion** of hazardous materials via contaminated food or water; and **direct contact** with skin or eyes.

Location and Extent

Hazardous materials incidents would likely be localized near the source of the incident, but major incidents could have extensive evacuation zones and affect a significant portion of Salem. The potential for casualties, including death and injury, is dependent on the location of incident, time of day, effectiveness of evacuation and materials involved.

The Office of State Fire Marshal maintains a hazardous materials database provided to city Fire Departments. The database includes information on chemicals stored by address with name, and phone number. Salem Environmental Services maintains a vast database (e.g., underground fuel tanks, waste generators, contaminated properties, etc.). These and other databases are linked to addresses of sites that use/generate hazardous materials/waste. The Salem Fire Department and Public Works have utilized the information in these databases and have a full-capacity hazmat response team to respond to hazardous materials incidents.

In Salem, specific places have higher than average risks for hazardous material releases. Trucking routes along I-5 and Highway 22 that run through Salem are vulnerable because of the quantity of materials transported along these routes. Also, the railroad lines that run through downtown Salem near the Capitol area are a concern because they carry significant quantities of hazardous materials transported through Salem each year. Figure 2-33 identifies important facilities and hazardous materials locations.

History

According to the Office of the State Fire Marshal *Community Right-to-Know (CR2K) Hazardous Substance Incident Search*, between 2013 and May 2017, there have been 102 (20 involving hazmat teams) reported hazardous materials incidents, most of which have been negligible. Gas leaks are reported as the most common type of hazardous materials incident reported in the city. Most incidents are reported as unintentional accidents, but there are a few incidents of intentional hazardous materials release and/or exposure, all of which were effectively, and safety managed.

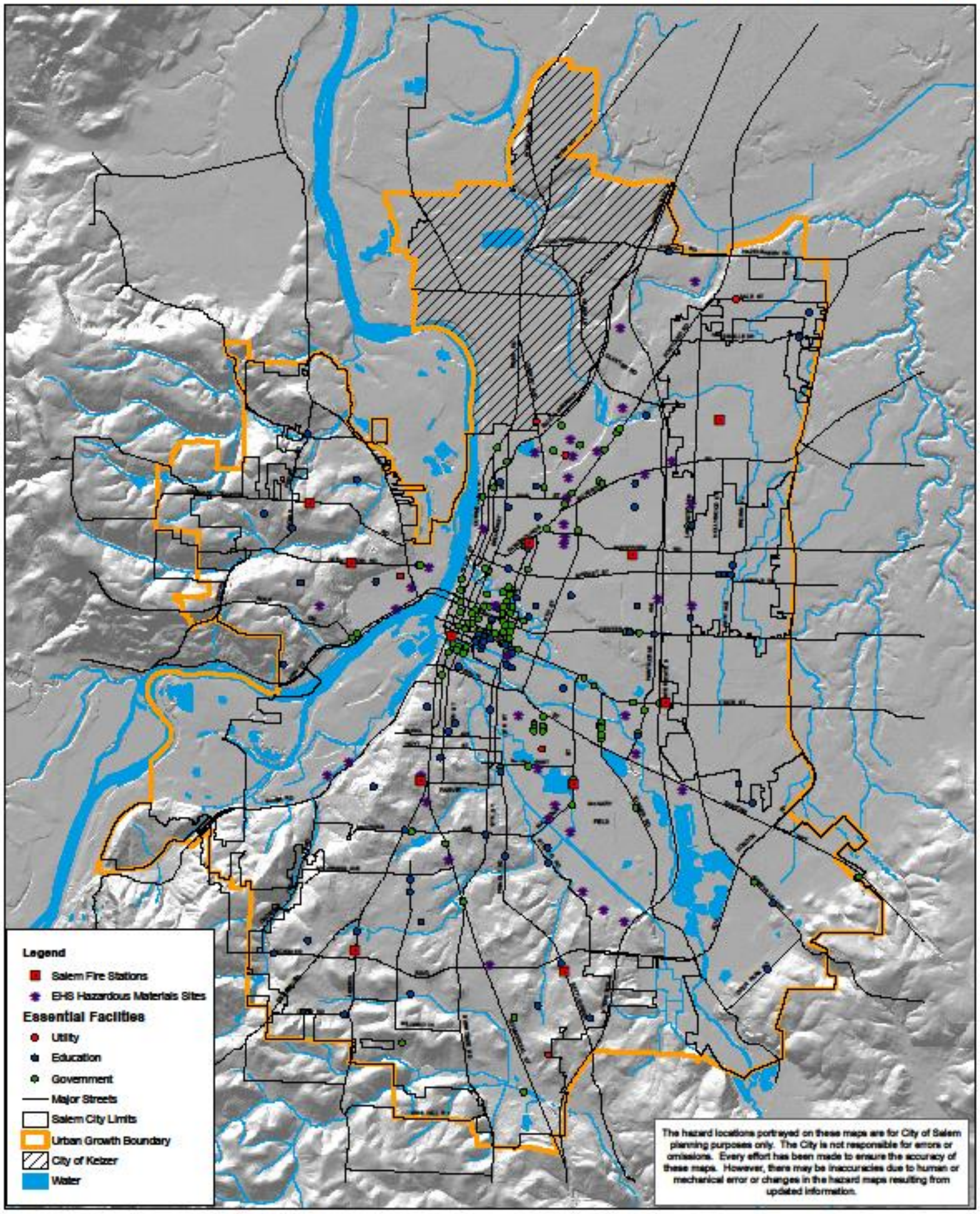
Future Climate Variability

Future climate variability does not affect the community’s hazardous materials incident risk.

Probability Assessment

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing a hazardous materials event is “moderate,”** meaning one incident is likely within the next 35-to-75-year period; this rating has not changed since the previous plan.

Figure 2-33 Important Facilities and Hazardous Materials Locations



Source: City of Salem

Vulnerability Assessment

Hazardous materials events in the past caused multiple minor injuries or a major injury impacting the health and safety of residents. However, the potential for injuries or deaths from past events or from similar events in other communities could escalate resulting in multiple deaths and major injuries. It is estimated that less than 10% of the city's population would be physically displaced by a hazardous materials incident, likely the result of a minor spill or leak, and there would be mild impact on community social networks.

Facilities throughout the city are anticipated to reflect minor damage to several facilities due to hazardous materials, estimated between $1 million to $10 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely 10-30% of businesses located in the city and surrounding area would experience commerce interruption for a period of at least a few days. Hazardous materials can be extremely dangerous, and businesses will be forced to closed if they are within the incident impact radius. Lastly, extreme heat would likely have extensive impacts on more than 75% of the city's ecological systems, including, clean water, wildlife habitat, and parks.

Many facilities throughout the city hold and store hazardous materials, the areas surrounding these facilities and the adjacent transport network that carry the substances are especially vulnerable. As such, the NHMP Steering Committee rated the city as having a **"high" vulnerability to hazardous materials hazards**, meaning that more than 10% of the city's population or assets would be affected by a major disaster; this rating has not changed since the previous plan.

Landslide

> **Significant Changes Since Previous Plan:**
>
> The Landslide Hazard section was reformatted and expanded with additional information since the previous plan.

Causes and Characteristics

A landslide is any detached mass of soil, rock, or debris that falls, slides or flows down a slope or a stream channel. Landslides are classified according to the type and rate of movement and the type of materials that are transported. In a landslide, two forces are at work: 1) the driving forces that cause the material to move down slope, and 2) the friction forces and strength of materials that act to retard the movement and stabilize the slope. When the driving forces exceed the resisting forces, a landslide occurs.

Natural conditions and human activities can both play a role in causing landslides. Certain geologic formations are more susceptible to landslides than others. The incidence of landslides and their impact on people and property can be accelerated by development. Landslides often occur together with other natural hazards, thereby exacerbating conditions, as described below:

- Shaking due to earthquakes can trigger events ranging from rockfalls and topples to massive slides.
- Intense or prolonged precipitation that causes flooding can also saturate slopes and cause failures leading to landslides.
- Landslides into a reservoir can indirectly compromise dam safety, and a landslide can even affect the dam itself.
- Wildfires can remove vegetation from hillsides, significantly increasing runoff and landslide potential.
- Natural conditions and processes including the geology of the site, rainfall, rapid snow melt, freeze/thaw cycles, wave and water action, and volcanic activity.

According to DOGAMI's *Landslide Hazards in Oregon* (2008), the following are other factors – natural or human-caused – that affect or increase the likelihood of landslides:

- Excavation and grading on sloping ground for homes, roads and other structures.
- 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 stormwater management and excess runoff due to increased impervious surfaces.
- Any combination of these factors.

Types of Landslides

Slides

Slides move in contact with the underlying surface. These movements include rotational slides where sliding material moves along a curved surface and translational slides where movement occurs along a flat surface. These slides are generally slow moving and can be deep. Slow-moving landslides can occur on relatively gentle slopes and can cause significant property damage but are far less likely to result in serious injuries than rapidly moving landslides, according to the 2020 Oregon NHMP.

Topples and Falls

Rock falls occur when blocks of material come loose on steep slopes. Weathering, erosion, or excavations, such as those along highways, can cause falls where the road has been cut through bedrock. They are fast moving with the materials free falling or bouncing down the slope.

In falls, material is detached from a steep slope or cliff. The volume of material involved is generally small, but large boulders or blocks of rock can cause significant damage. Rock falls have the potential to break off power poles located on hillsides (Eichorn, 2004).

Spreads

Spreads are an extension and subsidence of commonly cohesive materials overlying layers. They are commonly triggered by earthquakes. Spreads usually occur on gentle slopes near open bodies of water, according to DOGAMI's *Landslide Hazards in Oregon* (2008).

Flows

Flows are plastic or liquid movements in which land mass (e.g., soil and rock) breaks up and flows during movement. Earthquakes often trigger flows (Robert Olson Associates, 1999). Flows can be either channelized and unchannelized and may also be called debris avalanches and earth flows. Debris flows normally occur when a landslide moves downslope as a semi-fluid mass scouring, or partially scouring soils from the slope along its path. Flows are typically rapidly moving and tend to increase in volume as they scour out the channel (Robert Olson Associates, 1999). Flows often occur during heavy rainfall, can occur on gentle slopes, and can move rapidly for large distances.

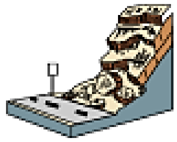
The channelized debris flow, which is sometimes referred to as "rapidly moving landslide" can be life threatening. They often initiate on a steep slope, move into a steep channel (or drainage), increase in volume by incorporating channel materials, and then deposit material, usually at the mouth of the channel on existing fans. Debris flows are commonly mobilized by other types of landslides that occur on slopes near a channel.

Over time, ditches and culverts beneath hillside roads can become blocked with debris. If the ditches are blocked, run-off from the slopes is inhibited during periods of precipitation. This causes the run-off water to collect in soil, and in some cases, cause a slide. Usually the slides are small (100 – 1,000 cubic yards), but the flow can be quite large.

Complex

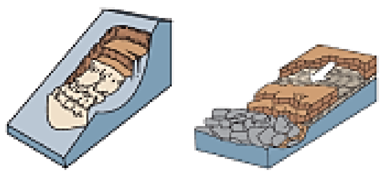
Complex landslides are the combinations of two or more types. A common complex landslide is a slump-earth flow, which usually exhibits slump features in the upper region and earth flow features near the toe (Burns & Madin, 2009).

Figure 2-34 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.

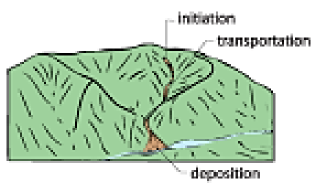
Topples are distinguished by forward rotation about some pivotal point, below or low in the mass.



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

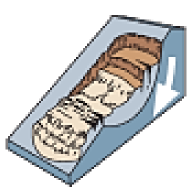
- **Rotational** slides move along a surface of rupture that is curved and concave.
- **Translational** slides displace along a planar or undulating surface of rupture, sliding out over the original ground surface.

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: Burns, W. J. et al. (2019, October). *Preparing for Landslide Hazards, A Land Use Guide for Oregon Communities*. Oregon DLCD and DOGAMI. Retrieved from https://www.oregon.gov/lcd/Publications/Landslide_Hazards_Land_Use_Guide_2019.pdf.

Location and Extent

The characteristics of the minerals and soils present in Salem indicate the potential types of hazards that may occur. Rock hardness and soil characteristics can determine whether an area will be prone to geologic hazards such as landslides.

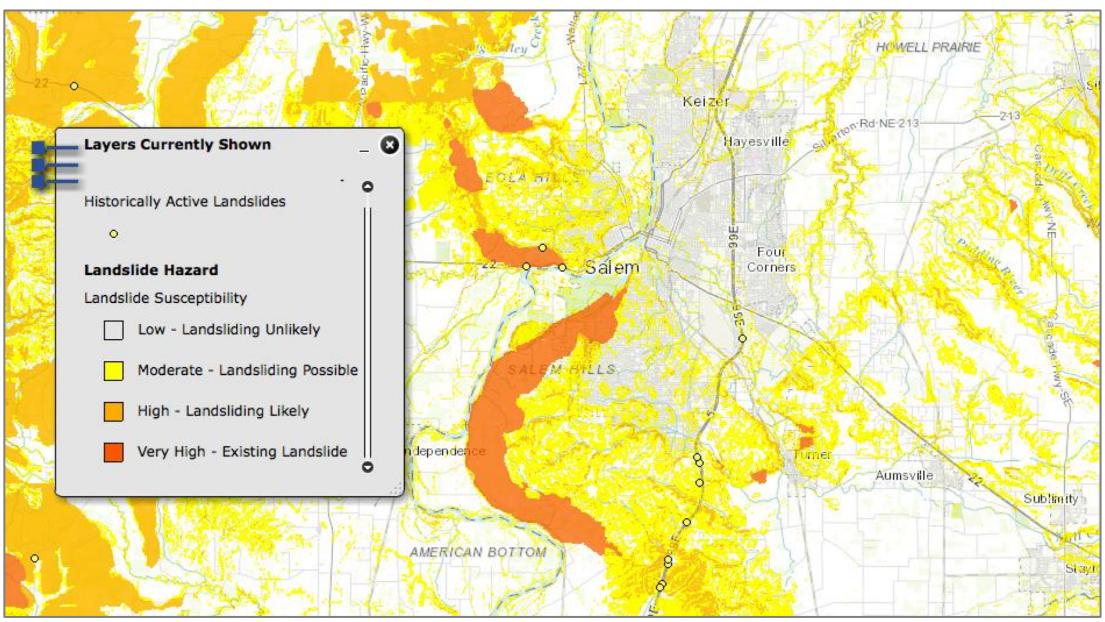
In general, areas at risk to landslides have steep slopes (25 percent or greater,) or a history of nearby landslides. In otherwise gently sloped areas, landslides can occur along steep river and creek banks, and along ocean bluff faces. At natural slopes under 30 percent, most landslide hazards are related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

Landslides and debris flows are possible in any of the higher slope portions of Salem, including much of the western portion of the city (see Figure 2-35).

DOGAMI's *Multi-Hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022), which includes Salem, acknowledges that most of the land in the county is located on gentle terrain, which is typically low susceptibility landslide zones. However, the report states areas of greater risk to landslide hazard include, "The residential neighborhoods in the southwestern portions of Salem and just outside of Salem (mapped as Very High susceptibility)."

Figure 2-35 Landslide Susceptibility Exposure



Source: DOGAMI Statewide Landslide Information Layer for Oregon (SLIDO)

More detailed landslide hazard assessment at specific locations requires a site-specific analysis of the slope, soil/rock and groundwater characteristics at a specific site. Such assessments are often conducted prior to major development projects in areas with moderate to high landslide potential, to evaluate the specific hazard at the development site.

Table 2-14 shows landslide susceptibility exposure for Salem. Approximately 7% of the city land has High or Very High landslide susceptibility exposure. Note that even if a city has a high percentage of area in a high or very high landslide exposure susceptibility zone, this does not mean there is a high risk, because risk is the intersection of hazard and assets.

Table 2-14 Landslide Susceptibility Exposure

Jurisdiction	Area, ft^2	Low	Moderate	High	Very High
Salem	1,368,874,853	69.3%	23.3%	3.5%	3.9%

Source: Burns, W. J., Mickelson K. A., & Madin, I. P. (2016*). Open-File Report O-16-02, Landslide susceptibility overview map of Oregon*. Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/p-O-16-02.htm.

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.

For more information, refer to the following reports:

Open-File Report: O-2016-02, Landslide Susceptibility Overview Map of Oregon

Open-File Report: O-2010-03, Digital geologic map of the southern Willamette Valley, Benton, Lane, Linn, Marion, and Polk Counties, Oregon

Open-File Report: O-2020-12, Landslide inventory for a portion of Marion County, Oregon

Open-File Report O-2021-14, Landslide, coseismic liquefaction susceptibility, and coseismic soil amplification class maps, Benton, Marion, Morrow, And Washington Counties, Oregon

Special Paper 34: Slope failures in Oregon: GIS inventory for three 1996/97 storm events, 2000

Additional reports are available via DOGAMI's Publications Center website: https://www.oregongeology.org/pubs/

Identifying Landslides

Landslides are very difficult to predict. Landslides are downhill or lateral movements of rock, debris, or soil mass. 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. Landslides are given different names depending on the type of failure and their composition and characteristics.

According to DOGAMI's *Landslides Hazards in Oregon*, all landslides can be classified into six types of movement: 1) slides, 2) topples, 3) falls, 4) spreads, 5) flows, and 6) complex, which are described above.

Although the factors determining what type of movement will manifest for any given landslide are very complex, the topographic nature of the slope and the type of slope material often play dominant roles. Most slope failures are complex combinations of these distinct types, but the generalized groupings provide a useful means for framing discussion of the type of hazard and potential mitigation alternatives. 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 the landslide behavior more fully. It is common for failures to reoccur where previous ones happened; this is true for all types of landslide movements and over periods much longer than human recorded history.

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, 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.

For a more complete description of the different types of landslides, see U.S. Transportation Research Board *Landslides: Investigation and Mitigation, Special Report 247* (Turner & Schuster, 1996), which has an extensive chapter on landslide types and processes.

Regarding identifying applicable conditions that may trigger a landslide or debris flow event, a notice starts with the National Weather Service. The NWS uses unique language in their flood watch products. Once this information is received, Oregon DOGAMI posts on their website an alert message including a link to the NWS notice and they send out a press release to affected areas. Oregon Department of Emergency Management broadcasts the alert message and ODOT will turn on highway warning signs at appropriate locations and post on the TripCheck website (https://tripcheck.com/).

History

Landslides are a chronic problem in Oregon, affecting both infrastructure and private property. Approximately 13,048 documented landslides have occurred in Oregon in the last 150 years. The combination of geology, precipitation, topography, and seismic activity makes portions of Oregon especially prone to landslides (Burns et al., 2019).

Landslides may happen at any time of the year. In addition to landslides triggered by a combination of slope stability and water content, earthquakes may also trigger landslides. Areas prone to seismically triggered landslides are generally the same as those prone to ordinary (i.e., non-seismic) landslides. As with ordinary landslides, seismically triggered landslides are more likely for earthquakes that occur when soils are saturated with water.

Debris flows and landslides are a very common occurrence in hilly areas of Oregon, including portions of Salem. Many landslides occur in undeveloped areas and thus may go unnoticed or unreported. For example, DOGAMI conducted a statewide survey of landslides from four winter storms in 1996 and 1997 and found 9,582 documented landslides, with the actual number of landslides estimated to be many times the documented number. For the most part, landslides become a problem only when they impact developed areas and have the potential to damage buildings, roads, or utilities.

In February 1996, November 1996, and December 1996/January 1997 the Willamette Valley experienced heavy rainfall and snowmelt which led to widespread landslide events throughout the state. Disaster declarations were issued for Marion County for the February 1996 and December 1996/January 1997 storms (Governor Executive Orders EO-96-12, EO-97-9). During these storms, many landslides occurred in the eastern portion of the state and are too numerous to list here. In 2000, DOGAMI mapped the historical instances of landslide events throughout the Willamette Valley for the 1996-1997 storms, including Salem (Harvey & Peterson, 1998). Landslides also occurred with heavy rain events in January 2012 (FEMA-4055-DR-OR), February 2014 (FEMA-4169-DR-OR), and December 2015 (FEMA-4258-DR-OR).

The geologic setting of the Salem Hills illustrates a historic pattern of landslides. Many prominent features that help identify the ancient landslide terrain are hummocky topography, disrupted drainage patterns, sag ponds, springs, back-tilted bedrock blocks, and subdued head scarps. In 2005, a landslide blocked traffic to the Salem along South River Road, near South Owen Street. The 2005 Slide did not damage any homes. Another landslide occurred in January of 2011 on South River Road between Owens Street and Croissan Creek. The slide brought down a boulder that blocked thoroughfare.

For additional history see flood section above for events that included landslides.

Future Climate Variability

According to the Marion County Future Projections Report, the climate risk primarily associated with landslides is heavy rain and its related metrics as landslides may result from the increased weight of soils saturated with water. “There is greater uncertainty in projections of future precipitation than projections of future temperature. Precipitation has high natural variability, and the atmospheric patterns that influence precipitation are represented differently among global climate models.” While “by the 2050s under the higher emissions scenario, the average number of days per year in Marion County on which the landslide risk threshold is exceeded is projected to remain about the same, with a change of -0.2 days,” landslide risk depends on multiple site-specific factors and this metric does not reflect all aspects of the hazard (Dalton, Fleishman, & Bachelet, 2022).

“Landslide risk also can become high when heavy precipitation falls on an area that burned within approximately the past five to ten years. By the year 2100, under the higher emissions scenario, the probability that an extreme rainfall event will occur within one year after an extreme fire-weather event in Oregon or Washington was projected to increase by 700% relative to 1980–2005 (Touma et al., 2022).” (Dalton, Fleishman, & Bachelet, 2022)

Probability Assessment

The probability of rapidly moving landslides occurring depends on several factors; these include steepness of slope, slope materials, local geology, vegetative cover, human activity, and water. There is a strong correlation between intensive winter rainstorms and the occurrence of rapidly moving landslides (debris flows). The Oregon Department of Forestry (ODF) tracks storms during the rainy season, monitors rain gauges and snow melt, and issues warnings as conditions warrant. Other agencies such as ODOT, DOGAMI, USGS, and National Weather Service also track weather conditions and potential landslide situations.

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing a landslide is "high,"** meaning at least one incident is likely within the next 35-year period.

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

National Weather Service

The National Weather Service issues severe winter storm watches and warnings when appropriate to alert government agencies and the public of possible or impending weather events. Four NWS offices cover Oregon: Portland (NW), Medford (SW), Pendleton (NE), and Boise (East and SE). The watches and warnings are broadcast over NOAA weather radio and are forwarded to the local news media for retransmission using the Emergency Alert System. The landslide warning system as developed in direct coordination with the Portland NWS office and state agencies (Burns, Francyzk, 2021), such as DOGAMI. State agency coordination is detailed below.

National Resources Conservation Service

The NRCS provides a suite of federal programs designed to assist state and local governments and landowners in mitigating the impacts of flood events. Since flood events can trigger landslide events, the NRCS programs provide a nexus. The Watershed Surveys and Planning Program and the Small Watershed Program provide technical and financial assistance to help participants solve natural resource and related economic problems on a watershed basis. The Wetlands Reserve Program and the Flood Risk Reduction Program provide financial incentives to landowners to put aside land that is either a wetland resource or that experiences frequent flooding. The Emergency Watershed Protection Program provides technical and financial assistance to clearing debris from clogged waterways, restoring vegetation, and stabilizing riverbanks. The measures taken under EWP must be environmentally and economically sound and generally benefit more than one property.

State Resources

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to coastal hazards, floods, and other natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909.

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of natural hazards including the Hazard Mitigation Grant Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, such as the landslide warning system, OEM notifies local public safety agencies and keeps them informed of potential and actual hazard events so prevention and mitigation actions can be taken.

Oregon Department of Geology and Mineral Industries

Regarding current landslide warning system in Oregon, DOGAMI's *History of Oregon Landslide Warning System* (2021) states,

> The current landslide warning system developed over years with additions and modifications to the language and changes to system responsibilities. As of 2019, a notice about the potential for landslides or debris flows starts with NWS, by using unique language in their flood watch products. After receiving NWS flood watches with landslide language via an RSS feed, DOGAMI posts on its website an alert message including a link to the NWS flood watch message, sends out a press release to the affected areas, and responds to media inquiries. OEM broadcasts the alert through the Oregon Emergency Response System (OERS). ODOT turns on highway warning signs at the appropriate locations and posts alerts on the TripCheck website (https://tripcheck.com/) The current process was outlined in a June 2018 DOGAMI internal communication document on landslide/debris flow alerts, developed by Bill Burns and then DOGAMI Communications Director Ali Hansen. Figure 7 graphically depicts the current communication process.

Vulnerability Assessment

Landslides are very difficult to predict. Vulnerability assessments assist in predicting how different types of property and population groups will be affected by a hazard. The optimum method for doing this analysis at the city or county level is to use parcel-specific assessment data on land use and structures. Data that includes specific landslide-prone and debris flow locations in the county can be used to assess the population and total value of property at risk from future landslide occurrences.

Landslides can occur on their own or in conjunction with other hazards, such as flash flooding. Depending upon the type, location, severity and area affected, severe property damage, injuries and loss of life can be caused by landslide hazards. Landslides can damage or temporarily disrupt utility services, block off or damage roads, critical lifeline services such as police, fire, medical, utility and communication systems, and emergency response. Communities may suffer immediate damages and loss of service. Disruption of infrastructure, roads, and critical facilities may also have a long-term effect on the economy. Utilities, including potable water, wastewater, telecommunications, natural gas, and electric power are all essential to service community needs. Loss of electricity has the most widespread impact on other utilities and on the whole community. Natural gas pipes may also be at risk of breakage from landslide movements as small as an inch or two.

Roads and bridges are subject to closure during landslide events. Because many Salem residents are dependent on roads and bridges for travel to work, delays and detours are likely to have an economic impact on city residents and businesses. To evaluate landslide mitigation for roads, the community can assess the number of vehicle trips per day, detour time around a road closure, and road use for commercial traffic or emergency access.

Lifelines and critical facilities should remain accessible if possible, during a natural hazard event. The impact of closed transportation arteries may be increased if the closed road or bridge is a critical lifeline to hospitals or other emergency facilities. Therefore, inspection and repair of critical transportation facilities and routes is essential and should receive high priority. Losses of power and phone service are also potential consequences of landslide events. Due to heavy rains, soil erosion in hillside areas can be accelerated, resulting in loss of soil support beneath high voltage transmission towers in hillsides and remote areas. Flood events can also cause landslides, which can have serious impacts on gas lines.

A quantitative landslide hazard assessment requires overlay of landslide hazards (frequency and severity of landslides) with the inventory exposed to the hazard (value and vulnerability) by considering:

1. Extent of landslide susceptible areas;
2. Inventory of buildings and infrastructure in landslide susceptible areas;
3. Severity of earthquakes or winter storm event (inches of rainfall in 24 hours);
4. Percentage of landslide susceptible areas that will move and the range of movements (displacements) likely; and
5. Vulnerability (amount of damage for various ranges of movement).

Currently, data does not allow for specific estimates of life and property losses during a given scenario.

Landslides in the past caused few minor injuries. However, the potential for injuries or deaths from past events or from similar events in other communities could escalate resulting in multiple minor injuries and a possible major injury. Salem estimates that less than 10% of the city's population could be physically displaced by a landslide, considering landslide events tend to have localized impacts; and there would be little to no impact on community social networks. As noted above and in the *Multi-Hazard Risk Report for Marion County, Oregon* report, it states that areas of greater risk to landslide hazard in the city include, "The residential neighborhoods in the southwestern portions of Salem and just outside of Salem (mapped as Very High susceptibility)" (Williams & Madin, 2022).

Multiple facilities throughout the city anticipate moderate damage due to a landslide, estimated at less than $1 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely that less than 10% of businesses located in the city and surrounding area could experience commerce interruption for a period of days. Landslide hazards have the potential to affect transportation and may inhibit access to businesses until roadways can be cleared. Lastly, landslides would likely have mild impacts on 10-25% of the City's ecological systems, including, clean water, wildlife habitat, and parks.

According to DOGAMI's *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022), during a high and very high susceptibility landslide scenario, there is the potential to have 12,356 displaced residents, 4,031 exposed buildings, 1 of which is a critical facility. Exposed building value of $1,378,070,000 (exposure ratio 9.3%).

As such, the NHMP Steering Committee rated the city as having a **"low" vulnerability to landslide hazards**, meaning that less than 1% of the city's population or assets would be affected by a major disaster.

Volcano

Significant Changes Since Previous Plan:

The Volcano Hazard section was reformatted and expanded with additional information since the previous plan.

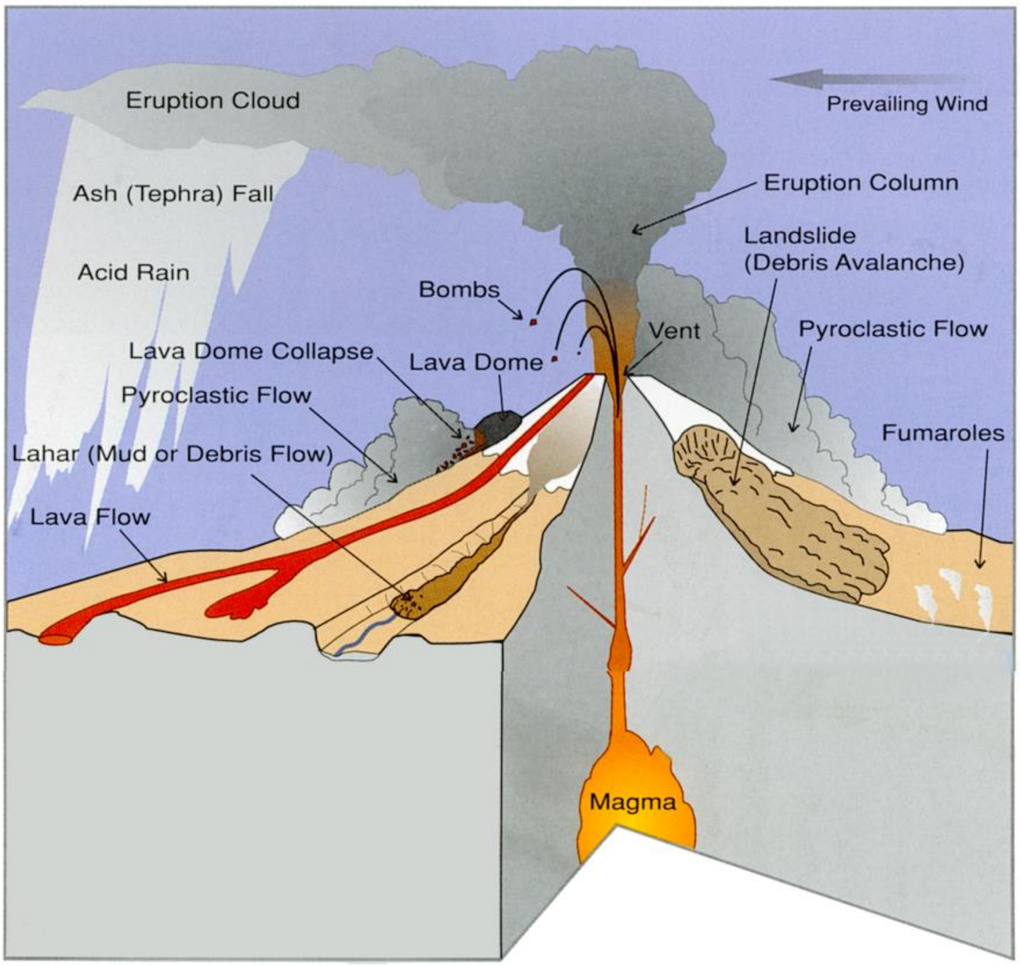
Causes and Characteristics

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

The primary threat to lives and property from active volcanoes is from violent eruptions that unleash tremendous blast forces, generate mud and debris flows, or produce flying debris and ash clouds. The immediate danger area in a volcanic eruption generally lies within a 20-

mile radius of the blast site. The following section outlines the specific hazards posed by volcanoes.

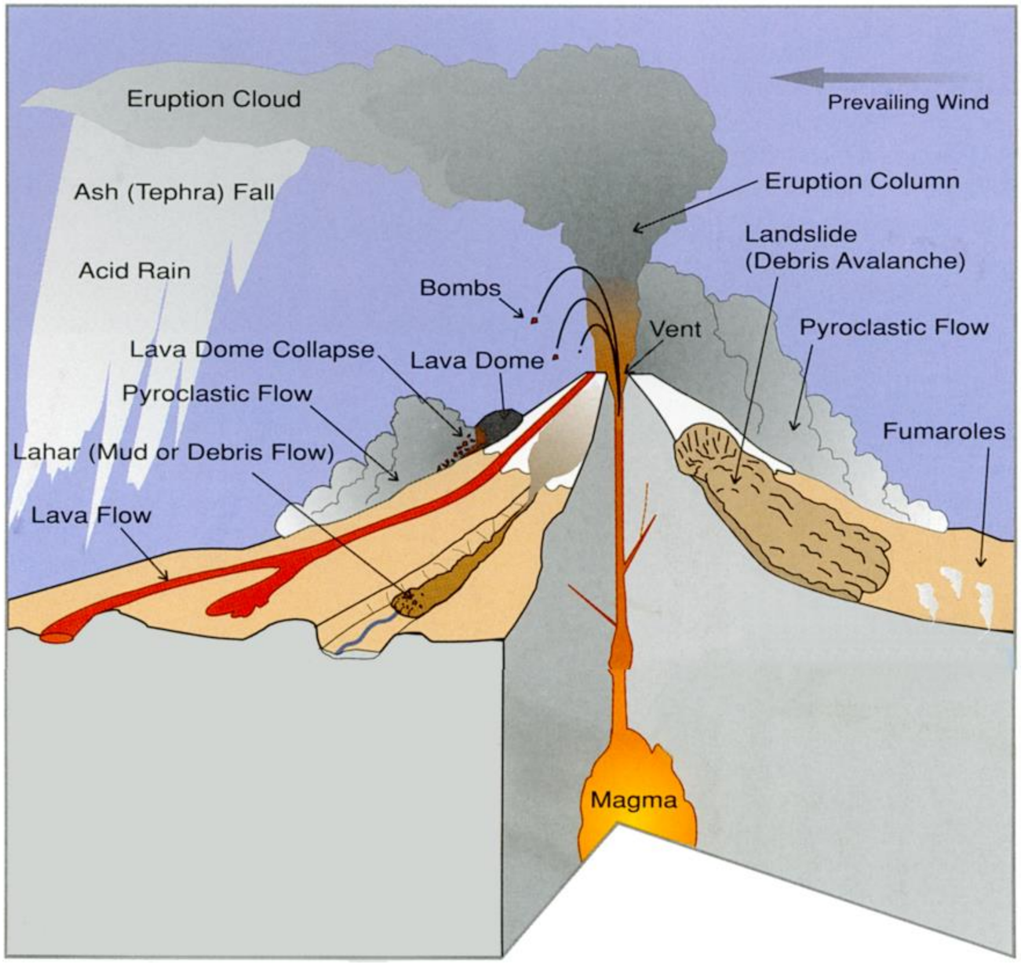
According to the USGS General Interest Publication, *Volcanoes* (Tillings, 1999), volcanoes are commonly conical hills or mountains built around a vent that connect with reservoirs of molten rock below the surface of the earth. Some younger volcanoes may connect directly with reservoirs of molten rock, while most volcanoes connect to empty chambers. Unlike most mountains, which are pushed up from below, volcanoes are built up by an accumulation of their own eruptive products: lava or ash flows and airborne ash and dust. When pressure from gases or molten rock becomes strong enough to cause an upsurge, eruptions occur. Gases and rocks are pushed through the opening and spill over or fill the air with lava fragments.



diagrams the basic features of a volcano.

Volcanic eruptions often involve several distinct types of hazards to people and property, as well evidenced by the Mount St. Helens eruption. Major volcanic hazards include eruption columns and clouds, volcanic gases, lava flows and domes, pyroclastic flows, volcanic landslides, and lahars, which are described below. Some of these hazards (e.g., lava flows) only affect areas very near the volcano. Other hazards may affect areas 10 to 20 miles away from the volcano, while ash falls may affect areas many miles downwind of the eruption site.

Figure 2-36 Volcanic Hazard from a Composite Type Volcano



Source: Walder, J. S., Gardner, C., Conrey, R. M., Fisher, B. J. & Schilling, S. P. (2000). *Open-File Report 99-24 Volcano Hazards in the Mount Jefferson Region, Oregon*. USGS. Retrieved from https://pubs.usgs.gov/of/1999/0024/.

Characteristics of Volcanoes

Eruption Columns and Clouds

An explosive eruption blasts solid and molten rock fragments called tephra and volcanic gases into the air with tremendous force. The largest rock fragments, called bombs, usually fall back to the ground within two miles of the vent. Small fragments (less than 0.1 inch across) of volcanic glass, mineral and rock (ash) rise high into the air forming a huge, billowing eruption column. Eruption columns creating an eruption cloud can grow rapidly and reach more than 12 miles above a volcano in less than 30 minutes. Volcanic ash clouds can pose serious hazards to aviation. Several commercial jets have nearly crashed because of engine failure from inadvertently flying into ash clouds.

Large eruption clouds can extend hundreds of miles downwind resulting in ash fall over enormous areas. Ash from the May 18, 1980 Mt. St. Helens eruption fell over an area of 22,000 square miles in the western U.S. Heavy ash fall, particularly when mixed with rain, can collapse buildings and even a minor ash fall can damage crops, electronics, and machinery.

Ash/Tephra

Tephra consists of volcanic ash (sand-sized or finer particles of volcanic rock) and larger fragments. During explosive eruptions, tephra together with a mixture of hot volcanic gas are ejected rapidly into the air from volcanic vents. Larger fragments fall near the volcanic vent while finer particles drift downwind as a large cloud. When ash particles fall to the ground, they can form a blanket-like deposit, with finer grains carried further away from the volcano. In general, the thickness of ash fall deposits decreases in the downwind direction. Tephra hazards include impact of falling fragments, suspension of abrasive fine particles in the air and water, and burial of structures, transportation routes and vegetation.

According to the *2020 Oregon Natural Hazard Mitigation Plan*, during an eruption that emits ash, the ash fall deposition is controlled by the prevailing wind direction. The predominant wind pattern over the Cascades is from the west, and previous eruptions seen in the geologic record have resulted in most ash fall drifting to the east of the volcanoes.

Volcanic Gases

Volcanoes emit gases during eruptions. Even when a volcano is not erupting, cracks in the ground allow gases to reach the surface through small openings called fumaroles. More than 90 percent of all gas emitted by volcanoes is water vapor (steam), most of which is heated ground water. Other common volcanic gases are carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen and fluorine. In higher concentrations, these gases can cause corrosion, contaminate domestic water supplies and harm or even kill vegetation, livestock, and people.

Lava Flows and Domes

Lava flows are streams of molten rock that erupt relatively non-explosively from a volcano and move downslope, causing extensive damage or destruction by burning, crushing, or burying everything in their paths. Secondary effects can include forest fires, flooding, and permanent reconfiguration of stream channels, according to the 2020 Oregon NHMP.

Pyroclastic Flows and Surges

Pyroclastic flows are avalanches of rock and gas at temperatures of 600 to 1500 degrees Fahrenheit. They typically sweep down the flanks of volcanoes at speeds of up to 150 miles per hour. Pyroclastic surges are a more dilute mixture of gas and rock. They can move even more rapidly than a pyroclastic flow and are more mobile. Both generally follow valleys but surges sometimes have enough momentum to overtop hills or ridges in their paths. Because of their high speed, pyroclastic flows and surges are difficult or impossible to escape. If it is expected that they will occur, evacuation orders should be issued as soon as possible for the hazardous areas. Objects and structures in the path of a pyroclastic flow are generally destroyed or swept away by the impact of debris or by accompanying hurricane-force winds. Wood and other combustible materials are commonly burned. People and animals may also be burned or killed by inhaling hot ash and gases. The deposit that results from pyroclastic flows is a combination of rock bombs and ash and is termed *ignimbrite.* These deposits may accumulate to hundreds of feet thick and can harden to resistant rock. The climactic eruption of Mount St. Helens generated a series of explosions that formed a huge pyroclastic surge which destroyed an area of 230 square miles and leveled trees six feet in diameter as far as 15 miles from the volcano.

Volcanic Landslides/Debris Avalanches

Volcanic eruptions can be triggered by seismic activity or earthquakes can occur during or after a volcanic eruption. Earthquakes produced by stress changes are called volcano-tectonic earthquakes. These earthquakes, typically small to moderate in magnitude, occur as rock is moving to fill in spaces where magma is no longer present and can cause land to subside or produce large ground cracks (Riley). In addition to being generated after an eruption and magma withdrawal, these earthquakes also occur as magma is intruding upward into a volcano, opening cracks and pressurizing systems (Scott, 2001). Volcano-tectonic earthquakes do not indicate that the volcano will be erupting but can occur at any time and cause damage to manmade structures or provoke landslides. (Wright & Pierson, 1992)

Lahars and Debris Flows

Lahar is an Indonesian term that describes a hot or cold mixture of water and rock fragments flowing down the slopes of a volcano or river valley, according to the USGS Cascades Volcano Observatory. Lahars typically begin when floods related to volcanism are produced by melting snow and ice during eruptions of ice-clad volcanoes like Mount Shasta, and by heavy rains that may accompany eruptions. Floods can also be generated by eruption-caused waves that could overtop dams or move down outlet streams from lakes.

Lahars react much like flash flood events in that a rapidly moving mass moves downstream, picking up more sediment and debris as it scours out a channel. This initial flow can also incorporate water from rivers, melting snow and ice. By eroding rock debris and incorporating additional water, lahars can easily grow to more than ten times their initial size. But as a lahar moves farther away from a volcano, according to USGS Cascades Volcano Observatory, it will eventually begin to lose its heavy load of sediment and decrease in size.

Lahars often cause serious economic and environmental damage. According to USGS, the direct impact of a lahar's turbulent flow front or from the boulders and logs carried by the lahar can easily crush, abrade, or shear off at ground level just about anything in the path of a lahar. Even if not crushed or carried away by the force of a lahar, buildings and valuable land may become partially or completely buried by one or more cement-like layers of rock debris. By destroying bridges and key roads, lahars can also trap people in areas vulnerable to other hazardous volcanic activity, especially if the lahars leave deposits that are too deep, too soft, or too hot to cross.

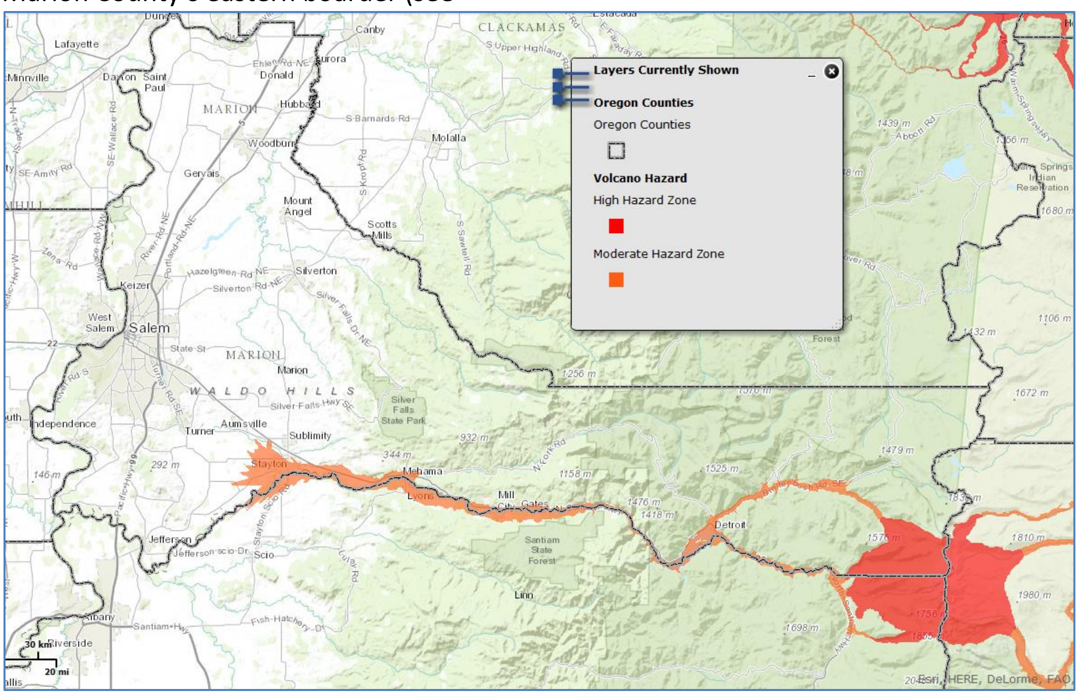
Earthquakes

Volcanic eruptions can be triggered by seismic activity or earthquakes can occur during or after a volcanic eruption. Earthquakes produced by stress changes are called volcano-tectonic earthquakes. These earthquakes, typically small to moderate in magnitude, occur as rock is moving to fill in spaces where magma is no longer present and can cause land to subside or produce large ground cracks (Riley). In addition to being generated after an eruption and magma withdrawal, these earthquakes also occur as magma is intruding upward into a volcano, opening cracks and pressurizing systems (Scott, 2001). Volcano-tectonic earthquakes do not indicate that the volcano will be erupting but can occur at any time and cause damage to manmade structures or provoke landslides.

Location and Extent

Volcanic eruption is not an immediate threat to the residents of Salem, as there are no active volcanoes within the city. Nevertheless, the secondary threats caused by volcanoes in the Cascade region must be considered. Volcanic ash can contaminate water supplies, cause electrical storms, create health problems, and collapse roofs.

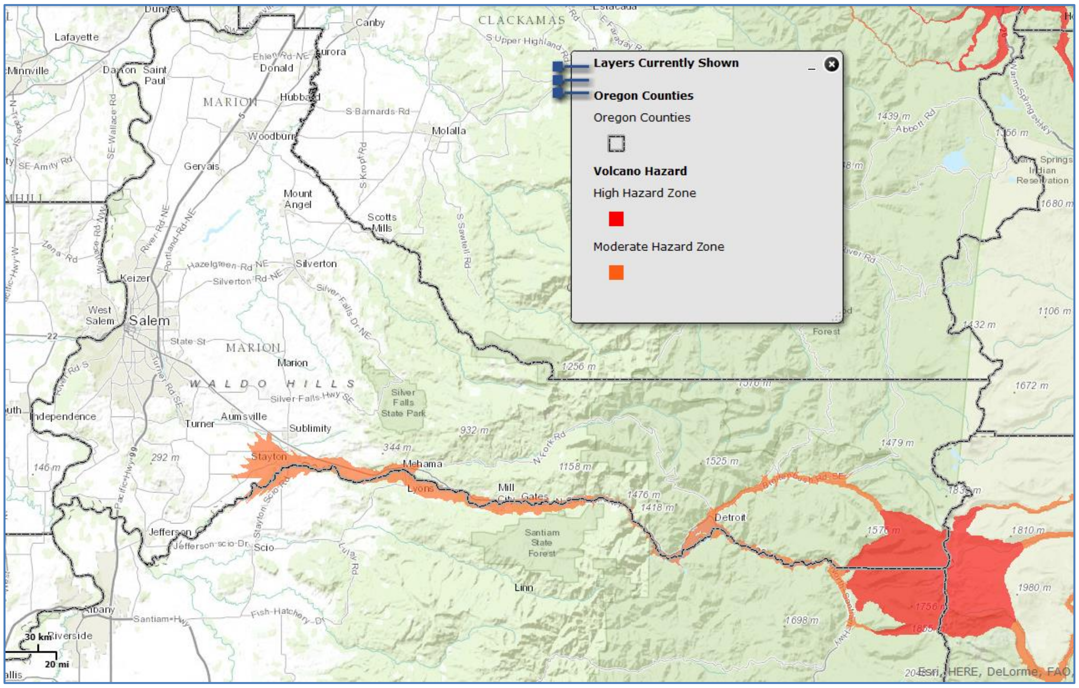
Salem is located on the Pacific Rim. Tectonic movement within the earth's crust can renew nearby dormant volcanoes resulting in ash fallout. Volcanic activity is possible from anywhere along the Cascade Range. Direct impacts from lava are possible in the southeast corner of Marion County in the Cascade Range. Lahar flows are possible along most of Marion County's eastern boarder (see



) as shown emanating from Mount Jefferson, the closest potential source of volcanic activity. Of particular concern are communities and infrastructure throughout the Santiam Canyon, southwest of Salem. However, ash fall is possible county wide, including Salem, with potential impacts to municipal water and transportation systems as well as sensitive mechanical and electrical equipment. The area affected by ash fallout depends upon the height attained by the eruption column and the atmospheric conditions at the time of the eruption.

The figure below was retained from the Marion County 2022 NHMP update because it shows Marion County along with neighboring Linn County to the south. The plate of the projected location of a lahar from Mount Jefferson into Marion County is included in the DOGAMI Multi-hazard Risk Assessment found in Appendix D.

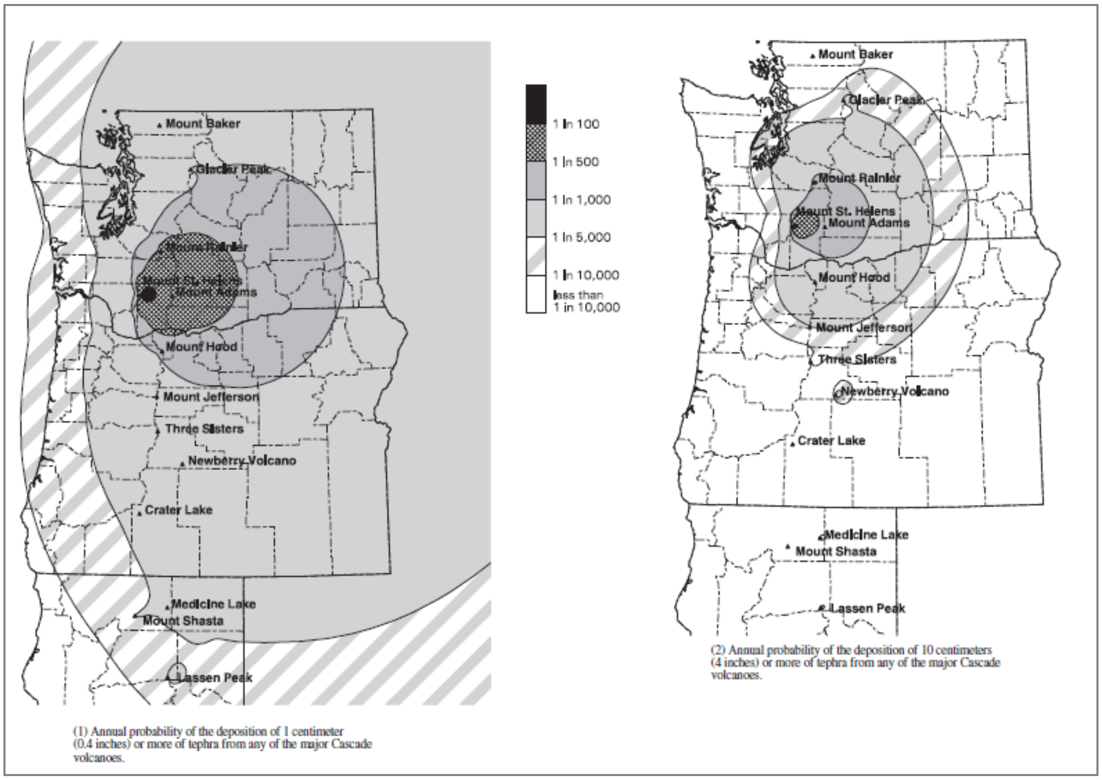
Figure 2-37 Volcano Hazard, Marion County, Oregon



Source: DOGAMI HazVu: Statewide Geohazards Viewer

Scientists use wind direction to predict areas that might be affected by volcanic ash; during an eruption that emits ash, the ash fall deposition is controlled by the prevailing wind direction. The predominant wind pattern over the Cascades originates from the west, and previous eruptions seen in the geologic record have resulted in most ash fall drifting to the east of the volcanoes. Regional tephra fall shows the annual probability of ten centimeters or more of ash accumulation from Pacific Northwest volcanoes. Figure 2-38 depicts the potential and geographical extent of volcanic ash fall in excess of ten centimeters from a large eruption of Mount St. Helens.

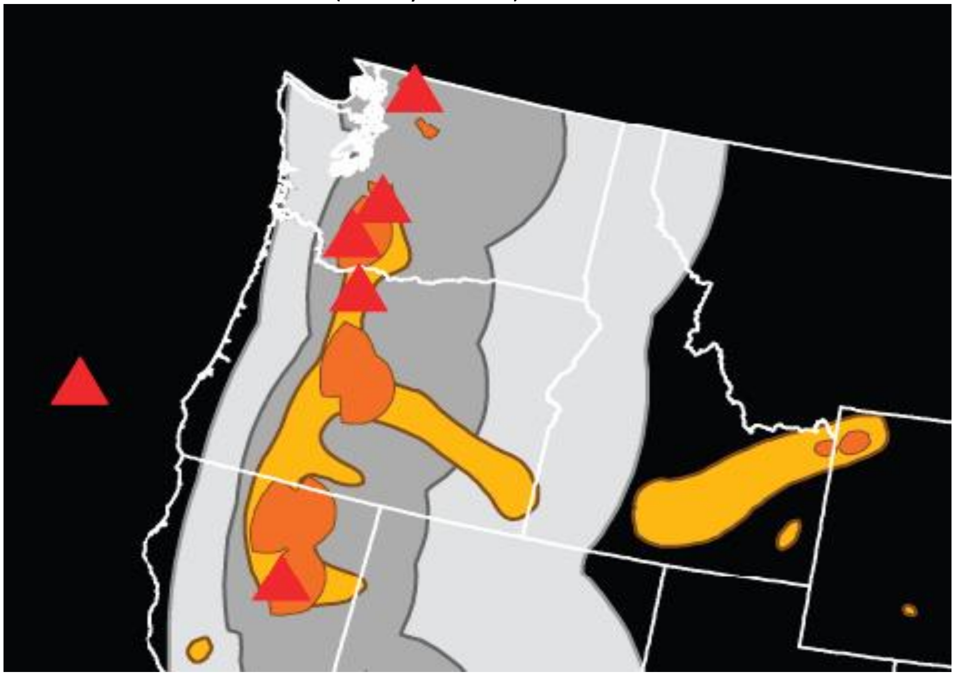
Figure 2-38 Regional Tephra-fall Maps



Source: Walder, J. S., Gardner, C., Conrey, R. M., Fisher, B. J. & Schilling, S. P. (2000). Open-File Report 99-24 Volcano Hazards in the Mount Jefferson Region, Oregon. USGS. Retrieved from https://pubs.usgs.gov/of/1999/0024/.

Identifying Volcanoes

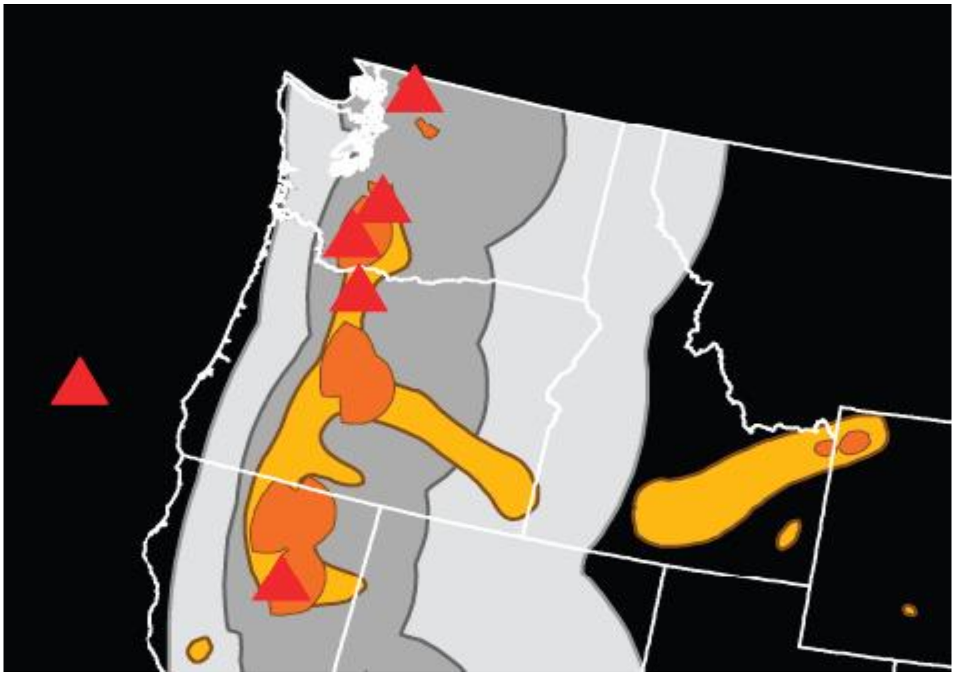
Communities that are closer to volcanoes may be at risk to the proximal hazards – ash fall, debris avalanches, pyroclastic flows, lahars, and lava flows - as well as the distal hazards - lahars, lava flows, and ash fall. The communities that are farther away are most likely only at risk from the distal hazards (mainly ash fall).



shows the locations of some of the Cascade Range volcanoes (red triangles) with relative volcanic hazard zones. The dark orange areas have a higher volcanic hazard; light-orange areas have a lower volcanic hazard. Dark-grey areas have a higher ash fall hazard; light-grey areas have a lower ash fall hazard.

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

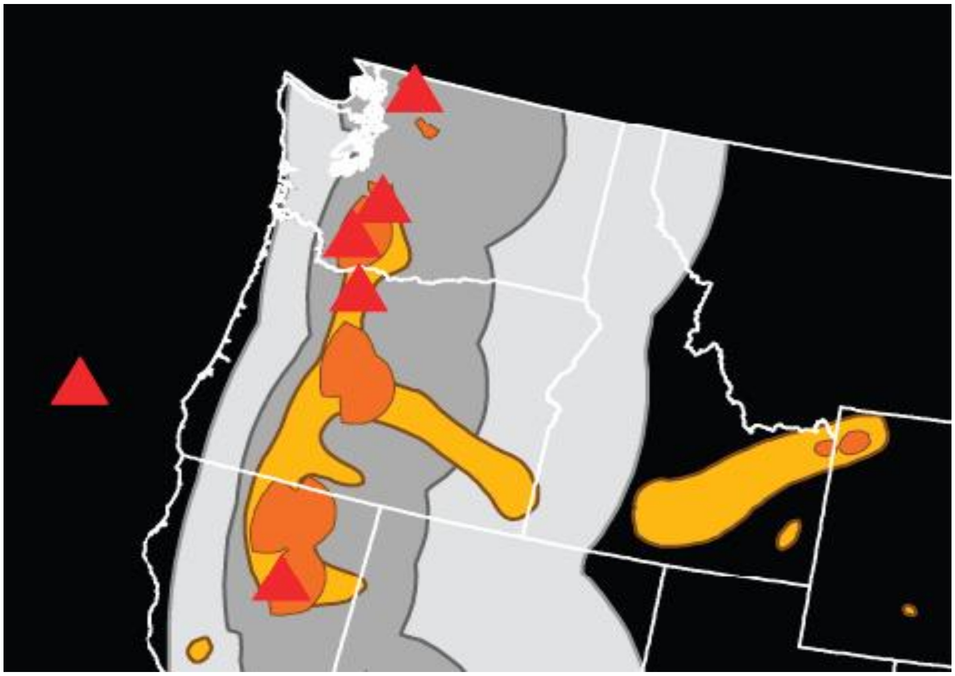
Figure 2-39 National Volcanic Hazard Map



Source: Image modified from USGS. (2006, February). *Fact Sheet 2006-3014 Volcano Hazards – A National Threat*. Retrieved from https://pubs.usgs.gov/fs/2006/3014/2006-3014.pdf.
Note: The red triangles are volcano locations. Dark-orange areas have a higher volcanic hazard; light-orange areas have a lower volcanic hazard. Dark-gray areas have a higher ash fall hazard; light-gray areas have a lower ash fall hazard. Information is based on data during the past 10,000 years.

Scientists also use wind direction to predict areas that might be affected by volcanic ash. During an eruption that emits ash, the ash fall deposition is controlled by the prevailing wind direction. The predominant wind pattern over the Cascade Range originates from the west, and previous eruptions seen in the geologic record have resulted in most ash fall drifting to the east of the volcanoes.

Regional tephra fall shows the annual probability of ten centimeters or more of ash accumulation from Pacific Northwest volcanoes.



above, depicts the potential and geographic extent of volcanic ash fall from several volcanoes in the Pacific Northwest.

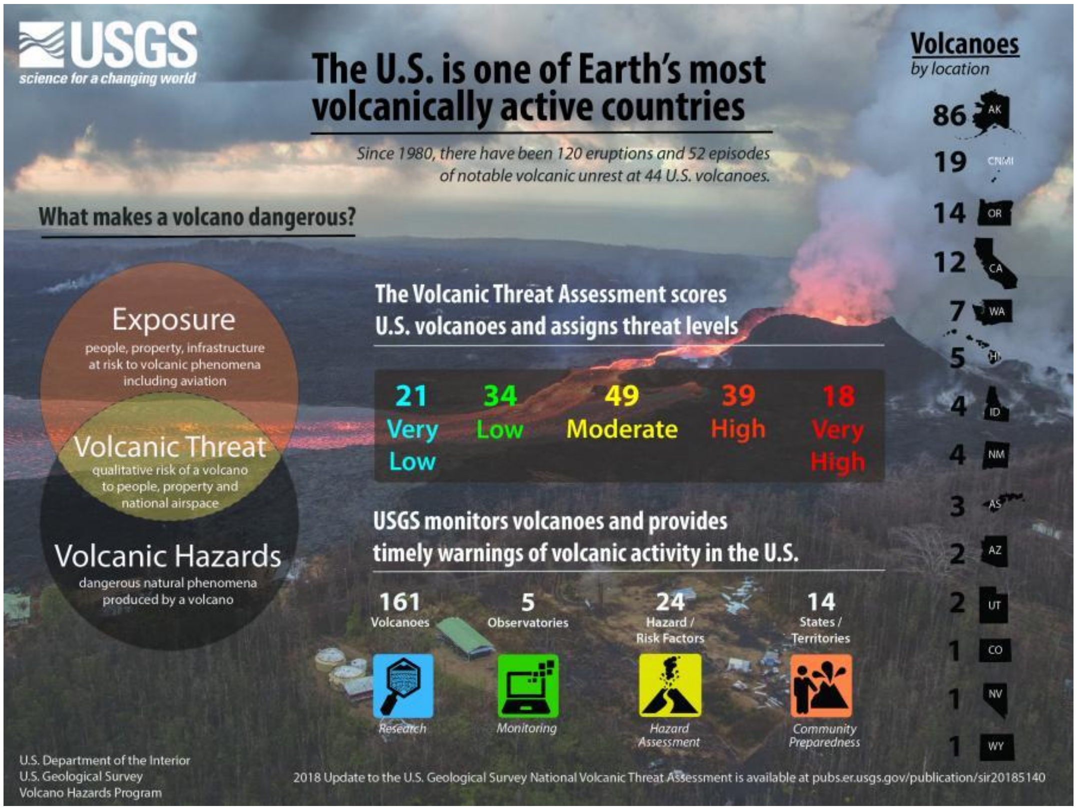
An excellent resource on volcanoes is published by USGS, most recently in 2018, which is called the *National Volcanic Threat Assessment*. The USGS assesses active and potentially active volcanoes in the U.S., focusing on history, hazards and the exposure of people, property and infrastructure to harm during the next eruption. They use 24 factors to obtain a score and threat ranking for each volcano that is deemed potentially eruptible, according to USGS.

In a description on the USGS website "the update names 18 very high threat, 39 high threat, 49 moderate threat, 34 low threat, and 21 very low threat volcanoes. The volcanoes are in Alaska, Arizona, California, Colorado, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming, American Samoa and the Commonwealth of the Northern Mariana Islands. The threat ranking is not an indication of which volcano will erupt next. Rather, it indicates how severe the impacts might be from future eruptions at any given volcano."

The USGS website further states, "Since 1980, there have been 120 eruptions and 52 episodes of notable volcanic unrest at 44 U.S. volcanoes. When erupting, all volcanoes pose a degree of risk to people and infrastructure. However, the risks are not equivalent from one volcano to another because of differences in eruptive style and geographic location."

The USGS describes that the volcanic threat assessment "helps prioritize U.S. volcanoes for research, hazard assessment, emergency planning, and volcano monitoring. It is a way to help focus attention and resources where they can be most effective, guiding the decision-making process on where to build or strengthen volcano monitoring networks and where more work is needed on emergency preparedness and response."

Figure 2-40 Volcanic Threat Assessment Statistics

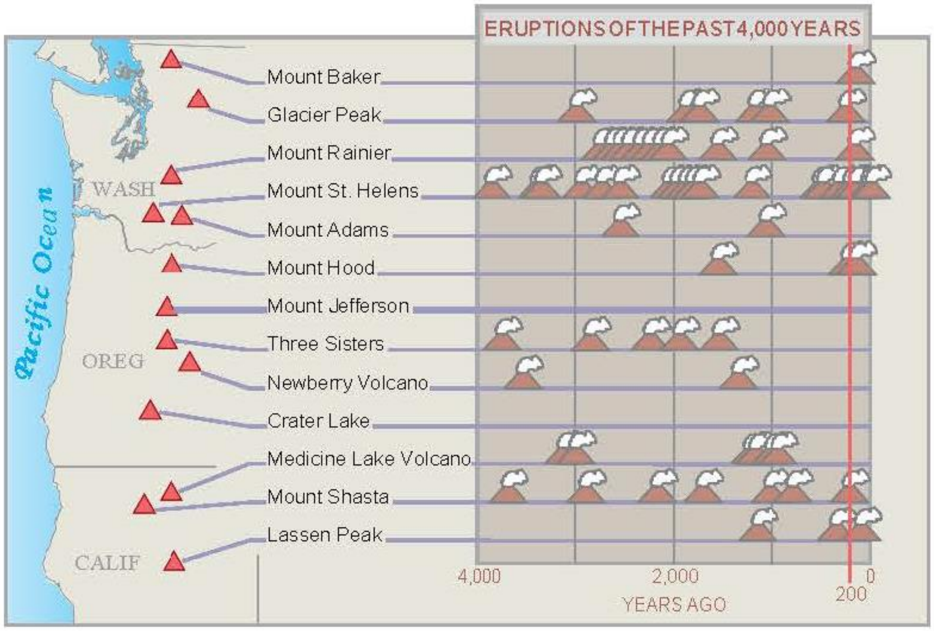


Source: U.S. Geological Survey. (n.d.). *Volcanic Hazards*. Retrieved from https://www.usgs.gov/programs/VHP.

History

Although there have been no recent volcanic events in the Marion and Polk County areas, it is important to note the area is active and susceptible to eruptive events since the region is a part of the volcanically active Cascade Range. The 1980 explosion of Mount Saint Helens in southern Washington State is the latest on record. Figure 2-41 displays the potentially active volcanoes of the western United States as identified by the USGS.

Figure 2-41 Potentially Active Volcanoes in the Western United States



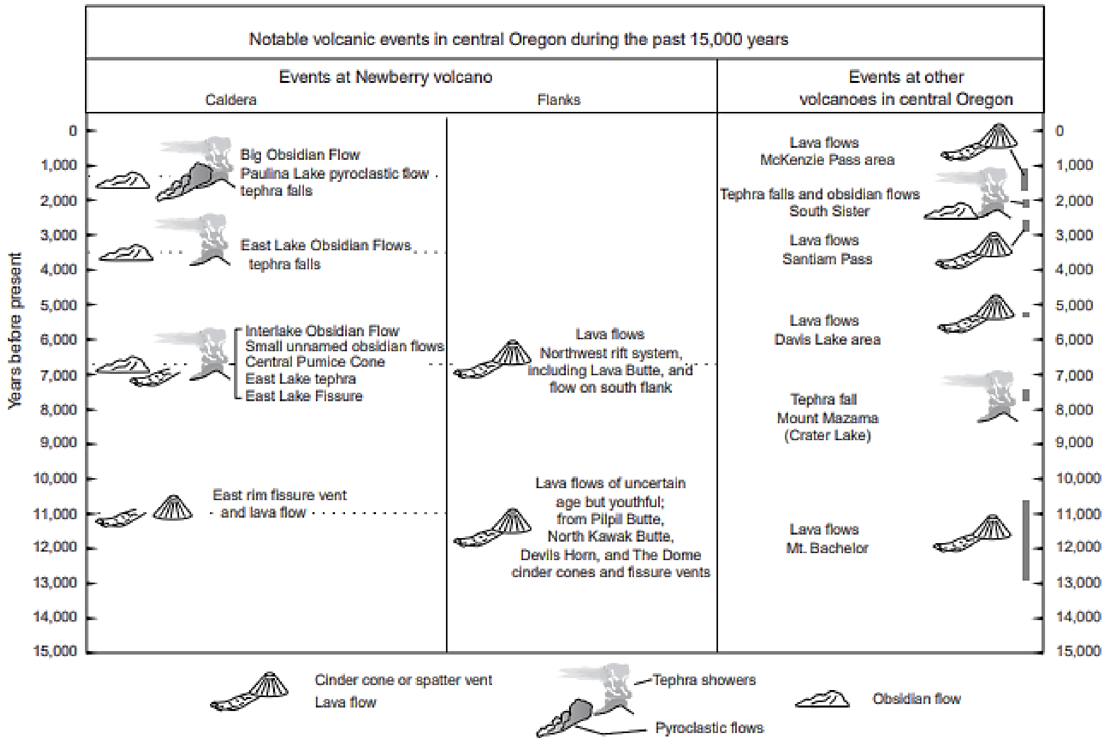
Of the 13 potentially active volcanoes in the Cascade Range of the Pacific Northwest, 11 have erupted in the past 4,000 years. More than 100 eruptions, most of which were explosive, have occurred during that period, making the volcanoes of the Cascade Range some of the most hazardous in the United States. Each eruption symbol in the diagram represents from one to several eruptions closely spaced in time at or near the named volcano. Eruptions have also occurred from other vents (not shown) scattered throughout the Cascade Range, especially in central Oregon and southwestern Washington.

Source: Dzurisin, D, Stauffer, P.H., & Hendley II, J. W. *USGS Fact Sheet 165–97 Living with Volcanic Risk in the Cascades*, USGS. Retrieved from https://pubs.usgs.gov/fs/1997/fs165-97/fs165-97.pdf.

There are active volcanic areas that could potentially impact Salem and the broader region. The regional volcanoes identified as very high threat include Mount Rainer, Mount Saint Helens, Mount Hood, Newbery Volcano, Three Sisters (North, Middle, and South Sister), Mount Mazama/Crater Lake, and Mount Shasta. Mount Bachelor falls within the moderate threat category, while Mount Jefferson, Blue Lake Crater, and Belknap Crater are a low threat (Ewert, Diefenbach, & Ramsey, 2018).

Volcanoes in the Cascade Range have been erupting for hundreds of thousands of years. Newberry Volcano, for example, has had many events in the last 15,000 years as shown in Figure 2-42. The Three Sisters region has also had some activity during this time while the last major eruptive activity at Mount Mazama occurred approximately 7,700 years ago, forming Crater Lake in its wake. Some of the most recent events include Big Obsidian Flow at Newberry Volcano. All the Cascade Range volcanoes are characterized by long periods of quiescence and intermittent activity. And these characteristics make predictions, recurrence intervals, or probability very difficult to ascertain.

Figure 2-42 Notable Volcanic Events in Central Oregon during the Past 15,000 Years



Source: Sherrod, D. R., Mastin, L. G., Scott, W. E., & Schilling, S. P. (1997). *Open-File Report 97-513 Volcano Hazards at Newberry Volcano, Oregon*. USGS. Retrieved from https://pubs.er.usgs.gov/publication/ofr97513.

In addition to the many online sources of information, a detailed report of the Pacific Northwest's catastrophic hazards and history written by Rick Gore appears in the May 1998 National Geographic, Vol. 193, No. 5. Table 2-15 describes volcanic events in Oregon and Washington.

Table 2-15 Significant Historic Volcanic Events

Date	Location	Description
Approximate Years: 18,000 to 7,7000 years before present (YBP)	Mount Bachelor, central Cascades	Cinder cones and lava flows.
20,000 to 13,000 YBP	Polallie eruptive episode, Mount Hood	Lava dome, pyroclastic flows, lahars, and tephra.
13,000 YBP	Lava Mountain, south central Oregon	Lava Mountain field and lava flows.
13,000 YBP	Devils Garden, south central Oregon	Devils Garden field and lava flows.
13,000 YBP	Four Craters, south central Oregon	Four Craters field and lava flows.
7,780 to 15,000 YBP	Cinnamon Butte, Southern Cascades	Balsatic scaria cone and lava flows.

Date	Location	Description
7,700 YBP	Crater Lake Caldera	Formation of Crater Lake caldera, pyroclastic flows, and widespread ashfall.
7,7000 YBP	Parkdale, north central Oregon	Eruption of Parkdale lava flow.
7,000 YBP	Diamond Craters, eastern Oregon	Lava flows and tephra in Diamond Craters field.
<7,700 YBP; 5,300 to 5,600 YBP	Davis Lake, southern Cascades	Lava flows and scoria cones in Davis Lake field.
10,000 to <7,7000 YBP	Cones south of Mount Jefferson; Forked Butte and South Cinder Peak	Lava flows.
4,000 to 3,000 YBP	Sand Mountain, central Cascades	Lava flows and cinder cones in Sand Mountain field.
<3,2000 YBP	Jordan Craters, eastern Oregon	Lava flows and tephra in Jordan Craters field.
3,000 to 1,5000 YBP	Belknap Volcano, central Cascades	Lava flows and tephra.
2,000 YBP	South Sister Volcano	Rhyolite lava flow.
1,500 YBP	Timberline eruptive period, Mount Hood	Lava dome, pyroclastic flows, lahars, and tephra.
1,300 YBP	Newberry Volcano, central Oregon	Eruption of Big Obsidian flow.
1,300 YBP	Blue Lake Crater	Spatter cones and tephra.
1760–1810	Crater Rock/Old Maid Flat on Mount Hood	Pyroclastic flows in upper White River; lahars in Old Maid Flat; dome building at Crater Rock.
1859/1865	Crater Rock on Mount Hood	Steam explosions and tephra falls.
1907 (?)	Crater Rock on Mount Hood	Steam explosions.
1980	Mount St. Helens (Washington)	Mt. St. Helens erupts: Debris avalanche, ashfall, and flooding on Columbia River. 57 people died.
1981-1986	Mount St. Helens (Washington)	Lava dome growth, steam, and lahars.
1989-2001	Mount St. Helens (Washington)	Hydrothermal explosions.
2004-2008	Mount St. Helens (Washington)	Lava dome growth, steam, and ash.

Sources: USGS; Wolfe & Pierson, 1995; Scott et al., 1997; University of Oregon; *2020 Oregon Natural Hazard Mitigation Plan;* FEMA, Disaster Declarations for Oregon.

A great deal of background information on Oregon and Washington volcanoes and volcanoes in general is available on several websites, including:

- United States Geological Survey (USGS) Volcano Hazards Program: Volcano Hazards | U.S. Geological Survey (usgs.gov) (http://volcanoes.usgs.gov/)

- Department of Geology and Mineral Industries (DOGAMI) Volcano Hazards in Oregon: DOGAMI Volcano Hazards | Oregon Department of Geology and Mineral Industries (oregongeology.org)

Future Climate Variability

The causal risk of a volcanic eruption is unrelated to future climate variability, but the potential impact of a volcanic eruption is elevated due to climate-related impacts of drought and wildfire on air quality. That is, air quality trends are expected to be negatively impacted by climate change, so vulnerable populations would be at greater risk of health problems resulting from ashfall or toxic air emissions from an eruption.

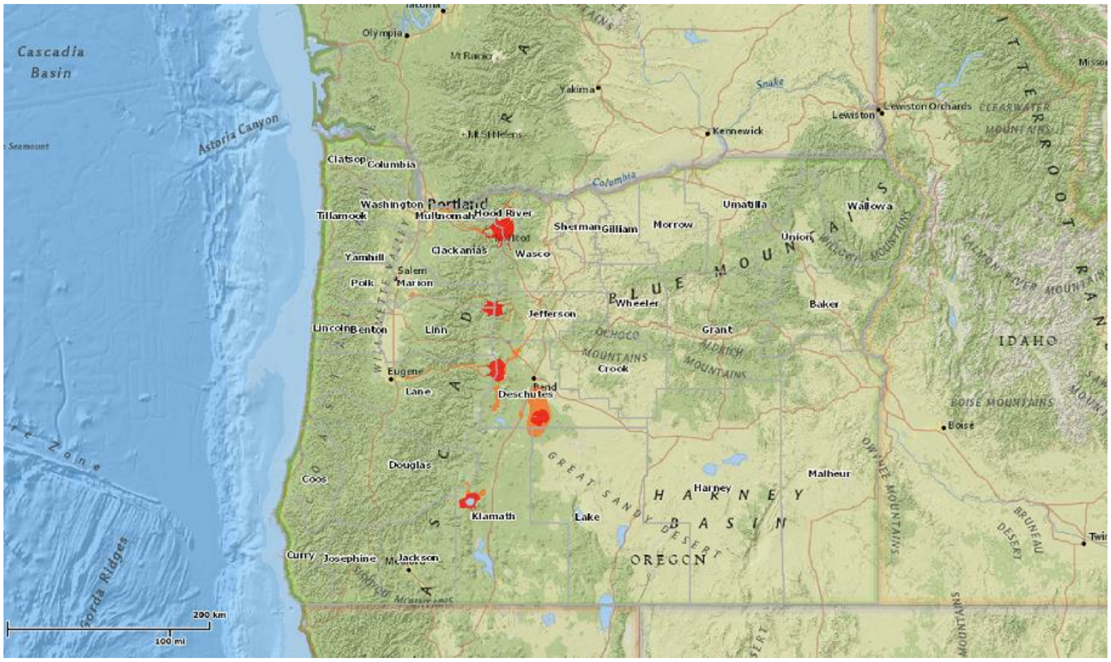
Probability Assessment

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing volcanic activity is "low,"** meaning one incident is likely within the next 100-year period.

Vulnerability Assessment

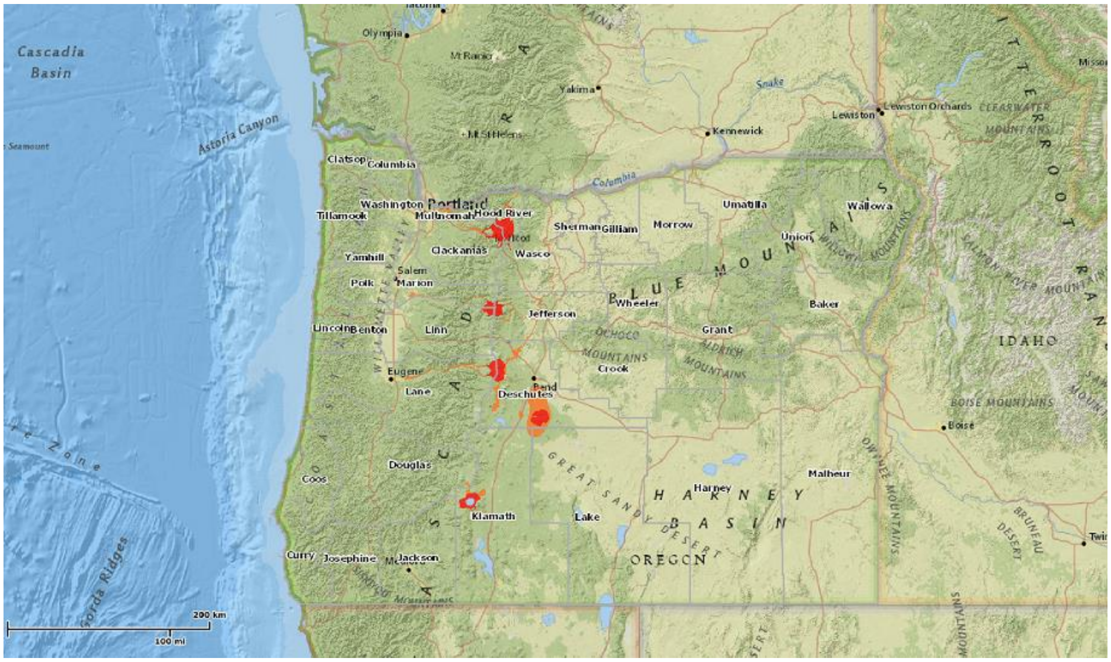
The Pacific Northwest region is vulnerable to impacts from volcanic activity. Like the rest of Oregon, Salem has some risk of being impacted by volcanic activity in the Cascade Range. The very high threat volcanoes in the region include Mount Rainer, Mount Saint Helens, Mount Hood, Newbery Volcano, Three Sisters (North, Middle, and South Sister), Mount Mazama/Crater Lake, and Mount Shasta. Because of its geographic distance from these volcanic sites, Salem is not at risk for proximal hazards such as lava flows. However, it is at risk for distal hazards, primarily ash fall (tephra). The location, size, and shape of the area affected by tephra fall is determined by both the vigor and duration of the eruption and the wind direction at the time of eruption, making prediction of the area to be affected impossible more than a few hours in advance. The vulnerability to ash fallout is multi-pronged. For example, ash can disrupt the engines of motor vehicles, reduce visibility, and exacerbate or induce respiratory illnesses.

While a quantitative vulnerability assessment – an assessment that describes number of lives or amount of property exposed to the hazard – has not yet been conducted for Salem volcanic eruption events, there are many qualitative factors – issues relating to what is in danger within a community – that point to potential vulnerability.



shows that that Salem is not within an identified high or moderate volcanic event hazard zone. DOGAMI used data from the USGS Cascades Volcano Observatory for this web application. The Cascades Volcano Observatory maintains proximal and distal hazard zone data for volcanic areas in the Western Cascades of Oregon. These areas include but are not limited to Mount St. Helens, Mount Hood, Crater Lake, Newberry, Mount Jefferson, and the Three Sisters. HazVu shows two hazard zones: the high hazard zone (proximal zone) and moderate hazard zone (distal zone). Mount Bachelor, which is listed as a moderate threat by the USGS (Ewert et al.,2018), is a dormant volcano monitored by the Jaffe Group at the University of Washington at Bothell.

Figure 2-43 Map of Generalized Vulnerability of the Region



Source: DOGAMI HazVu: Statewide Geohazards Viewer

Risks for Salem associated with regional volcanic activity would be ash fall, air quality, and possible economic or social disruption due to air traffic issues due to the ash cloud.

Though unlikely, the impacts of a significant ash fall are substantial. Persons with respiratory problems are endangered, transportation, communications, and other lifeline services are interrupted, drainage systems become overloaded/clogged, buildings can become structurally threatened, and the economy takes a major hit. Any future eruption of a nearby volcano (occurring during a period of easterly winds would likely have adverse consequences for the city.

Volcanic eruptions in the past caused multiple minor injuries or a major injury to the health and safety of residents. The potential for future injuries or deaths is anticipated to remain similar to historic events. It is estimated that less than 1% of the City's population would be physically displaced by a volcanic eruption, considering the primary volcanic hazard that could impact Salem is ash fallout, and there would be moderate impact on community social networks.

Several facilities throughout Salem anticipate mild damage due to a volcanic eruption, estimated between $1 million and $10 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely more than 75% of businesses located in the City and surrounding area would experience commerce interruption for a period of several weeks. Ash fall from volcanic eruptions has the potential to impact a wide region, inflicting damage to building circulation systems and road surface conditions. Lastly, volcanic eruptions would likely have extensive impacts on more than 75% of the City's ecological systems, including, clean water, wildlife habitat, and parks.

According to DOGAMI's *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022), during a medium zone (1,000 to 15,000 year) lahar scenario, there is the potential to have 7 displaced residents, 4 exposed buildings, none of which are critical facilities. Exposed building value of $772 (exposure ratio 0%).

As such, the NHMP Steering Committee rated the city as having a **"low" vulnerability to volcanic activity**, meaning that less than 1% of the city's population or assets would be affected by a major disaster (volcanic ash)

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

U.S. Geological Survey

A major existing strategy to address volcanic hazards is to publicize and distribute volcanic hazard maps and information through USGS and state agencies, such as DOGAMI.

The volcanoes most likely to constitute a hazard to Oregon communities have been the subject of USGS research. Open-file reports address the geologic history of these volcanoes and lesser-known volcanoes in their immediate vicinity. These reports also cover associated hazards, the geographic extent of impacts, and possible mitigation strategies. They are available for the active volcanoes such as Mount St. Helens, the Three Sisters, Newberry Volcano, and Crater Lake. While there is not an Open-file reports for Mount Bachelor, there are other resource materials that provide considerable information.

Of note, after the 1980 eruption of Mount St. Helens, Congress provided increased funding that enabled the USGS to establish a volcano observatory for the Cascade Range. Located in Vancouver, Washington, the David A. Johnston Cascades Volcano Observatory was named for a USGS scientist killed at a forward observation post by the May 18, 1980, eruption (https://pubs.usgs.gov/fs/1997/fs165-97/fs165-97.pdf).

For more information, please refer to USGS at https://www.usgs.gov/programs/VHP.

State Resources

State Natural Hazard Risk Assessment

The risk assessment in the 2020 Oregon NHMP provides an overview of volcanic hazards in Oregon and identifies the most significant volcanic eruptions in Oregon's recorded history. It has overall state and regional information and includes volcano related mitigation actions for the entire state.

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to coastal hazards, floods, and other natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon Department of Geology and Mineral Industries

A major existing strategy to address volcanic hazards is to publicize and distribute volcanic hazard maps and information through DOGAMI and USGS, as discussed above.

The volcanoes most likely to constitute a hazard to Oregon communities have been the subject of DOGAMI and USGS research. Open-file reports address the geologic history of these volcanoes and lesser-known volcanoes in their immediate vicinity. These reports also cover associated hazards, the geographic extent of impacts, and possible mitigation strategies. They are available for the active volcanoes such as Mount St. Helens, the Three Sisters, Newberry Volcano, and Crater Lake. While there is not an Open-file reports for Mount Bachelor, there are other resource materials that provide considerable information.

For more information, refer to DOGAMI at https://www.oregongeology.org/volcano/volcanoes.htm.

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of natural hazards including the Hazard Mitigation Grant Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, OEM notifies local public safety agencies and keeps them informed of potential and actual hazard events so prevention and mitigation actions can be taken.

Local Resources

Salem Emergency Management Plan

This description is excerpted from the *Salem Emergency Management Plan* (2014).

> This Emergency Management Plan is an all-hazard plan that describes how the City of Salem will organize and respond to emergencies and disasters in the community. It is based on, and is compatible with, Federal, State of Oregon, and other applicable laws, regulations, plans, and policies, including Presidential Policy Directive 8, the

National Response Framework, Oregon Office of Emergency Management Plan, and both Marion and Polk County Emergency Operations Plans.

Response to emergency or disaster conditions in order to maximize the safety of the public and to minimize property damage is a primary responsibility of government. It is the goal of the City of Salem that responses to such conditions are conducted in the most organized, efficient, and effective manner possible. To aid in accomplishing this goal, the City of Salem has, in addition to promulgating this plan, formally adopted the principles of the National Incident Management System, including the Incident Command System and the National Response Framework.

Consisting of a Basic Plan, Functional Annexes aligned with both Marion and Polk County Emergency Support Functions, and Incident Annexes, this Salem Emergency Management Plan provides a framework for coordinated response and recovery activities during a large-scale emergency. The plan describes how various agencies and organizations in the City of Salem will coordinate resources and activities with other Federal, State, local, tribal, and private-sector partners.

Water Quality/Water Emergency

Significant Changes Since Previous Plan:

The Water Quality/Water Emergency Hazard is new to Salem's NHMP.

Causes and Characteristics

The United States enjoys one of the world's most reliable and safest supplies of drinking water. Moreover, water systems, together with wastewater, is one of 16 critical infrastructure sectors identified by the U.S. Department of Homeland Security. According to the EPA, Approximately 150,000 public water systems, which includes Salem, provide drinking water to most Americans. When the water in our rivers, lakes, and oceans becomes polluted; it can endanger wildlife, make drinking water unsafe, and threaten the waters where we recreate. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that the water poses a health risk. Some people may be more vulnerable to contaminants in drinking water than the general population, according to the Salem *Annual Water Quality Report 2022*.

The sources of drinking water, both tap water and bottled water, include rivers, lakes, streams, ponds, reservoirs, springs, and groundwater wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals, and in some cases, radioactive materials. In addition, as water travels, it can pick up contaminants resulting from the presence of animal or human activity. As noted in the *Annual Water Quality Report 2022*, Salem regularly monitors activities that may impact its drinking water source, within the North Santiam River Watershed.

Location and Extent

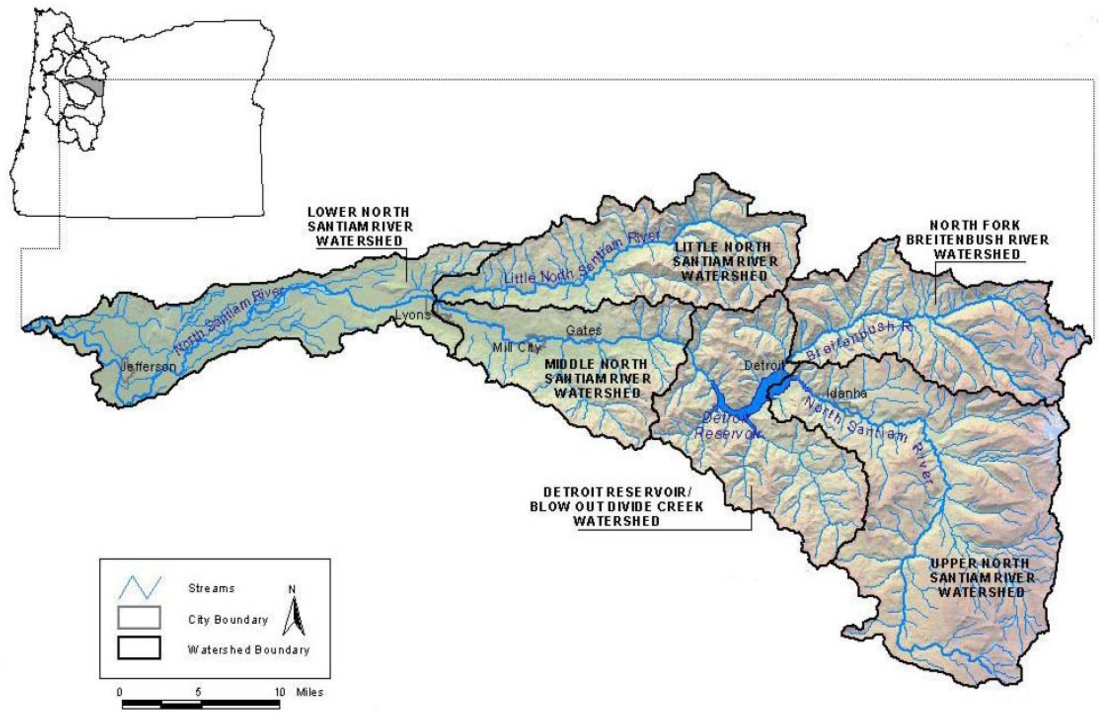
Surface Water

The Willamette Basin encompasses 12 subbasins including the North Santiam. Willamette Basin geographic area comprises the broad Willamette River valley, which is flanked by the forested slopes of the Coast and Cascade mountain ranges. The Willamette River and its tributaries support a wide variety of ecosystems and habitats including forested and depressional wetlands, riparian forests and shrublands, upland and wet prairies, chapparal, woodlands and oak savanna. Forestry, agriculture and urban uses dominate land use in the Willamette Basin.

According to Salem's *Annual Water Quality Report 2022*, the North Santiam River has served as the primary water source for Salem for over 80 years. Surface water is conveyed by gravity from the North Santiam River, which begins on the west side of the Cascade Range, near Mt. Jefferson and Three Fingered Jack. The North Santiam River flows for over 90 miles from the Cascade Range, through Detroit Reservoir, and toward the Mid-Willamette Valley, ultimately joining the Willamette River. This water source is considered "clean and pristine river water" and high-quality water. The North Santiam River Watershed is an area of about 760 square miles that is surrounded primarily by state and national forest. The North Santiam River also provides water for the many communities along its route.

Based on its high quality, the water from the North Santiam River is "suitable for more natural filtering process called Slow Sand Filtration at the Geren Island Water Treatment Facility located near Stayton." Geren Island, which is the largest Slow Sand Filtration system in the U.S., has used the Slow Sand Filtration process since the 1930s. However, the facility and processes have improved and changed over time. Salem also utilizes a state-of-the-art ozone treatment system to remove contaminants such as cyanotoxins.

Figure 2-44 North Santiam Subbasin



Source: Oregon DEQ. (2006, September). *Willamette Basin TMDL: North Santiam Subbasin. Chapter 8: North Santiam Subbasin TMDL*. Retrieved from https://www.oregon.gov/deq/FilterDocs/chpt8nsantiam.pdf.

Salem also holds two water rights to appropriate water from the Willamette River. The city is amid planning efforts to develop infrastructure to use its Willamette River water source, according to the Salem *Water Management and Conservation Plan* (2019).

Figure 2-45 City of Salem Water System

Source: City of Salem. (2022). *Annual Water Quality Report 2022, Drinking Water Quality Data from 2021*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/15380/637898465652470000.

Groundwater

Salem has groundwater sources that supplement surface water during emergencies, water quality events, and periods of peak demand. According to Salem's *Water Management and Conservation Plan* (2019), groundwater is appropriated and treated at Geren Island. Salem is exploring the feasibility of developing two additional collector wells on Geren Island to increase its shallow groundwater supply. Salem can appropriate groundwater from three additional wells on Geren Island, if necessary. There is also a limited amount of groundwater available from wells within Salem's water service area.

Aquifer Storage and Recovery

Salem's ASR system provides a supplemental water supply during periods of peak demand or emergencies. The ASR is located underground to store and recover finished water. Treated drinking water from the North Santiam River is injected into the Columbia River basalt aquifer via the ASR wells. The Salem *Annual Water Quality Report 2022* states,

> During the winter months, when flows in the river are high and there is a low demand for water by customers, treated drinking water is injected into the ASR system. The water is stored in a naturally existing groundwater aquifer located 350 feet below Woodmansee Park. During the summer months, when the river is flowing low and customer water demand is high, water is pumped back to the surface, sampled for quality and recovered from the ASR system. The recovered water is treated with calcium hypochlorite (chlorine) for disinfection and then conveyed to the distribution system, serving the south Salem water customers.

Salem began updates to the ASR treatment system in 2021. The updates include corrosion control and a common treatment facility where water recovered from all ASR wells will be disinfected and caustic soda added for pH adjustment.

Water Quality Contaminants

The following are contaminants that may be present in any source water. Contaminants that are monitored by Salem are also identified.

Sediments and Turbidity

This includes loose dirt, topsoil, minerals, sand and silt from roads and highways, excessive removal of vegetation from grazing animals, forest practices, and farming practices.

Microbial Contaminants

Microbial contaminants can include viruses and bacteria, which come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife. This also includes algal blooms, which are a natural process, but certain types of algal blooms known as cyanobacteria can produce cyanotoxins as a defense mechanism.

Microbial contaminants monitored at the Salem facilities include two cyanotoxins: Total Microcystins and Cylindrospermopsin. Other microbiological contaminants monitored are Turbidity, Total coliform, and E. coli bacteria.

Pesticides and Herbicides

These contaminants may come from a variety of sources such as agriculture, road maintenance, individual homes and businesses, and urban stormwater runoff.

Organic Chemical Contaminants

Organic chemicals may include synthetic and volatile chemicals, which are by-products of industrial processes, petroleum processes, wood processes and mills, gas and fueling stations, and auto and mechanical shops.

Organic contaminants monitored at the Salem facilities include Sodium, 2, 4-D, and Hexachlorocyclopentadiene.

Inorganic Contaminants

These contaminants include salts and metals, which can occur naturally in the geology, or result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas productions, and mining or agriculture.

Inorganic contaminants monitored at the Salem facilities include Fluoride, Copper, Nitrate, Nitrate-Nitrite, Barium, and Lead.

The Salem facilities also monitors for the following disinfection by-products, by-product precursors, and disinfectant residual contaminants: Haloacetic acids, Total Trihalomethanes, Total Organic carbon, and Chlorine Residual.

Radioactive Contaminants

Radioactive contaminants can be naturally occurring or be the result of oil and gas production, and mining activities.

Radioactive contaminants monitored at the Salem facilities include Gross Beta Particle Activity.

Identifying Water Quality Hazards

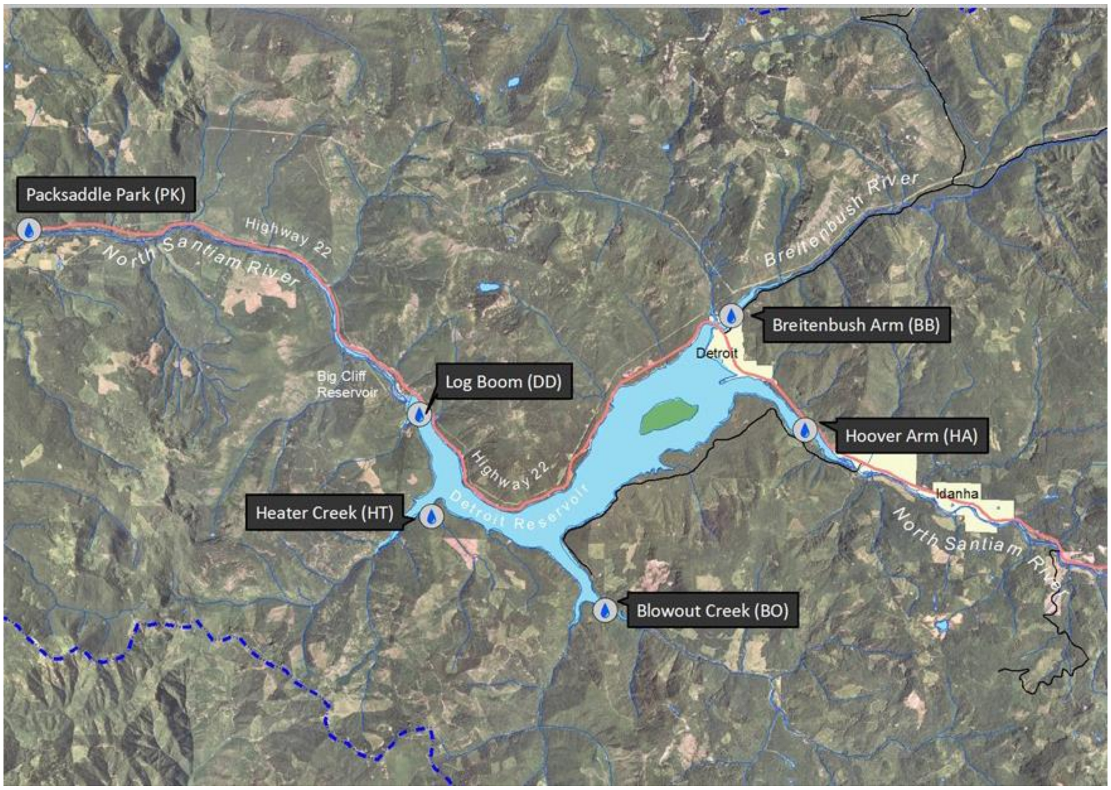
According to DEQ, Oregon is required to establish Total Maximum Daily Loads (TMDL) for streams segments which do not meet water quality standards. This information identifies the level of contaminants that a water body can absorb and still meet water quality standards. Moreover, TMDLs consider contaminants from all sources including discharges from industry and sewage treatment facilities; runoff from farms, forests and urban areas; and natural sources. Also included are safety margins to account for uncertainty. This information is then used to determine what changes must take place to achieve water quality standards. Water quality management plans (WQMP) are also developed based on the TMDLs. These plans document the ways that local landowners, local and federal agencies, forest and agricultural land managers, DEQ and others will implement a specific TMDL and work to improve water quality (DEQ, TMDL Program: Willamette Basin).

DEQ has established TMDLs to address elevated temperature and mercury levels throughout the North Santiam and South Santiam Subbasins. In addition, DEQ has planning targets for bacteria in the urban and agricultural areas, which are addressed in the WQMP.

In addition to the TMDL program addressed above, in compliance with the Federal Safe Drinking Water Act, Salem routinely collects and tests water quality samples for possible contaminants. Sampling and monitoring procedures occur within the distribution system (in town), at Geren Island, and at several locations in the North Santiam River watershed.

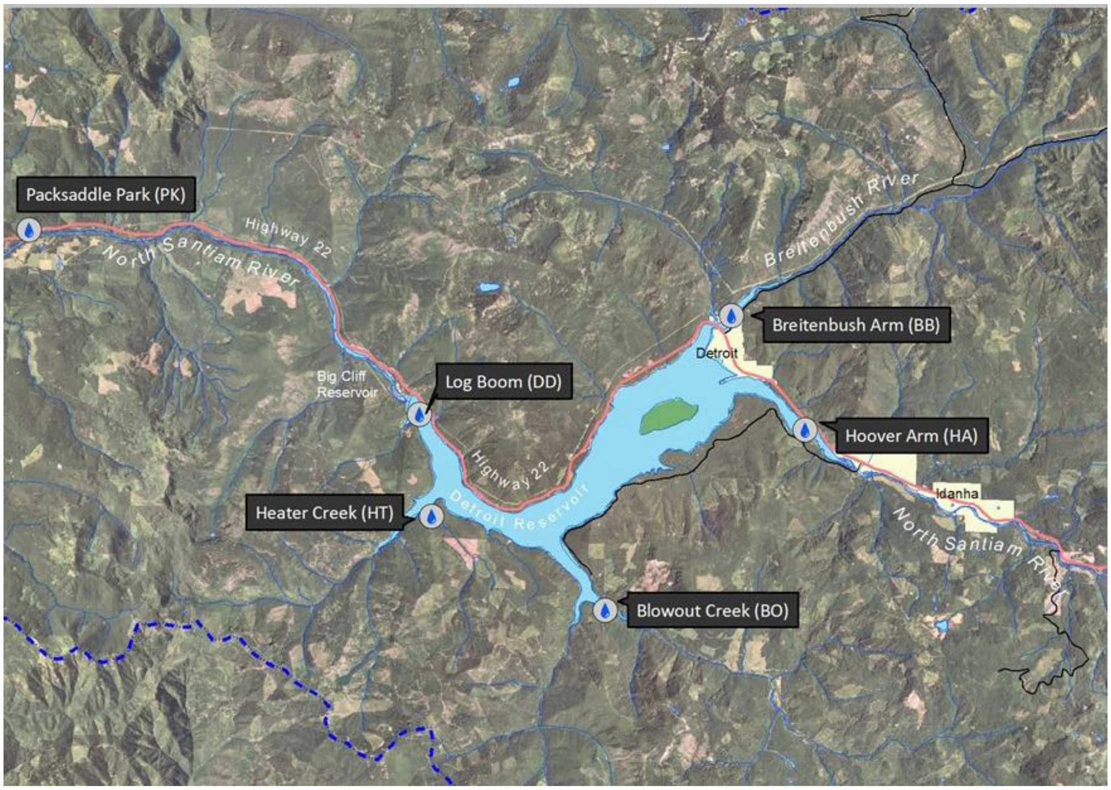
Under normal conditions for monitoring the distribution system, Salem collects water quality samples from 48 different locations. These sample locations were chosen with the assistance of the Oregon Health Authority Drinking Water Program, and are strategically located to provide monitoring in all areas of the distribution system. A bacteriological sample, in addition to temperature, pH, turbidity, chlorine residuals, and additional water quality parameters are collected. The Drinking Water Monitoring Program indicates that a summary of the water quality data collected each year is compiled in Salem's *2022 Annual Water Quality Report*.

Salem also monitors conditions in the North Santiam River and Detroit Reservoir. Algae and cyanotoxins, in addition to other water quality parameters, are monitored in the watershed. The Data collected from the watershed can be used to adjust drinking water treatment processes at Geren Island, if needed. Monitoring in the watershed typically begins in April or May and ends in September or October, depending on the weather conditions and Detroit Reservoir water levels.



shows the Salem watershed sampling locations.

Figure 2-46 Salem Watershed Sampling Locations



Source: City of Salem. (n.d.). *Drinking Water Monitoring Program*. Retrieved from https://www.cityofsalem.net/community/household/water-utilities/drinking-water-treatment/drinking-water-monitoring-program.

History

Salem's service population within the City of Salem in 2017 was 163,480, according to the *Water Management and Conservation Plan* (WMCP), which states,

> The City provides water to its retail customers and three wholesale customers outside city limits (Suburban East Salem Water District, City of Turner, and Orchard Heights Water District). The City's retail customers include customers within city limits as well as customers outside city limits, such as the Jan Ree area located within the northeast portion of the service area. The City estimates that its water service population in 2017 was 195,816. The City's total water service population includes populations within the City of Salem, the City of Turner (wholesale customer), Suburban East Salem Water District (wholesale Customer), Jan Ree Area, Eola-Chatnicka Area, and Orchard Heights Water District (wholesale customer).

Salem has nine customer categories for water: residential, multi-family, commercial, industrial, institutional, public, irrigation, wholesale, and fire services, which are further defined in the *Water Management and Conservation Plan*. The number of service connections for each customer category is identified in the following table.

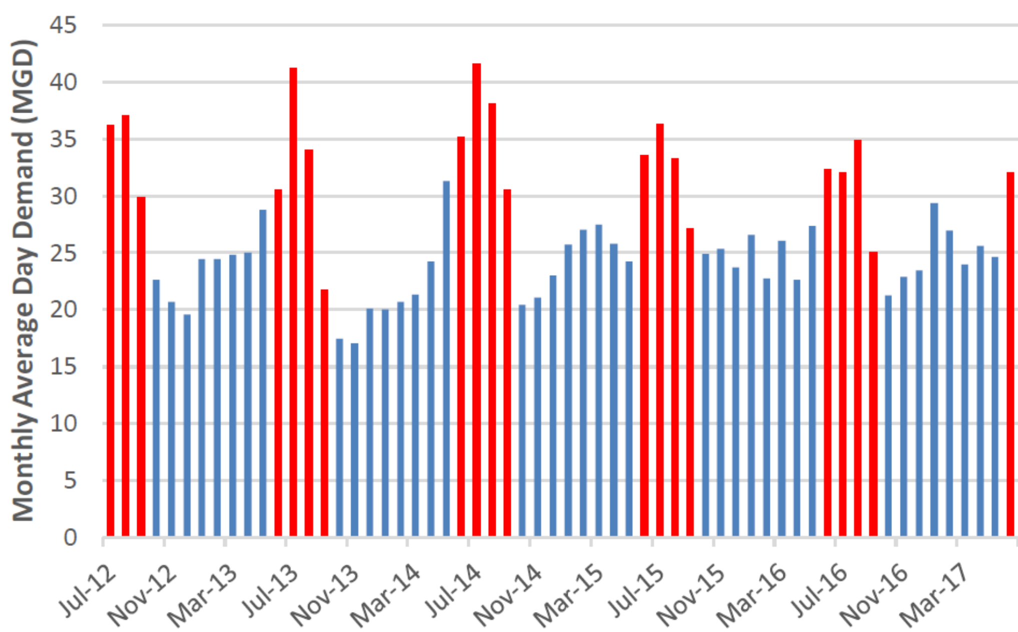
Table 2-16 Number of Service Connections, Fiscal Year 2016-2017

Customer Category	Number of Connections
Residential	42,605
Multi-Family	2,279
Commercial	2,931
Industrial	19
Institutional	8
Irrigation	655
Public	125
Wholesale	3
Total	48,625

Source: City of Salem. (2019, April). *Water Management and Conservation Plan*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/5170/637798392608930000.

Salem's WMCP provides information regarding water sources, demands, conservation, and curtailment. The WMCP also provides data on average annual, seasonal, monthly, daily, and per capita demands; in addition to, historic water loss. Figure 2-47 below shows the monthly average day demand between July 2012 and June 2017.

Figure 2-47 Salem Monthly Average Day Demand, July 2012 to June 2017



Source: City of Salem. (2019, April). *Water Management and Conservation Plan*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/5170/637798392608930000.

Note: Red indicates peak season months (June through September) while blue indicates non-peak season months

According to the WMCP, Salem has experienced a curtailment episode that stemmed from a series of events. The curtailment event occurred in July 2009 and was caused by the following conditions and events:

- Typical high summer water demands
- Reduced storage capacity because of required reservoir repairs
- Reduced production at Geren Island because of an algae bloom in Detroit Reservoir on the North Santiam River
- Reduced supply (i.e., flow) because of gate failures at Big Cliff Dam

A Level 2, voluntary, curtailment occurred between July 28, 2009 and August 2, 2009. During that curtailment, the following measures were implemented:

1. Salem customers were requested to suspend outdoor water uses, including car washing, sidewalk and patio cleaning, and residential lawn and turf watering. Garden watering was permitted.
2. Salem suspended irrigation at City parks. Watering of sensitive areas and areas actively being used for tournaments was permitted.
3. Salem suspended water supply to decorative fountains. Splash pads were kept in operation for recreation, to encourage citizens to use these facilities rather than residential irrigation systems.

Backup water supplies exist in the form of interties with other water providers, groundwater and the City's ASR system, according to the WMCP. Interties agreements with the Cities of Stayton and Keizer can provide some water to Salem; however, agreements with the cities do not guarantee water during an emergency event. The ASR wells and local wells can also provide limited water supply, but some wells "would require three to four weeks to activate…." The WMCP states, "Utilizing all of these available backup resources, Salem could produce up to 36.25 cfs (23.5 mgd). This is compared to an average day demand of finished water over the five-year period from FY 2012-2013 through 2016-2017 of 42.9 cfs (27.7 mgd)."

The USGS Oregon Water Science Center provides the following summary of the water quality issue that occurred in 2018 and the reason behind why the Salem NHMP steering committee elected to include the water quality/water emergency hazard to Salem's NHMP.

> Harmful algal blooms (HABs) have occurred in many of the large water storage reservoirs in the Willamette River Basin, resulting in health advisories for water contact recreation, and in 2018 for the first time in Oregon, a drinking water advisory due to cyanotoxins. A HAB in Detroit Lake during spring produced cyanotoxins that were transported downstream in the North Santiam River, affecting the State capital of Salem's drinking water for about a month. Similar types of cyanobacterial blooms occur in Blue River and Cougar Reservoirs, in the McKenzie River Basin, with similar threats to drinking water for the City of Eugene.
>
> To address this issue, and to complement on-going limnological surveys, the USGS partnered with the City of Salem, the Eugene Water and Electric Board, and the U.S. Army Corp of Engineers to monitor algal blooms in Detroit Lake and nearby Cougar

> Reservoir - and the downstream rivers - using continuous water-quality monitors that transmit data to water treatment plant operators, dam operations, researchers and the public in near real-time. Basic parameters, including water temperature, conductance, and turbidity, are collected vertically in the reservoirs approximately every meter for the top 10 meters, then every 5 meters down into the hypolimnion (bottom waters) to a maximum of 75-90 meters (230-295 feet) deep. HAB parameters include surrogates for algal biomass (total chlorophyll [fCHL] and blue-green pigment phycocyanin [PC]), indicators of photosynthetic activity (dissolved oxygen and pH) and fluorescing dissolved organic matter [fDOM] that is often a reliable surrogate for dissolved organic carbon. Each of these parameters is monitored hourly at the surface (~1-meter depth) and through the water column multiple times per day from locations near dam (at the log booms). Data are available (per parameter) as: Profiles with a slider scale to portray conditions with depth over time; Time-series plots, based on the hourly data collected at 1-meter depth; and in Contours, color plots of parameter values by depth over time. When taken together with the downstream continuous water-quality monitors these data provide an early-warning indicator of an algal bloom in the reservoir, or the possible release and transport of algae downstream to drinking-water intakes. These data also provide insights into the evolution, behavior, and decay of the seasonal blooms which can inform management strategies, modeling, and perhaps prediction of blooms in the future.[5]

Future Climate Variability

In the *2023 Salem NHMP*, there are several locations that describe future changing conditions or climate change as it relates to the natural hazards that impact Salem and the surrounding area. In the order of appearance in the NHMP it is in the Risk Assessment and the Hazard Characterizations.

The Willamette River at Salem is currently rain-dominated, whereas the Santiam River at Detroit Dam is in mix of rain-and-snow basin in which flow peaks during winter and during spring snowmelt. How such changes in frequency of rain-on-snow events are likely to affect streamflow, according to the OCCRI *Future Climate Projections Marion County, Oregon*. The report continues,

> Streams in the Northwest are projected to shift toward higher winter runoff, lower summer and fall runoff, and earlier peak runoff, particularly in snow-dominated regions (Raymondi *et al.*, 2013; Naz *et al.*, 2016). These changes are expected to result from increases in the intensity of heavy precipitation; warmer temperatures that cause more precipitation to fall as rain and less as snow, in turn causing snow to melt earlier in spring; and increasing winter precipitation and decreasing summer precipitation (Dalton *et al.*, 2017; Mote *et al.*, 2019; Dalton and Fleishman, 2021).

[5] HAB Site USGS 444306122144600, Detroit Lake at Log Boom Behind Detroit Dam, OR.

According to the Salem WMCP, future curtailment episodes could occur because of "significant drought affecting North Santiam River flow, failure of aging infrastructure, flooding and high turbidity events affecting filtration at Geren Island, system wide earthquake damage, or other catastrophic events that may affect water supply." Furthermore, a wildfire event will affect water balance, water quality, fluvial and riparian systems, and water infrastructure, according to OCCRI *Fifth Oregon Climate Assessment* (2021).

Regarding the water infrastructure and supply, the *Fifth Oregon Climate Assessment* (2021) states,

> Climate change-induced shifts in precipitation and rising temperatures are affecting the quantity and quality of Oregon's surface water and groundwater (*State of Climate Science*, this volume), and threaten the ability of water infrastructure systems to provide expected and timely services. …
>
> Projected drier summers and reduced snow-to-rain ratios (*State of Climate Science*, this volume), exacerbated by groundwater depletion in some regions, threaten the ability of existing water supply infrastructure to meet the growing demand for multiple uses of water (e.g., domestic, industrial, irrigation, recreation) (Clifton et al. 2018). The shift in seasonal flows may require adjustments to existing irrigation infrastructure, such as canals, pipes, storage reservoirs, ponds, and wells. Seasonal changes also may warrant adjustments to water rights, ideally allowing reused and other sources of water to be leveraged or existing resources to be conserved (Jaeger et al. 2017, ASCE 2019) to ensure that the water supply is reliable, water quality regulations are met, costs are managed, and systems are maintained. Adjustments by water utilities may include improving the efficiency of the distribution system to minimize losses (CPMC 2014a, b), promoting conservation behaviors and technologies (e.g., changes to building and plumbing codes; conversion of treated wastewater to potable water [ASCE 2019]), and identifying alternate sources and opportunities for enhancing storage capacity.

The *Salem Climate Action Plan* *2021,* includes numerous strategies to address a variety of climate-related challenges, including warming temperatures, changing precipitation patterns, and increased risk of wildfire. Some of the most significant projected climate impacts are the following, some or all of which will impact water quality for the City of Salem:

- The number of days with a heat index over 90°F will increase from a historic average of 7 per year to 33 per year by mid-century.
- Hotter and drier conditions are likely to cause more frequent droughts.
- More intense rainfall and rain-on-snow events could also lead to flood events in areas outside of historical high-risk zones.
- Wildfire is a significantly increasing risk across the state of Oregon. The number of extreme fire danger days in Salem will double by mid-century, increasing from a historic average of 10 per year to 20 per year. Extremely large, intense fires will become more likely under hotter and drier climate scenarios.

- Poor to hazardous air quality resulting from wildfires could greatly impact unsheltered populations and people with underlying health issues such as asthma, diabetes and obesity.

Probability Assessment

While it rarely occurs, water quality may become unsafe to drink or use otherwise because of a natural disaster or high levels of contaminants in the water source. Salem has begun to recognize the impacts of poor water quality with climate-related challenges such as warming temperatures, changing precipitation patterns, and increased risk of wildfire.

Based on the available data and research for Salem, the NHMP Steering Committee assessed the **probability of experiencing a water quality hazard as "high,"** meaning one incident is likely within a 10 to 35-year period.

Vulnerability Assessment

Salem has nine customer categories for water that include residential, multi-family, commercial, industrial, institutional, public, irrigation, wholesale, and fire services. When water quality emergencies occur, all sectors are impacted. Through the Salem WMCP, proactive measures are outlined in water curtailment plans. The intent of a curtailment plan is to minimize the impact of water supply shortages, which may result from incidents such as prolonged drought, mechanical or electrical equipment failure in the system, unanticipated catastrophic events (flooding, landslides, earthquakes and contamination), or events not under control of the water supplier (e.g., localized or area-wide power outages, harmful algal blooms, high turbidity, and intentional malevolent acts).

Salem Climate Action Plan 2021

The *Salem Climate Action Plan 2021* outlines the following potential vulnerabilities and consequences of various projected climate changes as it relates to water quality and supply.

Projected Temperature Increases

The issue of increasing cyanotoxins in drinking water due to algal blooms would be a significant risk to Salem's residents if not for the important water treatment efforts already underway.

- Warming temperatures will likely lead to sustained or increased frequency of cyanotoxins, or harmful algal blooms, in the freshwater systems surrounding Salem. Exposure to cyanotoxins can cause hay fever-like symptoms, skin rashes, respiratory and gastrointestinal distress, and drinking untreated water containing cyanotoxins can cause liver and kidney damage. Salem has been monitoring and treating drinking water for cyanotoxins for years, and recently invested in a new ozone filtration system at the Geren Island water treatment plant to ensure drinking water for residents will continue to be safe. But recreational activities in local lakes and rivers could be inhibited.
- Decreased water levels in the reservoirs on the North Santiam River which provide all of Salem's water.

Projected Precipitation Patterns

Though overall precipitation amounts are expected to remain consistent, increased temperatures noted above will lead to a water deficit. This deficit may impact water supply and demand for the nine customer categories that Salem provides water, including residential, multi-family, commercial, industrial, institutional, public, irrigation, wholesale, and fire services. Precipitation patterns may change, leading to increased frequency of heavy downpour events and flooding, which can also have an impact on water quality.

- Water use restrictions and food insecurity in periods of drought.

Projected Wildfire Risk

Increased temperatures and drier conditions will lead to increased fire risk in forested areas outside of Salem and in the North Santiam Watershed, where Salem's water source originates.

- Salem's drinking water source, the North Santiam River, could be degraded. Debris and chemicals in surface water following a fire could put additional pressure on water treatment facilities. The Geren Island water treatment plant could itself be at risk of wildfire.
- Higher than expected population growth. If people choose to relocate from other areas with higher climate change risk, the population influx could strain existing resources, services, and contribute to housing-related issues.

The Salem NHMP Steering Committee rated the city as having **a "moderate" vulnerability to water quality hazards**, meaning between 1 to 10% of the city's population or property would be affected by a major water quality emergency or disaster.

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

Environmental Protection Agency

According to the EPA, the Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1972.

The Water Quality Standards Regulation (40 CFR 131) establishes the requirements for states and tribes to review, revise and adopt water quality standards. It also establishes the procedures for EPA to review, approve, disapprove and promulgate water quality standards pursuant to section 303 (c) of the Clean Water Act.

Congress passed the Safe Drinking Water Act (SDWA) in 1974 to protect public health, including by regulating public water systems. The EPA has established protective drinking water standards for more than 90 contaminants, including drinking water regulations issued since the 1996 amendments to SDWA that strengthen public health protection. Over 92 percent of the population supplied by community water systems receives drinking water that meets all health-based standards all the time. EPA requires community water systems to deliver a Consumer Confidence Report, also known as an annual drinking water quality report, to their customers. These reports provide Americans information about their local drinking water quality.

State Resources

Oregon Health Authority

Access to safe drinking water is essential to human health. Oregon Health Authority (OHA) *Drinking Water Services* helps to keep drinking water safe for Oregonians. The Drinking Water Services administers and enforces drinking water quality standards for public water systems in the state of Oregon. It also focuses resources in the areas of highest public health benefit and promotes voluntary compliance with state and federal drinking water standards with an emphasis on prevention of contamination through source water protection. They also provide technical assistance to water systems and provides water system operator training.

Oregon Department of Environmental Quality

DEQ uses water quality standards to assess whether the quality of the state's rivers and lakes is adequate for fish and other aquatic life, recreation, drinking, agriculture, industry and other uses. DEQ also uses the standards as regulatory tools to prevent pollution of the state's waters. More information regarding DEQ's role in water quality can be found at https://www.oregon.gov/deq/wq/Pages/default.aspx.

Included in DEQ's water quality protection is Total Maximum Daily Load (TMDL), which is a clean water plan, used to clean up polluted water so that it meets state water quality standards. A TMDL defines the amount of a pollutant that can be present in a waterbody without causing water quality criteria to be exceeded. In December 2002, Oregon's Environmental Quality Commission adopted Oregon Administrative Rule (OAR) Chapter 340, Division 42, commonly referred to as the TMDL rule. The rule defines DEQ's responsibilities for developing, issuing, and implementing TMDLs as required by the CWA.

A Water Quality Management Plan (WQMP) is one of the 12 TMDL elements called for in OAR 340-042-0040. The WQMP is a general plan and framework for implementation of the TMDL. The WQMP framework is designed to work in conjunction with detailed plans and analyses provided in sector-specific or source-specific implementation plans. TMDLs, the WQMP, and associated implementation plans and activities are designed to restore water quality to comply with water quality standards. In this way designated beneficial uses, such as aquatic life, drinking water supplies, and water contact recreation, will be protected.

The EPA approved the Willamette Basin TMDL plan on September 29, 2006. Included in this plan is the *Willamette Basin Water Quality Management Plan*.

Water Supply Availability Committee and Drought Readiness Council

Oregon Revised Statute 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 interagency groups to evaluate water supply conditions, and to help assess and communicate potential drought related impacts, the Water Supply Availability Committee and the Drought Readiness Council.

The WSAC is a technical committee chaired by the OWRD. The WSAC provides the scientific foundation that decision-makers need to identify and respond appropriately to drought. The Committee consists of state and federal science and emergency preparedness agencies.

The WSAC meets 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

The other group that Oregon relies upon to evaluate water conditions is the DRC, which is co-chaired by the OWRD and OEM. The council consists of state agencies with natural resources management, public health, or emergency management expertise. The role of the DRC is to review local requests for assistance and make recommendations to the Governor regarding the need for state drought declarations.

Oregon Water Resources Department

OWRD serves the public by practicing and promoting responsible water management by directly addressing Oregon's water supply needs; in addition to, restoring and protecting stream flows and watersheds to ensure the long-term sustainability of Oregon's ecosystems, economy, and quality of life. OWRD has several programs including water rights; groundwater and wells; streams, lakes and dams; drought, and wildfire recovery. For more information on OWRD programs, refer to https://www.oregon.gov/owrd/programs/Pages/default.aspx.

OWRD evaluates applications for Aquifer Storage and Recovery authorization for proposed projects and their potential effects on the groundwater resource and other water users. ASR-related statutes (ORS 537.531 to 537.534) and rules (OAR 690-350-010 to 690-350-030) provide a legal framework for water users to store water underground during times of low demand and then recover it through wells during high demand periods. Extensive water quality and water quantity monitoring and reporting is part of all projects. Water quality issues are addressed through coordination with DEQ and OHA Drinking Water Services, according to OWRD Aquifer Storage and Recovery program.

Local Resources

Salem Geren Island Water Treatment Facility

Salem invested over $50 million for the design and construction of a state-of-the art ozone treatment facility at Geren Island to ensure the community has safe and resilient drinking water long into the future, according to Salem's Drinking Water Treatment program.

In May 2018, water quality samples revealed that harmful algal blooms (cyanotoxins) were detected in Salem's drinking water distribution system, above a Health Advisory Level for the first time. In response, a drinking water advisory was issued, based upon the level of cyanotoxins detected, to vulnerable populations in Salem. In addition to collaborative water quality monitoring with USGS, Eugene Water and Electric Board, and USACE, to address the issue, Salem took steps to establish an ozone treatment system at Geren Island. The ozone treatment system, in full operation in 2022, removes algal toxins as well as contaminants caused by wildfires, according to the Salem's *Annual Water Quality Report 2022*.

North Santiam Watershed Drought Contingency Plan

Since the last NHMP update, Salem participated in the development of the North Santiam Watershed Drought Contingency Plan (NSDCP), which was accepted in April 2018 by the Bureau of Reclamation. The NSDCP was developed by the North Santiam Watershed Task Force to foster a collaborative and non-regulatory approach to drought planning, monitoring, and response within the watershed. The goal of the NSW DCP is to build long-term resiliency to drought to minimize impacts to the communities, local economies, and the critical natural resources within the watershed. The NSDCP addresses the entire North Santiam watershed, in addition to, users outside the basin, such as City of Salem. The plan provides framework for drought monitoring, asset vulnerability, and other conditions resulting from drought. Mitigation actions are provided to reduce risks and impacts before a drought, response during a drought, and collaboration for promoting an efficient response to drought.

According to the NSDCP, low streamflow is identified at Salem's intake on the North Santiam River as a vulnerability (meaning the ability of the intake to divert water under low flow conditions is limited). Therefore, the plan identifies 7-day rolling average flows in the as one indicator of North Santiam Watershed stage 6 drought. Recommended responses to the drought stages fall into the following categories: conservation messaging, public education, and outreach; monitoring and evaluation; water rights management; water conservation; and emergency responses. If a drought is declared in Marion County, Salem will do the following:

- Communicate with customers about the drought declaration and the status of Salem's water supply via the city website, as well as encourage water conservation.
- Communicate with the NSDCP Task Force and take appropriate actions as outlined in the NSDCP.
- Implement the appropriate stage of water curtailment if the drought declaration coincides with an identified curtailment trigger.

Salem and Santiam Water Control District are sponsoring partners for the Bureau of Reclamation 2022 WaterSMART Drought Contingency Planning grant, which has funded an update to the NSDCP. The NSDCP update is aimed at continuing to build long-term resiliency to drought in the North Santiam Watershed. This update process began in November 2022 and is anticipated to be completed sometime in 2024.

Santiam Water Control District, Council of Water Leaders

The Council of Water Leaders (CWL) was created in 2022 to help address urgent water resource challenges in the North Santiam Watershed and provide a forum for increasing communication and coordination amongst decision-makers and other leaders on important issues in the North Santiam Watershed. CWL holds quarterly meetings and an annual symposium.

The CWL uses available science to develop long-term solutions to water management issues, such as the following:

- Emergency planning
- Post-fire recovery
- Drought contingency planning
- Water quantity (flow restoration and flow management)
- Water quality (source water protection and Willamette River mercury total maximum daily load (TMDL))
- Riparian and aquatic habitat restoration

Salem Climate Action Plan and Community Greenhouse Gas Inventory

Since the last NHMP update, Salem developed the *Salem Climate Action Plan 2021*. Salem is taking action to respond to climate change with this plan by outlining strategies and actions to reduce Greenhouse Gas emissions and increase climate resiliency in our community. Through the development of the CAP, it was determined that Salem's projected climate impacts will include three main categories: warming temperatures, changes in precipitation patterns, and increased risk of wildfires. Many of the strategies in the CAP are designed to help the community adapt to impacts and build resiliency for the future. The strategies seek to do the following:

- Expand the urban tree canopy and access to green spaces
- Create a climate related education and outreach program
- Create a network of indoor gathering places that can serve as community centers during times of need
- Engage underserved populations in co-creating resilient solutions
- Strengthen the local economy

Salem Clean Streams, Clear Choices Initiative

The City of Salem's Clean Streams, Clear Choices initiative was developed to educate the community on impactful choices you can make to help keep pollution out of the stormwater runoff and local streams. Stormwater runoff does not go to a treatment plant, but instead goes directly into the streams. Because of this, Salem's urban stormwater runoff carries pollutants to the stream that can affect the water quality and aquatic life within local streams. Salem provides information about what the community can do to help keep their streams clean and to reduce pollution.

Wildfire

Significant Changes Since Previous Plan:

The Wildfire Hazard section was reformatted and expanded with additional information since the previous plan.

The existing Marion County Community Wildfire Protection Plan was updated in 2017 and incorporated where applicable in this plan.

Causes and Characteristics

Wildfire is defined as an uncontrolled burning of wildland (forest, brush, or grassland). Wildfires occur in areas with large amounts of flammable vegetation that require a suppression response due to uncontrolled burning. Fire is an essential part of Oregon's ecosystem but can also pose a serious threat to life and property particularly in the state's growing rural communities. Wildfire can be divided into three categories: interface, wildland, and firestorms. 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 built-up urban areas, they have also left behind readily available fire services providing structural protection.

The following four factors contribute significantly to wildfire behavior and can be used to identify wildfire hazard areas.

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 parts of Salem, 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, 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.

Fuel

Fuel is the material that feeds a fire. Fuel is classified by volume and type. The type and condition of vegetation plays a significant role in the occurrence and spread of wildfires. Certain types of plants are more susceptible to burning or will burn with greater intensity. Dense or overgrown vegetation increases the amount of combustible material available to fuel the fire (referred to as the "fuel load"). The ratio of living to dead plant matter is also important. The risk of fire is increased significantly during periods of prolonged drought as the moisture content of both living and dead plant matter decreases. The fuel's continuity, both horizontally and vertically, is also an important factor.

Weather

The most variable factor affecting wildfire behavior is weather. Temperature, humidity, wind, and lightning can affect chances for ignition and spread of fire. Extreme weather, such as high temperatures and low humidity, can lead to extreme wildfire activity. By contrast, cooling and higher humidity often signals reduced wildfire occurrence and easier containment.

The frequency and severity of wildfires is also dependent upon other hazards, such as lightning, drought, equipment use, railroads, recreation use, arson, and infestations. If not promptly controlled, wildfires may grow into an emergency or disaster. Even small fires can threaten lives and resources and destroy improved properties. In addition to affecting people, wildfires may severely affect livestock and pets. Such events may require emergency watering/feeding, evacuation, and shelter.

The indirect effects of wildfires can be catastrophic. In addition to stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil, waterways, and the land itself. Soil exposed to intense heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams, thereby enhancing flood potential, harming aquatic life, and degrading water quality. Lands stripped of vegetation are also subject to increased debris flow hazards, as described above.

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. Looking at the future climate projections described in the 2020 Oregon NHMP, it is likely these situations are exacerbated by changes in the climate.

Location and Extent

Wildfire hazard areas are commonly identified in regions of the Wildland Urban Interface (WUI). The WUI occurs where wildland and developed areas meet or intermingle with both vegetation and structural development combining to provide fuel. If left unchecked, it is likely that fires in these areas will threaten lives and property. One challenge Salem faces is from the increasing number of houses being built in the urban/rural fringe as compared to twenty years ago. The interface between urban or suburban areas and the resource lands has significantly increased the threat to life and property from fires. Responding to fires in the expanding WUI area may tax existing fire protection systems beyond original design or current capability.

Ranges of the wildfire hazard are further determined by the ease of fire ignition due to natural or human conditions and the difficulty of fire suppression. The wildfire hazard is also magnified by several factors related to fire suppression/control, such as the surrounding fuel load, weather, topography, and property characteristics.

Fire susceptibility throughout the city dramatically increases in late summer and early autumn as summer thunderstorms with lightning strikes increases and vegetation dries out, decreasing plant moisture content and increasing the ratio of dead fuel to living fuel. However, various other factors, including humidity, wind speed and direction, fuel load and fuel type, and topography can contribute to the intensity and spread of wildfire. In addition, common causes of wildfires include arson and negligence from industrial and recreational activities.

While Salem does not have a specific wildfire management plan, the city is included in the *Marion County Community Wildfire Protection Plan* (CWPP). One of the core elements of a CWPP is developing an understanding of the risk of potential losses to life, property, and natural resources during a wildfire. This risk assessment adopts the approach produced by ODF under the National Association of State Foresters (NASF) guidance which includes the following three risk objectives:

- Identify Communities-at-Risk and the Wildland-Urban Interface
- Develop and conduct a wildfire risk assessment of all land in Marion County, surrounding the City of Salem.
- Identify and prioritize hazardous fuels treatment projects for all land in Marion County.

The Marion County wildfire risk assessment is the analysis of the potential losses to life, property, and natural resources. The analysis takes into consideration a combination of factors defined below:

Risk: the potential and frequency for wildfire ignitions (based on past occurrences).

Hazard: the conditions that may contribute to wildfire (fuels, slope, aspect, elevation and weather).

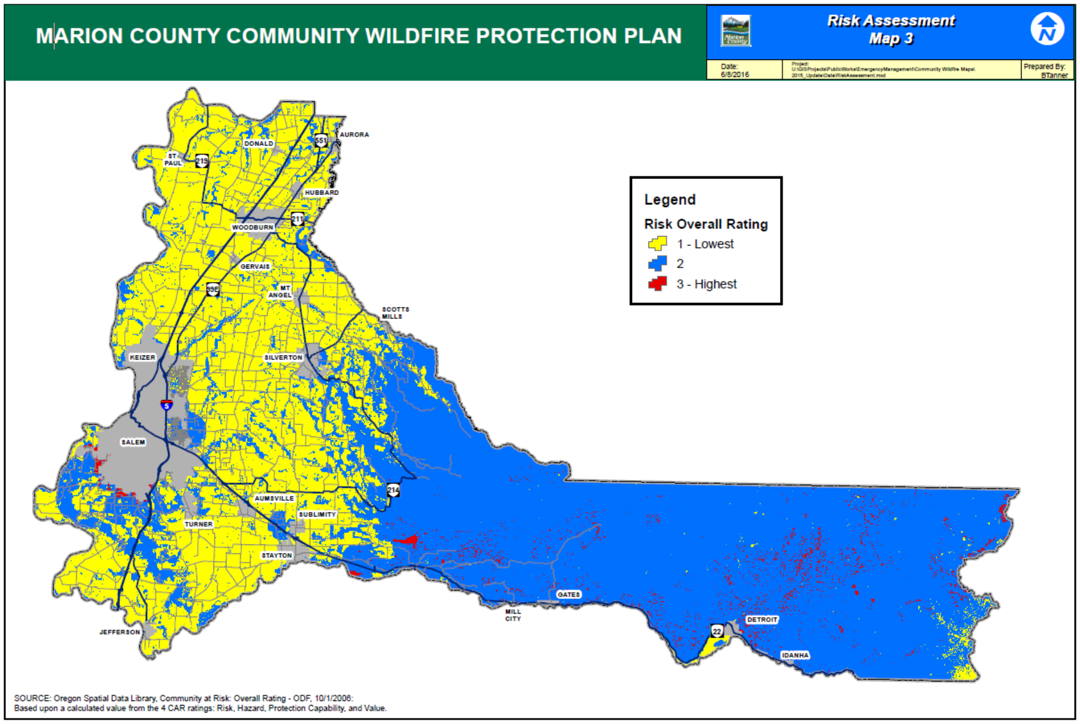
Values: the people, property, natural resources and other resources that could suffer losses in a wildfire event.

Protection Capability: the ability to mitigate losses, prepares for the hazard, responds to and suppresses wildland and structural fires.

Structural Vulnerability: the elements that influence the level of exposure of the hazard to the structure (roof type and building materials, access to the structure, and whether there is defensible space or fuels reduction around the structure.

The Marion County CWPP identifies Salem (south and east) as an at-risk community based upon residential density and Fire District serviceability. The extent of damage to Salem from WUI fires is dependent on many factors, including temperature, wind speed and direction, humidity, proximity to fuels, and steepness of slopes. WUI fires can be intensified by development patterns, vegetation, and natural fuels, and can merge into unwieldy and unpredictable events. Figure 2-48 shows the overall risk rating for Marion County.

Figure 2-48 Marion County Wildfire Risk Assessment Map



Source: Marion County. (2017, June). *Marion County, Oregon Community Wildfire Protection Plan*. Retrieved from https://www.co.marion.or.us/PW/EmergencyManagement/Documents/Community%20Wildfire%20Protection%20Plan.pdf.

Updated wildfire risk assessment information is now available through the West Wide Wildfire Risk Assessment (WWA).[6] The WWA, a multi-state assessment, provides multiple data sets that can be used to evaluate and weight the relative risk of various factors that contribute to wildfire risk. Because of the scale, modeling and assumptions that went into creating the WWA, caution is needed when interpreting the data at the local level. The ongoing CWPP update process will assess this new data and determine its relevance to wildfire risk and mitigation strategies in Marion County. Initial analysis of the WWA data does not indicate a significant variance from the analysis used in the Marion and Polk CWPPs.

Identifying Wildfire

The first phase of wildfire-hazard assessment is identification. Hazard identification identifies the geographic extent of areas subject to wildfire, expected intensity of a wildfire event at different locations, and probability of occurrence of wildfire events. In addition, the

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[6] The Oregon Department of Forestry, on behalf of the Council of Western State Foresters (CWSF) and the Western Forestry Leadership Coalition (WFLC), has conducted a wildfire risk assessment and report for the 17 western states and selected U.S. affiliated Pacific Islands. At the highest level, this assessment is known as the West Wide Wildfire Risk Assessment, or WWA (Oregon Department of Forestry, 2016).

level of wildfire hazard is determined by the ease of fire ignition, natural or human cause, and difficulty of fire suppression. Wildfire hazard can be magnified by several fire suppression and control factors, such as the fuel load, weather, topography, and property characteristics.

The use of Geographic Information System (GIS) tools and improved data can assist in fire hazard assessment, allowing further integration of fuels, weather, topography, and development data for fire behavior prediction, watershed evaluation, developing mitigation strategies, and hazard mapping.

According to the National Wildfire Coordinating Group (NWCG) *Glossary of Wildland Fire Terminology* (2012), wildfire can be divided into three main categories: interface, wildland, and firestorms. These descriptions are provided for a brief but comprehensive understanding of wildfire.

Interface or Wildland Urban Interface (WUI) Fires

An interface fire occurs where wildland and developed areas, structures and other human development, meet or intermingle with both vegetation and structural development combining to provide fuel. Figure 2-49 below illustrates higher risk areas of Salem's interface. This information was developed from the ODF wildfire risk classification data.

Wildland Fires

Wildland is an area where development is essentially non-existent, except for roads, railroads, powerlines, and similar transportation facilities. Structures, if any, are widely scattered. 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. Three distinct types of wildland fire include wildfire, wildland fire use, and prescribed fire, and are further defined below by the NWCG *Glossary of Wildland Fire Terminology* (2012).

Wildfire

An unplanned, unwanted wildland fire including unauthorized human-caused fires, escaped wildland fire use events, escaped prescribed fire projects, and all other wildland fires where the objective is to put the fire out.

Wildland Fire Use

The application of the appropriate management response to naturally-ignited wildland fires to accomplish specific resource management objectives in pre-defined designated areas outlined in Fire Management Plans. Operational management is described in the Wildland Fire Implementation Plan (WFIP).

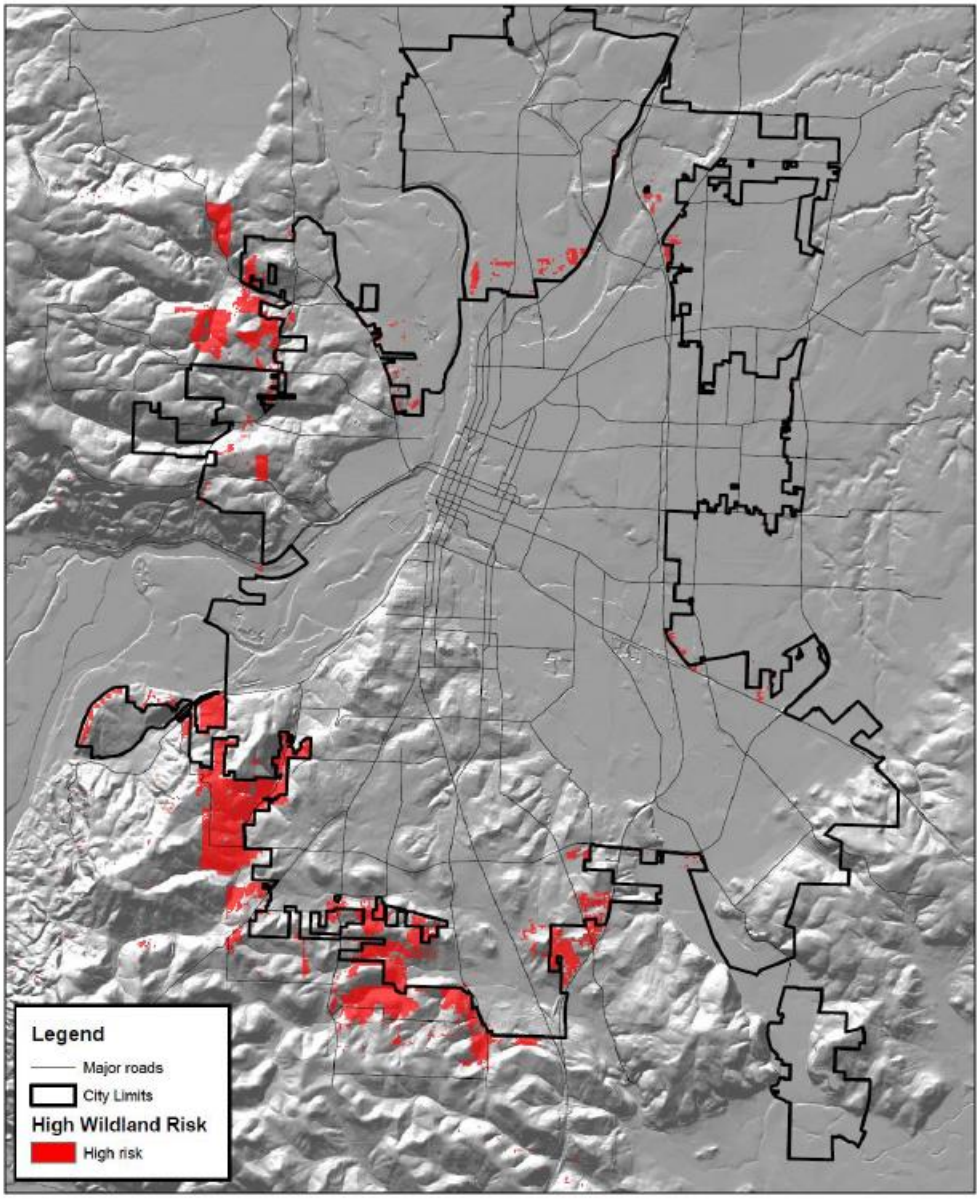
Prescribed Fire

Any fire ignited by management actions to meet specific objectives. A written, approved prescribed fire plan must exist, and NEPA requirements (where applicable) must be met, prior to ignition.

Fire Storms

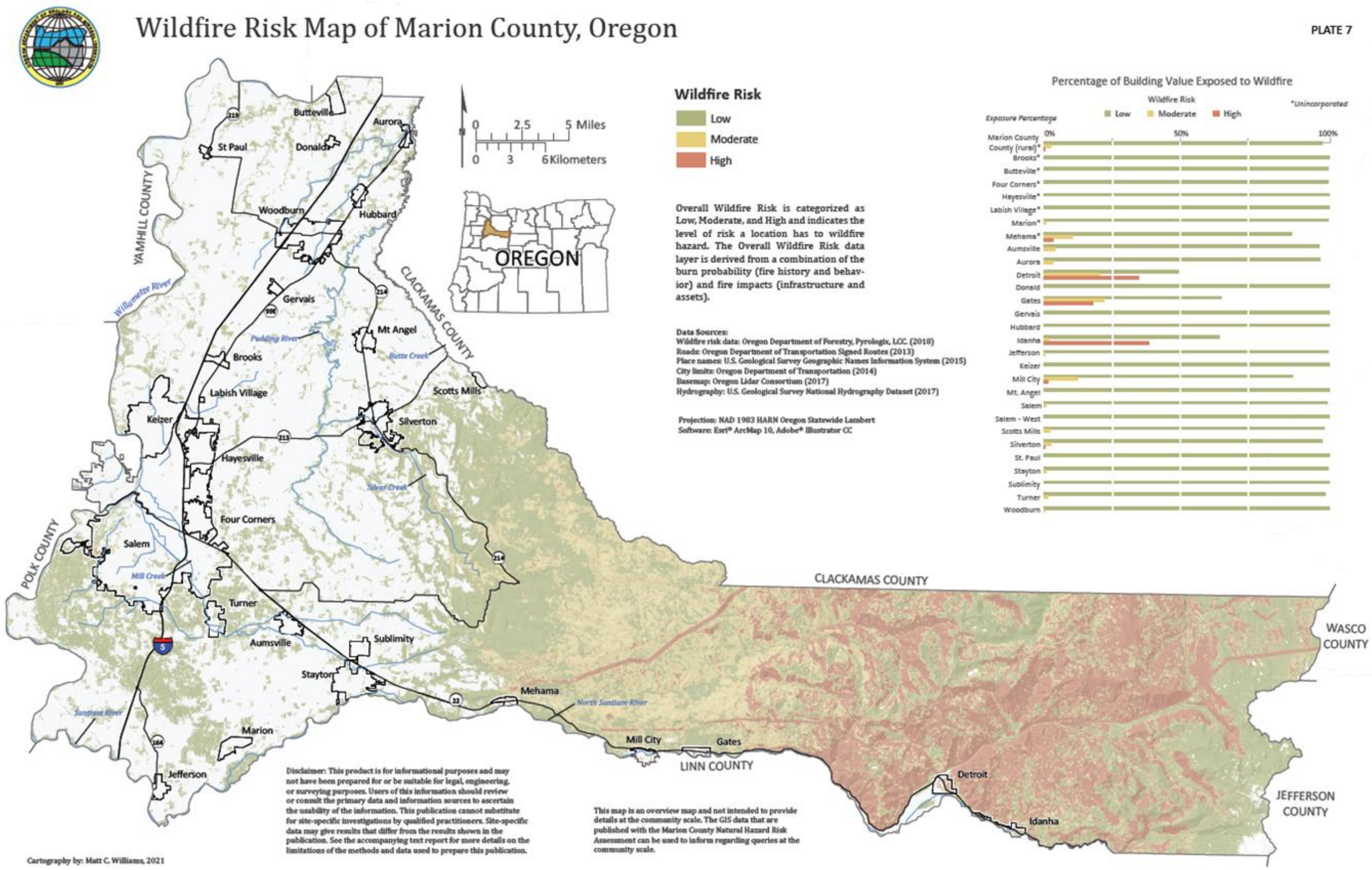
A fire storm is a very intense and destructive fire usually accompanied by high winds. As defined by NWCG, "Violent convection caused by a large continuous area of intense fire. Often characterized by destructively violent surface indrafts, near and beyond the perimeter, and sometimes by tornado-like whirl."

Figure 2-49 Wildland Interface Fire Risk Areas



Source: City of Salem. (n.d.). *2018-2023 Salem Fire Department Standards of Cover*. Retrieved from https://www.cityofsalem.net/home/showpublisheddocument/1194/637788988618800000.

Figure 2-50 Wildfire Risk Map of Marion County, Oregon



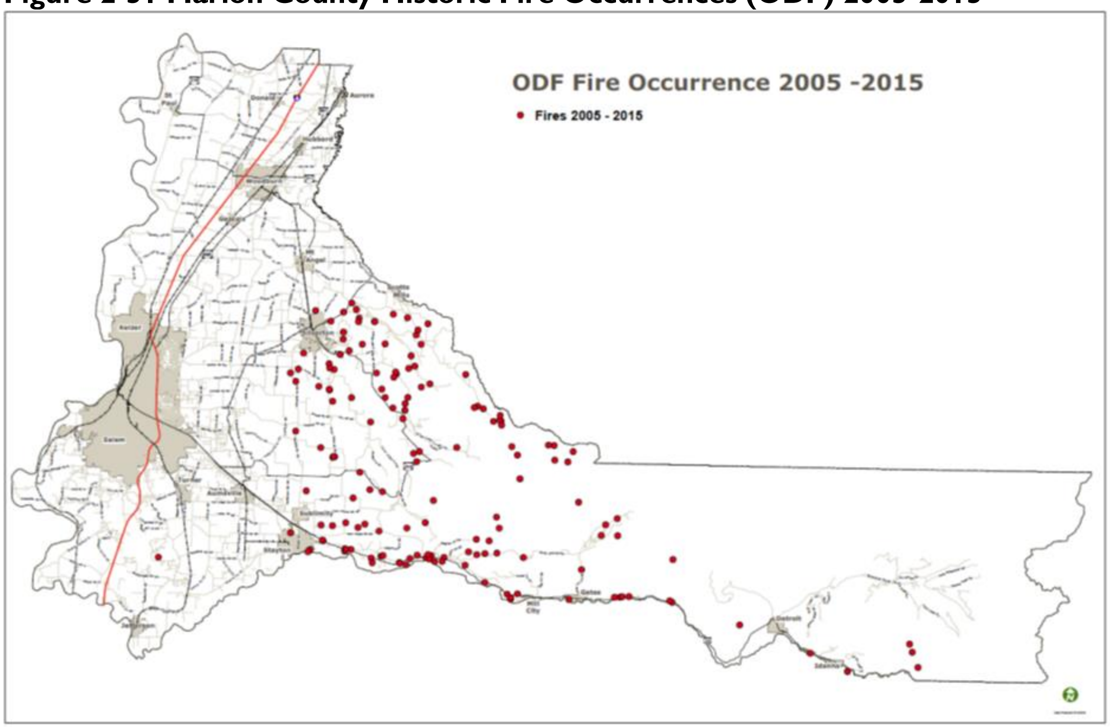
Source: Williams, M. C. & Madin, I. P. (2022). Open-file Report O-22-05 Multi-Hazard Risk Report for Marion County, Oregon. Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/O-22-05/p-O-22-05.htm.

History

Salem's climate, vegetation, and topography make wildland fire a rare but real risk to the community. Parts of the city have homes interspersed with large areas of natural vegetation. Many of these homes are located at the top of moderate to steep slopes, increasing the risk.

Historically, Salem experiences small, slow moving, wildland fires on a regular basis. Warm summer temperatures and strong winds can carry wildland fires into homes. However, fuel types found in this region do not support aggressive fire behavior. Salem has had relatively few occurrences of WUI Fire hazards that have resulted in minimal dollar losses. Refer to Figure 2-49 above that illustrates the WUI high risk areas in and near the city. Most fire incidents are human caused and include vegetation fires, forest/wood fires, brush and grass fires. In July 2014, a four-alarm grassfire just West of Salem caused at least two homes to be evacuated. The location of the grassfire was off Highway 22 between Doaks Ferry Road NW and College Drive NW. In July 2015, a 15-acre wildfire threatened 15-20 homes on SE Macleay Road between 74th and 78th avenues. One hundred firefighters responded to the fire and could contain the burn within about an hour. No damage to life or property was reported. Figure 2-51 shows the countywide wildfire history from 2005 to 2015 per the Marion County CWPP.

Figure 2-51 Marion County Historic Fire Occurrences (ODF) 2005-2015

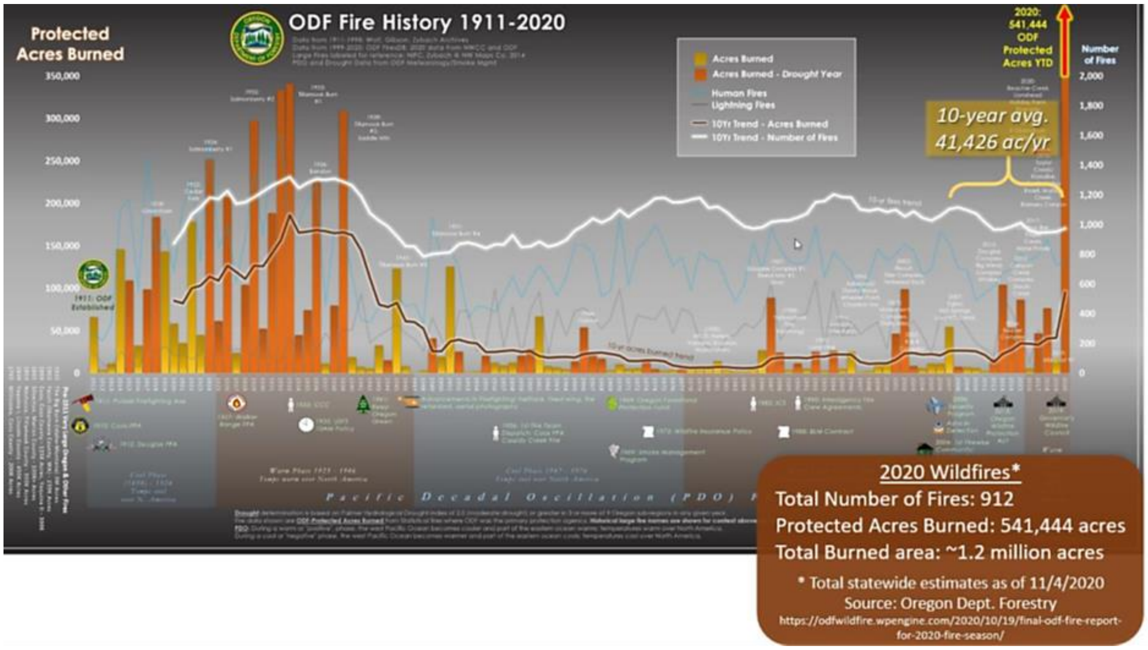


Source: Marion County. (2017, June). *Marion County, Oregon Community Wildfire Protection Plan*. Retrieved from https://www.co.marion.or.us/PW/EmergencyManagement/Documents/Community%20Wildfire%20Protection%20Plan.pdf.

2020 Oregon Wildfire Season

During 2020, wildfires burned over 1.2 million acres in Oregon and destroyed 4,000 homes. Nine civilians and two firefighters lost their lives. 2020 was the most destructive wildfire season in Oregon in history. Figure 2-52 provides a visual of wildfire history from ODF with several statistics for 2020 highlighted.

Figure 2-52 Oregon Department of Forestry, Fire History 1911-2020



Source: Adair, C. (2021, March 4). National Flood Services Expert Series Webinar presentation. 2020 Oregon Wildfires: Post-Wildfire Floodplain Management.

According to ODF's 2020 Fire Season document (Alcock, 2021), much of the state was in severe drought from spring onward. Numerous wildfires broke out in a very dry southern Oregon in April, leading Southwest Oregon to declare the start of fire season on May 1, which is a month earlier than usual. During the summer, human-caused wildfires were up slightly but fewer lightning-caused fires occurred until mid-August. In August, there were five days of lightning across the state. Fires started by those lightning strikes were fanned by winds and high temperatures into large blazes.

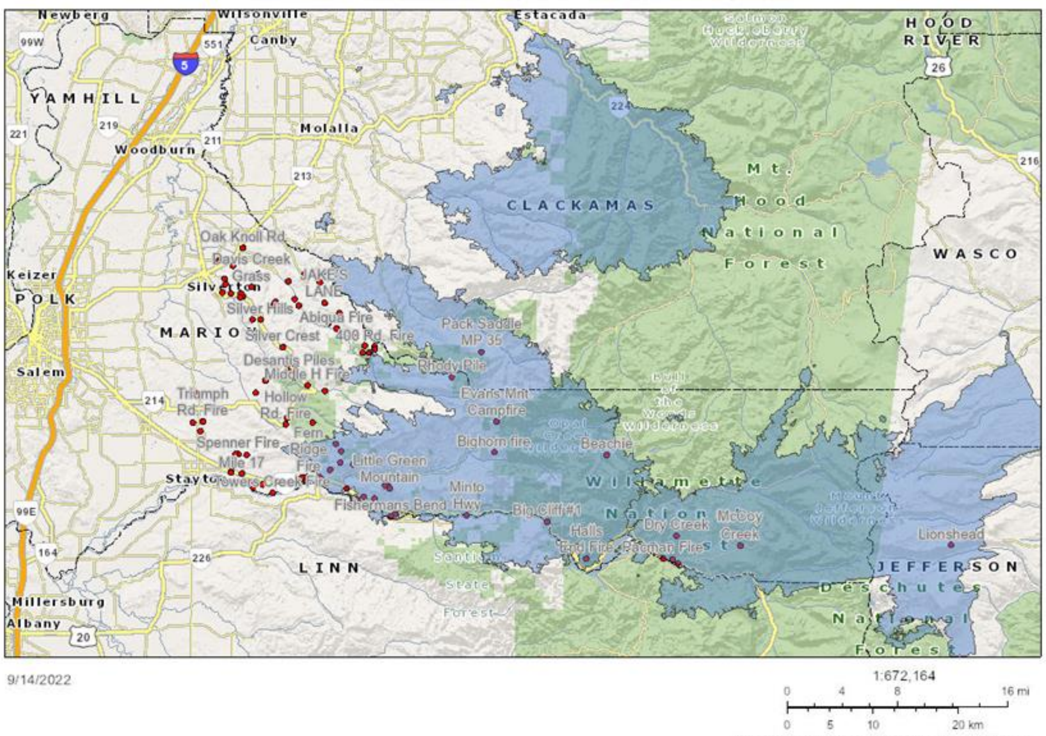
On August 19, 2020, Governor Brown declared a statewide State of Emergency. This made available the Oregon National Guard for firefighting, including personnel and equipment. On September 7, 2020, against a backdrop of drought and historically low fuel moistures and humidity, a high wind warning was issued. A strong cold front arrived in the early evening, with east-northeast winds at sustained speeds of 20 to 30 miles per hour (mph) and gusts to 50 to 60 mph. This was the strongest three-day easterly wind event during fire season since at least 1950 (winds were stronger in the 1962 Columbus Day storm, but that hit after fire season).

There were 14 fires from the Labor Day wind event that would be approved as a FEMA FMAG fire. Five fires in the Cascade Range soon spread west to become fire storms (over

100,000 acres), almost as many as occurred in Oregon in the entire 20th century. All five of these fires moved into Oregon's top 20 wildfires by size since 1900. Firefighting personnel and equipment poured into Oregon from more than 30 different U.S. states and Canada, peaking at about 7,500. The Labor Day wildfires were mostly contained by late September or October 2020.

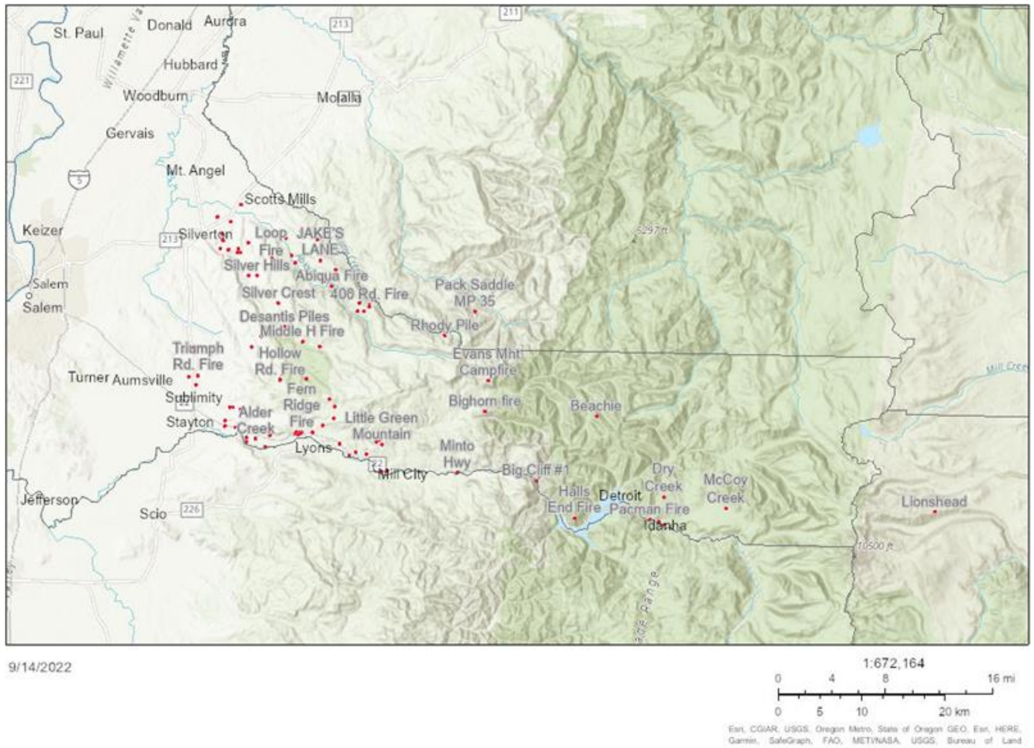
Of the 2020 Labor Day wildfires, Marion County was impacted by the Beachie Creek and Lionshead fires which merged in Marion County burning approximately 400,000 acres. In addition, the Riverside Fire burned in the northern part of the county. The Beachie Creek fire burned 193,565 acres of land in the counties of Linn, Marion and Clackamas including portions of the Mill City before it merged with the Lionshead fire. The Beachie Creek wildfire started on August 16, 2020, in the Opal Creek Wilderness in Marion County. The fire remained in a remote location through the month then grew rapidly in September because of the widespread wind gusts, noted above, of 50-70 miles per hour. The Strong winds caused widespread damage to trees, and downed numerous power lines across the region, which started at least 13 additional wildfires. Large portions of the cities of Detroit, Mehama, and Gates were destroyed, and significant portions of Idanha, Mill City, and Lyons also burned. The 2020 Labor Day wildfires burned a total of 1,000,000 acres (Wikipedia, 2022).

Figure 2-53 Marion County Wildfire Occurrences (2016-2021) and 2020 Wildfire Perimeters



Source: Oregon Department of Forestry. (2023, February 13). *ODF Fire*. ArcGIS Online. Retrieved September 2022 from https://www.arcgis.com/home/item.html?id=e3896b22b0ab41d4835f82574ed81fb0.

Figure 2-54 Marion County Cities and 2016-2021 Wildfire Occurrences



Source: Oregon Department of Forestry. (2023, February 13). *ODF Fire*. ArcGIS Online. Retrieved September 2022 from https://www.arcgis.com/home/item.html?id=e3896b22b0ab41d4835f82574ed81fb0.

Future Climate Variability

In the *2023 Salem NHMP*, there are several locations that describe future changing conditions or climate change as it relates to the natural hazards that impact Salem and to some extent, the surrounding areas. In the order of appearance in the NHMP, the Risk Assessment and the Hazards Annexes contain this information. Documents such as the DEQ *Oregon Air Quality Monitoring Annual Report: 2020* describe that with climate change we expect more fires in the Pacific Northwest and higher temperature days, resulting in more elevated ozone days.

Probability Assessment

Certain conditions must be present for significant interface fires to occur. The most common are hot, dry, and windy weather; the inability of fire protection forces to contain or suppress the fire; the occurrence of multiple fires that overwhelm committed resources; and a large fuel load (dense vegetation). Once a fire has started, several conditions influence its behavior, including fuel, topography, weather, drought, and development.

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing a wildfire is "high,"** meaning one incident is likely within the next 10 to 35-year period.

Vulnerability Assessment

Wildfires are a natural part of forest and grassland ecosystems. Past forest practices included the suppression of all forest and grassland fires. This practice, coupled with hundreds of acres of dry brush or trees weakened or killed through insect infestation, has fostered a dangerous situation. Present state and national forest practices include the reduction of understory vegetation through thinning and prescribed (controlled) burning.

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

Wildfires in the past have caused no personal injury or death. However, the potential for injuries or deaths from past events or from similar events in other communities could escalate resulting in multiple minor injuries or possible major injury. Salem estimates that less than 10% of the city's population could be physically displaced by a wildfire, considering the proximity of residential housing to WUI vulnerable areas; and there would be mild impact on community social networks. The west and south areas of the city are the most vulnerable, particularly the residential areas along Eola Ridge.

Multiple facilities throughout the city anticipate moderate damage due to wildfires, estimated at less than $1 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely that less than 10% of businesses located in the city and surrounding area could experience commerce interruption for a period of hours. The businesses most impacted are those near WUI areas. Lastly, wildfires could likely have mild impacts on 10-25% of the city's ecological systems, including, clean water, wildlife habitat, and parks.

According to DOGAMI's *Multi-hazard Risk Report for Marion County, Oregon* (Williams & Madin, 2022), during a high and moderate risk scenario, there is the potential to have 1,555 (1.1%) displaced residents, 432 exposed buildings, none of which are critical facilities. Exposed building value of $170,463,265 (exposure ratio 0.8%).

Salem Climate Action Plan 2021

The *Salem Climate Action Plan 2021* outlines the following potential vulnerabilities and consequences of various projected climate changes as it relates to wildfire.

Projected Wildfire Risk

Increased temperatures and drier conditions will lead to increased fire risk in forested areas outside of Salem. However, those impacts to Salem include health risks due to poor air quality, increased emergency operations and evacuations, and reductions in revenue and employment in the tourism industry.

- Poor to hazardous air quality resulting from wildfires would greatly impact vulnerable populations—for example, people who are unsheltered, people who work outdoors, and people who live with chronic medical conditions such as asthma.

- Salem's drinking water source, the North Santiam River, could be degraded. Debris and chemicals in surface water following a fire could put additional pressure on water treatment facilities. The Geren Island water treatment plant could itself be at risk of wildfire.
- Oregon's population growth could lead to increased pressure to build housing in fire-prone zones, further exacerbating fire risk.
- Higher than expected population growth. If people choose to relocate from other areas with higher climate change risk, the population influx could strain existing resources, services, and contribute to housing-related issues.
- Fire-damaged forests and trails and poor air quality may reduce tourism and outdoor events in the area, resulting in economic impacts.

The Marion County CWPP (2017) identifies the City of Salem as a community with **moderate/low** WUI fire risk priority based on three risk factors: fire behavior, values, and infrastructure. West Salem is in Polk County and is included within Zone 2 of the Polk County CWPP (an area covering a large section of the county east of the coast mountains), which has a **high** overall risk rating.

As such, the NHMP Steering Committee rated the city as having a **"moderate" vulnerability to wildfire hazards**, meaning that 1 to 10% of the city's population or assets would be affected by a major disaster; this rating has not changed since the previous plan.

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

The proposed role of the federal land managing agencies, such as the U.S. Forest Service and the Bureau of Land Management, in the wildland/urban interface is diverse. Their roles include reducing fuel hazards on the lands they administer; cooperating in prevention and education programs; providing technical and financial assistance; and developing agreements, partnerships, and relationships with property owners, local protection agencies, states, and other stakeholders in wildland/urban interface areas. These relationships focus on activities before a fire occurs, which render structures and communities safer and better able to survive a fire.

For more information, refer to the joint USDI and USDA site, *Forest and Rangelands* at https://www.forestsandrangelands.gov/.

Federal Emergency Management Agency Programs

FEMA is directly responsible for providing fire suppression assistance grants and, in certain cases, major disaster assistance and hazard mitigation grants in response to fires. The role of

FEMA in the wildland/urban interface is to encourage comprehensive disaster preparedness plans and programs, increase the capability of state and local governments, and provide for a greater understanding of FEMA's programs at the federal, state, and local levels.

Fire Suppression Assistance Grants

FEMA's Fire Suppression Assistance Grants may be provided to a state only if the state has an approved hazard mitigation plan for the suppression of a forest or grassland fire that threatens to become a major disaster on public or private lands. These grants are provided to protect life and improved property, encourage the development and implementation of viable multi-hazard mitigation measures, and provide training to clarify FEMA's programs.

The grant may include funds for equipment, supplies, and personnel. A Fire Suppression Assistance Grant is the form of assistance most often provided by FEMA to a state for a fire. The grants are cost-shared with states. Once the federal grant money is provided to the state, it is passed along to local jurisdictions. This money would ultimately be passed along to Linn County to be applied to projects. The U.S. Fire Administration (USFA) provides public education materials addressing wildland/urban interface issues, and the USFA's National Fire Academy provides training programs.

Hazard Mitigation Grant Program

Following a major disaster declaration, the FEMA Hazard Mitigation Grant Program provides funding for long-term hazard mitigation projects and activities to reduce the possibility of damages from all future fire hazards and to reduce the costs to the nation for responding to and recovering from the disaster.

National Wildland/Urban Interface Fire Protection Program

Federal agencies can use the National Wildland/Urban Interface Fire Protection Program to focus on wildland/urban interface fire protection issues and actions. The Western Governors' Association can act as a catalyst to involve state agencies, as well as local and private stakeholders, with the objective of developing an implementation plan to achieve a uniform, integrated national approach to hazard and risk assessment and fire prevention and protection in the wildland/urban interface. The program helps states develop viable and comprehensive wildland fire mitigation plans and performance-based partnerships.

U.S. Forest Service

The U.S. Forest Service (USFS) implements a fuel-loading program to assess fuels and reduce hazardous buildup on federal forestlands.

The USFS has a fuel-loading program to assess fuels and reduce hazardous buildup on U.S. forestlands. The USFS is a cooperating agency and, it has an interest in preventing fires in the WUI, as fires often burn up the hills and into the higher elevation U.S. forestlands.

According to USFS *Wildland Fire* website, the USFS and other federal, tribal, state, and local government agencies work together to respond to tens of thousands of wildfires annually. Each year, an average of more than 73,000 wildfires burn approximately 7 million acres of federal, tribal, state, and private land and more than 2,600 structures.

The USFS recognizes the wildland fire management environment has profoundly changed. Longer fire seasons; bigger fires and more acres burned on average each year; more extreme fire behavior; and wildfire suppression operations in the WUI have become the norm. To address the challenges, the USFS and its federal, tribal, state, and local partners have developed and are implementing a *National Cohesive Wildland Fire Management Strategy* that has three key components: Resilient Landscapes, Fire Adapted Communities, and Safe and Effective Wildfire Response.

For more information, refer to https://www.fs.fed.us/managing-land/fire.

Bureau of Land Management (BLM)

The Bureau of Land Management (BLM) is responsible for “managing public lands for a variety of uses such as energy development, livestock grazing, recreation, and timber harvesting while ensuring natural, cultural, and historic resources are maintained for present and future use.” According to their website, the BLM manages 1/10 of the nation’s surface area and 30% of the nation’s mineral and soils (https://www.blm.gov/about/our-mission).

In Oregon, BLM is responsible for fire protection for all federal agencies. They also provide fire protection on Oregon Department of State Lands (DSL) land and on some Oregon State Parks’ lands. BLM has a memorandum of agreement with Oregon to provide support to the Rangeland Fire Protection Associations (RFPA) (Crouch, 2019).

There is a new program through the BLM, called the Rural Fire Readiness Program. It’s a separate cooperative agreement that a RFPA can sign with BLM; it removes them from the statewide memorandum of agreement with Oregon. The cooperative agreement provides more money to the RFPAs for training and equipment (Crouch, 2019). See the descriptions of Rangeland Fire Protection Associations, ODF, and the US Forest Service for additional information.

Firewise

Firewise is a program developed within the National Wildland/Urban Interface Fire Protection Program and is the primary federal program addressing interface fire. It is administered through the National Wildfire Coordinating Group whose extensive list of participants includes a wide range of federal agencies. The program is intended to empower local planners and decision makers. Through conferences and information dissemination, Firewise increases support for interface wildfire mitigation by educating professionals and the general public about hazard evaluation and policy implementation techniques.

Firewise offers online wildfire protection information and checklists, as well as listings of other publications, videos, and conferences. The interactive home page allows users to ask fire protection experts questions, and to register for new information as it becomes available.

For more information on the Firewise program, contact Wildland/Urban Interface Fire Program C/o The National Fire Protection Association 1 Batterymarch Park, Quincy, MA 02269 and http://www.firewise.org.

FireFree Program

FireFree is a unique private/public program for interface wildfire mitigation involving partnerships among an insurance company and local government agencies. It is an example of an effective non-regulatory approach to hazard mitigation. Originating in Bend, Oregon the program was developed in response to that city's Skeleton Fire of 1996, which burned over 17,000 acres and damaged or destroyed 30 homes and other structures. Bend sought to create a new kind of public education initiative that emphasized local involvement. SAFECO Insurance Corporation was a willing collaborator in this effort. Bend's pilot program included:

- A short video production featuring local citizens as actors, made available at local video stores, libraries, and fire stations;
- Two city-wide yard debris removal events;
- A 30-minute program on a model FireFree home, aired on a local cable television station; and;
- Distribution of brochures featuring a property owner's evaluation checklist and a listing of fire-resistant indigenous plants.

The success of the program helped to secure $300,000 in FEMA "Project Impact" matching funds. By fostering local community involvement, FireFree also has the potential for building support for sound interface wildfire policy. For information on FireFree, contact: SAFECO Plaza T-8, Seattle, WA 98185, (206) 545-6188 https://www.firefree.org/

State Resources

Oregon Revised Statute 215.730

ORS 215.730, Additional Criteria for Forestland Dwellings, provides criteria for approving dwellings located on lands zoned for forest and mixed agriculture/forest use. Under its provisions, county governments must require, as a condition of approval, that single-family dwellings on lands zoned as forestland meet the following requirements:

1. Dwelling has a fire retardant roof;
2. Dwelling will not be sited on a slope of greater than 40 percent;
3. Evidence is provided that the domestic water supply is from a source authorized by OWRD and not from a Class II stream as designated by the State Board of Forestry;
4. Dwelling is located upon a parcel within a fire protection district or is provided with residential fire protection by contract;
5. If dwelling is not within a fire protection district, the applicant provides evidence that the applicant has asked to be included in the nearest such district;
6. If dwelling has a chimney or chimneys, each chimney has a spark arrester; and
7. Dwelling owner provides and maintains a primary fuel-free break and secondary break areas on land surrounding the dwelling that is owned or controlled by the owner.

If a governing body determines that meeting the fourth requirement is impractical, local officials can approve an alternative means for protecting the dwelling from fire hazards.

Oregon Revised Statute 477.015-061

Provisions in ORS 477.015-061, Urban Interface Fire Protection, were established through efforts of the ODF, the Office of the State Fire Marshal, fire service agencies from across the state, and the Commissioners of Deschutes, Jefferson, and Jackson Counties. It is innovative legislation designed to address the expanding interface wildfire problem within ODF Fire Protection Districts. Full implementation of the statute will occur on or after January 1, 2002. The statute does the following:

1. Directs the State Forester to establish a system of classifying forestland-urban interface areas;
2. Defines forestland-urban interface areas;
3. Provides education to property owners about fire hazards in forestland-urban interface areas. Allows for a forestland- urban interface county committee to establish classification standards;
4. Requires maps identifying classified areas to be made public;
5. Requires public hearings and mailings to affected property owners on proposed classifications;
6. Allows property owners appeal rights;
7. Directs the Board of Forestry to promulgate rules that set minimum acceptable standards to minimize and mitigate fire hazards within forestland-urban interface areas; and
8. Creates a certification system for property owners meeting acceptable standards. Establishes a $100,000 liability limit for cost of suppressing fires if certification requirements are not met.

Senate Bill 360

Senate Bill 360, passed in 1997, is state legislation put in place to address the growing wildland/urban interface problem. The bill has three purposes:

1. To provide an interface fire protection system in Oregon to minimize cost and risk and maximize effectiveness and efficiency;
2. To promote and encourage property owners' efforts to minimize and mitigate fire hazards and risks; and
3. To promote and encourage involvement of all levels of government and the private sector in interface solutions.

The bill has a five-year implementation plan that includes public education and outreach, and the development of rules, standards, and guidelines that address landowner and agency responsibilities. The success of Senate Bill 360 depends upon cooperation among local and regional fire departments, fire prevention cooperatives, and the ODF, which means that interagency collaboration, is vital for successful implementation of the bill. This cooperation is important in all aspects of wildland firefighting. Resources and funding are often limited, and no single agency has enough resources to tackle a tough fire season alone. The introductory language of Senate Bill 360 states, "The fire protection needs of the interface must be satisfied if we are to meet the basic policy of the protection of human life, natural resources, and personal property. This protection must be provided in an efficient and effective manner, and in a cooperative partnership approach between property owners, local citizens, government leaders, and fire protection agencies."

Senate Bill 762

In 2021, the Oregon Legislature passed Senate Bill 762 (SB-762) which required ODF to develop a new statewide wildfire risk map updating the current use of the 2018 Quantitative Wildfire Risk Assessment. ODF develop administrative rules with input from a 26-member rulemaking advisory committee. The rules, adopted by the Board of Forestry, establish the criteria by which the map is developed, updated, and maintained. The rules also included the following:

- Implement five statewide wildfire risk classes of extreme, high, moderate, low and no risk, based on weather, climate, topography, and vegetation.
- Develop a process in which a property owner may appeal a designation of wildfire risk class.
- Determine a process in which a property owner is notified of risk assignment of high or extreme.
- Develop maintenance criteria for the map.

The new Wildfire Risk Map was released on June 30, 2022, but was withdrawn for further consideration of public comment. When the map is re-released, it will show what properties in Oregon fall within the WUI, as defined by the Board of Forestry in rule in 2021. Oregon State University developed the map based on the rules adopted by the board and the best data available.

The map will show the assigned risk classification for every tax lot in the state. Those that are both within the WUI and classified as high or extreme risk will receive written notification from ODF and may be subject to future changes to defensible space and home building codes. There may also be changes to statewide land use planning programs and local plans and zoning codes.

Until the map is re-released the statewide wildfire risk maps presented through Oregon Wildfire Risk Explorer are from the 2018 Quantitative Wildfire Risk Assessment. This is also the dataset used by the DOGAMI geologic hazard analysis performed for this NHMP update in 2022. The plate below is from that Multi-Hazard Risk Report Marion County, Oregon.

State Natural Hazard Risk Assessment

The risk assessment in the 2020 Oregon Natural Hazards Mitigation Plan provides an overview of wildfires risk in Oregon and identifies the most significant wildfires in Oregon's recorded history. It has overall state and regional information, and includes wildfire mitigation actions for the entire
https://www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to wildfires and other natural hazards, including examples from communities in Oregon.
https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Oregon Department of Forestry

ODF is involved with local fire chiefs and local fire departments to provide training. Local firefighters can get a range of experience from exposure to wildland firefighting. Local firefighters can also obtain their red card (wildland fire training documentation) and attend extensive workshops combining elements of structural and wildland firefighting, defending homes, and operations experience (Wolf, 2001). ODF has been involved with emergency managers to provide support during non-fire events and for years, ODF has worked with industrial partners (big timber companies) to share equipment in the case of extremely large fires (Wolf, 2001).

Local Resources

Salem Building and Development Codes

All development within the City of Salem must comply with the fire protection construction standards in the Uniform Building Code (UBC) and the City of Salem Development Code, as well as additional standards set forth by the applicable rural fire protection districts. Salem also provides a community risk reduction resource page that includes information on fireworks safety and understanding the earning signs of youth fire setting behavior.

Zoning ordinances for City of Salem can be found here: https://www.cityofsalem.net/business/land-use-zoning.

Salem Emergency Management Plan

This description is excerpted from the *Salem Emergency Management Plan* (2014).

> This Emergency Management Plan is an all-hazard plan that describes how the City of Salem will organize and respond to emergencies and disasters in the community. It is based on, and is compatible with, Federal, State of Oregon, and other applicable laws, regulations, plans, and policies, including Presidential Policy Directive 8, the National Response Framework, Oregon Office of Emergency Management Plan, and both Marion and Polk County Emergency Operations Plans.
>
> Response to emergency or disaster conditions in order to maximize the safety of the public and to minimize property damage is a primary responsibility of government. It is the goal of the City of Salem that responses to such conditions are conducted in the most organized, efficient, and effective manner possible. To aid in accomplishing this goal, the City of Salem has, in addition to promulgating this plan, formally adopted the principles of the National Incident Management System, including the Incident Command System and the National Response Framework.
>
> Consisting of a Basic Plan, Functional Annexes aligned with both Marion and Polk County Emergency Support Functions, and Incident Annexes, this Salem Emergency Management Plan provides a framework for coordinated response and recovery activities during a large-scale emergency. The plan describes how various agencies and organizations in the City of Salem will coordinate resources and activities with other Federal, State, local, tribal, and private-sector partners.

Existing Fire Authorities

Mutual Aid Agreements exist among the various fire authorities for support and help as needed. Each authority has its regulations and limitations, which dictates its fire management activity. In and around Salem, there is the Salem Fire Department and the Salem Suburban Rural Fire Protection District (SSRFPD).

Salem Fire Department and the SSRFPD information can be found here: https://www.cityofsalem.net/community/safety/fire and https://www.cityofsalem.net/community/safety/fire/salem-suburban-rural-fire-protection-district

Rangeland Fire Protection Associations (RFPA)

Rangeland Fire Protection Associations (RFPAs) provide wildfire protection of private rangeland within some counties in Oregon. RFPAs (formed under ORS 477.315) protect over 3.2 million acres of private land in eastern Oregon with support from ODF. RFPAs operate as independent associations of landowners that provide their own protection with the support of the ODF (chiefly technical support for grants, grant writing, procurement of equipment and fire-fighting training) (Hoehna, 2021).

A statewide agreement between the Bureau of Land Management and Oregon exists. The ODF provides a small source of funding for the RFPAs, however, most funds come from federal grants (primarily Volunteer Fire Assistance and Rural Fire Assistance). Additional fees are collected from voluntary membership dues. As noted above, BLM also supports the RFPAs.

The RFPA has a responsibility to protect private lands of members and non-members alike pursuant the agreement formed with ODF when the RFPA is created. These all-volunteer crews of ranchers have training and legal authority to respond to fires on private and state lands where there had been no existing fire protection and can become authorized to respond on federal lands as well. Oregon has a robust network of 23 RFPAs covering over 16 million acres of rangeland, according to the BLM's *Facts at Your Fingertips* (2019) publication.

Salem Climate Action Plan 2021 and Community Greenhouse Gas Inventory

Salem is taking action to respond to climate change with a Climate Action Plan (CAP) that outlines strategies and actions to reduce Greenhouse Gas emissions and increase climate resiliency in our community. Through the development of the CAP, it was determined that Salem's projected climate impacts will include three main categories: warming temperatures, changes in precipitation patterns, and increased risk of wildfires. Many of the strategies in the CAP are designed to help the community adapt to impacts and build resiliency for the future. The strategies seek to do the following:

- Expand the urban tree canopy and access to green spaces
- Create a climate related education and outreach program
- Create a network of indoor gathering places that can serve as community centers during times of need
- Engage underserved populations in co-creating resilient solutions

- Strengthen the local economy

Marion County Community Wildfire Protection Plan

In August of 2017, Marion County adopted an updated Community Wildfire Protection Plan (CWPP). Developed in coordination with the Oregon Department of Forestry, the Marion County CWPP is the result of a countywide effort initiated to reduce wildland fire risk to communities, citizens, and environmental resources in Marion County. The CWPP was developed in accordance with provisions of the Healthy Forest Restoration Act of 2003. The DRAFT CWPP identifies the following wildfire mitigation related objectives:

General

- Provide oversight to all activities related to the MCCWPP.
- Ensure representation and coordination between the sub-committees.
- Develop and refine goals for fire protection in Marion County/Salem.
- Develop a long-term structure for sustaining efforts of the MCCWPP.

Risk Assessment

- Identify and update as needed Communities-at-Risk and the Wildland-Urban Interface.
- Develop and conduct a wildland fire risk assessment.
- Identify and prioritize hazardous fuels treatment projects.

Fuels Reduction

- Identify strategies for coordinating fuels treatment projects at a landscape scale.
- Coordinate administration of fuels program so that it is equitable across fire districts.
- Provide low-income special need citizens with an opportunity to reduce their fuels and participate in local programs.
- Identify opportunities for marketing and utilization of smaller diameter wood products.

With respect to wildfire risk, the CWPP identifies specific Communities at Risk. In addition, the plan includes a set of maps and data that specifically identify the location, severity, extent and probability of wildfire in Marion County/Salem. The final CWPP risk assessment, when adopted, is incorporated herein by reference as a specific wildfire supplement to the all-hazard risk assessment.

Windstorm

Significant Changes Since Previous Plan:

The Windstorm Hazard section was reformatted and expanded with additional information since the previous plan.

Causes and Characteristics

Extreme winds occur throughout Oregon and can occur in summer and winter. A windstorm is generally a short duration event involving straight-line winds and/or gusts more than 50 mph. The most persistent high winds take place along the Oregon Coast and in the Columbia River Gorge, with the Columbia River Gorge being the most significant east-west gap in the Cascade Range between California and Canada. Extreme weather events, however, occur in all regions of Oregon, according to the 2020 Oregon NHMP. West winds generated from the Pacific Ocean are strongest along the coast and slow down inland due to the obstruction of the Oregon Coast Range. Prevailing winds in Oregon vary with the seasons. In summer, the most common wind directions are from the west or northwest; in winter, they are from the south and east. Local topography, however, plays a major role in affecting wind direction (Statesman Journal, 2002).

Types of Damaging Winds

The NOAA National Severe Storms Laboratory's *Severe Weather 101* site describes the following eight types of damaging winds.

Straight-line wind

Straight-line wind is a term used to define any thunderstorm wind that is not associated with rotation and is used mainly to differentiate from tornadic winds.

Downdraft

A downdraft is a small-scale column of air that rapidly sinks toward the ground.

Macroburst

A macroburst is an outward burst of strong winds at or near the surface with horizontal dimensions larger than 4 km (2.5 mi) and occurs when a strong downdraft reaches the surface. To visualize this process, imagine the way water comes out of a faucet and hits the bottom of a sink. The column of water is the downdraft and the outward spray at the bottom of the sink is the macroburst. Macroburst winds may begin over a smaller area and then spread out over a wider area, sometimes producing damage similar to a tornado. Although usually associated with thunderstorms, macrobursts can occur with showers too weak to produce thunder.

Microburst

A microburst is a small, concentrated downburst that produces an outward burst of strong winds at or near the surface. Microbursts are small — less than 4 km across — and short-lived, lasting only five to 10 minutes, with maximum windspeeds sometimes exceeding 100 mph. There are two kinds of microbursts: wet and dry. A wet microburst is accompanied by heavy precipitation at the surface. Dry microbursts, common in places like the high plains and the intermountain west, occur with little or no precipitation reaching the ground.

Downburst

A downburst is the general term used to broadly describe macro and microbursts. Downburst is the general term for all localized strong wind events that are caused by a strong downdraft within a thunderstorm, while microburst simply refers to an especially small downburst that is less than 4 km across.

Gust Front

A gust front is the leading edge of rain-cooled air that clashes with warmer thunderstorm inflow. Gust fronts are characterized by a wind shift, temperature drop, and gusty winds out ahead of a thunderstorm. Sometimes the winds push up air above them, forming a shelf cloud or detached roll cloud.

Derecho

Derecho is a widespread, long-lived windstorm that is associated with a band of rapidly moving showers or thunderstorms. A typical derecho consists of numerous microbursts, downbursts, and downburst clusters. By definition, if the wind damage swath extends more than 240 miles (about 400 kilometers) and includes wind gusts of at least 58 mph (93 km/h) or greater along most of its length, then the event may be classified as a derecho.

Haboob

A haboob is a wall of dust that is pushed out along the ground from a thunderstorm downdraft at high speeds.

Tornadoes

The NOAA National Severe Storms Laboratory's site, identifies tornadoes as the following:

> A tornado is a narrow, violently rotating column of air that extends from a thunderstorm to the ground. Because wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust and debris. Tornadoes can be among the most violent phenomena of all atmospheric storms we experience.

Although rare, tornados can and do occur in Oregon. Tornadoes are the most concentrated and violent storms produced by the earth's atmosphere. They are created by a vortex of rotating winds and strong vertical motion, which possess remarkable strength and cause widespread damage. Wind speeds more than 300 mph have been observed within tornadoes, and it is suspected that some tornado winds exceed 400 mph. The low pressure at the center of a tornado can destroy buildings and other structures.

Tornadoes are most common in the Midwest and are more infrequent and generally small west of the Rockies. Nonetheless, Oregon and other western states have experienced tornadoes on occasion, many of which have produced significant damage and occasionally injury or death. Oregon's tornadoes can be formed in association with large Pacific storms arriving from the west. Most of them, however, are caused by intense local thunderstorms. These storms also produce lightning, hail, and heavy rain, and are more common during the warm season from April to October (Taylor, Bhoman, & Foster, 1996).

Table 2-17 Estimating Wind Speeds with Visual Clues

Estimating Wind Speeds with Visual Clues			
Beaufort number	Description	Speed	Visual Clues and Damage Effects
0	Calm	Calm	Calm wind. Smoke rises vertically with little if any drift.
1	Light Air	1 to 3 mph	Direction of wind shown by smoke drift, not by wind vanes. Little if any movement with flags. Wind barely moves tree leaves.
2	Light Breeze	4 to 7 mph	Wind felt on face. Leaves rustle and small twigs move. Ordinary wind vanes move.
3	Gentle Breeze	8 to 12 mph	Leaves and small twigs in constant motion. Wind blows up dry leaves from the ground. Flags are extended out.
4	Moderate Breeze	13 to 18 mph	Wind moves small branches. Wind raises dust and loose paper from the ground and drives them along.
5	Fresh Breeze	19 to 24 mph	Large branches and small trees in leaf begin to sway. Crested wavelets form on inland lakes and large rivers.
6	Strong Breeze	25 to 31 mph	Large brances in continous motion. Whistling sounds heard in overhead or nearby power and telephone lines. Umbrellas used with difficulty.
7	Near Gale	32 to 38 mph	Whole trees in motion. Inconvenience felt when walking against the wind.
8	Gale	39 to 46 mph	Wind breaks twigs and small branches. Wind generally impedes walking.
9	Strong Gale	47 to 54 mph	Structural damage occurs, such as chimney covers, roofing tiles blown off, and television antennas damaged. Ground is littered with many small twigs and broken branches.
10	Whole Gale	55 to 63 mph	Considerable structural damage occurs, especially on roofs. Small trees may be blown over and uprooted.
11	Storm Force	64 to 75 mph	Widespread damage occurs. Larger trees blown over and uprooted.
12	Hurricane Force	over 75 mph	Severe and extensive damage. Roofs can be peeled off. Windows broken. Trees uprooted. RVs and small mobile homes overturned. Moving automobiles can be pushed off the roadways.

Source: NOAA National Weather Service, Portland OR Weather Forecast Office. (n.d.). Estimating Wind. Retrieved from https://www.weather.gov/pqr/wind.

Location and Extent

The most common type of wind pattern affecting Salem is straight-line winds, which originate as a downdraft of rain-cooled air and reach the ground and spread out rapidly. Straight-line winds can produce gusts of up to 100 mph. For Salem, the wind hazard levels are generally highest near the Willamette River and then uniform across most of the rest of the city. In the mountainous areas, however, the level of wind hazard is strongly determined by local specific conditions of topography and vegetation cover. Mountainous terrain slows down wind movement, which is why Oregon's sheltered valley areas have the slowest wind speed in the state. However, in the foothills, the wind speeds may increase due to down-sloping winds from the mountains.

Although windstorms can affect the entirety of the city, they are especially dangerous in developed areas with significant tree stands and major infrastructure, especially above ground utility lines. A windstorm will frequently knock down trees and power lines, damage homes, businesses, public facilities, and create tons of storm related debris.

Identifying Windstorms

Windstorms in Salem and Marion County can occur in summer and winter; they usually occur from October to March. Their extent is determined by their track, intensity (the air pressure gradient they generate), and local terrain. The NOAA National Severe Storms Laboratory uses weather forecast models to predict oncoming windstorms, while monitoring storms with weather stations in protected valley locations throughout Oregon. Thunderstorms can bring high winds during the warmer months, April to October. Tornadoes are the most violent of windstorms and are occasionally caused by intense local thunderstorms, which are more common during the warm season.

Detection of Damaging Winds

According to the NOAA National Severe Storms Laboratory, severe and damaging wind events are difficult to forecast because any type of thunderstorm - even one that is dying – can produce them. The National Severe Storms Laboratory states,

> Doppler radar velocity data can show areas of diverging winds at the surface, and even the strength of those winds, indicating a downburst.
>
> Winds coming together at midlevels of the storm, known as convergence, can also be seen on velocity displays and can indicate the development of a downburst. One of the challenges in the severe storm warning process is forecasting the initial onset of damaging winds.

With the doppler radar, meteorologists look for signals in mid and upper levels of thunderstorms. They also look for signals in the environment surrounding the storms, and the behavior of storms. In addition, forecasters must also study the existing atmospheric environment and look for the amounts of dry air, moist air, strength of the updraft, and storm motion.

Detection of Tornadoes

According to the NOAA National Severe Storms Laboratory, when trying to identify a tornado, storm spotters look for a variety of characteristics. These characteristics include inflow bands, beaver's tail, wall cloud, rear flank downdraft, and condensation funnel. In addition, the strength of a tornado is determined by examining the damage caused, which can then estimate wind speed.

For more information on these tornado characteristics, visit NOAA National Severe Storms Laboratory's site https://www.nssl.noaa.gov/education/svrwx101/tornadoes/.

There are two types of tornado warnings – Tornado Watch and Tornado Warning. A Tornado Watch is issued by the NOAA Storm Prediction Center whose meteorologist watch the weather across the U.S. for conditions that are favorable for tornadoes and severe weather. A Tornado Watch can cover parts of one state or several states.

A Tornado Warning is issued by NOAA National Severe Storms Laboratory local forecast office, whose meteorologist watch the weather in a designated area. This means that storm spotters have reported a tornado or radar indicates, "there is a serious threat to life and property to those in the path of the tornado." A Tornado Warning can cover parts of counties or several counties.

History

In 2009, just outside of Salem on Highway 22, winds and a thunderstorm brought down several trees. In January 2012, severe winds accompanied a winter storm with gusts measuring 59 knots a causing multiple power outages (FEMA-4055-DR-OR). In March/April of 2012 Severe winds and storm conditions impacted a large multi-county region of Western Oregon, with considerable damage sustained in Salem. Disaster response efforts focused on debris removal, repair of heavily wooded transmission line, and restoration of flood-damaged structures. In March 2015, strong winds were measured at the Salem airport.

The most significant recent storm occurred in December of 2010 culminating in an EF2 tornado touching down in the City of Aumsville (17 miles SE of Salem) with wind speeds between 110 and 120 mph. This was the largest tornado recorded in Marion County to date and the second largest in the state since 1950. According to a December 23, 2010, NOAA storm survey report, the tornado traveled in a northeasterly direction and had a path length of approximately five-miles. The initial damage assessment estimated total losses at over $1.1 million (Marion County, 2010).

Windstorms occur yearly; more destructive storms occur once or twice per decade. The *Columbus Day Storm*, October 1962, was Oregon's most destructive storm to date with winds approaching 116 mph winds in Willamette Valley. An estimated 84 houses were destroyed, with 5,000 severely damaged and with a total damage estimate of $170 million. Recent storms occurred in January 2012 *(FEMA-4055-DR-OR),* February 2014 *(FEMA-4169-DR-OR), and December 2015 (FEMA-4258-DR-OR).*

Several additional, small windstorm events have occurred since the previous plan, see the Storm Events Database provided by the NOAA for more information.

All of Salem is susceptible to severe windstorms. Table 2-18 includes a list of windstorms and tornadoes that have occurred in Marion and Polk Counties between 2017-2022.

Table 2-18 Windstorm Events in Marion and Polk Counties 2017-2022

Zone	Begin Date	Begin Time	Event Type	Deaths
MARION COUNTY	10/12/2017	1200	Tornado	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	3/8/2018	800	Strong Wind	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	4/7/2018	1300	High Wind	0
MARION COUNTY	10/29/2018	1430	Tornado	0
MARION COUNTY	12/1/2018	1430	Funnel Cloud	0
CENTRAL WILLAMETTE VALLEY (ZONE)	12/18/2018	--	Strong Wind	0
CENTRAL WILLAMETTE VALLEY (ZONE)	1/5/2019	2025	Strong Wind	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	9/7/2020	1906	High Wind	0
NORTH OREGON CASCADES (ZONE)	9/7/2020	1906	High Wind	0
MARION COUNTY	9/17/2020	15	Thunderstorm Wind	0
MARION COUNTY	9/18/2020	15	Thunderstorm Wind	0
CENTRAL WILLAMETTE VALLEY (ZONE)	1/12/2021	2236	Strong Wind	0
POLK COUNTY	1/12/2021	2312	Thunderstorm Wind	0
CENTRAL WILLAMETTE VALLEY (ZONE)	5/22/2021	1335	Strong Wind	0
CENTRAL WILLAMETTE VALLEY (ZONE)	11/4/2021	850	Strong Wind	0
CENTRAL WILLAMETTE VALLEY (ZONE)	12/11/2021	600	High Wind	0
MARION COUNTY	3/28/2022	1200	Funnel Cloud	0
CENTRAL WILLAMETTE VALLEY (ZONE)	5/28/2022	1600	Strong Wind	0

Source: NOAA. (n.d.). Storm Event Database. Retrieved October 2022, from https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=41%2COREGON.
Note: The bolded Central Willamette Valley (Zone) events were windstorm that affected Salem and the surrounding areas.

Future Climate Variability

In the *2022 Salem NHMP*, there are several locations that describe future changing conditions or climate change as it relates to the natural hazards that impact Salem and the surrounding area. In the order of appearance in the NHMP it is in the Risk Assessment and the Hazard Characterizations.

Refer to the 2020 Oregon NHMP for climate change information about the Mid/Southern Willamette Valley Region (Region 3). Region 3 includes Linn, Lane (non-coastal), Marion, Polk, and Yamhill Counties. The hazards faced by Region 3 that are projected to be influenced by climate change include drought, wildfire, flooding, landslides, and extreme heat. The *2020 Oregon Natural Hazards Mitigation Plan* also states,

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

Probability Assessment

Windstorms in Salem usually occur in the winter from October to March, and their extent is determined by their track, intensity (the air pressure gradient they generate), and local terrain. Summer thunderstorms may also bring high winds along with heavy rain and/ or hail. The National Weather Service uses weather forecast models to predict oncoming windstorms, while monitoring storms with weather stations in protected valley locations throughout Oregon.

Table 2-19 shows the wind speed probability intervals that structures 33 feet above the ground would expect to be exposed to within a 25, 50 and 100-year period. The 100-year event for a windstorm in Region 3 is 1-minute average winds of 75 mph. A 50-year event has average winds of 68 mph. A 25-year event has average winds speeds of 60 mph.

Table 2-19 Probability of Severe Wind Events (Region 3)

	25-Year Event (4% annual probability)	50-Year Event (2% annual probability)	100-Year Event (1% annual probability)
Region 3: Mid/Southern Willamette Valley	60 mph	68 mph	75 mph

Source: Oregon DLCD. (2009). *Oregon Natural Hazards Mitigation Plan*.

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing a windstorm is "high,"** meaning one incident is likely within the next 35-year period.

Vulnerability Assessment

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

Fallen trees are especially troublesome. They can block roads and rails for long periods of time, impacting emergency operations. In addition, up rooted or shattered trees can down power and/or utility lines and effectively bring local economic activity and other essential facilities to a standstill. Much of the problem may be attributed to a shallow or weakened root system in saturated ground. In Salem, trees are more likely to blow over during the winter (wet season).

Windstorms in the past caused multiple minor injuries or a major injury. However, the potential for injuries or deaths from past events or from similar events in other communities could escalate resulting in multiple major injuries or possible death. Salem estimates that more than 10% of the city's population could be physically displaced by a windstorm, accounting for the number of homes that loose power or properties with downed trees; and there would be mild impact on community social networks.

Several facilities throughout the city anticipate mild damage due to a windstorm, estimated between $1 million and $10 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely 10-30% of businesses located in the city and surrounding area could experience commerce interruption for a period of a days. Windstorms have the potential to inflict widespread power outages and until power can be restored, business may experience interruption. Lastly, windstorms would likely have extensive impacts on more than 75% of the city's ecological systems, including, clean water, wildlife habitat, and parks.

As such, the NHMP Steering Committee rated the city as having a **"moderate" vulnerability to windstorm hazards**, meaning that between 1 to 10% of the city's population or assets would be affected by a major disaster.

Mitigation Activities and Resources

Mitigation through either regulatory or non-regulatory, voluntary strategies allow communities to gain cooperation, educate the public and provide solutions to ensure safety in the event of an earthquake, according to the *Planning for Natural Hazards: Oregon Technical Resource Guide*. Existing mitigation activities include current mitigation programs and activities that are being implemented by city, county, regional, state, or federal agencies and organizations.

Federal Resources

National Oceanic and Atmospheric Administration

Severe and damaging wind events are difficult to forecast because any type of thunderstorm can produce them. The NOAA National Severe Storms Laboratory use doppler radar to look for signals in mid and upper levels of thunderstorms. Meteorologists also look for signals in the environment surrounding the storms, and the behavior of storms. In addition, forecasters must also study the existing atmospheric environment and look for the amounts of dry air, moist air, strength of the updraft, and storm motion. Researching precursor's signals could help forecasters determining when a wind event is about to occur.

There are two types of tornado warnings – Tornado Watch and Tornado Warning. A Tornado Watch is issued by the NOAA Storm Prediction Center whose meteorologist watch the weather across the U.S. for conditions that are favorable for tornadoes and severe weather. A Tornado Watch can cover parts of one state or several states. A Tornado Warning is issued by NOAA National Severe Storms Laboratory local forecast office, whose meteorologist watch the weather in a designated area. This means that storm spotters have reported a tornado or radar indicates, “there is a serious threat to life and property to those in the path of the tornado.” A Tornado Warning can cover parts of counties or several counties.

Federal Emergency Management Agency

FEMA recommends having a safe room in homes or small businesses to prevent residents and workers from “dangerous forces” of extreme winds to avoid injury or death. (https://www.fema.gov/fema-p-320-taking-shelter-storm-building-safe-room-your-home-or-small-business).

State Resources

State Natural Hazard Risk Assessment

The risk assessment in the *2020 Oregon Natural Hazards Mitigation Plan* provides an overview of all the identified natural hazards in Oregon (in the State NHMP but not necessarily all the locally identified natural hazards) and identifies the most significant hazards in Oregon’s recorded history. It has overall state and regional information and includes mitigation actions for the entire state. 2020 Oregon NHMP

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon State Building Code Standards

The Oregon Building Codes Division adopts statewide standards for building construction that are administered by the state and local municipalities throughout Oregon. Building Codes standards (both residential and other codes) are set to withstand 80 mph winds (https://www.oregon.gov/bcd/codes-stand/pages/index.aspx).

The *2017 Oregon Residential Special Code* (*ORSC*) contains requirements for one- and two-family dwellings (https://codes.iccsafe.org/content/document/1018?site_type=public).

The *2019 Oregon Structural Special Code* (*OSSC*) contains provisions for grading and site preparation for the construction of building foundations (https://codes.iccsafe.org/content/OSSC2019P1).

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of natural hazards including the Hazard Mitigation Grant Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, OEM notifies local public safety agencies and keeps them informed of potential and actual hazard events so prevention and mitigation actions can be taken.

Roadway Maintenance

ODOT is responsible for performing precautionary measures to maintain the safety and operability of major roads during storm conditions. The road maintenance programs are designed to provide the best use of limited resources to maximize the movement of traffic within the community during inclement weather.

During storm events, most agencies at the county and city level focus on clearing major arterial and collector streets first, and then respond to residential connector streets, school zones, transit routes, and steep residential streets as resources become available. The state, counties, and cities, may have agreements, including mutual aid agreements, about road maintenance responsibilities during day-to-day operations and who does what in storm situations. In general, highways receive more attention. For those routes on the National Highway System network, primary interstate expressways, and primary roadways will be cleared more quickly and completely than other roads.

Local Resources

Salem Community Forestry Strategic Plan

The Salem's Community Forestry Strategic Plan recognizes that trees provide multiple economic, environmental, and social benefits. Due to all the advantages trees provide, Salem's Public Works decided to investigate ways to improve the city's community forest, with an emphasis on non-regulatory approaches and incentives. The plan establishes six goals and specific actions, priorities, and partnerships needed to achieve the goals. Goal 5 includes the development and implementation of a Community Forestry Management Plan that will help establish industry appropriate best management practices, standards, and protocols for tree care, risk and hazard reduction, and storm/hazard tree response, removal and replanting.

Salem Emergency Management Plan

This description is excerpted from the *Salem Emergency Management Plan* (2014).

> This Emergency Management Plan is an all-hazard plan that describes how the City of Salem will organize and respond to emergencies and disasters in the community. It is based on, and is compatible with, Federal, State of Oregon, and other applicable laws, regulations, plans, and policies, including Presidential Policy Directive 8, the National Response Framework, Oregon Office of Emergency Management Plan, and both Marion and Polk County Emergency Operations Plans.

Response to emergency or disaster conditions in order to maximize the safety of the public and to minimize property damage is a primary responsibility of government. It is the goal of the City of Salem that responses to such conditions are conducted in the most organized, efficient, and effective manner possible. To aid in accomplishing this goal, the City of Salem has, in addition to promulgating this plan, formally adopted the principles of the National Incident Management System, including the Incident Command System and the National Response Framework.

Consisting of a Basic Plan, Functional Annexes aligned with both Marion and Polk County Emergency Support Functions, and Incident Annexes, this Salem Emergency Management Plan provides a framework for coordinated response and recovery activities during a large-scale emergency. The plan describes how various agencies and organizations in the City of Salem will coordinate resources and activities with other Federal, State, local, tribal, and private-sector partners.

Other Existing Strategies and Programs

Existing strategies and programs at the state level are usually performed by the Oregon Public Utility Commission (OPUC), Building Code Division (BCD), ODF, OEM, and the Oregon Department of Transportation.

The Oregon Emergency Response System (OERS) coordinates and manages state resources in response to natural and technological emergencies and civil unrest involving multi-jurisdictional cooperation between all levels of government and the private sector (https://www.oregon.gov/oem/emops/Pages/OERS.aspx).

Oregon Public Utility Commission ensures operators manage, construct and maintain their utility lines and equipment in a safe and reliable manner. These standards are listed on this website: http://www.puc.state.or.us/PUC/safety/index.shtml. OPUC promotes public education and requires utilities to maintain adequate tree and vegetation clearances from high voltage utility lines and equipment.

Winter Storm

Significant Changes Since Previous Plan:

The Winter Storm Hazard section was reformatted and expanded with additional information since the previous plan.

Causes and Characteristics

Winter storms affecting Salem are generally characterized by a combination of heavy rains and high winds throughout the city, sometimes with snowfall, especially at higher elevations. Heavy rains can result in localized or widespread flooding, as well as debris slides and landslides. High winds commonly result in tree falls which primarily affect the electric power system, but which may also affect roads, buildings and vehicles. This chapter deals primarily with the snow and ice effects of winter storms.

The winter storms that affect Salem are typically not local events affecting only small geographic areas. Rather, the winter storms are usually large cyclonic low-pressure systems that move in from the Pacific Ocean and affect large areas of Oregon and/or the whole Pacific Northwest. These storms are most common from October through March.

Three basic ingredients are necessary to make a winter storm, according to NOAA National Severe Storms Laboratory:

> **Cold air**. Below freezing temperatures in the clouds and near the ground are necessary to make snow and/or ice.
>
> **Lift**. Something to raise the moist air to form the clouds and cause precipitation. An example of lift is warm air colliding with cold air and being forced to rise over the cold dome. The boundary between the warm and cold air masses is called a front. Another example of lift is air flowing up a mountainside.
>
> **Moisture**. To form clouds and precipitation. Air blowing across a body of water, such as a large lake or the ocean, is an excellent source of moisture.

With the three basic ingredients necessary to have a winter storm, there are then three types of winter precipitation that can be created, which include snow, sleet, and freezing rain.

Types of Winter Storms

The principal types of winter storms that occur include the following:

Snowstorms

Snowstorms require three ingredients of cold air, moisture, and air disturbance. The result is snow, small ice particles that fall from the sky. In Oregon, the further inland and north one moves, the more snowfall can be expected. Blizzards are included in this category.

Outside of mountainous areas, significant snow accumulations are much less likely in western Oregon than on the east side of the Cascades. However, if a cold air mass moves northwest through the Columbia Gorge and collides with a wet Pacific storm, then a larger than average snow fall may result.

Ice storms

Ice storms are a type of winter storm that forms when a layer of warm air is sandwiched by two layers of cold air. Frozen precipitation melts when it hits the warm layer and refreezes when hitting the cold layer below the inversion. Ice storms can include sleet (when the rain refreezes before hitting the ground) or freezing rain (when the rain freezes once hitting the ground). Of these, freezing rain can be the most damaging of ice formations. An ice storm is significant with ice accumulations of 0.25 inches or greater, according to FEMA's National Risk Index.

Extreme Cold

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

Location and Extent

Ice storms occasionally occur in northern areas of Oregon, resulting from cold air flowing westward through the Columbia Gorge. Freezing rain can be the most damaging of ice formations. While sleet and hail can create hazards for motorists when it accumulates, freezing rain can cause the most dangerous conditions within a community. Ice buildup can bring down trees, communication towers, and wires creating hazards for property owners, motorists, and pedestrians alike. The most common freezing rain problems occur near the Columbia Gorge. The Gorge is the most significant east-west air passage through the Cascades. Rain arriving from the west can fall on frozen streets, cars, and other sub-freezing surfaces, creating dangerous conditions.

The National Climatic Data Center has established climate zones in the United States for areas that have similar temperature and precipitation characteristics. Oregon's latitude, topography, and proximity to the Pacific Ocean give the state diversified climates. Salem is located within Zone 2: Willamette Valley (Figure 2-55). The climate in Zone 2 generally consists of cool, wet winters and warm, dry summers, according to Oregon Climate Service. These wet winters result in potentially destructive winter storms that produce heavy snow, ice, rain and freezing rain, and high winds.

Figure 2-55 Oregon Climate Divisions

Source: Oregon Climate Service. (n.d.). *Oregon Climate Service*. College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, Oregon. Retrieved from https://blogs.oregonstate.edu/orcs/.

Unlike most other hazards, it is not simple to systematically map winter storm hazard zones. The entire city is susceptible to damaging severe weather. Winter storms that bring snow and ice can impact infrastructure, business, and individuals. Those resources that exist at higher elevations will experience more risk of snow and ice, but the entire city can face damage from winter storms and, for example, the hail or life threateningly cold temperatures that winter storms bring.

Identifying Winter Storms

The magnitude or severity of severe winter storms is determined by several meteorological factors including the amount and extent of snow or ice, air temperature, wind speed, and event duration. Precipitation, an additional element of severe winter storms, is measured by gauging stations. The National Weather Service monitors the stations and provides public warnings on storm, snow, and ice events as appropriate.

Detection of Winter Storms

According to the NOAA National Severe Storms Laboratory, winter weather and storms use a variety of tools to forecast winter weather and storms.

As identified on NOAA National Severe Storms Laboratory's *Severe Weather 101* site, these tools are the following:

> **Satellite** images are very useful tools for determining cloud patterns and movement of winter storms. By looping a series of satellite pictures together, forecasters can watch a storm's development and movement.
>
> **Radar** is critical for tracking the motion of precipitation and for determining what kind of precipitation is falling.

The **NWS's dual-polarized radars** send electromagnetic wave fields at a 45-degree angle, rather than just horizontally. As these angled fields bounce off an object and are received back at the radar, a computer program separates the fields into horizontal and vertical information. This 2-D snapshot now gives forecasters a measure of the size and shape of the object. With this information, forecasters can clearly identify rain, hail, snow, ice pellets and even bugs. If they know what type of precipitation is falling, they will make more accurate estimates of how much to expect.

Doppler radar can show the wind direction too, which is helpful when forecasting near mountains and large bodies of water.

If the radar shows wind blowing up the mountain (upslope), forecasters know that automatically, one of the ingredients is in place of the development of precipitation: lift. If the radar shows wind blowing over a large section of a body of water (fetch), then they know that another ingredient is present for the formation of precipitation – moisture.

Radar velocities can help identify the location of cold fronts because there is usually a sharp change in wind direction and will show up as a on Doppler radar.

In addition to observing a wide network of satellites, Doppler radars and automated surface observing systems, forecasters use their experience, together with computer forecast models to write and issue forecasts on what will happen next.

There are various winter weather notices. The following is a list from NOAA National Severe Storms Laboratory's *Severe Weather 101* site.

Blizzard Warning: Issued when winds of 35 mph or greater are combined with blowing and drifting snow with visibilities of ¼ mile or less. Seek indoor shelter immediately and stay indoors until the severe conditions end.

Winter Storm Warning: Issued when a combination of hazardous winter weather in the form of heavy snow, heavy freezing rain, or heavy sleet is imminent or occurring. Winter Storm Warnings are usually issued 12 to 24 hours before the event is expected to begin.

Winter Storm Watch: Issued 12-48 hours in advance of the onset of severe winter conditions. The watch may or may not be upgraded to a winter storm warning, depending on how the weather system moves or how it is developing.

Winter Storm Outlook: Issued prior to a Winter Storm Watch. The Outlook is given when forecasters believe winter storm conditions are possible and are usually issued 3 to 5 days in advance of a winter storm.

Winter Weather Advisories: Issued for accumulations of snow, freezing rain, freezing drizzle, and sleet which will cause significant inconveniences and, if caution is not exercised, could lead to life-threatening situations.

Lake Effect Snow Warning: Issued when heavy lake effect snow is imminent or occurring.

Lake Effect Snow Advisory: Issued when accumulation of lake effect snow will cause significant inconvenience.

Wind Chill Warning: Issued when wind chill temperatures are expected to be hazardous to life within several minutes of exposure.

Wind Chill Advisory: Issued for a wind chill situation that could cause significant inconveniences, but do not meet warning criteria. Criteria for issuing Windchill Warnings and Advisories are set locally.

Dense Fog Advisory: Issued when fog will reduce visibility to ¼ mile or less over a widespread area.

Snow Flurries: Light snow falling for short durations. No accumulation or light dusting is all that is expected.

Snow Showers: Snow falling at varying intensities for brief periods of time. Some accumulation is possible.

Blowing Snow: Wind-driven snow that reduces visibility and causes significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground picked up by the wind.

History

All of Salem is susceptible to winter storms, which can occur yearly; more destructive storms occur once or twice per decade. According to FEMA's Disaster Declarations for States and Counties, several additional, winter storm events have occurred since the previous plan, including in February 2016 (FEMA-4258-DR-OR) and February 2021(FEMA-4599-DR-OR). Other occurrences include in early 2008, Over several weeks, the foothills of the Cascades received unusually high amounts of snow from a series of storms. Towns east of Salem, including Idanha and Detroit, were buried by 12-feet of snow over these two months. Several local agencies from Marion and Linn Counties, and the City of Salem were sent to assist these communities. Three dozen National Guard soldiers, along with snow removal equipment, inmate crews, and engineers, were sent by the State into the towns to remove snow and help those in need (Salem-News.com, 2008).

Another prolonged snowstorm hit the region during the 2008-2009 winter season. According to NWS, Salem received over a foot of snow and the Portland airport received a record 18.9 inches. (*Some of the Area's Snowstorms*). This snowstorm resulted in landslides and mudslides and warranted a Presidential Disaster Declaration on March 2, 2009, according to FEMA (DR-1824-OR). According to FEMA's DR-1824-OR declaration, ten Oregon counties were included in this disaster declaration, including Clackamas, Clatsop, Columbia, Hood River, Marion, Multnomah, Polk, Tillamook, Washington, and Yamhill Counties. In March of 2012, Salem experienced a relatively unusually late snowfall across the Willamette Valley. Salem received two to seven inches of snow, with the highest amounts on the hill in South Salem. This was the biggest snowstorm to strike Salem this late in the winter season. On average Salem receives 0.3 inches of snow in March. Other recorded late snowfalls occurred in March of 1951 totaling 9.6 inches and March of 1960, where Salem received 8.5 inches, according to the National Weather Service.

More recently, in February 2021, a major, widespread, multi-faceted winter storm that caused major problems across the northern Willamette Valley especially in the lowlands. Impacts were felt as far south as Albany. The Portland area had measured 10.1 inches of snow, followed by roughly 0.75 inches of ice. Significant impacts to infrastructure occurred, with over 400,000 people losing power at some point during the storm. The area impacted the hardest appears to be the southern portions of the Portland metro area from Oregon City and Silverton and as far south as Salem and Aumsville. Polk County was hit hard by ice as well, with 1.00 to 1.75 inches of ice reported. Some people in these areas hard-hit by ice lost power for over a week.

This was mostly an ice event for the Central Willamette Valley as a major ice storm occurred from freezing rain. By the end of the event, there were many reports of over 1 inch of ice accumulation, with as much as 1.75 inch reported in Sheridan. This was a crippling ice storm for the Salem metro area where generally amounts of 0.5 to 1.25 inches of ice were reported, and many were without power for days. Key impacts include widespread tree damage and power outages, including 110,000 customers without power in Salem. Multiple road closures as well including Highway 99.

Additional winter storm events are identified in Table 2-20 for all of Marion and Polk Counties between 2017-2022.

Table 2-20 Winter Storm Events in Marion and Polk Counties 2017-2022

Zone	Begin Date	Begin Time	Event Type	Deaths
NORTH OREGON CASCADES (ZONE)	10/12/2017	1400	Heavy Snow	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	2/20/2018	900	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	2/25/2018	700	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	4/7/2018	1700	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	12/11/2018	1400	Winter Weather	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	2/8/2019	2000	Heavy Snow	0
NORTH OREGON CASCADES (ZONE) NORTH OREGON CASCADES FOOTHILLS (ZONE)	2/10/2019	1900	Heavy Snow	0
NORTH OREGON CASCADES (ZONE) NORTH OREGON CASCADES FOOTHILLS (ZONE)	2/23/2019	1600	Heavy Snow	0
NORTH OREGON CASCADES (ZONE) NORTH OREGON CASCADES FOOTHILLS (ZONE)	2/24/2019	1600	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	11/26/2019	1200	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	1/10/2020	1100	Heavy Snow	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	1/13/2020	500	Heavy Snow	0

Zone	Begin Date	Begin Time	Event Type	Deaths
NORTH OREGON CASCADES (ZONE)	3/30/2020	2312	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	11/13/2020	100	Heavy Snow	0
CENTRAL WILLAMETTE VALLEY (ZONE)	1/26/2021	1300	Winter Weather	0
CENTRAL WILLAMETTE VALLEY (ZONE)	2/11/2021	1400	Ice Storm	0
NORTH OREGON CASCADES (ZONE) NORTH OREGON CASCADES FOOTHILLS (ZONE)	2/11/2021	1600	Winter Storm	0
NORTH OREGON CASCADES (ZONE)	2/25/2021	700	Winter Storm	0
NORTH OREGON CASCADES (ZONE)	12/11/2021	300	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	12/19/2021	700	Heavy Snow	0
NORTH OREGON CASCADES (ZONE) NORTH OREGON CASCADES FOOTHILLS (ZONE)	12/24/2021	500	Heavy Snow	0
CENTRAL WILLAMETTE VALLEY (ZONE)	12/25/2021	1600	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	1/2/2021	2100	Heavy Snow	0
NORTH OREGON CASCADES FOOTHILLS (ZONE)	1/3/2021	300	Heavy Snow	0
NORTH OREGON CASCADES (ZONE)	4/3/2022	2300	Winter Storm	0
NORTH OREGON CASCADES (ZONE) NORTH OREGON CASCADES FOOTHILLS (ZONE)	4/10/2022	1900	Winter Storm	0

Source: NOAA. (n.d.). *Storm Event Database*. Retrieved October 2022, from https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=41%2COREGON.
Note: This table does not include those storms that occurred in the Central Coast Range of W Oregon Zone. The bolded Central Willamette Valley (Zone) events were winter storms affected Salem and the surrounding areas.

Future Climate Variability

In the *2022 Salem NHMP*, there are several locations that describe future changing conditions or climate change as it relates to the natural hazards that impact Salem and the surrounding area. In the order of appearance in the NHMP it is in the Risk Assessment and the Hazard Characterizations.

Refer to the 2020 Oregon NHMP for climate change information about the Mid/Southern Willamette Valley Region (Region 3). Region 3 includes Linn, Lane (non-coastal), Marion, Polk, and Yamhill Counties. The hazards faced by Region 3 that are projected to be influenced by climate change include drought, wildfire, flooding, landslides, and extreme heat. The 2020 Oregon NHMP also states, “There is no current research available about changes in the incidence of winter storms in Oregon due to changing climate conditions. However, the warming climate will result in less frequent extreme cold events and high-snowfall years.”

Probability Assessment

The recurrence interval for a severe winter storm is about every 13 years. However, there can be many localized storms between these periods. Severe winter storms occur in western Oregon regularly from November through February. Salem experiences winter storms a couple times every year, to every other year.

Based on the available data and research for Salem the NHMP Steering Committee determined the **probability of experiencing a winter storm is "high,"** meaning one incident is likely within the next 35-year period.

Vulnerability Assessment

Given current available data, no quantitative assessment of the risk of winter storm was possible at the time of this NHMP update. However, assessing the risk to Salem from winter storms should remain an ongoing process determined by community characteristics and physical vulnerabilities. Weather forecasting can give city resources (emergency vehicles, warming shelters) time to prepare for an impending storm, but the changing character of the city population and resources will determine the impact of winter storms on life and property in Salem.

The most likely impact of snow and ice events on Salem are road closures limiting access/egress to/from some areas, especially roads to higher elevations. Winter storms with heavy wet snow or high winds and ice storms may also result in power outages from downed transmission lines and/or poles.

Winter storms which bring snow, ice and high winds can cause significant impacts on life and property. Many severe winter storm deaths occur because of traffic accidents on icy roads, heart attacks may occur from exertion while shoveling snow, and hypothermia from prolonged exposure to the cold. The temporary loss of home heating can be particularly hard on the elderly, young children and other vulnerable individuals.

Property is at risk due to flooding and landslides that may result if there is a heavy snowmelt. Additionally, ice, wind and snow can affect the stability of trees, power and telephone lines and TV and radio antennas. Down trees and limbs can become major hazards for houses, cars, utilities and other property. Such damage in turn can become major obstacles to providing critical emergency response, police, fire and other disaster recovery services.

Severe winter weather also can cause the temporary closure of key roads and highways, air and train operations, businesses, schools, government offices and other important community services. Below freezing temperatures can also lead to breaks in un-insulated water lines serving schools, businesses, industries, and individual homes. All these effects, if lasting more than several days, can create significant economic impacts for the affected communities, surrounding region, and region. In the rural areas of Oregon severe winter storms can isolate small communities, farms, and ranches.

At the time of this update, sufficient data was not available to determine winter storm vulnerability in terms of explicit types and numbers of existing and future buildings, infrastructure, or critical infrastructure.

Winter storms in the past caused multiple major injuries or death. The potential for future injuries or deaths is anticipated to remain similar to historic events. Salem estimates that less than 10% of the City's population could be physically displaced by a winter storm, accounting for families that may not have access to warm shelter; and there would be moderate impact on community social networks due to poor driving conditions.

Several facilities throughout Salem anticipate mild damage due to winter storms, estimated at less than $1 million for hazard response, structural repairs and equipment replacement. In terms of commercial business, it is likely that more than 75% of businesses located in Salem and surrounding area could experience commerce interruption for a period of days until driving conditions improve. Winter storms will likely have the greatest impacts on the transportation system, as snow and ice can cause dangerous driving conditions. Lastly, winter storms could likely have extensive impacts on more than 75% of the City's ecological systems, including, clean water, wildlife habitat, and parks.

As such, the NHMP Steering Committee rated the city as having a **"high" vulnerability to winter storm hazards**, meaning that greater than 10% of the city's population or assets would be affected by a major disaster.

Mitigation Activities and Resources

Existing mitigation activities include current mitigation programs and activities that are being implemented by the community to reduce the community's overall risk to natural hazards. Documenting these efforts can assist the community in better understanding its risk and can assist in documenting successes.

Driving in Oregon's winters can be challenging. Using traction tires or traction devices can be more effective than all-weather tires on icy or snowy roads. Traction tires are studded tires, retractable studded tires, or other tires that meet the tire industry definition as suitable for use in severe snow conditions. Studded tires can be used in Oregon from November 1 to March 31. Research shows that traction tires are more effective than all-weather tires on icy roads or in severe snowy conditions but can be less effective in most other conditions. Traction devices such as chains or chain-like devices can be more effective than studded tires. Winter storm hazard is similar to windstorm in terms of strategies and programs at the state level.

Federal Resources

National Oceanic and Atmospheric Administration

According to the NOAA National Severe Storms Laboratory, winter weather and storms use a variety of tools to forecast winter weather and storms. The National Severe Storms Laboratory is a major contributor to the scientific and engineering development of dual-polarized weather radar, which is now installed on the NWS weather radars. Dual-polarization radar can clearly identify rain, hail, snow, or ice pellets inside the clouds. In addition to observing a wide network of satellites, Doppler radars and automated surface observing systems, forecasters use their experience, together with computer forecast models to write and issue forecasts on what will happen next regarding winter weather and storms.

Federal Emergency Management Agency

FEMA recommends preparing the home and the car for winter weather. For the home, keeping out the cold with insulation, caulking and weather stripping. It is also recommended to learn how to keep pipes from freezing and to install and test smoke alarms and carbon monoxide detectors with battery backups. Creating an emergency kit is recommended in case the power is out for several days, keeping in mind each person's and pets special needs. For the car, FEMA recommends creating an emergency kit that will include jumper cables, sand, a flashlight, warm clothes, blankets, bottled water, non-perishable snacks, and a full tank of gas. (https://www.ready.gov/winter-weather)

State Resources

State Natural Hazard Risk Assessment

The risk assessment in the *2020 Oregon Natural Hazards Mitigation Plan* provides an overview of all the identified natural hazards in Oregon (in the State NHMP but not necessarily all the locally identified natural hazards) and identifies the most significant hazards in Oregon's recorded history. It has overall state and regional information and includes mitigation actions for the entire state. 2020 Oregon NHMP

Planning for Natural Hazards: Oregon Technical Resource Guide

This guide describes basic mitigation strategies and resources related to natural hazards, including examples from communities in Oregon. https://scholarsbank.uoregon.edu/xmlui/handle/1794/1909

Statewide Planning Goals

There are 19 Statewide Planning Goals that guide land use in the State of Oregon. These became law via Senate Bill 100 in 1973. One goal, Goal 7, focuses on land use planning and natural hazards. Goal 7, Areas Subject to Natural Disasters and Hazards, requires local governments to identify hazards and adopt appropriate safeguards for land use and development. Goal 7 advocates the continuous incorporation of hazard information in local land use plans and policies. The jurisdictions participating in this 2022 Salem NHMP have approved comprehensive plans that include information pertinent to Goal 7. https://www.oregon.gov/lcd/OP/Pages/Goals.aspx

Oregon State Building Code Standards

The Oregon Building Codes Division adopts statewide standards for building construction that are administered by the state and local municipalities throughout Oregon. Building Codes standards (both residential and other codes) are set to withstand specific snow loads (https://www.oregon.gov/bcd/codes-stand/pages/index.aspx).

The *2017 Oregon Residential Special Code* (*ORSC*) contains requirements for one- and two-family dwellings (https://codes.iccsafe.org/content/document/1018?site_type=public).

The *2019 Oregon Structural Special Code* (*OSSC*) contains provisions for grading and site preparation for the construction of building foundations (https://codes.iccsafe.org/content/OSSC2019P1).

Oregon Department of Emergency Management

OEM is involved in many programs that mitigate the effects of natural hazards including the Hazard Mitigation Grant Program, co-sponsoring and participating in training workshops. Also, as part of its warning responsibilities, OEM notifies local public safety agencies and keeps them informed of potential and actual hazard events so prevention and mitigation actions can be taken.

Roadway Maintenance

ODOT is responsible for performing precautionary measures to maintain the safety and operability of major roads during storm conditions. The road maintenance programs are designed to provide the best use of limited resources to maximize the movement of traffic within the community during inclement weather.

During storm events, most agencies at the county and city level focus on clearing major arterial and collector streets first, and then respond to residential connector streets, school zones, transit routes, and steep residential streets as resources become available. The state, counties, and cities, may have agreements, including mutual aid agreements, about road maintenance responsibilities during day-to-day operations and who does what in storm situations. In general, highways receive more attention. For those routes on the National Highway System network, primary interstate expressways, and primary roadways will be cleared more quickly and completely than other roads.

Local Resources

Salem Snow and Ice Control Plan

The Salem *Snow and Ice Control Plan* (2019) establishes policies, procedures, and training to meet specified levels of service and is routinely reviewed. Collaboration occurs with City of Salem and all adjoining transit, school transportation, municipal, county, federal, and state agencies, to compare and share new technologies, practices, materials, and methods, and to confirm shared and exchanged response routes along the periphery of each jurisdiction. Assigned snow and ice response routes will be prioritized by volume of traffic, grade of roadway, terrain, elevation, neighborhood inter-connecting traffic patterns, and locations of government and emergency facilities, with flexibility to adapt to heavy commute patterns.

Salem Community Forestry Strategic Plan

The Salem's *Community Forestry Strategic Plan* (2013) recognizes that trees provide multiple economic, environmental, and social benefits. Due to all the advantages trees provide, Salem's Public Works decided to investigate ways to improve the city's community forest, with an emphasis on non-regulatory approaches and incentives. The plan establishes six goals and specific actions, priorities, and partnerships needed to achieve the goals. Goal 5 includes the development and implementation of a Community Forestry Management Plan that will help establish industry appropriate best management practices, standards, and protocols for tree care, risk and hazard reduction, and storm/hazard tree response, removal and replanting.

Salem Emergency Management Plan

This description is excerpted from the *Salem Emergency Management Plan* (2014).

> This Emergency Management Plan is an all-hazard plan that describes how the City of Salem will organize and respond to emergencies and disasters in the community. It is based on, and is compatible with, Federal, State of Oregon, and other applicable laws, regulations, plans, and policies, including Presidential Policy Directive 8, the National Response Framework, Oregon Office of Emergency Management Plan, and both Marion and Polk County Emergency Operations Plans.
>
> Response to emergency or disaster conditions in order to maximize the safety of the public and to minimize property damage is a primary responsibility of government. It is the goal of the City of Salem that responses to such conditions are conducted in the most organized, efficient, and effective manner possible. To aid in accomplishing this goal, the City of Salem has, in addition to promulgating this plan, formally adopted the principles of the National Incident Management System, including the Incident Command System and the National Response Framework.
>
> Consisting of a Basic Plan, Functional Annexes aligned with both Marion and Polk County Emergency Support Functions, and Incident Annexes, this Salem Emergency Management Plan provides a framework for coordinated response and recovery activities during a large-scale emergency. The plan describes how various agencies and organizations in the City of Salem will coordinate resources and activities with other Federal, State, local, tribal, and private-sector partners.

Other Existing Strategies and Programs

Existing strategies and programs at the state level are usually performed by the Oregon Public Utility Commission (OPUC), Building Code Division (BCD), ODF, OEM, and the Oregon Department of Transportation.

The Oregon Emergency Response System (OERS) coordinates and manages state resources in response to natural and technological emergencies and civil unrest involving multi-jurisdictional cooperation between all levels of government and the private sector (https://www.oregon.gov/oem/emops/Pages/OERS.aspx).

Oregon Public Utility Commission ensures operators manage, construct and maintain their utility lines and equipment in a safe and reliable manner. These standards are listed on this website: http://www.puc.state.or.us/PUC/safety/index.shtml. OPUC promotes public education and requires utilities to maintain adequate tree and vegetation clearances from high voltage utility lines and equipment.

Community Vulnerability Identification and Assessment

Vulnerability assessment is the second phase of this Risk Assessment. Vulnerability assessment endeavors to identify important community assets and system vulnerabilities. Vulnerabilities include both physical assets such as businesses, homes, roads and critical infrastructure like drinking water sources, and public service and health service establishments as well as community assets including people, historic places, and environmental assets. The bases for updates to this phase of the Risk Assessment are the Hazard Vulnerability Assessment ranking exercise and research results of demographic and economic sources.

The Steering Committee engaged in a Hazard Vulnerability Assessment exercise based on the OEM methodology to identify the relative vulnerability of the City of Salem is to the hazards identified in phase one of the Risk Assessment and to describe the aspects of the community that are most at risk. A description of this HVA exercise and its results are contained in the Hazard Vulnerability Assessment section.

DOGAMI mapping also informs the assessment of vulnerability by illustrating the dispersed nature of rural residential structures. As part of DOGAMI's Risk Report for Marion County, including the City of Salem in both Marion and Polk Counties, analysts mapped building location and type, as well as population density. This mapping forms part of the full report analyzing the exposure of people and property and their susceptibility to four of the identified hazards (Flood, Earthquake, Wildfire and Volcanic Events) by overlaying high hazard areas with existing structures and populations.

Hazard Vulnerability Assessment

Hazard Vulnerability Assessment Methodology

The hazard vulnerability assessment methodology in Oregon (primarily to inform Emergency Operations Planning) was first developed by FEMA circa 1983, and gradually refined by OEM over the years.

The methodology produces scores that range from 24 (lowest possible) to 240 (highest possible). Vulnerability and probability are the two key components of the methodology. Vulnerability examines both typical and maximum credible events, and probability endeavors to reflect how physical changes in the jurisdiction and scientific research modify the historical record for each hazard. Vulnerability accounts for approximately 60% of the total score, and probability approximately 40%. We include the hazard analysis summary here to ensure consistency between the EOP and NHMP.

The Oregon method provides the jurisdiction with a sense of hazard priorities, or relative risk. It doesn't predict the occurrence of a particular hazard, but it does "quantify" the risk of one hazard compared with another. By doing this analysis, planning can first be focused where the risk is greatest.

In this analysis, severity ratings, and weight factors, are applied to the four categories of history, vulnerability, maximum threat (worst-case scenario), and probability as demonstrated below.

History (Weight Factor = 2)

History is the record of previous occurrences. Events to include in assessing history of a hazard are events for which the following types of activities were required:

- The Emergency Operations Center (EOC) or alternate EOC was activated;
- Three or more Emergency Operations Planning (EOP) functions were implemented, e.g., alert & warning, evacuation, shelter, etc.;
- An extraordinary multi-jurisdictional response was required; and/or
- A "Local Emergency" was declared.

Low = 0 to 1 event in the past 100 years, scores between 1 and 3 points
Moderate = 2 to 3 events in the past 100 years, scores between 4 and 7 points
High = 4+ events in the past 100 years, scores between 8 and 10 points

Probability (Weight Factor = 7)

Probability is the likelihood of future occurrence within a specified period of time.

Low = one incident likely within 75 to 100 years, scores between 1 and 3 points
Moderate = one incident likely within 35 to 75 years, scores between 4 and 7 points
High = one incident likely within 10 to 35 years, scores between 8 and 10 points

Vulnerability (Weight Factor = 5)

Vulnerability is the percentage of population and property likely to be affected under an "average" occurrence of the hazard.

Low = < 1% affected, scores between 1 and 3 points
Moderate = 1 - 10% affected, scores between 4 and 7 points
High = > 10% affected, scores between 8 and 10 points

Maximum Threat (Weight Factor =10)

Maximum threat is the highest percentage of population and property that could be impacted under a worst-case scenario.

Low = < 5% affected, scores between 1 and 3 points
Moderate = 5 - 25% affected, scores between 4 and 7 points
High = > 25% affected, scores between 8 and 10 points

The HVA exercise was conducted during the November 15, 2022 and December 14, 2022 Steering Committee meetings to rank these hazards using the OEM methodology. Table 2-21 below displays the ranking of each of these hazards according to the group present at these meetings.

Hazard Vulnerability Assessment Matrix

The hazard vulnerability assessment matrix involves estimating the damage, injuries, and costs likely to be incurred in a geographic area over time. Risk has two measurable components: (1) the magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous sections), and (2) the likelihood or probability of the harm occurring. The methodology for the hazard analysis was first developed by FEMA and refined by the OEM, which is discussed above.

Table 2-21 presents the entire updated hazard analysis matrix for Salem. The hazards are listed in rank order from high to low. The table shows that hazard scores are influenced by each of the four categories combined. With considerations for past historical events, probability or likelihood of a hazard event occurring, vulnerability to the community, and maximum threat or worst-case scenario, the Salem steering committee ranked extreme heat, air quality, and winter storm events as the top hazard threats to the city. Earthquake, flood, wildfire, and water quality rank in the upper middle tier. Drought and windstorm events rank in the lower middle tier. Landslide and volcano events comprise the lowest ranked hazards in the city . Other hazards such as hazardous materials incident event was not reviewed.

Table 2-21 City of Salem 2022/2023 Natural Hazard Vulnerability Assessment

HAZARD	HISTORY			PROBABILITY			VULNERABILITY			MAX THREAT			RISK	RISK LEVEL
	WF = 2			WF = 7			WF = 5			WF = 10			SCORE	H-M-L
Extreme Heat	2 x	10 =	20	7 x	10 =	70	5 x	10 =	50	10 x	10 =	100	240	High
Air Quality	2 x	9 =	18	7 x	10 =	70	5 x	9 =	45	10 x	10 =	100	233	High
Winter Storm	2 x	9 =	18	7 x	10 =	70	5 x	9 =	45	10 x	10 =	100	233	High
Earthquake	2 x	3 =	6	7 x	9 =	63	5 x	8 =	40	10 x	10 =	100	209	Medium/ High
Flood	2 x	10 =	20	7 x	10 =	70	5 x	5 =	25	10 x	9 =	90	205	Medium/ High
Wildfire	2 x	9 =	18	7 x	10 =	70	5 x	5 =	25	10 x	9 =	90	203	Medium/ High
Water Quality	2 x	6 =	12	7 x	9 =	63	5 x	7 =	35	10 x	9 =	90	200	Medium/ High
Drought	2 x	4 =	8	7 x	9 =	63	5 x	5 =	25	10 x	9 =	90	186	Medium
Windstorm	2 x	8 =	16	7 x	8 =	56	5 x	4 =	20	10 x	9 =	90	182	Medium
Landslide	2 x	8 =	16	7 x	9 =	63	5 x	2 =	10	10 x	4 =	40	129	Low
Volcano	2 x	2 =	4	7 x	2 =	14	5 x	2 =	10	10 x	10 =	100	128	Low

Source: Salem NHMP Steering Committees 2022-2023.

The following subsections describe relevant information for each hazard. For additional background on the hazards, vulnerabilities and general risk assessment information for hazards in the Mid/Southern Willamette Valley (Region 3) refer to the https://www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_09_RA3.pdf.

DOGAMI Multi-hazard Risk Assessment

The Department of Geology and Mineral Industries (DOGAMI) performed a risk assessment for the communities of Marion County, Oregon, with funding provided by the Federal Emergency Management Agency. The City of Salem is located in Marion and Polk Counties. The west portion of Salem that is within Polk County is included in this report, examined individually and designated as City of Salem (West Salem). The report, which is attached as Appendix D describes the methods and results of natural hazard risk assessments performed in 2021 and 2022 by DOGAMI within the study area shown below in Figure 2-57. The purpose of this project is to provide communities within the study area a detailed risk assessment of the natural hazards that affect them to enable them to compare hazards and act to reduce their risk. The risk assessment contained in this project quantifies the impacts of natural hazards to these communities and enhances the decision-making process in planning for disaster.

The DOGAMI Geohazards Analyst arrived at these findings and conclusions by completing three main tasks: compiling an asset database, identifying, and using best available hazard data, and performing natural hazard risk assessment.

In the first task, he created a comprehensive asset database for the entire study area by synthesizing assessor data, U.S. Census information, Hazus-MH[7] general building stock information, and building footprint data. This work resulted in a single dataset of building points and their associated building characteristics. With these data he was able to represent accurate spatial location and vulnerability on a building-by-building basis.

The second task was to identify and use the most current and appropriate hazard datasets for the study area. Most of the hazard datasets used in this report were created by DOGAMI; some were produced using high-resolution lidar topographic data[8]. While not all the data sources used in the report are countywide, each hazard dataset was the best available at the time of writing.

In the third task the DOGAMI Geohazards Analyst, Matt Williams, performed risk assessments using Esri® ArcGIS Desktop® software. He took two risk assessment approaches: (1) estimated loss (in dollars) to buildings from flood (recurrence intervals) and earthquake scenarios using FEMA Hazus®-MH methodology, and (2) calculated number of buildings, their value, and associated populations exposed to earthquake, and flood scenarios, or susceptible to varying levels of hazard from landslides, channel migration, wildfire, and volcanic lahar.

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[7] Hazus is a nationally standardized risk modeling methodology developed by FEMA. Hazus-MH (for Multi-Hazard) identifies areas with high risk for natural hazards and estimates physical, economic, and social impacts of earthquakes, hurricanes, floods, and tsunamis.

[8] Lidar (Light Detection and Ranging) is a remote sensing technology that uses light in the form of a pulsed laser to measure variable distances to the Earth. When combined with other data, it will generate precise, accurate, and high-resolution three-dimensional images of the surface of the earth, vegetation, and the built environment.

The findings and conclusions of this report show the potential impacts of hazards in communities within Marion County.

- While earthquake damage will occur throughout the entire county, extensive damage and losses are more probable in the northeastern portion of the county and areas of high liquefaction prone soils. Hazus-MH earthquake simulations illustrate the potential reduction in earthquake damage through seismic retrofits.
- Some communities in the study area have moderate risk from flooding, and DOGAMI quantified the number of elevated structures that are less vulnerable to flood hazard. The areas that are most vulnerable from flood hazard within the study are buildings along the Mill Creek (near Salem) between Turner and Salem and along Labish Ditch in Keizer.
- The analysis shows that new landslide mapping based on improved methods and lidar information show some communities are at risk to landslide hazard, including developed areas in the southwest part of Salem.
- Exposure to channel migration hazard is high for areas and communities along the Pudding River and Santiam and North Santiam Rivers.
- The wildfire hazard data used in this study was created prior to the unprecedented 2020 Labor Day Wildfires, however the results corresponded to the actual impacts of the 2020 Labor Day Wildfires in the county.
- Lahar hazard is a potential risk and could have significant impact for areas and the communities along the North Santiam River. The study's findings indicate that most of the critical facilities in the study area are at high risk from an earthquake and channel migration. DOGAMI found that the two biggest causes of population displacement are earthquake and landslide hazard.

Results were broken out for the following geographic areas (City of Salem in bold):

- Unincorporated Marion County (rural)
- Community of Hayesville
- Community of Brooks
- Community of Marion
- City of Aumsville
- City of Detroit*
- City of Gates*
- City of Hubbard
- City of Jefferson
- City of Mill City*
- City of St. Paul
- **City of Salem (West Salem)***
- City of Scotts Mills
- City of Sublimity
- City of Woodburn
- Community of Four Corners
- Community of Butteville
- Community of Labish Village
- Community of Mehama
- City of Aurora
- City of Donald
- City of Gervais
- City of Idanha
- City of Keizer
- City of Mount Angel
- **City of Salem**
- City of Silverton
- City of Stayton
- City of Turner

*Portions of the cities of Detroit, Gates, and Mill City that were within Linn County are included in this report. The City of Salem that was within Polk County was examined individually and designated as City of Salem (West Salem).

The following table provides selected county data regarding total number buildings in the county, the number of buildings affected by a hazard event, and estimated loss value of those affected buildings.

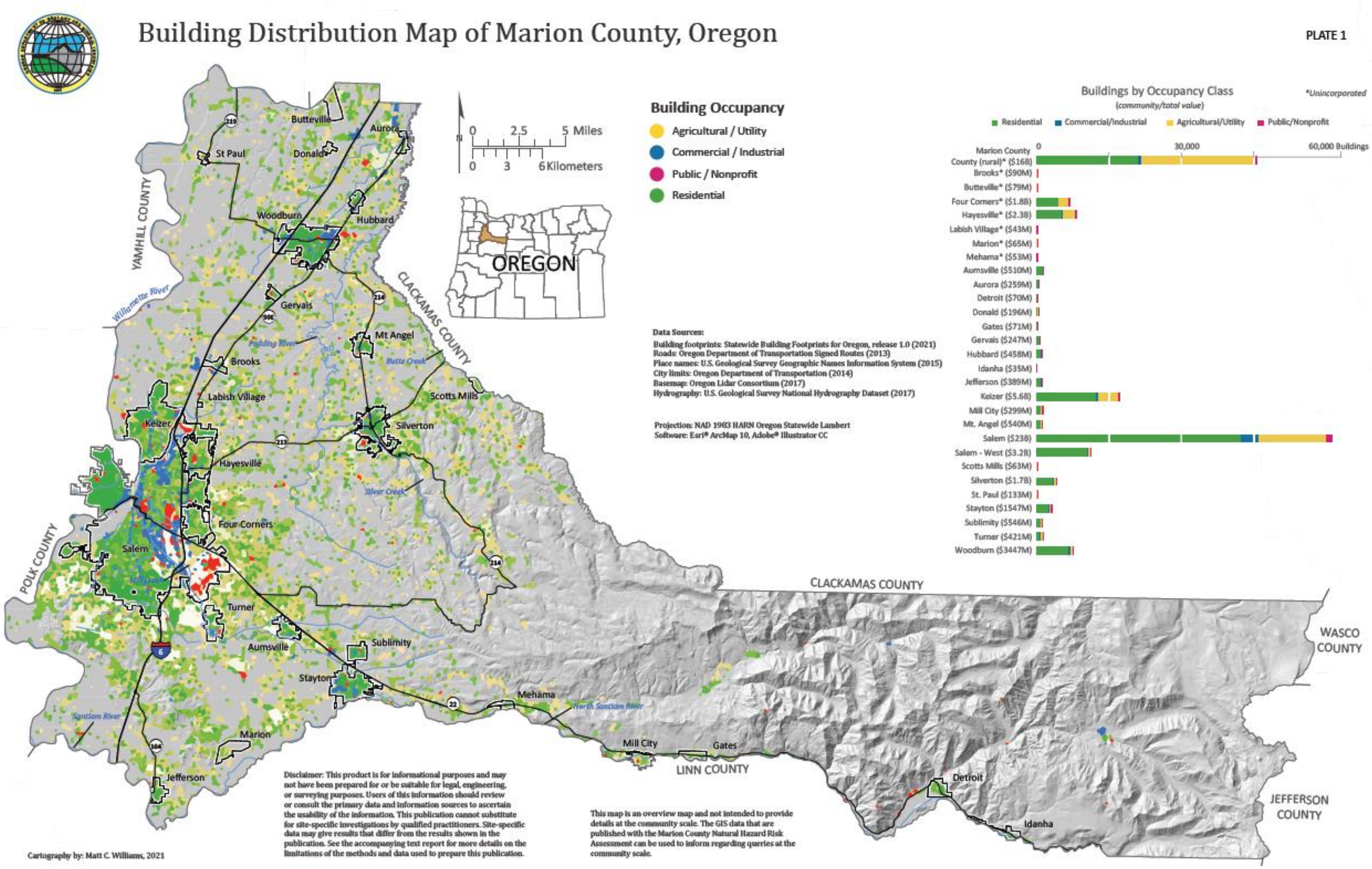
Table 2-22 Selected Countywide Results

Selected Countywide Results Total buildings: 170,562 Total estimated building value: $62 billion	
Mt. Angel Deterministic Magnitude 6.8 Earthquake Scenario Red-tagged buildings[a]: 7,479 Yellow-tagged buildings[b]: 17,028 Loss estimate: $6.7 billion	**100-year Flood** Number of buildings damaged: 2,552 Loss estimate: $126 million
Landslide (High and Very High-Susceptibility) Number of buildings exposed: 7,470 Exposed building value: $2.7 billion	**Channel Migration Zone (30-year):** Number of buildings exposed: 826 Exposed building value: $300 million
Wildfire (High and Moderate Risk): Number of buildings exposed: 2,819 Exposed building value: $814 million	**Lahar (1,000 to 15,000-year):** Number of buildings exposed: 1,789 Exposed building value: $415 million

[a]Red-tagged buildings are considered uninhabitable due to complete damage.
[b]Yellow-tagged buildings are considered limited habitability due to extensive damage.

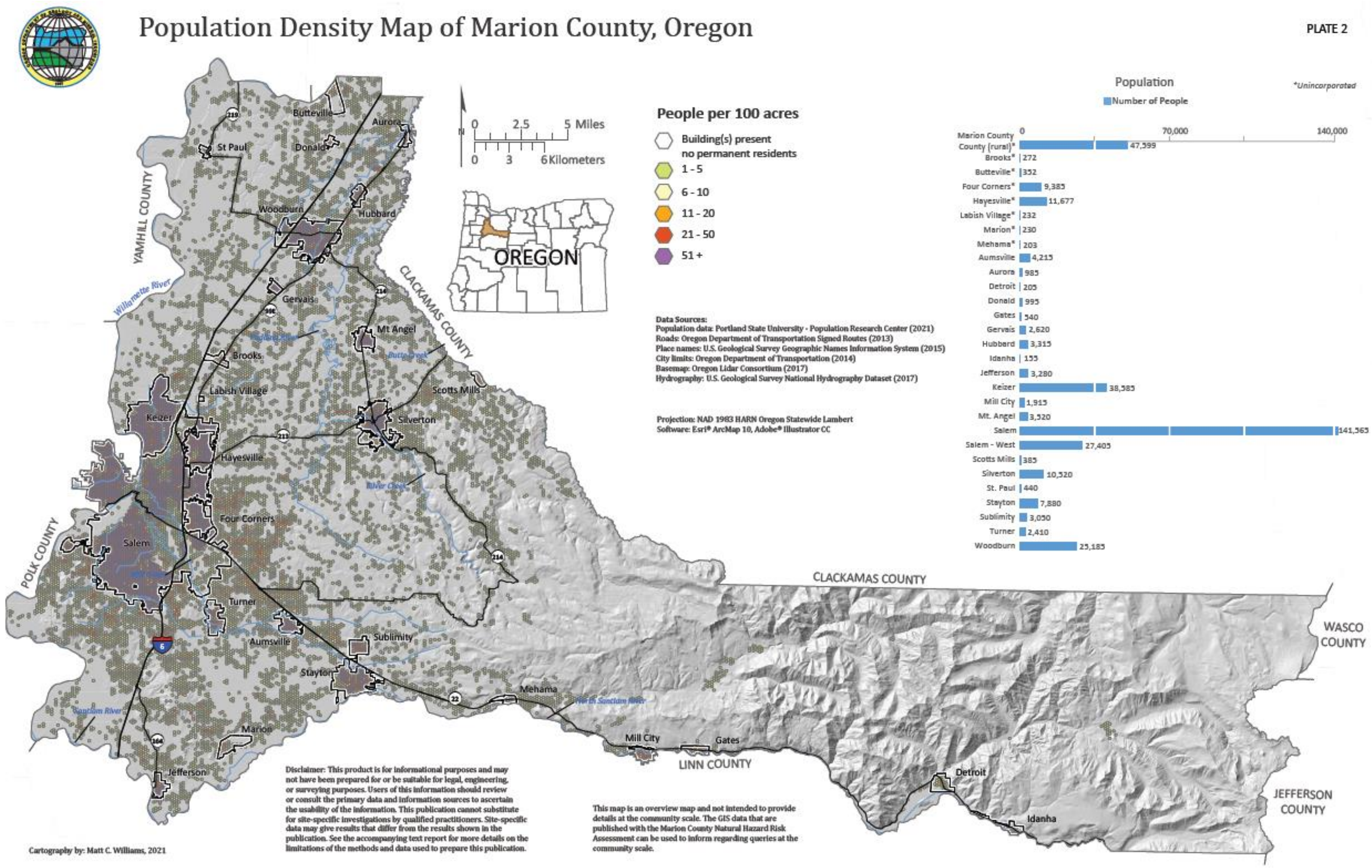
Source: Williams, M. C. & Madin, I. P. (2022). *Open-file Report O-22-05 Multi-Hazard Risk Report for Marion County, Oregon.* Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/O-22-05/p-O-22-05.htm.

Figure 2-56 Building Distribution Map of Marion County, Oregon



Source: Williams, M. C. & Madin, I. P. (2022). *Open-file Report O-22-05 Multi-Hazard Risk Report for Marion County, Oregon.* Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/O-22-05/p-O-22-05.htm.

Figure 2-57 Population Density Map of Marion County, Oregon



Source: Williams, M. C. & Madin, I. P. (2022). *Open-file Report O-22-05 Multi-Hazard Risk Report for Marion County, Oregon.* Oregon DOGAMI. Retrieved from https://www.oregongeology.org/pubs/ofr/O-22-05/p-O-22-05.htm

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Future Climate Projections

Oregon's Department of Land Conservation and Development contracted with the Oregon Climate Change Research Institute (OCCRI) to analyze the influence of climate change on natural hazards. The complete report is available as Appendix E. The scope of the analysis that yielded the report entitled *Future Climate Projections Marion County, Oregon* is limited to the geographic area encompassed by Marion County, however OCCRI has performed this analysis for many other Oregon counties to inform the Natural Hazard Mitigation Plan update process. A small portion of Salem is in Polk County; however, OCCRI has not executed a *Future Climate Projections* report for Polk County. Based on the commonality between the two counties when it comes to current and future climate projections, this NHMP relies on the Marion County report issued in June 2022.

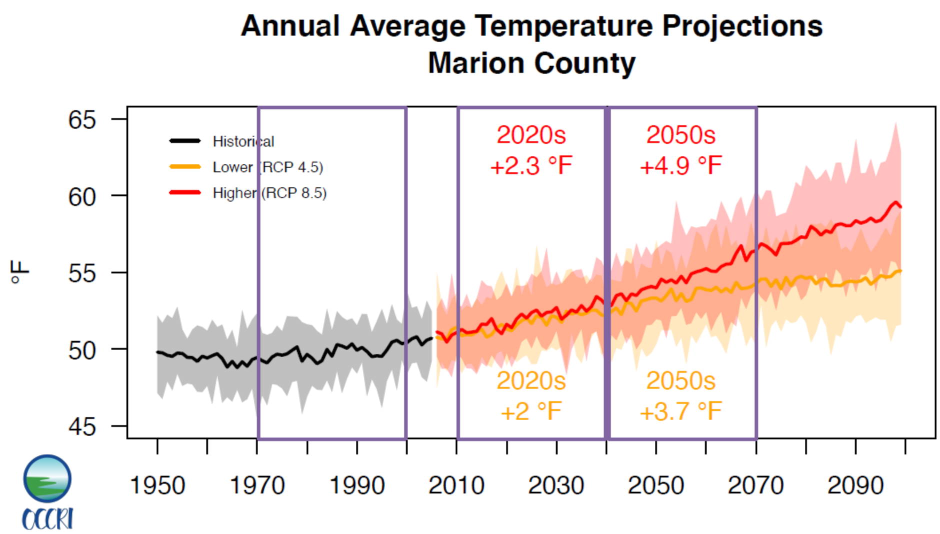
The *Future Climate Projections Marion County, Oregon* report states,

> Industrialization has increased the amount of greenhouse gases emitted worldwide, which is causing Earth's atmosphere, oceans, and lands to warm (IPCC, 2021). Climate change and its effects already are apparent in Oregon (Dalton et al., 2017; Mote et al., 2019; Dalton and Fleishman, 2021). Climate change is expected to increase the likelihood of natural hazards such as heavy rains, river flooding, drought, heat waves, wildfires, and episodes of poor air quality, and to decrease the likelihood of cold waves.

During the twenty-first century, the average temperature in Marion County is projected to warm at a rate like that of Oregon as illustrated in Figure 2-58.

Figure 2-58 Annual Average Temperature Projections, Marion County

Historical Baseline	2020s	2050s
1971–2000	2010–2039	2040–2069



Source: Dalton, M., Fleishman, E., & Bachelet, D. (2022, June). *Future Climate Projections Marion County, Oregon*. OCCRI. College of Earth, Ocean and Atmospheric Sciences. Oregon State University, Corvallis, Oregon. Retrieved from https://oregonstate.app.box.com/s/me7ih3b6vvlffrm6ndwmt8a5ag6zs6xw.

The OCCRI report states that climate change is expected to increase the occurrence of many climate-related natural hazards. Confidence levels and changes in natural hazard risks are illustrated in Figure 2-59. Confidence that the risk of heat waves will increase is very high given strong evidence in the peer-reviewed literature, consistency among the projections of different global climate models, and robust theoretical principles underlying increasing temperatures in response to ongoing emissions of greenhouse gases. Additionally, confidence that the risk of many other natural hazards (e.g., drought, reduced air quality, and flooding) will increase as climate changes is high or medium, reflecting moderate to strong evidence and consistency among models. However, these risks are influenced by multiple secondary factors, in addition to, increasing temperatures. Confidence in changes in risks is indicated as low for windstorms, for example, if projections suggest relatively few to no changes or evidence is limited.

OCCRI analysts projected the direction of change in the risks of climate-related natural hazards and the level of confidence in those changes. Very high confidence means that the direction of change is consistent among nearly all global climate models and there is strong evidence in the peer-reviewed literature. High confidence means that the direction of change is consistent among more than half of models and there is moderate to strong evidence in the peer-reviewed literature. Medium confidence means that the direction of change is consistent among more than half of models and there is moderate evidence in the peer-reviewed literature. Low confidence means that the direction of change is small compared to the range of model responses or there is limited evidence in the peer-reviewed literature.

Figure 2-59 Confidence Level and Changes in Natural Hazard Risk

	Low Confidence	Medium Confidence	High Confidence	Very High Confidence
Risk Increasing ↑		Drought Expansion of Non-native Invasive Species Reduced Air Quality Loss of Wetlands	Heavy Rains Flooding Wildfire	Heat Waves
Risk Unchanging =	Windstorms			
Risk Decreasing ↓				Cold Waves

Source: Dalton, M., Fleishman, E., & Bachelet, D. (2022, June). *Future Climate Projections Marion County, Oregon*. OCCRI. College of Earth, Ocean and Atmospheric Sciences. Oregon State University, Corvallis, Oregon. Retrieved from https://oregonstate.app.box.com/s/me7ih3b6vvlffrm6ndwmt8a5ag6zs6xw.

Future climate projections for Marion County are presented in the OCCRI report are relevant to specified natural hazards for the 2020s (2010–2039) and 2050s (2040–2069) relative to the 1971–2000 historical baseline. The projections are presented for a lower greenhouse gas emissions scenario (RCP[9] 4.5) and a higher greenhouse gas emissions scenario (RCP 8.5) and are based on multiple global climate models. All projections in this executive summary refer to the 2050s, relative to the historical baseline, under the higher emissions scenario. Projections for both time periods and emissions scenarios are included in the main report.

Heat Waves

The number, duration, and intensity of extreme heat events is expected to increase as temperatures continue to warm.

In Marion County, the number of extremely hot days (days on which the temperature is 90°F or higher) and the temperature on the hottest day of the year are projected to increase by the 2020s and 2050s under both the lower (RCP 4.5) and higher (RCP 8.5) emissions scenarios.

[9] Representative Concentration Pathways (RCPs)

In Marion County, the number of days per year with temperatures 90°F or higher is projected to increase by an average of 16 days (range 5–27 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

In Marion County, the temperature on the hottest day of the year is projected to increase by an average of about 7°F (range 2–10°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Cold Waves

Cold extremes will become less frequent and intense as the climate warms. In Marion County, the number of cold days (maximum temperature 32°F or lower) per year is projected to decrease by an average of 4 days (range -2– -5 days) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

In Marion County, the temperature on the coldest night of the year is projected to increase by an average of 6°F (range 1–11°F) by the 2050s, relative to the 1971–2000 historical baselines, under the higher emissions scenario.

Heavy Rains

The intensity of extreme precipitation is expected to increase as the atmosphere warms and holds more water vapor.

In Marion County, the number of days per year with at least 0.75 inches of precipitation is not projected to change substantially. However, by the 2050s, the amount of precipitation on the wettest day and wettest consecutive five days per year is projected to increase by an average of 14% (range 0–35%) and 11% (range 0–24%), respectively, relative to the1971–2000 historical baselines, under the higher emissions scenario.

In Marion County, the number of days per year on which a threshold for landslide risk, which is based on prior 18-day precipitation accumulation, is exceeded is not projected to change substantially. However, landslide risk depends on multiple factors, and this metric does not reflect all aspects of the hazard.

River Flooding

Winter flood risk at mid- to low elevations in Marion County, where temperatures are near freezing during winter and precipitation is a mix of rain and snow, is projected to increase as winter temperatures increase. The temperature increase will lead to an increase in the percentage of precipitation falling as rain rather than snow.

Drought

Drought, as represented by low summer soil moisture, low spring snowpack, low summer runoff, and low summer precipitation, is projected to become more frequent in Marion County by the 2050s.

Wildfire

Wildfire risk, expressed as the average number of days per year on which fire danger is very high, is projected to increase in Marion County by 13 days (range -6–32) by the 2050s, relative to the historical baseline, under the higher emissions scenario.

In Marion County, the average number of days per year on which vapor pressure deficit is extreme is projected to increase by 27 days (range 9–43) by the 2050s, compared to the historical baseline, under the higher emissions scenario.

Reduced Air Quality

The risk of wildfire smoke in Marion County is projected to increase. The number of days per year on which the concentration of wildfire-derived fine particulate matter results in poor air quality is projected to increase by 19%, and the concentration of fine particulate matter is projected to increase by 91%, from 2004–2009 to 2046–2051 under a medium emissions scenario.

Loss of Wetlands

In Marion County, losses of wetlands in recent decades largely were caused by conversion to agriculture. Projected effects of climate change on wetlands in the Northwest include reductions in water levels and hydroperiod duration. If withdrawals of ground water do not increase, then wetlands that are fed by ground water rather than surface water may be more resilient.

Windstorms

Limited research suggests little if any change in the frequency and intensity of windstorms in the Northwest as a result of climate change.

Expansion of Non-native Invasive Species

In general, non-native invasive plant species in Marion County are likely to become more prevalent in response to projected increases in temperature, especially minimum winter temperature, and increases in the frequency, duration, and severity of drought. However, many of these responses are uncertain, are likely to vary locally, and may change over time.

Community Characteristics

Vulnerability assesses the extent to which people are susceptible to injury or other impacts resulting from a hazard as well as the exposure of the built environment or other community assets (social, environmental, economic, etc.) to hazards. The exposure of community assets to hazards is critical in the assessment of the degree of risk a community has to each hazard. Identifying the populations, facilities and infrastructure at risk from various hazards can assist the county in prioritizing resources for mitigation and can assist in directing damage assessment efforts after a hazard event has occurred. The exposure of county and city assets to each hazard and potential implications are explained in each hazard section and within each Addendum in Volume II.

Community vulnerabilities are an important component of the NHMP risk assessment. Vulnerability includes the percentage of population and property likely to be affected under an "average" occurrence of the hazard. For more information regarding specific community vulnerabilities, reference each Hazard Identification section above and Appendix A: Community Profile. Data sources for the following community vulnerability information can be found in Appendix A – Community Profile, unless otherwise noted below. City of Salem and the DLCD natural hazards planners evaluated the best available vulnerability data to develop the vulnerability evaluation presented below.

Population

The socio-demographic qualities of the community population, in terms of language, race and ethnicity, age, income, educational attainment, and health are significant factors that can influence the community's ability to cope, adapt to and recover from natural disasters. In addition, other indicators such as graduation rate, quality of schools, and median household income can have long term impacts on the City of Salem economy and stability of the community ultimately affecting future resilience. Historically, 80 percent of the disaster burden falls on the public, according to the U.S. Census Bureau. Of this number, a disproportionate burden is placed upon unrepresented and socially vulnerable populations, particularly children, elderly, disabled people, minorities, and low-income persons. Population vulnerabilities can be reduced or eliminated with proper outreach and community mitigation planning.

Population Vulnerabilities

The following information was obtained from the U.S. Census Bureau's American Community Survey.

- Even though approximately 90% of the city population is reported as proficient in English, approximately 24.1% of the population speaks another language other than English at home. These populations would serve to benefit from mitigation outreach, with special attention to cultural, visual and technology sensitive materials.
- Salem is experiencing demographic changes in terms of age of the population. Persons 65 years of age and older made up 15.0% of the total City of Salem population in 2021, increasing 1.7% in two years. Persons 18 years and younger comprised 24.2% of the population, a level that was nearly stable from the previous two years. Socially vulnerable populations, particularly the younger and older populations, require additional support from the community at large.
- As of 2020, approximately 15% of Salem's population is over the age of 64; that percent is less than the State (18.6%), Marion County (16.4%), and Polk County (18.7%).
- The Salem age dependency ratio, which is the ratio of population typically not in the work force (less than 15, greater than 64), is 64.5. This is about the same for Oregon (63.5) but lower than Marion County (67.7) and Polk County (69.1); the age dependency figure for the Marion County increased by 13 in the past five years
- Approximately 13.3% of Salem population over age 64 lives alone.
- Approximately 7.0% of the City of Salem population has a mobility (ambulatory) difficulty, and this expands to 24.5% of the population for people over 64. Moreover, the population with a cognitive difficulty averages 6.9%.
- Salem's real median income ($63,927) is lower than the State ($71,562), Marion County ($64,406), and Polk County ($71,532).
- Approximately 12.8% of the total Salem population lived at or below the poverty line in 2020, including 14.3% of children under 18.
- Approximately 88% of the population over 25 has graduated high school or higher and about 28.9% have a bachelor's degree or higher; 12% of the population does not have a High School degree.

- About 52.8% of Salem renters and 36% of owners with a mortgage spend more than 30% of their income on housing.

Economy

Economic diversification, employment and industry are measures of economic capacity. However, economic resilience to natural disasters is far more complex than merely restoring employment or income in the local community. Building a resilient economy requires an understanding of how the component parts of employment sectors, workforce, resources, and infrastructure are interconnected in the existing economic picture. The current and anticipated financial conditions of a community are strong determinants of community resilience, as a strong and diverse economic base increases the ability of individuals, families, and the community to absorb disaster impacts for a quick recovery.

Economic Vulnerabilities

- According to the Oregon Employment Department, Salem unemployment as of December 2022 has increased to 4.5% from 3.5% in December 2021 . In the event of a large—scale disaster, unemployment has the potential to rise when businesses and companies are unable to overcome the ramifications of the hazard event.
- The largest sectors of employment in the Salem Metropolitan Service Area are Trade, Transportation, and Utilities (16%), Private Educational and Health Services (16%), Local Government (10%), Manufacturing (9%), and State Government (7.5%), according to the Oregon Employment Department's Mid-Valley Industry Employment Forecast 2021-2031. In the event of a natural disaster, the government sector may not be as vulnerable in the short term as other sectors; however, other large industries such as agriculture, wholesale trade of electronic equipment and manufacturing of food products are industries that may be significantly affected by a disaster as these basic industries tend to rely on sales outside of the community.
- The Transportation, Warehousing, and Utilities sector is expected to have the most growth from 2021 to 2031 at 44%. Leisure and Hospitality (36%) is the next closest growth sector (Oregon Employment Department, 2023).
- Two-thirds of Salem's workforce lives outside of the city limits.

Natural Environment

The capacity of the natural environment is essential in sustaining all forms of life including human life, yet it often plays an underrepresented role in community resiliency to natural hazards. The natural environment includes land, air, water, and other natural resources that support and provide space to live, work and recreate (Mayunga, 2007). Natural capital such as wetlands and forested hill slopes play significant roles in protecting communities and the environment from weather-related hazards, such as flooding and landslides. When natural systems are impacted or depleted by human activities, those activities can adversely affect community resilience to natural hazard events.

Environmental Vulnerabilities

- Forest ecosystems are vulnerable to drought, wildfire, and severe storm impacts.
- The primary river that flows through Salem is the Willamette River; other important streams that pass through are Mill Creek, the Mill Race, Pringle Creek, and the

Shelton Ditch. Smaller streams in the eastern part of the city include Clark Creek, Jory Creek, Battle Creek, Croisan Creek and Clagget Creek, while glen Creek and Brush Creek flow through West Salem. These streams frequently flood, and while this can provide natural benefits, flooding can inflict personal injury and property damage.
- According to the *Annual Water Quality Report* 2022, Salem obtains its drinking water from the North Santiam River watershed, located in the Cascade Foothills. As this is the primary source of drinking water for Salem, it is imperative to consider the hazards that can affect water quality, including flooding, landslides and drought.
- The combination of a growing population and development intensification can lead to the increasing risk of hazards, threatening loss of life, property and long-term economic disruption if land management is inadequate, such as floodplain development that is common throughout the City of Salem.

Built Environment, Critical Infrastructure Sectors, and Lifelines

Critical facilities (i.e., police, fire, and government facilities), housing supply and physical infrastructure are vital during a disaster and are essential for proper functioning and response. The lack or poor condition of infrastructure can negatively affect a community's ability to cope, respond and recover from a natural disaster. Following a disaster, communities may experience isolation from surrounding cities and counties due to infrastructure failure. These conditions force communities to rely on local and immediately available resources.

Housing Vulnerabilities

- Mobile home and other non-permanent residential structures account for 4.2% of the housing in Salem. These structures are particularly vulnerable to certain natural hazards, such as earthquake, windstorms, and heavy flooding events, according to the U.S. Census.
- Based on U.S. Census data, approximately two-thirds of the residential housing in Salem was built before the current seismic building standards of 1990.
- Approximately 54% of residential structures were constructed prior to the local implementation of the flood elevation requirements of the 1970's (city Firms- were not completed until 1979).

Critical Infrastructure Sector Vulnerabilities

According to the U.S. Department of Homeland Security, there are various critical infrastructure sectors whose, "assets, systems, and networks, whether physical or virtual, are considered so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof." There are 16 recognized sectors[10] some of which is

[10] Critical infrastructure sectors include chemical; commercial facilities; communications sector; critical manufacturing; dams; defense industrial base; emergency services; energy; financial services; food and

addressed here for City of Salem. According to FEMA's Local Mitigation Handbook (2013), critical facility is "Structures and institutions necessary, in the community's opinion, for response to and recovery from emergencies. Critical facilities must continue to operate during and following a disaster to reduce the severity of impacts and accelerate recovery."

- Salem is the State Capital and the second largest city in Oregon, it is critical to maintain the quality of built capacity (transportation networks, critical facilities, utility transmission, etc.) throughout the area, as it is likely that surrounding jurisdictions will seek assistance from Salem.
- Roads and bridges in the City of Salem are highly vulnerable to hazards specifically earthquakes. Because bridges vary in size, materials, siting, and design, any given hazard will affect them differently. Salem must also consider roads and bridges obstructed beyond the city limits, as this will likely have significant impacts on access in and out of Salem.
- Virtually all state and city roads and bridges in Salem are vulnerable to multiple hazards including flood, landslide, and earthquake. Impacts to the transportation system can result in the isolation of vulnerable populations, limit access to critical facilities such as hospitals and adversely impact local commerce, employment, and economic activity.
- All of Salem's power is generated outside the region; there is no redundancy in power transmission and only limited redundancy in the power distribution network.

The list on the following pages identifies the critical facilities, essential facilities, public infrastructure, and social service facilities considered critical by the 2022/2023 City of Salem NHMP Steering Committee. Some critical facilities are also identified above in the Hazard Identification and Assessment section, either listed by name or simply noted the number of critical facilities that will be affected by a specific hazard event.

Table 2-23 Critical and Essential Facilities for the City of Salem

Facility Name	Property Use	Facility Priority
COMMUNICATIONS		
AT&T Cell Tower Generator	Utility or Distribution system- other	1
AT&T Cell Tower Generator Building	Outbuilding or shed	1
Cctv Studio	Radio- television studio	1
Verizon Cell Tower	Property Use- other	1
AT&T Cell Tower @ Mission Mill	Utility or Distribution system- other	2
CenturyLink	Communications center	2
Salem Clinic - Call Center	Communications center	2
EMERGENCY COORDINATION/COMMUNICATION		
Anderson Readiness Center	Undetermined	1
Willamette Valley Communication Center	Public or government- other	1

agriculture; government; healthcare and public health; information technology; nuclear reactors, materials, and waste; transportation systems; and water and wastewater systems.

Facility Name	Property Use	Facility Priority
EMERGENCY RESPONSE		
Bureau Of Criminal Id.	Mercantile- business- other	1
City of Salem - Sand Storage	Undetermined	1
City of Salem Public Works Operations	Public or government- other	1
Falck Office/Warehouse - Bldg Shell	Undetermined	1
Fire Station # 9	Fire station	1
Fire Station # 7	Fire station	1
Fire Station #1	Fire station	1
Fire Station #10	Fire station	1
Fire Station #2	Fire station	1
Fire Station #3	Fire station	1
Fire Station #8	Fire station	1
Marion County Maint. Shop	Mercantile- business- other	1
Marion County Public Works Fuel Tank	Service station- gas station	1
Marion County Sherriff's Office	Business office	1
Oregon National Guard Military HQ	Defense- military installation	1
Oregon National Guard Open Hanger- Hanger 2- Hanger 3- Flight Ops	Defense- military installation	1
Oregon State Police (OSP)	Mercantile- business- other	1
Oregon State Police Headquarters	Business office	1
OSP Fleet Services	Police station	1
OSP Installation Center	Mercantile- business- other	1
Fire Station #11	Fire station	1
Salem Fire Ems Office	Mercantile- business- other	1
Fire Station #5	Fire station	1
Salem Police Department	Police station	1
Fire Station #4	Fire station	1
Fire Station #6	Fire station	1
GOVERNANCE		
City Hall / Civic Center	Undetermined	1
City of Salem It Department	Undetermined	1
State Capitol Bldg	Assembly- other	1
National Weather Service	Electric-generating plant	3
MEDICAL		
Kaiser Permanente Dental	Office: veterinary or research	1
Marion County Dog Control	Office: veterinary or research	1
Marion County Health & Human Services - Psychiatric Crisis Center	Hospital - medical or psychiatric	1
Northbank Surgical Center	Clinic- clinic-type infirmary	1
Or. State Hospital Cottage R-02	Residential board and care	1
Oregon State Hospital	Hospital - medical or psychiatric	1

Facility Name	Property Use	Facility Priority
Oregon State Prison	Clinic- clinic-type infirmary	1
Permanente (Kaiser) Dental (Skyline)	Doctor- dentist or oral surgeon office	1
Psychiatric Facility	Hospital - medical or psychiatric	1
Rehabilitation Center	Hospital - medical or psychiatric	1
Salem Audiology Clinic	Office: veterinary or research	1
Salem Hospital	Hospital - medical or psychiatric	1
Urgent Care - Salem Hospital	Doctor- dentist or oral surgeon office	1
West Salem Clinic Mental clinic	Health care- detention- & correction- other	1
West Salem Family Medical Clinic	Doctor- dentist or oral surgeon office	1
Willamette Surgery Center	Hospital - medical or psychiatric	1
Willamette Urology Clinic - Bldg Shell	Clinic- clinic-type infirmary	1
Work Release Center	Health care- detention- & correction- other	1
TRANSPORTATION		
ODOT	Warehouse	1
ODOT	Public or government- other	1
ODOT	Rapid transit station	1
Airport Passenger Terminal- Tower	Undetermined	3
Chemeketa Parking Structure	Parking garage- general vehicle	3
Courthouse Square	Parking garage- general vehicle	3
Greyhound	Passenger terminal- other	3
Hospital Parking Garage	Parking garage- general vehicle	3
Liberty Square Parking	Parking garage- general vehicle	3
Library Parking	Parking garage- general vehicle	3
Marion St Parking Struct	Parking garage- general vehicle	3
Pringle Parking Structure	Parking garage- general vehicle	3
Salem Transit	Mercantile- business- other	3
Salem Aviation Fueling - Bulk Storage	Parking garage- general vehicle	3
Transit Mall	Bus station	3
WATER SYSTEMS		
City Aquifer/Storage	Water utility	1
City of Salem - PW Pump Station	Sanitation utility	1
City of Salem Water Reservoir Control - Bldg Shell	Water utility	1
City of Salem Wet Weather Treatment - Bldg Shell	Sanitation utility	1
City of Salem Pump Station	Water utility	1
City of Salem Reservoir Ops. Bldg.	Ind.- utility- defense- agriculture- mining- other	1
City of Salem River Rd Pump Station	Sanitation utility	1
City Water Pump Station	Water utility	1
D & O Garbage Wash Rack - Bldg Shell	Sanitation utility	1
D.O.T. Materials Testing Lab	Ind.- utility- defense- agriculture- mining- other	1
Marion County Archives	Ind.- utility- defense- agriculture- mining- other	1

Facility Name	Property Use	Facility Priority
Marion County Hazardous Waste Facility	Sanitation utility	1
National Guard Armory Auditorium	Ind.- utility- defense- agriculture- mining- other	1
Orchard Heights Pump Station	Water utility	1
Oregon Dept Of Agriculture	Ind.- utility- defense- agriculture- mining- other	1
Public Works Water Meter Repair	Warehouse	1
Pump Station - City of Salem - Bldg Shell	Undetermined	1
Salem ASR	Water utility	1
Septic Building	Sanitation utility	1
Woodmansee Pumphouse	Water utility	1
ENERGY		
BPA Salem Substation	Electrical distribution	2
Comcast - Electrical Bldg	Electrical distribution	2
NW Natural	Mercantile- business- other	2
PGE	Electrical distribution	2
PGE Energy Storage Facility	Energy production plant- other	2
Portland General Electric (PGE)	Mercantile- business- other	2
Salem Electric	Mercantile- business- other	2
MISCELLANEOUS		
Marion County Housing Authority	Undetermined	3
Salem Housing Authority		3
School District 24J Reprographics	Warehouse	3
MASS CARE AND SHELTER		
Dept Of Corrections	Undetermined	4
Dept Of Forestry - Fire Cache	Warehouse	4
Abioua Middle School	High school/junior high school/middle school	4
Alice Yoshikai Elementary School	Elementary school- including kindergarten	4
Avamere- Bldg Shell	Elementary school- including kindergarten	4
Baker School	Elementary school- including kindergarten	4
Battle Creek Elementary	Elementary school- including kindergarten	4
Boone Rd Fuel Tank	Public or government- other	4
Brush College Elementary	Elementary school- including kindergarten	4
Bush Elem School	Elementary school- including kindergarten	4
Capitol Christian School	Elementary school- including kindergarten	4
Career Technical Educational Center-SKSD	High school/junior high school/middle school	4
Cep Office Building - Bldg Shell	Public or government- other	4
Chapman Hill Elementary	Elementary school- including kindergarten	4
Chemawa Indian School	High school/junior high school/middle school	4
Columbia Hall	Convention center- exhibition hall	4
Convention Center - Bldg Shell	Convention center- exhibition hall	4
Corban University	Educational- other	4

Facility Name	Property Use	Facility Priority
Crossler Middle School	Educational- other	4
Department Of Business & Cons. Services - Bldg Shell	Public or government- other	4
Dept Of Motor Vehicles	Manufacturing- processing	4
DPSST - Academic-Classrooms & Office	Public or government- other	4
Dyehouse	Public or government- other	4
Eagle Charter School	Elementary school- including kindergarten	4
Elementary School	Elementary school- including kindergarten	4
Englewood School	Elementary school- including kindergarten	4
Environmental Learning Center - North Sa	High school/junior high school/middle school	4
Faye Wright Elem School	Elementary school- including kindergarten	4
Grant School	Elementary school- including kindergarten	4
Hammond Elementary School	Elementary school- including kindergarten	4
High School	High school/junior high school/middle school	4
Highland Elementary School	Elementary school- including kindergarten	4
Hillcrest School - School Building	Undetermined	4
Hoover School	Elementary school- including kindergarten	4
Houck Middle School	Educational- other	4
Howard St School	Educational- other	4
Howard Street Charter School	High school/junior high school/middle school	4
Immanuel Elementary School	Educational- other	4
Internal Revenue Service	Public or government- other	4
Jackman-Long Building	Convention center- exhibition hall	4
Jesse M. Harritt Elementary	Elementary school- including kindergarten	4
Joint Forces Headquarters	Defense- military installation	4
Judson Middle School	High school/junior high school/middle school	4
Lee Elementary School	Elementary school- including kindergarten	4
Leslie Middle School	Educational- other	4
Liberty School -Main Building	Elementary school- including kindergarten	4
Marion County Courthouse	Courthouse	4
Marion County Health Department	Undetermined	4
Marion County Historical	Public or government- other	4
Marion County Jail	Jail- prison (not juvenile)	4
McKay High School	High school/junior high school/middle school	4
McKinley School	Elementary school- including kindergarten	4
Meyers Elementary School	Elementary school- including kindergarten	4
Middle School	High school/junior high school/middle school	4
Miller Elementary School	Elementary school- including kindergarten	4
Montessori Children House	Schools- non-adult- other	4
Morningside School	Elementary school- including kindergarten	4
North Salem High	High school/junior high school/middle school	4

Facility Name	Property Use	Facility Priority
ODOT Traffic Signal	Warehouse	4
Office of the State Chief Information Officer	Public or government- other	4
Old Pringle School House	Elementary school- including kindergarten	4
Or. Dept General Services Warehouse	Warehouse	4
Or. Dept Of Human Services	Manufacturing- processing	4
Or. Dept. Of Corrections- Metal Fab	Manufacturing- processing	4
Or. Sch. For Blind-Irvine Hall	High school/junior high school/middle school	4
Oregon Center For Clinical Investigation	Laboratory or science laboratory	4
Oregon Dept. Of Transportation	Manufacturing- processing	4
Oregon Judicial Department - Human Resources Services Division	Public or government- other	4
Oregon State Archives	Warehouse	4
Oregon State Lottery	Public or government- other	4
Parrish Middle School	High school/junior high school/middle school	4
Pringle School	Elementary school- including kindergarten	4
Public Work/Carpenter	Warehouse	4
Queen Of Peace School	Elementary school- including kindergarten	4
Richmond School	Elementary school- including kindergarten	4
Riviera Christian School & Daycare	Elementary school- including kindergarten	4
Roberts High School (Alt Ed)	High school/junior high school/middle school	4
Roots Academy	High school/junior high school/middle school	4
S.E.C. Modular #2	Elementary school- including kindergarten	4
Salem Academy High School	High school/junior high school/middle school	4
Salem Academy-Elementary	Elementary school- including kindergarten	4
Salem Armory Auditorium	Convention center- exhibition hall	4
Salem Christian Academy	Elementary school- including kindergarten	4
Salem Clinic	Warehouse	4
Salem Heights School	Elementary school- including kindergarten	4
Salem Keizer School District	Educational	4
Salem Reserve Center Modular	Defense- military installation	4
Salem Senior Center (Center 50+)	Assembly- other	4
Santiam Correctional Facility	Jail- prison (not juvenile)	4
Schirle School	Elementary school- including kindergarten	4
South Salem High School	High school/junior high school/middle school	4
South Salem Senior Center	Public or government- other	4
Sprague High School	High school/junior high school/middle school	4
St John’s Lutheran School	Day care- in commercial property	4
St Joseph’s Elementary School	Educational- other	4
St Vincent De Paul School	Elementary school- including kindergarten	4
Stephens Middle School	High school/junior high school/middle school	4
Stephens Middle School	High school/junior high school/middle school	4

Facility Name	Property Use	Facility Priority
Straub Middle School	High school/junior high school/middle school	4
Sumpter School	Elementary school- including kindergarten	4
Supreme Court Building	Public or government- other	4
Swegle Elementary School	Elementary school- including kindergarten	4
Tokyo International University	Educational- other	4
U.S. Dept Of Agriculture	Warehouse	4
Waldo Middle School	High school/junior high school/middle school	4
Walker Middle School	Elementary school- including kindergarten	4
Washington School	Elementary school- including kindergarten	4
West Salem Foursquare School	Elementary school- including kindergarten	4
West Salem High School	High school/junior high school/middle school	4
Wildfire Defense Systems	Warehouse	4
Willamette Academy- College Prep	High school/junior high school/middle school	4
Willamette Career Academy	High school/junior high school/middle school	4
Willamette University	Mercantile- business- other	4
SPECIAL NEEDS		
Assisted Living - Bldg Shell	Undetermined	4
Battle Creek Memory Care	24-hour care Nursing homes- 4 or more persons	4
Bonaventure	Residential board and care	4
Boone Ridge Senior Living Community	24-hour care Nursing homes- 4 or more persons	4
Bridgeway Recovery	Health Care- Detention & Correction	4
Brookdale Senior Living	24-hour care Nursing homes- 4 or more persons	4
Brookstone Alzheimer Special Care Center	Health care- detention- & correction- other	4
Capitol Manor Health Care Complex	24-hour care Nursing homes- 4 or more persons	4
Care Takers House - Bldg Shell	1 or 2 family dwelling	4
Carroll's Group Care Home	Residential board and care	4
CCPC Group Home (Licensed)	Residential board and care	4
Center for Autism & Related Disorders (CARD)	Mental retardation/development disability facility	4
Court St House	Health care- detention- & correction- other	4
Davita Salem Dialysis	Clinics- doctors' offices- hemodialysis center- other	4
Day Care - Bldg Shell	Day care- in commercial property	4
Developmental Disability Services - IDD Services	Mental retardation/development disability facility	4
Englewood East	Health care- detention- & correction- other	4
Family Head Start Preschool	Mental retardation/development disability facility	4
Faye Wright Square Building #1	24-hour care Nursing homes- 4 or more persons	4
Firehouse Diabetes & Endocrine Center	Doctor- dentist or oral surgeon office	4
Fmc- D.S. Of West Salem	Hemodialysis unit	4
Gibson Creek Assisted Living Residence	Residential board and care	4
Great Circle Recovery	Alcohol or substance abuse recovery center	4

Facility Name	Property Use	Facility Priority
Harmony House	Health care- detention- & correction- other	4
Harmony House Of Salem	Residential board and care	4
Harmony Manor	Health care- detention- & correction- other	4
Hawthorne House Of Salem	24-hour care Nursing homes- 4 or more persons	4
Hidden Lakes Retirement Residences	Mental retardation/development disability facility	4
Immediate Care & Med Clinic	Health care- detention- & correction- other	4
Iuditas' Memory Care	24-hour care Nursing homes- 4 or more persons	4
Juvenile Department	Hemodialysis unit	4
Juvenile Probation	Health care- detention- & correction- other	4
Kairos NW - Cadenza	24-hour care Nursing homes- 4 or more persons	4
Kroc Center RJ's Preschool	Preschool	4
Kuebler Early Learning Center	Preschool	4
Little Bird Preschool	Preschool	4
Little Me Academy	Preschool	4
Little Red Schoolhouse	Day care- in commercial property	4
Madrona Hills Ret Ctr	Health care- detention- & correction- other	4
Mainstream Housing	Health care- detention- & correction- other	4
Marion & Polk Healthy Start	Health care- detention- & correction- other	4
Marion County Alcohol & Drug Treatment	Mercantile- business- other	4
Marion County Dog Control	Health care- detention- & correction- other	4
Marion County Health & Human Services - Adult Mental Health	Clinics- doctors' offices- hemodialysis center- other	4
Marion County Health and Human Service - Horizon House	Residential board and care	4
Marion County Health & Human Services - Adult Behavioral Health	Residential board and care	4
Marion County Juv. Dept- Boys Gap Program	Health care- detention- & correction- other	4
Marion County Juvenile Detention	Reformatory- juvenile detention center	4
Marion County Juvenile- Girls Gap Program	Health care- detention- & correction- other	4
Meadow Creek Village	Health care- detention- & correction- other	4
Mid-Willamette Valley Hospice	Residential board and care	4
Monica Custer Care Home	Health care- detention- & correction- other	4
Neil Carroll Group Home	Residential board and care	4
Northwest Human Services	Clinics- doctors' offices- hemodialysis center- other	4
Northwest Rehabilitation Associates- Inc	Clinics- doctors' offices- hemodialysis center other	4
NW Human Services - West Salem Clinic Mental Health	Clinics- doctors' offices- hemodialysis center- other	4
Oregon Medical Centers- LLC dba First Choice Chiropractic and Rehabilitation	Clinics- doctors' offices- hemodialysis center- other	4
Pacific Cardiovascular Surgical Center	Clinics- doctors' offices- hemodialysis center- other	4
Pheasant Hill-Labor 27	Health care- detention- & correction- other	4

Facility Name	Property Use	Facility Priority
Prestige Senior Living at Orchard Height	Residential board and care	4
Psychiatric Crisis Center (Marion County Health & Human Services)	Residential board and care	4
Records Storage	Health care- detention- & correction- other	4
Redwood Crossing Residential Care & Shelter Facility	Residential board and care	4
Redwood Heights Assisted Living	Health care- detention- & correction- other	4
Regency Woodland	24-hour care Nursing homes- 4 or more persons	4
Seed of Faith Ministries	Residential board and care	4
Seniors Care Sweet Home	24-hour care Nursing homes- 4 or more persons	4
Serenity Lane Treatment Center	Alcohol or substance abuse recovery center	4
Sherman Manor	Health care- detention- & correction- other	4
Simonka House	Health care- detention- & correction- other	4
Skilled Nursing - Bldg Shell	24-hour care Nursing homes- 4 or more persons	4
So. Salem Rehabilitation	24-hour care Nursing homes- 4 or more persons	4
Substation Sheriff Office	Health care- detention- & correction- other	4
Sunny Manor Inc	Health care- detention- & correction- other	4
Sunnyglen Retirement	Health care- detention- & correction- other	4
Sweet Bye & Bye - Coral Springs	Residential board and care	4
Sweet Bye N Bye	24-hour care Nursing homes- 4 or more persons	4
Team Bailey Inc	Residential board and care	4
The Springs at Willowcreek	Health care- detention- & correction- other	4
The Sweet Bye N Bye - Reflections Memory Care	Residential board and care	4
Tierra Rose Care Center	24-hour care Nursing homes- 4 or more persons	4
Union Gospel Mission of Salem	Residential board and care	4
Valley Mental Health	Clinics- doctors' offices- hemodialysis center- other	4
Via Verde - Cottage 15	Asylum- mental institution	4
Vickie Harbaugh House	Residential board and care	4
Vida Integrative Medicine & Mental Health	Clinics- doctors' offices- hemodialysis center- other	4
Whitewood Gardens of Salem	24-hour care Nursing homes- 4 or more persons	4
WindSong at Eola Hills Memory Care	24-hour care Nursing homes- 4 or more persons	4
Windsor Health & Rehabilitation Center	Health care- detention- & correction- other	4
Women at The Well Grace House	Residential board and care	4
Work Unlimited	Mental retardation/development disability facility	4

Source: Salem 2022/2023 NHMP Steering Committee

Lifeline Sector Vulnerabilities

Community Lifelines, as with critical infrastructure and facilities, are the most fundamental services in the community that, when stabilized, enable all other aspects of society to function. The integrated network of assets, services and capabilities that provide community lifeline services are used day to day to support recurring needs. Lifelines enable the continuous operation of critical government and business functions and are essential to human health and safety or economic security, as described in the National Response Framework, 4th Edition.

The following lifeline sector analysis summary evaluates key resources and facilities within specific sectors through sector stakeholder feedback. The 2022/2023 Salem NHMP Steering Committee evaluated and ultimately decided to retain the information below that was originally presented in the 2017 Salem NHMP. Please see **Appendix G** for the full lifeline sector analysis.

Energy

The energy sector is critical to modern life. Electricity is vital for virtually all household, business and emergency operations; liquid fuel is used for transportation, facility construction and repair, and backup power; natural gas is used for electricity generation, heating, cooking, powering vehicles, and other uses. The resilience, redundancy, and interdependencies of the energy sector will largely determine the timeline for emergency response and long-term community recovery. Diverse and redundant energy supply and distribution can significantly increase regional resilience.

Energy Summary Table

Critical Interdependencies:	Critical Vulnerabilities:
Systems of all types are dependent on other systems to function. To operate, the communication sector is particularly DEPENDENT ON: • Transportation • Communication **Other critical lifeline sectors that DEPEND ON the communication sector to operate include:** • Public Safety and Emergency Management • Transportation • Water • Communication • Economy	**Each sector is vulnerable to a variety of impacts. The energy sector is particularly vulnerable to the following:** • Consumption consists almost entirely of one of three forms: electricity, liquid fuels, natural gas. • Dependence on BPA for electric power; Marion County produces very little power locally. • Lead time for ordering critical system components (e.g., transformers) • Concentration of liquid fuel storage facilities in Portland; limited local fuel storage and supply. • Lack of capability to pump fuel locally without power. • Reliance on supply and distribution facilities located outside Marion County.

Major Findings:
• Generators are co-located by equipment and are used at critical infrastructure throughout the county; however, require various fuel types depending on the unit. • Oregon's fuel storage facilities are in Portland and are susceptible to failure due to soil liquefaction. The storage capacity on a normal day is six days; therefore, it is anticipated that fuel will be an undersupplied commodity during a Cascadia event. It will take 3-6 weeks to reacquire fuel. • Energy is critically interdependent with the transportation, communication, and water sectors. For example, not having access to roads nor having the ability to communicate with responders leaves the energy sector extremely vulnerable. In addition, there is a need for energy in powering water treatment plants. These vulnerabilities are particularly heightened in areas where accesses via bridges or singular roads are susceptible to failure. • The EPA regulates energy in terms of emissions limiting the capacity to produce additional energy resources. • Damage assessments will be critical to capture the impacts to this lifeline. Downed trees, accumulating ice, and high winds can impact the resiliency of energy as a lifeline. • The energy sector also prepares and mitigates against human-made disasters, such as cyberattacks. • The energy sector grants people with uninterrupted services due to medical status during non-catastrophic events. • An estimated 1-3 months of electrical service interruption during a Cascadia event.

Communications

The communication sector facilitates the rapid exchange of information across a broad range of systems and technologies. These include broadcast television and radio, telephone, cellular phone, cable, internet, two-way radio, and Ham (or amateur) radio.

Communication is an essential aspect of virtually all public and private sector activities. The ability to communicate is especially critical during an emergency. Notably, FEMA's Emergency Support Function #2 – Communications (ESF #2) specifically supports the restoration of communications infrastructure. The scope of ESF #2 includes "restoration of public communications infrastructure" and assisting "State, tribal, and local governments with emergency communications and restoration of public safety communications systems and first responder networks."

The assessment focused on (1) the adaptive capacity of the communications sector, (2) hazard-specific vulnerabilities to communication infrastructure, and (3) mitigation opportunities that can support uninterrupted or rapid restoration of communication capability during or following emergency or disaster event.

Communication Sector Summary

Critical Interdependencies:	**Critical Vulnerabilities:**
Systems of all types are dependent on other systems to function. To operate, the communication sector is particularly <u>DEPENDENT ON</u>: • Electricity • Energy (fuel) • Transportation	**Each sector is vulnerable to a variety of impacts. The communications sector is particularly vulnerable to the following:** • All systems rely on electricity for operation and maintain generators for backup power. Generators rely on fossil fuels to operate leading to questions about what systems and services would be prioritized for gasoline/diesel fuel use if there were a disruption to fuel supply. Also, some generates

<table>
<tr>
<td>Other critical lifeline sectors that <u>DEPEND ON</u> the communication sector to operate include:
• Water (SCADA)
• Electricity
• Public Safety and Emergency Management
• Transportation
• Economy</td>
<td>operate on propane or natural gas, neither of which are included in state or federal energy assurance plans.
• All systems rely on infrastructure (towers, antennae) spread across large areas, often in remote locations. Road access to repair equipment is a primary concern.
• 911 service and other emergency communication relies on line-of-site microwave transmission. Even small changes in antennae alignment can disrupt transmission and require recalibration to re-establish connections between towers. Fiber infrastructure is vulnerable to earthquake damage, where lines are connected to bridge spans.</td>
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<tr>
<td colspan="2">Major Findings:
• Many providers share infrastructure and or have their infrastructure co-located.
• Stakeholders are well prepared to address winter storms and other disasters if there is access to their facilities. Transportation, water, and energy are equally dependent on communication infrastructure. In addition, trees, wind, and ice are hazards that can impact this lifeline.
• During a power outage, battery and generator backups provide limited power for a varying duration of time depending on the fuel source and capacity. Redundancy is a needed resource for critical infrastructure that requires access and the supply of multiple fuel types, primarily gasoline and diesel. Notably, propane is a fuel source for some generators; however, propane will not be provided through state resources. Some generates operate on propane or natural gas, neither of which are included in state or federal energy assurance plans.
• All providers anticipate a 75-100% shutdown after a Cascadia event. Due to the roads and bridges being impassable, network connections could be severed.
• Largest barriers to respond in a Cascadia event include staff ability to respond, access to facilities, shortage of supplies to repair infrastructure, time, funding, and political support.
• Stakeholders recognize that their staff and families need to be prepared. To address this need, they are supporting a proactive approach to disasters. The Communications sector is working to train employees to be prepared for disasters so they can address their own immediate needs before safely addressing the needs of the sector post-event.
• Some towers have fiber optic lines as a redundancy. However, these lines are vulnerable in a catastrophic earthquake, in particular where lines are connected to bridge spans.
• Water infrastructure systems rely on communication for operations and maintenance through a “Supervisory Control and Data Acquisition” (SCADA) system. The system provides remote monitoring and control of the water system components. Radio system capability is needed for these systems to operate effectively. Much of this infrastructure is isolated. For example, Salem’s infrastructure is located on an island.
• Amateur Radio provides critical back up to public safety radio communications in a disaster but does not provide the necessary capacity to meet emergency management needs. Jurisdictions should consider investing in satellite voice and data capabilities.
• Local servers may be damages in an earthquake. Jurisdictions should consider "cloud based" data storage solutions to backup vital records.</td>
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Transportation

Transportation is critical lifeline infrastructure. The transportation network facilitates the movement of people, goods, resources, and commerce throughout Marion County and beyond. The transportation system consists of local, state, and federal road and highway networks; passenger and freight rail; passenger and freight air service; pipelines; transit; dedicated bicycle and pedestrian systems; and limited water-based modes. All lifeline sectors depend on the transportation system.

Access to means of transportation is fundamental to human existence. Transportation infrastructure facilitates everything from a local trip to the park, drugstore, or place of employment to international trade and commerce. Furthermore, the ability to move people, goods and services is vital before, during and after emergency events. It is no accident that FEMA's number one Emergency Support Function is transportation. Emergency Support Function #1 – Transportation Annex (ESF #1) covers the following:

- Aviation/airspace management and control
- Transportation safety
- Restoration/recovery of transportation infrastructure
- Movement restrictions
- Damage and impact assessment

The scope of ESF #1 includes supporting, ". . . prevention, preparedness, response, recovery and ***mitigation*** activities among transportation stakeholders . . . [emphasis added]" and coordinating, "the restoration of the transportation systems and infrastructure."

Transportation lifeline sector participants identified several interconnected resources and elements of their operations. These include included roads, bridges, buses, and physical buildings. While this assessment focusses on infrastructure, participants noted that transportation staff and professionals are a critical resource as well.

Transportation Summary Table

Critical Interdependencies:	Crucial Vulnerabilities:
Systems of all types are dependent on other systems in order to function. In order to operate, the transportation sector is particularly DEPENDENT ON: • Energy and Fuel • Communication • Business and Industry • Public Works **Other critical lifeline sectors that DEPEND ON the transportation sector to operate include:** • Water • Electricity • Liquid fuel • Public Safety and Emergency Management • Public Works • Economy	**Each sector has a number of vulnerabilities. The transportation sector is particularly vulnerable to the following:** • Federal, state and local bridge infrastructure is particularly vulnerable to earthquake (especially ODOT facilities over the Willamette). • System relies heavily on fossil fuels for construction, operation, and maintenance. • Hwy 22 is the primary east-west connection; there are few redundant east-west routes. • Significant backlog of deferred transportation maintenance projects.

Major Findings:

- ODOT considers I-5 and Highway 22 to be critical routes. Other critical concerns include bridges, roads, communication, and energy including power and fuel.
- Much of the existing transportation infrastructure, including those of major roadways such as I-5, Highway 22, and Mission Road, are not seismically retrofitted and will likely experience structural failures during a Cascadia event.
- Following a Cascadia event, transportation will be limited for 6-12 months; aftershocks may extend that timeframe.
- Transportation is interdependent with communication, water, and energy systems and requires coordination and collaboration during the response and recovery process.
- Although winter storms continue to impact transportation systems, stakeholders respond to these events efficiently and continue to improve plans with every winter weather event. Downed trees, debris, and accumulated ice impact the response of this lifeline.
- Salem-Keizer Transit operates city and regional buses, dial-a-ride, CherryLift for people with disabilities, and coordinates non-emergent medical transportation services. They provide about 4 million rides a year and are currently working to improve individual employee preparedness as well as existing emergency plans.
- Salem-Keizer Public Schools transports an estimated 22,000 students a day including about 2,000 medically fragile students. The top priority for this organization is student safety.
- The electricity grid in Oregon is not particularly dependent on the transportation sector to operate. However, the power generation and distribution network does rely on the transportation network for construction as well as ongoing maintenance and repairs.
- Conversely, all of the liquid fuel in the state is transported by one of three primary transportation modes: truck, rail, and pipeline. Therefore, the distribution fuel in the state is completely dependent on the transportation sector.
- Like the electric grid, the communications sector is not particularly dependent on the transportation sector to operate. However, the power generation and distribution network does rely on the transportation network for construction as well as ongoing maintenance and repairs.
- Business and industry are very dependent on the transportation sector. From the movement of raw material, to getting employees to and from work, to getting finished products to market, virtually all business and industry activity in the region is facilitated by transportation.
- Public works is dependent on transportation in two primary ways. First, the transportation sector facilitates the movement of equipment, materials, and workers. Second, significant portions or components of public works’ infrastructure are collocated within transportation rights of way.

Water

For the purposes of this assessment, the water sector includes information pertaining to drinking water, stormwater, and wastewater. Stakeholder participants included a range of local and regional infrastructure and service providers. The information provided in this summary is based on research of the county’s water resources and infrastructure.

Ready access to virtually unlimited amounts of clean drinking water is often taken for granted, particularly here in the Pacific Northwest. Water is vital for basic daily living, for business and industry especially including agriculture, for fire protection and medical service provision, and for wastewater management. In addition, stormwater facilities provide critical protection from a variety of localized flood risks. FEMA Emergency Support Function #3 – Public Works and Engineering Annex (ESF #3) covers public works, including water, wastewater and stormwater services. Ensuring that all water related public works infrastructure is operational is critical to the function of any community.

Water Summary Table

<table>
<tr>
<td>Critical Interdependencies:
Systems of all types are dependent on other systems to function. To operate, the water sector is particularly <u>DEPENDENT ON</u>:
• Electricity
• Communication
• Transportation
• Liquid Fuel
Other critical lifeline sectors that <u>DEPEND ON</u> the water sector to operate include:
• Fire and EMS
• Business and industry
• Electricity</td>
<td>Crucial Vulnerabilities:
Each sector has many vulnerabilities. The transportation sector is particularly vulnerable to the following:
• The water sector in Marion County consists of numerous local and regional systems.
• Several reservoirs, transmission lines and the Salem Treatment Facility are vulnerable to multiple hazards.
• Aquifer storage capacity not sufficient to meet need as a backup source.</td>
</tr>
<tr>
<td colspan="2">Major Findings:
• People living in unincorporated areas of Marion County rely on wells and septic tanks.
• Low water reserves and low river flow pose a serious threat to the water supply.
• Some infrastructure pertaining to water systems are old which increases the risk vulnerability to withstand a Cascadia event. Impacted infrastructure located near rivers could cause service disruptions and flooding during an event or incident. Power is vital to the water facilities.
• Generators are co-located at critical facilities and need to be maintained requiring various fuel types in order to support redundancy.
• Road access is vital to conduct damage assessments and or repair impacted facilities.</td>
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</table>