Section 2
Risk Assessment

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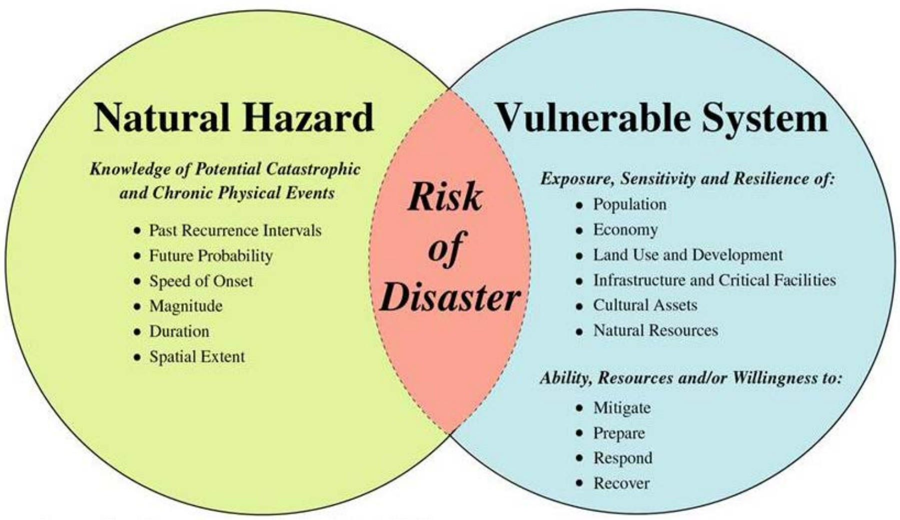
Section 2

Risk Assessment

This section provides information of the natural hazard risk assessment for the City of Beaverton.

The information presented in this section, along with information presented in Appendix G: Hazard Analysis and Appendix C: Community Profile, are used to inform the risk reduction actions identified in Section 3: Mitigation Strategy. Understanding Risk is graphically depicted in Figure 2-1 below. Ultimately, the goal of hazard mitigation is to reduce the area where hazards and vulnerable systems overlap. The Risk Assessment satisfies the NHMP plan requirement identified in 44 CFR 201.6(b)(2).

Figure 2-1 Understanding Risk



Source: http://pubs.usgs.gv/fs/2011/3008

What is a Risk Assessment?

A risk assessment is the process for identifying threats and vulnerabilities of natural hazards for specific communities. Conducting a risk assessment can provide information on the areas where the hazards may occur, the value of existing land and property in those areas; and an analysis of the potential risk to life, property, and the environment that may result from natural hazard events. Specifically, the levels of a risk assessment per Federal Section 322 requirements are as follows:

1) ***Hazard Identification*** identifies the geographic extent of the hazard, the intensity of the hazard, and the probability of its occurrence. Maps are frequently used to display hazard identification data. Beaverton identified seven major hazards that consistently affect this

geographic area. These hazards – floods, landslides, drought, severe weather – windstorms, severe weather – winter storms, earthquakes, and volcanic eruptions (Ash Fall) – were identified through a process that utilized input from a project steering committee as well as through the Beaverton Hazard Analysis, in the City's Operations Plan. The City's Geographic Information Systems (GIS) Service, using the best available data, has identified the geographic extent of each of the identified hazards. The Map Section of this plan contains the maps used for this plan.

2) ***Profiling Hazard Events*** describes the causes and characteristics of each hazard, how they have affected Beaverton in the past, and what part of Beaverton's population, infrastructure, and environment has historically been vulnerable to each specific hazard. A profile of each hazard addressed in this plan is provided in the hazard specific sections.

3) ***Vulnerability Assessment/Inventorying Assets*** combines the hazard identification with an inventory of existing (or planned) property and population that would be exposed to a hazard. Critical facilities are of particular concern because they provide essential products and services that are necessary to preserve the welfare and quality of life in the City and fulfill important public safety, emergency response, and/or disaster recovery functions. The critical facilities have been identified, mapped, and are illustrated in Map Section of this plan. A description of the critical facilities in the City is also provided in the Community Profile Appendix C. A vulnerability summary is included in each hazard section that identifies the most vulnerable and problematic areas in the City, including critical facilities and other public and private property.

4) ***Risk Analysis/Estimating Potential Losses*** involves estimating the damage, injuries, and financial losses likely to be sustained in a geographic area over a given period of time. This level of analysis typically involves using mathematical models. The two measurable components of risk analysis are magnitude of the impact that may result from the hazard event and the likelihood of the hazard occurring. Describing vulnerability in terms of dollar losses provides the community and the state with a common framework in which to measure the effects of hazards on assets. Where available, the best available data was used to determine the magnitude and likelihood of future natural hazard events. For each hazard where data was available, quantitative estimates for potential losses are included in the hazard assessment.

5) ***Assessing Vulnerability/ Analyzing Development Trends*** provides a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions. This plan provides comprehensive description of the character of Beaverton in Appendix C: Community Profile. This description includes the geography and environment, population and demographics, land use and development, housing and community development, employment and industry, transportation and commuting patterns, and historic and cultural resources. Analyzing these components of Beaverton can help in identifying potential problem areas and can serve as a guide for incorporating the 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, and state agency sources.

Table 2-1. Federal Criteria for Risk Assessment

Section 322 Requirement	How this is addressed in the plan.
Identifying Hazards	The Risk Assessment section includes a description of the best available data sources that identify hazard areas. To the extent that GIS data is available, the City developed maps identifying the location of the hazards within City limits.
Profiling Hazard Events	Information on each hazard in the Risk Assessment Section includes documentation of the history, characteristics and probability of the hazard in the city.
Assessing Vulnerability: Identifying Assets	Information on each hazard in the Risk Assessment Section provides information on the vulnerable areas of the city. Vulnerabilities are also touched on in the Community Profile Annex.
Assessing Vulnerability: Estimating Potential Losses	The Risk Assessment section and associated hazards maps identify critical and essential facilities. Vulnerability assessments were completed for each hazard where date was available.
Assessing Vulnerability: Analyzing Development Trends	The Community Profile Annex provides a description of the development trends in the City, including geography and environment, population and demographics, land use and development, housing and community development, employment and industry, transportation and community patterns, and historic and cultural resources.

Climate Change

The most reliable information on climate change to date is at the state level[1]. The state information indicates that hazards projected to be impacted by climate change in Region 2 include drought, wildfire, flooding, and landslides. Climate models project warmer drier summers and a decline in mean summer precipitation for Oregon. Coupled with projected decreases in mountain snowpack due to warmer winter temperatures, all eight regions are expected to be affected by an increased incidence of drought and wildfire. In addition, flooding and landslides are projected to occur more frequently throughout western Oregon. An increase in extreme precipitation is projected for some areas of Region 2 and can result in a greater risk of flooding in certain basins, including an increase in size and frequency of occurrence. Landslides in Oregon are strongly correlated with rainfall, so increased rainfall — particularly extreme events — will likely trigger increased landslides.

While winter storms and windstorms affect Region 2, there is little research on how climate change influences these hazards in the Pacific Northwest. For more information on climate drivers and the projected impacts of climate change in Oregon, see the Introduction to Climate Change section (Section 2.2.1.2; page 60) of the Oregon Natural Hazards Mitigation Plan.

Hazard Identification

The City's hazard analysis identified seven natural hazards that could have significant impact. Summary information for each of these hazards is presented below; additional information pertaining to the types and characteristics of each hazard is available in the Oregon Natural Hazard Mitigation Plan Region 2 Risk Assessment (Tornado is covered within the Windstorm section of the Oregon NHMP). Table 2-2 lists the hazards identified in the city in comparison to the hazards identified in the Oregon NHMP for the Northern Willamette Valley/ Portland Metro (Region 2), which includes Washington County, and Washington County's NHMP.

Table 2-2. City of Beaverton Hazard Identification

City of Beaverton	State of Oregon NHMP Region 2: Northern Willamette Valley/ Portland Metro	Washington County NHMP
Severe Weather – Windstorm	Windstorm	Windstorm • Tornado
Severe Weather – Winter Storm	Winter Storm	Winter Storm
Earthquakes	Earthquakes	Earthquakes
Flood	Flood	Flood
Volcano (Ash Fall)	Volcano	Volcano
Drought	Drought	Drought
Landslides and Debris flow	Landslide	Landslide
Wildland Fire*	Wildfire	Wildland Fire

Sources: City of Beaverton Hazard Analysis 2016
Oregon NHMP, Region 2: Northern Willamette Valley/Portland Metro (2015)
Washington County Hazard Analysis (2015)
*Wildland Fire is not covered in the City's NHMP

Hazard Analysis Methodology

This NHMP includes a summary of the revised City of Beaverton Hazards Analysis (2017). The hazard analysis methodology used is the same that is use by counties and some cities in Oregon as part of their emergency response planning. The methodology was first developed by FEMA circa 1983 and has been gradually refined by the Oregon Military Department's Office of Emergency Management over the years.

The methodology produces scores that range from 24 (lowest possible) to 240 (highest possible). Vulnerability and probability are the two key elements of the methodology.

Vulnerability examines both typical and maximum credible events and probability and 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%.

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. Specific information on the scoring of each of the hazards contained in this plan can be found in Appendix G: Hazard Analysis.

Risk has two measurable components:

- The magnitude of the harm that may result, defined through the vulnerability assessment (assessed in the previous section),
- The likelihood or probability of the harm occurring.

Table 2-3, contains the natural hazards (except pandemic) that are included in the Hazard Vulnerability Analysis (2016) for the City of Beaverton. 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. Considering past historical events, the probability or likelihood of a particular hazard event occurring, the vulnerability to the community, and the maximum threat or worst-case scenario, winter storm, windstorm, and earthquake events rank as the top hazard threats to the city.

Table 2-3. City of Beaverton Hazard Rankings

City of Beaverton	City Hazard Score
Severe Weather – Windstorm	208
Severe Weather – Winter Storm	203
Earthquakes	203
Flood	188
Volcano (Ash Fall)	178
Drought	155
Landslides and Debris flow	86
Wildland Fire*	58

Sources: City of Beaverton Hazard Analysis 2016
*Wildland Fire is not covered in the City's NHMP

Hazard Information

The following subsections briefly describe relevant information for each hazard. For additional background on the hazards, vulnerabilities and general risk assessment information for hazards in the Northern Willamette Valley/Portland Metro (Region 2) refer to the State of Oregon NHMP Risk Assessment (2015).

Wildland Fire

Wildland Fire is not included as one of the City's hazards addressed in the Natural Hazards Mitigation plan. The Washington County Wildfire Protection Plan (2007) shows the City as High Density Urban area that is not a Federal Register Community at Risk and is not in one of the plan's Strategic Planning areas. The city's "wildland-urban interface" is defined as an *occluded wildland-urban interface,* which exists where islands of wildland vegetation occur inside a largely urbanized area. These islands are primarily parks maintained by Tualatin Hills Park & Recreation District, with others being undeveloped lands on the edge of city limits. Based on this and supported by the significantly lower score that Wildland Fires scored than any of the other natural and man-caused hazards in the City's Hazard Analysis (58 on a scale of 24 to 240), it's not addressed in this plan.

Severe Weather – Windstorm

Severe wind events pose a significant threat to life, property, and the local economy in Beaverton by creating conditions that disrupt essential regional services such as public utilities, telecommunications, and transportation routes. Such storms can produce high winds, which can destroy trees and power lines, potentially interrupting utility services. A windstorm in 1995 damaged numerous homes, businesses and public facilities, and generated tons of disaster related debris. Washington County sought and received a Presidential Disaster Declaration to recover from the event.

Characteristics/Types of Windstorm Hazards

A windstorm is generally a short duration event involving straight-line winds and/or gusts in excess of 50 mph. Most of the winds that come from the west are subdued by the time they reach the Beaverton area because of the influence of the Coast Range. The most destructive winds are those which blow from the south, parallel to the major mountain ranges.[2] Windstorms affect areas of Beaverton with significant tree stands, as well as areas with exposed property, major infrastructure, and above ground utility lines. The lower wind speeds typical in the lower valleys are still high enough to knock down trees, bring down power lines, and cause other property damage. The Columbus Day Storm of 1962 was a classic example of a south windstorm. The storm developed well off the coast of California and moved from the southwest, then turned and came directly from the south toward the Oregon Coast. Atmospheric pressure fell rapidly ahead of the storm center and rose rapidly once the storm center passed, creating very tight and sharp pressure gradients. When the strong surface winds are further reinforced by upper airflow in the same direction, as was the case in the Columbus Day Storm, the surface wind speed is enhanced.[3]

Location and Extent

Although windstorms can affect the entirety of the City and Washington County, they are especially dangerous in developed areas with significant tree stands and major infrastructure, especially above ground utility lines. A windstorm will frequently knock down trees and power lines, damage homes, businesses, and public facilities, and create tons of storm related debris. Increasing population and new infrastructure in Beaverton means that more lives and property are exposed to risk; this situation creates a higher probability that damage will occur from severe windstorm events. In some cases, other areas of Washington County and the Metro area have received significant damages and power outages, while the City had minimal impacts.

Windstorms have the ability to cause damage over 100 miles from the center of storm activity. Wind pressure can create a direct frontal assault on a structure, pushing walls, doors, and windows inward. Conversely, passing currents can create lift and suction forces that act to pull building components and surfaces outward. The effects of winds are magnified in the upper levels of multi-story structures. The forces applied by the wind to the building's protective envelope (doors, windows, and walls) can cause the failure of some of the building's components resulting in considerable structural damage.

While relatively rare, tornados can and do occur in the Portland metropolitan area. A small, short-lived tornado near Forest Grove in June 1966.[4] In December 8, 1993 a tornado developed near Newberg and was the most powerful tornado to occur in Oregon in many years. A dairy farm was damaged, roofs were blown off some small buildings, and many trees were broken. People reported that the funnel was sucking water from the Willamette River as it moved northeast and severely damaged a mobile home park.

History

Destructive storms, producing high winds have occurred throughout Northwestern Oregon's history. However, the most destructive windstorm occurred in 1962. The Columbus Day Storm of 1962 brought extensive damage to Beaverton, as it did to the rest of the state. During the storm, School District 48 (which includes Beaverton) suffered damage totaling approximately $194,600, in 1962 dollars ($1,613,061.16 in 2018 dollars)[5]. The storm significantly damaged many other structures throughout the City and caused multiple injuries.

On December 12, 1995 a large low pressure system hit Washington County. Gusts of over 100 mph occurred along the coast while gusts in the Willamette Valley exceeded 60 mph. Hundreds of thousands of people in the state lost power and there was widespread damage to homes, buildings, and boats. The damage resulted in a presidential disaster declaration. Four Oregonians lost their lives during the storm.

The dates below represent occurrences of windstorms meeting the following established criteria:

- Damage from high winds generally resulted in downed utility lines and trees.
- The interruption of electrical power ranged anywhere from a few hours to two or three days.

October 1962	November 1962	October 1967	January 1971
November 1981	November 1982	January 1991	December 1995
January 2006	February 2006	December 2007	September 2014

Probability

New areas of development are often more at risk from natural hazards. New homes and development are pushed into hazard prone areas and "new development leaves some stands of trees vulnerable to 'wind throw' by removing the edges of the stand."[6]

There is a high probability that the City will be impacted by severe weather events over the next several years. A **high probability** incident can be expected once within a 10 to 35 year period and, based on the City's history of notable severe wind weather events in the last 25 years, there is a high probability that such events will continue to occur fairly frequently.[7]

Vulnerability

Vulnerability assessment is the second phase of a hazard assessment. It combines the information generated through severe weather identification with an inventory of the existing development exposed to this hazard, assisting in the prediction of how different types of property and population groups will be affected by a hazard.[8] Data including the areas exposed to severe weather in Beaverton can be used to assess the population and total value of property at risk from severe storms.

Old or poorly constructed structures are vulnerable to strong winds and can be heavily damaged. Well-built and newly constructed structures are more resilient to strong wind events, although the entire built environment is vulnerable high winds and may experience varying degrees of damage.

When severe windstorms strike a community, downed trees, power lines, and damaged property can be major hindrances to emergency response and disaster recovery. Debris carried along by extreme winds can directly contribute to injuries or loss of life and indirectly to the failure of protective building envelopes, siding, or walls of buildings. Storm winds can damage buildings, power lines, and other property and infrastructure by means of falling trees and branches. During wet winters, saturated soils cause trees to become less stable and more vulnerable to uprooting from high winds.

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 Beaverton severe weather storm events, there are many qualitative factors (issues relating to what is in danger within a community) that point to potential vulnerability. Severe weather can cause power outages and transportation and economic disruptions, and pose a high risk for injuries and loss of life. The events can also be typified by a need to shelter and care for adversely impacted individuals. Beaverton has suffered severe weather in the past that brought economic hardship and affected the life safety of City residents. Future severe weather events may cause similar impacts citywide.

The City of Beaverton's 2017 hazard analysis rated the city as having a **high vulnerability** to windstorm hazards, meaning that between 1-10% of the City's population and or property will be affected

Severe Weather – Winter Storm

Severe winter storms pose a significant risk to life and property in the city of Beaverton by creating conditions that disrupt essential regional systems such as public utilities, telecommunications, and transportation routes. Severe winter storms can produce rain, freezing rain, ice, snow, cold temperatures, and wind. Ice storms accompanied by high winds can have destructive impacts, especially to trees, power lines, and utility services. Severe ice storms occur more frequently in areas exposed to east winds blowing out of the Columbia River Gorge. Severe freezes, where high temperatures remain below freezing for five or more days, occur every three to five years in Washington County which includes the city of Beaverton. Severe or prolonged snow events occur less frequently, but have widespread impacts on people and property in the city.

Severe storms affecting Beaverton with snow and ice typically originate in the Gulf of Alaska or in the central Pacific Ocean. These storms are most common from October through March.[9]

Characteristics/Types of Hazards

The principal types of winter storms that occur include:

- **Snowstorms:** require three ingredients: 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.
- **Ice storms:** are a type of winter storm that forms when a layer of warm air is sandwiched by two layers of cold air. Frozen precipitation melts when it hits the warm layer, and refreezes when hitting the cold layer below the inversion. Ice storms can include sleet (when the rain refreezes before hitting the ground) or freezing rain (when the rain freezes once hitting the ground).
- **Extreme Cold:** Dangerously low temperatures accompany many winter storms. This is particularly dangerous because snow and ice storms can cause power outages, leaving many people without adequate heating.

Unlike most other hazards, it is not simple to systematically map winter storm hazard zones. The City in its entirety is susceptible to damaging winter storms. 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 county, including Beaverton, may be impacted by winter storms and the hail or dangerously cold temperatures that winter storms bring.

Location and Extent

While snow is relatively rare in Western Oregon, the Columbia Gorge provides a low-level passage through the mountains. Cold air, which lies east of the Cascades, often moves westward through the Gorge, and funnels cold air into the Portland Area. If a wet Pacific storm happens to reach the area at the same time, larger than average snow events may result.[10]

Ice storms occasionally occur in northern areas of Oregon, resulting from cold air flowing westward through the Columbia Gorge.[11] Like snow storms, ice storms are comprised of cold temperatures and moisture, but subtle changes can result in varying types of ice formation, including freezing rain, sleet, and hail.[12]

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 Columbia 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.[13]

History

In January 1969 one of the fiercest winter storms in recent history occurred causing heavy icing on Beaverton streets and sidewalks. Canyon Road closed briefly as the storm continued through the end of January. As the movement of traffic in and out of the Portland Metro area was severely limited, livestock shipments were delayed, causing beef to become unavailable in stores for a short period. The storm was also responsible for one death.[14]

In early January 1979 a severe winter storm struck, causing the closure of several schools and business due to broken pipes. Pipes also ruptured in several homes throughout Beaverton. A 1,500 gallon oil truck lost control on icy roads, spilling its entire contents. The storm's freezing rain lead to several minor accidents throughout Beaverton.[15] Later in mid-January 1979, 10,000 Washington County residents lost power due to broken limbs and downed trees brought down by freezing rain. An ice-generated electrical short led to a fire causing $35,000 in damages to one Beaverton home.[16]

In early January of 1980 a snowstorm hit Beaverton, and several businesses reported a sharp drop in business due to traffic difficulties.[17]

In February 1989 and December 1990, severe storms caused school closings, accidents, and widespread incidence of broken pipes and downed power lines. Approximately 14,000 residents of Beaverton lost power in February 1989.[18] A section of Highway 217 closed briefly due to the hazardous conditions caused by the storm of December 1990.[19]

The last severe freeze that affected the City occurred in December 1998. This freeze significantly affected the Tualatin Valley Water District water system by causing multiple breaks in the mainline water system.

In 2008, three different weather systems brought snow to the area at different periods of time from December 14 to 26. The majority of the snow fell from Saturday December 20 through Monday December 22. During that 3-day period, Beaverton received over 16 inches of snow greatly surpassing the previous record of 5 inches that occurred 24 years before.

The city of Beaverton endured a significant snow event from December 2015 into January 2016 which had considerable impacts on the transportation infrastructure. This included abandoned vehicles, stranded motorists and an abundance of automobile collisions and delays in traffic.

Probability

Beaverton is at risk from two types of winter storms: snow and ice. The impacts of both storms are similar.

- Heavy snowfall rarely occurs in Beaverton. When it does occur, many of the subsequent problems are directly related to the public's unfamiliarity in dealing with such conditions.
- Ice storms may occur as a result of a combination of weather factors, either with or without a related snowfall.
- The heavy ice on utility lines typically results in outages throughout the City.
- Heavy snow or ice that occurs before the trees lose all of their leaves can knock down limbs and possibly entire trees and consequently power and telephone lines.

There is a high probability that the City will be impacted by windstorm events over the next several years. In the hazard analysis methodology used, probability is based on the likelihood of another occurrence within a specified period of time. A high probability incident can be expected once within a 10 to 35 year period.

Based on the City's history of severe winter storm events during the last 25 years, probability that such events will continue to occur fairly frequently, is high.[20]

Vulnerability

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 Beaverton severe weather storm events, there are many qualitative factors (issues relating to what is in danger within a community) that point to potential vulnerability. Severe weather can cause power outages, transportation and economic disruptions, and pose a high risk for injuries and loss of life. The events can also be typified by a need to shelter and care for adversely impacted individuals. Beaverton has endured severe winter storms in the past that brought economic hardship and affected the life safety of City residents. Future winter storm events may cause similar impacts citywide.

Beaverton is susceptible to direct impacts on infrastructure and property, and indirect costs stemming from business closures and lost work time resulting from winter storms. Industry and commerce can suffer losses from power interruptions and extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from winter storms related to both physical damages and interrupted services.

Rising population growth and new infrastructure in the county creates a higher probability for damage to occur from winter storms as more life and property are exposed to risk. As both an industry best practice and hazard mitigation action, Washington County's electric infrastructure is increasingly being built, or retrofitted, underground which lessens the risk from winter storms.

The City of Beaverton's 2017 hazard analysis rated the city as having a **moderate vulnerability** to winter storm hazards, meaning that between 1-10% of the City's population and or property will be affected.

Earthquakes

Earthquakes pose a serious threat to many Oregon communities. The state ranks third in the nation for future earthquake damage estimates. Scientific evidence shows us that a Cascadia Subduction Zone earthquake could happen at any time. The Oregon Department of Geology and Mineral Industries (DOGAMI) has released a new study that examines potential impacts of a Cascadia earthquake for Clackamas, Multnomah, and Washington Counties.[21]

By using updated data and the latest mapping and modelling techniques, this study greatly improves our understanding of potential earthquake impacts for our region – and for each neighborhood within the counties that were studied. These new estimates of building damages, injuries and fatalities, and people needing shelter helps us plan and prepare for potential impacts, and take action to reduce them. The full report is available on-line at: http://www.oregongeology.org/pubs/ofr/p-O-18-02.htm[22]

Local governments, planners, emergency managers, and engineers must consider this threat as they seek to balance development and risk. Identifying locations susceptible to seismic activity generated by local faults or the Cascadia Subduction Zone, adopting strong policies and implementing measures, and using other mitigation techniques are essential to reducing risk from seismic hazards in Beaverton.[23]

Social and geological records show that Oregon has a history of seismic events. Recent research suggests that the Cascadia Subduction Zone is capable of producing magnitude 9 earthquakes.

Characteristics/Types of hazards

Earthquakes from three different sources threaten communities in Oregon and the Pacific Northwest. These sources are crustal, subduction zone and intraplate earthquakes.

Crustal are the most common earthquakes. Crustal earthquakes typically occur along faults, or breaks in the earth's crust, at shallow depths of 6-12 miles (10-20 km) below the surface. The two largest earthquakes in recent years in Oregon, Scotts Mills (magnitude 5.6) and the Klamath Falls main shocks (magnitude 5.9 and magnitude 6.0) of 1993, were crustal earthquakes.

Subduction zone earthquakes occur in places where the tectonic plates that make up the surface of the earth collide. When these plates collide, one plate slides (subducts) beneath the other, where it is reabsorbed into the mantle of the earth. This dipping interface between the two plates is the site of some of the most powerful earthquakes ever recorded, often having magnitudes of 8 to 9 or larger. The 1960 Chilean (magnitude 9.5) and the 1964 Great Alaska (magnitude 9.2) earthquakes were subduction zone earthquakes.

Deeper intraplate earthquakes occur within the remains of the ocean floor that is being subducted beneath North America. This type of earthquake could occur beneath much of the Northwest at depths of 25–37 miles (40–60 km). The magnitude 6.8 intraplate Nisqually earthquake that struck the Puget Sound area on February 28, 2001 caused $2 billion in damage but was much less destructive than a crustal earthquake of the same magnitude. This would have been because of its great depth (33 miles deep). Intraplate earthquakes have also caused damage in the Puget Sound region in 1949 and again in 1965.

Location and Extent

Based on recorded and geologic history, geologists say the northwest will experience major to large earthquakes. However, there is no method to estimate when they will take place. Recent evaluation of the earthquake threat in Oregon indicates the area may experience a "great" subduction zone earthquake.

Earthquake hazard mapping identifies the potential of major damage for Beaverton.

Beaverton has mostly silt-type soil, which is subject to liquefaction. Liquefaction happens when earthquake waves cause water pressures to increase in the sediment and sand grains to lose contact with each other, leading the sediment to lose strength and behave like a liquid. The soil can lose its ability to support structures, flow down even very gentle slopes, and erupt to the ground surface to form sand boils. Many of these phenomena are accompanied by settlement of the ground surface — usually in uneven patterns that damage buildings, roads and pipelines.[24]

History

Earthquakes felt in Beaverton, have originated in other areas. The Scotts Mills earthquake on March 25, 1993, was the first significant earthquake (in recorded history) to originate close enough to Beaverton to be felt. Beaverton experienced only minor damage, but surrounding counties, including Clackamas, incurred significant damage and received a federal disaster declaration.

The Nisqually earthquake on February 28, 2001, was felt in the city but did very little damage. Numerous small quakes occurred in the Portland Metro area in 2013, 2014, and 2015. Most of these earthquakes were not strong enough to be felt. Though too small to be felt, in 2003 a small quake was detected under Cooper Mountain, in the southern part of the City, on a fault that had been previously designated by geologists as "inactive."

Probability

The City of Beaverton is susceptible to deep intraplate events within the CSZ where the Juan de Fuca Plate is diving beneath the North American plate, ruptures of the CSZ, and shallow crustal events within the North American plate.

Establishing a probability for earthquakes is difficult and could vary between the types of earthquakes that could impact the City. Based on history, there is a high probability of and earthquake occurring in the region that could be felt in Beaverton. The probability of a damaging earthquake, however, is harder to determine. The 2008 United States National Seismic Hazard Map shows that the city lies in an area where there is a 2% chance in a 50 year period that it will experience significant horizontal shaking. The level of shaking is expressed as a percentage "g" which is the rate of acceleration of a falling object due to gravity. The region that includes Beaverton will experience horizontal shaking of at a level of 32 to 48% of "g."[25]

Based on the available data and research for City of Beaverton, the 2017 Hazard Analysis determined the **probability of experiencing an earthquake is "high"** meaning one incident is likely within the next 10-35 year period.

Vulnerability

The effects of earthquakes span a large area, and an earthquake occurring in the city would likely be felt throughout the county. However, the degree to which the earthquakes are felt, and the damages associated with them may vary. At risk from earthquake damage are large stocks of old buildings and bridges, many high tech and hazardous material facilities, extensive sewer, water, and natural gas pipelines, a petroleum pipeline, and other critical facilities and private property located in the city. The areas that are particularly vulnerable to potential earthquakes in the city have been identified as those areas near the crustal fault lines.

The relative or secondary earthquake hazards, which are liquefaction, ground shaking, amplification, and earthquake-induced landslides, can be just as devastating as the earthquake.

A Cascadia Subduction Zone (CSZ) magnitude 9.0 earthquake will have a severe impact on the three-county area. Although damage estimates vary widely throughout the study area, no community will be unharmed. Depending on the time of day an earthquake occurs, casualties may be in the thousands or low tens of thousands. The earthquake will generate several millions of tons of debris from damaged buildings. Damage and casualty estimates resulting from a magnitude 6.8 Portland Hills fault earthquake are more than twice as high as a CSZ earthquake, primarily because the Portland Hills fault is located below densely populated and heavily developed areas. However, the likelihood of a Portland Hills fault earthquake is considerably less than a Cascadia Subduction Zone earthquake.[26]

Table 2-4 looks at the estimated damages for 4 different scenarios; Cascadia subduction zone magnitude 9.0 during dry versus saturated soil conditions and the Portland Hills fault magnitude 6.8 during dry versus saturated soil conditions.

Table 2-4. City of Beaverton Earthquake Loss Estimates				
Population*	89,803			
Number of Buildings	24,005			
Square Footage (Thousand)	96,327			
Building Value (Million)	$13,813			
Earthquake Loss Scenarios	**Cascadia Subduction Zone magnitude 9.0 earthquake**		**Portland Hills fault magnitude 6.8 earthquake**	
	Dry Soil Conditions	**Wet (saturated) Soil Conditions**	**Dry Soil Conditions**	**Wet (saturated) Soil Conditions**
Building Repair Costs (Million)	$1,230	$1,943	$3,510	$5,201
Building Loss Ratio**	9%	14%	25%	38%
Debris (Thousands of Tons)	548	751	1,310	1,775
Long-Term Displaced Population	1,227	6,267	5,597	19,130
Daytime	845	1,313	2,721	3,850

Total Casualties (Includes fatalities)				
Nighttime Total Casualties (Includes fatalities)	223	633	787	1,861
*2010 U.S. Census **Building damage expressed as a loss ratio — the total repair cost estimate for all buildings in a given spatial unit divided by the total replacement cost for all buildings				

Source: DOGAMI Open-File Report O-18-02; EARTHQUAKE REGIONAL IMPACT ANALYSIS FOR CLACKAMAS, MULTNOMAH, AND WASHINGTON COUNTIES, OREGON

The City of Beaverton's 2017 Hazard Analysis rated the City as having **a "high" vulnerability to earthquake hazards**, meaning more than 10% of the region's population or assets would be affected by a major disaster.

Flood

The City of Beaverton has a long-standing, historic relationship with flooding, including repetitive flood losses. Due to the City's ongoing growth and development, Beaverton faces potential increased frequency of flooding. Development generally removes vegetation and increases impervious surfaces, a combination that increases storm water runoff and velocity.

Characteristics/Types of Hazards

Flooding results when rain and snowmelt creates water flow that exceeds the carrying capacity of rivers, streams, channels, ditches, and other watercourses. In Oregon, flooding is most common from October through April when storms from the Pacific Ocean bring intense rainfall. Most of Oregon's destructive natural disasters have been floods.[27]

During this seven-month period, Beaverton receives approximately 81% of its annual precipitation. Snowfall occurs a few days each year, with depths seldom exceeding six inches. Figure 2-2 illustrates the average monthly precipitation that Beaverton receives in inches.

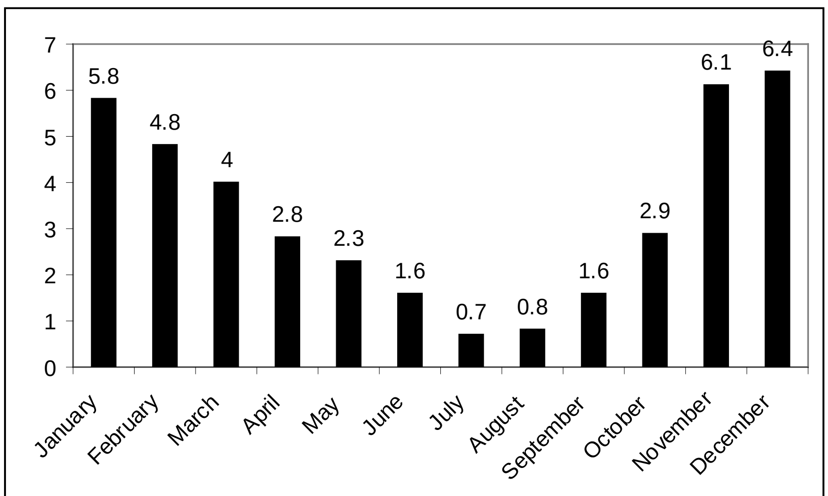


Figure 2-2. Average Monthly Rainfall for Beaverton, OR

Source: Washington County Natural Hazard Mitigation Plan Geography

Two types of flooding primarily affect Beaverton: *urban* flooding and *riverine* flooding. In addition, any low-lying area has the potential to flood. Flooding of developed areas may occur when the amount of rainfall and runoff exceeds a storm water system's (creek, ditch, or storm drain) capability to remove it. Unlike some urban areas, all storm water runoff in Beaverton is directed to the nearest creek or stream. At no point is storm water intentionally directed into the sanitary sewer system.

Urban Flooding

Urbanization of the watershed changes the hydrologic systems of the basin. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb and slowly release rainfall. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds, to the ground, and into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise very rapidly and peak with violent force. The resulting high water volume and turbidity contribute to erosion of streambanks.

A majority of land within Beaverton is urbanized, and has a high concentration of impervious surfaces that either collect water or concentrate the flow of water in unnatural channels. During periods of urban flooding, streets can become swift moving rivers and basements can fill with water. Storm drains and catch basins often back up with vegetative debris causing additional, localized flooding.

There are currently numerous areas subject to urban flooding and the potential exists for more as development continues throughout Beaverton. Continued development and re-development in the city contributes to the city's future flood risk. This development generates more surface area that does not absorb rain (e.g., roofs, parking lots, and roads), increasing the amount of water that runs off into creeks and streams, causing them to flood quicker and more often than in the past.

Riverine Flooding

Riverine flooding, when rivers and streams flow over their banks, is the largest single form of flooding in Beaverton. Streams in the City regularly overflow their banks and inundate low-lying areas. The natural processes of riverine flooding add sediment and nutrients to fertile floodplain areas. Flooding in large river systems typically results from large-scale weather systems that generate prolonged rainfall over a wide geographic area, causing flooding in hundreds of smaller streams, which then drain into the major rivers.[28]

Shallow area flooding is a special type of riverine flooding. FEMA defines shallow flood hazards as *"areas that are inundated by the 100-year flood with flood depths of only 1 to 3 feet*." These areas are generally flooded by low-velocity sheet flows of water.

Location and Extent

Beaverton Creek, the most significant stream in the community, drains approximately 36 square miles as it flows northwesterly through the major commercial area of Beaverton. Streams in the city include five tributaries to Beaverton Creek: South Fork Beaverton Creek, Johnson Creek, Hall Creek, Willow Creek, and Cedar Mill Creek.

Erickson Creek flows northwesterly through central Beaverton and drains 1.7 square miles. South Johnson Creek flows northerly along the Beaverton western corporate limits and has a 3.7-square mile drainage area. Hall Creek, which drains 3.6 square miles, flows westerly, entering Beaverton Creek just upstream of the Hall Boulevard Bridge. Willow Creek, which drains 6.2 square miles, flows westerly through the North Section of Beaverton entering the community just south of Highway 26. Fanno Creek, another significant stream, flows westerly to State Highway 217, then southerly through the city to its confluence with the Tualatin River, after draining 32 square miles. Cedar Mill Creek flows northwesterly and has a drainage area of 8.6 square miles.

There are a total of 18 flood loss properties in Beaverton that are dispersed throughout the City but concentrations occur near the following locations: (as of 2011)

Highway 217 and Denny Road (Fanno Creek);

Near 217 between the Beaverton-Hillsdale Highway and Canyon Road (Beaverton Creek); and

Near the intersection of Murray and Allen Boulevards, along the Johnson Creek corridor.

The potential for property damage from Beaverton Creek flooding is especially severe for several reasons. Inadequate size and moderate grade of the channel causes over-bank flooding during even mild storms. Many culverts and bridges constrict Beaverton Creek flow; additionally, banks that were artificially constricted by farmers in the first half of the last century and the last half of the previous century result in increased upstream flood heights. The potential for property damage is significant due to the extensive commercial and residential development within the Beaverton Creek floodplain. The City experiences flooding frequently from rising creeks and streams as well as localized flooding from overtaxed storm water systems.

The single largest impact on communities from flood events is the loss of life and property. Washington County has experienced millions of dollars in flood damage in the past three decades, with Beaverton's losses reflecting a subtotal of this amount. Loss from floods strikes both private property and public property. Public sector impacts (e.g., impacts to water and sewer systems, roads, etc.) state-wide resulted in approximately two-thirds of the damage from the 1996 flood events.[29]

In a survey of stakeholders, Clean Water Services (CWS, formerly Unified Sewerage Agency) found that stakeholders desired a greater connection between flood control, water quality, the mitigation of growth impacts, and the effectiveness of land use systems. Many citizens are concerned about the relationship between rapid urban growth and flood damage. While there are no strong sentiments to stop growth, some Beaverton residents are concerned that growth is pushing development into floodplains. CWS manages wastewater treatment and sets minimum standards for surface water management within the urbanized area of Washington County. The City of Beaverton sets higher standards for control of damaging run-off rates from new developments than are used by Clean Water Services for areas outside the current City limits.

History

Beaverton residents share a statewide concern regarding flood events. According to the National Flood Insurance Program (NFIP), Oregon has 256 flood-prone communities throughout the state's 36 counties.[30] That number includes a majority of Oregon's 240 incorporated communities and counties, of which Beaverton is one. Flooding can cause severe damage to public and private property and pose a threat to life and safety. Oregon's largest economic loss from natural disasters have resulted from flooding.[31]Damage during the Christmas Flood of 1964 totaled over $157 million dollars, and 20 Oregonians lost their lives.[32]

In 1996, many rivers and creeks throughout the Willamette River watershed rose to 100-year flood levels (flood levels that have a 1% annual chance of occurring). Washington County sought and received a Presidential Disaster Declaration to obtain federal assistance for its flood recovery effort in February 1996. Fortunately, in Beaverton, the intensity of the storms experienced locally didn't approach the predicted 100-year flood event potential (1% annual chance of occurring). For example, the February event levels were only slightly higher than a 10-year flood event; however, several creeks rose to these levels a number of times over three consecutive days. A November 1996 flood event on Beaverton Creek neared a 10-year flood event (10% annual chance of flooding), and, within the City limits, Fanno Creek flooded to slightly greater than a 50-year event (2% annual chance of flooding). Within Beaverton, this inundation of low-lying areas caused natural gas line regulators to flood, threatening the operations facility of Northwest Natural Gas. Since those events, the company has developed a back-up emergency plan and put backup emergency positions and systems in place.

Table 2-5. NFIP Community Status

Community Name	City of Beaverton
County	Washington County
Effective FIRM (Flood Insurance Rate Map) and FIS (Flood Insurance Survey)	11/04/16
Initial FIRM	09/28/84
Initial FHBM (Flood Hazard Boundary Map)	02/01/74

Total Policies	275
Post-FIRM Policies	0
Post-FRIM Policies in the SFHA (Special Flood Hazard Area)	
Pre-FIRM Policies	199
Pre-FRIM Policies in the SFHA	80
Source: The National Flood Insurance Program Community Status Book https://www.fema.gov/cis/OR.html Loss Statistics from Jan 1, 1978 through 1/31/2018 And State NFIP Coordinator	

Repetitive Loss Properties

A Repetitive Loss (RL) property is any insurable building for which two or more claims of more than $1,000 were paid by the National Flood Insurance Program (NFIP) within any rolling ten-year period, since 1978.[33] A RL property may or may not be currently insured by the NFIP. Currently there are over 122,000 RL properties nationwide. (FEMA.gov site) The National Flood Insurance Program (NFIP) indicates that Beaverton has 6 recorded repetitive loss properties, according to NFIP data dated 4/26/2018. All but one of the repetitive loss properties has had two losses apiece. The other had three. None of the properties meet the definition of a Severe Repetitive Loss Property. There are no "clusters" of repetitive loss properties within the City; but one location with two neighboring homes (#4 & #5) had one event in common but suffered the other losses at different times.

Table 2-6. NFIP Loss Statistics

Community Name	City of Beaverton
Insurance in Force	$80,376,300
Total Paid Claims	31
Pre-FIRM Claims Paid	26
Substantial Damage Claims	0
Total Payments	$448,027
Repetitive Loss Structures	6*
Severe Repetitive Loss Properties	0
CRS Class Rating	10
Last Community Assistance Visit	5/25/2016
Source: State NFIP Coordinator *FEMA Sources show 7 properties but one is outside City limits	

Table 2-7 - Repetitive Loss Properties

Property Ref	Zone	Nearby Stream/ Creek	Insured?	Date of Loss	Date of Loss	Date of Loss
1	Unk	Fanno Creek	No	11/08/80	12/02/80	
2	A02	Johnson Creek	No	02/06/96	11/19/96	
3	C	Hall Creek	No	02/08/96	11/19/96	
4	X	None	Yes	12/9/2010	6/25/2014	
5	X	None	Yes	6/25/2014	10/31/2015	12/7/2015
6	AE	Fanno	Yes	1/2/2009	12/7/2015	

Source: State NFIP Coordinator

Probability

Flood hazard areas identified on the Flood Insurance Rate Map are identified as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. Moderate flood hazard areas are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood.[34]

Based on the available data and research for the City of Beaverton, the 2017 Hazard Analysis determined the **probability of experiencing a flood is "high"**, meaning one incident is likely within the next ten year period.

Vulnerability

Vulnerability assessment is the second phase of flood hazard assessment. It combines the floodplain boundary, generated through hazard identification, with an inventory of the property within the floodplain. It identifies the number of properties at risk from flooding, and the dollar value of the property at risk. Floodplain data for Beaverton can be used to conduct a preliminary vulnerability assessment for flood and drainage hazard areas.

The floodplains in Beaverton are generally located along Beaverton Creek, Fanno Creek, and its tributaries. There are approximately 750 acres within the 100-year floodplain boundaries in the City's jurisdiction. A total of 845.69 acres of tax lots that lie within the 100-year flood plain in Beaverton. Within the tax lots, there are 320 total structures valued at $339,537,830. See Table 2-10 for a breakdown of these properties by types of tax lots.

Table 2-8. Vulnerability Assessment for the 100-year Floodplain[35]

Building Code Category	Number of Properties	Assessed Improved Value	Acreage within 100-year floodplain
COMMERCIAL	34	$78,014,890	103.26
INDUSTRIAL	39	$126,973,670	226.27
SINGLE FAMILY RESIDENTIAL	199	$29,201,790	171.75
MULTI-FAMILY RESIDENTIAL	48	$105,347,480	344.41
TOTAL	**320**	**$339,537,830**	**845.69**

Source: City of Beaverton GIS, 2003

Soils in and around Beaverton are silt loams that range in grade from nearly level to steep slopes. Drainage characteristics for those soils are poor along the level areas of the flood plains, but drainage (run off) improves on sloping terrain. Trees, grass and shrubs are the dominant vegetation type. The rapid urbanization of the City is leading to decreased vegetation, and thus an increase in impervious surface and infringement of natural drainage areas.

Changes to development patterns since 2010 have the potential to incur increased risk of flooding. However, Metro and county development regulations restrict new development in areas identified as floodplain. This reduces the impact of flooding on future buildings. As new land has been brought into the regional Urban Growth Boundary, the applicable development codes have been written to prevent the siting of new structures in flood prone areas.

At the time of publication of this plan, data was insufficient to conduct a full risk analysis for flood events in Beaverton. However, in accordance with the 2017 City Hazard Analysis, Beaverton is **rated with a "moderate" vulnerability** to flood hazards, meaning that between 1-10% of the region's population or assets would be affected by a major disaster.

Table 2-9 –Flood Insurance Policies by Building Type

Single Family	2 to 4 Family	Other Residential	Non-Residential	Minus Rated A Zone	Minus Rated V Zone
109	44	52	12	6	0

Volcano-Related Hazard

Beaverton and the Pacific Northwest lie on 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 the hotter molten materials, or magma, rise to the surface.

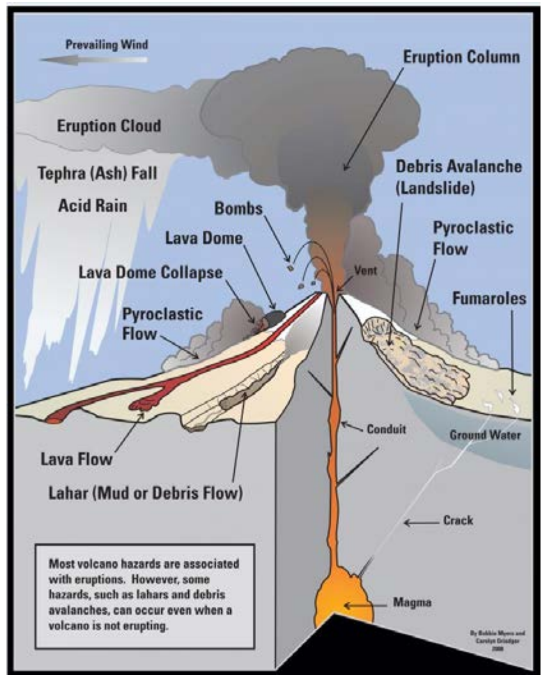
The primary threat to lives and property from active volcanoes is from violent eruptions that unleash tremendous blast forces, generate mud and debris flows, and produce flying debris and ash clouds. The immediate danger area in a Volcano-Related event generally lies within a 20-mile radius of the blast site. Although there are no active volcanoes in Beaverton or Washington County, there are a number of active volcanoes within the 100-mile danger areas that do pose a threat to city residents and property. The threat they pose is associated primarily with ash fall.

Characteristics/Types of Hazards

This section describes hazards related to Volcano-Related Events. Figure 2-3 shows a cross-section of a volcano and some of the hazards associated with volcanoes. Tephra, or ash, is the primary volcano related hazard that may impact the city.

Tephra consists of sand-sized or finer particles of volcanic rock and larger fragments. During explosive eruptions, tephra, together with a mixture of hot volcanic gases, is ejected rapidly into the air from volcanic vents. The suspended materials are carried high into the atmosphere and begin to move downwind. As the ash particles cool or become moisture laden they start to fall under the influence of gravity. The larger fragments fall near the volcanic vent, while finer particles drift downwind as a large cloud and then fall to the ground to form a blanket-like deposit of ash.[36]

Figure 2-3. Cross section of a volcano



Source: United States Geological Survey. https://volcanoes.usgs.gov/observatories/cvo/hazards.html

Location and extent

Due to Beaverton's proximity to nearby volcanos, volcanic hazards such as lava flows, lahars and debris flows do not pose a threat. However volcanic ash from an eruption can contaminate water supplies, cause electrical storms, create health problems, and clog conveyance systems. Additionally, lahars (mudflows) from Mt. Hood can cause the loss of potable water supply for the county from the Bull Run Watershed.

There are five major volcanoes in the Cascade region that are in relative proximity and pose a potential threat to Beaverton. They include Mount St. Helens, Mount Hood, Mount Rainier, Mount Adams, and Mount Jefferson. Of the five, all are known or suspected to be active, and most have geological records that indicate past histories of explosive eruptions with large ash releases. Mount Hood is the only volcano that has no geological evidence of large explosive events, though it still poses a threat of ash releases.

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.

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.

History

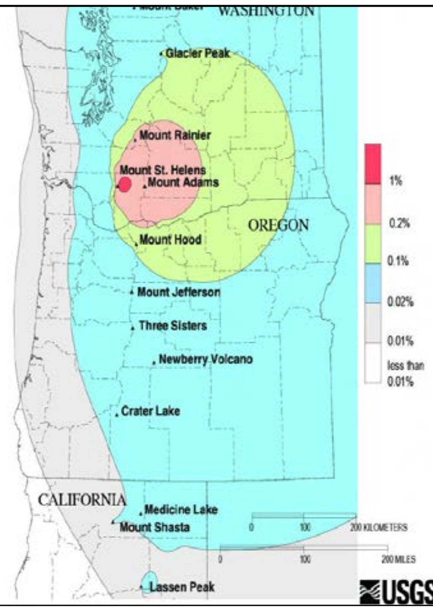
The only historical incidence of a volcano directly affecting Beaverton was the eruption of Mount St. Helens on May 18, 1980. The Beaverton *Valley Times* followed the story of "mountain watchers" who watched the volcano from a campground near Cougar, Washington, throughout the spring of 1980. The eruption resulted in massive mudflows, floods and other land-changing forces."[37] Ash from the eruption clouded the air in the Portland Metropolitan area, but did not ultimately cause damage in Beaverton. Emergency management in Washington County was prepared for the ash by providing facemasks and preparing for road closures. Because wind direction continued to head to the east after the eruption, Beaverton escaped significant accumulations of ash fall.[38]

A few millimeters of ash fell onto Beaverton during small events on May 25, June 12, and October 16-18, 1980. The May 25 event left ash covering buildings, vehicles, lawns, and streets. For days, even weeks afterward, residents and government officials worked to clear away the fine powder and local hospitals treated a large number of patients suffering from respiratory problems attributed to the ash. They handed out surgical masks to help filter the ash, but the masks were largely ineffective. Residents and government officials worked aggressively to remove the ash deposits by flushing them into storm drains or sweeping them up and hauling them to landfill sites. Parks and outdoor swimming pools were particularly hard hit, requiring pool drainage and frequent filter cleaning. Ash also worked its way into equipment causing premature failures or requiring unscheduled maintenance.[39]

Probability

The USGS/Cascades Volcano Observatory (CVO) produced volcanic hazard zonation reports for Mount St. Helens and Mount Hood in 1995 and 1997 as well as an update to the Mount Hood report in 2000. The reports include a description of potential hazards that may occur to immediate communities. In 2001, the CVO created an updated map on the annual probability of tephra fall for the Cascade region, which can be used by the City as a guide for forecasting potential tephra hazard problems.

Figure 2-4. Map showing one-year probability of accumulation of 1 centimeter (0.4 inch) eruptions of or more of tephra from volcanoes in the Cascade Range.



Source: United States Geological Survey-Cascades Volcano Observatory (CVO), (Figure assembled by OPDR)

The map is based on the combined likelihood of tephra-producing eruptions occurring at Cascade volcanoes. Probability zones extend farther east of the range because winds blow from westerly directions most of the time. The map (figure 2-4) shows annual probabilities for a fall of one centimeter (about 0.4 inch). The patterns on the map show the dominating influence of Mount St. Helens as a tephra producer. Because small eruptions are more numerous than large eruptions, the probability of a thick tephra fall at a given location is lower than that of a thin tephra fall. The annual probability of a fall of one centimeter or more of tephra is about 1 in 10,000 on the county level, even less for the City.

Based on the available data and research and as determined in the 2017 City of Beaverton Hazard Analysis, the **probability of experiencing a volcano related hazard is "medium"**, meaning one incident is likely within the next 35-50 year period.

Vulnerability

While a quantitative vulnerability assessment (an assessment that describes number of lives or amount of property exposed to the hazard) has not been conducted for volcano-related events in Beaverton, there are many qualitative factors (issues relating to what is in danger within a community) that point to potential vulnerability. Beaverton faces no direct threat from a volcano-related event. However, its proximity to a number of Cascade Range volcanoes places the City at risk from ash fallout originating from such an event. The amount of ash fall experienced and its impact will depend, to a large degree, on the weather conditions. A substantial portion of the city could be impacted by the ash fall generated by a volcanic eruption of Mt. St. Helens while volcanologists also consider Mt. Hood to be potentially active as well.

While Mount Hood has shown no recent signs of volcanic activity, scientists predict the next eruption will consist of lava dome growth accompanied by small explosions, and lava-dome collapse generating pyroclastic flows, ash clouds, and lahars. Future eruptions from Mount Hood could seriously disrupt transportation, water supplies, and hydroelectric power generation and transmission in northwestern Oregon and southwestern Washington.

The impacts of a significant ash fall are substantial. Persons with respiratory problems are at risk, transportation, communications, and other lifeline services are interrupted, drainage systems become overloaded/clogged, buildings can become structurally threatened, ventilation systems can become clogged and the economy takes a major hit. Any future eruption of a nearby volcano (e.g., Hood, St. Helens, or Adams) occurring during a period of easterly winds would likely have adverse consequences for the city.

The City of Beaverton's 2017 hazard analysis rated the city as having a **moderate vulnerability** to volcanic hazards, meaning that between 1-10% of the City's population and or property will be affected

More information on this hazard can be found in the Risk Assessment for Region 2, Northern Willamette Valley/ Portland Metro, of the Oregon NHMP (2015).

Drought

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 and county.

Characteristic/Types of Hazards

There are four different ways that drought can be defined or grouped:

- **Meteorological Drought-** defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region.[40]

- **Agricultural Drought-** 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, reduced groundwater or reservoir levels, and so forth. 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 should be able to account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity.[41]
- **Hydrological Drought-** Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., streamflow, reservoir and lake levels, groundwater). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with or lag 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.[42]
- **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 aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on weather. Because of the natural variability of climate, water supply is ample in some years but unable to meet human and environmental needs in other years. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.[43]

Location and Extent

Drought may occur in the City of Beaverton and may have profound effects on the economy, particularly the agricultural and recreational sectors, which are a small part of the City’s overall economy. Drought is typically measured in terms of water availability in a defined geographical area. It is common to express drought with a numerical index that ranks severity. Most federal agencies use the Palmer Method which incorporates precipitation, runoff, evaporation, and soil moisture. However, the Palmer Method does not incorporate snowpack as a variable. Therefore, it is not believed to provide a very accurate indication of drought conditions in Oregon and the Pacific Northwest.

History

Although Beaverton has suffered periods of drought in the past, the impacts have not been severe enough to reach major emergency or disaster proportions. The drought of 2000-01 is the worst on record for the City. Hagg Lake, the reservoir behind Scoggins Dam, fell to a record low of 9%. A combination of effective water management, significant conservation on the part of local irrigators, and adequate potable water supplies from the City ASR (Aquifer Storage and Reclamation) wells averted a major water crisis that year. A major drought affected several Oregon counties in 2015 but did not directly affect Beaverton.

Probability

Climate change forecasts highlight an increased risk for drought conditions in the Pacific Northwest. According to the U.S. National Climate Assessment report Climate Change Impacts in the United States Highlights "Changes in the timing of streamflow related to changing snowmelt are already observed and will continue, reducing the supply of water for many competing demands and causing far-reaching ecological and socioeconomic consequences."[44]

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 eight and 12 years. Based on the 2017 Hazard Analysis for the City of Beaverton the **probability of experiencing a severe drought is "moderate,"** meaning that one incident is likely in the next 35-75 year period.

Vulnerability

The environmental and economic consequences can be significant, especially for the agricultural sector. Drought also increases the probability of wildfires. Drought can affect all segments of the City of Beaverton's population, particularly those employed in water- dependent activities (e.g., agriculture, recreation, etc.). Also, domestic water-users may be subject to stringent conservation measures (e.g., rationing)

Potential impacts to community and farming water supplies are the greatest threats. Additionally, long-term drought periods of more than a year can impact forest conditions and set the stage for potentially destructive wildfires. The 2017 Hazard Analysis for the City of Beaverton rated the City as having a **"moderate" vulnerability to drought hazards**, meaning between 1-10% of the region's population or assets would be affected by a major drought emergency or disaster.

Landslides

There is an abundance of settlements that are located among the steep and mountainous slopes of the Pacific Northwest. Due to the urbanization process, many of these areas have become increasingly unsteady, as the integrity of the land has become compromised. Landslides, which are often secondary hazards generated by earthquakes, heavy rains, melting snow, or rapidly declining water levels at the base of the slope, are also in and of themselves considered a major geological hazard.

Nationally, landslides cause 25 to 50 deaths each year.[45] The best estimates of the direct and indirect costs of landslide damage in the United States range between $1 billion to $2 billion annually.[46] In Oregon, a significant number of locations are at risk to dangerous landslides. While landslides have had little to no impact in Beaverton, they have created a number of problems throughout Washington County. Although not all landslides result in private property damage, many landslides impact transportation corridors, fuel and energy conduits, and communication facilities.[47] They can also pose a serious threat to human life.

Landslides can be broken down into two categories: (1) rapidly moving; and (2) slow moving. Rapidly moving landslides (debris flows and earth flows) 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. A rapidly moving debris flow in Douglas County killed five people during the storms of 1996. Slow moving landslides can cause significant property damage, but are less likely to result in serious human injuries.

Characteristics/Types of Hazards

Landslides are downhill or lateral movements of rock, debris, or soil mass. The size of a landslide usually will depend on the geology and the triggering mechanism. Landslides initiated by rainfall tend to be smaller, while those initiated by earthquakes may be very large.

Slides associated with volcanic eruptions are typically large and can include as much as one cubic mile of material. Slides caused by erosion occur when ditches or culverts beneath hillside roads become blocked with debris. If the ditches are blocked, run-off from 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 some have been known to be quite large.

Landslides can 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 of the characteristics that determine the type of landslide are the 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. Types of landslides include slides, rock falls, and flows.

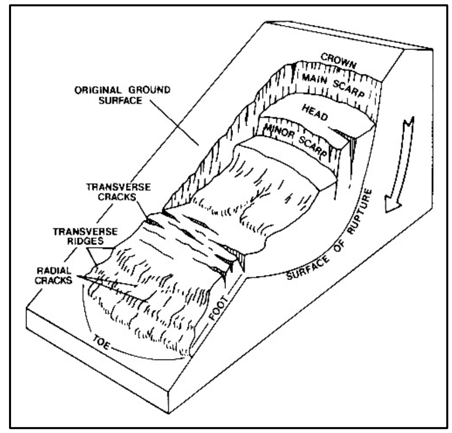


Figure 2-5. Rotational Slide

Source: *Planning for Natural Hazards: The Oregon Technical Resource Guide*, DLCD

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. Slumps are small rotational slides that are generally shallow (See Figure 2-5). 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.[48]

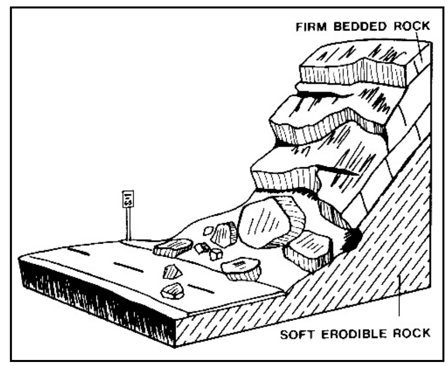


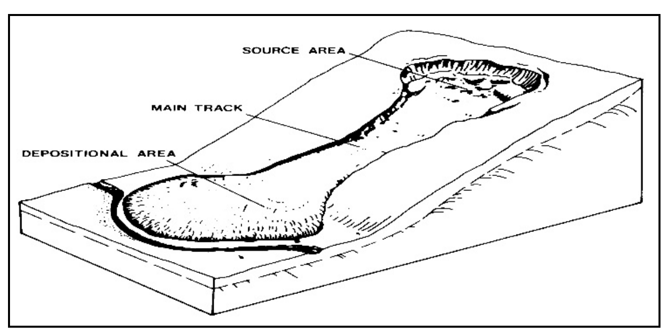
Figure 2-6. Rock Fall

Source: *Planning for Natural Hazards: The Oregon Technical Resource Guide*, DLCD

Rock falls (see Figure 2-6) occur when blocks of material come loose on steep slopes. Weathering, erosion, or excavations, such as those along highways, where the road has been cut through bedrock can cause falls. These slides are fast moving with the materials free falling or bouncing down the slope. The total volume of material involved is generally small, but individually the boulders or blocks of rock can be large and can cause significant damage.

Flows (see Figure 2-7) are slides in which soil and rock breaks up and flows like a plastic or liquid. 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 fast moving and also tend to increase in volume as they scour out the channel.[49] Flows often occur during heavy rainfall, can occur on gentle slopes, and can move rapidly for large distances. One example of a flow in Oregon is the Dodson debris flow that occurred in 1996. This debris flow started high on the Columbia Gorge

Figure 2-7. Earthflow



Source: *Planning for Natural Hazards: The Oregon Technical Resource Guide*, DLCD cliffs, and traveled far down steep canyons to form debris fans at Dodson.[50] Earthquakes often trigger flows as well.[51]

Landslides are typically triggered by periods of heavy rainfall or rapid snowmelt but earthquakes, volcanic activity, and excavations might also trigger them. Certain geologic formations are more susceptible to landslides than others are. Human activities, including development on or near steep slopes, can increase susceptibility to landslide events. Because of their general nature, landslides on steep slopes are typically more dangerous because they can occur with little warning and their movements can be very rapid.

Locations at risk from landslides or debris flows include areas with one or more of the following conditions:

- On or close to steep hills;
- Steep road-cuts or excavations into steep slopes;
- Existing landslides or places of known historic landslides (such sites often have tilted power lines, trees tilted in various directions, cracks in the ground, and irregular-surfaced ground);
- Steep areas where surface runoff is channeled, such as below ground in culverts, V-shaped valleys, canyon bottoms, and steep stream channels;
- Fan-shaped areas of sediment and boulder accumulation at the outlets of canyons, large boulders (2 to 20 feet diameter) perched on soil near fans or adjacent to creeks; and
- Occurrences of logjams in streams.[1]

Location and extent

While recent landslide events near Beaverton have not been the rapidly moving debris flows, the potential for their occurrence exists. Debris flows generally occur during intense periods of rainfall on previously saturated soil. They typically start on steep slopes and can accelerate to speeds as great as 35 mph. Debris flows have caused most of the recent landslide related injuries and deaths in Oregon,[52] and they have been the catalyst for the creation of two state agencies: (1) the Oregon Department of Forestry (ODF); and (2) the Department of Geology and Mineral Industries (DOGAMI) to map these types of landslides.

Please refer to Hazard Map in the Map section of the NHMP for more information regarding landslide locations in the Beaverton area.

History

Landslides in surrounding areas of Beaverton have primarily been slow moving and caused greatest impact to roads and culverts.[53] There has only been one known landslide that has occurred within current city boundaries. The slide occurred on a man-made slope which is part of the Highway 217 overpass over the Beaverton-Hillsdale Highway. There was no direct impact on the roadways, utilities, or structures. Other than that single event, the City of Beaverton has no known locations susceptible to landslides, avalanches, or debris flows. This may change with future annexations of areas to the north and north east of current City boundaries.

Probability

Landslides tend to move repeatedly over time. As such, the location of existing landslides is critical for predicting the locations of future landslides. However, the location of existing landslides alone is not enough to predict the future. The geology, slope and triggering factors such as water, earthquakes, volcanic eruptions and man also must be considered. All of these factors combined result in landslide susceptibility, or the more- or less-likely locations of future landslides. Inventory and susceptibility maps can be used to guide assessments for future developments and can be used to assist in planning and mitigation of existing landslides.[54]

Based on the single occurrence and existing steep slopes in the City, the **probability of future landslide events in the City is "moderate"**. Probability is based on the likelihood of another occurrence within a specified period of time and a medium probability event is likely to occur once within 35 to 50 years.[55]

Please visit http://www.oregongeology.org/sub/slido/index.htm for Statewide Landslide information database (SLIDO). The interactive map lets you view information on location, type, and other attributes related to identified landslides in Oregon. The original studies vary widely in scale, scope, and focus, which is reflected in a wide range in the accuracy, detail, and completeness with which the landslides are mapped.[56]

Vulnerability

Vulnerability assessment is the second phase of the hazard assessment. It combines the information generated through landslide identification with an inventory of the existing development exposed to landslide hazards. Vulnerability assessments assist in predicting how different types of property and population groups will be affected by a hazard.[57] The optimum method for doing this analysis at the county or jurisdiction level is to use parcel-specific assessment data on land use and structures.[58] Data that includes known landslide and debris flow locations can be used to assess the population and total value of property at risk from future landslide occurrences.

There are several steep slopes (slopes greater than or equal to 25%) within the City. LIDAR (Light Detection and Ranging) technology shows evidence of landslide deposits at the base of some of these slopes indicating that the slope has slid in the past (See Hazards Map in the Map Section).

- 4 minor slides are within city limits
- 1 large slide area is both inside and outside the city limits
- 1 large slide area is outside, but close to the city limits

Other than these ancient slides, there are no known active locations prone to landslides, avalanches, or debris flows inside city limits. This may change with future annexations of areas to the north, north east and southwest of current City boundaries

While a quantitative vulnerability assessment (an assessment that describes number of lives or amount of property exposed to the hazard) has not been conducted for the Beaverton landslide event, there are many qualitative factors (issues relating to what is in danger within a community) that point to potential vulnerabilities existing in other areas identified for future annexations. Landslides can impact major transportation arteries, blocking residents from essential services and businesses. While past landslide events have not caused major property damage or significantly impacted City residents, continuing to map City landslide and debris flow areas will help in preventing future loss.

The City of Beaverton's 2017 hazard analysis rated the city as having a **low vulnerability** to landslide hazards, meaning that less than 1% of the City's population and or property will be affected

Multi-Hazard Risk

While remote, the potential exists that the city could experience the impacts of two different natural hazards at the same time. Additionally, there are potential impacts that are common among more than one of the hazards covered in this plan, as well as other hazards not addressed (i.e., structural damage can be caused by earthquake, high-winds, or landslides). There are also mitigation measures and potential action items that can be applicable to more than one hazard. Addressing these multi-hazards items together rather than by specific hazard offers a more practical, coordinated, and cost effective approach than trying to address them within each hazard

Since the multi-hazard items relate to multiple hazards, the established methodology for identifying the hazard, vulnerability, and risk of the specific hazards is not applicable. The primary assessment criteria for the multi-hazard risks are that the actions address more than one of the natural hazards covered in this plan.

Vulnerability Assessment

Community vulnerabilities are an important component of the NHMP risk assessment. For additional information regarding specific community vulnerabilities see Appendix C: Community Profile.

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.

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[1] Oregon Department of Land Conservation and Development. 2015. *Oregon Natural Hazards Mitigation Plan* http://www.oregon.gov/LCD/HAZ/Pages/nhmp.aspx#Oregon_Natural_Hazards_Mitigation_Plan

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

[3] Ibid (entire paragraph)

[4] National Weather Service, Portland Bureau, (March 2001) www.wrh.noaa.gov/Portland

[5] US Department of Labor, Bureau of Labor Statistics CPI Inflation Calculator. https://www.bls.gov/data/inflation_calculator.htm

[6] Fryer, Barbara, Planning Department, Stakeholder Interview

[7] City of Beaverton, *Emergency Response and Recovery Plan (ERRP)*; *Tab B – Hazard Analysis*; revised April 2010.

"Probability is based on the likelihood of another occurrence within a specified period of time. A high probability incident can be expected once within a 10 to 35 year period, a medium probability once within 35 to 50 years and low, once in 75 to 100 hundred years."

[8] Burby, R. (Ed.) *Cooperating with Nature: Confronting Natural Hazards with Land Use Planning for Sustainable Communities*. Washington D.C. (1998), Joseph Henry Press.

[9] Interagency Hazard Mitigation Team, *State Hazard Mitigation Plan* (2000) Oregon State Police – Office of Emergency Management.

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

[11] Ibid.

[12] Ibid.

[13] Ibid.

[14] Valley Times, "Worst Storm since '62 Hits Area Monday Night," 1967 and Beaverton Valley Times, 1/31/69

[15] Ibid. 1/3/79

[16] Ibid. 1/10/79

[17] Ibid. 1/9/80

[18] Ibid. 2/9/89

[19] Ibid. 2/9/89

[19] Ibid. 12/23/90

[20] City of Beaverton, *Emergency Response and Recovery Plan (ERRP)*; *Tab B – Hazard Analysis*; revised April 2010.

"Probability is based on the likelihood of another occurrence within a specified period of time. A high probability incident can be expected once within a 10 to 35 year period, a medium probability once within 35 to 50 years and low, once in 75 to 100 hundred years."

[21] RDPO/DOGAMI Earthquake Regional Impact Analysis-Summary of the Study, Pg 2. March 2018

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[24] "About Liquefaction." USGS, 18 AUG. 2006, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/aboutliq.html

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[26] Oregon Department of Geology and Mineral Studies. (Nov 30, 2017) Earthquake Regional Impact Analysis for Clackamas, Multnomah, and Washington Counties, Oregon Report to the Regional Disaster Preparedness Organization Oregon

[27] Taylor, George H. and Chris Hannan. *The Oregon Weather Book*. Corvallis, OR: Oregon State University Press. 1999

[28] *Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Ch. 4.

[29] *Floodplain Management: a Local Administrator's Guide to the National Flood Insurance Program*. FEMA, Region 10.

[30] The Interagency Hazards Mitigation Team, *State Hazard Mitigation Plan*, (Oregon State Police – Office of Emergency Management, June 2000).

[31] *Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Ch. 4.

[32] Ibid

[33] FEMA.gov, Retrieved at https://www.fema.gov/pdf/rebuild/repetitive_loss_faqs.pdf

[34] FEMA Flood Zones, http://www.fema.gov/floodzones

[35] The data used to create these files were; Beaverton Zoning current as of July 2003, Beaverton City Limits current as of July 2003, Beaverton Building footprints current as of March 2001, Metro Floodplain current as of June 2002

The taxlot base does not have positional accuracy, and the Metro Floodplain may be outdated. The building footprints are positionally accurate but not up to date, as there have been buildings added and removed since the file was created. All these things have to be taken into consideration.

For the analysis - taxlots with a zone description of (CV, OC, NS, CS, TC-SR and GC) to create the Commercial category. All taxlots with a zone description of (CI, IP and LI) to create the Industrial category. All taxlots with a zone description of (R10, R7, R5 and R4) to create the Single Family Residential category. All taxlots with a zone description of (R3.5, R2 and R1) to create the Multi Family Residential category.

Clip Commercial (then Industrial...) with Floodplain. Intersect this with Planimetric Building Footprints. Calculate table statistics. Number of properties = Count field. For more information on this analysis contact Doug Taylor in Beaverton's GIS Department.

[36] Community Planning Workshop, 2002

[37] The Valley Times, May 21, 1980. Vol.60 No.37.

[38] The Valley Times, May. 23, 1980. Vol.60 No.38

[39] Community Planning Workshop, 2002

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[43] Ibid

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[50] *Planning for Natural Hazards: The Oregon Technical Resource Guide,* Department of Land Conservation and Development (July 2000), Ch. 5.
[51] Robert Olson Associates, *Metro Regional Hazard Mitigation Policy and Planning Guide* (June 1999) Metro.

[52] Interagency Hazard Mitigation Team, *State Hazard Mitigation Plan* (2000) Oregon State Police – Office of Emergency Management.

[53] *Washington County Hazard Analysis* (May 2000) Washington County Emergency Management.

[54] Oregon Department of Land Conservation and Development. (2015). *Oregon Natural Hazards Mitigation Plan.* State Interagency Hazard Mitigation Team

[55]City of Beaverton, *Emergency Response and Recovery Plan (ERRP)*; *Tab B – Hazard Analysis*; revised April 2010.

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[57] Burby, R.(Ed.) Cooperating with Nature. (1998) Washington D.C.: Joseph Henry Press.

[58] Ibid