# 3.4 Severe Weather

Winter weather events occur annually in Multnomah County, sometimes becoming severe (Oregon Department of Land Conservation and Development [DLCD], 2015). All of the infrastructure and population in the Planning Area are subject to severe weather. It is common in winter months for heavy rains to cause flooding and landslides throughout the county.

Communities near the Columbia River Gorge are especially vulnerable to ice storms that impact roadways and damage trees and utilities. This includes all four cities and some unincorporated areas.

***Level of Risk* to Severe Weather Hazards***

**High**

- Gresham
- Fairview
- Troutdale
- Wood Village

**Moderate**

- Unincorporated Multnomah County

**Low**

- None

**Level of risk is based on the local OEM Hazard Analysis scores determined by each jurisdiction in the Planning Area. See **Appendix C** for more information on the methodology and scoring.*

## 3.4.1 Overview

All communities within Multnomah County are subject to severe weather events. Severe weather events that commonly take place in winter months occur more frequently and have a greater impact on our communities than do those that take place during summer months. Much of the time, severe weather storms result from large-scale weather systems moving inland from the Pacifc Ocean and can affect a large portion of the Pacific Northwest.

### *Types*

Severe weather affecting the Planning Area is generally characterized by winter rather than summer storm events. Typically, winter events include a combination of heavy rains and high winds, sometimes with snow and ice, especially at higher elevations. Multiple hazards can result from severe winter weather. For example, heavy rains can result in localized or widespread flooding and landslides. See sections **3.2 Flooding** and **3.3 Landslides** for more information about how these hazards are impacted by severe weather.

Less frequent severe weather events that typically occur in summer include thunderstorms, hail, lightning strikes, tornadoes and drought/heatwave. Because summer severe weather events are infrequent and tend to have little impact on the Planning Area, little data is available for these hazards. As such, this section assesses the risk to these hazards to a lesser degree. A more robust analysis has been conducted for severe winter weather events.

**Table 3.4-1** shows which types of severe weather impact each of the communities in the Planning Area throughout the year.

**Table 3.4-1 Types of Severe Weather Hazards that Impact Each Jurisdiction**

| Jurisdiction | Heavy Rain | Windstorm | Snow & Ice | Thunderstorm | Hail | Lightning | Tornado | Drought / Heatwave |
|---|---|---|---|---|---|---|---|---|
| Unincorporated Multnomah County | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Fairview | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Gresham | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Troutdale | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Wood Village | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |

Source: DLCD, 2015; and Natural Hazard Mitigation Plan (NHMP) Steering Committee, 2016

## Location and Extent

Typically, winter storms that affect the Planning Area are large cyclonic low-pressure systems moving inland from the Pacific Ocean. These storms usually affect large areas of Oregon, or even the whole Pacific Northwest. Summer storms tend to be more localized. All of the infrastructure and population within the Planning Area are exposed to severe weather. However, history shows that transportation systems are more frequently impacted and thus are at higher risk of damage from severe weather events than buildings. The location and severity of these events varies widely based on specific local conditions.

The data for rainfall, snowfall and temperature discussed below is from the National Weather Service (NWS) and the Western Regional Climate Center (WRCC). Data for the City of Portland and unincorporated areas of Multnomah County west of I-205 come from the weather data collection site at the Portland International Airport. Data for the cities of Troutdale, Fairview, Wood Village and Gresham and the unincorporated areas east of I-205 comes from the weather data collection site at the Troutdale Airport.

## Severe Winter Storms

### Heavy Rainfall

Whether flooding occurs at specific sites depends heavily on specific local rainfall totals during individual storms and local drainage conditions. For example, two inches of rain in one area may cause no damage at all, while two inches of rain in a nearby area may cause road washouts and flooding of buildings. Typically, small local drainage basins have very short response times, and may reach flood levels within a few hours or less. Large drainage basins, such as the Columbia River Basin, usually have response times of a week or more.

Precipitation varies significantly across the Planning Area, with higher precipitation at higher elevations, especially on the slopes of Mount Hood. The impact of heavy rainfall depends on the total inches of rain, rain-induced snowmelt and the intensity of rainfall (inches per hour or inches per day). Topographic and hydrological conditions — such as steep or flat terrain, or poorly or well-drained soil — also affect the magnitude, duration and extent of heavy rainfall. Identification of specific sites subject to localized flooding is based on historical occurrences of repetitive flooding. Flood data are addressed in section **3.2 Flood.**

Flash floods, which are produced by episodes of intense heavy rains (usually within six hours or less) or dam failures, are rare in western Oregon but do present a potential hazard. See section **3.2 Flood** for more information about dam failure.

Heavy rainfall also can trigger landslides in areas with saturated soil. See section **3.3 Landslides**.

## *Windstorm*

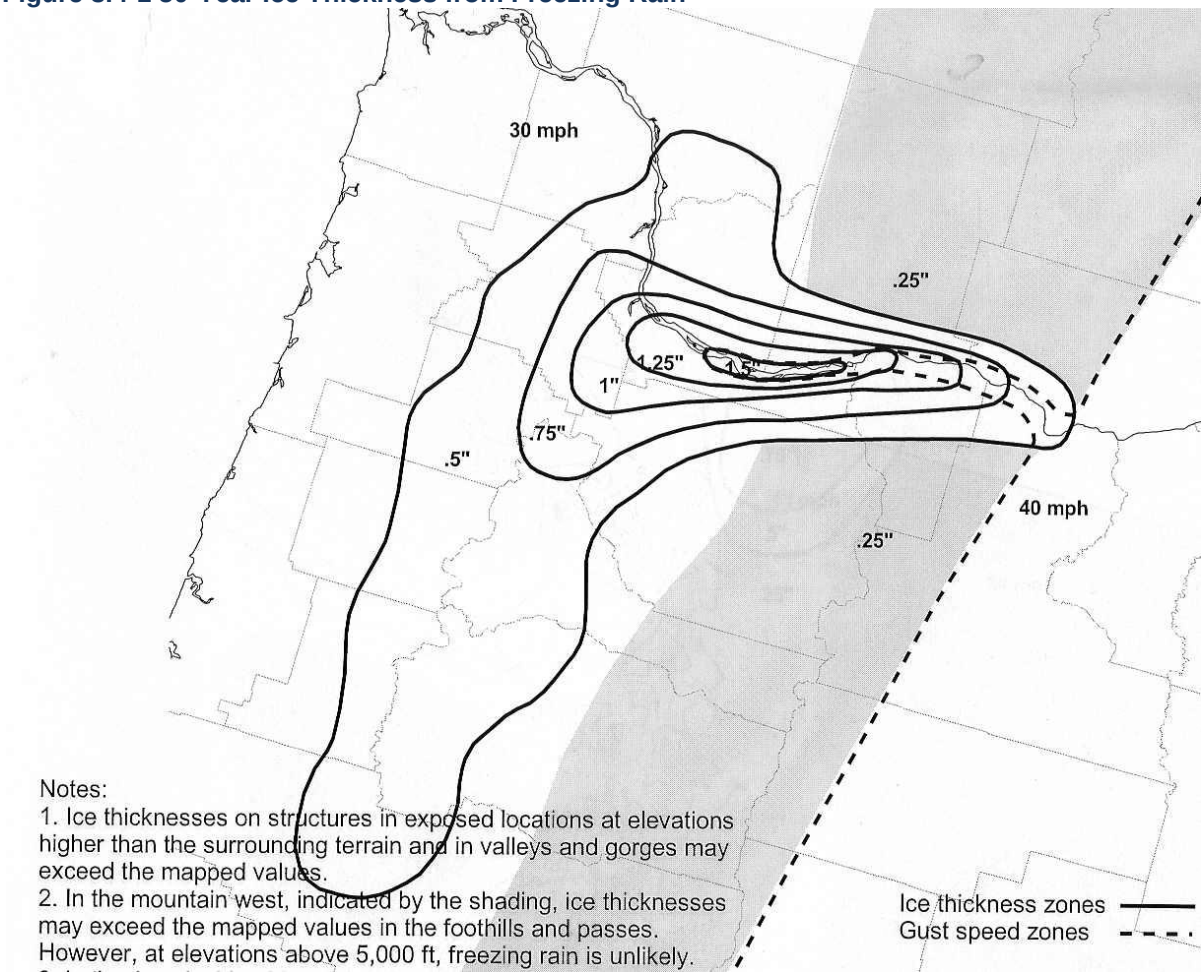
Wind speeds associated with winter storms vary depending on meteorological conditions and local topography. Wind speeds in much of the Planning Area are higher than many locations in western Oregon, other than the coast, because of the unusually high winds common in the Columbia River Gorge. High elevations, such as on Mount Hood, experience even higher wind speeds.

The highest sustained wind speed recorded at the Portland International Airport was 88 mph during the 1962 Columbus Day windstorm. The peak gust recorded during this storm was 104 mph before the wind equipment was damaged; thus, the actual peak gust likely was higher than 104 mph.

## *Snow and Ice*

The level of risk to snow and ice storms is relatively high for the Planning Area, especially ice storms. Higher elevations receive much higher snowfall than areas at lower elevations. Risk of ice storms in western Oregon is highest along the Columbia River (**Figure 3.4-1**). In fact, this area has the highest level of ice storm in the entire United States, according to a report from the American Lifelines Alliance (2004).

**Figure 3.4-1 50-Year Ice Thickness from Freezing Rain**




Source: American Lifelines Alliance, 2004

### *Other Severe Weather*

Other severe weather events including severe thunderstorms, hail, lightning, tornadoes and drought/heatwave tend to impact the Planning Area during summer months. These events are less frequent and have a lesser impact on our communities than do severe winter storms. Typically, these events are too minor to be recorded and damage is localized. As such, little data is available for these hazards. Nonetheless, these types of severe weather events impact communities in the Planning Area to some extent and should be mentioned.

## 3.4.2 History

Recent winter storms affecting Multnomah County in 2008, 2009, 2010, 2012 and 2015 brought multiple countywide rain, ice and snow storms. Rains caused flooding and landslides. Freezing rain turned to ice.

The most recent major snow storm affecting the Planning Area occurred in December 2008. This storm dumped more than a foot of snow and ice on the area. The major effects were road closures, including closures on hilly streets, and along Interstate 84 through the Columbia River Gorge for two days. The storm also caused many local power outages.

Ice storms have affected communities in the Planning Area throughout history. **Figure 3.4-2** shows downtown Troutdale after the ice storm of November 18, 1921.

**Figure: 3.4-2 Ice Storm in Downtown Troutdale, November 18, 1921**

Source: Unknown.

In February 1996, rain, snow, flooding and landslides resulted in power outages, road closures and property damage. Also in 1996, there was a significant ice storm in December that covered parts of the Columbia River Gorge in up to four to five inches of ice. Interstate 84 was closed for four days. There were hundreds of downed trees and power lines, with widespread power outages in the greater Portland metro area. Both 1996 events were recognized with disaster declarations, DR-1099 and DR-1160 respectively.

The National Climatic Data Center (NCDC) database lists seven hail events in Multnomah County between 1991 and 2010. Six of the events had hail diameters of 0.5 inches to 1.5 inches. Two of these events resulted in minor damages, with a total of roughly $10,000 per event. There is little data before 1991, indicating the database likely is incomplete for earlier years.

The NCDC database lists an additional seven severe lightning events for Multnomah County. Only three events reported damages, in 1995, 2005 and 2008. Two of these events occurred in Gresham during the month of June: in 1995, with $115,000 in damages; and in 2005, with $50,000 in damages.

The NWS identifies four historic tornadoes (1972, 1978, and two in 1991) and one cyclonic storm (1904) within Multnomah County. The 1972 tornado caused relatively minor damage in the county and approximately $6 million in damage in Vancouver, Washington. This event demonstrates the low probability but significant damage that can result from tornadoes.

These and other significant severe weather events that have impacted the Planning Area are listed in **Table 3.4-2**.

**Table 3.4-2 Significant Historic Severe Weather**

| Date | Location | Type of Severe Weather | Description |
|---|---|---|---|
| Dec. 1861 | Statewide | Snow | Snowfall 1-3 inches. Snow in Willamette Valley until late February 1862. |
| Winter 1862, 1866, 1884, 1885, 1890, 1892, 1895 | Portland area / Northern Willamette Valley | Snow | Severe winter conditions, especially in Portland area. Record-breaking snowfalls (especially in 1892). |
| Mar. 1904 | E. Portland | Tornado | “Cyclonic storm” damaged the Lewis and Clark Fairgrounds, several shacks and a large warehouse. |
| Jan. 1916 | Statewide | Snow | Two snow storms, each dropped five inches or more. |
| Dec. 1919 | Portland area | Snow | Third heaviest snowfall on record. Columbia River froze, closing navigation. |
| Jan. 1921 | Multnomah County | Ice storm | |
| Nov. 1921 | Troutdale | Ice storm | Closed downtown Troutdale. |
| Winter 1927, 1936, 1937, 1943, 1949 | Portland area, W. Oregon | Snow | Heavy snowfall. |
| Apr. 1931 | W. Oregon | Winter storm | Unofficial wind speeds reported at 78 mph. Damaged fruit orchards and timber. |
| Jan. 1950 | Statewide | Snow | Friday the 13th Storm. Heaviest snowfall since 1890. Freezing rain. Deep snowdrifts closed all highways west of the Cascades and through the Columbia River Gorge. Roads and schools closed. Downed power lines. Severed communication. Hundreds of thousands of dollars in property damage. |

| Date | Location | Type of Severe Weather | Description |
|---|---|---|---|
| Nov. 1951 | W. Oregon | Winter storm | |
| Dec. 1951 | W. Oregon | Winter storm | Statewide storm with wind speeds 60 mph in Willamette Valley. Widespread damage to transmission and utility lines. Damaged buildings. |
| Dec. 1955 | W. Oregon | Winter storm | |
| Winter 1956 1960, 1962 | W. Oregon | Snow, ice | Packed snow became ice. Many auto accidents. |
| Nov. 1958 | Statewide | Winter storm | Every major highway blocked by fallen trees during windstorm. Gusts up to 71 mph. |
| Mar. 1960 | Statewide | Snow | Snowfall amounts were 3-12 inches, depending on location. |
| Oct. 1962 | W. Oregon | Winter storm | 1962 Columbus Day Storm. Most severe windstorm for western Oregon due to sustained wind speeds and damage levels. Highest sustained winds, 88 mph, at Portland International Airport. Winds in the Willamette Valley up to 116 mph. Estimated damages $170 million. 84 homes destroyed, 5,000 severely damaged. |
| Dec. 1964 | Statewide | Heavy rains and flooding | DR-184. Occurred on Dec. 24, 1964. |
| Mar. 1963 | W. Oregon | Winter storm | |
| Oct. 1967 | W. Oregon | Winter storm | |
| Jan. 1969 | Statewide | Snow | Record-breaking snowfalls. $3 to $4 million in property damage. |
| Mar. 1971 | W. Oregon | Winter storm | Great damage in the Willamette Valley; homes and power lines destroyed by falling trees. |
| Jan. 1972 | W. Oregon | Storms and flooding | DR-319. Storm and flooding events on Jan. 21, 1972. |
| Apr. 1972 | Portland area | Tornado | F3 tornado, the most violent tornado in Oregon's recorded history. About $250,000 damages across the state. About $5 million damages, six deaths, 300 injuries in Vancouver, WA. |
| Aug. 1978 | Near Gresham | Tornado | Small tornado touched ground briefly with some damage to buildings and crops. |
| Jan. 1980 | Statewide | Winter storm | Series of storms bringing snow, ice, wind and freezing rain. Six fatalities. |
| Nov. 1981 | W. Oregon | Winter storm | |
| Feb. 1985 | Statewide | Snow | Western valleys received 2-4 inches of snow. Massive power failures (tree limbs broke power lines). |
| Dec. 1985 | Willamette Valley | Snow | Heavy snowfall throughout valley. |
| Mar. 1988 | Statewide | Winter storm | Strong winds. Heavy snow. |
| Feb. 1989 | Statewide | Winter storm | Heavy snowfall. Record low temperatures. |
| Jan. 1990 | Statewide | Winter storm | Heavy rain with winds greater than 75 mph; significant damage; one death. |
| Feb. 1990 | Statewide | Snow | Average snowfall from one storm was about four inches in the Willamette Valley. |
| Apr. 1991 | Near Gresham | Tornado | Small weak tornado touched down. Slight damage. |
| Nov. 1991 | Near Troutdale | Tornado | Small tornado damaged fencing, with minor damage to one building. |
| Dec. 1992 | W. Oregon | Snow | Heavy snow. Interstate 5 closed. |
| Feb. 1993 | W. Oregon | Snow | Record snowfalls. |
| Jun. 1995 | Gresham | Lightning | $115,000 in damages. |
| Dec. 1995 | Statewide | Winter storm | Winds reached 62 mph in the Willamette Valley. |

| Date | Location | Type of Severe Weather | Description |
|---|---|---|---|
| Feb. 1996 | Columbia Gorge | Winter storms, flooding, landslides | DR-1099. Winter storms with rain, snow, ice, floods and landslides. Power outages, road closures and property damage. |
| Dec. 1996 | Statewide | Winter storm | DR-1160. Severe snow and ice. Up to four to five inches of ice in the Columbia River Gorge. Interstate 84 closed for four days. Hundreds of downed trees and power lines. Widespread power outages in the greater Portland area, including Multnomah County. |
| Nov. 1997 | W. Oregon | Wind storm | Uprooted trees. Considerable damage to small airports. Winds up to 52 mph. |
| Winter 1998-1999 | Statewide | Snow | Series of storms. One of the snowiest winters in Oregon history. |
| Jan.- Feb 1999 | NW Oregon | Rain, Rain on snow, flooding, landslides, mudslides | Widespread flooding on smaller rivers and streams; numerous landslides and mudslides. Historic Columbia River Highway east of the Sandy River Bridge covered with slides coming from the cliffs above. |
| Feb. 2002 | W. Oregon | Winter storm | Damages $6.14 million. Downed power lines and trees. Buildings damaged. Power outages caused some water supply problems. |
| Dec. 2003-Jan. 2004 | Statewide | Snow and ice | DR-1510. Much of Portland area shut down. Twenty-six counties received assistance from the Federal Emergency Management Agency (FEMA). |
| Jun. 2005 | Gresham | Lightning | $50,000 in damages. |
| Dec. 2005 | Multnomah, Clackamas & Washington counties. | Wind storm | $9,000 in property damage in Multnomah, Clackamas and Washington counties. |
| Jan. 2006 | Willamette Valley | Windstorm | Winds up to 58 mph caused total of $500,000 in damages over Clackamas, Columbia, Washington, Multnomah, Yamhill, Marion and Polk counties. |
| Feb. 2006 | Multnomah, Clackamas, Washington, and Columbia Counties | Windstorm | Winds caused $167,000 in damages for Multnomah, Clackamas, Washington and Columbia counties; impacts also in Region 1 & 3 for a total of $575,000 in damages. |
| May 2006 | Statewide | Storms, flooding, landslides, mudslides | DR-1632. Statewide impacts from storms, floods, landslides and mudslides. |
| Jul. 2006 | Statewide | Heatwave | Multiple days of temperatures over 100 degrees Fahrenheit. |
| Dec. 2006 | W. Oregon | Winter storm | |
| Jul. 2007 | Multnomah & Washington Counties | Windstorms | Wind gusts up to 58 mph, several downed trees; $5,000 in damage ($1,000 in Beaverton). |
| Sep. 2007 | Multnomah County | Wind storm | Severe storm with hail and tornado; $5,000 in damages. |
| Dec. 2007-Jan. 2008 | W. Oregon | Winter storm | DR-1824. Severe winter storm, record and near-record snow, landslides and mudslides. Gresham received 26 inches of snow . |
| Jul. 2008 | Fairview | Lightning | $2,000 in damages. |
| Dec. 2008-Jan. 2009 | W. Oregon | Winter storm | |
| Dec. 2009 | Statewide | Winter storm | Snow and freezing rain in Salem, and from Portland to Hood River. I-84 closed for 22 hours. |
| Nov. 2010 | Statewide | Winter storm | Snow, freezing rain and ice from Portland to Hood River. |

| Date | Location | Type of Severe Weather | Description |
|---|---|---|---|
| Jan. 2011 | Statewide | Winter storm | DR-1956. Severe winter storm, flooding, mudslides, landslides and debris flows. |
| Jan. 2012 | Multnomah County | Winter storm | Snow and ice east of Troutdale. I-84 closed for nine hours. |
| Dec. 2015 | W. Oregon | Winter storm | DR-4258. Severe winter storms, straight-line winds, flooding, landslides and mudslides. |

Sources: Taylor and Hatton, 1999; DLCD, 2015; NOAA, no date; NCDC, no date; FEMA Disaster Declarations website.

## 3.4.3 Probability

### *Severe Winter Weather*

#### *Heavy Rainfall*

Extreme precipitation is perhaps the most common and widespread natural hazard in Oregon (DLCD, 2015). Severe or prolonged storms can raise rivers and streams to their flood stages and keep them there for several days. Typically, the area experiences flooding after more than three days of rain or when heavy rain falls on already saturated soil in a short period of time.

Areas with high risk to flooding are identified in Flood Insurance Rate Maps (FIRMs) created by FEMA. Data from FIRMs have been used to create flood risk maps found in **Chapter 3.2 Flood.** These maps illustrate the 0.1% and 0.2% annual chance of flooding across the county.

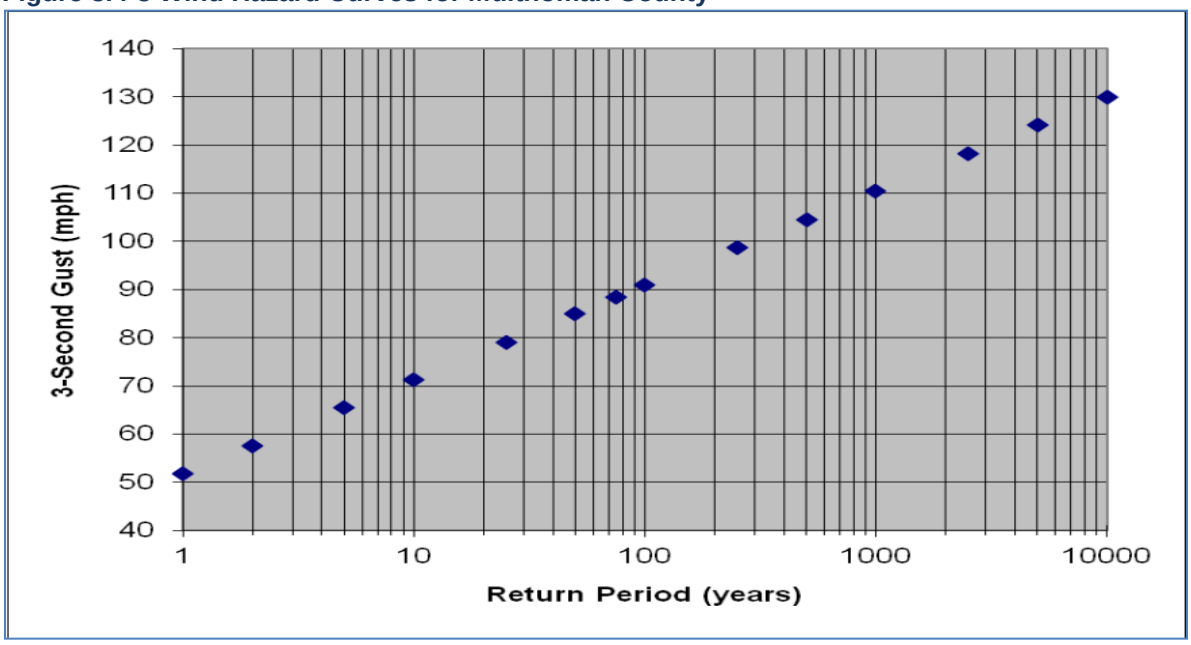
*Temperature and precipitation extremes are projected to increase in the Northwest.*

*– Oregon Climate Change Research Institute, 2013*

#### *Windstorm*

The wind hazard curves for Multnomah County, based on the American Society of Civil Engineers (ASCE) 7-10 probability relationships for standard wind design locations, is shown in **Figure 3.4-3.** The 10-year and 100-year return period for high wind events are approximately 71 mph and 91 mph respectively. These wind speeds are three-second gusts which typically are about 30% higher than sustained wind speeds.

**Figure 3.4-3 Wind Hazard Curves for Multnomah County**

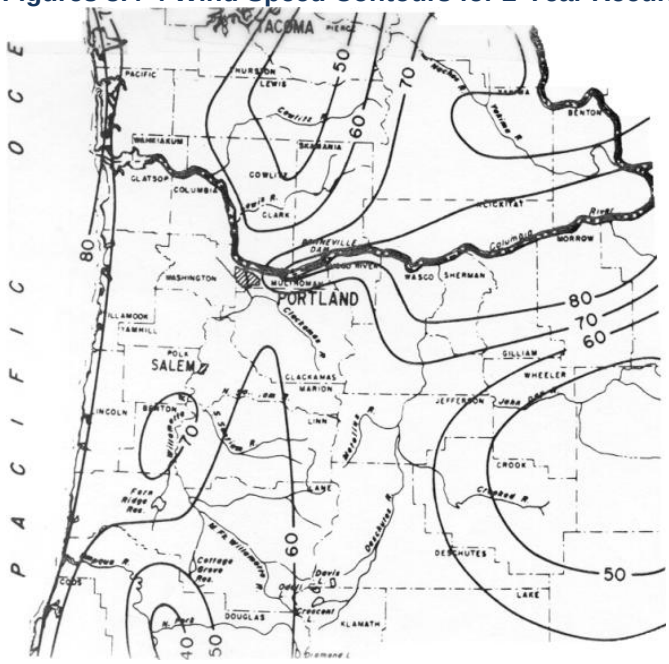



Source: Unknown.

**Figures 3.4-4** and **3.4-5** show wind speed contours for recurrence intervals of two years and 50 years. These data are for sustained wind speeds. Peak gusts are commonly 30% or so higher than sustained winds. Though this data is fairly old, published in *The Journal of Applied Meteorology* in 1981, according to the NWS the information is still representative of overall wind conditions in Oregon and communities within Multnomah County (Tyree Wilde, NWS, personal communication, 2016).

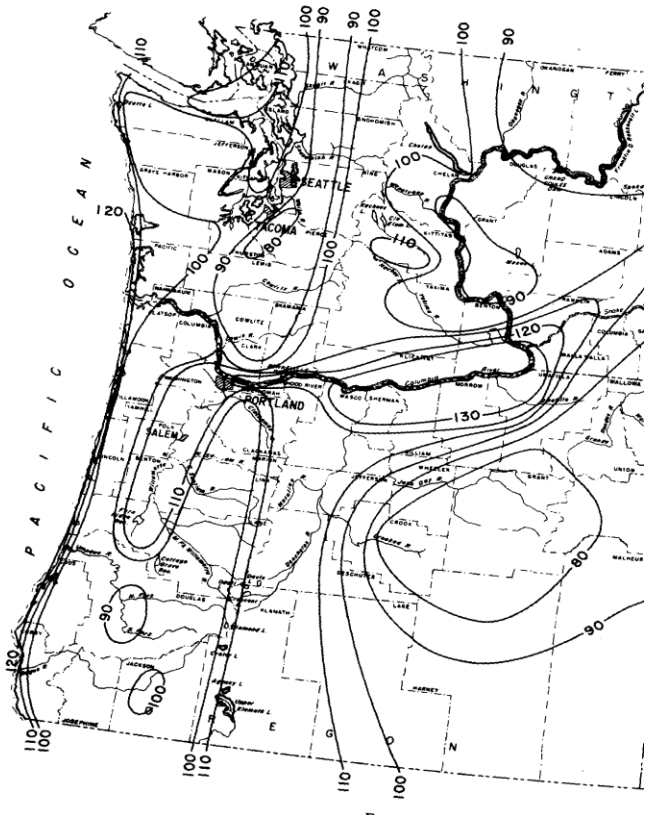
These wind speeds are high enough to cause widespread damage, and exposed sites may experience severe damage. Winter storms that create significant wind damage occur about once every decade. Storms producing major wind damage occur about once every few decades.

**Figures 3.4-4 Wind Speed Contours for 2-Year Recurrence Interval (km/hour)**




Source: Source: Wantz and Sinclair, 1981

**Figures 3.4-5 Wind Speed Contours for 50-Year Recurrence Interval (km/hour)**




Source: Wantz and Sinclair, 1981

### *Snow and Ice*

Average annual snowfall in the Planning Area is only about 5 to 6 inches. As described earlier, there are years of no snow on record, and many years with 10 or more inches. Snowfall amounts and locations vary. However, as history shows, the Planning Area is susceptible to notable snow and ice storms that can impact the larger Pacific Northwest region.

Ice thickness can reach about 1.5 inches in a 50-year return period in the Planning Area**.** Ice thicknesses for 25-year and 10-year ice storms would be about 1.2 and about 0.75 inches respectively. That is enough ice to cause significant (0.75 to 1.2 inches) to substantial (1.5 inches) widespread damage, especially to trees and utility lines (American Lifelines Alliance, 2004).

### *Climate Change*

According to the 2015 Oregon Natural Hazards Mitigation Plan (NHMP), there is little research on how climate change influences winter storms in the Pacific Northwest. However, climate models do project hotter, drier summers with more high-heat days, and warmer winters with the potential for more intense rain events. For more information on how climate change is projected to influence flooding, landslides and wildfire, see sections **3.2 Flood, 3.3 Landslide** and **3.6 Wildfire.**

As temperature and precipitation patterns change, there is likely to be more data about severe summer weather events, including drought. Future iterations of this plan will assess the Planning Area's risk to more severe weather events as new data become available.

A declining snowpack is an important indicator of a changing climate. The Pacific Northwest has experienced the largest decline in average snowpack in the western United States (Multnomah County and City of Portland, 2014). A 2013 study by the Oregon Climate Change Research Institute states two key findings related to impacts of reduced snowpack on our water systems:

- "Reduced snowpack and shifts in streamflow seasonality due to climate change pose an additional challenge to reservoir system managers as they strive both to minimize flood risk and to satisfy warm season water demands.
- Reduced snowpack and shifts in timing and magnitude of precipitation and runoff could significantly affect culturally and economically important aquatic species, such as salmon."

## 3.4.4 Vulnerability

As cold arctic winds blow down the Columbia River Gorge over east Multnomah County, it is not uncommon to have severe ice and sleet storms in the Planning Area. According the 2015 Oregon NHMP, the Portland metro area is the most vulnerable [to severe winter weather], and these storms can have negative impacts on the economy statewide. Winter storms have delayed air traffic and closed the Portland International Airport. Ice and sleet storms on roads create extremely dangerous driving conditions and can cripple the movement of goods and services across the state (DLCD, 2015). Road closures during winter storms are common due to washouts, deep water on roads, high winds, heavy wet snow, or ice storms. Closures on Interstate 84 outside of Multnomah County may affect transportation to/from the county. Due to the large population and large truck commodity transport through the Portland metro region, it is extremely costly when severe winter storms close roads (DLCD, 2015).

Severe weather events can affect buildings and infrastructure directly and indirectly. Direct effects include damages within the county. Indirect effects involve damages outside the area that affect the county, such as damages that interrupt or stop transportation routes or utility services.

Ice and high winds can cause branches, trees and power lines to break or fall, ultimately creating power disruptions or outages. Tree-fall-induced power outages primarily affect local electric distribution systems. Fortunately, transmission system cables generally are less prone to tree-fall damage because of design and better tree trimming maintenance.

In severe wind storms, direct wind damage or wind-driven debris can damage buildings, especially more vulnerable types of construction such as mobile homes. A significant portion of the housing stock in Wood Village and east of the Sandy River consists of manufactured homes, roughly 30% and 20% respectively, making these communities particularly vulnerable to wind storms. See **2.4 Housing** in section **2 Community Profile** for more information.

**Annex I: Human-Caused and Technological Hazard Identification and Risk Assessment** identifies earthquakes and severe weather events as posing the greatest threat to long-term utility interruption or failure. The impacts from utility failures often are widespread and can affect thousands of people, even when small areas of infrastructure are affected.

Probable impacts of winter storms to the Planning Area are summarized in **Table 3.4-3**

**Table 3.4-3 Probable Impacts of Winter Storms**

| Inventory | Probably Impacts |
|---|---|
| Portion of Multnomah County affected | Severe winter storms may affect all of Multnomah County, although the severity of impacts typically varies significantly with location within the county. |
| Buildings | Isolated damage from tree falls, wind, heavy snow loads, landslides and localized flooding. Mobile homes are more vulnerable to high winds. |
| Streets and Roads within Multnomah County | Road closures due to snow or ice, tree falls, landslides or flooding. |
| Highways to/from Multnomah County | Road closures also may affect major highways to/from Multnomah County, especially Interstate 84 through the Columbia River Gorge |
| Airports | Severe weather may result in temporary closures of Portland International Airport and smaller airports in Multnomah County |
| Electric Power* | Loss of electric power may be localized or widespread due to effects of wind, snow, ice, and tree falls on local distribution lines or very widespread transmission line fail |
| Other Utilities* | Generally minor impacts on other utilities from winter storms, except for possible effects of loss of electric power; however, telephone and other telecommunications systems with above-ground lines also may experience outages. |
| Casualties | Potential for casualties (deaths and injuries) from tree falls or contact with downed power lines, or from traffic accidents. |

*See **Annex I: Human-Caused and Technological Hazard Identification and Risk Assessment** for information on the vulnerability of utility systems in the Planning Area.

Source: Unknown.

## 3.4.5 References

American Lifelines Alliance report: Extreme Ice Thicknesses from Freezing Rain. (2004, September). Retrieved from http://www.americanlifelinesalliance.com/pdf/ALAIceLoadFinalReport092804.pdf

Federal Emergency Management Agency (FEMA). (2016). Presidential Disaster Declaration information. Retrieved from https://www.fema.gov/disasters

The Journal of Applied Meteorology. (1981). "Distribution of Extreme Winds in the Bonneville Power Administration Service Area."

Multnomah County, & City of Portland. (2014). Climate Change Preparation Strategy: Preparing for Local Impacts in Portland and Multnomah County 2014.

National Oceanic and Atmospheric Administration (NOAA). (no date). National Weather Service Forecast Office, Portland, Oregon. Retrieved from http://www.wrh.noaa.gov/pqr/paststorms/index.php

National Climatic Data Center (NCDC). (no date). Retrieved from http://www.ncdc.noaa.gov/

Oregon Climate Change Research Institute. (2010). Oregon Climate Assessment Report, Dello, K.D., & Mote, P.W. (Eds). College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon. Retrieved from http://occri.net/wp-content/uploads/2011/03/exec_summaryOCAR.pdf.

Oregon Climate Change Research Institute. (2013). Climate Change in the Northwest: Implications for our Landscapes, Waters, and Communities, Dalton M. M., Mote, P. W., & Snover, A. K. (Eds). Retrieved from http://occri.net/wp-content/uploads/2013/11/ClimateChangeInTheNorthwestExecutiveSummary.pdf.

Oregon Department of Land Conservation and Development (DLCD). (2015). 2015 Oregon Natural Hazard Mitigation Plan. Retrieved from http://www.oregon.gov/LCD/HAZ/pages/nhmp.aspx

Portland Tribune. (2012, January 17). Confirmation of November 21, 1921, winter storm date. Retrieved from http://portlandtribune.com/go/43-opinion/18378-gorge-ice-30-feet-thick-in-1922?tmpl=component&print=1

Taylor, G. H., & Hannan, C. The Oregon Weather Book. (1999). Oregon State University Press.

U.S. Army Corps of Engineers, Portland District. (no date). The Bonneville Lock & Dam Fact Sheet. Retrieved from http://www.nwp.usace.army.mil/Portals/24/docs/locations/bonneville/Bonneville_FS.pdf.

Wantz, J. W., & Sinclair, R. E. (1981, August 31). Distribution of Extreme Winds in the Bonneville Power Administration Service Area.

Western Regional Climate Center. (no date). Retrieved from http://www.wrcc.dri.edu

Wilde, T. (2016, May 10 and 12). National Weather Service, personal communication, Referenced documents: KPDX 1940-2015 Annual Summaries; KTTD 1948-2015 Annual Summaries; and PDX Seasonal Snowfall 1871-2012.