Volume II: Hazard Annexes[1]

[1] Pages 14-45 of the 2012 Hood River County Hazard Identification and Vulnerability Analysis (HIVA)

DROUGHT

Hazard Definition

Drought is a condition of climatic dryness severe enough to reduce soil moisture and water below the minimum necessary for sustaining plant, animal, and human life systems.

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 that 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. For more information on the *Palmer Index* see **Appendix D**.

The Oregon Drought Severity Index is the most commonly used drought measurement in the state. It is considered to be a better indicator of drought severity because it incorporates both local conditions and mountain snowpack. The Oregon Drought Severity Index categorizes droughts as mild, moderate, severe, and extreme. The index is available from the Oregon Drought Council.

Early Oregon records, dating back to the late 1800s, clearly associate drought with a departure from expected rainfall. Concern for mountain snowpack, which feeds the streams and rivers, came later. Droughts were particularly noteworthy in the 1890s and during the following years:

History

Occurrences (Oregon State)

1904-05:	Drought period of about 18 months
1917-31:	Very dry period punctuated by brief wet spells (1920, 1927)
1939-41:	Three-year intense drought
1965-68:	Three-year drought following the big regional floods of 1964-65
1976-77:	Brief very intense statewide drought
1985-94:	Generally dry period, capped by statewide droughts in 1992 and 1994
2005:	Dry period (Governor declares drought conditions in **Hood River County)**

Hazard Identification

Nearly all areas of the county may be vulnerable to drought.

As recently as 2005, Hood River County has suffered from extended drought conditions. Water flows, on bodies of water, such as Fifteen Mile Creek were regulated back to historic water rights first established in 1860. During this same time period, Eight Mile Creek and Tygh Valley were regulated back to 1909 rights, and even at that, there was not enough water to satisfy the demand. Badger Lake was expected to be empty by mid August, 2 to 3 weeks earlier than usual.

Temperatures remained in the upper 90's/ low 100's and no measurable precipitation occurred.

On August 8, 2005, Hood River at the Tucker Bridge measured a flow of 211 cubic feet per second (cfs). Over the previous 45 years, flows on that date have average 419 cfs.

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In every drought, agriculture has felt the impact, especially in non-irrigated areas such as farms. Droughts have left their major impact on individuals (farm owners), on the agricultural industry, and to a lesser extent, on other agriculture-related sectors.

There is increased danger of wildland fires. Millions of board feet of timber have been lost. In many cases, erosion has occurred which caused serious damage to aquatic life, irrigation, and power development by heavy silting of streams, reservoirs, and rivers.

Low stream flows have created high temperatures, oxygen depletion, disease, and lack of spawning areas for our fish resources.

All of the above effects result in economic and revenue losses for business, cities and the county.

History suggests a **high probability of occurrence.** The entire population of the county is vulnerable to the effects of drought. Transportation and communications infrastructure would be minimally impacted, if at all. As growth places more pressure on limited local resources, future impacts may be greater, suggesting **high vulnerability**. A **high risk rating** is assigned.

Conclusions

As a result of droughts, new techniques have occurred in agriculture. Federal and state governments have also assumed an active role in developing new water projects and soil conservation programs. ORS 536.700 pertains to drought relief and emergency water shortage powers.

Better forest fire protection techniques have been developed and total acreage burned has continually decreased.

Progress is being made in dealing with the impact of droughts through proper management of Oregon's water resources. Hopefully, information being collected and shared will assist in the formulation of effective programs for future water-short years.

EARTHQUAKE

Hazard Definition

An earthquake is the shaking of the ground caused by an abrupt shift of rock along a fracture in the earth, called a fault. There are three categories of quakes and each type may, to differing degrees affect Hood River County. The first is a shallow or crustal quake. These occur at a depth of 5 to 10 miles beneath the earth's surface. These quakes are associated with fault movement within a surface plate. The second type of earthquake is an intraplate, or "deep" earthquake. Intraplate quakes occur when an earthquake on a geologic plate affects another plate. In Pacific Northwest geology, intraplate quakes happen when the Juan de Fuca plate breaks up underneath the continental plate, approximately 30 miles beneath the earth's surface. The third type of quake is a subduction zone earthquake. These occur when two converging plates become stuck along their interface. Continued movements between the plates will build up energy across the locked surface until the plates abruptly slip along the interface when the strain is released.

Magnitude is the measure of the strength of an earthquake, or the strain energy released by it, as determined by seismographic observations (size or length of a seismic signal). There are several types of magnitude scales of which the Richter Scale is the best known. Magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude of 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude. As an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value. See **Appendix D** for more information on earthquake measuring scales.

History

Each year, since 1980, the Pacific Northwest Seismograph Network has recorded an average of more than two thousand earthquakes in Washington and Oregon. The vast majority is shallow earthquakes and 99% had a magnitude less than 3.0.

The shallow 1872 earthquake in North Cascades of Washington was the largest in the history of Washington and Oregon. It had an estimated magnitude of 7.4 and was followed by many aftershocks. In 1993, a magnitude 5.6 earthquake in the Willamette Valley of Oregon caused $28 million in damages, including damage to the Oregon State Capital in Salem. A pair of earthquakes near Klamath Falls, Oregon of magnitude 5.9 and 6.0, caused two fatalities and $7 million in damage. Large shallow quakes occur in the Pacific Northwest about once every 50 years.

Because we do not have a complete history of Oregon earthquakes, we cannot fully assess the future risk. In western Oregon, the high rainfall promotes high erosion rates and dense ground cover, both of which tend to hide faults.

- Approximate years: 1400 BCE,1050 BCE,600 BCE,400,750,900, Offshore, Cascadia subduction zone, Probably 8-9, Researchers Brian Atwater and Eileen Hemphill-Haley have dated earthquakes and tsunamis at Willapa Bay, Washington; these are the midpoints of the age ranges for these six events.

- January 26, 1700, Offshore, Cascadia subduction zone, Approximately 9, generated a tsunami that struck Oregon, Washington and Japan; destroyed Native American villages along the coast.

- November 23, 1873, Oregon/California border, near Brookings, 6.8, Felt as far away as Portland and San Francisco; may have been an intraplate event because of lack of aftershocks.

- July 15, 1936, Milton-Freewater, 6.4, Two foreshocks and many aftershocks felt; $100,000 damage (in 1936 dollars).

- April 13, 1949, Olympia, Washington, 7.1, Eight deaths and $25 million damage (in 1949 dollars); cracked plaster, other minor damage in northwest Oregon.

- November 5, 1962, Portland/Vancouver, 5.5, Shaking lasted up to 30 seconds; chimneys cracked, windows broke, furniture moved.

- 1968 Adel Swarm, largest 5.1 Swarm, lasted May through July, decreasing in intensity; increased flow at a hot spring was reported.

- April 12, 1976, Near Maupin, 4.8, Sounds described as distant thunder, sonic booms, and strong wind.

- April 25, 1992, Cape Mendocino, California,7.0, Subduction earthquake at the triple junction of the Cascadia subduction zone and the San Andreas and Mendocino faults.

- March 25, 1993, Scotts Mills, 5.6, On Mount Angel-Gales Creek fault; $30 million damage, including Molalla High School and Mount Angel church.

- September 20, 1993, Klamath Falls, 5.9 and 6.0, Two deaths, $10 million damage, including county courthouse; rock falls induced by ground motion.

A northwest subduction zone earthquake has not occurred locally since the 1700's. However, similar subduction zones worldwide have produced earthquakes of magnitude 8 or larger. An example is the 9.2 Alaska earthquake of 1964. Geologic evidence indicates that the Cascadia Subduction Zone has generated great earthquakes at roughly 500 year intervals, most recently about 300 years ago. Researchers estimate there is a 10% chance of a local subduction zone earthquake within the next 200 years.

Hazard Identification

The Pacific Northwest is a very seismically active area. Potential earthquake sources in Hood River County are not well known because there have not been frequent large earthquakes here as there have been in California. Estimations of possible earthquake sources are limited to studies of many small earthquakes, investigations of known faults, and other geological surveys.

Earthquakes in Hood River County are most likely to originate from two sources: 1) the Cascadia Subduction Zone and 2) faults near the eastern end of the Columbia River Gorge.

Cascadia Subduction Zone - The Cascadia Subduction Zone lies about 50 miles offshore, extending from near Vancouver Island to northern California. The zone is where the oceanic Juan de Fuca plate dives beneath the continental North American plate. These plates are converging at a rate of 1 – 1.5 inches per year.

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The entire county population, property, commerce, infrastructure and services may be vulnerable to an earthquake. The scope of damage is a function of earthquake magnitude and level of preparedness. Damage could range from minimal to moderate loss of life and destruction of property.

Most injury, death, and property damage in an earthquake result from seismic impacts on structural and non-structural materials. The vulnerability of certain areas partially depends on the types of structures in that area. A wood frame residential structure that is adequately secured to the foundation is relatively safe. Un-reinforced masonry buildings are at greatest risk from seismic impacts. Most injuries in earthquakes result from non-structural materials such as light fixtures, equipment, and furniture, falling on people and causing injury.

There is really no past "recent" history of earthquakes in Hood River County. County residents have felt some earthquakes distant from Hood River County. Even with this lack of history, geology clearly shows that the county has been impacted by significant events in the last 500 years. It is this 500-year history that Oregon Department of Geology and Mineral Industries based the 1999 damage estimates on.

Cascadia Subduction Zone Model

Expected losses in Hood River County from the magnitude 8.5 Cascadia earthquake include:

- No casualties or deaths
- No buildings extensively damaged
- Over $3,800,000.00 of economic damage

500 Year Return Interval model

Every part of Oregon has earthquakes. The 500-year model is an attempt to quantify the risk across the state. This estimate does not look at a single earthquake. Instead, this study includes many faults, each with a 10 percent chance of producing an earthquake in the next 50 years. It assumes each fault will produce a single "average" earthquake during this time. More and higher magnitude earthquakes than used in this study may occur.

This model under-represents losses, because a single fault might produce the "average" event, and also larger or smaller events, but only the average magnitude event is counted. So, if all expected earthquakes were included, the cumulative losses over the next 500 years would be higher than the estimated losses reported in this study.

Expected losses in Hood River County from the 500-year model include:

- 30 casualties, 1 death
- Over 5% buildings extensively damaged
- Over $78 million of economic damage

Most injury, death, and property damage in an earthquake result from seismic impacts on structural and non-structural materials. The vulnerability of certain areas partially depends on the types of structures in that area. A wood frame residential structure that is adequately secured to the foundation is relatively safe. An un-reinforced masonry building is at greatest risk from seismic impacts. Most injuries in earthquakes result from non-structural materials such as light fixtures, equipment, and furniture, falling on people and causing injury.

Another factor in earthquake vulnerability is soil type. Water-saturated loose sand and silt loses its ability to support structures in an earthquake. Areas in Hood River County that are near the flood plains near the Columbia River or areas with silt deposits are at the greatest risk during an earthquake.

Within the limits of predictability, we must assume a **moderate probability of occurrence** for a damaging earthquake during the next 50 years. A large earthquake centered in Western Oregon could have a minor impact on Hood River County suggesting **moderate vulnerability**. Accordingly, a **moderate-risk rating** is assigned.

Hood River County	8.5 Cascadia subduction zone event	500 year model
Injuries	0	30
Deaths	0	1
Displaced households	0	56
Short term shelter needs	0	40
Economic losses for buildings	$3 million	$62 million
Operating the day after the quake:		
Fire stations	99%	NA
Police stations	100%	NA
Schools	98%	NA
Bridges	95%	NA
Economic losses to:		
Highways	$704,000	$12 million
Airports	$76,000	$3 million
Communication systems:		
Economic losses	$17,000	$1 million
Operating the day of the quake	96%	NA
Debris generated (thousands of tons)	1	41

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

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

8.5 Cascadia event	Percentage of buildings in damage categories				
Building type	None	Slight	Moderate	Extensive	Complete
Agriculture	97	3	1	0	0
Commercial	96	3	1	0	0
Education	97	3	1	0	0
Government	97	3	1	0	0
Industrial	96	3	1	0	0
Residential	98	2	0	0	0

500 year model	Percentage of buildings in damage categories				
Building type	None	Slight	Moderate	Extensive	Complete
Agriculture	65	15	13	6	1
Commercial	57	17	17	8	1
Education	63	15	15	6	1
Government	57	16	17	7	2
Industrial	55	16	18	9	2
Residential	77	15	6	1	0

Conclusions

It is difficult to identify a part of the community that is not vulnerable to an earthquake. People, buildings, emergency services, hospitals, transportation lifelines, and water and wastewater utilities are susceptible to the effects of an earthquake. In addition, electric and natural gas utilities and dams have a potential to be damaged.

Earthquakes are unique in impact to structures. Injuries result from structural materials falling on people and creating hazards.

Effects of a major earthquake in the Pacific Northwest could be catastrophic, providing the worst case disaster short of war. Thousands of persons could be killed and many tens of thousands injured or left homeless. A major earthquake may create additional hazards such as pipeline line leaks and ruptures, hazardous materials releases, train derailments, and fires.

Mitigation activities such as the following should be instituted and maintained to lessen the potential problems.

a. Examination, evaluation, and enforcement of effective building and zoning codes.

b. Geologically hazardous areas, as defined by the Growth Management Act, should be identified and land use policies adopted to lessen risk.

c. Public information on what to do before, during, and after an earthquake should be provided to citizens.

d. Local and state governments should develop and maintain response procedures and keep mitigation programs ongoing.

FLOOD

Hazard Definition

Floods are common disaster in Oregon State and Hood River County. The State's climate, topography, and geology are conducive to flooding. Normal annual precipitation is approximately 32 inches in Hood River.

The main cause of Northwest floods is the moist air masses that regularly move over the region in the winter. In Hood River County, the weather that produces the most serious flooding events are extensive wet conditions that follow a period of mid and high elevation ice and snow pack development.

Riverine and flash floods may both occur in Hood River County. Riverine floods happen when the amount of water flowing through a river channel exceeds the capacity of that channel. Riverine floods are the most common types of flooding. Flash flooding occurs during sudden rainstorms when a large amount or rain falls in a very short period of time. These happen in steeply sloping valleys and in small waterways.

A secondary category of flood is the storm water or urban flood. Storm water flooding occurs when runoff from rainfall concentrates in developed areas, drainage, and low-lying areas. Poor drainage, elevated groundwater levels, and ponding are all symptoms of storm water flooding that can cause property damage.

Storm water flooding should be a concern in Hood River County because of rapid development.

History

January 1923 – Record flood levels on the Hood River.

May 1928 – Columbia River flooding occurred.

March 1931 - Flooding occurred on the Clackamas River.

May 30, 1948 – Columbia River crested at 34.4 ft. Flood stage at that time was 15 ft. This is the flood that destroyed the City of Vanport. Fifteen people died in the flood.

July 1956 – Flash flooding occurred in Central Oregon.

December 1964 – Region wide flooding occurred.

January - February 1996 - This widespread flood in the Pacific Northwest was the result of heavy rain and warming on heavy mid elevation snowpack, and was similar to regional flooding in December 1964. The Columbia River crested at 27.1 ft. on February 9. This flood occurred because of the confluence of several factors. The winter of 1995/96 was extremely rainy. Prior to the flooding period, the region experienced a cold snap with low elevation freezing, ice, and snow.

December 1996 – **February 1997** – Region wide flooding occurred.

November 2006 - November was a wildly wet month in Hood River County. Two of the wettest days of this record-breaking month were Nov. 6th, when 1.61 inches of rain fell, and Nov. 7th, with 1.97 inches. Total rainfall for November was 14.67 inches. The previous record for November was 11.09 inches in 1973. Estimated flood damages in the county came to $27 million.

Hazard Identification

Rivers in Hood River County historically flood every few years. These include the Hood River, Indian Creek, Phelps Creek and the Columbia River. Flood hazard areas are along the East, Middle and West forks of the Hood River, and along Emil, Odell, Baldwin and Neal Creeks. Flooding on these rivers and creeks usually occurs between October and March. Long periods of heavy rainfall and mild temperatures coupled with snowmelt contribute to flooding conditions.

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Hood River County participates in the National Flood Insurance Program and has developed local ordinances to better regulate and direct development in flood plain areas. These local ordinances regulate planning, construction, operation, and maintenance of any structures, and improvements, private or public. They work to insure that these developments are properly planned, constructed, operated, and maintained to avoid adversely influencing the regimen of a stream or body of water or the security of life, health, and property against damage by flood water.

Unfortunately, residents who live in flood plains face far greater risks than needed. These homeowners probably face greater financial liability than they realize. During a 30-year mortgage period, a home in a mapped flood plain has about a 26 percent chance of being damaged by a 100 year-flood event. The same structure has only about a one percent of being damaged by fire. Many homeowners who live in flood plains carry fire insurance, but do not carry flood insurance.

With some uninsured structures located in flood plains, Hood River County home and business owners are vulnerable to flood damage. Adding to this vulnerability, are increases in the percentage of households and population living in flood plains as new growth creates increasing pressure to develop more marginal land. Furthermore, as the density of development increases and permeable natural surfaces are replaced with homes and roads, the volume of storm water runoff and the area over which it floods will increase. As a result, unknown numbers of homes that were once outside mapped flood plains will face an increased threat of flooding, a threat they were never built to withstand. In fact, 35-40 percent of the National Flood Insurance claims are currently coming from outside the mapped flood plains.

According to the Hood River County Generalized Floodplain Report, published in 1975 by the U.S. Department of Agriculture, Soil Conservation Services, there are a total of 3,650 acres of private land and 1,220 acres of public land within the 100-year flood plain in the Central Valley area of the County. However, the report states that flood damage in this area has historically not been extensive as the creeks and rivers usually flow through deep ravines and canyons.

Historically, flooding occurs along one or more of the County's waterways every few years, suggesting a **high probability of occurrence.** Because of the relative land area and population affected, the County is exposed to **moderate vulnerability**. The frequency of flooding, the potential for simultaneous flooding events, plus the historical record of recurrent flooding and cumulative costs, all suggest the assignment of a **high risk rating.**

Conclusions

Floods can cause loss of life and great damage to structures, crops, land resources, flood control structures, roads, and utilities of all kinds.

Building in established floodplain areas must be regulated. Human-made developments within flood plains should be limited to non-structures such as parks, golf courses, farmlands, etc. These facilities have the least potential for damage, but maximize land use.

The general public should be made aware of hazardous areas and be given flood insurance and emergency preparedness information.

The National Weather Service has an extensive river and weather monitoring system and usually provides adequate and timely warning. The National Weather Service provides weather information to local jurisdictions and the public in a variety of ways, radio, Teletype, and telephone.

WILDLAND FIRE

Hazard Definition

Any instance of uncontrolled burning within a forested area is a forest fire, where as uncontrolled burning in grassland, brush, or woodlands is classified as a wildfire.

History

Wildfires reported in Hood River County since the turn of the century include the following:

Year	Name	Area	Acres
1902		Columbia Gorge	170,000
1991	Falls Fire	Columbia Gorge	1,100
2003	Herman Creek	Columbia Gorge	300
2006	Frankton Road Fire	Columbia Gorge	37
2008	Gnarl Ridge	Columbia Gorge	3,280
2009	Microwave Fire	Columbia Gorge	1,264

Hazard Identification

Hood River County's fire season usually runs from mid-May through October. However, any prolonged period of lack of precipitation presents a potentially dangerous problem. The probability of a forest fire in any one locality on a particular day depends on fuel conditions, topography, the time of year, the past and present weather conditions, and the activities (debris burning, land clearing, camping, etc.) which are or will be taking place.

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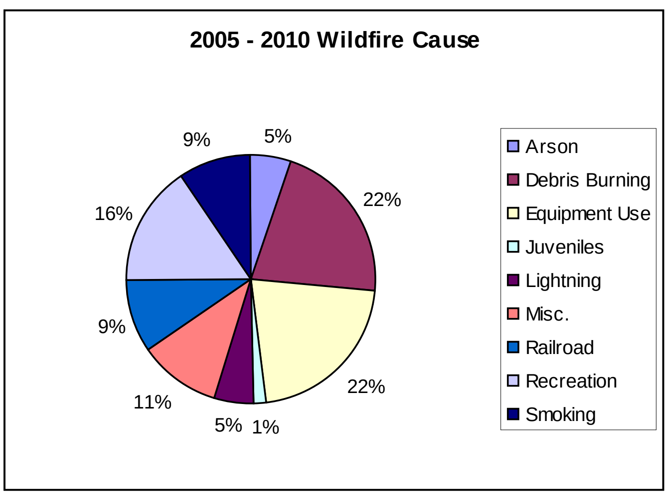
The effects of wildland fires vary with intensity, area, and time of year. Factors affecting the degree of risk of fires include extent of rainfall, humidity, wind speed, type of vegetation, and proximity to fire fighting agencies. The greatest short-term loss is the complete destruction of valuable resources, such as timber, wildlife habitat, scenic vistas, and watersheds. There is an immediate increase in vulnerability to flooding due to the destruction of all or part of the watershed. Long-term effects are reduced amounts of timber for commercial purposes and the reduction of travel and recreational activities in the affected area. There were 75 reported wildfires in Hood River County from 2005 – 2010. See **Appendix G** Wildfire in Hood River County – 2005 – 2010 for a complete listing.



Home building in and near forests increases risks from forest fires.

These areas of new homes are referred to as interface areas. Often, structures have been built and maintained with minimal awareness of the need for protection from exterior fire sources, or the need to minimize interior fires from spreading to forested lands.

Historically, it appears that the instance of wildfire is increasing through the region. Additionally, the existence of open lands and large forested areas, increasing population and recreational activities, and the uncertain impact of a changing climate combine to suggest a **high probability of occurrence**. The destruction of large tracts of forest land would have immediate economic impact to the community through lost jobs, reduced taxes, and increased public support while collateral economic and social effect could impact the County for years, suggesting **moderate vulnerability**. Accordingly, a **high risk rating** is assigned.

Conclusions

The following steps should be accomplished to preclude major loss of life and reduce the actual number of fires in hazard areas:

1. Since people start the vast majority of forest fires, forest fire prevention education and enforcement programs can significantly reduce the total number of forest fires.

2. Effective early fire detection program and emergency communications systems are essential. The importance of immediately reporting any forest fire must be impressed upon local residents and persons utilizing the forest areas.

3. An effective warning system is essential to notify local inhabitants and persons in the area of the fire. An evacuation plan detailing primary and alternate escape routes is also important.

4. Fire-safe development planning and appropriate wildfire mitigation strategy should be done by local jurisdictions, such as the implementation of safety recommendations to include.

    a. Sufficient fuel-free areas around structures.
    b. Fire resistant roofing materials.
    c. Adequate two-way (ingress and egress) routes and turnarounds for emergency response units.
    d. Adequate water supplies with backup power generation equipment or other means to cost-effectively support fire fighting efforts.
    e. Development of local ordinances to control human caused fires; i.e. from debris burning, fireworks, campfires, etc.

5. Road criteria should ensure adequate escape routes for new sections of developments in forest areas.

6. Road closures should be increased during peak fire periods to reduce the access to fire-prone areas.

7. Steps the public can take to better protect lives, property, and the environment from wildfires include:

    a. Maintaining appropriate defensible space around homes.
    b. Providing adequate access routes (two-way with turnaround) to homes for emergency equipment.
    c. Minimizing “fuel hazards” adjacent to homes.
    d. Using fire-resistant roofing materials
    e. Maintaining adequate water supplies.
    f. Ensuring home address is visible to first responders.

8. Some forest fires are allowed to burn in limited areas as part of forest management.

LANDSLIDE

Hazard Definition

Landslides are the sliding movement of masses of loosened rock and soil down a hillside or slope. The term landslide includes a wide range of ground movement, such as rock falls, deep failure of slopes, and shallow debris flows. It is most common for landslides to occur on water saturated slopes when the base of the slope can no longer support the weight of the soil above it. Landslides are commonly associated with heavy rain and flooding conditions but they may also be associated with earthquakes (the 1994 Northridge Earthquake caused an estimated 11,000 landslides) and with volcanic activity.

Hazard History

Landslides occur in Hood River County during or after periods of heavy rain and flooding. The period from December1996 to February 1997 saw a number of landslides in Hood River County.

Hazard Identification

Slides in Hood River County generally range in size from thin masses of soil of a few yards wide to much larger, deep-seated bedrock slides. Travel rate may range in velocity from a few inches per month to many feet per second, depending largely on slope, material, and water content. The recognition of ancient dormant slide masses is important as they can be reactivated by earthquakes or unusually wet winters. Also, because they consist of broken materials and disrupted ground water, they are more susceptible to construction-triggered sliding than adjacent undisturbed material.

Hood River County has many areas adjacent to the Columbia River Gorge where landslides have taken place and several areas that are susceptible to landslides.

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Typical effects include damage or destruction of portions of roads and railroads, sewer lines, pipelines, and water lines, electrical and communications distribution lines, and destroyed homes and public buildings. Disruption of shipping and travel routes result in losses to commerce. Many of the losses due to landslides may go unrecorded because no claims are made to insurance companies, lack of coverage by the press, or the fact that transportation network slides may be listed in records simply as “maintenance.”

Hood River County has a history of landslides suggesting a **moderate probability of occurrence**. Landslides tend to occur in isolated, sparsely developed areas threatening individual structures and remote sections of the transportation, energy and communications infrastructure suggesting **low vulnerability**. Because of the moderate probability of occurrence, a **moderate risk rating** is assigned.

Conclusion

The most significant effect of landslides is the disruption of transportation and the destruction of private and public property. Some work has been done to prevent developments on top of or below slopes subject to sliding without geotechnical investigations and preventative improvements. Much more needs to be done to educate the public and to prevent development in vulnerable areas.

SEVERE LOCAL STORM

Hazard Definition

Hood River County is vulnerable to a variety of severe storm hazards. Tornadoes are described separately. Ice, snow, and windstorms all have the ability to severely impact the County. Severe local storms seldom cause death and serious property damage but they can cause major utility and transportation disruptions.

Ice Storm

Ice storms or freezing rain (black ice) conditions can occur in Hood River County. Ice storms occur when rain falls from warm moist upper layers of the atmosphere into a cold, dry layer near the ground. The rain freezes on contact with the cold ground and accumulates on exposed surfaces. This has the possibility to create real havoc when the ice accumulates on tree branches, and power lines. This can cause power outages and can obstruct transportation routes.

Snow Storm or Blizzard

The northern Oregon Cascades exert a profound effect on Oregon climate and weather. Mid-latitude storms approaching from the West are forced to rise as they encounter the Cascades, resulting in large amounts of orographic (terrain-induced) precipitation on the western slopes. So effective are the Cascades in removing moisture from the Pacific air masses, however, that most of Oregon east of the Cascades lies in a "rain shadow," resulting in large areas with annual precipitation less than 12 inches.

It is possible for significant snowfall to occur in the Northwest. Hood River County has had accumulations that vary depending on geographic location. For example, accumulations in excess of 150 inches may be predicted in areas of the Mt. Hood National Forest around the higher elevations Mt. Hood. In the area of the Hood River Experimental Station, average snowfall may accumulate to approximately 12 inches, depending on the year. Accumulations of snow usually increase with distance and elevation as the terrain rises to the South of the Columbia River. January is usually the month with the greatest snowfall.

Wind Storm

Every so often the Northwest is severely impacted by strong windstorms. In the past, peak wind gusts have gone above 100 miles per hour. Strong winds that impact Hood River County comes from two sources. Frequent and widespread strong winds come from the west and are associated with strong storms moving onto the coast from the Pacific Ocean. Strong west winds may also originate in the Columbia River Gorge when high atmospheric pressure is over the upper Columbia River Basin and low pressure is over the Pacific Ocean. The Columbia River Gorge acts as a funnel, concentrating the intensity of the winds as they flow from the West. This generates strong winds throughout the Gorge and at its outlet. The *Beaufort Wind Scale* which can be found in **Appendix D** measures wind speed.

History

On February 14-16, 1990 a storm brought 24 to 35 inches of snow to the Columbia Gorge cities of Cascade Locks and Hood River, 16 inches at Timberline Lodge. On the 16th, 20 to 35 inches fell in the North Cascades. The Columbia Gorge had up to

6 inches of snow while the Willamette Valley had 2 to 5 inches more. On December 22, 2008, over 22" inches of snow fell on Hood River in a 24 hour period. The record snowfall in the region occurred December 20-23, 1892. In Southwest Washington and Northwest Oregon, 15 to 30 inches of snow fell, while Portland had 27.5 inches.

The Columbus Day Storm on October 12, 1962 was the worst windstorm to occur in the Northwest since records have been kept. Thirty-eight people died and monetary losses were estimated somewhere between $175 and $200 million. The Portland Airport reported a peak gust of 88 miles per hour. At the Morrison Bridge in Downtown Portland there was a peak gust of 114 mph. The strongest windstorm since the Columbus Day Storm occurred November 13-15, 1981. This storm was nearly as strong as the Columbus Day Storm but it tracked farther west. This was actually two strong windstorms, the stronger first storm arriving November 13 and early November 14 and the second storm hit on November 15.

Snow Climatology – Hood River County

Climate Data from Western Region Climate Center (http://www.wrcc.dri.edu)

Hood River

Period of Record : 1/ 1/1893 to 4/30/2010

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ave
Average Max. Temperature (F)	39.5	45.5	53.5	61.2	68.5	74.1	81.1	80.8	74.0	63.1	49.1	41.2	61.0
Average Min. Temperature (F)	27.7	30.3	34.1	38.4	44.0	49.6	53.5	52.4	45.9	39.1	34.0	30.2	39.9
Average Total Precipitation (in.)	5.13	3.84	3.12	1.64	1.06	0.74	0.22	0.37	1.01	2.25	5.31	5.83	30.53
Average Total SnowFall (in.)	14.6	7.3	2.2	0.1	0.0	0.0	0.0	0.0	0.4	0.1	2.7	8.7	36.0
Average Snow Depth (in.)	3	1	0	0	0	0	0	0	0	0	0	1	0

Parkdale

Period of Record : 8/ 1/1981 to 4/30/2010

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ave
Average Max. Temperature (F)	41.5	45.6	53.1	59.2	66.8	73.1	80.8	80.8	74.5	62.3	47.9	39.0	60.4
Average Min. Temperature (F)	27.6	28.3	31.9	35.1	40.3	45.1	49.0	48.3	42.5	36.2	31.6	26.2	36.8
Average Total Precipitation (in.)	5.67	4.04	3.15	2.07	1.45	0.94	0.35	0.44	0.92	2.68	6.12	5.65	33.49
Average Total SnowFall (in.)	15.1	10.1	3.9	0.8	0.0	0.0	0.0	0.0	0.0	0.2	6.1	17.7	53.8
Average Snow Depth (in.)	4	2	0	0	0	0	0	0	0	0	1	3	1

Hazard Identification

All of the hazards described above impact communities in similar ways. Even moderate storms can bring down power lines, and tree and tree limbs obstructing roadways and falling onto houses and other structures with enough force to cause damage. Downed power lines create widespread electrical hazards. Severe windstorms will usually cause the greatest damage to ridgelines that face into the winds. There is an additional hazard in newly developed areas that have been thinned of trees to make way for new structures. Large unprotected trees in these areas are more like to fall. Severe storms causes massive power and telephone outages. Severe storms in Hood River County have left thousands without power. In certain areas it may take several days for utility providers to restore power. This can create life-threatening problems for people with life support equipment such as dialysis machines, respirators, and oxygen generators.

Severe local storms create hazardous driving conditions that can slow down and completely inhibit traffic. This can hinder police, fire, and medical responses to urgent calls. These types of storms also can wreak havoc on first response operations. Law enforcement resources are often tied up in responding to welfare inquiries and in traffic control, while fire departments are tied up with electrical hazards and debris removal. The long-term challenge for severe local storms is in debris removal. Hundreds of tons of debris can pile up in residential and commercial areas.

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The entire County is vulnerable to the effects of a storm. High winds can cause widespread damage to trees and power lines and interrupt transportation, communications, and power distribution. Prolonged heavy rains cause the ground to become saturated, rivers and streams to rise, and often results in local flooding and landslides.

Ice storms occur when rain falls out of a warm atmospheric layer into a cold one near the ground. The rain freezes on contact with cold objects including the ground, trees, structures, and power lines, causing power lines to break.

Snowstorms primarily impact the transportation system and the availability or timing of public safety services. Heavy snow accumulations can also cause roofs to collapse. Snow accompanied by high winds is a blizzard, which can affect visibility, cause large drifts and strand residents for up to several days. Melting snow adds to river loading and can turn an otherwise benign situation into a local disaster.

Each of these when in combination with any other or if accompanied by freezing temperatures can exacerbate a storm’s impact. Isolated residents without power are more likely to use wood fires to stay warm or to cook, possibly resulting in an increase in the number of structural fires. Residents without food or water may attempt to use impassable roads and thereby increase the number of rescues.

The effects can vary with the intensity of the storm, the level of preparation of local jurisdictions and residents, and the equipment and staff available to perform necessary tasks to lessen the effects of severe local storms.

Storm history suggests a **high probability of occurrence**. Historical damage and cumulative costs of destructive storms suggest **high vulnerability**. Accordingly, a **high risk rating** is assigned.

Conclusion

Severe local storms seldom cause death and injury and seldom result in severe property damage. However, severe storms have caused serious emergency conditions in Hood River County and they will do so again. Perhaps the one thing that will do the most to prevent death and injury is to ensure that people stay off roads and remain in a safe place before the brunt of a storm passes. This is best done through effective employee and student dismissal plans and event cancellation. It is also important to promptly notify the public of severe weather watches and warnings.

In the responding to a severe local storm, often a sticking point is the prioritization of phone and power restoration services. Emergency managers and first responders need to work closely with utility providers and telephone companies to ensure that power and phone service is quickly restored to essential facilities.

Once the general public has weathered a severe storm and their power and phone service is restored their highest priority is to quickly and efficiently remove the debris on their property and on the roads they drive. Debris removal planning is essential so that systems are in place to efficiently manage and finance prompt debris removal.

TORNADOES

Hazard Definition

Tornadoes are the most violent weather phenomena known. They are characterized by funnel clouds of varying sizes that generate winds as fast as 500 miles per hour. They can affect an area of ¼ to ¾ of a mile and seldom more than 16 miles long. Tornadoes normally descend from the large cumulonimbus clouds that characterize severe thunderstorms. They form when a strong crosswind (sheer) intersects with strong warm updrafts in these clouds causing a slowly spinning vortex to form within a cloud. Eventually, this vortex may develop intensity and then descend to form a funnel cloud. When this funnel cloud touches the ground or gets close enough to the ground to affect the surface it becomes a tornado. Tornadoes can come from lines of cumulonimbus clouds or from a single storm cloud. Tornadoes are measured using the Fujita Scale ranging from F0 to F6. Details on the Fujita Scale can be found in Appendix D.

History

No recorded instance of a tornado causing damage in Hood River County is available.

Hazard Identification

Tornadoes are not normal occurrence in the Northwest the way they are in the Midwest. Tornadoes require a confluence of warm surface temperatures and warm fronts coming from the south with cold fronts coming from the north. Northwest climates do not normally generate the temperature variations conducive to tornado formation. For example, Washington State is ranked 43 in the United States for total number of tornadoes. Nonetheless, the tornado threat should be taken very seriously. The conditions conducive to tornado formation rarely develop in Hood River County and it is uncommon for funnel clouds to be reported in this region.

With the exception of the April 1972 disaster occurring in Clark County, Washington tornadoes in Washington and Oregon tend to be light or moderate, with winds ranging from 40 to 112 mph. There are notable minorities of tornadoes that cause significant to severe damage with winds going as high as 200 mph. The peak season for tornadoes is April through July. However, tornadoes may occur in the late summer months and, in a few rare cases, may occur in the winter months. While tornadoes are sometimes formed in association with large Pacific storms; most of them are caused by intense local thunderstorms. Tornadoes almost exclusively occur in the late afternoon and early evening.

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It has not been demonstrated that there is a likelihood of tornadoes impacting Hood River County. Typically, Pacific Northwest tornadoes are moderate but it is possible for serious tornadoes to develop causing death and serious injury.

Typically, tornadoes may cause severe damage to everything in their path. Walls collapse, roofs are ripped off, trees and power lines are destroyed. The challenge is that tornadoes, especially in the northwest, are very difficult to predict and their onset is sudden. Unlike the tornado-prone areas in the plains states, there is little awareness of the tornado threat and the forecasting and warning systems are less well developed. It is extremely rare for a tornado watch or warning to be issued anywhere in the Northwest. As such, there is little public awareness of the warning systems and self-protection measures common to the tornado prone states.

History suggests a **low probability of occurrence** and **low vulnerability**. A **low risk rating** is assigned.

Conclusions

While violent tornadoes are not a characteristic of the Hood River County climate, the weather systems that may generate tornadoes appear regularly. Emergency response agencies and emergency management officials should be prepared for the rapid notification of the public and for the efficient management of a mass casualty incident, and the prioritization of debris clearance.

VOLCANOES

Hazard Definition

A volcano is a vent in the earth's crust through which molten rock, rock fragments, gases or ashes are ejected from the earth's interior. Volcanoes are a deadly hazard. From 1980 to 1995 volcanoes killed approximately 29,000 people, forced the evacuation of 830,000 people, and caused economic losses in excess of $3 billion (Simkin and Siebert, 1994)

There are a wide variety of hazards related to volcanoes and volcano eruption. With volcano eruptions, the hazards are distinguished by the different ways in which volcanic materials and other debris flow from the volcano. Following is a list of the different types of hazards that exist in cascade volcanoes.

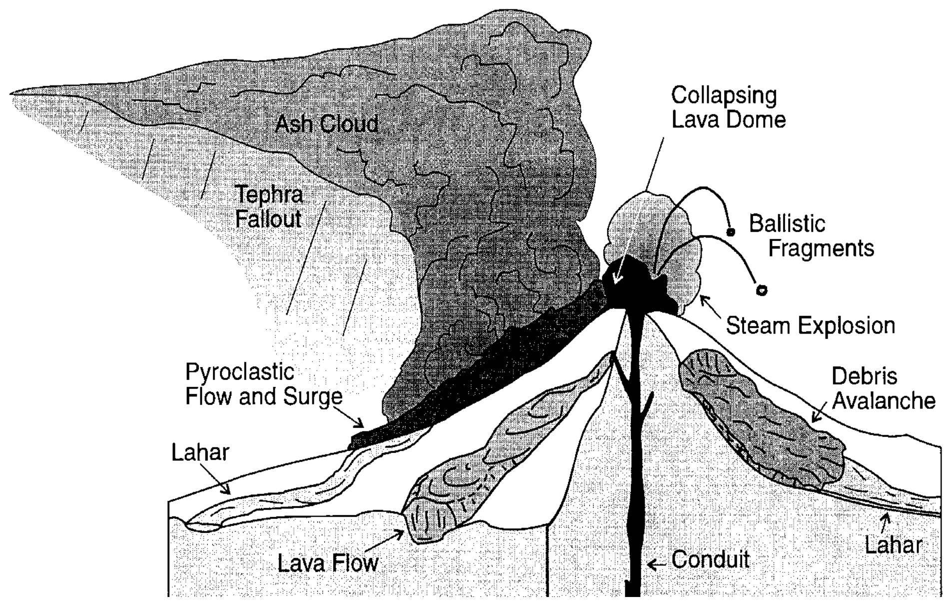

Figure A - Types of volcanic hazards[i]

Pyroclastic Flows and Surges

Pyroclastic flows are avalanches of hot (300-800°C), dry, volcanic rock fragments and gases that descend a volcano's flanks at speeds ranging from 20 to more than 200 miles per hour. They originate from the actual explosion related to an eruption. Pyroclastic flows and surges are a lethal hazard. They result in incineration, asphyxiation, burial, and impact. Because of their speed they cannot be outrun.

Pyroclastic flows are heavier than air and will seek topographically low areas. Pyroclastic surges composed of hot mixtures of gas and rock will flow above the ground and they may go over topographical barriers such as ridges and hills.

Lava Flows

Lava flows are normally the least hazardous threat posed by volcanoes. The silica content of the lava determines the speed and viscosity of a lava flow. The higher the silica content, the more viscous (thick) the lava becomes. Low silica basalt lava can move 10 to 30 mph. High silica andesite and dacite tend to move more slowly and travel short distances. Cascades volcanoes are normally associated with slow moving andesite or dacite lava. However, 2,000 years ago Mt. St. Helens produced a large amount of basalt.

Large lava flows may destroy property and cause forest fires but, since they are slow moving, pose little threat to human life. Perhaps the greater hazard presented by lava flows is that their extreme heat can cause snow and ice to melt very quickly, adding to lahar, debris avalanche, and flooding hazards.

Tephra

The ash and the large volcanic projectiles that erupt from a volcano into the atmosphere are called tephra. The largest fragments (bombs, >64mm) fall back to the ground fairly near the vents, as close as a few meters and as far as 10 km (6 mi.). The smallest rock fragments (ash) are composed of rock, minerals, and glass that are less than two millimeters in diameter. Tephra plume characteristics are affected by wind speed, particle size, and precipitation.

Tephra falls pose a variety of threats. Ash only 1 cm thick can impede the movement of most vehicles and disrupt transportation, communication, and utility systems. During the past 15 years about 80 commercial jets have been damaged by inadvertently flying into ash, and several have nearly crashed. Airborne tephra will seldom kill people who are a safe distance from the vent. However, tephra may cause eye and respiratory problems, particularly for those with existing medical conditions. Short-term exposure should not have any long-term health effects. Some tephra material may have acidic aerosol droplets that adhere to them. This may cause acid rain or corrosion of metal surfaces they fall on.

Ash may also clog ventilation systems and other machinery. When tephra is mixed with rain it becomes a much greater nuisance. Wet ash is much heavier and it can cause structures to collapse. Most of the 330 deaths associated with the Mt. Pinatubo eruption were caused by roofs collapsing under the weight of rain soaked ash. Wet ash may also cause electrical shorts. Ash falls also decreases visibility and may cause psychological stress and panic.

Lahars

Lahars are rapidly flowing mixtures of water and rock debris that originate from volcanoes. While lahars are most commonly associated with eruptions, heavy rains, debris accumulation, and even earthquakes may also trigger them. They may also be termed debris or mud flows. Lahars can travel over 50 miles downstream, reaching speeds between 20 and 40 mph. The highest recorded speed of a lahar during the 1980 Mt. St. Helens eruption was 88 mph. Beyond the flanks of a volcano, lahars will normally be channeled into waterways. The threat from lahars comes from their speed and from the debris they carry. Abrasion from the heavy sediment and impacts from heavy debris can destroy forests as well as human made structures including bridges, dams, roads, pipelines, buildings, and farms. Lahars may also fill in channels, obstructing shipping lanes and impact a channel's ability to handle large volumes of water.

Debris Avalanches

Volcanoes are prone to debris and mountain rock avalanches that can approach speeds of 160 kilometers per hour (100 mph). Volcanoes are characterized by steep slopes of weak rock. Volcanic rock material is weakened by the acidic ground water that seeps through rock cracks and turns rigid rock into clay. Minor eruptions, earthquakes, or releases of built up water and debris may trigger large avalanches of this material.

Volcanic Gases

All active volcanoes emit gases. These gases may include steam, carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, and fluorine. Sometimes, these chemicals can be absorbed by ash and impact ground water, livestock, and metal objects. Even when a volcano is not erupting, gases can escape through small surface cracks. The greatest danger to people comes when large quantities of toxic gases are emitted from several sources or when there are topographic depressions that collect gases that are heavier than air. These gases can accumulate to the point where people or animals can suffocate. Neither of these conditions exists in Cascade volcanoes, though this could change if magma were to come close to the surface. Mt. St. Helens emitted thousands of tons of Sulfur Dioxide every day in the early 80's. These gases were easily dispersed by the wind.

History

Cascade Range volcanoes in the U.S. have erupted more than 200 times during the past 12,000 years for an average of nearly two eruptions per century. At least five eruptions have occurred during the past 150 years.

The most recent eruptions in the Cascade Range are the well-documented 1980-1986 eruptions of Mt. St. Helens, which claimed 57 lives and caused nearly a billion dollars in damage and response costs. The effects were felt throughout the northwest.

Hazard Identification

Mount Hood has erupted intermittently for hundreds of thousands of years, but historical observations are meager, so most of our information about its past behavior comes from geologic study of the deposits produced by prehistoric events. Observations of recent eruptions at other similar volcanoes around the world allow us to better understand what future eruptions of Mount Hood might be like. A brief description of the kinds of events that have occurred at Mount Hood and are likely to happen in the future follows.

Lava Eruptions, Pyroclastic Flows, and Related Lahars

Lava has erupted at Mount Hood chiefly in two modes. Numerous lava flows issued from vents on the upper flanks and traveled up to 12 kilometers (7 miles) down valleys. Erosion of new valleys along flow margins has left many of these lava flows as ridges, such as Cathedral Ridge, that radiate out from the center of the volcano. Observations of lava flows at similar volcanoes suggest that Mount Hood flows move down valleys as tongues of fluid lava a few to tens of meters thick (10 to 200 feet) encased in a cover of hardened lava rubble. Such lava flows can destroy all structures in their paths, but they advance so slowly that they seldom endanger people. Lava domes formed stubby lava masses on the upper flanks and summit of Mount Hood as lava welled out of a vent and piled up, too viscous to flow away. A recent example is the lava dome that grew in the crater of Mount St. Helens between

1980 and 1986. Past lava domes growing on the steep upper flanks of Mount Hood were typically unstable and collapsed repeatedly as they grew higher and steeper.

Collapse of a growing lava dome or the front of a thick lava flow generates landslides of hot rock called pyroclastic flows. Pyroclastic flows are fluid mixtures of hot rock fragments, ash, and gases that sweep down the flanks of volcanoes at speeds of 50 to more than 150 kilometers per hour (30 to 90 miles per hour) destroying vegetation and structures in their paths. Most are confined to valley bottoms, but pyroclastic surges, overriding clouds of hot ash and gases, are more mobile and can overwhelm even high ridge tops. At Mount Hood, pyroclastic flows have traveled at least 12 kilometers (7 miles) from lava domes; pyroclastic surges probably traveled even farther. Pyroclastic flows and surges also produce ash clouds that can rise thousands of meters (tens of thousands of feet) into the atmosphere and drift downwind for hundreds of kilometers (hundreds of miles). The consequences of this ash are discussed in a later section called Tephra Fall.

Pyroclastic flows and surges can also melt snow and ice and generate lahars (also called volcanic mudflows or debris flows). Lahars are rapidly flowing, water-saturated mixtures of mud and rock fragments, as large as truck-size boulders that range in consistency from mixtures resembling freshly mixed concrete to very muddy water. Lahars can travel more than 100 kilometers (60 miles) down valleys. They move as fast as 80 kilometers per hour (50 miles per hour) in steep channels close to a volcano, but slow down to about 15 to 30 kilometers per hour (10-20 miles per hour) on gently sloping valley floors farther away. Past lahars at Mount Hood completely buried valley floors in the Sandy and Hood River drainages all the way to the Columbia River and in the White River drainage all the way to the Deschutes River.

Growth and collapse of lava domes have dominated eruptive activity at Mount Hood during the past 30,000 years. The last two episodes of eruptive activity occurred 1,500 and 200 years ago. Repeated collapse of lava domes extruded near the site of Crater Rock, Mount Hood's youngest lava dome, generated pyroclastic flows and lahars and built much of the broad smooth fan on the south and southwest flank of the volcano.

The newly formed fans of debris on the lower flanks of Mount Hood and deposits of lahars in river valleys were highly erodible, which caused additional impacts. Normal rainfall, snowmelt, and streams remobilized the sediment and continued to move it farther downstream for years after eruptions. For example, after the last eruptive period, the Sandy River became choked with sediment and within about a decade buried the preeruption valley floor over 20 meters (65 feet) deep between Sandy and Troutdale. Ultimately, much of the sediment from past eruptions entered the Columbia River. A recurrence of such events would greatly affect the Columbia River, its shipping channel, and, potentially, hydroelectric installations, such as Bonneville Dam.

Debris Avalanches and Lahars

Rapidly moving landslides, called debris avalanches, occurred numerous times in the past when the steep upper parts of Mount Hood collapsed under the force of gravity.

Warm acidic ground water that circulates in cracks and porous zones inside volcanoes alters strong rock to weak slippery clay, thereby gradually weakening them and making them more susceptible to debris avalanches than other mountains. Volcanoes are further weakened as erosion, especially by glaciers, over steepens slopes. The destabilizing forces of magma (molten rock) pushing up into a volcanic cone prior to an eruption can trigger debris avalanches as occurred at Mount St. Helens in 1980. Unexpected earthquakes (both smaller local ones and larger distant ones) or steam explosions can also trigger debris avalanches. A debris avalanche can attain speeds in excess of 160 kilometers per hour (100 miles per hour); the larger the avalanche, the faster and farther it can move. Small-volume debris avalanches typically move only a few kilometers (1 to 3 miles), but large-volume debris avalanches are capable of reaching tens of kilometers (tens of miles) from the volcano. Debris avalanches destroy everything in their paths and can leave deposits 10 to more than 100 meters (30 to more than 300 feet) thick on valley floors. Depending upon their water content, debris avalanches can transform into lahars, which, like lahars formed by pyroclastic flows, can move down valleys for even greater distances.

About 1,500 years ago, a moderate-size debris avalanche originating on the upper southwest flank of Mount Hood (see photograph) produced a lahar that flowed down the Zigzag and Sandy River valleys. It swept over the entire valley floor in the Zigzag-Wemme- Wildwood area, and inundated a broad area near Troutdale, where the Sandy flows into the Columbia Rivera total distance of about 90 kilometers (55 miles). More than 100,000 years ago, a much larger debris avalanche and related lahar flowed down the Hood River, crossed the Columbia River, and flowed several kilometers up the White Salmon River on the Washington side. Its deposit must have dammed the Columbia River at least temporarily.

During noneruptive periods, relatively small lahars present a hazard along channels and on floodplains on the flanks of Mount Hood. Although of modest size compared to lahars generated by eruptions or large debris avalanches, they occur much more frequently. Twenty-one lahars, including single flows as large as several hundred thousand cubic meters (cubic yards), whose effects were chiefly limited to areas within 15 kilometers (9 miles) of Mount Hoods' summit, are reported in the historical record. Most occurred during autumn and early winter rains. Glacial outburst floods caused at least two and probably as many as seven others. A highly damaging lahar occurred in December 1980 when intense warm rain (with rapid snowmelt) triggered a flow in Polallie Creek that killed a camper at the creek mouth and temporarily dammed the East Fork Hood River. The ensuing dambreak flood destroyed about 10 kilometers (6 miles) of Oregon Highway 35 and other downstream facilities and caused about $13 million in damage.

Tephra Falls

Mount Hood has typically not produced thick, extensive deposits of tephra (fragmented solidified lava that rises into the air, is carried by winds, and falls back to the ground) as has nearby Mount St. Helens. Rather, relatively modest amounts of tephra were produced during past lava-flow and lava-dome eruptions. Most tephra fallout was caused by clouds of sand- and silt-size particles that rose from moving pyroclastic flows produced by lava-dome collapse. Tephra was also generated by explosions driven by volcanic gases. Both types of tephra clouds probably reached altitudes of 1,000 to 15,000 meters (3,000 to 50,000 feet) above the volcano and were then carried away by the prevailing wind, which blows toward sectors northeast, east, or southeast of Mount Hood about 70 percent of the time. Winds that would carry tephra toward the Portland metropolitan area are rather uncommon, occurring only a few percent of the time. On the flanks of the volcano, each event deposited, at most, a few centimeters (inches) of tephra. Thickness of tephra fallout decreased rapidly downwind to probably just a few millimeters (one-tenth inch) or less at 100 to 200 kilometers (60-120 miles) from the volcano. During future explosions at Mount Hood, large, dense ballistic fragments (more than 5 cm (2 inches) in diameter) that can damage structures and kill or injure people may be thrown up to 5 kilometers (3 miles) from vents.

Tephra fallout produced by future eruptions of Mount Hood poses little threat to life or structures in nearby communities. But tephra clouds can create tens of minutes or more of darkness as they pass over a downwind area, even on sunny days, and reduce visibility on highways. Tephra ingested by vehicle engines can clog filters and increase wear. Deposits of tephra can short-circuit electric transformers and power lines, especially if the tephra is wet and thereby highly conductive, sticky, and heavy. This effect could seriously disrupt hydroelectric power generation and transmission along the Columbia River and power line corridors north and east of the volcano. Tephra clouds often spawn lightning, which can interfere with electrical and communication systems and start fires. A serious potential danger of tephra stems from the grave effects of even small, dilute tephra clouds on jet aircraft that fly into them. Major air routes pass by Mount Hood, and tephra clouds produced repeatedly during an eruptive episode would interfere greatly with air traffic.

Lessons learned in eastern Washington during the 1980 eruption of Mount St. Helens can help prepare governments, businesses, and citizens for future tephra falls. Communities experienced significant disruptions in transportation, business activity, and services during fallout of from 0.5 to 8 centimeters (1/4 to 3 inches) of tephra and for several days thereafter. The greater the amount of tephra that fell, the longer the recovery time. As perceived by residents, tephra falls of less than 0.5 centimeter (1/ 4 inch) were a major inconvenience, whereas falls of more than 1.5 centimeters (2/3 inch) constituted a disaster. Nonetheless, all communities resumed normal activities within about two weeks. On the basis of the type and magnitude of tephra production we would expect from Mount Hood in the future, only nearby communities, such as Government Camp, Rhododendron, and Parkdale, would likely receive a tephra thickness approaching 1.5 centimeters (2/3 inch) in any one event. However, some other nearby volcanoes in the Cascade Range do produce large explosive tephra eruptions that could affect the Mount Hood region

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Hood River County may be impacted by a volcanic eruption at anytime. The above assessments of volcano hazards consider past activity to determine the most likely pattern and probability of a future eruption. It is possible that unexpected volcanic activity may occur that may significantly impact Hood River County.

The factor that most limits Hood River County's vulnerability to a major eruption of Mt. Hood is the modern capability to accurately detect eruptive activity well before an eruption occurs. The USGS constantly monitors seismic activity directly underneath Cascade volcanoes. Clusters or 'swarms' of small earthquakes underneath a volcano have proven to be a precursor to renewed volcanic activity. Mt. St. Helens and Mt. Hood are both closely monitored, in terms of ground movement and seismic activity. It is up to emergency managers and other responsible agencies to ensure an aggressive response to these warnings.

Proximal Hazard Zones

Proximal hazard zones include areas from the summit out to 24 km (15 miles) along major valleys and out to about 12 kilometers (7 miles) in between major valleys. These zones are subject to several types of rapidly moving, devastating flows. Pyroclastic flows and surges will travel out to a maximum distance of about 12 kilometers in less than 10 minutes, whereas lahars and debris avalanches can travel out to the 24- km hazard boundary in as little as 30 minutes. Areas up to 5 kilometers (3 miles) from a vent could also be subject to showers of large (more than 5 centimeters or 2 inches) ballistic fragments within a few minutes of an explosion. Owing to such high speeds, escape or survival is unlikely in proximal hazard zones. Therefore, evacuation of proximal hazard zones prior to onset of an event is realistically the only way to protect lives. Lava flows issuing from vents on the upper flanks of Mount Hood would be largely restricted to proximal hazard zones, but they would move much more slowly than these other types of flows.

During the past 1,500 years, lava-dome growth has been localized in the area around Crater Rock, the youngest lava dome on Mount Hood, which lies in a steeply sloping, breached crater south of the summit ridge. It is thought that this same area is the most likely vent location during the next eruption as well. Therefore, a proximal hazard zone A (PA), which encompasses those areas that, could be affected by events accompanying dome growth at or near Crater Rock. A less likely event is the opening of a vent elsewhere on the upper east, north, or west flank. Should this occur, the corresponding hazard zone would be all or part of proximal hazard zone B (PB). Depending on vent location, especially if at the summit, all or part of zone PA also could also be at risk. On the lower south and west flanks, hazard zone PB extends beyond the limit of zone PA because a lava dome growing at the summit would be at a higher altitude than Crater Rock and would have the potential to generate farther-reaching pyroclastic flows. On the basis of past eruption frequency, we estimate the probability of an eruption impacting part of zone PA in the next 30 years (the 30-year probability) to be about 1 in 15 to 1 in 30 [4]. In contrast, the 30-year probability of part of zone PB being affected is on the order of 1 in 300 [4]. These probabilities are based solely on the long-term behavior of the volcano. Any signs of increased restlessness at Mount Hood will increase these probabilities dramatically.

Several major valleys within the proximal hazard zones are highlighted on the map by a hachured line pattern because they are more likely than others to be affected by future pyroclastic flows and lahars related to collapse of growing lava domes, especially during initial stages of dome building. These valleys, along with Polallie Creek valley, are also areas subject to frequent small lahars, floods, and debris avalanches triggered by storms or other noneruptive causes. If a lava dome grows near Crater Rock, the White and Zigzag River valleys and the valley of Zigzag Glacier and its melt water stream, an unnamed tributary of the upper Sandy, are the most likely pyroclastic-flow and lahar paths. If an eruptive episode continues for a long enough time period that debris fills the heads of these drainages, pyroclastic flows and lahars will be able to sweep over a broader area, which could include the Little Zigzag River, Still Creek (including the area around Government Camp), and Salmon River valleys. Likewise in zone PB on the north or east flank, the main valleys below a growing lava dome would initially be the most likely flow paths. For example, dome growth on the upper northeast flank would initially affect the valleys of Newton Creek and Eliot Branch. The large area in the proximal hazard zone between these valleys that is drained by Polallie and several other creeks does not presently head directly on the upper flanks and probably would not be affected initially. Before these drainages could be inundated by pyroclastic flows, the valley heads of Newton Creek and (or) Eliot Branch would have to be partly filled with debris.

While the subdivision of the proximal area into zones PA and PB based on vent location applies well to pyroclastic flows and lahars produced by lava dome collapse, several other types of events are not so neatly restricted by this hazard zonation. First, the earthquakes and deformation associated with future intrusion of magma into Mount Hood can trigger landslides of fractured and weakened rock from the steep upper slopes. Therefore, even though dome building is localized at one site, landslides elsewhere on the upper flanks can generate debris avalanches and related lahars in valleys not otherwise affected by dome growth. Such events, largely restricted to the hachured areas in zone PB, occurred on the east, north, and west flanks during the past 1,500 years, while dome growth and collapse affected valleys on the south and southwest flanks. Furthermore, owing to the pronounced filling of valleys on the south side by debris during the past 1,500 years, the majority of high cliffs and spurs subject to land sliding lie on other flanks. Thus, regardless of which zone a dome is growing in, potential hazards from debris avalanches and lahars exist in other parts of the proximal zones. Second, explosive eruptions driven by volcanic gases can also affect both proximal zones. Explosions can generate highly mobile pyroclastic flows as material falls back to the ground and can hurl large ballistic fragments outward up to 5 kilometers (3 miles). Such events are less constrained by topographic features than are pyroclastic flows from dome collapse, so explosions at a vent in one proximal zone could impact parts of the other proximal zone, especially with ballistics.

Distal Hazard Zones

White River Drainage

Lahars spawned by lava-dome collapses swept through the White River valley about 200 years ago and inundated large parts of Tygh Valley. Hazard zone DA encompasses these deposits as well as adjacent areas that lie up to 12 meters (40 feet) higher depending on valley width. Lahars of this magnitude would inundate the broad flood plain of White River in Tygh Valley, but probably not reach the town itself. Lahars that reach the Deschutes River probably would be diluted to muddy floods that would transport large amounts of sediment into the Columbia River upstream from The Dalles Dam. The 30-year probability of an area in zone DA along White River being inundated by a debris avalanche or lahar is about 1 in 15 to 1 in 30.

Hood River Drainage

The Hood River and its tributaries drain about one-half of Mount Hood, but have apparently not been affected by lahars that extended outside of the proximal hazard zone, or substantially out of channels, during the past 15,000 years. Recent eruptions that produced pyroclastic flows and lahars in the Sandy and White River valleys only indirectly affected upper parts of the Hood River basin by producing modest debris avalanches and related lahars. However, dome growth on the east or north flank, a condition that is considered of lower probability than renewed activity near Crater Rock, would substantially impact Hood River and its tributaries.

Owing to the lack of evidence of young events in the Hood River Valley, areas along Hood River in distal hazard zone DB are included, and estimate a 30-year probability of inundation by lahars or debris avalanches on the order of 1 in 300 [4]. Two types of events are considered. First, several masses of partly altered and highly fractured rock on the steep upper east and north flanks could generate a debris avalanche and related lahar with a volume of about 50 million cubic meters (65 million cubic yards), which is roughly the volume of the largest debris avalanche and lahar generated in the Sandy River valley during the past 1,500 years. Second, dome growth on the upper east or north flank could generate lahars similar to those produced by dome growth and collapse near Crater Rock during the past 1,500 years.

History suggests a **low probability of occurrence**. Because of potential impact to the Hood River valley from a lahar flow from the Hood River, there is **moderate vulnerability**. Because Mt. Hood is relatively quiet, this hazard is assigned a **low risk rating**.

Conclusions

Mount Hood is a potentially active volcano close to rapidly growing communities and recreation areas. The most likely widespread and hazardous consequence of a future eruption will be for lahars (rapidly moving mudflows) to sweep down the entire length of the Sandy (including the Zigzag) and White River valleys. Lahars can be generated by hot volcanic flows that melt snow and ice or by landslides from the steep upper flanks of the volcano. Structures close to river channels are at greatest risk of being destroyed. The degree of hazard decreases as height above a channel increases, but large lahars can affect areas more than 30 vertical meters (100 vertical feet) above riverbeds. The probability of eruption- generated lahars affecting the Sandy and White River valleys are 1-in-15 to 1-in-30 during the next 30 years, whereas the probability of extensive areas in the Hood River Valley being affected by lahars is about ten times less.

Volcano-hazard- zonation maps outline areas potentially at risk and shows that some areas may be too close for a reasonable chance of escape or survival during an eruption. Future eruptions of Mount Hood could seriously disrupt transportation (air, river, and highway), some municipal water supplies, and hydroelectric power generation and transmission in northwest Oregon and southwest Washington.

Communities, businesses, and citizens need to plan ahead to mitigate the effects of future eruptions, debris avalanches, and lahars. Long-term mitigation includes using information about volcano hazards when making decisions about land use and siting of critical facilities. Development should avoid areas judged to have an unacceptably high risk or be planned to reduce the level of risk. For example, a real-estate development along a valley could set aside low-lying areas at greatest risk from lahars for open space or recreation, and use valley walls or high terraces for houses and businesses.

When volcanoes erupt or threaten to erupt, emergency responses are needed. Such responses will be most effective if citizens and public officials have an understanding of volcano hazards and have planned the actions needed to protect communities. Mount Hood has a settlement (Government Camp), major highways (US 26 and OR 35), and popular tourist and recreation areas (Timberline Lodge and Mount Hood Meadows Ski Area) on its flanks. Furthermore, several thousand people live within 35 kilometers (22 miles) of Mount Hood along the channels and flood plains of rivers that drain the volcano. Such areas are at greatest risk from lahars and debris avalanches and could be inundated within one hour of an event onset.

Because an eruption can occur within days to months of the first precursory activity and because some hazardous events can occur without warning, suitable emergency plans should be made before hand. Public officials need to consider issues such as public education, communications, and evacuations. Emergency plans already developed for floods may apply, with modifications, to hazards from lahars.

Businesses and individuals should also make plans to respond to volcano emergencies. Planning is prudent because once an emergency begins, public resources can often be overwhelmed, and citizens may need to provide for themselves and make informed decisions. The Red Cross recommends numerous items that should be kept in homes, cars, and businesses for many types of emergencies that are much more probable than a volcanic eruption. A map showing the shortest route to high ground will also be helpful.

The most important additional item is knowledge about volcano hazards and, especially, a plan of action based on the relative safety of areas around home, school, and work. Lahars pose the biggest threat to people living in valleys that drain Mount Hood. The best strategy for avoiding a lahar is to move to the highest possible ground. A safe height above river channels depends on many factors including size of the lahar, distance from the volcano, and shape of the valley. For areas beyond the proximal hazard zone, few lahars will rise more than 30 meters (100 feet) above river level. Be aware that an approaching lahar will cause a loud roaring noise like a gradually approaching jet plane. Once audible, a lahar may be only a few minutes away.

W.E. Scott, T.C. Pierson, S.P. Schilling, J.E. Costa, C.A. Gardner, J.W. Vallance, and J.J. Major, 1997, Volcano Hazards in the Mount Hood Region, Oregon: USGS Open-File Report 97-89

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