11.0 VOLCANIC HAZARDS

11.1 Overview

The Cascades, which run from British Columbia into northern California, contain more than a dozen major volcanoes and hundreds of smaller volcanic features. In the past 200 years, seven of the Cascade volcanoes in the United States have erupted, including: Mt. Baker, Glacier Peak, Mt. Rainier, Mount St. Helens, Mt. Hood, Mt. Shasta, and Mt. Lassen.

Over the past 4,000 years (a geologically short time period) in Oregon there have been three eruptions of Mt. Hood, four eruptions in the Three Sisters area, two eruptions in the Newberry Volcano area and minor eruptions near Mt. Jefferson, at Blue Lake Crater, in the Sand Mountain Field, near Mt. Washington, and near Belknap Crater. During this time period, the most active volcano in the Cascades has been Mount St. Helens in Washington State with about 14 eruptions.

Many other volcanoes in Oregon and Washington are deemed active or potentially active. The Smithsonian Institution's Global Volcanism Project lists 20 active volcanoes in Oregon and 7 in Washington. These volcanoes are listed below

Table 11.1
Active Volcanoes in Oregon

Volcano	Type	Last Eruption
Mt. Hood	Stratovolcano	1866
Mt. Jefferson	Stratovolcano	950 main volcano inactive for >10,000 years
Blue Lake Crater	Crater	1490 BC
Sand Mountain Field	Cinder cones	1040 BC?
Mt. Washington	Shield volcano	620 main volcano inactive
Belknap Field	Shield volcanoes	460?
North Sister Field	Complex volcano	350
South Sister	Complex volcano	50 BC?
Mt. Bachelor	Stratovolcano	5800 BC
Davis Lake	Volcanic field	2790 BC?
Newberry Volcano	Shield volcano	620 crater formation 300,000 to 500,000 years ago
Devis Garden	Volcanic field	unknown
Squaw Ridge Lava Field	Volcanic field	unknown
Four Craters Lava Field	Volcanic field	unknown
Cinnamon Butte	Cinder cones	unknown
Crater Lake	Caldera	2290 BC Crater formation about 7,700 years ago
Diamond Craters	Volcanic field	unknown
Saddle Butte	Volcanic field	unknown
Jordan Craters	Volcanic field	1250 BC
Jackies Butte	Volcanic field	unknown

Table 11.2
Active Volcanoes in Washington

Volcano	Type	Last Eruption
Mt. Baker	Stratovolcano	1880
Glacier Peak	Stratovolcano	1700 ± 100
Mt. Rainier	Stratovolcano	1825 (?)
Mt. Adams	Stratovolcano	950 AD (?)
Mount St. Helens	Stratovolcano	1980 - 2008
West Crater	Volcanic Field	5760 BC (?)
Indian Heaven	Shield Volcanoes	6250 ± 100 BC

On a longer geological time scale, volcanic activity in the Cascades has been very widespread. A DOGAMI report on prehistoric and historic volcanic eruptions in Oregon (see website below) notes that in the Cascades as a whole, over 3000 large and small volcanoes have erupted over the past five million years. Within historical times, between 1843 and 1860 there were a series of 21 eruptions in the Cascades and there is some scientific speculation that the Northwest may be entering another period of volcanic activity.

A great deal of general background information on Oregon volcanoes and on volcanoes in general is available on several websites, including the following.

Table 11.3
Volcano Websites

Institution	Website
Smithsonian Institution (Global Volcanism Project)	www.volcano.si.edu
United States Geological Survey (USGS) - general site	www.usgs.gov
USGS Cascades Volcano Observatory (Vancouver, WA)	http://vulcan.wr.usgs.gov
DOGAMI	www.oregongeology.com

The numerous volcanoes of the Cascades differ markedly in their geological characteristics. The largest volcanoes are generally what geologists call composite or stratovolcanoes. These volcanoes may be active for tens of thousands of years to hundreds of thousands of years. In some cases, these large volcanoes may have explosive eruptions such as Mt. St. Helens in 1980 or Crater Lake about 7,700 years ago. The much more numerous sites of volcanic activity are generally what geologists call mafic volcanoes. This type of volcano is typically active for much shorter time periods, up to a few hundred years, and generally forms small craters or cones. Mafic volcanoes are not subject to large explosive events.

11.2 Volcanic Hazard Types

In Oregon, awareness of the potential for volcanic eruptions was greatly increased by the 1980 eruption of nearby Mount St. Helens in Washington which killed 57 people. In this eruption, lateral blast effects covered 230 square miles and reached 17 miles northwest of the crater, pyroclastic flows covered six square miles and reached 5 miles north of the crater, and landslides covered 23 square miles. Ash accumulations were about 10 inches at 10 miles downwind, 1 inch at 60 miles downwind, and ½ inch at 300 miles downwind. Lahars (mudflows) affected the North and South Forks of the Toutle River, the Green River, and ultimately the Columbia River as far as 70 miles from the volcano.

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

Lava flows are eruptions of molten rock. Lava flows for the major Cascades volcanoes tend to be thick and viscous, forming cones and thus typically affecting areas only very near the eruption vent. However, flows from the smaller mafic volcanoes may be less viscous flows that spread out over wider areas. Lava flows obviously destroy everything in their path.

Blast effects may occur with violent eruptions, such as Mount St. Helens in 1980. Most volcanic blasts are largely upwards. However, the Mount St. Helens blast was lateral, with impacts 17 miles from the volcano. Similar or larger blast zones are possible in future eruptions of any of the major Cascades volcanoes.

Pyroclastic flows are high-speed avalanches of hot ash, rock fragments and gases. Pyroclastic flows can be as hot as 1500 ^{o}F and move downslope at 100 to 150 miles per hour. Pyroclastic flows are extremely deadly for anyone caught in their path.

Ash falls result when explosive eruptions blast rock fragments into the air. Such blasts may include tephra (solid and molten rock fragments). The largest rock fragments (sometimes called “bombs”) generally fall within two miles of the eruption vent. Smaller ash fragments (less than about 0.1”) typically rise into the area forming a huge eruption column. In very large eruptions, ash falls may total many feet in depth near the vent and extend for hundreds or even thousands of miles downwind.

Lahars or mudflows are common during eruptions of volcanoes with heavy loading of ice and snow. These flows of mud, rock and water can rush down channels at 20 to 40 miles an hour and can extend for more than 50 miles. For some volcanoes, lahars are a major hazard because highly populated areas are built on lahar flows from previous eruptions.

Landslides or debris flows are the rapid downslope movement of rocky material, snow and/or ice. Volcano landslides can range from small movements of loose debris to massive collapses of the entire summit or sides of a volcano. Landslides on volcanic slopes may be triggered be eruptions or by earthquakes or simply by heavy rainfall.

11.3 Volcanic Hazards for Multnomah County

11.3.1 Ashfalls

Of the active volcanoes in Oregon and nearby, the two which pose the most significant risk for Multnomah County are Mt. Hood because of its proximity and Mount St. Helens because of its high level of volcanic activity. Mt. Hood is located near the boundary of Clackamas County and Hood River County, about 10 miles from the southeast corner of Multnomah County. Mount St. Helens is approximately 50 miles from downtown Portland.

For Multnomah County, volcanic hazards from Mount St. Helens are limited to ash falls. USGS estimates of return periods for ashfalls are shown in Figures 11.1 and 11.2 on the following page. Interpolating between the map contours of Figures 11.1 and 11.2, return periods for 1 centimeter (about 0.4 inch) or more and 10 centimeters (about 4 inches) or more of volcanic ash are about 1,000 years and about 4,000 years, respectively. The corresponding annual probabilities are about 0.1% and about 0.025%, respectively. These ashfall maps predominantly reflect volcanic eruptions at Mount St. Helens, because this volcano is much more active than the other volcanoes in the Cascades.

The relatively low probabilities of significant ash falls (i.e., long return periods) for Multnomah County arise because ash falls in the County would require volcanic eruptions to produce ash and wind directions carrying ash towards Multnomah County, such as winds that deposit ash southward from Mount St. Helens or north-westward from Mt. Hood. These wind directions do occur, but are much less common than the prevailing westerly winds.

Figure 11.1
Annual Probability of 1 Centimeter (about 0.4 inch) or More of Volcanic Ash

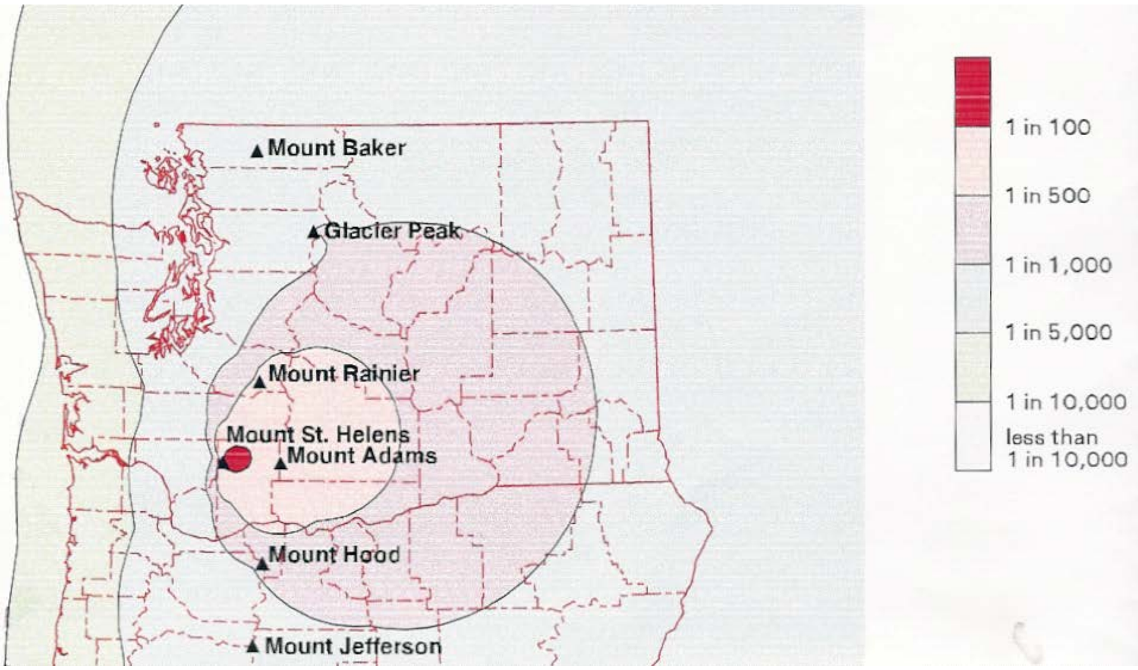
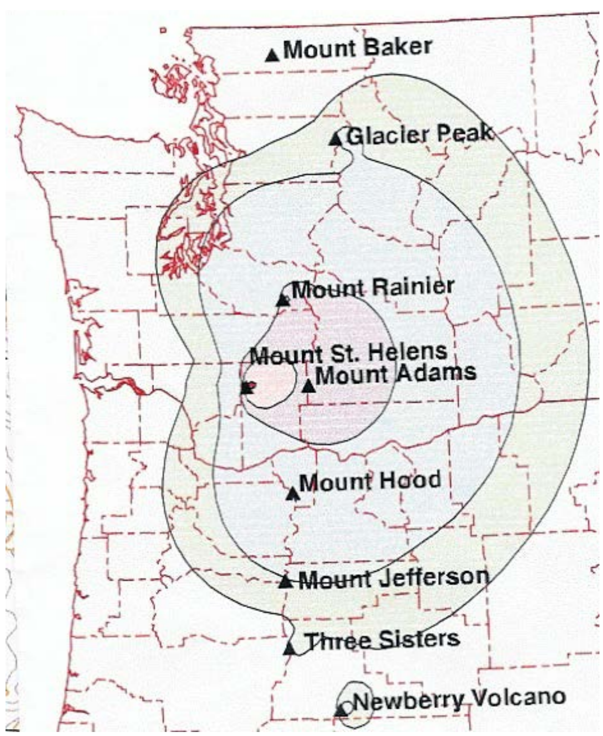


Figure 11.2
Annual Probability of 10 Centimeters (about 4 inches) or More of Volcanic Ash
(same scale as Figure 11.1 above)



11.3.2 Volcanic Hazards from Mt. Hood

The history of volcanic activity of Mt. Hood and analyses of volcanic hazard zones around Mt. Hood are summarized in the 1997 USGS Open File Report 97-89: Volcano Hazards in the Mount Hood Region, Oregon and in the accompanying map.

As documented in the above USGS report, the proximal (nearby) hazard zone for Mount Hood includes areas subject to lava flows, blast effects and pyroclastic flows. This extreme hazard area includes portions of Clackamas, Hood River and Wasco Counties, including several small communities. However, none of these hazard zones extend to Multnomah County.

Multnomah County, which is subject to ash falls from Mount Hood and other active volcanoes, is also subject to lahars or debris flows down the Sandy River. Figures 11.3 and 11.4, excerpted from the USGS Mount Hood map, show the hazard areas within Multnomah County. Figure 11.5 shows an overlay of the lahar maps for Troutdale with parcels and structures. Troutdale is the largest developed area in Multnomah County with high risk from lahars. However, portions of Wood Village and Fairview are also at risk, as well as small communities along the Sandy River between Troutdale and Mount Hood.

As shown on the Figure 11.4, the arrival time in Multnomah County for a lahar down the Sandy River ranges from about 2 hours and 30 minutes near the southern border of the county to about 3 hours and 30 minutes in Troutdale.

Figures 11.3, 11.4 and 11.5 show the expected inundation area for two sizes of lahars: a large lahar with a 30-year probability of approximately of 1 in 15 to 1 in 30 and a worst-case (largest possible) lahar with a 30-year probability of less than 1 in 3,000. The return periods for these lahars are approximately 450 to 900 years for the large lahar and about 10,000 years for the worst-case lahar.

The large lahar inundation area (shown in pink on Figures 11.3 and 11.4 and in beige on Figure 11.5) includes a large portion of Troutdale, including:

- The developed areas along the Sandy River and the lower reach of Beaver Creek, and
- Nearly all of Troutdale north of Interstate-84.

The worst-case lahar (shown in violet in Figures 11.3, 11.4 and 11.5) inundates even larger areas. Within these inundation areas the damage level would be extreme, with complete destruction of almost all structures.

Figure 11.3
Lahar Hazard Areas[1]

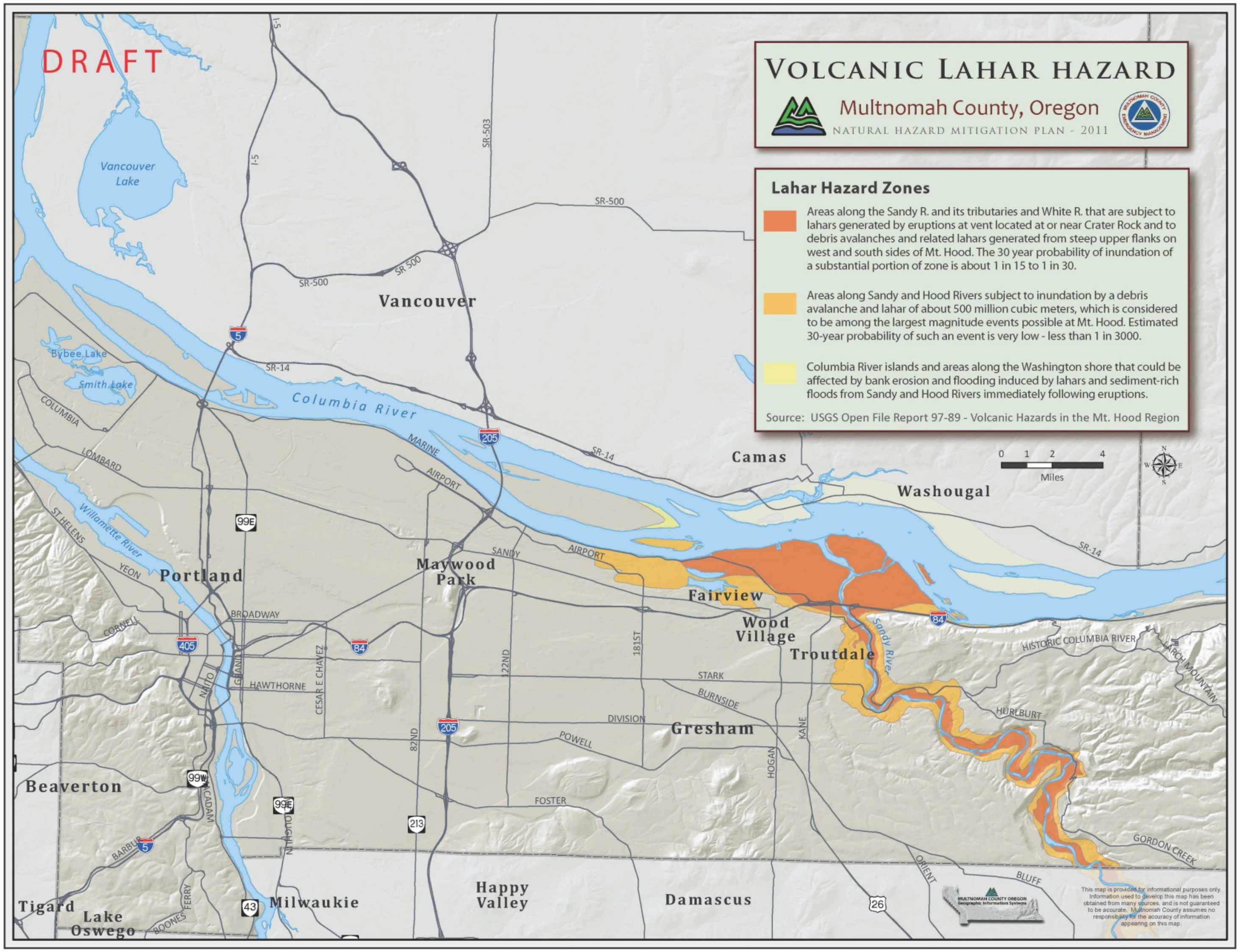
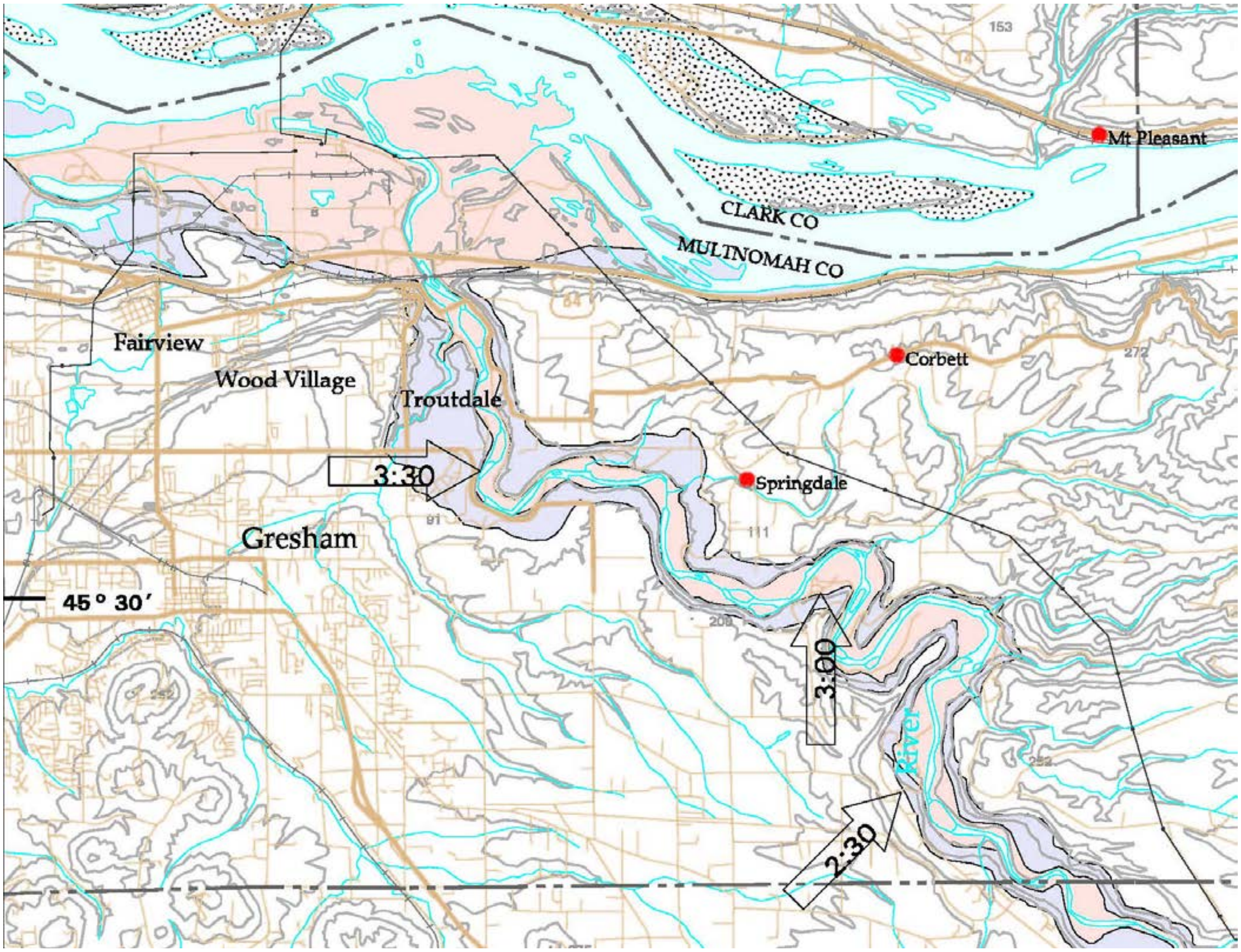


Figure 11.4
USGS Mount Hood Hazard Map (Excerpt) from OFR 97-89
Showing Arrival Times from the Time of Eruption

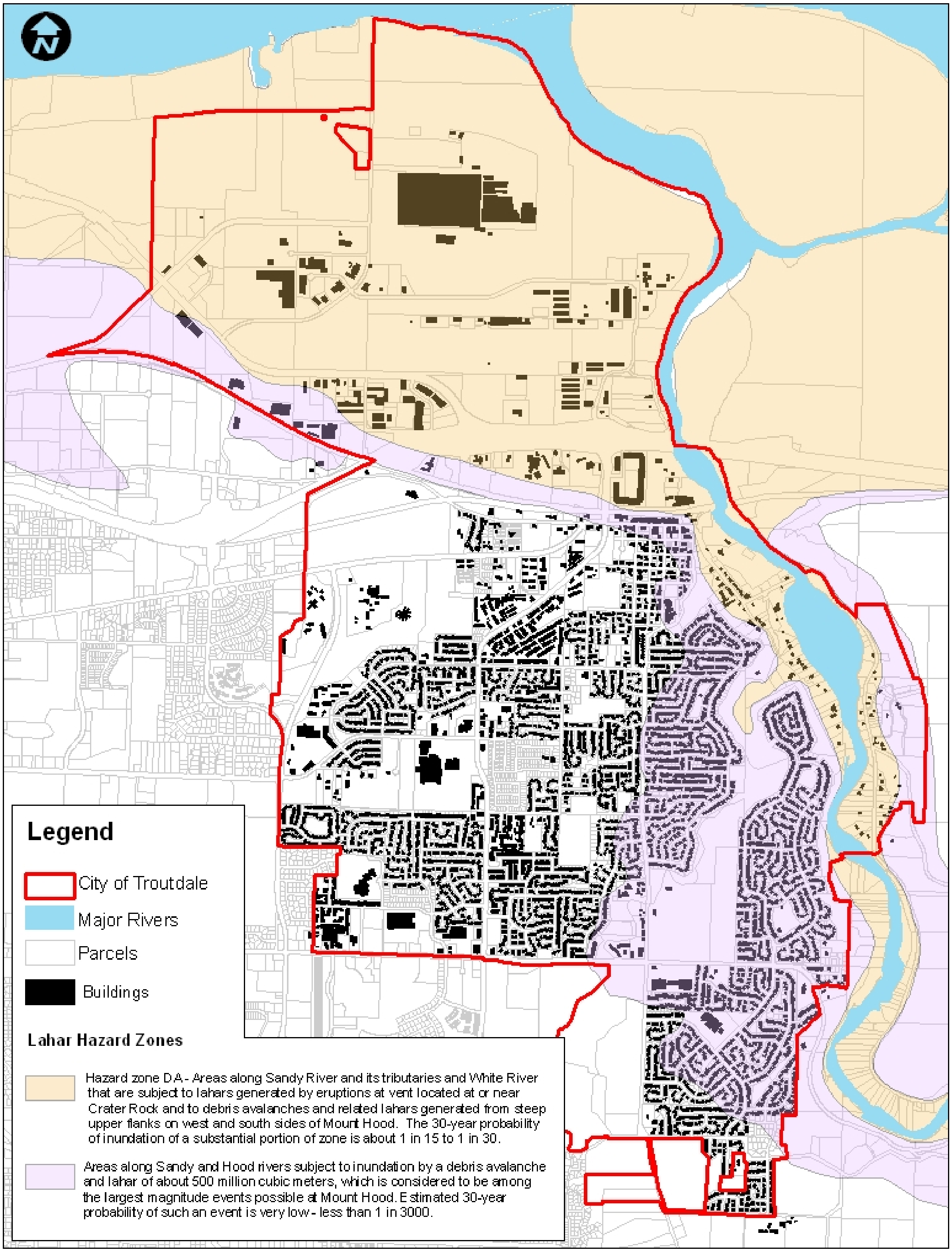


The USGS definitions of the lahar hazard zones shown above and in Figure 11.4 are:

Hazard zone DA — Areas along Sandy River and its tributaries and White River that are subject to lahars generated by eruptions at vent located at or near Crater Rock and to debris avalanches and related lahars generated from steep upper flanks on west and south sides of Mount Hood. The 30–year probability of inundation of a substantial portion of zone is about 1 in 15 to 1 in 30

Areas along Sandy and Hood Rivers subject to inundation by a debris avalanche and lahar of about 500 million cubic meters, which is considered to be among the largest magnitude events possible at Mount Hood [9]. Estimated 30–year probability of such an event is very low—less than 1 in 3000

Figure 11.5
Overlay of Lahar Hazard Map with Troutdale Parcels and Structures



11.4 Probable Consequences of Volcanic Events

The probable impacts of potential volcanic eruptions on Multnomah County include ash falls and lahars.

Ash Falls

Depending on the volume of volcanic ash ejected by an eruption and on prevailing wind directions at the time of eruption, various thicknesses of ash falls may affect Multnomah County. The impacts of ash falls on Multnomah County include:

a) Respiratory problems for at-risk population such as elderly, young children or people with respiratory problems,

b) Impacts on public water supplies drawn from surface waters, including degradation of water quality (high turbidity) and increased maintenance requirements at water treatment plants,

c) Possible electric power outages from ash-induced short circuits in distribution lines, transmission lines, and substations,

d) Disruptions of air traffic from the Portland Airport, other Multnomah County airports and/or other airports in the Pacific Northwest,

e) Clogging of filters and possible severe damage to vehicle engines, furnaces, heat pumps, air conditioners, commercial and public building combined HVAC systems (heating, ventilation and air conditioning) and other engines and mechanical equipment, and

f) Clean-up and ash removal from roofs, gutters, sidewalks, roads vehicles, HVAC systems and ductwork, engines and mechanical equipment.

In all but the most extreme events, ash falls for Multnomah County are likely to be very minor with an inch or less of ash likely. However, even minor amounts of ash fall can result in significant impacts, as noted above.

Lahars

Lahars down the Sandy River pose a greater threat to Multnomah County. As shown in Figures 11.3, 11.4 and 11.5 large lahars could inundate developed areas near the river. The consequences would be extreme levels of damage in the inundated areas and a high potential for casualties unless complete evacuations were carried out before the lahar reached populated areas. The moderately large and worst case lahar events have 30-year probabilities estimated by the USGS to be about 1 in 15 to 1 in 30 for the moderately large lahars and less than 1 in 2,000 for the worst-case lahar events, respectively. The moderately large lahar events are shown in dark orange in Figure 11.3 and in tan in Figures 11.4 and 11.5. The worst case lahar events are shown in light orange in Figure 11.3 and in violet in Figures 11.4 and 11.5

Lahar events could also profoundly disrupt transportation to/from Multnomah County if the Interstate-84 bridge and other bridges across the Sandy River were to fail. In the event of bridge failures, the time to construct new bridges would likely be at least six months or longer.

The number of buildings located in the major and extreme lahars, defined as in the previous figures, are shown below in Table 11.4.

Table 11.4
Numbers of Buildings in Lahar Zones

Building Type:	Industrial	Commercial	Multi-Family Residential	Parks - Open Space	Mixed Use Residential	Single Family Residential	Mixed Use Other	Rural	**Total**
Unincorporated Multnomah County									
Major Lahar	8	0	0	0	0	51	0	149	**208**
Extreme Lahar[1]	0	0	0	0	0	130	0	218	**348**
Extreme Lahar (total)	8	0	0	0	0	181	0	367	**556**
Incorporated Multnomah County									
Major Lahar	139	0	6	58	48	143	0	3	**397**
Extreme Lahar[1]	135	8	105	5	33	2,073	10	7	**2,376**
Extreme Lahar (total)	274	8	111	63	81	2,216	10	10	**2,773**
Multnomah County (Entire)									
Major Lahar	147	0	6	58	48	194	0	152	**605**
Extreme Lahar[1]	135	8	105	5	33	2,203	10	225	**2,724**
Extreme Lahar (total)	282	8	111	63	81	2,397	10	377	**3,329**

[1] Numbers of buildings in Extreme Lahar rows is the additional number of buildings inundated beyond those inundated in the Major Lahar event.

As shown above, a major lahar event with a return period of about 450 to 900 years would inundate, and completely destroy, about 600 buildings in Multnomah County. For the extreme lahar event, with a return period of about 10,000 years, a total of about 3,300 buildings would be inundated and completely destroyed.

11.5 Mitigation of Volcanic Hazards

There are no practical physical mitigation measures possible to protect at risk areas from lahars that are feasible from an engineering perspective or an economic perspective. Therefore, the primary means of addressing lahar risk are warning systems, public education and evacuation planning.

The USGS monitors volcanic activity in the Cascades via networks of seismic sensors (which can detect earthquakes related to magma movements) as well as very accurate ground surface measurements. The USGS also has a volcanic warning system with several levels of alert as a potential eruption becomes more likely and more imminent. The USGS volcanic warning system has parallel warnings for people on the ground and for air traffic: U.S. Geological Survey's Alert Notification System for Volcanic Activity (USGS Fact Sheet 2006-3139.

Figure 11.6
Volcanic Alert Levels for People on the Ground

Volcano Alert Levels Used by USGS Volcano Observatories

Alert Levels are intended to inform people on the ground about a volcano's status and are issued in conjunction with the Aviation Color Code. Notifications are issued for both increasing and decreasing volcanic activity and are accompanied by text with details (as known) about the nature of the unrest or eruption and about potential or current hazards and likely outcomes.

Term	Description
NORMAL	Volcano is in typical background, noneruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to noneruptive background state.
ADVISORY	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
WATCH	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, **OR** eruption is underway but poses limited hazards.
WARNING	Hazardous eruption is imminent, underway, or suspected.

Figure 11.7
Volcanic Alert Levels for Air Traffic

Aviation Color Code Used by USGS Volcano Observatories

Color codes, which are in accordance with recommended International Civil Aviation Organization (ICAO) procedures, are intended to inform the aviation sector about a volcano's status and are issued in conjunction with an Alert Level. Notifications are issued for both increasing and decreasing volcanic activity and are accompanied by text with details (as known) about the nature of the unrest or eruption, especially in regard to ash-plume information and likely outcomes.

Color	Description
GREEN	Volcano is in typical background, noneruptive state or, *after a change from a higher level,* volcanic activity has ceased and volcano has returned to noneruptive background state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background level or, *after a change from a higher level,* volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, **OR** eruption is underway with no or minor volcanic-ash emissions [ash-plume height specified, if possible].
RED	Eruption is imminent with significant emission of volcanic ash into the atmosphere likely **OR** eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible].

Multnomah County's emergency planning includes warning, notification and evacuation protocols for volcanic events.

The following table includes the volcanic hazards mitigation action items from the master Action Items table in Chapter 4.

Table 11-5
Volcanic Hazards Mitigation Action Items

Hazard	Action Item	Coordinating Organizations	Timeline	Plan Goals Addressed				
				Life Safety	Protect Property and Infrastructure	Emergency Management Capabilities	Public Awareness and Education	Environmental Stewardship
Volcanic Hazards Mitigation Action Items								
Short-Term #1	Develop emergency evacuation protocols for lahar events and conduct exercises to test the protocols.	Multnomah County Emergency Management	3 Years	X		X	X	
Short-Term #2	Update public education, emergency notification procedures and emergency planning for ash fall and lahar events.	Multnomah County Emergency Management	1-2 Years	X		X	X	