Final - Hazard Profile – Volcano

Volcano

LAHAR

Frequency	50+ yrs	10-50 yrs	1-10 yrs	Annually
People	<1,000	1,000-10,000	10,000-50,000	50,000+
Economy	1% GDP	1-2% GDP	2-3% GDP	3%+ GDP
Environment	<10%	10-15%	15%-20%	20%+
Property	<$100M	$100M-$500M	$500M-$1B	$1B+
Hazard scale	< Low to High >			

Risk Level – Lahar

- Frequency – Lahar incidents do not occur annually.
- People – With the early detection and advance of a lahar, significant loss of life can be avoided. Due to the size of the communities in some potential hazard zones for a lahar event, a large number of people may be affected.
- Economy – In a catastrophic lahar, the economy can be expected to suffer severely in the beginning stages of the response and recovery. It can also suffer in the end if major infrastructure is damaged and areas affected by the lahar are not available for redevelopment for years to decades as river channels get reestablished and a lot of sediment is transported downstream.
- Environment – According to subject matter experts, the threshold for inclusion of this category is unlikely to be met in a single lahar.
- Property – State and international statistics indicate that there is the potential for property damage from a large lahar to exceed $1 billion. In some areas of the State the damage could be much larger.

ASHFALL

Frequency	50+ yrs	10-50 yrs	1-10 yrs	Annually
People	<1,000	1,000-10,000	10,000-50,000	50,000+
Economy	1% GDP	1-2% GDP	2-3% GDP	3%+ GDP
Environment	<10%	10-15%	15%-20%	20%+
Property	<$100M	$100M-$500M	$500M-$1B	$1B+
Hazard scale	< Low to High >			

Risk Level – Ash Fall

- Frequency – Volcanic ash fall incidents do not occur annually.
- People – An incident of volcanic ash fall is unlikely to result in significant losses of life.
- Economy – An incident of volcanic ash fall has the potential to affect the economy of Washington from slightly to severely depending on the amount of ash dispersed over the state and the resources needed to restore normal business operations following such an incident.
- Environment – An incident of volcanic ash fall is unlikely to result in the loss of 10% of a single species or habitat.
- Property – State and international statistics indicate that there is the potential for property damage from a volcanic ash fall incident to exceed $1 billion.

Summary

- The hazard – Washington State has five active volcanoes – Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens, and Mount Adams. These volcanoes are all capable of generating destructive lahars, ash fall, lava and pyroclastic flows, and debris avalanches. In addition, there are several volcanic fields in southern Washington that could host future eruptions. The phenomenon that poses the greatest threat is ash fall and lahars from the five major volcanoes. Mount Hood in Oregon also poses a threat to communities along the Washington side of the Columbia River. These volcanoes pose a high to very high threat to life, property, the economy, and civil and military aviation from near the volcano to areas hundreds of miles away from the volcanoes' slopes.

- Previous occurrences – All five volcanoes have been active in the past 4,000 years. Mount St. Helens has been the only one active in the past 30 years with a massive eruption in 1980, followed by dome building eruptions in the 1980-1986 and 2004-2008. All five volcanoes have generated ash fall and / or lahars in the past 300 years.

- Probability of future events – Washington's volcanoes will erupt again, as shown by recent activity at Mount St. Helens. There is a 1 in 500 probability that portions of 2 counties will receive 10 centimeters (4 inches) or more of volcanic ash from any Cascades volcano in any given year, and a 1 in 1,000 probability that parts or all of 3 more counties will receive that quantity of ash. There is a 1 in 100 annual probability that small lahars or debris flows will impact river valleys below Mount Baker or Mount Rainier, and less than a 1 in 1,000 annual probability that the large destructive lahars would flow down the slopes of Glacier Peak, Mount Adams, Mount Baker, and Mount Rainier. There is a much higher probability that significant areas of the State will experience smaller amounts of ash fall.

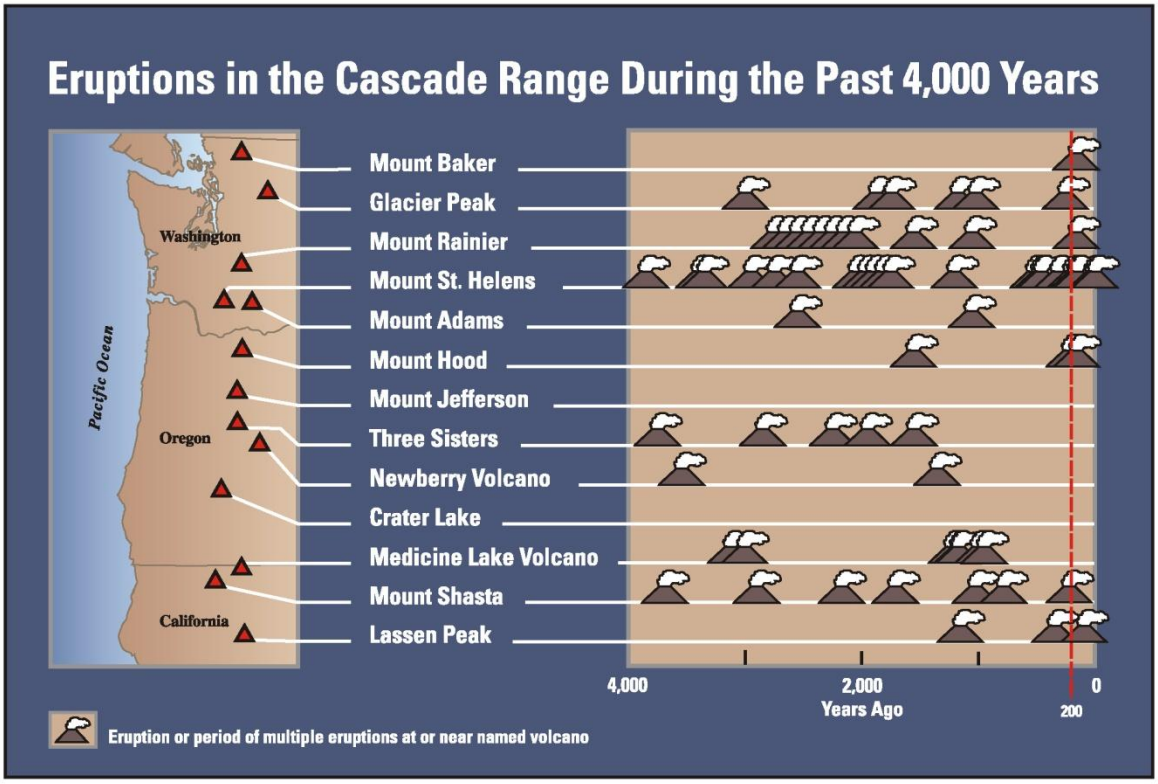
- Jurisdictions at greatest risk – Communities to the northeast, east, and southeast of Mount St. Helens are at greatest risk of receiving damaging ash fall. Communities generally to the west and / or south of the volcanoes are at risk to the impact of damaging lahars.

- Special Note - The Cascade Volcano Observatory monitors the Washington State volcanoes for unrest and eruptive behavior and provides an early warning system.

The Hazard[1, 2, 3, 4, 5] 6

A volcano is a vent in the earth's crust through which magma, rock fragments, gases, and ash are ejected from the earth's interior. Over time, accumulation of these erupted products on the earth's surface creates a volcanic mountain.

Washington State has five major volcanoes in the Cascade Range – from north to south they are Mount Baker, Glacier Peak, Mount Rainier, Mount St. Helens and Mount Adams. These mountains are composite or strato-volcanoes, a term for steep-sided, often symmetrical cones constructed of alternating layers of lava flows, ash, and other volcanic debris. Composite volcanoes tend to erupt explosively and pose considerable danger to nearby life and property. In contrast, the gently sloping shield volcanoes, such as those in Hawaii, typically erupt non-explosively, producing fluid lavas that can flow great distances from the active vents. Although Hawaiian-type eruptions may destroy property, they rarely cause death or injury. Young lava-flow volcanoes similar to Hawaiian volcanoes form much of the southern part of the Cascades south of Mount St. Helens and Mount Adams to the Columbia River.



5.12 Error! No text of specified style in document.**-Figure 1 Eruptions in the Cascade Range during the past 4,000 years**

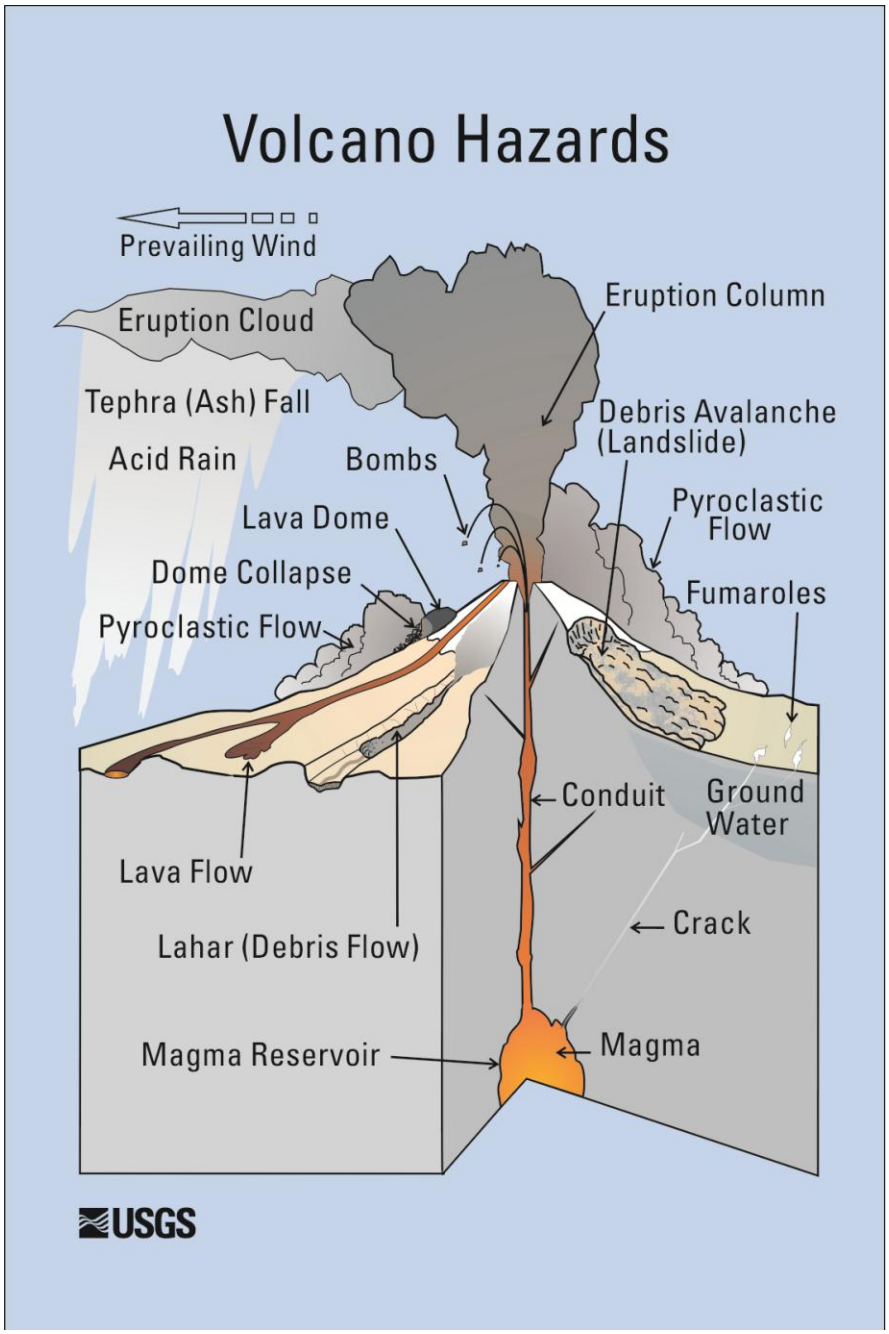
Volcanoes can lie dormant for centuries between eruptions making the risk posed by volcanic activity not always apparent. When Cascade Range volcanoes do erupt, high-speed avalanches of hot ash and rock called pyroclastic flows, lava flows, and landslides can devastate areas 10 or

more miles away, while huge mudflows of volcanic ash and debris called lahars can inundate valleys more than 50 miles downstream. Falling ash from explosive eruptions can disrupt human activities hundreds of miles downwind, and drifting clouds of fine ash can cause severe damage to the engines of jet aircraft hundreds or thousands of miles away. Because people are moving into areas near these volcanoes at a rapid pace, the state's volcanoes are among the most dangerous in the United States.

Legislation passed by the United States Congress in 1974 established the U.S. Geological Survey (USGS) as the lead agency in charge of providing reliable and timely warnings of volcanic hazards to State and local authorities. Under this Congressional mandate, following the Mount St. Helens eruption of May 1980, the USGS established the Cascades Volcano Observatory, a permanent regional office located in Vancouver, Washington. "Observatory scientists, technicians, and support staff work in partnership with colleagues at other USGS centers, universities, and other agencies to monitor restless volcanoes and provide timely warning of eruptions, assess hazards from volcanoes, including water-related hazards in valleys draining volcanoes, share volcano information with emergency management and planning officials, develop new techniques and methods to better monitor and predict behavior of volcanoes, study volcanic processes, and educate public officials, citizens, and the news media."[7]

The National Volcano Early Warning System (NVEWS) is a proposed national-scale effort by the USGS Volcano Hazards Program and other affiliated partners to ensure that volcanoes are monitored at a level commensurate with the threat that they pose. Of the 169 U.S. volcanoes identified by the NVEWS assessment, four Washington State volcanoes were ranked as very high threat. Specifically, Mount St. Helens was ranked 2nd, Mount Rainier was ranked 3rd, Mount Baker was ranked 11th and Glacier Peak was ranked 12th. Mount Adams was ranked 19th and considered a high threat volcano. Additionally, Oregon's Mount Hood was ranked 4th. It is about 50 miles southeast of Portland and poses some threat to areas of southwest Washington along the Columbia River. Indian Heaven and West Crater volcanic fields in southwest Washington were ranked as low threat volcanoes. This National Volcano Early Warning System seeks to establish enhanced instrumentation and monitoring at targeted volcanoes and a continuously manned volcano watch office to improve the ability to provide rapid, reliable hazard warnings.

Scientists define a volcano as active if it has erupted in recent geologic time or is seismically or geothermally active. Volcanoes commonly repeat past behavior. Typically, volcanoes provide warning signals before they erupt. As magma pushes its way upward, it produces earthquakes, and causes the sides of the volcano to deform. Neither the earthquakes nor the deformation may be apparent to people, but they are detectable with instruments. Heat and gases from the rising magma may cause changes in the temperature, discharge rate and composition of hot springs and vapors on the volcano and are thus also detectable. In contrast, some landslides and debris flows could occur without specific warning.



5.12-Figure Error! No text of specified style in document.**2 USGS Schematic drawing of various Volcanic Hazards**

Long-term, a volcanic eruption can affect an area in a number of ways, including clogging rivers and streams with sediment, smothering agricultural fields, disrupting wildlife habitat and behavior, damaging timber stands and minimizing recreational opportunities. Additionally, transported sediment can affect watersheds for decades by reducing their capacity to carry floodwaters, inhibiting their ability to recover, destabilizing their banks, and filling navigable shipping channels. Recent studies show continued movement of large amounts of sediment through the watersheds below Mount St. Helens more than 30 years after its 1980 eruption.

Among the specific effects of volcanic activity are:

- Lava erupted from vents can form lava flows or steep-sided lava domes. Cascade Range lava flows are relatively short, seldom reaching more than 10 miles from the source, and slow moving. The heat of lava flows can melt ice and snow, creating lahars, or start forest or grass fires. They can bury roads and escape routes. Lava domes extruded on steep slopes are subject to collapse, which is one way a pyroclastic flow forms.

- Pyroclastic flows are high-speed avalanches of hot ash, rock fragments, and gas that move down the sides of a volcano during explosive eruptions or when the steep edge of a lava flow or part of a lava dome breaks apart and collapses. These flows, which can reach 1,500 degrees F and move up to 100-150 miles per hour, are capable of knocking down and burning everything in their paths. Pyroclastic flows from Cascade volcanoes rarely travel more than 5 to 10 miles from vents. A pyroclastic surge, a more energetic and dilute mixture of searing gas and rock fragments, also travels very fast. Pyroclastic surges move easily up and over ridges, while flows tend to follow valleys.[8] Pyroclastic flows and surges can swiftly melt ice and snow to form lahars that can extend far down valleys.

- Debris avalanches, a type of landslide consisting of rock, glacial ice, snow, and other debris, cause damage down slope and in valleys. Such avalanches can range in size from small movements of loose debris on the surface of a volcano to massive failures of the entire summit or flanks of a volcano such as occurred during the 1980 eruption of Mount St. Helens. They travel rapidly and can carry large amounts of material; many, especially smaller ones, occur with little or no warning. Wet debris avalanches can transform into lahars, which can flow much farther downstream.

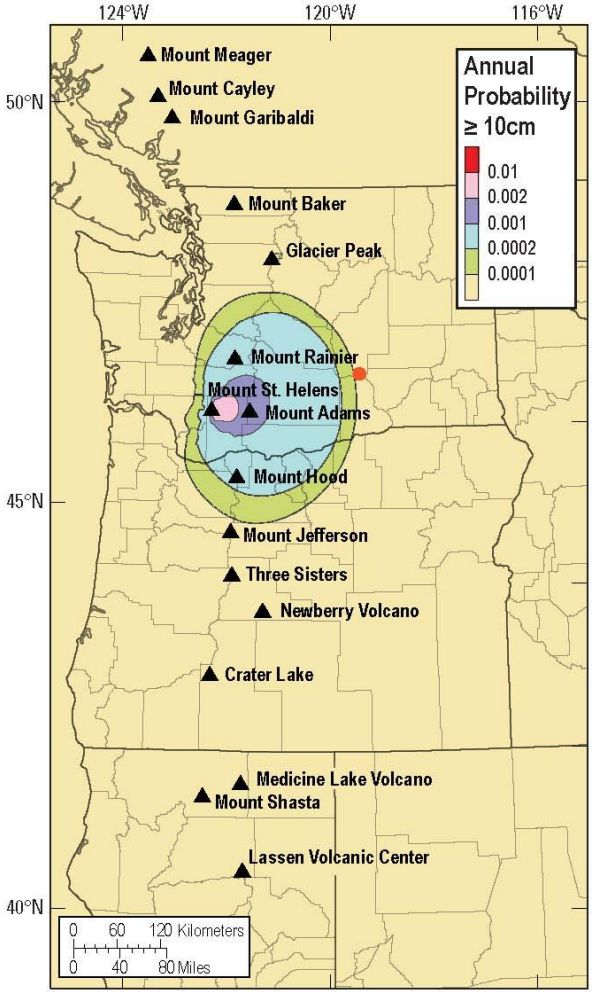
- Lahars are a flowing mixture of rock debris and water that originates on the slopes of a volcano. Lahars are also referred to as volcanic mudflows or debris flows.[9] Lahars originate from landslides of water-saturated debris, from the sudden melting of snow and ice by eruptive processes, from heavy rainfall eroding volcanic deposits, or from an outbreak of floodwater from a glacier or from lakes in craters or water dammed by volcanic deposits. Lahars move faster on the steep slopes nearest their source, attaining speeds up to 40 miles per hour or more; large ones can travel more than 50 miles downstream. Close to the volcano, lahars have the strength to rip huge boulders, trees, and buildings from the ground and carry them down valley. Farther downstream, they slow typically to 5-20 miles per hour, deposit material, and can entomb everything in their path in mud. Historically, lahars have been one of the most deadly volcanic hazards.[10]

- Tephra falls are produced by explosive eruptions that blast fragments of rock and ash into the air. Large fragments fall to the ground close to the volcano. Small fragments called ash can travel thousands of miles downwind and rise tens of thousands of feet

into the air. In some cases, ash can harm the human respiratory system. Heavy ash fall can create darkness. Ash can clog waterways and machinery, cause electrical short circuits, harm mechanical and electronic equipment, and drift into roadways, railways, and runways. Ash can cause jet engines on aircraft to stall. The weight of ash, particularly when it becomes water saturated, can cause structural collapse, especially when it exceeds 10 centimeters or 4 inches depth. Ash resuspended by winds or traffic can be a hazard to animals, people, machinery and transportation systems for months after an eruption.

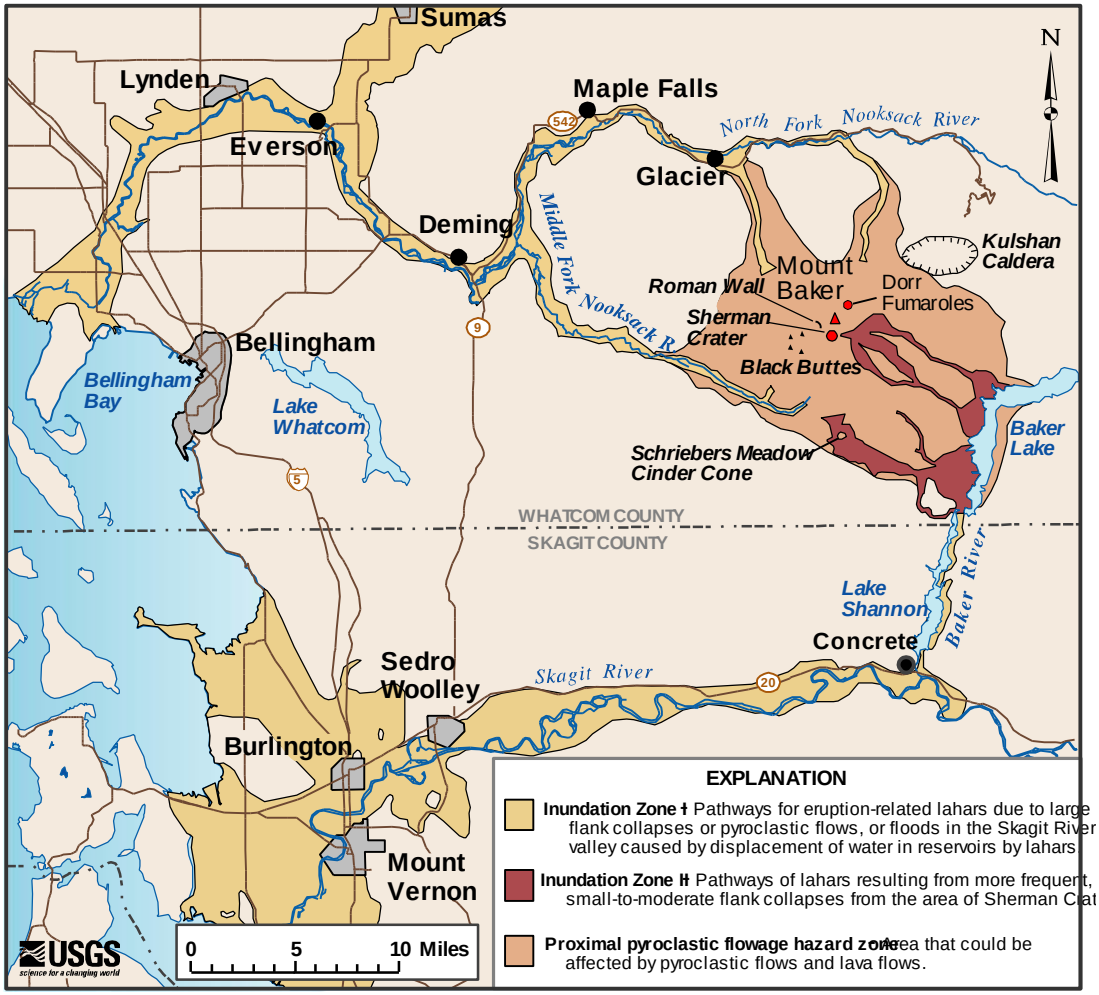
The most serious tephra hazard in the region is from Mount St. Helens, the most prolific producer of tephra falls in the Cascades during the past few thousand years. The map below provides estimates of the annual probability of tephra fall of 10 centimeters or greater affecting the region from all volcanoes. Probability zones extend farther east of the range because prevailing winds are from the west most of the time. It is very unlikely they would reach densely settled areas: 1 in 5,000 to 1 in 10,000 annual probabilities.

Figure 3. Preliminary probabilistic tephra-hazard map for Pacific Northwest[11]



***Mount Baker*[12, 13]**

- Mount Baker in Whatcom County erupted in the mid-1800s for the first time in several thousand years. Activity at steam vents in Sherman Crater, near the volcano's summit, increased in 1975 and is still vigorous, but there is no evidence that an eruption is imminent.
- Skagit County areas at risk – Burlington, Concrete, Conway, Edison, Hamilton, La Conner, Mount Vernon, and Sedro Woolley, and the valleys of Baker and Skagit Rivers.
- Whatcom County areas at risk - Deming, Everson, Ferndale, Glacier, Kulshan, Lynden, Nooksack, and Sumas, valleys of the North Fork Nooksack, Middle Fork Nooksack, and Nooksack Rivers, and the shores of Baker Lake.



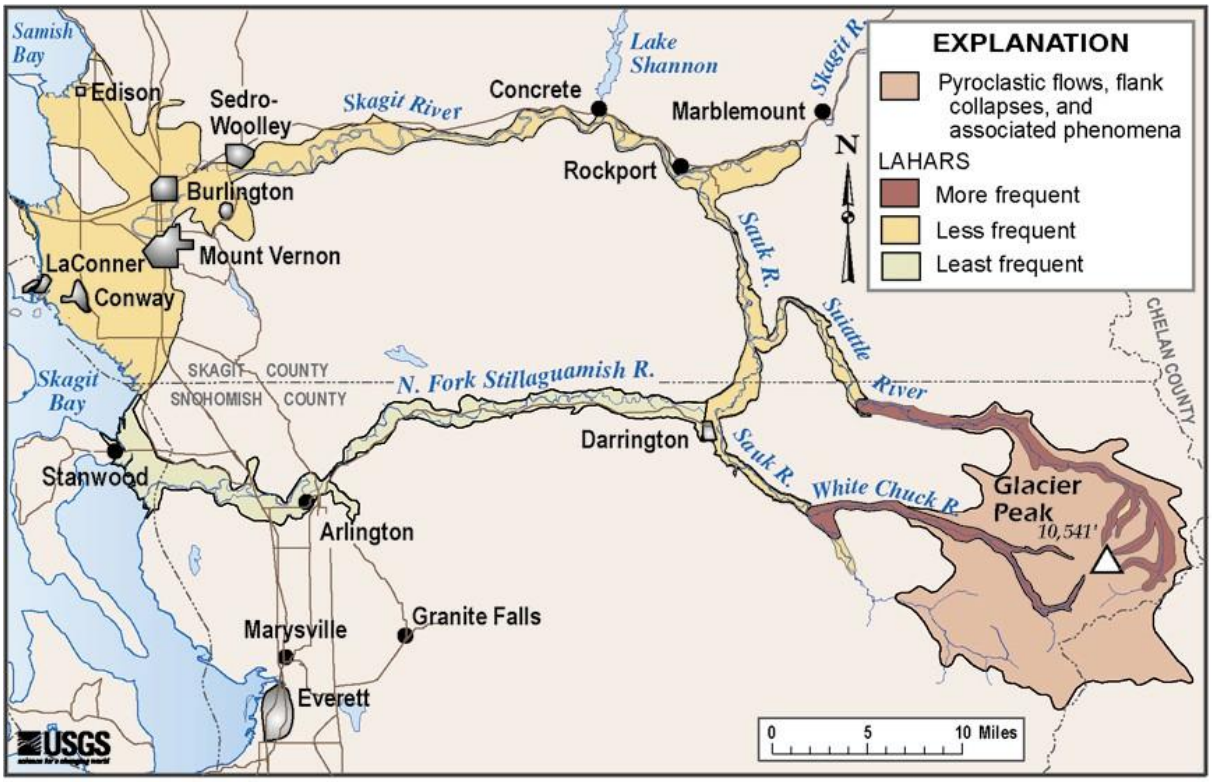
Hazard zonation map for Mount Baker. Map modified from Gardner and others, 1995; U.S. Geological Survey Open-File Report 95-498.

Mount Baker is not showing signs of renewed activity, but will again; its main hazards are lahars and debris avalanches. These may occur without an accompanying eruption. Mount Baker has not produced large amounts of tephra in the past and probably will not in the future. The

annual likelihood of one centimeter or more of tephra falling in eastern Whatcom County, western Okanogan County, and parts of Skagit and Chelan Counties and southern British Columbia from an eruption of Mt. Baker is one chance in 50,000.

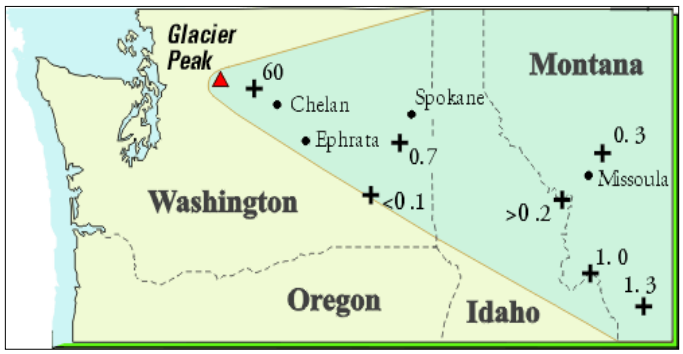
Glacier Peak[14, 15]

- Glacier Peak in Snohomish County has erupted at least six times in the past 4,000 years, the last time about 300 years ago with ash and steam eruptions and small lahars. An especially powerful series of eruptions about 13,000 years ago deposited volcanic ash at least as far away as Wyoming.
- Skagit County areas at risk – Burlington, Concrete, Conway, Edison, Hamilton, La Conner, Mount Vernon, Rockport, and Sedro Woolley, plus valleys of the Suiattle, Sauk, and Skagit Rivers.
- Snohomish County areas at risk – Arlington, Darrington, and Stanwood, plus valleys of the White Chuck, Sauk, and North Fork Stillaguamish Rivers.



Areas at risk from lahars, lava domes, pyroclastic flows, and associated phenomena from Glacier Peak . Map modified from R.B. Waitt and others, U.S. Geological Survey Open-File Report 95-499.

Glacier Peak has erupted several times since the Ice Age glaciers retreated 15,000 years ago – most recently around the 18th century. About 13,000 years ago, Glacier Peak hosted a series of explosive eruptions as large as those from Mount St. Helens. Lahars represent the greatest hazard, followed by tephra fall. The annual probability of lahars inundating the Stillaguamish River valley is thought to be less than 1 in 10,000.



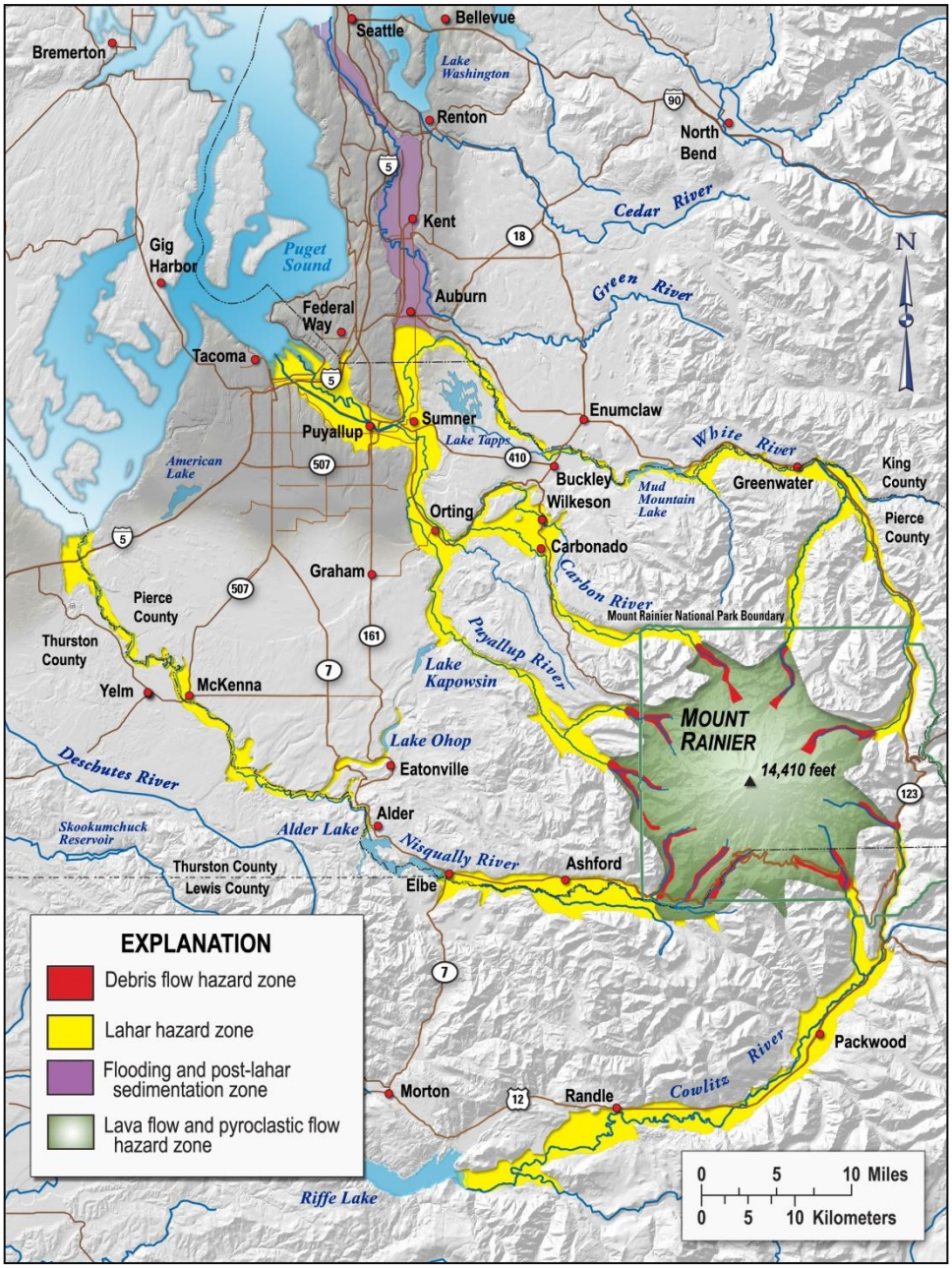
Thickness of Ash from Glacier Peak during a Series of Eruptions about 13,100 years ago. Light blue indicates approximate area covered by ash (spot thickness in inches) during these eruptions.

In future eruptions, lava flows and ballistic projectiles probably will be contained within 5 to 6 miles of the summit. Pyroclastic flows could travel 13 miles to the west and north of the summit, while pyroclastic surges could travel another three miles farther.

Mount Rainier[16, 17, 18, 19, 20, 21]

- Mount Rainier in Pierce County is one of the most hazardous volcanoes in the United States. It has produced several eruptions and numerous lahars in the past 4,000 years. It is capped by more glacial ice than the rest of the Cascades volcanoes combined, and parts of Rainier's steep slopes have been weakened by hot, acidic volcanic gases and water. These factors make this volcano especially prone to landslides and lahars. More than 150,000 people live on deposits of past lahars in river valleys below the volcano.
- King County areas at risk – Auburn, Greenwater, Kent, Pacific, Seattle (Duwamish River), and Tukwila, and the valleys of the Duwamish, Green, and White Rivers.
- Pierce County areas at risk – Ashford, Buckley, Carbonado, Elbe, Fife, McKenna, Orting, Puyallup, South Prairie, Sumner, and Tacoma, and the valleys of the Carbon, Nisqually, Puyallup, and White Rivers.
- Thurston County areas at risk – The Nisqually River valley.
- Lewis County areas at risk – Packwood and Randle, and the Cowlitz River valley.

From Mount Rainier, lahars have traveled at a rate of 45-50 miles per hour with depths of over 100 feet were confined in valleys near the volcano, slowing and thinning in the wide and now populated valley floors below. During the past 10,000 years, at least 60 lahars have moved down valleys that begin on Mount Rainier. Lahars are the greatest threat to communities below the volcano. More than 150,000 people live on deposits of old lahars. Lahars that reached the Puget Sound lowland have occurred about every 500 to 1,000 years. Scientists believe there is a one in seven chance that a lahar will reach the Puget Sound lowland in the average human lifespan if future lahars occur at rates similar to those of previous lahars.



Lahar Warning System

Because of the higher level of risk from lahars in the Carbon and Puyallup River valleys, the U.S. Geological Survey and Pierce County in the mid 1990s installed lahar detection and warning systems in the valleys just outside the national park. The system consists of arrays of five acoustic flow monitors along each river that detect the ground vibrations caused by a lahar. Computerized evaluation of data confirms the presence of a flowing lahar and issues an automatic alert to the State EOC, which sends out notices so emergency managers can initiate

response measures such as evacuations. This system reduces, but does not eliminate, risk in the lahar pathways.

The U.S. Geological Survey has estimated travel times for a Case I lahar for both the Puyallup and Carbon River basins in the following table. A lahar is projected to reach the following communities in the estimated times after the lahar warning system sounds an alarm.

Puyallup River lahar		
Community	**Distance from the Source**	**Estimated Arrival After Alarm**
Orting	32 miles	42 minutes
Sumner	40 miles	65 minutes
Puyallup	43 miles	78 minutes
Auburn	46 miles	96 minutes
Commencement Bay, Tacoma	49 miles	108 minutes

Carbon River lahar		
Community	**Distance from the Source**	**Estimated Arrival After Alarm**
Carbonado	24 miles	12 minutes
Wilkeson	27 miles	18 minutes
Orting	32 miles	42 minutes

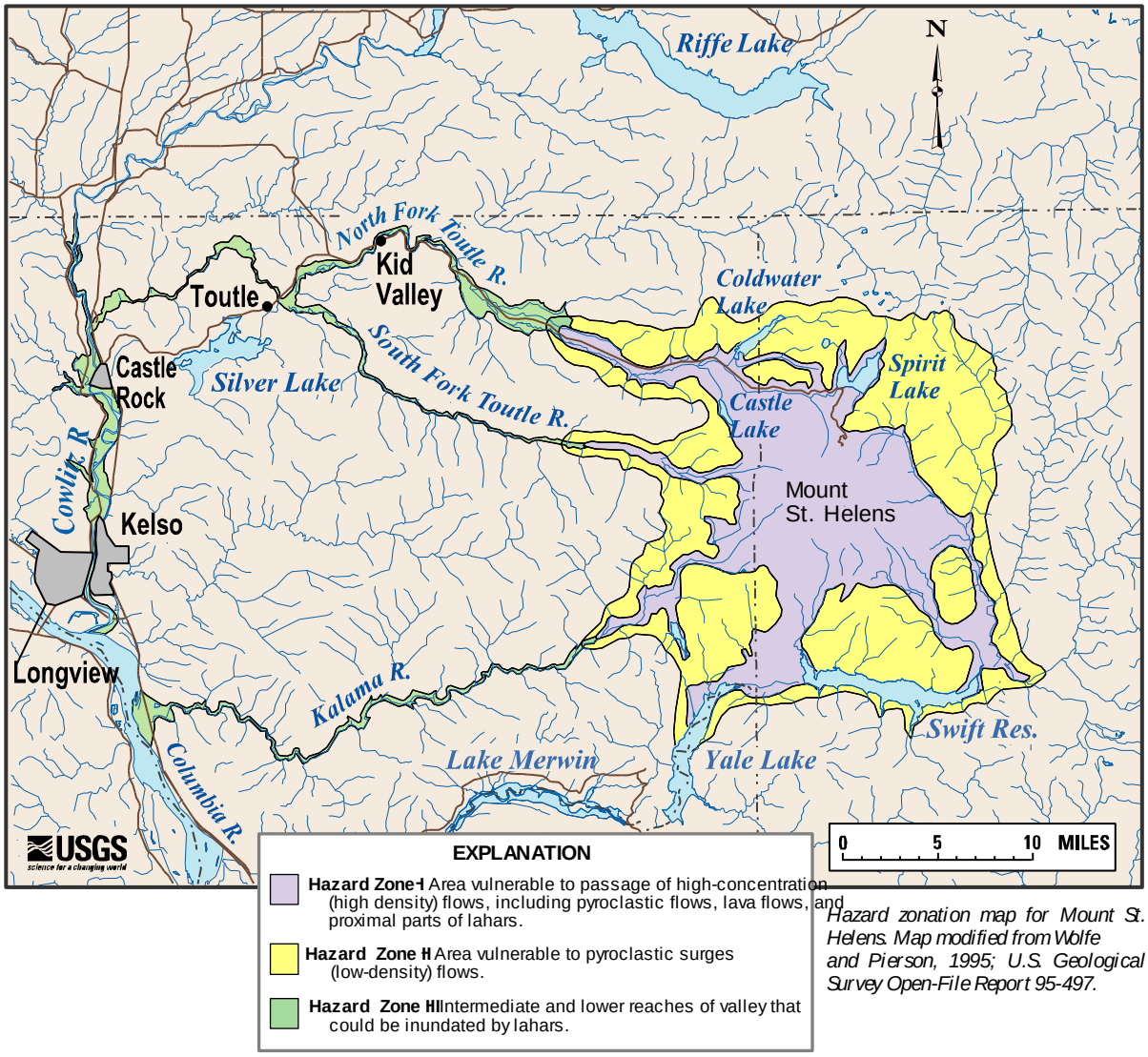
Larger lahars would reach downstream communities more quickly; smaller ones more slowly.

In future eruptions, pyroclastic flows, pyroclastic surges, lava flows and ballistic projectiles probably will not extend beyond the national park boundaries. The annual probability of pyroclastic flows, pyroclastic surges, lava flows, and ballistic projectiles affecting some part of the area is less than 1 percent.

Mount St. Helens[22, 23, 24]

- Mount St. Helens in Skamania County is the youngest, most frequently active, and often the most explosive volcano in the Cascades. During the past 4,000 years, it has produced many lahars and a wide variety of eruptive activity, from relatively quiet outflows of lava to explosive eruptions much larger than the one on May 18, 1980.
- Cowlitz County areas at risk - Castle Rock, Kelso and Longview, and the valleys of the Cowlitz, Kalama, Lewis, and Toutle Rivers.
- Skamania County areas at risk – unincorporated areas.

Mount St. Helens remains an active and dangerous volcano. In the last 515 years, it produced four major explosive eruptions and dozens of lesser eruptions. One of those, in 1480, was about five times larger than the May 18, 1980 eruption; even larger eruptions have occurred during Mount St. Helens' lifetime.



Hazard zonation map for Mount St. Helens. Map modified from Wolfe and Pierson, 1995; U.S. Geological Survey Open-File Report 95-497.

Lahars are a greater threat to life and property in communities of the Cowlitz and lower Toutle River drainages than any other volcanic phenomenon. Previous lahars, including those from the May 18, 1980 eruption, traveled 30 to 60 miles, often reaching the Columbia River via the Toutle, Kalama or Lewis Rivers. Non-eruption events such as intense storm runoff over erodible sediment, landslides, or failure of the Castle Lake impoundment can generate lahars. Neither a large debris avalanche nor a major lateral blast like those of May 18, 1980 is likely now that a deep, open crater has formed.

Based on the behavior of lahars from the May 1980 eruption, estimated travel times have been developed for lahars traveling down the North Fork Toutle River valley, and the South Fork Toutle River, Pine Creek, Muddy River, and Kalama River valleys:

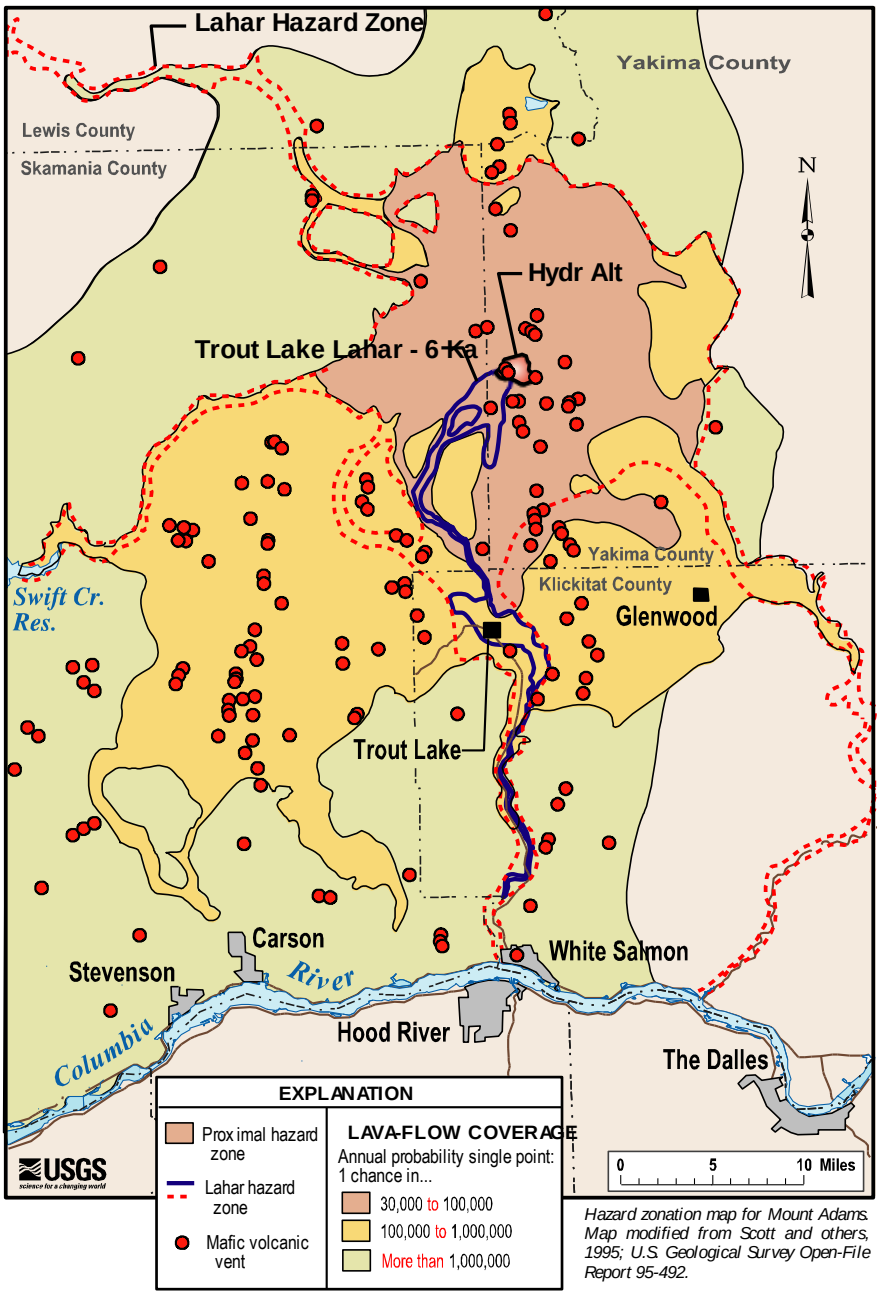
Distance from Mount St. Helens	Projected Lahar Travel Time	
	N. Fork Toutle River	S. Fork Toutle River, Pine Creek, Muddy River, Kalama River
20 Kilometers (12.4 miles)	37 minutes	30 minutes
40 kilometers (24.9 miles)	1hour, 8 minutes	1 hour, 21 minutes
60 kilometers (37.3 miles)	3 hours, 27 minutes	2 hours, 20 minutes
80 kilometers (49.7 miles)	4 hours, 43 minutes	3 hours, 31 minutes
100 kilometers (62.1 miles)	8 hours, 50 minutes	5 hours, 12 minutes

Mount St. Helens repeatedly has produced voluminous tephra. While tephra from the May 18, 1980 eruption covered about 22,000 square miles, the lethal impact from falling tephra is likely only in the immediate vicinity of Mount St. Helens; damaging impacts from falling tephra, were seen hundreds of miles away.

The calculated annual probability that four or more inches of tephra from a large eruption will fall as far as 40 miles directly east of Mount St. Helens is about 1 in 500. The calculated annual probability that such an eruption would deposit four or more inches 40 miles directly west of Mount St. Helens is less, between 1 and 2 in 10,000.

Mount Adams[25, 26]

- Mount Adams in Yakima and Skamania Counties has produced few eruptions during the past several thousand years. This volcano's most recent activity was a series of small eruptions about 1,000 years ago followed by a debris avalanche and lahar that inundated part of the Trout Lake lowland less than 500 years ago.
- Klickitat County areas at risk – Lyle, Trout Lake and the lower White Salmon River valley.
- Skamania County areas at risk – Carson, Stevenson, and unincorporated areas in the eastern part of the county including valleys of the Cispus and Lewis Rivers.
    - Numerous communities along the Columbia River in both Klickitat and Skamania Counties lie in the local proximal hazard zone for lava flow.
- Lewis County areas at risk – Unincorporated areas of the Cispus River valley, including Riffe Lake.
- Yakama Nation and Yakima County areas at risk - . Unincorporated areas of the far western reaches.



Hazard zonation map for Mount Adams. Map modified from Scott and others, 1995; U.S. Geological Survey Open-File Report 95-492.

Mount Adams dominates a volcanic field in Lewis, Skamania, Yakima, and Klickitat counties of south-central Washington. The volcano has erupted little during the past 10,000 years; it is less active than neighboring Mounts St. Helens, Rainier, and Hood. Highly explosive eruptions of Mount Adams have been rare. Much of the hazard area for eruptive events lies in the Gifford Pinchot National Forest or remote areas of the Yakama Indian Reservation. Areas of greatest concern are located along the channels and floodplains of the White Salmon, Klickitat, Lewis, and Cispus Rivers that are subject to lahars.

The dominant type of eruption at Mount Adams, as well as in the adjacent volcanic fields, produces lava flows, or streams of molten rock. Several significant lava flows have occurred in

the region during the past 10,000 years and most of them traveled between 8 and 20 miles. The annual probability of a lava flow occurring on Mount Adams or its lower flanks is about 1 in 1,000, but because a lava flow would only cover part of the area, the annual probability of a given point being covered is much less, about 1 in 30,000 to 1 in 100,00.

Rivers that drain the north and northwest flanks of Mount Adams can discharge sediment from lahars into Swift Reservoir on the Lewis River and Riffe Lake on the Cowlitz River. Streams that drain the southwest and east flanks can deliver sediment to the Columbia River and could affect navigation and hydroelectric operations at Bonneville Dam. Lahars large enough to reach the Trout Lake lowland have annual probabilities of about 1 in 100 to 1 in 1,000. A lahar the size of the Trout Lake lahar has an annual probability of about 1 in 1,000 to 1 in 10,000, whereas a lahar of sufficient magnitude to inundate the entire length of one or more valleys has not occurred in the last 10,000 years and has an annual probability less than 1 in 10,000.

Tephra from Mount Adams does not pose a serious or widespread hazard; eruptions have blanketed only areas within a few miles from the volcano with ash fall of several inches. Thinner deposits probably extended tens of miles father.

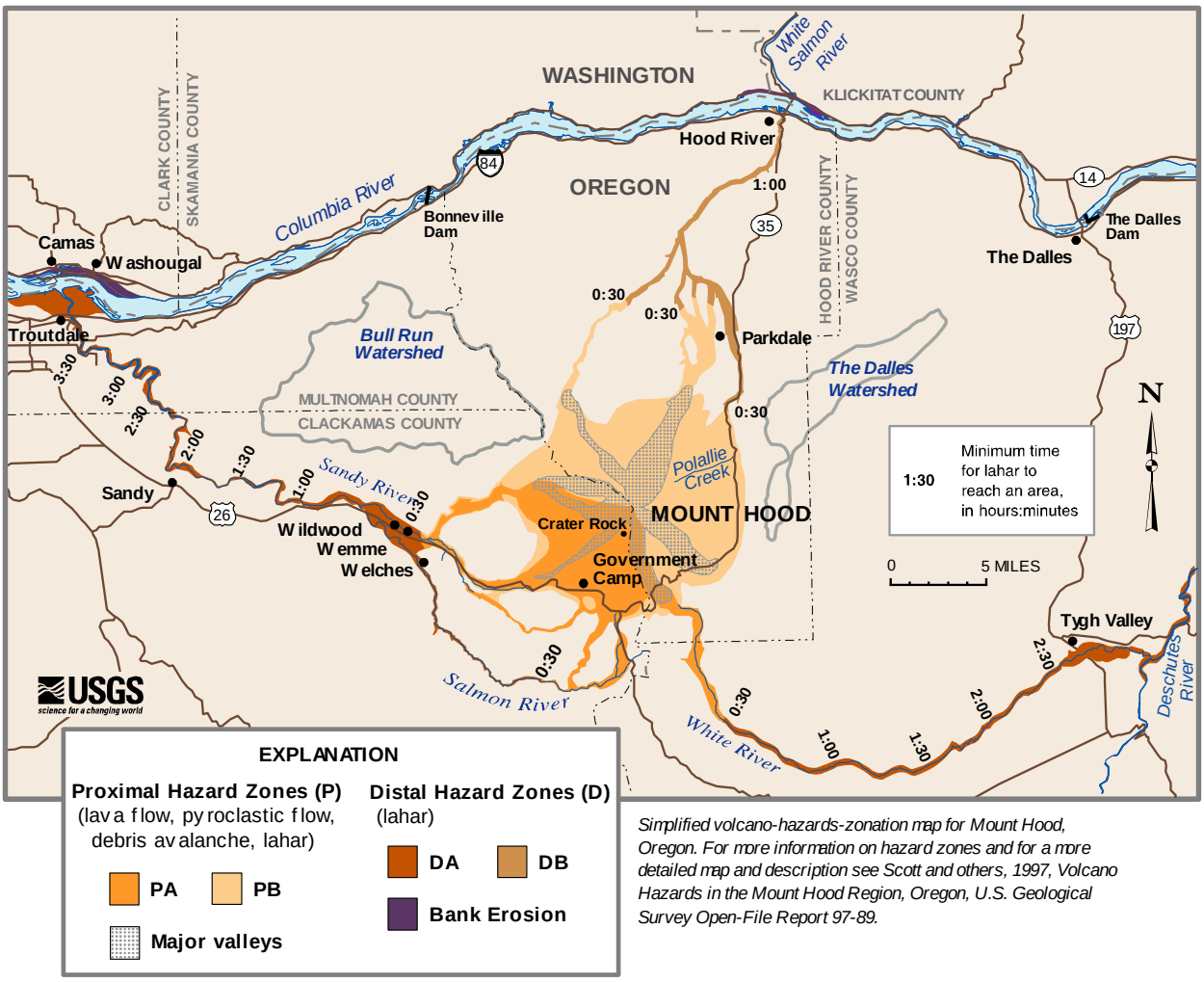
Mount Hood, Oregon[27, 28]

- Clark County areas at risk – Camas and Washougal, and nearby unincorporated areas.
- Klickitat County areas at risk – Unincorporated areas near White Salmon.
- Skamania County areas at risk – Stevenson, and unincorporated areas.

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 in Klickitat County. Scientists believe this deposit temporarily dammed the Columbia River.

Future lahars and eruption-induced sedimentation are likely to build the Sandy River delta farther out into the Columbia River and narrow the existing channel, which could lead to progressive bank erosion and inundation of land in the Camas-Washougal area of Clark County. The 30-year probability that lahars will inundate areas of the Sandy River valley is about 1 in 15 to 1 in 30.

Mount Hood is a relatively modest tephra producer, and much of the tephra fall would occur east of the mountain due to prevailing winds.



Simplified volcano-hazards-zonation map for Mount Hood, Oregon. For more information on hazard zones and for a more detailed map and description see Scott and others, 1997, Volcano Hazards in the Mount Hood Region, Oregon, U.S. Geological Survey Open-File Report 97-89.

Jurisdictions Threatened and Vulnerable to Volcanic Hazards

The jurisdictions vulnerable to lava flow, lahars, and ash fall from volcanic eruptions come from U.S. Geological Survey hazard reports and hazard zone maps published for each volcano. The fourteen counties threatened are listed below in the table.

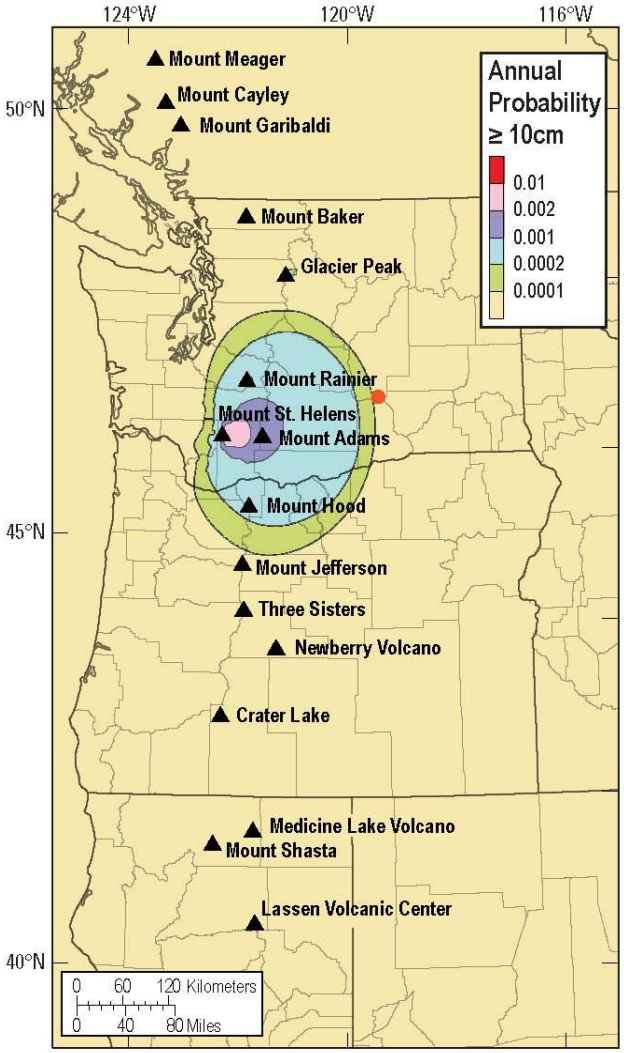
County Jurisdictions Vulnerable to Volcanic Hazards				
Chelan (ash)	Clark (ash, lahar)	Cowlitz (ash, lahar)	King (ash, lahar)	Kittitas (ash)
Klickitat (ash, lahar)	Lewis (ash, lahar)	Pierce (ash, lahar)	Skagit (lahar)	Skamania (ash, lahar)
Snohomish (lahar)	Thurston (lahar)	Whatcom (lahar)	Yakima (ash)	

Jurisdictions at risk to lava flow and lahar are identified in the table below with annual probabilities. Once a volcano becomes restless or begins to erupt, the probability for lahars and other effects increases greatly over these long-term averages.

Annual Probability of Occurrence of a Lahar		
Volcano	***Lahar***	*Annual Probability*
Glacier Peak	Inundates Lower Suiattle River	**1-2 in 1,000**
	Reaches Puget Sound	**1-2 in 10,000**
	Inundates Stillaguamish River	**< 1 in 10,000**
Mount Adams	Reaches Trout Lake	**1 in 100 to 1 in 1,000**
Mount Baker	Debris Flows along flanks	**≥1 in 100**
	Inundates Nooksack River	**≤1 in 500**
	Reaches Puget Sound	**1 in 14,000**
Mount Rainier	Debris Flows within National Park	**≥1 in 100**
	Inundates Nisqually River (National Lahar)	**1 in 100 to 1 in 500**
	Reaches Puget Sound lowlands (Electron Mudflow)	**1 in 500 to 1 in 1,000**
	Reaches Puget Sound (Osceola Mudflow)	**≤ 1 in 10,000**

Mount St. Helens	**Not calculated due to 1980 eruption**	
Mount Hood	Inundates Sandy River	**≥1-2 in 1,000**
Source: U.S. Geologic Survey volcano hazard reports, 1995 and 1998 These probabilities are based on mean rates (length of time divided by number of events) but events are clustered in time		

Jurisdictions at-risk to ash fall are those with a 1 in 1,000 chance of receiving 10 centimeters (4 inches) of ash fall each year on the map below. However, ash fall considerably less than 10 cm is still a nuisance and capable of producing a lot of problems for jurisdictions. Since the prevailing winds are westerly, many eastern Washington counties will have to deal with some level of ash fall in the future.



Potential Climate Change Impacts[29,30,31,32]

With the advent of climate change coming into worldwide focus; it is necessary to take into account the potential effects this emerging climate crisis may have on the dangers associated with volcanoes. The research done so far indicates the potential for unusual or more frequent heavy rainfall and flooding is greater is some areas while the potential for drought is predicted in other areas. Landslide frequency is correlated with heavy rainfall and flooding events.

Recognizing Washington's vulnerability to climate impacts, the Legislature and Governor Chris Gregoire directed state agencies in 2009 to develop an integrated climate change response strategy to help state, tribal and local governments, public and private organizations, businesses and individuals prepare. The state Departments of Agriculture, Commerce, Ecology, Fish and Wildlife, Health, Natural Resources and Transportation worked with a broad range of interested parties to develop recommendations that form the basis for a report by the Department of Ecology: *Preparing for a Changing Climate: Washington State's Integrated Climate Change Response Strategy*.

Over the next 50 - 100 years, the potential exists for significant climate change impacts on Washington's coastal communities, forests, fisheries, agriculture, human health, and natural disasters. These impacts could potentially include increased annual temperatures, rising sea level, increased sea surface temperatures, more intense storms, and changes in precipitation patterns. Therefore, climate change has the potential to impact the occurrence and intensity of natural disasters, potentially leading to additional loss of life and significant economic losses. Recognizing the global, regional, and local implications of climate change, Washington State has shown great leadership in addressing mitigation through the reduction of greenhouse gases.

At-Risk State Agency Facilities

State Agency facilities identified as being at-risk to lahar were determined using geo-spacial software to match their location to the lahar hazard zone identified by the U.S. Geological Survey. The hazard zones chosen were for the worst-case, largest lahars possible.

State Agency Structures At Risk		**VULNERABILITY ASSESSMENT**
Number and Function of Buildings	**Approx. Square Footage of Facilities**	**Approx. Value of Owned and Leased Structures and Building Contents**
Total at-risk buildings: 859 state facilities were identified as being in the lahar hazard zone potentially at-risk to direct damage or to the indirect impacts of lahar (utility services reductions, transportation restrictions, etc.).	6,368,709	$1,273,741,800
Function of at-risk buildings: Included in the state facilities potentially at-risk to the direct and indirect impacts of a worst-case lahar are the following:		

- Campuses of the Rainier School for individuals with developmental disabilities, and of the Washington Soldiers Home and Colony.
- Arlington, Kendall Creek, Fallart Creek, North Toutle, Voights Creek, Soos Creek, and Klickitat hatcheries of the Department of Fish and Wildlife.
- Picnic, comfort, shelter, and other facilities at four parks operated by the State Parks and Recreation Commission, and a number of public access areas operated by the Department of Fish and Wildlife.
- Campuses of Skagit Valley College; Northwest Washington and Puyallup Research and Extension Centers operated by Washington State University; and Pack Forest operated by the University of Washington.
- Five weigh stations and detachment offices in Enumclaw and Burlington of the Washington State Patrol.

Total at-risk critical facilities: 119 state critical facilities were identified as being in the lahar hazard zone potentially at-risk to direct damage or to the indirect impacts of lahar (utility services reductions, transportation restrictions, etc.).	970,570	$194,114,000

Function of at-risk critical facilities: Included in the state facilities potentially at-risk to the direct and indirect impacts of a worst-case lahar are the following:

- Pump houses, chemical storage, power plants and emergency generators, and other facilities at state parks, state fish hatcheries, transportation department installations, WSU research centers, campuses of the Rainier School and Washington Soldiers Home, .
- Five weigh stations and detachment offices in Enumclaw and Burlington of the Washington State Patrol.

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