VOLCANIC HAZARDS CHAPTER

The volcanic peaks of the Cascade Range provide some of Oregon's most spectacular scenery, popular recreational areas, and convenient transportation corridors. The beauty of these mountains comes with a price: as volcanoes, they also present a hazard.

The 1980 eruption of Washington's Mount St. Helens showed how much these sleeping giants can affect not just individual communities, but the region as a whole. In response to the volcanic hazard, the U.S. Geological Survey (USGS) opened the Cascades Volcano Observatory (CVO) in Vancouver, Washington. CVO scientists continually monitor the peaks and study the geologic processes. Oregon's Department of Geology and Mineral Industries (DOGAMI) also keeps an eye on the sleeping giants.

As population increases in Oregon, more areas near active volcanoes are being developed and recreational usage is expanding. As a result, more people and property are at risk from volcanic activity. The next eruption in the Cascades could affect hundreds of thousands of people.

Hazard Analysis/Characterization

The volcanic Cascade Range extends southward from British Columbia into northern California. The volcanoes are a result of the complex interaction of *tectonic plates* along the *Cascadia Subduction Zone* (Figure V-1). *Subduction* is the process that results in the seafloor plate subducting, or sinking, underneath the North American plate on which we live. As the subducted plate descends, it heats up and begins to melt. This provides the reservoir of heat and molten rock needed to create the *magma* chambers that lie kilometers deep underneath the Cascades.

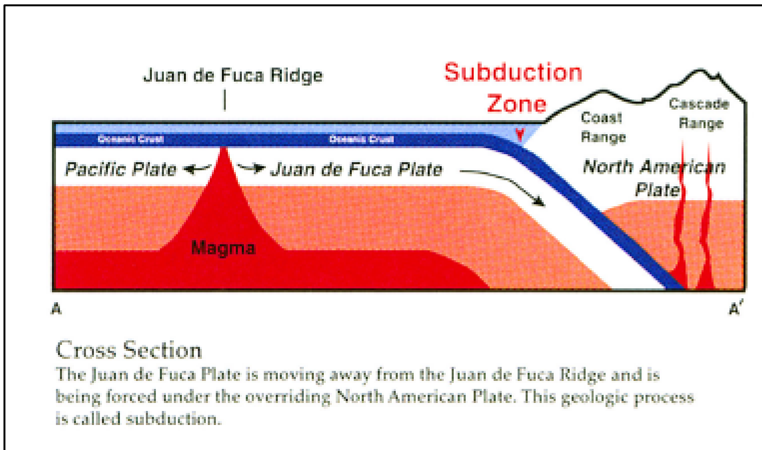

Figure V-1: Cascadia Subduction Zone (DOGAMI graphic)

Mount Hood with Portland in foreground (photo courtesy of USGS, Weiprecht)

Volcanoes such as Mt. Hood are *stratovolcanoes* (see photograph to the left), built layer by layer (called strata by geologists) by a combination of *lava flows*, *pyroclastic flows*, and *volcanic ash*. Eruptions often build more height, as lava is extruded to the surface and ash falls on its flanks. Intermittent slope failures in the form of debris avalanches also sculpt the distinctive cone shape. Eruptions from stratovolcanoes can be very explosive, although the explosions are usually aimed upwards. Sometimes, as in the case of Mount St. Helens in 1980, they are so violent that part of the volcano is blown away. This is not the typical eruption for our Cascade mountains.

The Cascade Range has a long history of eruption and intermittent quiescence. Figure V-2 depicts the known eruptions of Cascade volcanoes during the past 4,000 years. Note that each has a different frequency of eruptions. Not all Cascade volcanoes have been active in the recent past. This is typical of a volcanic range and is one of the reasons forecasting eruptions can be difficult.

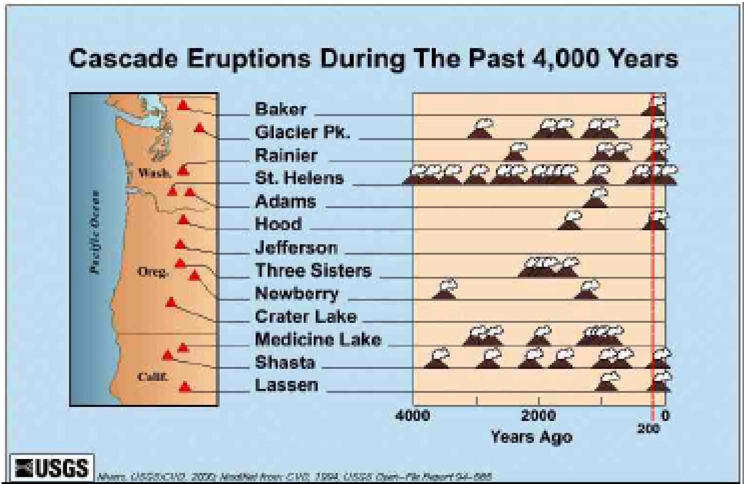

Figure V-2: graph of Cascade eruptions during the most recent 4000 years

Volcano-Associated Hazards

There are a number of hazards associated with volcanoes (Figure V-3). Some are cause for greater concern than others. Some occur only during an eruption, but there are secondary hazards that can happen without an eruption.

Each eruption will be a unique combination of hazards; not all of them will be present in all eruptions and the degree of damage will vary. It is important to know that during an active period for a volcano many individual eruptions may occur and each eruption may vary in intensity and length. For example, Mount Saint Helens' first eruption occurred in May 1980 but the volcanic activity continued with minor eruptions and dome building until October 1986.

A glossary of geologic terms appears in Appendix V-1 to this chapter.

Eruptive hazards (in alphabetical order)

Ashfall

One of the most serious hazards from an eruption is the rock (*bombs*) and dust-sized ash particles - called *tephra* - blown into the air. The dust-sized ash particles can travel enormous distances and are a serious by-product of volcanic eruptions.

Within a few miles of the vent, the main tephra hazards to man-made structures and humans include high temperatures, being buried, and being hit by falling fragments. Within ten to twelve miles, hot tephra may set fire to forests and flammable structures.

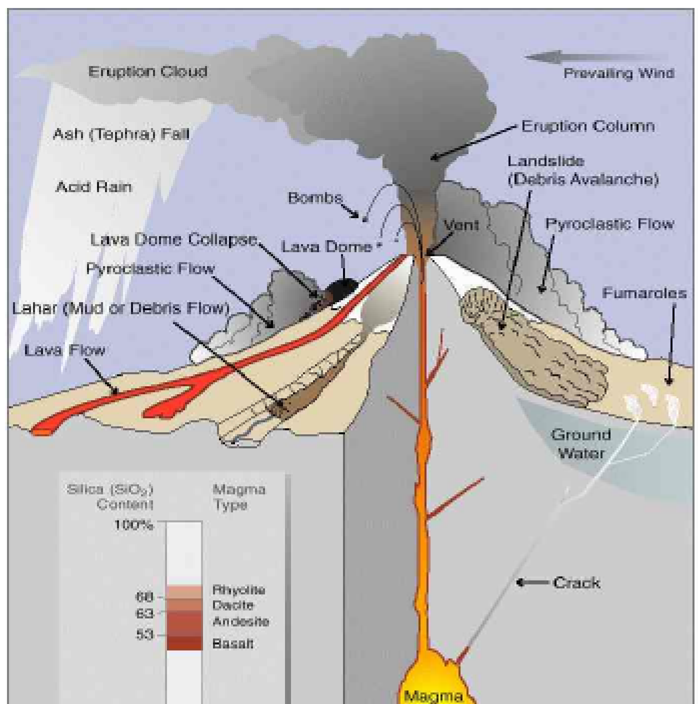

Figure V-3: schematic drawing of various volcanic hazards (fact sheet 002-97, Meyers, USGS)

Structural damage can also result from the weight of ash, especially if it is wet. Four inches of wet ash may cause buildings to collapse. A half inch of ash can impede the movement of most vehicles and disrupt transportation, communication, and utility systems, and cause problems for human and animal respiratory systems. It is extremely dangerous for aircraft, particularly jet planes, as the volcanic ash accelerates wear to critical engine components, can coat exposed electrical components, and erodes exposed structure. Ashfall may severely decrease visibility, even cause darkness, which can further disrupt transportation and other systems.

Ashfall can severely degrade air quality, triggering health problems. In areas with considerable ashfall, people with breathing problems might need additional services from doctors or emergency rooms. In severe events, an air quality warning, similar to those given on summer problem air quality days, could be issued. This would, for example, warn people with breathing problems not to go outside.

On roads and streets, ashfall can create serious traffic problems as well as road damage. Vehicles moving over even a thin coating of ash can cause great clouds of ash to swell. This results in grave visibility problems for other drivers, calling for speed restrictions, and often forcing road closures. It also adds to the potential for health problems for residents of the area.

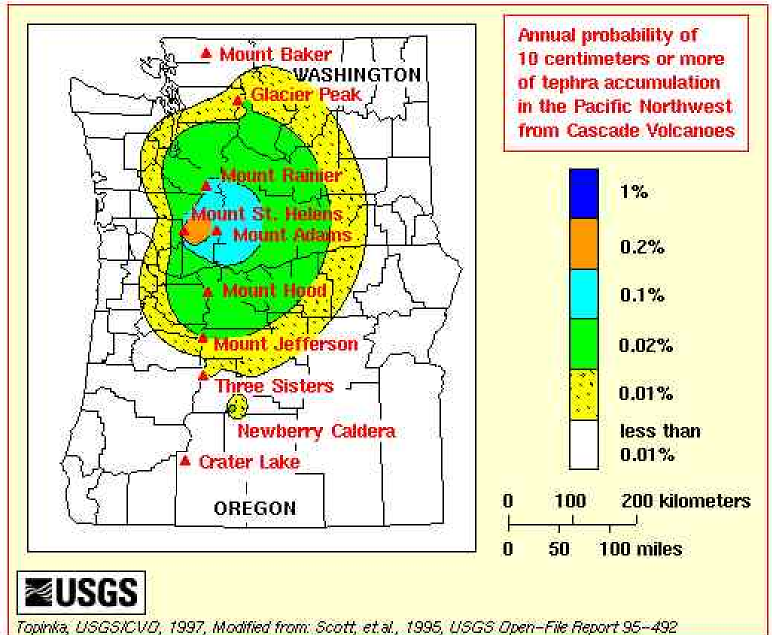

Figure V-4: map showing annual probability of 10 cm (~4 inches) or more tephra accumulation in Oregon and Washington from eruptions throughout the Cascade Range

Extremely wet ash creates very slippery and hazardous road conditions. Ash filling roadside ditches and culverts can prevent proper drainage and cause shoulder erosion and road damage. Blocked drainages can also trigger debris flows or lahars if they cause water to pool on or above susceptible slopes.

Conventional snow removal methods do not work on dry ash, as they only stir it up and cause it to resettle on the roadway. When ash is pushed to the side of travel lanes, wind and vehicle movement continue to cause it to billow.

During an eruption that emits ash, the ashfall deposition is controlled by the prevailing wind direction. The predominant wind pattern over the Cascades is from the west, and previous eruptions seen in the geologic record have resulted in most ashfall drifting to the east of the volcanoes. The potential and geographical extent of volcanic ashfall in the Pacific Northwest is depicted in Figure V-4.

Lava flows

Lava flows are generally not life threatening because people can usually out-walk or out-run them. Lava flows are streams of molten rock that erupt relatively non-explosively from a volcano and move downslope, causing extensive damage or total destruction by burning, crushing, or burying everything in their paths. Secondary effects can include forest fires, flooding, and permanent reconfiguration of stream channels.

Pyroclastic flows and surges

Pyroclastic flows are avalanches of rock and gas at temperatures of 600 to 1500 degrees Fahrenheit. They typically sweep down the flanks of volcanoes at speeds of up to 200 miles per hour. Pyroclastic surges are a more dilute mixture of gas and rock. They can move even more rapidly than a pyroclastic flow and are more mobile. Both generally follow valleys, but surges especially sometimes have enough momentum to overtop hills or ridges in their paths. Because of their high speed, pyroclastic flows and surges are difficult or impossible to escape. If it is expected that they will occur, evacuation orders should be issued as soon as possible for the hazardous areas.

Objects and structures in the path of a pyroclastic flow are generally destroyed or swept away by the impact of debris or by accompanying hurricane-force winds. Wood and other combustible materials are commonly burned. People and animals may also be burned or killed by inhaling hot ash and gases. The deposit that results from pyroclastic flows is a combination of rock bombs and ash and is termed *ignimbrite.* These deposits may accumulate to hundreds of feet thick and can harden to resistant rock.

Post-eruptive hazards

Lahars and debris flows

Lahar is an Indonesian term describing a hot or cold mixture of water and rock fragments flowing down the slope of a volcano, usually along a stream channel. A lahar can be generated by volcanic activity (for example, melting snow or glacier), prolonged rain, or other weather conditions resulting in rapid snow melt. When moving, a lahar resembles a mass of wet concrete carrying rocks and boulders. Lahars vary in size and speed. Large lahars may be hundreds of meters wide, tens of meters deep, and move faster than a person can run. The Cascade Mountains and nearby floodplains contain abundant evidence of lahar activity and destruction.

Debris flows are sudden and very rapid movements of rock and soil downhill; they are often called mudslides. They can be triggered by a variety of phenomena, including weather conditions, very steep slopes, and earthquakes. Debris flows can travel miles and attain speeds as high as 100 miles per hour. Structures and objects in their path (e.g., dams, bridges) will sometimes be incorporated into the flow. They often contain enough water to transform into lahars. Debris flows are common throughout the steep volcanoes of the Cascade Range.

The major hazard to human life from lahars and debris flows is from burial and impact by boulders and other debris. Buildings, dams, bridges, and other property in the path of a lahar can be buried, smashed, or carried away. Because of their relatively high density and viscosity, lahars can move, or even carry away, vehicles and other large objects such as bridges. Flooding can occur behind temporary dams created by logjams or other debris in streams.

Lahars and debris flows can result in the disruption of utility and transportation systems. Municipalities, industries, and individuals who take their water from streams affected by lahars may have water quality and/or quantity issues. Endangered species could be adversely affected by changes in streams, including the deposition of debris in streambeds and floodplains. For example, salmonids trying to spawn could find it impossible to swim upstream.

Both debris flows and lahars can occur for many years after an eruptive episode at a volcano.

Landslides (debris avalanches)

Because the stratovolcanoes that form the Cascade Mountains are composed of layers of weak fragmented rock and lava they are prone to gravity driven failure such as landslides. Landslides range in size from small to massive summit or flank failures. They may be triggered by erosion that oversteepens slopes or during times of excessive rainfall or snowmelt. Speeds of movement range from slow creep to more catastrophic failure. If enough water is incorporated into the material the failure will become a lahar. Primary hazards are to roads, bridges, dams, and buildings that might be constructed on the landslide or be damaged by the movement.

Characterization of Individual Volcanoes

Each volcano presents a different set of hazards. The explosive 1980 Mount St. Helens eruption is only one style of Cascade eruption. Most events are less explosive. The following is a thumbnail sketch of the volcanoes and their hazards most likely to cause problems for Oregonians: Crater Lake, Mount Jefferson, Mount Hood, Mount St. Helens, Newberry Volcano, and Three Sisters. For a detailed inventory of each volcano's history and hazards, please refer to the appropriate USGS report, listed in Appendix V-2.

Crater Lake

Almost 7,700 years ago, ancient Mount Mazama erupted with great violence, leaving the *caldera* that Crater Lake now occupies. Layers of ash produced from that eruption have been found in eight western states and three Canadian provinces. The countryside surrounding Crater Lake was covered by pyroclastic flows. Wizard Island is the result of much smaller eruptions since that cataclysm. The most recent eruption was about 5,000 years ago and occurred within the caldera. No eruptions have occurred outside the caldera since 10,000 years ago.

This potentially active volcanic center is contained within Crater Lake National Park. The west half of the caldera is considered the most likely site of future activity. Effects from volcanic activity (ashfall, lava flows, etc.) are likely to remain within the caldera. If an eruption was centered outside the caldera, pyroclastic flows and lahars could affect valleys up to a few dozen miles from the erupting vent. The probability of another caldera-forming eruption is very low as is the probability of eruptions occurring outside the caldera.

Mount Jefferson

Mount Jefferson is located in a relatively unpopulated part of the Cascade Range. The last eruptive episode at Mount Jefferson was about 15,000 years ago. Research at stratovolcanoes of the world indicates that Mount Jefferson should be regarded as dormant, not extinct.

The steep slopes of the volcano provide the setting for possible debris flows and lahars, even without an eruption. These would be confined to valleys, generally within 10 miles of the volcano.

A major eruption, however unlikely in the short term, could generate pyroclastic flows and lahars that would travel up to a few dozen miles down river valleys. There are two reservoirs that could be affected by pyroclastic flows from a major eruption: Detroit Lake and Lake Billy Chinook. An explosive eruption could spew ash for hundreds of miles in the downwind direction.

Many smaller volcanoes are located between Mount Jefferson and Mount Hood to the north and Three Sisters to the south. Eruptions from any of these would be very localized, primarily erupting *cinders* and ash to form a cinder cone.

Mount Hood

The last major eruption of Mount Hood occurred in approximately 1805. The Sandy River that drains the volcano's northwest side was originally named Quicksand River by Lewis and Clark who traversed the area only a couple of years after an eruption. Lahars had filled the river channel with debris, most of which has now been scoured away. There were two other minor periods of eruptions during the last 500 years, the last in the mid-1800s. Typically, these involved some lava flow near the summit, pyroclastic flows, and lahars, but little ashfall. The volcano is most likely to erupt from the south side, based on recent history, but planning should be done assuming eruptions could be centered anywhere on the mountain. A large eruption could generate pyroclastic flows and lahars that could inundate the entire length of the Sandy and White River Valleys. An eruption from the north flank could affect the Hood River Valley.

Its proximity to the Portland metropolitan area, the presence of major east-west highways, the Bull Run Reservoir which supplies water to a majority of Portland area residents, and the ski and summer recreation areas make Mount Hood the greatest potential volcanic hazard to Oregonians. In addition, a large volume of debris and sediment in lahars could affect shipping lanes in the Columbia River or the operation of Bonneville and The Dalles dams.

In recent years, numerous lahars and glacier outburst floods have flowed down river drainages, even without eruptions. Highway 35 is periodically closed for repair work after these events damage the bridge over the White River.

Mount St. Helens

The May 18, 1980 eruption is the best-known example of volcanism to Oregonians. That eruption included a debris avalanche as part of the volcanic edifice collapsed. This caused a lateral blast of rock, ash, and gas that devastated areas to the north of the volcano. Lahars rushed down the Toutle and Cowlitz River valleys reaching the Columbia River and halting shipping for some time. All other river valleys on the volcano experienced smaller lahars. Pyroclastic flows devastated an area up to five miles north. Ashfall deposits affected people as far away as Montana, and ash circled the earth in the upper atmosphere for over a year.

Except for the debris avalanche and lateral blast, the events of this eruptive period are typical of a Mount St. Helens' eruption and can be expected to occur again. The primary hazards that will affect Oregonians are lahars that affect the Columbia River, and ashfall. Another eruption from Mount Saint Helens is very likely in the near future.

Newberry Volcano

Newberry Volcano is a different type of volcano than the stratovolcanoes of the Cascade Range. It is a *shield volcano*, with broad, relatively gently sloping flanks. It is about 600,000 years old, and has had thousands of eruptions both from the central vent area and along its flanks. The most recent eruption was 1,300 years ago when rhyolite lava erupted within the caldera, but it has been active at other times in the past 10,000 years. Newberry Volcano has attracted interest for its geothermal potential. The heat under the volcano, with temperatures in some areas in excess of 265 degrees Centigrade, is evidence that it is only dormant.

Future eruptions are likely to include lava flows, pyroclastic flows, lahars, and ashfall. Most effects from these activities would be felt within, or up to a few miles beyond, the existing caldera. Ash could fall a few dozen miles from the eruptive center.

Three Sisters

North Sister has probably have been inactive for at least 100,000 years; Middle Sister last erupted between 25,000 and 15,000 years ago, and South Sister has a very small ongoing uplift occurring, which began in 1996. The uplift is about one inch a year and may indicate movement of a small amount of magma. At this writing, there is no indication that the uplift will ever develop into a volcanic eruption. However, that possibility cannot be ruled-out. Hence, the CVO has increased their monitoring of the area over the past two years.

Future eruptions at South Sister (and possibly Middle Sister) are likely to include lava flows, pyroclastic flows, and lahars. The possibility exists for lahars to travel many miles down valley floors, if an eruption melts a large amount of snow and ice. Ashfall would likely be contained within 20 miles of the vent.

Other volcanic areas of Oregon

On the scale of geologic time, there are other parts of Oregon that may see eruptions. However, on a human time scale, the probability of an eruption outside the Cascades is so low as to be negligible.

Although the snow-topped mountains of the Cascades are Oregon’s most visible volcanoes, there are other potential eruptive centers. These include the smaller peaks in the Cascades, such as Belknap in Central Oregon, which had a lava flow about 1,400 years ago. Most of these basaltic volcanoes are active for only brief periods, so forecasting an eruption for any specific site is impossible. However, eruptions of this type will likely continue in the Cascades, with the most recent one being in 1851, near Lassen Peak, California. These eruptions are typically not explosive, consisting mostly of lava flows concentrated in a small area.

There is a very low probability that volcanic activity would resume in south-central and southeastern Oregon. Cinder cones as recent as 5,000 years ago erupted in this Basin and Range Province.

Probability: Anticipating Volcano Hazards In Oregon

Geologists can make general forecasts of long-term volcanic activity based on careful characterization of past activity, but they cannot supply a timeline. Several USGS Open File Reports provide the odds of certain events taking place at particular volcanoes. However, the USGS stresses that government officials and the public must realize the limitations in forecasting eruptions and be prepared for such uncertainty.

Short-range forecasts, on the order of months or weeks, are often possible. There are usually several signs of impending volcanic activity that may lead up to eruptions. The upward movement of magma into a volcano prior to an eruption generally causes a significant increase in small, localized earthquakes, and an increase in emission of carbon dioxide and compounds of sulfur and chlorine that can be measured in volcanic springs and the atmosphere above the volcano. Changes in the depth or location of magma beneath a volcano often cause changes in elevation. These changes can be detected through ground instrumentation or remote sensing (this was, for example, how the South Sister Bulge was discovered).

CVO employs scientists from a range of disciplines to continually assess the state of the Cascades. If anomalous patterns are detected (for example, an increase in earthquakes), they coordinate the resources necessary to study the volcano.

Existing Strategies and Programs

The Pacific Northwest Seismograph Network, operated jointly by the Geophysics Program at the University of Washington and the USGS, monitors earthquake activity throughout western Oregon and Washington. An additional seismic network has been set-up in the Cascades and is monitored by CVO. The scientific research and abilities of CVO staff is an important safety net for residents of the Pacific Northwest.

A major existing strategy to address volcanic hazards is to publicize and distribute volcanic hazard maps through DOGAMI and USGS. The volcanoes most likely to constitute a hazard to Oregon communities or activities have been the subject of USGS research. Open File Reports (OFR) address the geologic history of these volcanoes plus that of lesser-known volcanoes in their immediate vicinity. These reports also cover associated hazards and possible mitigation strategies. They are available for the following volcanoes in or near Oregon: Mount Saint Helens, Mount Adams, Mount Hood, Mount Jefferson, Three Sisters, Newberry Volcano, Crater Lake, and Mount Shasta.

Most of the land occupied by the Cascade volcanoes is in public ownership (e.g., National Forests, National Park Service). Still, ownership and the size of the land parcel are not as important as the location of land near a volcano. For example, a small private lot could have its potable water source cut off by volcanic activity. Potentially affected land is owned by Native American tribes (e.g., Confederated Tribes of the Warm Springs), private landholders, or administered as mining claims. Both federal and state governments have stringent standards that tend to curtail development on these lands, thereby reducing vulnerability to volcano hazards. The Portland Water Bureau, which takes its water from the Bull Run Reservoir along the western flank of Mount Hood, has a backup system of water wells for use if Bull Run water is not available, either because of transmission or quality issues.

Proposals to develop federal lands (e.g., widen a highway, or expand or create a ski area) must undergo lengthy public hearings and environmental scrutiny. Proposals to develop private land are subject to Oregon's land use laws (Oregon Revised Statutes, Ch. 197). Volcano hazards may be a consideration in both instances.

Oregon Statewide Planning Goal 7 does not require counties and incorporated cities to address volcano hazards in their mandatory comprehensive land use plans. However, revised Goal 7 language (effective June 1, 2002) states "local governments may identify and plan for other natural hazards" (Oregon Administrative Rule Chapter 660, Division 15). Although some communities have addressed volcanic hazards in their land use plans, the resource goals (e.g., protection of forest lands) are the greatest deterrent to development in areas with volcanic hazards. In addition, communities are required to plan for earthquakes and landslides, both of which generally occur as part of a volcanic eruption.

Hazard Mitigation Successes

1. ***Mt. Hood Volcano Coordination Plan***

   Recently federal, state, and local governments worked together to revise a coordination plan for Mount Hood eruptions. The plan reviews geologic history, lists the agencies that developed and approved the contents of the plan, delineates education and coordination activities appropriate between and during eruptions, and requires a yearly meeting of participants to update the plan. At a minimum, preparation of the plan has made all potentially affected jurisdictions aware of the nature of the hazard, has outlined response strategies, and has produced a directory of agency phone numbers that will be needed in an emergency.

2. **Cascade Fury**

   During April 2002, Oregon Department of Transportation and Oregon State Police (including Oregon Emergency Management) took part a multi-state emergency response exercise "Cascade Fury." This exercise, sponsored by the U.S. Department of Transportation and the Federal Emergency Management Agency, focused on the impacts a volcanic eruption would have on transportation systems in the Pacific Northwest. State transportation departments and state emergency management agencies from Washington, Idaho, and Alaska also took part.

Short-Term Actions

Short-term actions are those actions that agencies are capable of implementing within their existing resources and authorities. Only state agencies are listed under “lead” or “support” below. Occasionally federal agencies, local governments, and other organizations may be shown in the text of the proposed action as a cooperating partner in implementing the action. Progress on actions is reported to the State Interagency Hazard Mitigation Team.

1. Develop coordination plans for other volcanoes in Oregon

Mount Hood is the only volcano in Oregon with an adopted coordination plan. Communities around other volcanoes thought capable of eruption could benefit from producing a similar plan. FEMA and USGS led the process to bring together effected jurisdictions to write the Mount Hood plan. If resources are available, they will be involved in writing plans for other volcanoes.

Lead: OEM, DOGAMI, FEMA
Support: ODOT
Timeline: FY 2004 and ongoing
Resources: existing

2. Encourage local emergency managers with potential volcanic hazards to include volcanoes in their response plans

State and local emergency managers plan responses for a variety of hazards, including volcanoes. Clackamas County, which includes the southwest portion of Mount Hood, was the first jurisdiction in the nation to complete a FEMA-approved natural hazards mitigation plan, which includes short and long-term proposed actions to mitigate the effects of volcanic eruptions. Local response plan chapters (annexes) developed for volcanic hazards should include pre-eruption through post-eruption sections.

Lead: OEM
Support: DOGAMI
Timeline: FY 2004 and ongoing
Resources: existing

3. Encourage local jurisdictions to develop volcanic hazard evacuation maps

Volcanic eruptions often produce lahars that travel down river valleys. Evacuation maps should include the hazard area as well as preferred evacuation routes and evacuation sites. USGS staff should support local and state agencies in this effort.

Lead: OEM
Support: ODOT, DOGAMI
Timeline: FY 2004 and ongoing
Resources: existing

4. Encourage local jurisdictions to disseminate volcano preparedness educational materials

Preparedness materials should include what to do in the event of an eruption, evacuation maps, and volcano specific items to include in first aid kits (e.g., breathing masks and goggles). The USGS and FEMA have existing educational materials.

Lead: OEM
Support: DOGAMI
Timeline: FY 2004 and ongoing
Resources: existing

Long-Term Action Plan

Long-term actions are those that will require new or additional resources or authorities to implement. Only state agencies are listed under “lead” or “support” below. Occasionally federal agencies, local governments, and other organizations may be shown in the text of the proposed action as a potential cooperating partner in implementing the action. Progress on actions is reported to the State Interagency Hazard Mitigation Team.

1. Encourage communities to include volcano hazards, if appropriate, in their multi-hazard mitigation planning process

How a community might respond to volcano hazards depends on a number of things including: proximity of the community to the volcano; the nature of the volcano hazards; local volcano history; what is at risk/vulnerable to volcano hazards; and the probability of when or if an event might occur.

The difficulty in predicting when, how often, and how catastrophic volcano-associated hazards might be creates a problem for land use planning solutions. Except for a few Oregon communities on or very near a volcano (e.g., Government Camp on Mount Hood), stringent standards solely based on the prospect of volcanic activity are not realistic.

The best approach may be multi-hazards instead of treating volcano-associated hazards separately. A multi-hazard approach would take all natural hazards into consideration during a community’s planning process. For example, prohibiting development in the 100-year (1%) floodplain[1] ensures some degree of safety from flood, lahars, earthquake damage (e.g., liquefiable soils), etc. while preserving the floodplain for natural and beneficial uses. In addition, siting standards for infrastructure and/or critical facilities would include volcano-associated hazards among other hazards to be avoided. DOGAMI published two Special Papers to help communities look at multi-hazard mitigation: *Mitigating Geologic Hazards in Oregon: a Technical Reference Manual* and *Geologic Hazards: Reducing Oregon’s Losses.* These publications have been widely distributed to local governments.

Secondary effects also need to be incorporated into the multi-hazard framework. These effects include degradation or loss of habitat for endangered species (or species that may become endangered after a major eruption), the economic loss if timber resources are destroyed or made inaccessible, and the loss of surface water as a source of drinking water, irrigation, or for industrial needs. Each of these can have a long-lasting economic effect on Oregonians, as well as the physical changes in the landscape made by an eruption.

Lead: DLCD and OEM
Support: DOGAMI
Timeline: FY 2004 and ongoing
Resources: existing

[1] The 100-year floodplain is the geographic area and elevation for which there is a 1% chance each and every year of floodwaters reaching or exceeding.

Appendix V-1: Glossary of Geologic Terms

The following glossary of geologic terms was taken, except as noted, from the USGS website: http://wrgis.wr.usgs.gov/docs/parks/misc/glossaryAtoC.html

Ash: Fine particles of volcanic rock and glass blown into the atmosphere by a volcanic eruption

Bombs: Fragments of tephra (particles ejected into the air during volcanic eruptions) larger than 2.5 inches

Caldera: Large, generally circular, fault-bounded depression caused by the withdrawal of magma from below a volcano or volcanoes; commonly the magma erupts explosively as from a giant volcano, and falling back to Earth as volcanic ash, fills the caldera so formed

Cascadia Subduction Zone: The area where the seafloor plate (the Juan de Fuca or Gorda) is sliding down and below the North American plate (from DOGAMI)

Cinder: A bubbly (vesicular) volcanic rock fragment that forms when molten, gas-filled lava is thrown into the air, then solidifies as it falls

Ignimbrite: The rock formed by the widespread deposition and consolidation of pyroclastic flows or surges (from *Volcano and Geologic Terms* http://volcano.und.nodak.edu/vwdocs/glossary.html)

Lahar: A type of mudflow that originates on the slopes of volcanoes when volcanic ash and debris becomes saturated with water and flows rapidly downslope

Lava: Magma that reaches the Earth's surface through a volcanic eruption; when cooled and solidified, forms extrusive (volcanic) igneous rock

Magma: Molten rock; magma may be completely liquid or a mixture of liquid rock, dissolved gases and crystals; molten rock that flows out onto the Earth's surface is called lava

Pyroclastic flow: An extremely hot mixture of gas, ash and pumice fragments that travels down the flanks of a volcano or along the surface of the ground at speeds up to 150 miles per hour and tends to flow down valleys

Pyroclastic surge: A dilute version of a pyroclastic flow, which can move even more rapidly and easily moves up and over ridges

Shield volcano: A gently sloping volcano in the shape of a flattened dome and built almost exclusively of lava flows (from *Volcano and Geologic Terms* http://volcano.und.nodak.edu/vwdocs/glossary.html)

Stratovolcano: A relatively long-lived volcano built up of both lava flows and pyroclastic material

Subduction: Process of one crustal plate sliding down and below another crustal plate as the two converge; the **subduction zone** is the area between the two plates

Tectonic plate: A slab of rigid lithosphere (crust and uppermost mantle) that moves over the asthenosphere

Tephra: General term for all sizes of particles ejected into the air during volcanic eruptions; includes particles as tiny as volcanic ash and as large as bombs and blocks (see pyroclastic)

Appendix V-2: Bibliography and Related Websites

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Scott, et al., *Volcano Hazards in the Mount Hood Region, Oregon*, USGS Open-File Report 97-89, 1997

Scott, et al., *Volcano Hazards in the Three Sisters Region, Oregon*, USGS OFR 99-437, 2001

Sherrod, et al., *Volcano Hazards at Newberry Volcano, Oregon*, USGS Open-File Report 97-513, 1997

Walder, et al., *Volcano Hazards in the Mount Jefferson Region, Oregon*, USGS OFR 99-24, 1999

Wolfe and Pierson, *Volcanic-Hazard Zonation for Mount St. Helens, Washington*, USGS OFR 95-497, 1995

Websites with further information:

Cascade Volcano Observatory
http://vulcan.wr.usgs.gov/

Oregon Department of Geology and Mineral Industries
www.oregongeology.com

Hawaii County
http://www.mothernature-hawaii.com/county_hawaii/volcano_local_mit_act_agen-hawaii.htm

USGS glossary
http://wrgis.wr.usgs.gov/docs/parks/misc/glossaryAtoC.html

Volcano World glossary
http://volcano.und.nodak.edu/vwdocs/glossary.html