3.8 Risk Assessment: Volcanic Eruptions

Description

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. There are a wide variety of hazards related to volcanoes and volcanic eruptions. Volcanic hazards may be divided into two categories based on the range of their impact from the eruptive center or active vent. Proximal hazards have an impact limited to a distance of 30 miles or less from the active vent. Distal hazards have an impact far beyond the active vent.

Not all volcanic activity will result in all of the hazards listed here. The nature of the lava (rhyolitic or basaltic - rhyolitic lava tends to result from explosive events, and basaltic lava tends to result from non-explosive events and has a lower viscosity (i.e., is more fluid) than rhyolitic lava), the history of eruptions at the site, the presence of groundwater, and other factors influence the size, character, and duration of the eruption and the resultant hazards.

Figure 3.8.A. East Butte Volcanic

East Butte, a rhyolitic volcanic dome, lies on the eastern Snake River Plain in southern Idaho / Source: Scott Hughes, Idaho State University

Proximal Hazards

Lava Flows are pouring or oozing collections of lava extruded from vents. These flows can destroy all structures in their paths and start forest fires, but they advance relatively slowly, so they seldom endanger people. Lava flows damage or destroy everything in their paths by burying, crushing, or burning. Large areas of productive and/or developable lands may be lost to lava flows. They can also generate additional hazards by damming or diverting streams.

Pyroclastic Flows are avalanches of hot ash, rock fragments, and gas that move down the sides of a volcano during explosive eruptions or lava dome collapses. These flows can be as hot as 1,500°F and move at speeds of up to 100 to 150 miles per hour. They are capable of knocking down and incinerating everything in their paths. Such flows tend to follow valleys and are generally restricted to the immediate vicinity of the volcano. Lower-density pyroclastic flows, called pyroclastic surges, can easily overflow ridges hundreds of feet high.

Lahars and Debris Avalanches: Lahars are mud or debris flows, composed mostly of eruptive materials, on the flanks of a volcano. These flows can travel at speeds of 20 to 40 miles per hour and cover long distances. Debris avalanches are rapid downhill movements of rock, snow, and/or ice. They range from small movements of loose debris on the surface of a volcano to massive collapses of the entire summit or side of a volcano. Debris avalanches on volcano slopes are triggered when eruptions, heavy rainfall, or large earthquakes cause these materials to break free and move downhill.

Volcanic Gases: Volcanoes emit a number of potentially toxic gases, both during and between eruptions. The majority of the gas is water vapor (steam), derived from recent precipitation and groundwater. Other common volcanic gases include carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, and fluorine.

Toxic gases can have both short-term effects and long-term effects on human lives and the natural environment. Carbon dioxide is heavier than air and can be trapped in low areas in concentrations that are deadly to people and animals. Sulfur dioxide is a respiratory poison and also reacts with atmospheric water to create acid rain, causing corrosion and harming vegetation. Hydrogen sulfide is a highly toxic respiratory poison. Fluorine is a highly toxic respiratory poison and can be absorbed onto volcanic ash particles that later fall to the ground, poisoning livestock grazing on ash-coated grass and also contaminating domestic water supplies.

Tephra is solid and molten rock fragments, ranging in size from large "bombs" (from fist-sized to over 3 feet in diameter) to fine dust. The largest rock fragments usually fall back to the ground within 2 miles of the vent. Tephra deposits can pose a risk to lives and structures if they accumulate in a thickness sufficient to collapse roofs. More commonly, they reduce visibility and clog vehicle air filters, posing a hazard on highways. Deposits can topple or short-circuit electric transformers and power lines and clog other infrastructure such as water and sewage treatment facilities. Tephra clouds also commonly generate lightning that can interfere with electrical and communication systems and start fires. The fine material is extremely slippery, hampering driving and walking, and can damage the lungs of small infants, the elderly, and those with respiratory problems.

Distal Hazards

Eruption Columns and Clouds are created when small fragments (less than about 0.1 inch across) of volcanic glass, minerals, and rock are released during explosive eruptions and rise high into the air. Eruption columns can grow rapidly and reach more than 12 miles above a volcano, forming an eruption cloud. Large eruption clouds can extend hundreds of miles downwind, resulting in falling ash over enormous areas; the wind carries the smallest ash particles the farthest. Recent volcanic eruptions in Iceland caused tens of millions of dollars in losses to European counties due to travel restrictions, airline cancellations, and lost tourism.

Ashfall: As an eruption cloud drifts downwind from the volcano, the material that falls from the cloud typically becomes smaller in size and forms a thinner layer. Though called "ash," volcanic ash is not the product of combustion, like the soft fluffy material created by burning wood, leaves, or paper. Volcanic ash is hard, does not dissolve in water, is extremely abrasive and mildly corrosive, and conducts electricity when wet. Damages from ashfall are similar to those from tephra (ash being a form of tephra). Communities far from the actual eruption may be seriously disrupted by ashfall. The volcanic ash in an eruption cloud can pose a serious hazard to aviation; engines of jet aircraft have suddenly failed after flying through clouds of even, thinly dispersed material. The weight of ashfall can collapse buildings.

Location, Extent, and Magnitude

Currently there are no active volcanoes in Idaho, but there is evidence of several types of volcanoes. According to the U.S. Geological Survey (USGS), three active and potentially active areas of volcanic activity are most likely to have direct effects on Idaho: the Snake River Plain, particularly the "Craters of the Moon" area in south-central Idaho; the Yellowstone Caldera, which overlaps Idaho, Wyoming, and Montana; and the Cascade Mountains to the west. The Snake River Plain and the Yellowstone Caldera have not had eruptions within the past 2,000 years, but Yellowstone is being particularly closely watched because of seismicity and ground deformation in recent decades.

There are more than a dozen potentially active volcanoes in the Cascade Mountains (see Figure 3.8.B). The composite volcanoes are the most likely to have a far-reaching impact, as they tend to erupt more explosively and over longer periods of time (tens to hundreds of thousands of years) than other types of volcanoes found in the Cascades. Mount St. Helens and Mount Shasta are examples of composite volcanoes in the Cascade Mountains.

Figure 3.8.B: Potentially Active Volcanoes in the Western U.S.

Source: USGS, 1999

The Volcanic Explosivity Index (VEI) is one way to describe the relative size of explosive volcanic eruptions (see Figure 3.8.C). Scores range from 0 to 8, with each number representing an increase in magnitude from the previous number by a factor of approximately ten. Several factors are taken into consideration to determine the magnitude, including the volume of erupted pyroclastic material (for example, ashfall, pyroclastic flows, and other ejecta), height of eruption column, duration in hours, and qualitative descriptions. VEI does not necessarily relate to the amount of sulphur dioxide injected into the atmosphere, which is critical in determining the climatic impacts of an eruption.

If a large eruption of a composite volcano in the Cascade Mountains were to occur, Idaho would likely experience distal impacts. Effects from the 1980 Mount St. Helens eruption can serve as an example of potential effects from future volcanic eruptions in the northwest region. This eruption measured at 5 on the VEI scale. As shown in Figure 3.8.D, roughly half of Idaho experienced ashfall from this event, and portions of the State experienced some of the event's highest concentrations of ashfall.

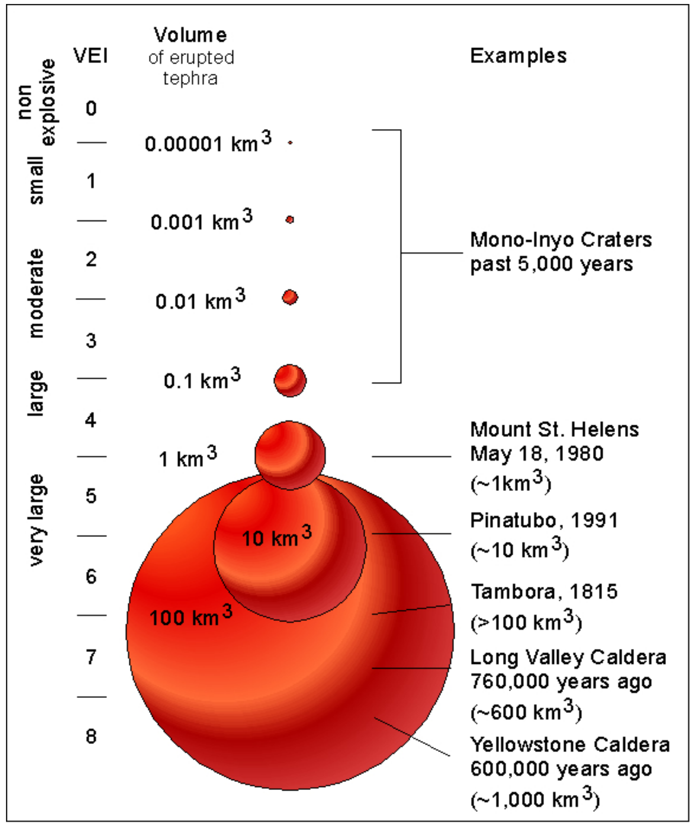


Figure 3.8.C. Volumes of several past explosive eruptions and the corresponding Volcanic Explosivity Index (VEI)
Source: USGS Volcanic Hazards Program (2010)

Severity

A 1-inch deep layer of ash weighs an average of 10 pounds per square foot, causing danger of structural collapse. Ash is harsh, acidic and gritty, and it has a sulfuric odor. Ash may also carry a high static charge for up to two days after being ejected from a volcano. When an ash cloud combines with rain, sulfur dioxide in the cloud combines with the rainwater to form diluted sulfuric acid that may cause minor, but painful burns to the skin, eyes, nose and throat.

Warning Time

The USGS operates five volcanic observatories, including one in the Yellowstone region and one in the Cascades region. These observatories maintain websites and issue warnings as well as weekly updates on volcanic activity.

The best warning of a volcanic eruption is one that specifies when and where an eruption is likely and what type and size eruption should be expected. Such accurate predictions are sometimes possible but still rare. The most accurate warnings are those in which scientists indicate an eruption is probably only hours to days away, based on significant changes in a volcano's earthquake activity, ground deformation, and gas emissions. Experience from around the world has shown that most eruptions are preceded by such changes over a period of days to weeks. A volcano may begin to show signs of activity several months to a few years before an eruption. However, a warning that specifies months or years in advance when it might erupt are extremely rare.

Relationships to Other Hazards

Secondary Impacts

A volcanic event would certainly have a large impact and influence over many of the hazards that pose a risk to the State. The location of the eruption would dictate these impacts. For a repeat event in the Cascade Range, ashfall would be the main cause for concern. The secondary hazards associated with volcanic eruptions are mudflows and landslides and possibly seismic activity in the region of the eruption. This could increase susceptibility for avalanches, by depositing a weak layer in the snowpack. An ashfall event could also affect the short term storm patterns. Ashfall from volcanoes may cause impacts to critical infrastructure and lead to energy outages. The electrical generation, transmission and distribution networks can experience:

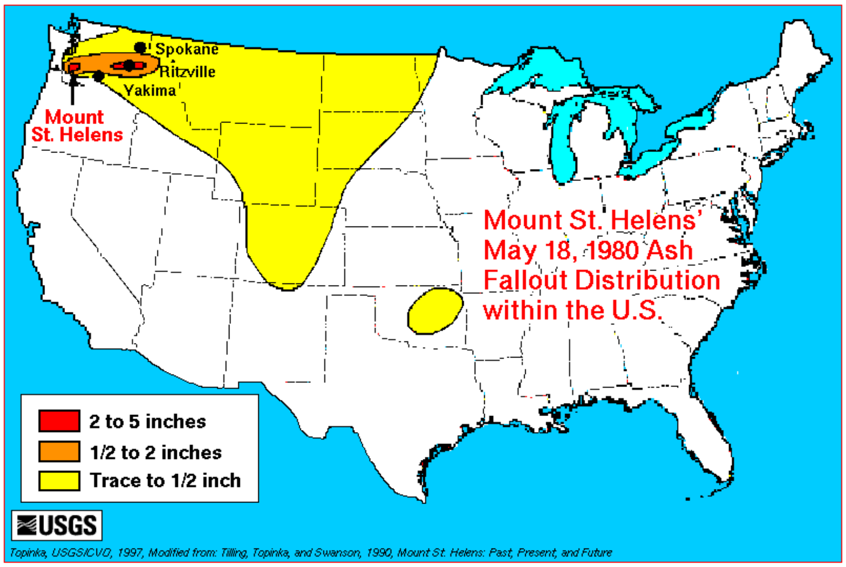


Figure 3.8.D. Generalized map shows the distribution of ash fallout within the United States, from May 18, 1980 eruption / *Source: Cascades Volcano Observatory (1997)*

- Supply outages from insulator flashover caused by ash contamination
- Controlled outages during ash cleaning
- Line breakage due to ash loading
- Abrasion and corrosion of exposed equipment
- Disruption of generation facilities

Ashfall can also affect water supplies by physically disrupting or damaging water sources and components of water supply, treatment and distribution systems. The deposition of ash into surface waters can also change its physical and chemical characteristics (Wilson, T.M., et al.). Additionally, the movement of magma upward during an eruption could initiate seismic events.

A Yellowstone event would pose the greatest threat to the State, and has the ability to increase the risk posed by many of the natural hazards. The largest impact would relate to human-caused hazards, such as a cyber disruption and hazardous material due to ashfall and negative effects of the ash accumulation, dramatically increasing the likelihood of all to occur. "When volcanic ash accumulates on buildings, its weight can cause roofs to collapse, killing and injuring people. A dry layer of ash 4 inches thick weighs 120 to 200 pounds per square yard, and wet ash can weigh twice as much. The load of ash that different roofs can withstand before collapsing varies greatly—flat roofs are more likely to collapse than steeply pitched ones. Because wet ash conducts electricity, it can cause short circuits and failure of electronic components, especially high-voltage circuits and transformers. Power outages are common in ashfall areas, making backup power systems important for critical facilities, such as hospitals. Eruption clouds and ash fall commonly interrupt or prevent telephone and radio communications in several ways, including physical damage to equipment, frequent lightning (electrical discharges), and either scattering or absorption of radio signals by the heated and electrically charged ash particles" (USGS Fact Sheet 027-00, 2000).

Past Occurrence

The only significant volcanic event in Idaho during recorded history was ashfall from the eruption of Mount St. Helens in 1980 (detailed below). The area has seen extensive volcanic activity in the more distant past, however. Within the Snake River Plain, the Craters of the Moon lava field had extensive flows up to 2,000 years ago, and the Boise area experienced large lava flows 1 million years ago. The Gem Valley area in southeastern Idaho has also been volcanically active; the last eruptive activity occurred about 30,000 years ago.

In the Yellowstone region, major explosive eruptions occurred 2, 1.3, and 0.6 million years ago. The most recent eruptions, 75,000-150,000 years ago, produced thick lava flows. With respect to Cascadian eruptions, an average of two eruptions occur per century - the most recent were at Mount St. Helens, Washington (1980-86), and Lassen Peak, California (1914-17). Although not the case with this most recent eruption at Lassen Peak, Rockland Ash from an eruption at Lassen 600,000 years ago can be found in southern Idaho.

FEMA Disaster Declarations

Between 1954 and 2017, FEMA declared that Idaho experienced one volcano-related major disaster (DR) declaration. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. However, not all counties were included in the disaster declarations as determined by FEMA (FEMA 2017).

Based on all sources researched, known volcanic eruption events that have affected Idaho and were declared a state and/or FEMA disaster, are identified in Table 3.8.E. This table provides information on the disaster declarations for volcanic eruptions, including date of event, state disaster declaration, federal disaster declaration and disaster number, and counties affected.

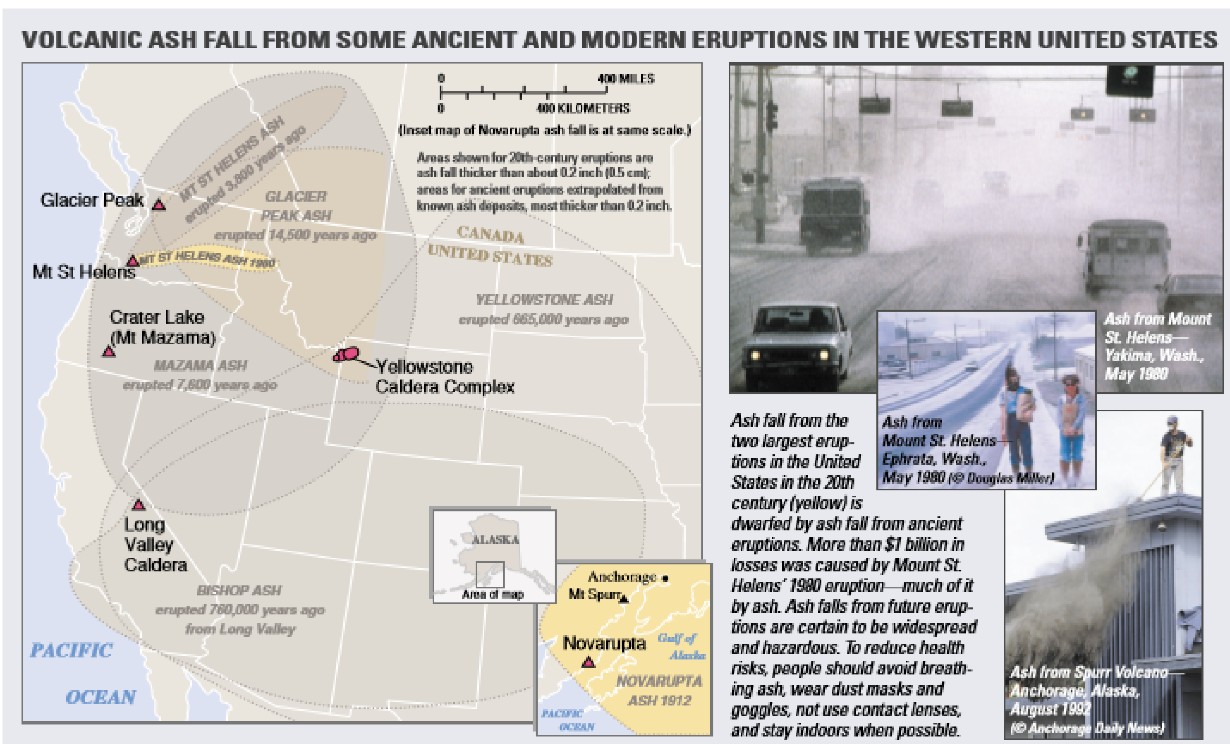
Table 3.8.E. Volcanic Eruptions Affecting Idaho, 1980 - 2017

Date(s) of Event	Event Type	Counties Affected	Description
May 18, 1980	Volcano Eruption DR-624	Benewah, Bonner, Boundary, Clearwater, Kootenai, Latah, Nez Perce, Shoshone	***Mount St. Helens:*** On May 18, 1980, Mount St. Helens, Washington, erupted, killing 57 people and causing over 1 billion dollars of damage in the Northwest. The eruption followed two months of earthquakes and minor eruptions, and this warning allowed most people in the proximal hazard area to evacuate prior to the eruption. Ashfall from the 1980 eruption of Mount St. Helens impacted northern Idaho, covering roads, affecting crops, machinery and vehicles, and creating health issues.

Future Occurrence

Idaho faces two likely future volcanic hazard scenarios that have a low probability of occurring based on past explosive eruptions. One is distal hazards from volcanic activity in the Cascades, and the other is proximal as well as distal hazards from the Yellowstone Caldera.

Figure 3.8.F. Volcanic Ash Fall in the Western United States



Source: USGS Fact Sheet 027-00)

Volcanic eruptions generally occur only after significant warning. Volcano monitoring can detect and measure changes caused by magma movement beneath the volcano. This movement will typically lead to swarms of earthquakes, swelling or subsidence of a volcano's summit or flanks, or release of volcanic gases from the ground and vents. Monitoring can project volcanic activity within a time frame of days to months. Longer-term hazard projection is more difficult and is generally dependent on analyses of past activity.

The USGS operates five volcanic observatories, including one in the Yellowstone region and one in the Cascades region. These observatories maintain websites and issue warnings as well as weekly updates on volcanic activity. In 2010, the Yellowstone Volcano Observatory developed protocols for a geologic hazards response in the Yellowstone region. The report states, "Within the next few decades, large and moderate earthquakes and hydrothermal explosions are certain to occur. Volcanic eruptions are less likely, but are ultimately inevitable in this active volcanic region." Similarly, the Cascades Volcano Observatory produces hazard assessments for the multitude of volcanoes in the Cascades.

"Given the potentially large geographic dispersal of volcanic ash, and the substantial impacts that even thin (a few mm in thickness) deposits can have for society, [this future occurrence section] elaborates upon the ash component. The areas affected by volcanic ash are potentially much larger than those affected by ash falling to the ground, as fine particles can remain aloft for extended periods of time. For example, large portions of European airspace were closed for up to five weeks during the eruption of Eyjafjallajökull, Iceland, in 2010 because of airborne ash (with negligible associated ash falls outside of Iceland). The distance and area over which volcanic ash is dispersed is strongly controlled by wind conditions with distance and altitude from the vent, but also by the size, shape and density of the ash particles, and the style and magnitude of the eruption. These factors mean that ash falls are typically deposited in the direction of prevailing winds during the eruption and thin with distance. Forecasting ash dispersion and the deposition 'footprint' is typically achieved through numerical simulation" (Jenkins et. Al, 2014).

Projected Idaho Events

Yellowstone Caldera: The hydrothermal features of the Yellowstone National Park area are fueled by the large magma plume (the "hotspot") that lies below the region. These features are volcanic activity, although not of a generally hazardous nature. The high levels of seismic activity and active deformation of the surface in the area also indicate the volcanic potential of Yellowstone. However, if one were to use past eruptions as a guide, the yearly probability of another catastrophic eruption within Yellowstone is 1 in 730,000 (the average of the years between past events). A more likely type of volcanic eruption from Yellowstone (averaging every 16,000 years in the past) is a basaltic eruption along the margins, including the basin of Island Park, Idaho. The principle hazard from such an event would be coverage of an area of several square kilometers by lava, one to a few tens of meters thick.

The latest eruption from Yellowstone caldera proves that two eruptions occurred back to back within 170 years apart from each other. Thus both eruptions ended and cooled the planet temporarily, reversing the warming trend. But the exact prediction as to when the Yellowstone volcano will erupt again is unknown (Science Daily October 26, 2017).

Snake River Plain: Over the past 30 million years, this region has experienced extensive stretching. Most past volcanic activity in the Snake River Plain was confined to "volcanic rift zones," linear areas of cracks in the earth's crust. Volcanic activity in this area has been characterized by eruptions of basaltic lavas resulting in extensive lava flows. A recent example of these on-going forces was the 1983 Mount Borah earthquake. During that event the highest point in Idaho, Mount Borah, got a bit higher when a magnitude 6.9 earthquake occurred across the base of the Lost River Range. Mount Borah rose about 1 foot (.3 m) and the Lost River Valley in that vicinity dropped about 8 feet (2.4 m.). On the Eastern Snake River Plain, rather than producing mountain ranges, these tensional forces have triggered volcanic activity. The stretching of the crust releases pressure on the hot rocks below causing them to melt. The magma can then travel to the surface along planes of weakness like the Great Rift. As long as these forces continue to act, more eruptions will eventually occur. The time between eruptive periods in the Craters of the Moon Lava Field averages 2,000 years and it has been more than 2,000 years since the last eruption. (https://www.nps.gov/crmo/learn/nature/geologicactivity.htm)

Cascades: Ten volcanoes (or volcanic centers) within the Cascade Mountains have been active within the last 2,000 years; an additional four are regarded as potentially active. As the eruption of Mount St. Helens demonstrated in 1980, activity in this region can have significant impact over a wide area, including Idaho. According to the U.S. Geological Survey, portions of Idaho have a 1:1,000-1:5,000 annual probability of receiving 1 centimeter or more of ashfall from any major Cascade volcano; there is a less than 1:10,000 probability of 10 centimeters or more.

Environmental Impacts

The environment is vulnerable to the effects of a volcanic eruption, even if the eruption does not directly impact the planning area. This is highly dependent upon the amount of tephra accumulation. Rivers and streams are vulnerable to damage due to ash fall, especially since ash fall can be carried by these water courses. The sulfuric acid contained in volcanic ash could be damaging to area vegetation, waters, wildlife and air quality.

In areas of the State where proximal volcanic hazard exists, a volcanic eruption could cause dramatic environmental effects. Vegetative communities, wildlife, historic and archeological sites, farms, and parks could be buried, crushed and burned by a lava flow. Volcanic eruption would affect geology and soils in areas of Idaho proximal to the event. Long-term effects could include forced changes in land-use patterns. Throughout the State, distal volcanic hazards could reduce air quality, damage historic resources (e.g., ashfall on old roofs), clog streams, and have health impacts on fish and wildlife.

Climate Change Impacts

Human activity is not affecting volcanic eruptions. According to a recent study published in September 2017 in the *Proceedings of the National Academy of Sciences* found that glacial retreat in Antarctica 17,700 years ago was connected to a series of volcanic eruptions over a 200-year period. This occurred because the ice and ocean water created pressure on the Earth's crust, capable of containing magma. If a glacier retreats in a relatively quick period of time, the magma is more likely to push toward the Earth's surface, said Michael Manga, a professor of earth and planetary science at the University of California, Berkeley. "After big glaciers melt, we see more volcanoes erupt, so not only do volcanoes affect climate, but climate also affects volcanism," he said.

Development Trend Impacts

An understanding of population and development trends can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. The State considered the following factors to examine previous and potential conditions that may affect hazard vulnerability: potential or projected development; projected changes in population; and other identified conditions as relevant and appropriate. The U.S. EPA's Integrated Climate and Land-Use Scenarios (ICLUS) project generated projected population and land use projections for the United States through 2100. The project examined multiple scenarios taking into account various population growth and economic development parameters that have been used as the baseline for the Intergovernmental Panel on Climate Change's (IPCC) Special Report on emissions Scenarios (SRES). Population change took into account assumptions regarding fertility, mortality, and immigration, which was then used to drive the land use projections. Map 2.F. in Chapter 2 (State Profile) displays the projected population growth by 2026. It is anticipated that the human exposure and vulnerability to volcanic impacts will be similar to what currently exists.

All future development has the potential of being impacted by ash fall generated from a volcanic event. While this potential impact on the built environment is not considered to be significant, the economic impact on industries that rely on machinery and equipment such as agriculture or civil engineering projects could be significant. The extent of this hazard is difficult to gauge because it is dependent upon many variables, so the ability to institute land use recommendations based on potential impacts of this hazard is limited. While the impacts of volcanic hazards are sufficient to warrant risk assessment for emergency management purposes, the impacts are not considered to be sufficient to dictate land use decisions.

Because volcanic eruptions tend to be far apart in time, it is unlikely that the threat of their effects will be considered in overall development trends. When an eruption does occur, economic activity can be stymied even far from the center of activity, as evidenced from the disruption to flight schedules in the wake of the 2010 Iceland volcanic eruption. If an eruption occurs within Idaho, developable land can be lost to lava flows, as in the Craters of the Moon volcanic field.

Vulnerability Assessment

No specific, statewide vulnerability assessment exists for the volcano hazard. Geologic history has shown that volcanic activity associated with the Yellowstone Caldera could be catastrophic if it were to occur in today's environment. Refer to Figure 3.8.B in the Hazard Profile for the location of volcanoes in the Western United States. The probability of such an event occurring in the near term is up for geologic debate.

A more likely scenario is volcanic activity in the Cascade Mountains producing a significant amount of ashfall within the State. It is anticipated that no one would be injured or killed, but businesses and non-essential government facilities would be closed until the cloud passes. People and animals without shelter would be affected. Structures would be safe, but private property left out in the open, such as farm equipment, might be damaged by the fine ash dust.

Using the 1980 eruption from Mount St. Helens as an example, the following counties were impacted by ashfall and indicate the more vulnerable counties in the State: Benewah, Bonner, Boundary, Clearwater, Kootenai, Latah, Nez Perce, and Shoshone. The areas near Island Park are at greater risk than other areas of the State for lava flow.

Critical Infrastructure and State Facility Impacts

All infrastructure and State facilities could be at risk of ashfall from a major eruption. Critical facilities near Island Park are at greater risk than other areas of the State for lava flow.

No specific, vulnerability assessment for State owned and leased facilities exists for the volcano hazard, however Figures 3.8.G through 3.8.I give some base planning loss estimates for general building damage from the ashfall that Idaho would likely receive in the event of an eruption. If a large eruption of a composite volcano in the Cascade Mountains were to occur, Idaho would likely experience distal impacts. All State assets could be at risk to ashfall from a major eruption. "While post-eruption impact assessment studies will continue to strengthen and diversify our understanding of ash fall impacts, this research model[s] rarely allow for detailed analysis to determine with any certainty how and why observed impacts occurred. There is a lack of empirical knowledge regarding how ash properties such as abrasiveness and corrosiveness affect critical infrastructure components over varying timescales. Understanding how the geotechnical properties and surface chemistry of ash influences impacts to societal elements is a current gap in understanding" (Jenkins, et. al, 2014). Damage to buildings and building support systems from ashfall can range from minor cosmetic damage to building exteriors to catastrophic structural damage in extreme cases. The level of impact is dependent on the amount and characteristics of the ashfall, the design and quality of the building and building support system and the environmental conditions at the time of and after ashfall (USGS, 2015). State assets and critical facilities near Island Park are at greater risk than other areas of the State for lava flow.

Hazard Mitigation Vulnerability Assessments

Volcanic-ash hazards are far reaching and disruptive and can impact people, infrastructure, and daily activities more so than any other volcanic hazards. Short-term effects from ashfall may include respiratory impacts and potentially exacerbate pre-existing respiratory diseases such as asthma. Ashfall may cause poor visibility impacting transportation (vehicular, air) over large areas for hours to days. It may also lead to widespread loss of electricity impacting communities, businesses and critical life-support services (USGS 2015).

Loss Estimation

No specific, statewide loss estimation exists for this hazard. "Vulnerability to ashfall impacts is dependent on building or infrastructure condition, construction, maintenance, network design, ash volume and particle characteristics, as well as the effectiveness of applied mitigation strategies. The values provided in [Figures 3.8.G through 3.8.I] are intended as broad indicators only and are subject to significant uncertainty; few empirical data are available and, by necessity, vulnerability studies are typically supplemented by expert judgement. A number of assumptions have been made in these impact estimates: namely, that assets were subject to one discrete ash fall event; ash was not removed during deposition (either by wind, water or human actions); and no mitigation actions had been taken prior to impact (e.g. internal strengthening of the building). The sectors shown in [Figures 3.8.G through I] are those for which ash fall thickness is an appropriate measure of hazard intensity relative to damage and functional state. This list is therefore not exhaustive, but highlights some key sectors that are expected to suffer damage or disruption under ash falls" (Jenkins, et. al, 2014).

Figure 3.8.G. Approximate median (and interdecile) hazard intensities (using dry ash thickness as a proxy) that relate to key damage and functionality states for a range of critical infrastructure.

Critical Infrastructure Type:	Code:	D0	D1	D2	D3	D4	D5
	Description:	No damage	Cleaning required		Repair required		Beyond economic repair
Airports	Function	Fully functional	Closure of runway				Indefinite closure
Airports	Damage	No damage (but loss of revenue costs)		Possible runway surface degradation	Collapse of critical buildings; possible runway surface degradation [3]		Complete burial
Airports	Thickness	0 mm	>0 mm				>500 mm
Power	Function	Fully functional	Temporary disruption, e.g. flashover of insulators		Disruption requiring repair		Permanent disruption
Power	Damage	No damage	No damage to components		Damage to critical components; long delays in receiving replacement components.		Structural damage
Power	Thickness	0 (0-20) mm	5 (1-20) mm		20 (2-100) mm		>500 mm (100-1000 mm)
Railways	Function	Fully functional	Reduced visibility and traction	Signals disrupted	Loss of traction making operation unsafe; Possible derailing through ash accumulation		Impassable
Railways	Damage	No damage		Possible abrasion and/or corrosion of signal components and track			Complete burial
Railways	Thickness	0 (0-5) mm	0.5 (0.1-10) mm	1 (0.1-20) mm	30 (2-100) mm		100 (50-200) mm
Roads	Function	Fully functional	Reduced visibility and traction	Road markings obscured	2WD vehicles obstructed	4WD vehicles obstructed	Impassable
Roads	Damage	No damage		Possible road surface and marking abrasion	Road surface and marking abrasion		Complete burial
Roads	Thickness	0 (0-5) mm	0.5 (0.1-10) mm	2 (1-20) mm	50 (10-100) mm	150 (50-300) mm	n/a [4]

Source: Jenkins, et. al, 2014. Note: Water and telecommunication networks are not included here because damage states are difficult to relate them to a single hazard intensity, i.e. thickness. The response of a system or network to ash fall thicknesses will depend upon the system/network design and type, its components and the characteristics of the ash fall.

Figure 3.8.H. Approximate median (and interdecile) hazard intensities that relate to key damage and functionality states for a range of generic roof types

Code:	D0	D1	D2	D3	D4	D5
Description:	No damage	Minor/basic repair required	Moderate repair required	Major/specialist repair required		Beyond economic repair
Function:	Functional	Repeated clean-up required; Some loss of functionality for some contents and fittings	Ash infiltration or threat of roof and/or wall collapse may prohibit habitation			Retired
Cost (% of replacement cost):	0 – 1	1 – 5	5 – 20	20 – 60		>60
Structural damage:	No damage	No damage	No damage to principal roofing supports	Partial or complete failure of the supporting structure, e.g. battens or trusses; Partial or moderate damage to the vertical structure		Collapse of roof and supporting structure over 50% of roof area; External walls may be destabilised
Non-structural damage:	No damage	Minor damage to roof coverings, e.g. abrasion and corrosion of metallic roofs.	Potential damage to gutters and roof covering, e.g. excessive bending, and overhangs	Severe damage or partial collapse of roof overhangs; Collapse or partial collapse of roof covering		Partition wall/s destroyed in some cases
Contents and fittings:	Some infiltration of ash possible	Ash infiltration and potential damage to fittings, e.g. air-con, and appliances	Variable levels of contamination and damage			Damage to most contents and fittings is irreversible, or salvage is uneconomical
GENERIC ROOF TYPES: Timber board on weak timber supports	1 mm?	10 mm?	200 mm (100 – 400 mm) [6]			
GENERIC ROOF TYPES: Tiles on timber supports			300 mm (150 – 600 mm) [6]			
GENERIC ROOF TYPES: Modest sheeting on timber supports			300 mm (150 – 600 mm) [6]			
GENERIC ROOF TYPES: Domestic reinforced concrete			700 mm (400 - 1400 mm) [6]			

Source: Jenkins, et. al, 2014. Note: Approximate cost ratios are estimated, following the work of Blong, 2003a and unpublished studies around Vesuvius, Italy 5. Dry ash fall thickness (in mm) is used as a proxy for hazard intensity and a load density of 1000 kg/m2 is assumed. A saturated ash deposit would result in the damage states identified at as little as half the suggested thicknesses.

Figure 3.8.I. Approximate median (and interdecile) hazard intensities (using dry ash thickness as a proxy) that relate to key levels for loss of production for a range of agriculture types.

Code:			D0	D1	D2	D3	D4	D5
Description:			No damage	Disruption to harvest operations and livestock grazing of exposed feed	Minor productivity loss: less than 50 %/crop	Major productivity loss: more than 50 %/crop; Remediation required	Total crop loss; Substantial remediation required	Major rehabilitation required/ Retirement of land[7]
AGRICULTURE TYPE:	Horticulture & Arable	Ground Crops & Arable	0 mm (0-20 mm)	1 mm (0.1-50 mm)	5 mm (1-50 mm)	50 mm (1-100 mm)	100 mm (25-200 mm)	300 mm (100- 500 mm)
AGRICULTURE TYPE:	Horticulture & Arable	Tree Crops	0 mm (0-20 mm)	1 mm (0.1-50 mm)	5 mm (1-50 mm)	50 mm (1-100 mm)	200 mm (5-500 mm)	300 mm (200- 500 mm)
AGRICULTURE TYPE:	Pastoral		0 mm (0-20 mm)	3 mm (0.1-50 mm)	25 mm (1-70 mm)	60 mm (20-150 mm)	100 mm (30-200 mm)	300 mm (100- 500 mm)
AGRICULTURE TYPE:	Paddies		0 mm (0-50 mm)	1 mm (0.1-50 mm)	30 mm (1-75 mm)	75 mm (20 - 300 mm)	150 mm (75 – 300 mm)	300 mm (100- 750 mm)
AGRICULTURE TYPE:	Forestry		0 mm (0-75 mm)	5 mm (0.1-75 mm)	200 mm (20-300 mm)	1000 mm (100-2000 mm)	1500 mm (100->2000 mm)	?

Source: Jenkins, et. al, 2014. Note: These hazard-loss of productivity relationships are based on expert judgement and very few empirical and experimental data. Impacts assume that the crops are in the growing stage (a worst-case impact); season modifiers will allow impacts during other periods of the growing cycle to be accounted for. These estimates are thus intended as broad guidelines and should be refined for individual cases and conditions.

Local Hazard Mitigation Plan Loss Estimations

Because no local mitigation plans ranked volcanic eruptions as a major hazard, these data were not aggregated, and it is assumed that annual loss estimates would be low. Detailed information related to local loss estimates may be found in local hazard mitigation plans.

Consequence Analysis Evaluation

On June 8, 2017, a Consequence Analysis Evaluation was conducted aligning with hazards profiled in the State Hazard Mitigation Plan. The assessment was conducted by a diverse planning team comprised of subject matter experts from across the State. This effort mirrored a similar exercise that occurred during both the 2010 and 2013 State Hazard Mitigation Plan updates.

The exercise is intended to provide another way to assess the State's vulnerability to its hazards and was conducted as a group exercise. Participants were asked to individually rank the following systems on a scale from 0 (no consequences) to 5 (most severe consequences), separately evaluating both the short-term (0-6 month) and long-term (6+ months) consequences of the scenario.

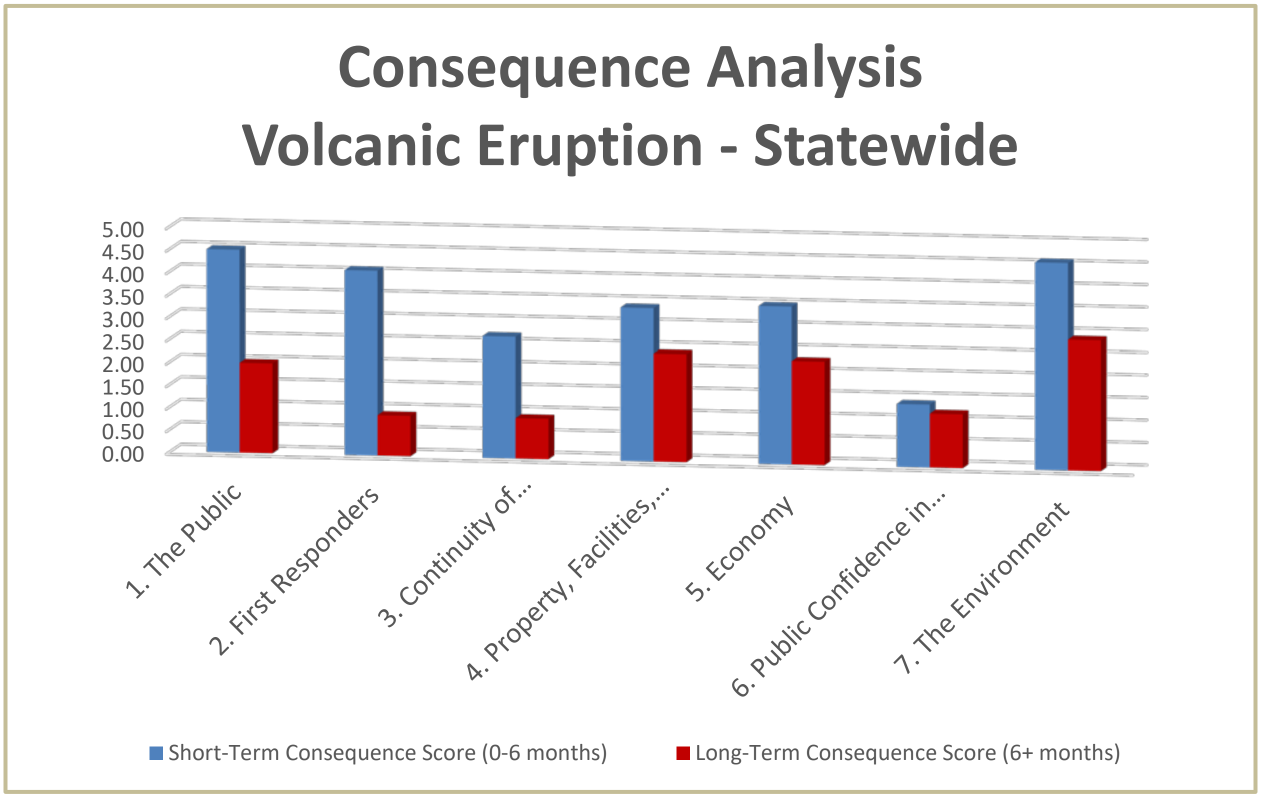
Systems Evaluated:

- The public
- First responders
- Continuity of operations
- Property, facilities, and infrastructure
- Economic conditions
- Public confidence in government

Scenario

May: In March, a series of earthquakes were recorded beneath Mount St Helens in the Washington Cascades. The USGS issued a hazard watch on March 27 and shortly thereafter the first eruption of steam from the summit sent a column of ash and steam 6000 feet into the air. Numerous volcanic tremors have been recorded since then and on the morning of May 18, a 5.1 magnitude earthquake was registered. Within seconds, the volcano erupted and the north face of the mountain was blown apart. Within an hour, massive mudflows were moving through the river systems to the west and southeast of Mount St Helens. A Plinian eruption column filled with hot ash, gas, and rock rose over 20 km into the atmosphere. By mid-afternoon, eastern Washington and northern Idaho were plunged into darkness as the thick ash clouds rolled in overhead. Day turned to night as light sensitive streetlamps flickered to life and tiny ash particles began to blanket the towns like snow. Overall, the ash affected Washington, Idaho, Montana, Wyoming, Colorado, and the northern part of New Mexico and ranged from heavy ash fall to hazy skies. In Idaho, around two inches of ash fell on towns from Moscow to Coeur d'Alene but ash fall extended from McCall to Canada. Unlike ash from fires, volcanic ash is composed of tiny shards of sharp glass and rock that forms a concrete-like material when wet and can significantly damage a person's lungs.

Results



Looking at the short-term consequences of this volcanic eruption event, exercise participants felt that the most severe consequences would be felt by the environment, the public, and first responders. From a long-term standpoint, the three systems suffering the most severe consequences (in decreasing order) include the environment, the built environment, and the economy. A major takeaway from this exercise is the fact that the short-term impacts of this type of volcanic event are greater than the expected long-term consequences across all sectors.

Some observations of the group to note included:

- While this event could lead to a number of short-term impacts, its long-term effects would be relatively small.
- Economic impacts related to the Lewiston port's operability could be rather large.
- Consequences would be very similar to those experienced during the last major Mount St. Helens eruption.
- A number of other hazards could be initiated by this event, including: earthquakes, flooding, mudslides, and public health emergencies.

Mitigation Rationale

Volcanic eruption has a relatively low probability (compared with other hazards) in any given year. Additionally, the most likely event, a volcanic eruption in the Cascade Mountains, is expected to only produce moderate impacts within Idaho.

While improbable, the potential for severe damages resulting from a major event in Idaho is real. The geologic history of Idaho and the region has a significant component of volcanic activity. Consequently, the State is well advised to undertake mitigation planning.

General Mitigation Approaches

Given the low probability and unique nature of these events, volcanic eruptions pose a special problem for emergency management personnel. Some special characteristics that influence emergency response and mitigation include:

- Eruptions generally have many precursors, but these potential warnings are often ambiguous (i.e., we can often forecast activity generally, but rarely precisely).
- There is a large range in the magnitude/frequency relation for eruptions (i.e., there is no way to easily anticipate the scale of the impending eruption).
- The scale of eruptions may far surpass any other hazard.
- Some of the hazards associated with an eruption can be fast moving.
- The impacts from volcanic eruptions can be very long lasting – centuries or more.

Volcanic eruptions are outside of most people's realm of experience; consequently, the public has a minimal appreciation of the hazards.

Hazard Management

As eruptive activity rarely comes without significant warning, mitigation efforts in likely proximal hazard zones should ensure that critical or high-investment development is not sited in high-risk areas. This will reduce the potential overall disaster cost without unnecessarily constraining land use.

Information/Outreach and Public Education

Because of the infrequent nature of volcanic activity in the State, the public's appreciation of the hazards is limited. Information regarding distal hazards should be made available to citizens and property owners through the State. Information on proximal hazards should be prepared and readily available if an event does become likely.

Yellowstone Volcano Observatory. The Yellowstone Volcano Observatory (YVO) is a consortium of agencies, including USGS, the National Park Service, the University of Utah (which operates the Yellowstone seismic network), University NAVSTAR Consortium(UNAVCO) (which maintains GPS stations, borehole tiltmeters and strainmeters, and lake monitors within Yellowstone National Park), the University of Wyoming, the Montana Bureau of Mines and Geology, the Wyoming State Geological Survey, and the Idaho Geological Survey. YVO's principal objectives are:

(1) provide monitoring that enables reliable and timely warnings of possible renewed volcanism and related hazards in the Yellowstone region;
(2) notify federal, state and municipal officials, as well as the public, of significant earthquakes or volcanic events;
(3) improve scientific understanding of tectonic and magmatic processes that influence ongoing seismicity, surface deformation, and hydrothermal activity;
(4) assess the long-term potential hazards of volcanism, earthquakes, and explosive hydrothermal activity in the region;
(5) communicate effectively the results of these efforts to responsible authorities and to the public; and
(6) improve coordination and cooperation among the various groups studying current activity and potential hazards of the Yellowstone volcanic system.

With respect to Yellowstone, the Idaho Geological Survey (IGS) plays a role in helping inform and communicate as to the geologic setting and volcanic, hydrothermal, and seismogenic hazards throughout the region. During times of volcanic, seismic or hydrothermal unrest, the IGS liaison to YVO and/or other IGS staff may serve as a critical source of information to state leaders and emergency responders. The IGS may also contribute geologic or other expertise to YVO as needed and desired by the parties involved.

Planning and Preparedness

While the State of Idaho does not contain any currently active volcanoes, there are higher volcanic threats to the east, west, and northwest that will likely impact Idaho from an ashfall perspective. There are many planning and preparedness mechanisms that can be considered in preparing for ashfall in the event of a volcanic eruption. In general, emergency operations and response plans should include volcanic ashfall cleanup and safeguarding procedures, ash disposal sites and protocols, situational monitoring through USGS, and backup power sources. Plans should be integrated at all levels with state, regional, and local emergency response plans.

1. Reducing the exposure of electronics and computer equipment to ashfall is the most effective mitigation measure and can be achieved by sealing the equipment, or the building in which it is housed.
    a. Plans should include ensuring stocks of protective equipment such as plastic sheeting and duct tape, limiting ash ingestion into buildings which house electronic equipment, and moving any outdoor electronic equipment indoors prior to an ashfall.
2. Fresh water supply and wastewater collection and treatment become vulnerable during a volcanic ashfall.
    a. At risk water and wastewater treatment plants should ensure that their emergency response plans include provision for ashfall events, including site cleanup. The use of alternative, non-potable water sources should be used for cleanup and firefighting,

cleanup using brooms and shovels rather than hoses should be addressed, and non-essential equipment should be shut down while covering exposed essential equipment (such as generators).

3. Prompt ash cleanup is essential in urban areas is essential to minimize damage and disruption.
4. Road networks are vulnerable to ash impacts, but can be kept operational.
    a. Operational plans for volcanic ashfall should be developed and address the identification of a hierarchy of roads for priority of cleanup, road closure protocols, and equipment and labor requirements for cleanup operations.
5. Volcanic ashfall can cause electricity outages and issues with power transmission and distribution systems.
    a. Cleaning ash contaminated sites and components, especially insulators, is commonly required after an ashfall. Both live-line and de-energized cleanup plans should include: priority schedule for inspecting/cleaning sites and lines, standardized ashfall cleanup procedures, and ready access to cleaning supplies and equipment.
6. Volcanic ashfall can quickly lead to the widespread loss of electricity.
    a. At risk power generation facilities should address the following additional planning considerations: installing turbidity monitoring instrumentation at intake and identify threshold for closure; develop a priority schedule for inspecting/cleaning, and hydroelectric plant facilities may consider hardening turbines during design and refurbishment programs.
7. Adverse impacts on buildings and structures is a problem with volcanic ashfall.
    a. At risk and critical facilities should additionally consider identifying entry/exit points required for building operation, areas which need sealing and restricted access to limit spreading ash, ensuring supplies of necessary equipment, outlets and downpipes are covered to reduce ash ingress into drainage networks, ensure critical service delivery is accounted for in backup power generation and covering water tanks, and that roofs where ash accumulation will need to be removed have pre-installed fall arrest or anchor points and that a safe means of access is identified.
8. Airport operations can be disrupted when there is volcanic ashfall present.
    a. Airport emergency operations plans should be integrated with airline plans, and should also take into consideration standing arrangements prior to volcanic eruptions, collaborate response efforts, and post eruption cleanup for airport re-opening.

Regulatory

Infrastructure should not be sited in probable proximal hazard zones if feasible alternatives exist. Building codes should ensure that new development can withstand probable ashfall loads. Land-use regulations can mandate the siting considerations discussed under Hazard Management.

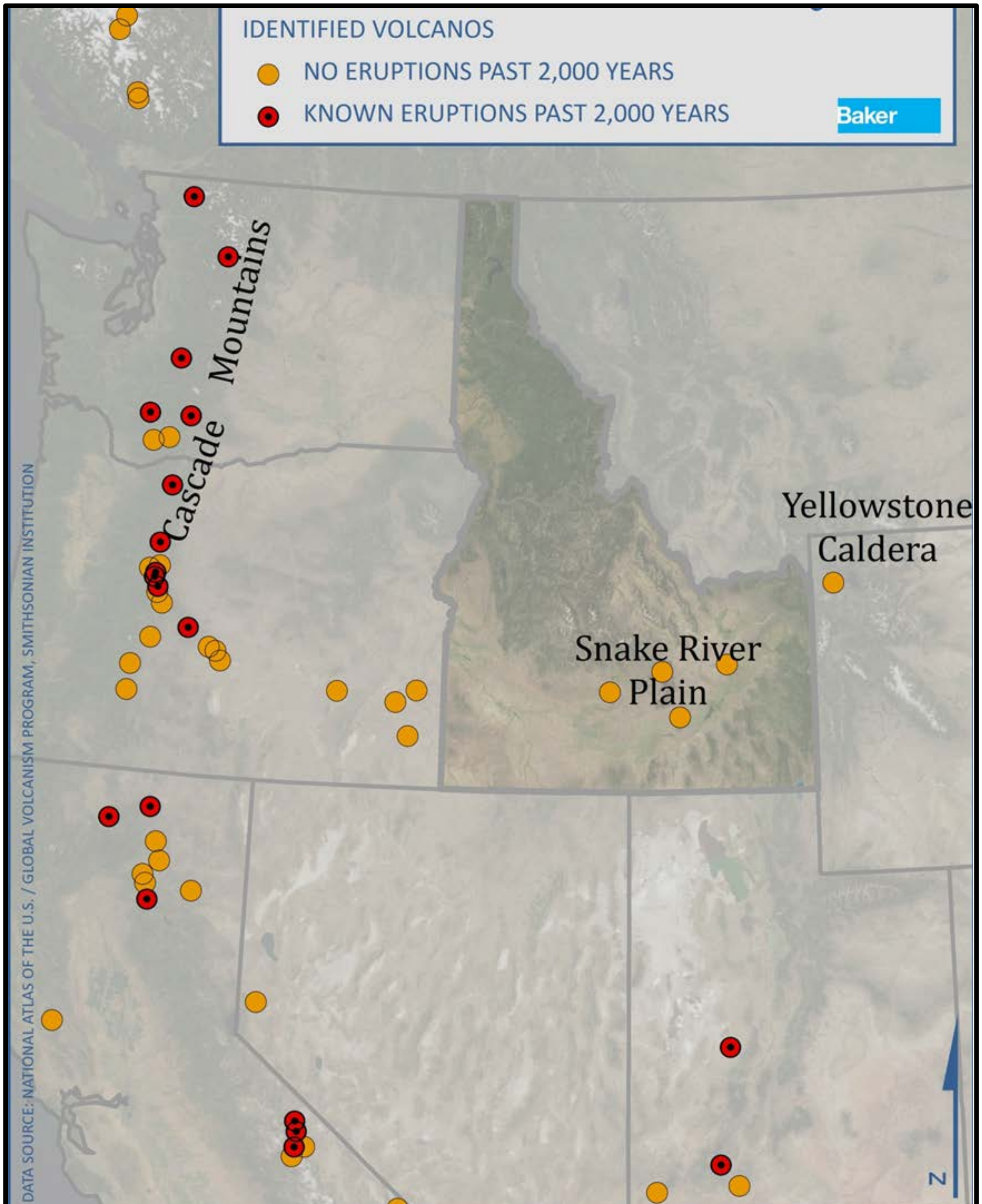


Figure 3.8.J. Volcano Locations and Extent

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