Module 1, Investigation 1:
Cause and effect statements

1. Volcanic deposits literally reshaped the entire region around the mountain.
2. The mountain "awoke" with a series of steam explosions and bursts of ash.
3. The mountain shook from a strong, magnitude 4.2 earthquake.
4. The entire face of the mountain broke free and slid downward in a giant rock avalanche.
5. The lava contained dissolved water that exploded into superheated steam.
6. Shipping channels were blocked.
7. Thousands of deer, elk, bear, and other animals died.
8. Almost 594 square kilometers of forest were destroyed.
9. A global network of Volcanic Ash Advisory Centers was created to observe volcanic eruptions in order to improve aircraft safety.
10. Tiny ash particles were thrust 24 kilometers into the sky and were airborne for about nine hours.
11. Many communities and agricultural areas were affected by falling ash. Machinery and crops were damaged.

12.	A small airplane narrowly avoided disaster when the pilot put the plane into a steep dive to gain speed and turned south, away from the cloud.
13.	Enormous mudflows gushed down the mountain.
14.	Small ash particles reached the eastern United States within three days of the blast and circled the globe within two weeks.
15.	Composite volcanoes erupt explosively.
16.	Composite volcanoes are made of alternating layers of lava, ash, and other volcanic debris.
17.	Plant growth was severely slowed for years after the eruption.
18.	Magma contains high concentrations of gas that may cause an explosion that breaks magma into pumice and tiny ash particles.
19.	Within hours of the blast, mixtures of gas, pumice, and ash swept down the north side of the volcano at speeds up to 160 kilometers per hour (100 miles per hour) and at temperatures over 648˚ C (1200˚ F).
20.	A fan-shaped pumice plain developed to the north and directly in front of the crater.
21.	Layers of pyroclastic flow (pumice, ash, and gas) were deposited as thick as 20 meters deep along the north side of the volcano.
22.	The Columbia River was closed to freighter traffic for several days to remove debris.
23.	Trees were stripped from hillsides as far as 10 kilometers from the volcano.

24. Around the edges of the blowdown zone, trees were killed simply by the intense heat of the blast. These trees are called Standing Dead.
25. From May to September 1980, the U.S. Army Corps of Engineers removed 32 million cubic meters of debris from the Cowling River.
26. Levees and retaining structures were built to control sediment and debris deposits. This prevents deposits from clogging the rivers and hindering boat traffic or causing flooding downstream.
27. Flood gates were installed to prevent potential flooding of Spirit Lake caused by future volcanic activity.
28. A debris avalanche blocked the natural outlet of Spirit Lake.
29. Several new lakes were formed by debris deposits, but these natural dams were unstable and could fail and flood the streams.
30. A fish transport system was built to help fish get around the sediment-retention structure. This provided safe passage for salmon and steelhead returning from the sea.
31. Scientists carefully watch the activity of magma under Mount St. Helens. Nonetheless, heat from the magma has led to avalanches (melting snow) and explosions of steam (heated water) without warning.
32. The U.S. Geological Survey and University of Washington are watching for volcanic activity of Mount St. Helens. Information on lahar (mud slides) and flood hazards is now collected by the USGS and the National Weather Service who then issues warnings.

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

Background

Volcanoes are like good news, bad news jokes. The good news is that they offer humans benefits such as rich soil. The bad news is that they are very destructive when they erupt. Because of this contradiction between productivity and destruction, areas around volcanoes need to be evaluated for safety. Creating a safety zone around a volcano helps to minimize a volcano's effect on humans. Creating a safety or buffer zone, however, requires information about the extent of previous eruptions compared to human settlement patterns. In this investigation you use data at different scales to study the impact of volcanic eruptions on the environment and its inhabitants in order to establish a buffer zone.

Objectives: In this investigation, you

- categorize the causes and effects of volcanic eruptions and human responses to them,
- measure the extent of damage of the Mount St. Helens 1980 eruption, and
- analyze images of a volcano to suggest a settlement buffer zone.

Procedures for the Investigation:

1. Read the account of the Mount St. Helens 1980 eruption.
2. Define the following elements of Earth's physical systems:

   hydrosphere: ____________________

   lithosphere: ____________________

   atmosphere: ____________________

   biosphere: ____________________

3. Categorizing causes, effects, and responses

   Organize the Cause and Effect Statements into three categories. List the strip numbers under each category title.

Causes	Effects	Human Responses

Divide the strips into more specific categories using the headings on Log 2: Cause and effect organizer. Be prepared to explain your choices.

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

4. Look at Figure 1. This is a false color image, which means the features in the figure do not have the same color as they do in real life. The volcano is in the lower left corner. In this image, the vegetation (plant life) appears reddish and the water appears dark blue or black. Locate the following.
   Mount St. Helens volcano
   Spirit Lake
   A river
   Areas of vegetation

5. Go back to the Cause and Effect Statements that you organized earlier in this investigation. Write down three changes that you expect to observe in an image taken after an eruption.

   1) ____

   2) ____

   3) ____

6. Place a transparency over Figure 1. Mark the corners of the image onto the transparency to line up the other images. With a transparency marker, outline the base of the volcano's cone. Create a key at the bottom of your transparency. Label the first colored line as **Volcano** on the key.

7. With a different color transparency pen, draw a line representing the nearest point to the volcano where you think people could safely build houses and businesses. This creates a buffer zone.

8. Look at Figure 2, another false color image of Mount St. Helens. This was taken *after* the 1980 eruption. Compare Figure 1 and Figure 2. Write down three changes that occurred.

   1) ____

   2) ____

   3) ____

9. With another color transparency pen, trace the extent of the disruption caused by Mount St. Helens' 1980 eruption. Add this color to the key and label it **Damage.**

10. Think back to the Cause and Effect Statements. What would the area shown in this image look like from the ground?

11. Do you think the area has recovered to the way it was before the eruption in 1980? What is the extent of damage today? Sketch your predicted area on the transparency using dashed lines**.** Add the dashed line to your key and label it **Estimate for Today**.

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____

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

12. How is Figure 4 different from Figures 1 and 2?

13. Where has the vegetation around the volcano begun to grow back? Where has it not?

14. Write one reason why some of the areas have recovered from the 1980 blast while other areas still have not.

15. With a different color transparency pen, draw a second buffer zone line based on all three images. Should the area be larger than your last prediction? How should you deal with the areas of regrowth and recovery? Record this color on your key and label it Buffer 2.

16. Review the Cause and Effect Statements from the beginning of the investigation. Which of these statements would be different if an effective buffer zone was in place before the 1980 eruption?

Module 1, Investigation 1: Log 1

How close is safe? Buffer zone development

17. Write a paragraph discussing both the importance and limitations that buffer zones have when dealing with Earth's systems.

References

http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html Use this website for more information about Mount St. Helens and other volcanoes in the Cascades Range

http://volcano.und.nodak.edu/vwdocs/volc_images/volc_images.html Use this website to locate additional volcanoes to research

Module 1, Investigation 1: Briefing
Narrative of Mount St. Helens 1980 eruption

A Slumbering Volcanic Giant

Mount St. Helens was once one of the most beautiful mountains in the entire Cascade Range of the American Northwest. In 1805, William Clark in the Lewis and Clark expedition described Mount St. Helens as "perhaps the greatest pinnacle in America."

The serenity of the mountain and its surroundings was misleading. One of the Indian names for Mount St. Helens was "fire mountain." Local Indians were reluctant to approach the mountain despite the abundant game in the area.

To the experienced observer, the cone shape and composition of rocks on the mountain boldly proclaimed Mount St. Helens' true nature—it was a volcano. Lava flows and multiple layers of ash (powdered volcanic rock) lay everywhere under the carpet of trees—abundant evidence of many prior eruptions. Volcanic deposits had reshaped the region around the mountain. Even beautiful Spirit Lake was a volcanic accident created by a giant mudflow that rolled down the mountain 3,000 years ago and backed up a stream.

Mount St. Helens was active between 1832 and 1857 during the early settlement of the area by Easterners. But the eruptions were small, and the mountain then "dozed off" for the next century. Small settlements became towns, and towns became cities like Portland and Seattle. These new neighbors of Mount St. Helens knew the mountain only as a sleeping giant. Its violent past was largely ignored.

The Awakening

The quiet ended abruptly in March 1980, with a series of steam explosions and bursts of ash. The following story of the eruption of Mount St. Helens illustrates the potential dangers of an eruption from Mount Ranier—a volcano about 120 kilometers southwest of Seattle, Washington.

During the months following the initial outbursts, vulcanologists and seismologists watched the mountain closely. Small earthquakes accompanied the bursts and indicated the movement of fresh lava into the heart of the mountain. Enormous cracks appeared in the summit and sides of the mountain, and the entire northern face expanded outward some 137 meters. Locals perceived this initial activity as minor, so in spite of warnings and the designation of the mountain and its surroundings as a dangerous "Red Zone," tourists flocked to the area to get a close view of the fireworks. Residents were strongly advised to move away, but some refused to go. Likewise, logging companies working in the area refused to shut down, claiming to "know the mountain." Vulcanologists established several camps around the mountain to monitor its activity. Some of the camps had to be dangerously close to the mountain to provide the necessary data. The scientists who manned the camps in shifts knew they were at risk.

The Main Eruption

On May 18, a quiet Sunday morning, a few observers were at their stations, watching Mount St. Helens. Tourists and loggers were also nearby. At 8:32 a.m. a small aircraft with two geologists aboard flew directly over the central cone.

Eleven seconds later, a strong earthquake shook Mount St. Helens. The whole north face of the mountain broke free and slid downward as a giant rock avalanche. In seconds, pressure in the mass of hot lava inside the mountain dropped; water that had been dissolved in the lava turned into superheated steam, fragmenting the lava into a fine powder ash. This mass of superheated steam and ash blasted upward and outward over the top of the avalanche, roaring to the north and west at speeds reaching hundreds of miles an hour. The pilot of the small aircraft narrowly avoided disaster by putting the "plane into a steep dive to gain speed" and turning sharply south, away from the expanding ash cloud.

Every living thing within about 16 kilometers of the volcano on the north side—tree or bush, human or animal, scientist or layman—was destroyed. Some of the people took a few quick pictures. Then, realizing their situation, most ran or tried to drive away from the approaching cloud of dust and steam. The near-supersonic blast of rock, ash, and hot gas engulfed the area with enough force to uproot trees. The temperature within the cloud reached 260°C (500°F), more than enough to start fires or burn exposed skin. The rock avalanche roared over Spirit Lake and the valley of the North Fork of the Toutle River, burying them under layers of rock up to several hundred feet thick.

Moments after the rush of the avalanche and ash cloud, enormous mudflows—formed when glacial ice and snow that had capped the mountain were melted by the intense heat—surged down the mountain. Masses of mud poured down the nearby river valleys, sweeping away buildings, vehicles, trees, and bridges. One flow even blocked the shipping channel of the Columbia River, 88 kilometers downstream.

Millions of tons of fine ash were thrown high into the air and carried hundreds and thousands of miles downwind. These clouds, visible in satellite images, dropped several inches of ash over many communities and agricultural areas, ruining machines and crops.

The Toll

To the nation, and especially to those living nearby, the May 18 eruption was apocalyptic. The crown and heart of a whole mountain had been blasted away, and the surrounding countryside devastated. The energy released by the eruption was estimated at 10 megatons, an explosion thousands of times stronger than an atomic bomb.

- Thousands of deer, elk, bear, and smaller animals perished—in addition to 57 humans.
- Over 593 square kilometers of forest were destroyed, including three billion board feet of timber estimated at $400 million in value.
- Numerous buildings, bridges, roads, and machines were destroyed, and farms and communities up to 1,600 kilometers away were partially buried in ash.
- One hundred sixty-nine lakes and more than 4,800 kilometers of streams had either been marginally damaged or destroyed.
- Losses to property and crops were set at more than $1.8 billion.

Yet, the impact on human life could have been much greater if the main eruption had occurred on a workday or if the blast had been directed southwest toward the Portland/Vancouver metropolitan area (just 72 kilometers away) or if the wind had been blowing toward the southwest.

As large and destructive as the May 18 eruption appeared, it was a relatively small eruption when seen in context. Thick deposits of older volcanic rock around Mount St. Helens attest to much larger eruptions in its past. Mount St. Helens is also only one of many volcanoes that dot the Cascade Range. All of these volcanoes grew in the same geologic setting. Some eruptions at other Cascade volcanoes have been truly huge, such as the explosion nearly 7,000 years ago—100 times larger than the May 18 eruption—that reduced Mount Mazama to Crater Lake. Eruptions ranging in size from the May 18 eruption to the Mazama blast could occur at any time at any of the Cascade volcanoes. For the metropolitan centers of Portland, Seattle-Tacoma, and San Francisco that have grown up among the Cascade volcanoes, this is a serious concern.

Source: *NASA's Classroom of the Future*. http://www.cotf.edu/ete/modules/volcanoes/vnarrative1.html
For an extended discussion of Mount St. Helens, see http://vulcan.wr.usgs.gov/ljt_slideset.html

Module 1, Investigation 1: Log 2

Cause and effect organizer

Causes	Effects	Human Responses
Structure of the Volcano	Effects on the Lithosphere	Clean-Up Efforts
	Effects on the Hydrosphere	
		Responses to Environmental Hazards
	Effects on the Biosphere	
The Eruption Event		
	Effects on the Atmosphere	
		Monitoring Efforts
	Effects on Human Activities	

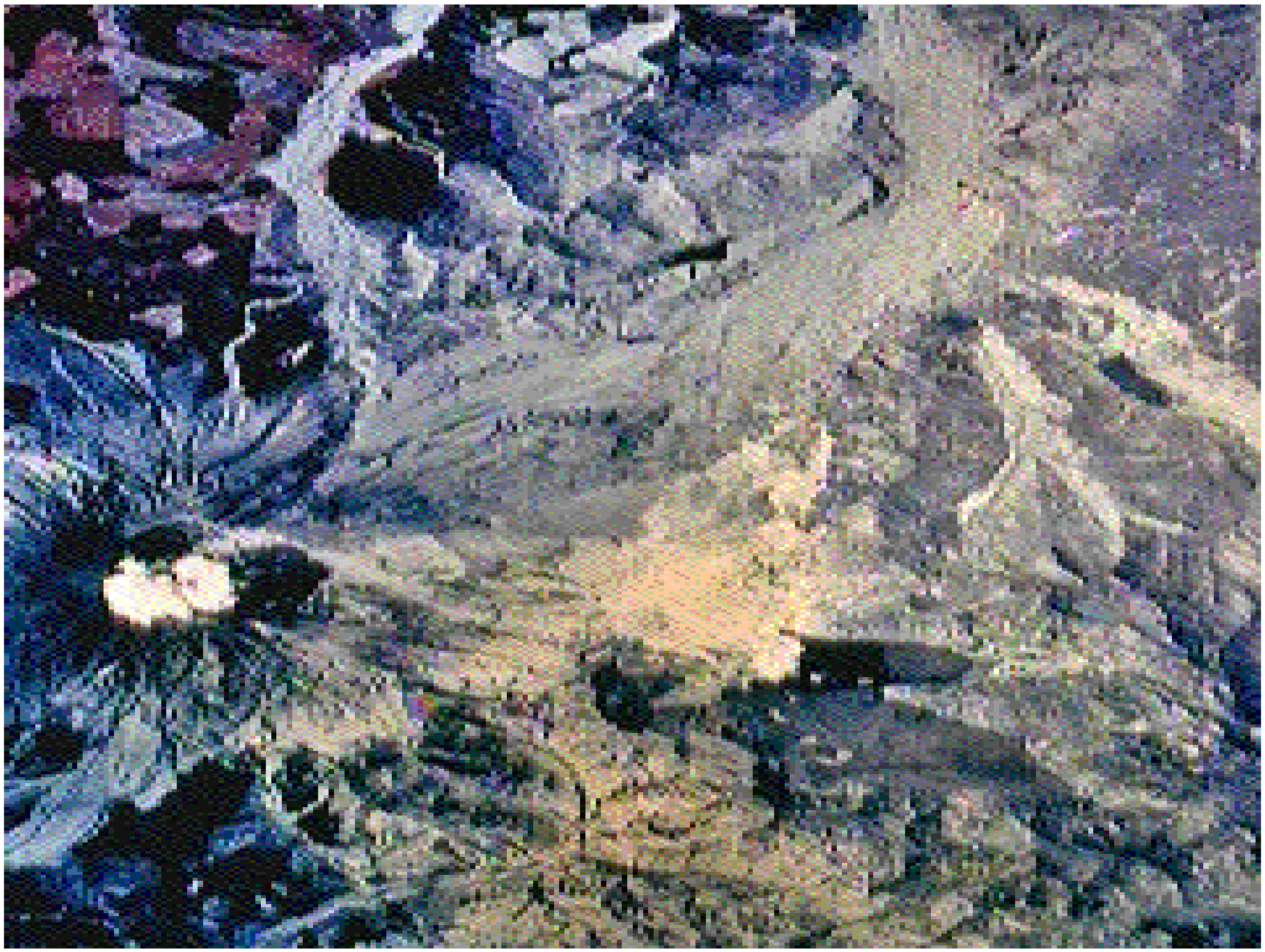
Module 1, Investigation 1: Figure 1

Mount St. Helens, March 1980, before the eruption

Infrared false color Landsat image of Mount St. Helens and the surrounding area in March 1980.
The reddish areas are living vegetation.
Source: LandSat satellite http://volcano.und.nodak.edu/vwdocs/msh/ov/ovs/ovssl.html

Module 1, Investigation 1: Figure 2

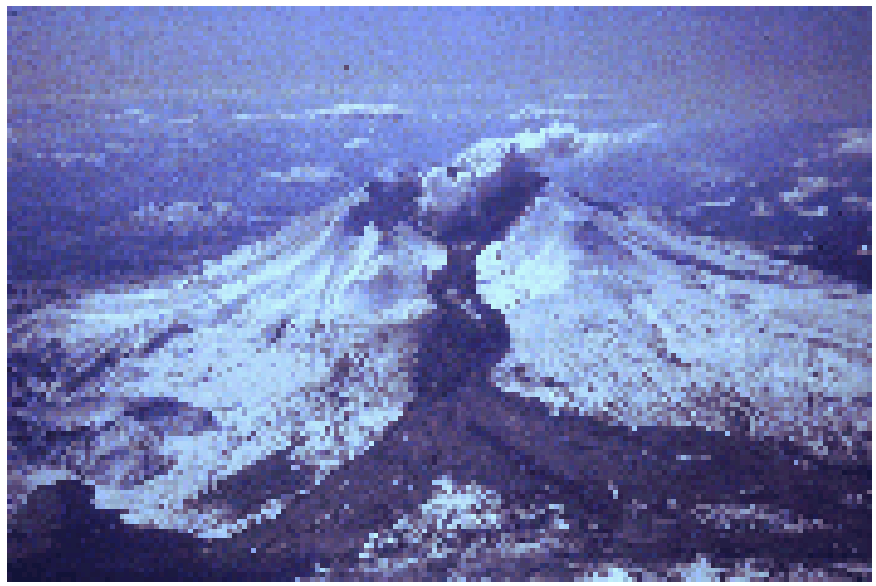
Mount St. Helens, June 1980, after the eruption



Infrared false color Landsat image of Mount St. Helens and the surrounding areas in June 1980.
Orientation: NNE
Source: http://volcano.und.nodak.edu/vwdocs/msh/ov/ovs/ovssl.html

Module 1, Investigation 1: Figure 3

Aerial photograph of 1980 damage to Mount St. Helens



Mount St. Helens' 1980 eruption triggered massive debris flows down the north face of the volcano as seen in this photograph.

Source: Cascade Volcano Observatory by Thomas Casadevall http://denali.gsfc.nasa.gov/research/volc2/volc_top.html

Module 1, Investigation 1: Figure 4

Mount St. Helens in December 1999

True color Landsat image of Mount St. Helens in 1999. Some areas have yet to rebound from the 1980 eruption.

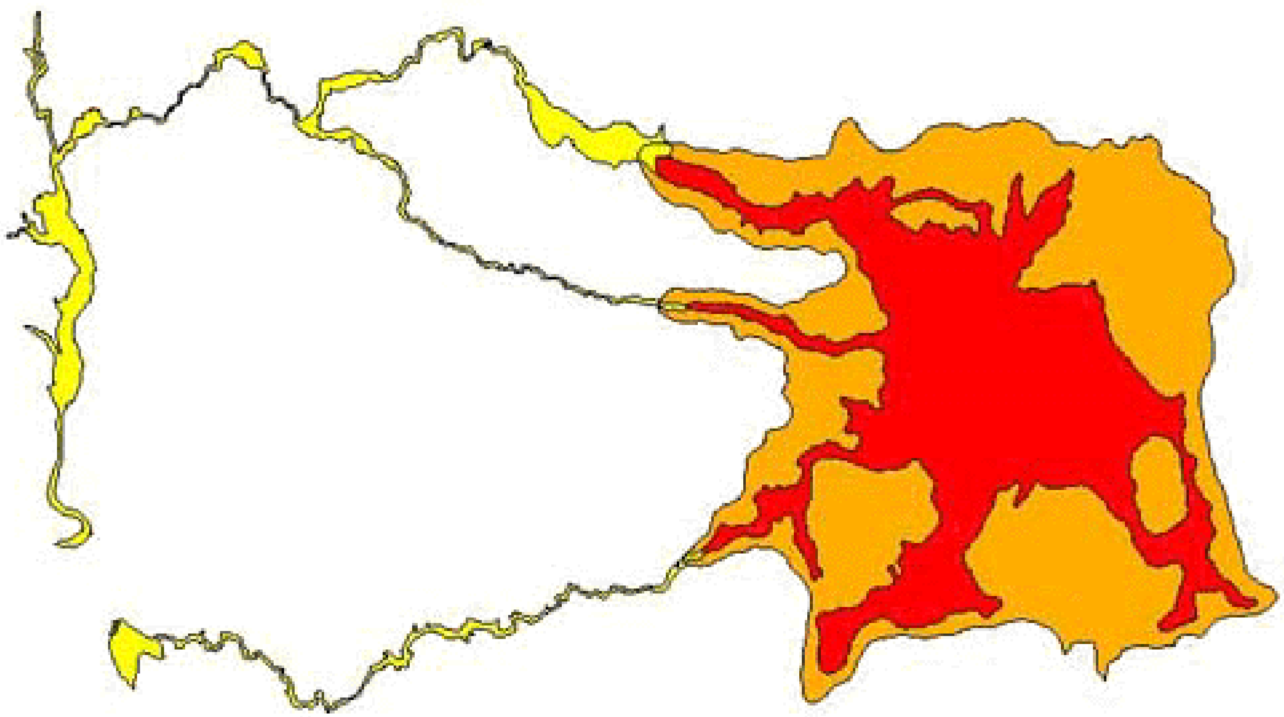
Key: green = forest
white = snow and glaciers
grey = areas destroyed by 1980 debris flow which have not recovered

Orientation: NNE

Source: http://volcano.und.nodak.edu/vwdocs/volc_images/img_st_helens.html

Module 1, Investigation 1: Figure 5

Mount St. Helens hazards map



0 10,000 20,000
kilometers

Hazard Zones

Zone 1: Vulnerable to high-density flows, including pyroclastic flows, lava flows, and parts of lahars

Zone 2: Area that could be overrun by low-density pyroclastic surges

Zone 3: Intermediate and lower reaches of valleys that could be inundated by lahars

Source: E. W. Wolfe and T. C. Pierson. 1995. Volcanic-Hazards Zonation for Mount St. Helens, Washington, 1995. USGS Open-File Report 95-497. http://vulcan.wr.usgs.gov/Volcanoes/MSH/Hazards/OFR95-497/framework.html