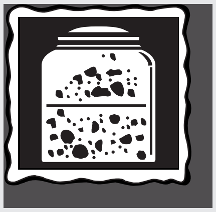
Lahar in a Jar!



Grade Level: 6-10

Learner Objectives:

Students will:

- Recognize lahars as the principal volcano hazard at Mount Rainier
- Become familiar with some of the more significant lahars that originated on Mount Rainier
- Recognize the role of lava flows, pyroclastic flows, landslides, and glaciers that initiate debris flows and lahars
- Recognize that an abundance of surface water and loose, weakened rock makes Mount Rainier highly susceptible to lahars and debris flows
- Observe how only a small amount of water is required to initiate a debris flow or lahar
- Become familiar with the nature of lahars and debris flows, and the proper usage of the terms

Setting: classroom

Timeframe: 50 minutes

USGS
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NATIONAL PARK SERVICE

Living with a Volcano in Your Backyard-
An Educator's Guide with Emphasis on Mount Rainier

Prepared in collaboration with the National Park Service

U.S. Department of the Interior
U.S. Geological Survey

General Information Product 19

Overview

Explore how small amounts of water can mobilize loose rock to form lahars by making a small lahar within the safety of a beaker or jar and analyzing it using scientific methods.

Teacher Background

Lahars are fast flowing torrents of rock, mud, and water

Lahars, also known as volcanic mudflows or ***debris flows***, are worthy of attention because they are the principal volcanic hazard in the valleys that head on Mount Rainier. The word lahar is an Indonesian term that refers to any rapidly flowing and gravity-driven mixture of rock, mud, and water that rushes down the slopes of a volcano. Lahars have been known to travel distances of more than one 100 kilometers (60 miles) at speeds of 60 kilometers per hour (40 miles per hour).

While many scientists treat the terms lahar and debris flow synonymously, scientists and officials working at Mount Rainier seek to reduce confusion locally by modifying word usage. They reserve the word lahar for large flows of eruption or ***landslide*** origin with potential to travel to densely populated valleys, and use debris flow for much smaller events caused by glacier floods and precipitation, which stay generally within park boundaries.

Materials:

- 100 ml or larger graduated cylinder
- Wide-mouth 1 liter beaker
- Large wooden spoon or paint stirrer
- 200 to 400 ml of lahar deposit or rock debris, as prepared in accompanying recipe
- Calculator
- Copies of *"Lahar in a Jar"* student page
- One-meter (three-foot) long flat board or gutter
- Graphic *"Three Prominent Lahars at Mount Rainier"*
- Graphic *"Mount Rainier and Emmons Glacier"*
- Graphic *"Extension Maps of Lahar Hazard Zones"*
- Graphic *"Debris Flow on Tahoma Creek, 1986"*
- Graphic *"Mount Rainier Lahar Hazards Zone"*
- Graphic *"Tahoma Creek After Debris Flow, 1986"*

Vocabulary: Beaker, debris flow, flank collapses, glacier outburst flood, graduated cylinder, hydrothermal alteration, lahar, landslide, lava flow, pyroclastic flow

Skills: Observation, record, calculation, prediction

Benchmarks:

Please see the Mount Rainier National Park Education Program website for the most recent alignment of these activities with Washington State and nationally approved education standards

http://www.nps.gov/mora/forteachers/curriculummaterials.htm

Once witnessed, lahars and debris flows are seldom forgotten

The ground shakes and rumbles in a way similar to that of an approaching train. Dust plumes rise into the air above the flow front and small pebbles splash skyward. The flow, tan or gray in color, looks and behaves like a river of flowing concrete. Boulders crush and grind vegetation, which releases a strong stench of organic oils that hangs in the air long after the event is over. Where valley walls widen, lahars spread, drain and cease motion. Boulders and trees that had been buoyed and pushed to flow margins come to rest as blocky ridges along the flow's margin.

The speed of a lahar and debris flow depends upon its volume and the slope gradient. Some of the faster flows have been clocked at speeds of 30 to 60 kilometers per hour (20 to 40 miles per hour). Lahars may last for hours or days; debris flows generally last for half an hour to several hours. Both leave behind an inhospitable surface of tightly-packed mud, boulders, and vegetative debris.

Abundant water and rock debris make Cascade volcanoes highly susceptible to lahars and debris flows

Eruptions have built vast volcanic slopes at high elevation that are scattered with lava fragments and that retain snow and glacier ice. Mount Rainier's slopes are covered by approximately 4.4 cubic kilometers (one cubic mile) of snow and ice, an amount equivalent to that on all the other Cascade volcanoes combined!

Most lahars form during volcanic eruptions, but landslides can also produce lahars.

Almost all lahars happen during volcanic eruptions when hot ***pyroclastic flows*** and ***lava flows*** interact with snow and ice. This scenario repeated at Mount Rainier many times has resulted in thick sequences of lahar layers beneath the floors of some valleys.

Not to be discounted are large landslides, known as ***flank collapses,*** that can also produce lahars. The largest landslide-induced lahars have occurred during eruptive periods and involved rock that had been weakened by long-term exposure to hot acidic groundwater, a process called ***hydrothermal alteration***.

What triggers a flank collapse? Accepted mechanisms include instability at the onset of or during volcanic eruptions, large earthquakes, intense ground deformation by rising magma and perhaps long-term exposure to gravity. While the chance of a flank collapse is greatest during eruptive periods, the possibility exists of failure during non-eruptive times.

Rocks at the head of the Puyallup River valley are more prone to landslides than rocks elsewhere on Mount Rainier, because they contain hundreds of millions of cubic meters (cubic yards) of hydrothermally altered and weakened rocks. At least seven landslide-initiated lahars have covered valley floors in the southern Puget Sound area over the past six thousand years.

Small events caused by rainfall and glacier floods

Conditions that favor debris flow formation are ***glacier outburst floods*** in mid-summer and intense rainfall in late fall. These events are small when compared to lahars produced during eruptions, having a thickness of only tens of meters (feet) and traveling only a few kilometers (miles) from their source. Lahars can reach a thickness of 100 meters (300 feet) or more and travel far from source. Debris flows happen once or twice a year at some Cascade volcanoes, whereas lahars happen much less frequently.

What to do if in danger from a debris flow or lahar

Most large-volume lahars are associated with volcanic unrest and eruptions. Usually earthquakes or other precursory activity at a volcano serve as a warning that an eruption is immiment. While debris flows happen frequently and large volume lahars happen infrequently, the necessary response is the same. Get to high ground off the valley floor.

Procedure

What to do Before Class Begins:

- Decide if you are going to do a large group demonstration or have the students work independently or in small groups.
- Collect materials.
- Make copies of student page Lahar in a Jar.
- Prepare to show graphics.

Lahar Debris Recipe

Obtain and mix ingredients to the volume proportions shown below. Mix a batch that is sufficient to provide 400 milliliters to each student group. All ingredients should be dry.

Note that while scientists generally measure contents by weight, this activity provides a general conversion from percent weight to volume so that the activity can be conducted with ease in the field or classroom. This method does not account for porosity (air spaces between the particles) of the solids.

Quantities provided make enough lahar material for (10) 400 milliliter experiments. Place the following in a dry 5-gallon bucket or other container:

- 2.0 L gravel from a driveway (pea to marble-size)
- 3.0 L sand from a sand box or river bank
- 2.0 L garden soil (soil with high clay content and minimal organic matter works best. Look for clay loam or silt loam commercially)
- 0.6 L dry potters clay powder (available from pottery supply stores)

Sidebar 1

Some Significant lahars and debris flows at Mount Rainier

The Osceola Mudflow

A volcanic eruption about 5,600 years ago triggered a flank collapse that removed three cubic kilometers (0.7 cubic miles) from the summit and eastern flank of Mount Rainier. Because the landslide contained a lot of water and also picked up snow melt and river water, it transformed into a lahar that rushed down the White and Nisqually River valleys as far as northern Puget Sound. In the White River valley, the lahar deposited a layer of debris that ranged from approximately one 1 meter (3 feet) to 60 meters (200 feet) thick, and covered the region now occupied by the communities of Enumclaw, Buckley, Auburn, Kent, Sumner, and Puyallup. The lahar left behind giant mounds of orange-colored debris that are visible east of the communities of Enumclaw and Ashford. The Osceola Mudflow is the largest lahar known to have occurred on Mount Rainier.

The Electron Mudflow

A landslide initiated this mudflow (lahar) around 500 years ago. Weakened rock on the west flank of Mount Rainier collapsed and slid into the Puyallup River valley, where it transformed into a lahar that flowed approximately 100 kilometers (60 miles), all the way to the outskirts of Puyallup and perhaps to Puget Sound. This lahar deposited sediment as thick as 30 meters (100 feet), and buried the base of trees in an old growth forest. Construction workers excavating ground for utilities continue to find large logs and stumps buried by the lahar. There is no conclusive evidence that an eruption triggered the Electron Mudflow although it may have happened at the onset of or during minor eruptive activity. The Electron Mudflow reminds us of the possibility that lahars may have non-eruption origins.

The National Lahar

The National Lahar is one of the larger lahars formed from the melting of snow and ice during eruptive activity. This lahar swept down the Nisqually River Valley to the Puget Sound 100 kilometers, (60 miles) away, between 2,200 and 500 years ago. Between Ashford and the western entrance of Mount Rainier National Park, it deposited a 3-meter (10-foot) thick layer on the valley floor. Loose rock layers deposited by the National Lahar look like large boulders set into a matrix of fine-grained material.

Debris flows

Debris flow activity at Mount Rainier has been significant in the valleys of Tahoma Creek, Kautz Creek, Van Trump Creek, Nisqually River, and the West Fork of the White River, where loose debris has been deposited during eruptions or left behind from glacier recession. Periods of intense debris flow activity tend to occur during glacier recession, or when excessive water from rainfall or snowmelt flows across loose rock deposited by the retreating glacier.

Years of some prominent debris flow events

Tahoma Creek 1967, 1968, 1970, 1971, 1979, 1981, 1986-2006

Kautz Creek 1947, 1961, 1985, 1986, 2005, 2006

Pyramid Creek 2005, 2006

Van Trump Creek 2001, 2003, 2005 2006

Nisqually River 1926, 1932, 1934, 1955, 1968, 1970, 1972, 1986

West Fork White River 1987, 2006

Activity Procedure:

Introducing Lahars and Debris Flows:

Introduce students to lahars and debris flows through class discussion and graphics, and then conduct the experiment.

1. Instruct students to list some of the distinctive components and characteristics of Mount Rainier that are visible in the photograph entitled ***"Mount Rainier and Emmons Glacier."*** Lead the discussion towards these three features: glaciers, loose rocks, steep slopes. Ask them to explain how volcanic heat, glaciers and snow might interact.Introduce the concept of a lahar as a mixture of rock, mud, and water that rushes down the slopes of a volcano and its river valleys. Rapid melting of snow and ice during eruptions generally cause lahars, though landslides can also initiate them.

2. Instruct students to hypothesize about what happens when an excess of stream water, originating with intense snowmelt in mid-summer or extreme rainfall, flows across valley bottoms strewn with loose rock. Explain that these conditions can lead to debris flows.

3. Instruct students to hypothesize whether or not Mount Rainier is a potential site for lahars. They should explain their reasoning. ***Yes, it is the site of frequent debris flows (almost annually). There is an abundance of loose volcanic rock from eruptions and glacier action, and water from snow and ice melt and rain. In addition, rock fall and landslides can initiate lahars.***

4. Tell students to use their knowledge of debris flows and lahars to identify the types of terrain over which lahars and debris flows generally travel. ***Answer: in river valleys.***

5. Use the graphic ***"Tahoma Creek Debris Flow, 1986"*** to illustrate the appearance of a lahar on Tahoma Creek on the west side of Mount Rainier National Park. Use the graphic ***"Three Prominent Lahars"*** to follow the pathway of three major Mount Rainier lahars—Osceola, Electron, and National. These three prominent lahars provide the basis for lahar hazard zones on the graphics ***"Mount Rainier Lahar Hazards Map"*** and ***"Extension Maps of Lahar Hazard Zones."*** Display the lahar hazards map and ask students which valleys would be affected by lahars and debris flows on each side of the volcano. Ask students to name the communities that are at risk.

6. Explain to students that debris flows tend to happen during intense rainfall and periods of rapid snowmelt at Mount Rainier. By definition, debris flows travel over terrain within the park and do not generally flow beyond park boundaries. Follow the pathway of some recent debris flows.

7. Determine whether you live, work, or go to school on the debris from one of the lahars shown on the lahar hazard map. Discuss how lahars are significant to your community. Ask students to find the safest locations near their communities.

Make a lahar in a jar

Learn how only a small amount of water in motion can mobilize loose rock to form a lahar. Conduct this activity either as a teacher demonstration or in small groups.

1. Divide class into groups of 3-4 students.

2. Distribute ***"Lahar in a Jar"*** student page.

3. Instruct students to place approximately 400 milliliters of loose lahar material from recipe sample onto a large piece of paper and break up any large clumps of dirt and debris. Dump the loose rock into a ***beaker***. Press it firmly with your hands to remove spaces from between the particles. Record the exact volume on the student page.

4. Ask students to predict how much water they think is required to make the deposit flow like a lahar. 10 ml? 100 ml? More? Students record their prediction on the student activity sheet.

5. Fill the ***graduated cylinder*** with water and record the starting amount of water on the student page.

6. Instruct the students to begin pouring water in the beaker in increments of 10 ml.

7. Students should stir the loose rock after each addition of water.

8. After each addition of water, students should tilt the beaker to the side and gently rotate it sideways to determine if the mixture "flows" around the jar sides as a lahar would. The consistency initially is like that of dry dirt, but with the addition of water, changes to the consistency of cookie dough and later to that of thick cake batter. Decrease the amount of water added each time as your lahar begins to flow. Remember, it does not take much water to get debris flowing.

9. Students sum the amount of water used after the rock debris forms a lahar in the jar and record the amount on the student page.

10. Instruct students to compare the total volume of lahar and water and determine the percent water required to produce a lahar in a jar. Ask whether the amount of water was as predicted. ***Answer: will probably be between 20-40%, depending on the material used. At Cascade Volcanoes, the water content in debris flows and lahars is generally between 30 and 45 percent.***

11. Each student group should pour their lahar onto the inclined gutter or board for all of the class to see. Ask for hypotheses about what happens when slope of the gutter or board is changed, then test the hypotheses. Inquire about any interesting observations made of the lahar mixture. ***The lahar may flow in single or multiple surges. Velocity of the flow increases with slope.***

12. Ask students to follow the path of energy transformation, and to write about this, or draw a diagram on the reverse side of their student pages. ***Students should report that the lahar while still in the jar has potential energy. Kinetic energy is released as the lahar slides down the gutter or board.***

13. Ask students what conditions exist on Cascade volcanoes that promote development of lahars. ***Answers: Loose rock, abundant water, steep slopes, heat.***

Adaptations

- Provide students with sand, clay, garden soil and gravel and instruct them to hypothesize about what happens when the amount of clay is increased and decreased. Instruct students to design and conduct experiments with different proportions of materials.
- Obtain rock debris from other sources in your community, such as streambeds, lahar deposits, gardens, etc., and repeat Lahar in a Jar again. Compare results with your lahar recipe mixture.

Extensions

- Instruct students to draw a diagram and/or a flow chart that illustrates the initiation and activity of lahars and debris flows.
- Use library and Internet searches to learn more about the lahar history of Mount Rainier and the other snow-clad volcanoes of the Cascades.
- This experiment does not account for the porosity (air space between the particles) of the solids. Instruct students to design an experiment that accounts for porosity.

Assessment

Use the questions in the ***"Introducing Lahars and Debris Flows"*** and ***"Making a Lahar in a Jar"*** to assess students' understanding of the conditions required to form lahars and debris flows. Look for evidence that students understand the following concepts: debris flows and lahars form where there is an abundance of rock debris, groundwater, and free-flowing surface water; that only a small amount of water is required do initiate a debris flow or lahar; lava flows, pyroclastic flows, landslides and glaciers, and weakened rock make Mount Rainier susceptible to lahars and debris flows; that lahars are the principal eruptive hazard at Mount Rainier, even many kilometers (miles) distant. As the activity progresses, look for evidence that students think globally, and recognize that lahars and debris flows occur on volcanoes worldwide. Understanding the character and chronology of these events at a volcano helps scientists identify communities at risk from lahars
today. Students should recognize that knowledge of lahars and debris flows enables scientists to identify when and where people are at risk; this knowledge ultimately can help citizens live responsibly and improves the health and well-being of communities.

References

Driedger, C.L., and Fountain, A.G., 1989, Analysis of recent glacial outburst floods on Mount Rainier: Annals of Glaciology, 1988, pp. 51–59.

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Walder, J.S., and Driedger, C.L., 1993, Glacier-generated debris flows at Mount Rainier: U.S. Geological Survey Fact Sheet, Open-File Report 93–124, 2 p.

Zehfuss, P.H., Atwater, B.F., Vallance, J.W., Brenniman, H., Brown, T.A., 2003, Holocene lahars and their by-products along the historical path of the White River between Mount Rainier and Seattle: in Swanson, T.W., ed, Western Cordillera and adjacent areas: Boulder, Colorado, Geological Society of America Field Guide 4, p. 209–223.

Refer to **Internet Resources Page** for a list of resources available as a supplement to this activity.

Photo Credits

1. Mount Rainier and Emmons Glacier, Photo by Carolyn Driedger, USGS
2. Debris Flow on Tahoma Creek on July 26, 1988, Photo by G. G. Parker, USGS
3. Tahoma Creek after Debris Flows, 1988, Photo by Carolyn Driedger, USGS

Team Names ______________________________

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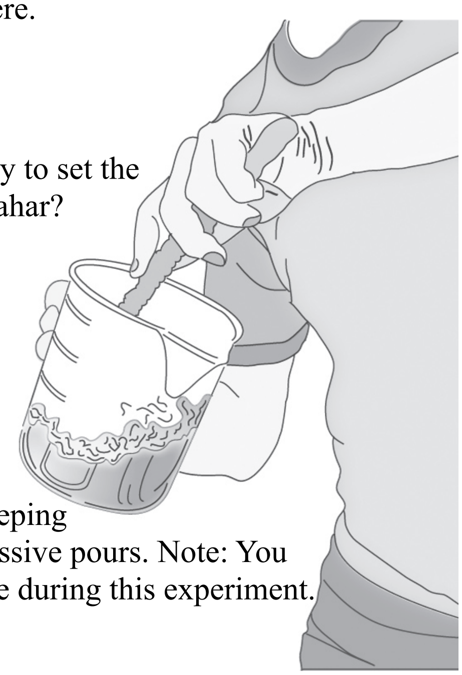
Lahar in a Jar

Instructions: *Follow the procedures below to make a small lahar in a jar.You will mix known volumes of rock debris and water. Give your mixed lahar a run down a gutter or board provided by your teacher.*

1. Place approximately 200 to 400 milliliters of "lahar" into a beaker. Break up any large clumps of dirt and debris. Record the exact volume here.



2. Make a prediction. How much water will be necessary to set the rock debris sample into motion as a small, in-the-jar lahar? 10 ml? 100 ml? Record your prediction.

3. During this experiment, you will pour water into the beaker repeatedly, in increments of approximately 10 ml. In the space below, develop a procedure for keeping track of the amount of water that you tip during successive pours. Note: You may need to fill the graduated cylinder more than once during this experiment.

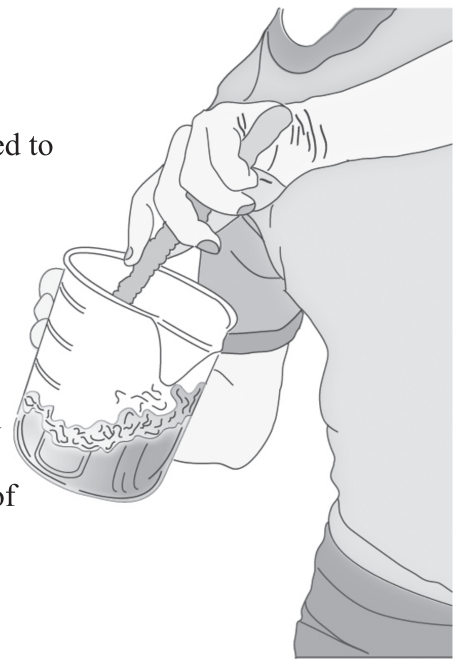
4. Pour water into the beaker in increments of approximately 10 ml. Stir the lahar rocks and water with a spoon or a stick after each addition of water. Tilt the beaker and gently rotate it sideways to observe if the mixture "flows" around the jar sides as a lahar would move. Repeat as much as necessary, and test for flowing. When the mixture begins to flow, STOP! Add no more water! Note that the mixture first appeared as dry dirt, but with the addition of water, has changed to the consistency of cookie dough and now resembles thick cake batter.

Team Names ______________________

Lahar in a Jar-continued

5. Compare the total volume of water to the cumulative volume of lahar rocks and water. Use the space below to calculate the percent water required to form a lahar in the beaker. Record your result here.

$$\textbf{Percent water} = \frac{\textbf{ml water added}}{\textbf{ml lahar deposit + ml of water added}} \textbf{ X 100}$$



6. Determine whether the actual percent of water required to make a lahar is more or less than your prediction.

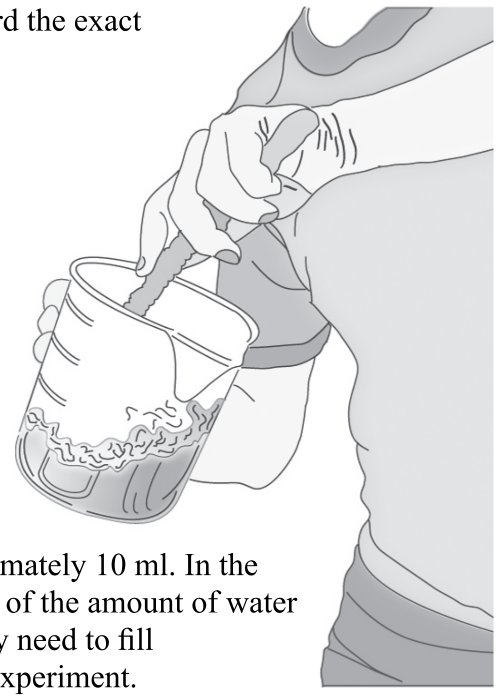
7. After completion of this experiment, preserve your sample for its run down a gutter or board as provided by your teacher. Explain why the slopes of Cascade volcanoes are an ideal location for the development of debris flows and lahars.

8. Describe or draw a diagram of the energy transformations that happen as a lahar rushes down the flanks of a volcano and comes to rest.

Teacher Page

Lahar in a Jar

Instructions: *Follow the procedures below to make a small lahar in a jar.You will mix known volumes of rock debris and water. Give your mixed lahar a run down a gutter or board provided by your teacher.* ***Answers provided on the teacher page are derived from a trial run with the mixture of lahar material noted in the lahar recipe. Answers will vary, depending upon your sample's clay content, compaction, density, and moisture content.***



1. Place approximately 400 milliliters of "lahar" into a beaker. Break up any large clumps of dirt and debris. Record the exact volume here.

ANSWER:

400 ml

2. Make a prediction. How much water will be necessary to set the rock debris sample into motion as a small, in-the-jar lahar? 10 ml? 100 ml? Record your prediction.

ANSWER:

20 ml in this trial run

3. During this experiment, you will pour water into the beaker repeatedly, in increments of approximately 10 ml. In the space below, develop a procedure for keeping track of the amount of water that you tip during successive pours. *Note:* You may need to fill the graduated cylinder more than once during this experiment.

Students might choose to keep track of water increments added, or subtract the final reading from the top reading. Students will need to fill the graduated cylinder more than once during this experiment.

4. Pour water into the beaker in increments of approximately 10 ml. Stir the lahar rocks and water with a spoon or a stick after each addition of water. Tilt the beaker and gently rotate it sideways to observe if the mixture "flows" around the jar sides as a lahar would move. Repeat as much as necessary, and test for flowing. When the mixture begins to flow, STOP! Add no more water! Note that the mixture first appeared as dry dirt, but with the addition of water, has changed to the consistency of cookie dough and now resembles thick cake batter.

In this trial run, we added 130ml of water before the mixture began to "flow" when the beaker was rotated.

Lahar in a Jar-continued

5. Compare the total volume of water to the cumulative volume of lahar rocks and water. Use the space below to calculate the percent water required to form a lahar in the beaker. Record your result here.

ANSWER:

25 percent water but answer will range from 20-40 percent

6. Determine whether the actual percent of water required to make a lahar is more or less than your prediction.

ANSWER:

In this trial run, the actual value exceeded the predicted value.

7. After completion of this experiment, preserve your sample for its run down a gutter or board as provided by your teacher. Explain why the slopes of Cascade volcanoes are an ideal location for the development of debris flows and lahars.

ANSWER:

There is an abundance of surface water and loose volcanic rocks on the steep slopes of Cascade stratovolcanoes.

8. Describe or draw a diagram of the energy transformations that happen as a lahar rushes down the flanks of a volcano and comes to rest.

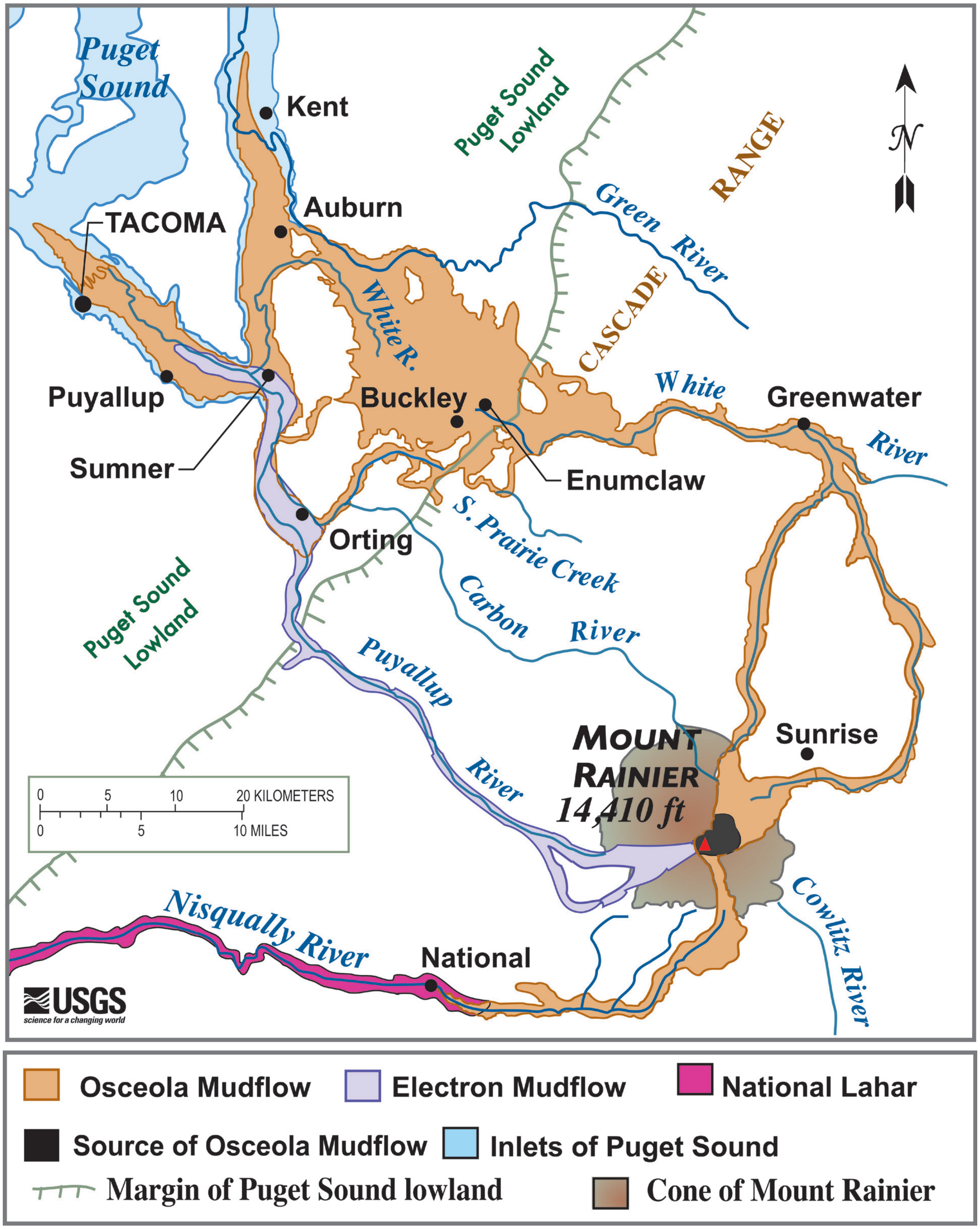
ANSWER:

The rock debris embedded within riverbeds and embankments holds potential energy Kinetic energy is released as the debris flow or lahar mobilizes the rock debris and carries it down valley.

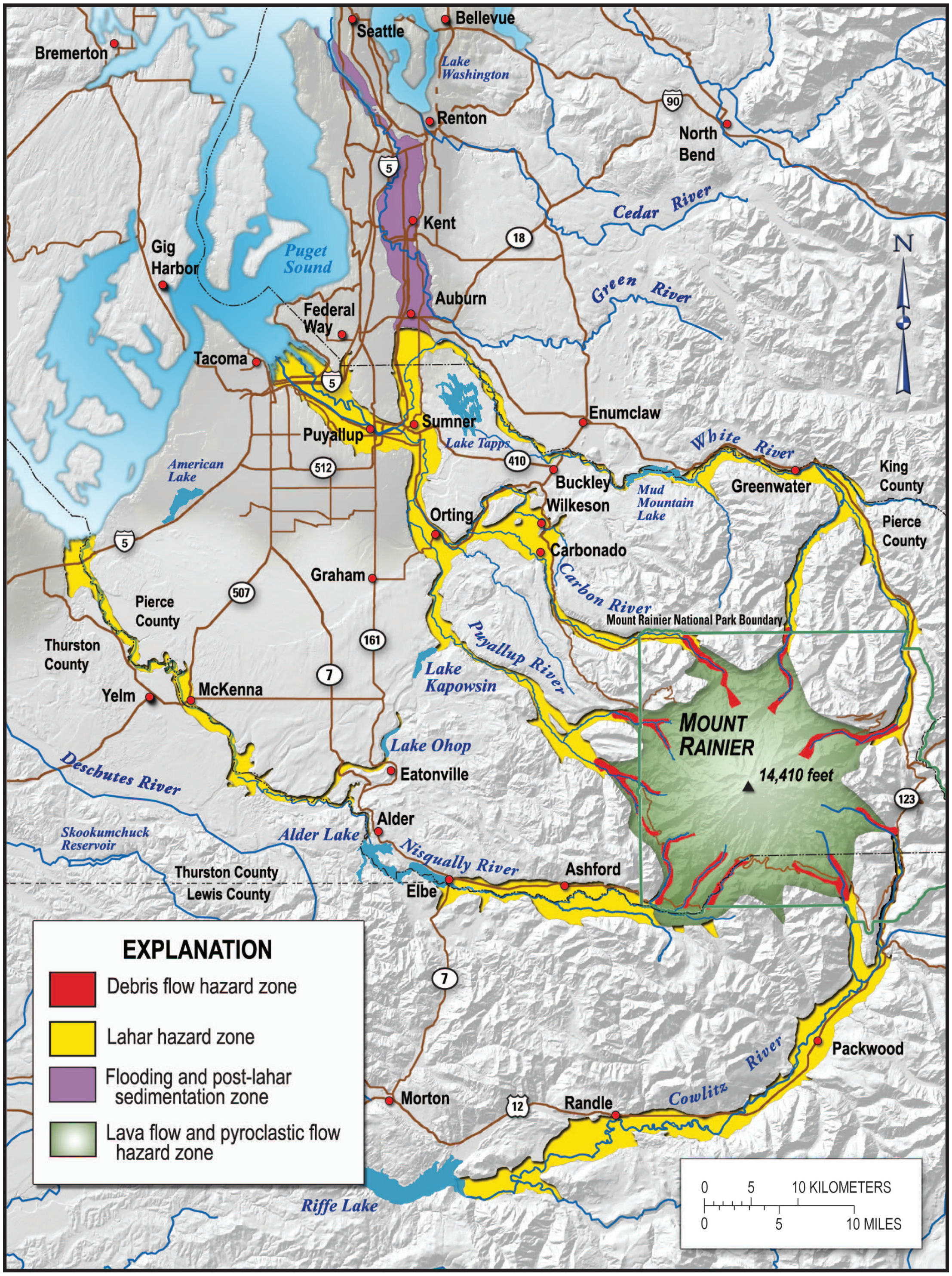
Mount Rainier and Emmons Glacier


Photo by Carolyn Driedger, USGS

Three Prominent Lahars - Map

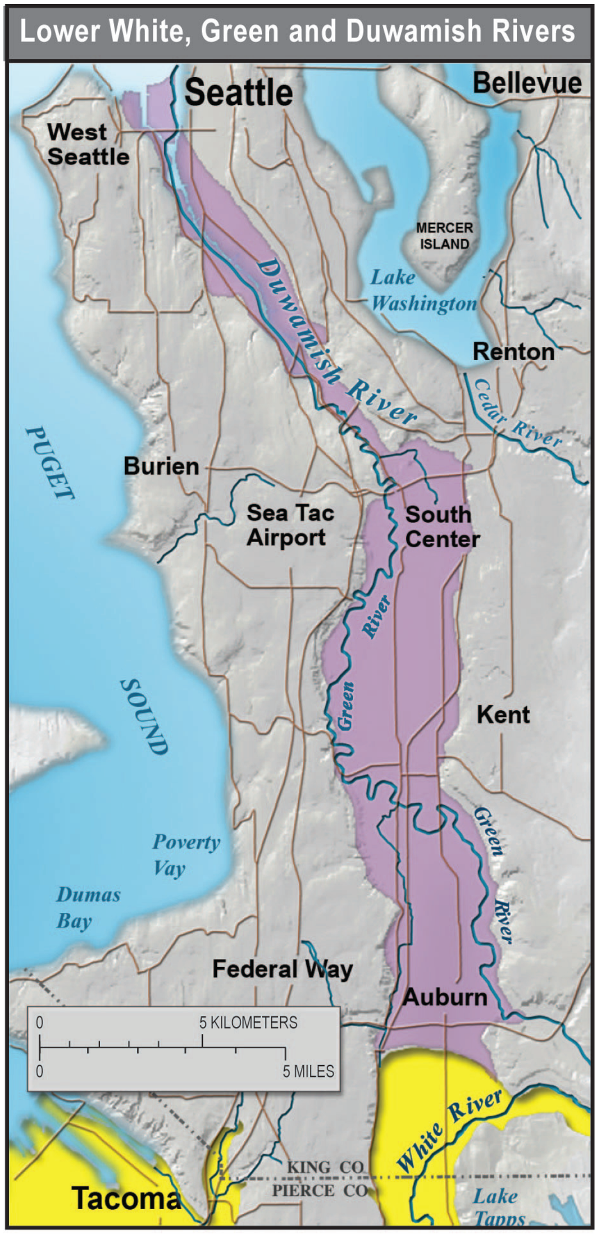


Map of Lahar Hazard Zones



Revised March 15, 2011

Extension Maps of Lahar Hazard Zones



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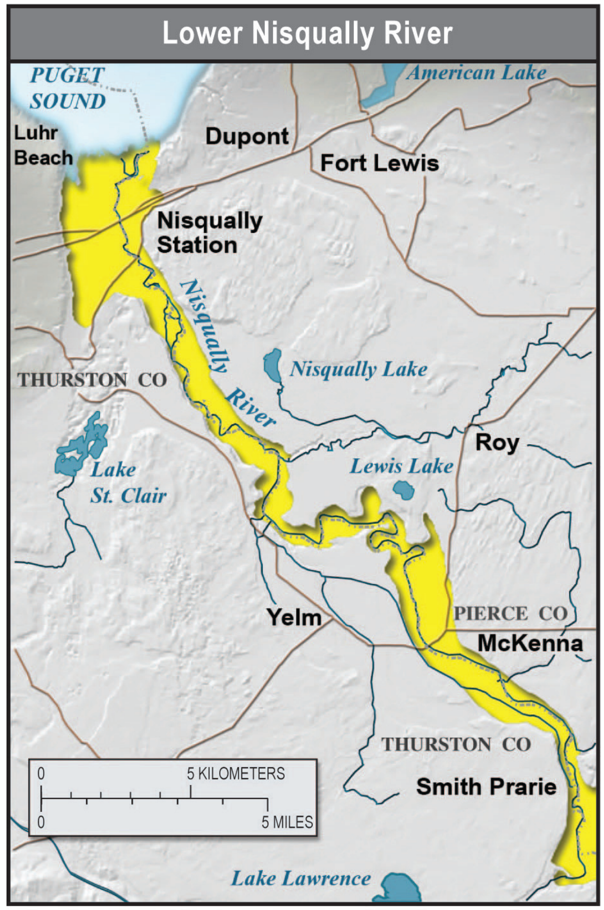

Revised March 15, 2011

EXPLANATION

- Debris flow hazard zone
- Lahar hazard zone
- Flooding and post-lahar sedimentation zone
- Lava flow and pyroclastic flow hazard zone

Debris Flow on Tahoma Creek, 1988

Photo by G.G. Parker, USGS

Tahoma Creek After Debris Flows, 1988

Photo by Carolyn Driedger, USGS