

Learning to Live with Geologic and Hydrologic Hazards

The Seattle, Washington, area is known for its livability and its magnificent natural setting. The city and nearby communities are surrounded by an abundance of rivers and lakes and by the bays of Puget Sound. Two majestic mountain ranges, the Olympics and the Cascades, rim the region. These splendid natural features are products of dynamic forces—landslides, (fig. 1) earthquakes, tsunamis, glaciers, volcanoes, and floods. The same processes that formed this

beautiful landscape pose hazards to the ever-growing population of the region. To maintain the Seattle area's livability, public and private policymakers must learn to manage the area's vulnerability to natural hazards and protect its three million residents from loss and damage from future natural disasters (fig. 2).

The U.S. Geological Survey (USGS) is working with other Federal and State agencies, the city of Seattle, and other local governments to provide necessary

scientific information that will help communities manage the natural hazards. This information will be useful in planning future development, siting public facilities and businesses, and developing effective emergency plans.

Seattle Area Natural Hazards Project

In 1997 the USGS began a 5-year project designed to increase scientific understanding of the hazards and make the information more accessible to officials and business leaders in communities at risk. The USGS's goal has been to work closely with State government, communities at risk, and the private sector to identify the hazards and provide information in a form easily used.

The USGS approach includes the following efforts:

- ◆ Improve scientific understanding of the causes of individual hazards.
- ◆ Identify areas at risk and make spatial information on hazards and risk available to officials and citizens in a format compatible with Geographic Information Systems (GIS) and accessible through the Internet (see back page for addresses).



FIGURE 1. Landslide in northwest Seattle. Foundation of house on right edge of photograph and decks of neighboring houses have been undermined. (Photo by *Alan F. Chleborad, USGS*, January 9, 1997.)

- ◆ Compile information necessary for policymakers to assess natural hazards.
- ◆ Work with officials at Federal and State levels on scientific research and mitigation issues and develop information data bases. Assist public officials and their constituents as they apply new information about hazards.

In order to reach a broad audience, the USGS works closely with the City of Seattle, Washington Department of Natural Resources, and the University of Washington (UW) in a cooperative effort to inform public and private policymakers of the hazards they face and help them learn how to coexist with these hazards. In addition, the USGS is working with the Federal Emergency

Management Agency's "Project Impact Communities" of Seattle, King/Pierce Counties and Kitsap County.

Natural Hazards in the Seattle Area

Natural processes that built the present landscape will certainly recur. Landslides will erode unstable bluffs (fig. 1); earthquakes will periodically shake the land; volcanoes will disrupt the lives of local inhabitants with ashfall and lahars (volcanic mudflows) as they have done in the past; and floods will regularly inundate vulnerable lowland and carve new channels. Neither scientists nor public officials can stop these events nor easily predict their arrival and size. Scientists can, however, estimate their timing and magnitude by monitoring geologic and hydrologic processes and by studying the evidence of previous events.

The following is a summary of hazards in the region and some USGS products in progress or currently available.

Landslides

Landslides are caused by heavy rainfall, rapid snowmelt, earthquakes, and volcanic processes (fig. 1). These events may affect large geographic areas by triggering many small neighborhood landslides, as in the winter storms of 1996-97. Although less common, landslides that originate on volcanoes, such as the Electron Mudflow of 500 years ago, hold potential to disrupt the economy of the Seattle metropolitan area. Even though most landslides are small, they

commonly affect transportation routes, utility corridors, businesses, and private residences. In all cases, landslide hazards pose a danger to life and property that can be managed with proper land-use planning, building practices, and warning systems.

In conjunction with the ongoing Landslide Hazards Program, the following products are being completed during the 5-year study for use in better understanding and managing the hazards associated with landslides:

- ◆ Landslide inventory map of the Regional Transit Authority route corridor
- ◆ Landslide susceptibility map for Seattle
- ◆ Probability maps of landslides caused by rainfall and earthquake ground shaking for the Seattle area

Earthquakes

The Pacific Northwest is a geologically active region. The Seattle area is located on a highly stressed region of the Earth's crust that has been shaken by two damaging earthquakes in recent history, a magnitude 7.1 in 1949 and a magnitude 6.5 in 1965 (fig. 3). These historic earthquakes were deep below the earth's surface and not related to shallow crustal faults. In the last few years, scientists at the USGS and UW realized that crustal faults in the region such as the Seattle fault represent a major earthquake hazard. Crustal faults in the Puget Basin are difficult to find and study because they are often concealed beneath glacial deposits or hidden by vegetation and urban development.

In conjunction with the ongoing USGS Earthquake Hazards Program, the following products are being completed during the 5-year study for use in better understanding and managing the hazards associated with earthquakes:

- ◆ Maps of the major faults in the Seattle area



FIGURE 2. Seattle, Washington, area showing location of natural hazards project with counties and cities identified. (Photo produced from *Landsat Thematic Mapper image*, USGS)



FIGURE 3. Chimney damage to single-family house as a result of the 1965 Seattle-Tacoma Puget Sound earthquake (Reprinted with permission from the *Karl V. Steinbrugge Collection, Earthquake Engineering Research Center*).

- ◆ Earthquake hazard and site response maps
- ◆ Strong ground shaking map for Seattle
- ◆ Recurrence times and profile of a characteristic earthquake on the Seattle fault
- ◆ Liquefaction susceptibility maps

Volcanoes

Mount Rainier (fig. 4) is an active volcano that is currently at rest although the possibility of non-volcanic landslides is a constant threat. Mount Rainier last erupted steam and ash in the 19th century. Its next eruption may produce volcanic ash, lava flows, and pyroclastic flows which are hot avalanches of lava fragments and gas. Volcanic eruptions produce excessive snowmelt that transforms into fast moving and destructive mudflows called *lahars*. During the last 5,600 years lahars and river sediments have raised the surface level of the Puyallup and Kent-Auburn valleys. Both valleys are now densely populated and at risk from future

lahars. The USGS and UW monitor Mount Rainier to detect initiation of volcanic restlessness and lahar activity.

In conjunction with the ongoing Volcano Hazards Program, the following products are being completed during the

5-year study for use in better understanding and managing the hazards associated with Mount Rainier:

- ◆ Probabilistic assessment of lahar hazards in the Puget Sound lowlands
- ◆ Volcanic ash hazard map
- ◆ Assessment of recent eruptions of Mount Rainier
- ◆ Educational materials for use by public officials and educators

Floods

Riverine flooding from heavy rainfall and snowmelt are common in the Seattle area (fig. 5). The USGS maintains a network of real-time streamflow gages to monitor flooding. The Seattle area is also affected by localized groundwater flooding and geologically young river channels which are actively eroding and moving. These processes create additional, previously little-known hazards to structures located within floodplains.



FIGURE 4. View of Mount Rainier above new homes in the Puyallup River valley, May 1999 (Photograph by *David Wieprecht, USGS*).

In conjunction with the ongoing Water Resources Program, the following products are being completed during the 5-year study for use in better understanding and managing the hazards associated with flooding:

- ◆ Flood frequency analysis on a regional scale
- ◆ Floodplain maps using new and more accurate methods and technology
- ◆ Identification of the characteristics of ground-water flooding, and areas at risk from future groundwater flooding
- ◆ Maps of river channel migration hazards
- ◆ Real-time flood inundation maps to be delivered over the internet

Tsunamis

Inland waterways are vulnerable to tsunamis produced by local earthquakes and landslides in the Puget Sound area.

This project is completing a tsunami inundation map for use in better understanding and managing the tsunami hazard.

Hazards Information Available in GIS

The Seattle Area Natural Hazards Project provides spatial information in Geographic Information Systems (GIS) formats that will be Internet accessible. This will allow users to select information pertinent to their region and consider multiple hazards concurrently. The project is completing new geologic and topographic map coverage of the region. These products will aid policy-makers seeking a comprehensive approach to reducing future casualties from natural hazards.

For more information on natural hazards of the Seattle area contact:

U.S. Geological Survey
Home page: <http://www.usgs.gov>

**U.S. Geological Survey
Earth Science Information Center**
Home page: <http://mapping.usgs.gov/esic>

Seattle Area Natural Hazards Project
Home page: <http://seattlehazards.usgs.gov>

National Earthquake Information Center
U.S. Geological Survey, Federal Center
Box 25046
Denver, CO 80225
(303) 273-8500
URI: <http://www.ineic.cr.usgs.gov>

National Landslide Information Center
U.S. Geological Survey, Federal Center
Box 25046
Denver, CO 80225
1-800-654-4966
URI: <http://landslides.usgs.gov>

Cascades Volcano Observatory
U.S. Geological Survey
5400 MacArthur Boulevard
Vancouver, WA 98661
(360) 696-7693
URI: <http://vulcan.wr.usgs.gov>

**U.S. Geological Survey
Water Resources Division**
Washington District Office
1201 Pacific Ave.
Tacoma, WA 98402
(253) 428-3600
URI: <http://water.wr.usgs.gov>

Washington Department of Natural Resources
Geology and Earth Resources
P.O. Box 47007
Olympia, WA 98504
(360) 902-1450
URI: www.wa.gov/dnr/htdocs/ger/ger.html

University of Washington Geophysics Program
Box 351650
Seattle WA 98195
(206) 543-8020
URI: <http://www.geophys.washington.edu>

Information on other USGS products and services, call 1-888-ASK-USGS or use the EARTHFAK fax-on-demand system at (703) 648-4888

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FIGURE 5. Flooding in the Snoqualmie River Valley near Monroe, looking upstream toward Carnation. Peak flow at Carnation 12 hours earlier was 42,000 cubic feet per second, making this a moderate flood event. Photo by *Allen Kam*, National Weather Service, NOAA, November 9, 1995.

