WASHINGTON STATE DEPARTMENT OF
Natural Resources
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DGER NEWS

DIVISION OF GEOLOGY AND EARTH RESOURCES
"Washington State's Geological Survey since 1890"

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IS WASHINGTON STATE READY FOR A GREAT EARTHQUAKE AND LOCAL TSUNAMI?

by Timothy J. Walsh

Washington is a geologically hazardous place to live because it is situated next to the Cascadia subduction zone (CSZ), a collisional boundary between two tectonic plates (Fig. 1). Movement along the CSZ has produced earthquakes, tsunamis, and volcanoes. The CSZ lies offshore of North America from southern British Columbia to northern California. Its two plates—the continental North American plate and the oceanic Juan de Fuca plate—are converging at a rate of about 3 to 4 cm/year (~2 in./year). In addition, the Pacific plate is pushing the Juan de Fuca Plate north, causing complex seismic strain to accumulate.

GREAT EARTHQUAKES AND TSUNAMIS ON THE CSZ

Great earthquakes (magnitude 8–9) occur along the interface between tectonic plates and are caused by the abrupt release of slowly accumulated strain. The CSZ, only 80 miles off the coast of Washington, is capable of producing such an earthquake. Figure 2 shows the similarities between the Indonesian subduction zone (Sunda trench), which produced the great earthquake and tsunami of December 26, 2004, and the CSZ.

Compelling evidence for great earthquakes on the CSZ was discovered by Brian Atwater in the late 1980s in the form of a drowned forest along the Copalis River and sand sheets typical of those deposited by tsunamis (Atwater and Hemphill-Haley, 1997). These earthquakes were evidently enormous (Magnitude 8–9+) and recur on average every 550 years. The recurrence interval, however, has apparently been irregular—as short as 300 years and as long as about 1300 years. The last of these great earthquakes struck Washington about 300 years ago.

Satake and others (2003, 1996) found records for a large tsunami that hit Japan on January 26, 1700, that was not associated with an earthquake there. From the distribution of wave heights, they concluded that the tsunami originated in North or South America and was generated by an earthquake of about magnitude 9. Because historical records in South America would have included an earthquake that large, but do not, they concluded that the tsunami was most likely generated by a magnitude 9 earthquake on the CSZ. This has been corroborated by tree ring dates from Washington forests that were drowned by the local tsunami (Yamaguchi and others, 1997).

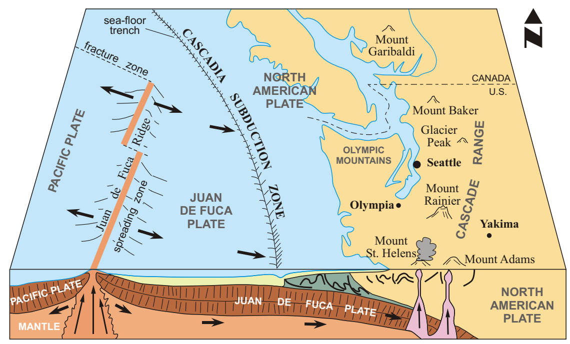

Figure 1. Cross section through the Cascadia subduction zone at about 47°N latitude. Adapted from Pringle (2002).

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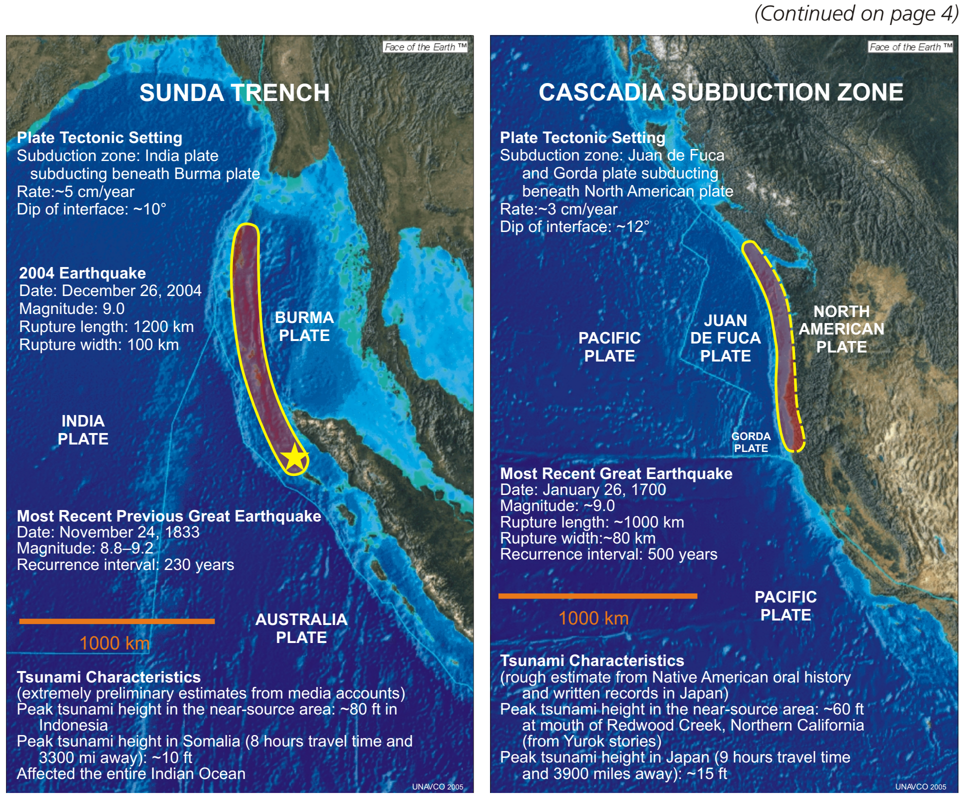


Figure 2. Comparison of the Sunda trench and the Cascadia subduction zone. Rupture zones red with yellow border; star, epicenter of 2004 Indonesia earthquake; plate boundaries pale blue. Redrawn from an illustration compiled by Lori Dengler, Humboldt State University. Indonesia source area from USGS. Cascadia source area from Satake and others (2003). Base image from the Jules Verne Voyager project at http://jules.unavco.org/.

NEW DGER BUDGET INITIATIVES FOR THE 05-07 BIENNIUM

Ron Teissere
State Geologist

The 03-05 biennium was what we hope was our budgetary low point, when DGER suffered a 40 percent reduction in funding. The result was the virtual elimination of state-funded work on urban landslides and seismic hazards, mineral resources, and subsurface aquifer studies. The budget cuts also eliminated most of our technical support to local governments and others.

Over the past year, DGER has developed a strategic plan to identify critical geologic work that will be of greatest assistance to decision-makers at all levels of government. We identified four areas that need immediate attention to enhance public safety and protect property. These four areas are:

- Seismic hazards related to soil conditions,
- Landslide risk assessments,
- Subsurface geology, especially in relation to groundwater aquifers, and
- Aggregate resources.

We are proposing projects in each of these areas that can be done cost-effectively over three to four biennia and have either significant economic or population growth implications. Each of these proposals has been submitted in our 05-07 budget request. None were recommended for funding in the Governor's Budget. The decision now rests in the Legislature. The proposals are described in more detail below. For further information, contact Ron Teissere (360-902-1440; ron.teissere@wadnr.gov) or Dave Norman (360-902-1439; dave.norman@wadnr.gov).

SEISMIC SOIL HAZARD MAPS

Summary

Develop detailed soil site condition maps of urban areas and update our county maps for use by state and local building officials, planning agencies and departments, and the construction industry. Maps will be in geographic information system (GIS) or PDF formats and available free on the Internet.

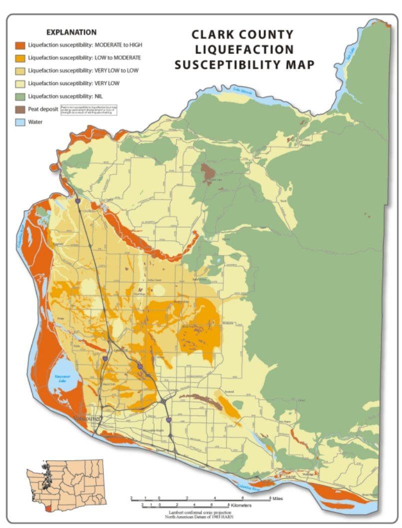
Description of Proposal

In 2003, the Washington State Legislature adopted the International Building Code (IBC) and International Residential Code (IRC) as the statewide building codes. Structural design procedures within the 2003 IBC and IRC require that determination of seismic design ground motions incorporate a soil site classification. These changes will affect every proposal for new building construction and revisions to local comprehensive plans over the next few years.

Funding DNR to complete detailed urban seismic soil hazard maps and update county maps will (1) allow us to provide local government and developers with site mapping and subsurface seismic velocity information to help them meet the new IBC requirements, (2) expand the current program to include detailed site-class mapping for most communities in the state, and (3) provide technical assistance in the proper application of these maps.

These products will be of significant value in the implementation of the 2003 IBC and IRC. Local government permit writers and planners will have high-quality, immediately useable information on soil conditions available digitally from the Internet. The information will be scaleable and can be overlain on any base map to get an immediate picture of critical areas.

This project is strongly supported by both the Building Code Council and Growth Management Division of the Department of Community, Trade, and Economic Development. Other state agencies that would directly use the project's products include the Department of Transportation (Environmental and Engineering Program – Bridge and Foundation Design), Department of Ecology (Water Resources – Dam Safety Office and Solid Waste Programs), Washington Military Department (Emergency Management Division), and the University of Washington (Pacific Northwest Seismographic Network). Local government should realize substantial efficiency savings as this information becomes available.



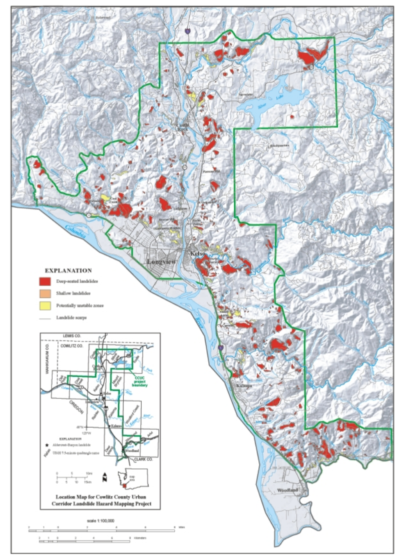
Seismic soil hazard maps can:

- Improve the safety of people and property,
- Improve the ability of state government to achieve its results efficiently and effectively.

LANDSLIDE RISK ASSESSMENTS

Summary

Provide landslide risk assessments and inventory maps for all jurisdictions abutting Puget Sound and other high risk areas in time for the next round of Comprehensive Plan updates in 2011.



Description of Proposal

In the last decade in Washington, at least five lives, hundreds of homes, and hundreds of millions of dollars in property have been lost in landslides. Recent examples are devastating costly landslides in King, Thurston, and Cowlitz Counties. Much of this loss could have been prevented by land-use planning or engineering mitigation, but only if credible risk-assessment information had been available.

Every jurisdiction in the state is required to assess geologic hazards and make plans to protect against them under the Growth Management Act . These plans must be updated every seven years (the updates are in process now). DGER proposes to provide new mapping to all coastal jurisdictions in Puget Sound and other high-risk jurisdictions statewide in time for their next plan updates in 2011. This project would significantly improve the availability of risk assessment information for local jurisdictions, particularly those with inadequate resources to generate this information themselves.

The continued lack of hazard assessment information will result in local jurisdictions remaining in an entirely reactive mode in dealing with landslides. The cost of slope failures will increase as the lack of information allows for additional development in areas where adequate information would eliminate or reduce losses.

The state's shoreline areas continue to be the focus of intense development pressure, and as lowland areas of western Washington are filled, development moves on to steeper slopes. Currently, no funding is available at the state level to address landslide risks outside the state's forested areas. This project addresses these risks in urban areas in a prioritized way.

Landslide hazard maps can:

- Improve the safety of people and property,
- Improve the ability of state government to achieve its results efficiently and effectively.

SUBSURFACE GEOLOGY PROGRAM

Summary

Develop a statewide, Internet-accessible subsurface geology database to support decision-making processes related to water resources, water rights, geological hazards, and infrastructure planning. Complete subsurface studies and 3-D geological models of important basins.

Description of Proposal

The future economic growth of Washington is tied to water availability and the mitigation of geological hazards. Subsurface geology is the key to addressing both of these issues. A lack of understanding of subsurface geology and aquifer characteristics can impair processing of water rights applications because of uncertainty about water resource availability. It is also costly if the wrong decisions are made. A subsurface program is also key for hazard mitigation strategies, transportation planning, and designation of critical areas under the Growth Management Act. DGER proposes to develop a statewide database of subsurface geological information and make this information available online to a wide variety of end users, including the other state agencies, local governments, industry, and academics. The most immediate beneficiaries would be the Department of Ecology, the Department of Transportation, the Department of Community, Trade, and Economic Development, and local governments.

The program would initially focus on aquifers in eastern Washington to provide information critical to decision-making on ground water rights. Information from existing water wells, geotechnical studies, and existing small subsurface databases would be incorporated into the system over time. New data would be collected from the geophysical logging of water wells and other borings. The database will provide objective, scientifically sound subsurface information.

A subsurface geology program can:

- Improve the economic vitality of businesses and individuals,
- Improve the safety of people and property,
- Improve the quality of Washington's natural resources,
- Improve the ability of state government to achieve its results efficiently and effectively.

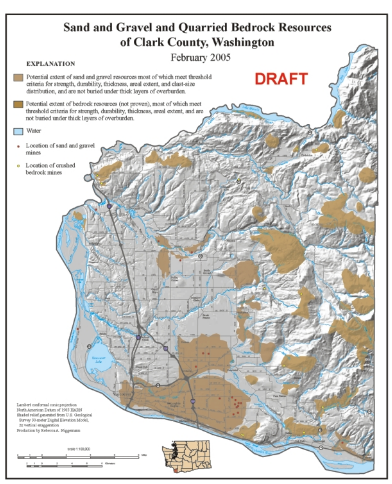
AGGREGATE RESOURCE MAPS

Summary

Develop a county-by-county inventory of aggregate resources, including maps and aggregate quality and volume information for use by local governments in designating mineral resource overlays under the Growth Management Act and by industry and the public. Maps (GIS or PDF formats) and data available online.

Description of Proposal

The Report to the Legislature required by SSB 5305 included several recommendations intended to improve local planning under the Growth Management Act (GMA) and the efficiency and effectiveness of local permitting of aggregate resource projects. The first recommendation was the identification of aggregate resources (sand, gravel, and crushed stone used in construction) through geologic mapping. The identification of these resources is required by the GMA for designating mineral resource overlays. The second recommendation was preparation of a Programmatic Environmental Impact Statement (PEIS) addressing the common impacts associated with aggregate mining projects and related activities.



The projected demand for aggregate in Washington is significantly above the current designated volume, which is well short of the 20-year planning horizon recommended for this type of resource planning. The projected demand for aggregate in Washington is documented in *The Aggregates Industry in Washington—Economic Impact and Importance*, a study done for the Washington Aggregate and Concrete Association by Pacific Lutheran University. The report notes that permitting aggregate mines is one of the most time-consuming, costly, and confusing processes among all development projects. The burden on the applicant and government entities involved bears little relationship to the actual impacts. Currently, no statewide framework or guidance exists for local governments to use in permitting these projects. The result is that each project is evaluated from scratch using ad hoc approaches. This inefficiency leads to permitting delays, process challenges, duplicative environmental studies, and higher costs for both government and industry.

In keeping with the recommendations of the SSB 5305 report, the 2004 legislature appropriated funding to DNR to prepare aggregate resource maps for two counties. Funding this proposal will allow DGER to continue this work for the other counties. The goal is to have all of the state mapped within three biennia. The GIS database created by the project would allow each local jurisdiction to obtain maps and volume and quality data for aggregate resources in their area. The same information would be available online to the public, the aggregate industry, and state agencies. Lack of this information drives up the cost of permitting, increases the controversy associated with GMA planning requirements, and makes the local Comprehensive Plan process less effective. During the 05-07 biennium, the Geology Division would prepare the PEIS to assist local governments in the evaluation and permitting of aggregate projects and in the designation of mineral resource overlays.

Aggregate resource maps and a PEIS provided to counties can:

- Improve the economic vitality of businesses and individuals,
- Improve the quality of Washington's natural resources,
- Improve the State's efficiency in the permitting of aggregate mining projects. ■

Figure 3. Damage to the State HIghway 109 bridge over the Copalis River near Copalis Beach caused by a distant tsunami from the 1964 Alaska earthquake. Courtesy of the *Daily World*, Aberdeen, Wash.

(Continued from page 1)

WHAT ARE TSUNAMIS?

Tsunamis are generated when geologic events cause large, rapid movements of the sea floor that displace the water column above. This creates a series of high-energy waves (tsunamis) that radiate outward like ripples on a pond. Tsunamis are long-wavelength (large distance between wave crests), long-period (several minutes to more than an hour between wave crests) seismic sea waves. They are erroneously called tidal waves because they are sometimes preceded by a recession of water resembling an extreme low tide.

Tsunamis can strike shorelines within minutes of an earthquake and can cross the ocean at speeds as great as 600 miles/hour. For example, the tsunami in the Indian Ocean caused by the magnitude 9.0 earthquake in Indonesia reached Sumatra and Southeast Asia's shores in minutes, while waves reached Indian and African shores hours later.

In the open ocean, tsunamis are not felt by ships because the wavelength is many tens of miles, with a height of only a few feet or less. This also makes them virtually unnoticeable from the air, although NOAA (National Oceanic and Atmospheric Administration) scientists were able to map the Indian Ocean tsunami at four different times along four different traverses with satellite radar altimetry; see http://www.noaanews.noaa. gov/stories2005/s2365.htm.

As the waves approach the coast, shallowing of the ocean bottom causes their speed to decrease and their height to increase. The first wave is commonly not the largest in the series of waves, nor the most significant. Furthermore, one coastal community may experience no damaging waves while another, not far away, may experience destructive deadly waves due to differences in ocean floor topography. Rarely waves have been known to be over 100 feet high. However, waves that are 10 to 20 feet high can be very destructive and cause many deaths or injuries.

NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM

Congress created the National Tsunami Hazard Mitigation Program (NTHMP) in 1996 to provide warning guidance, hazard assessment, and preparedness and mitigation tools for both local and distant tsunamis. It is directed by a steering committee with two members from each of the five Pacific Coast states and members from the U.S. Geological Survey (USGS), Federal Emergency Management Agency (FEMA), and NOAA. (See http://www.pmel.noaa.gov/tsunami-hazard/ for more information.) The NTHMP has made significant strides toward mitigating tsunami hazards to the U.S.

WARNING GUIDANCE

The Tsunami Warning System

Washington is at risk from two types of tsunamis—those generated by a distant earthquake and those generated locally by an earthquake on the CSZ, a fault crossing Puget Sound, or a landslide. Tsunamis from a distant source, such as those that struck Thailand and Sri Lanka on December 26, 2004, allow several hours of lead time before they strike a coastline. Tsunamis from Japan or Chile take more than ten hours to get here, while tsunamis from Alaska arrive in only three to six hours (Fig. 3). Tsunamis from distant sources can move down the Strait of Juan de Fuca into Puget Sound, but lose energy as they move further inland.

The Tsunami Warning System (Fig. 4) was put into place to help minimize loss of life and property from tsunamis. The West Coast/Alaska Tsunami Warning Center in Palmer, Alaska, monitors for earthquakes and subsequent tsunami events. If a tsunami is generated, the center issues warnings for Alaska, British Columbia, Washington, Oregon, and California. The Pacific Tsunami Warning Center in Ewa Beach, Hawaii, provides the same service for the Aloha State as well as all other American territories in the Pacific. They also serve as the International Tsunami Warning Center for 25 other member countries in the Pacific Ocean basin.

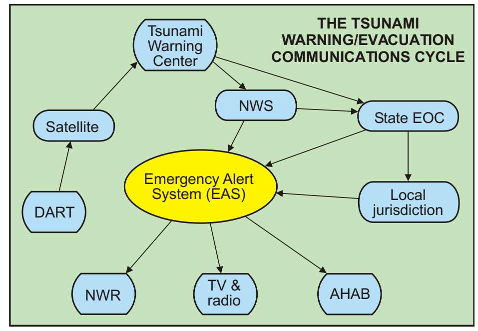


Figure 4. Chart showing the flow of communications during a tsunami warning/evacuation alert. NWS, National Weather Service; EOC, Emergency Operations Center; AHAB, All-Hazard Alert Broadcast; NWR, NOAA Weather Radio; DART, Deep Ocean Assessment and Reporting of Tsunamis. Courtesy of the Washington Emergency Management Division.

Tsunami bulletins are initially issued based solely on seismic data. The centers have been upgraded in recent years to permit rapid and robust determinations of earthquake magnitude, location, and focal mechanism (that is, whether an earthquake is strike-slip or thrust). Tsunami bulletins are issued to state and provincial emergency management agencies, FEMA, National Weather Service (NWS) offices, Federal Aviation Administration offices, the U.S. Coast Guard, military bases, local emergency managers, USGS offices, and many other recipients in the U.S. and Canada. Bulletins are disseminated by telephone, satellite phone, e-mail, satellite broadcast, VHS broadcast, and over the Internet. Individuals can sign up for e-mail notification at http://wcatwc.arh.noaa.gov/watcher.htm.

Once a warning has been issued, the warning centers monitor water level data to assess the tsunami hazard using tide gauges, and a new tool—DART (Deep Ocean Assessment and Reporting of Tsunamis) buoys (Fig. 5). Developed by NOAA's Pacific Marine Environmental Laboratory (PMEL) and operated by NOAA's National Data Buoy Center (NDBC), DART buoys have been sited in regions with a history of generating destructive tsunamis.

DART systems consist of an anchored seafloor bottom pressure recorder (BPR) and a companion moored surface buoy for real-time communications.

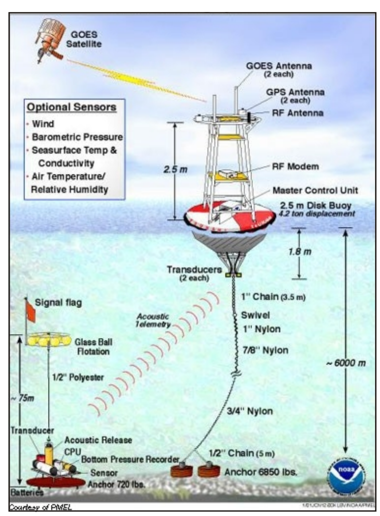


Figure 5. The DART mooring system.

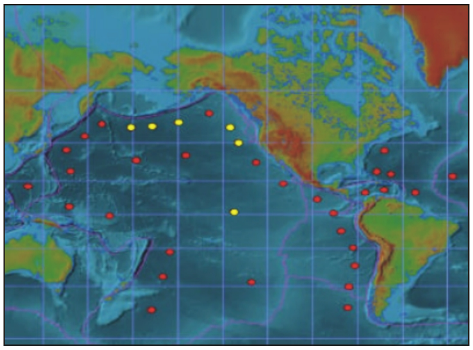


Figure 6. Location of existing DART System buoys (yellow dots). Red dots are NOAA's suggested locations for an expanded Pacific, Caribbean, and Atlantic tsunami monitoring system. Courtesy of the Office of Science and Technology Policy.

An acoustic link transmits data from the BPR on the seafloor to the surface buoy. The data are then relayed via a satellite link to ground stations, which disseminate the data to NOAA's Tsunami Warning Centers, NDBC, and PMEL.

Six of these buoys are now deployed in the Pacific (Fig. 6). They can detect a tsunami moving across the ocean, and using numerical models of hypothetical or historical tsunamis from the known source regions, forecast wave heights at selected shorelines. More of these buoys are needed to improve coverage as well as provide backup, since the buoys suffer outages in their harsh environment. (For more information about DART, go to http://www.ndbc.noaa.gov/Dart/dart.shtml.)

Upon receipt of a tsunami warning, coastal NWS offices, such as those in Seattle and Portland, activate the Emergency Alert System (EAS) via NOAA Weather Radio (Fig. 4). All broadcasters (TV, radio, cable) receive the message simultaneously. NOAA Weather Radio also activates the All-Hazard Alert Broadcast (AHAB) units (Fig. 7). AHAB is a self-sufficient outdoor warning system that activates a brilliant blue U.S. Coast Guard light and a siren that can be heard for at least a mile.

When local emergency management officials receive the warning, they can decide to activate the EAS to evacuate low-lying coastal areas. Their EAS messages are also received by broadcasters, weather radio receivers, and AHABs to provide widespread dissemination of these messages. Weather radios with EAS-programmable features are available at most electronics retailers and on the Internet. They remain operational during a power outage and cost about $50.

HAZARD ASSESSMENT

Tsunami Inundation Maps

DGER works cooperatively with federal, state, and local agencies to help Washington State prepare for tsunamis. Cooperative efforts help each agency be more effective and use limited resources more efficiently.

For the past several years, DGER has been producing tsunami inundation maps (Walsh and others, 2000, 2002b,c, 2003a,b, c, 2004a,b) for the Washington coast as part of the National Tsunami Hazard Mitigation Program (NTHMP) to aid local governments in designing evacuation plans for areas at risk from damaging tsunamis. The landward limit of tsunami inundation is based on a computer model of waves generated by two different scenario earthquakes on the Cascadia subduction zone.

The earthquake scenarios adopted for this model were Scenario 1A (Fig. 8; Myers and others, 1999; Priest and others, 1997) and Scenario 1A with an asperity offshore of Washington, which appear to fit the available paleoseismic evidence reasonably well. The earthquake is a magnitude (M_w) 9.1 Cascadia subduction zone (CSZ) event with a rupture length of 650 miles (1050 km) and a rupture width of 45 miles (70 km). The asperity is an area of locally greater fault slip, or displacement along the fault plane, that generates a higher uplift of about 20 feet (6 m), offshore of northern Washington. The land surface along the coast was modeled to subside by about 5 feet (1–1.5 m) during ground shaking. This scenario has been adopted for tsunami inundation mapping in Oregon as well.

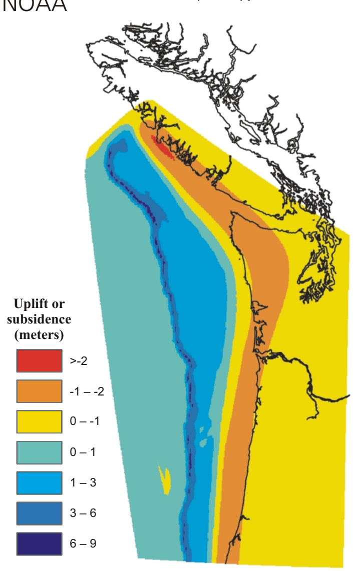


Figure 8. Map of uplift and subsidence along the Cascadia subduction zone for earthquake scenario 1A. Negative numbers indicate subsidence.

Arrival time and duration of flooding are key factors to be considered in evacuation strategies. These maps show time histories (Fig. 9) of the modeled waves at various localities. The time histories give the change in water surface elevation with time for 8 hours of modeling. Negative elevations are wave troughs, or times when water is flowing out to sea. Positive elevations are wave crests. For locations on the outer coast, the first wave crest is generally predicted to arrive at between 30 and 60 minutes after the earthquake, whereas within Willapa Bay and Grays Harbor, the first crest is not expected to arrive for more than an hour. In all of the time histories, the first arrival is a wave trough, which, if correct, implies that flooding is delayed by a few tens of minutes. However, significant flooding can occur before the first crest arrives because a CSZ earthquake is expected to lower the ground surface along the coast. Flooding of areas less than about 6 feet (1.8 m) above tide stage is expected immediately, rendering evacuation time even shorter. Maximum flooding depth and extent will depend on tide height at the time of tsunami arrival.

Figure 7. All Hazard Alert Broadcasting (AHAB) Radio on a pole installed October 30, 2003, Port of Port Townsend. Courtesy of the Washington Emergency Management Division.

Large-format tsunami inundation maps for Anacortes/Whidbey Island, Bellingham, Neah Bay, Port Angeles, Port Townsend, Quileute, Seattle, and the southern Washington coast (GM-49) are online at http://www.dnr.wa.gov/geology/pubs/pubs_ol. htm#hazards. Printed copies of GM-49 are available at http://www.prt.wa.gov/.

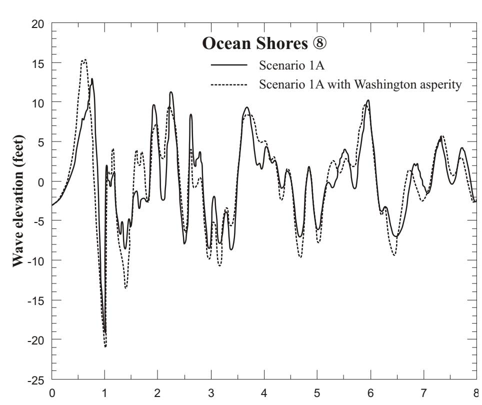


Figure 9. Typical time history of modeled waves for Ocean Shores.

PREPAREDNESS AND MITIGATION

Tsunami Evacuation Maps

Tsunamis generated by a Cascadia subduction zone earthquake will arrive at the outer Washington coast in less than 40 minutes. For these events, as was the case in Banda Aceh in Indonesia, the earthquake must be the warning. The waves could be several tens of feet high. We can also expect parts of the coast to sink as much as 6 feet and the ground and roadways to become broken and debris-strewn. Tsunamis are more damaging when they strike a coastline that has suffered earthquake-induced subsidence. Citizens must know where to evacuate from, where to evacuate to, and how to do it.

DGER, Washington Emergency Management Division (EMD), and Grays Harbor and Pacific Counties have just completed tsunami inundation and evacuation brochures (Fig. 10) for communities on the southern Washington coast. These brochures show tsunami hazard zones and evacuation routes and give instructions for what to do when you feel an earthquake. Legal-size brochures for Aberdeen/Hoquiam, Bay Center, Copalis Beach, Cosmopolis, Long Beach, North Cove, Ocean Park, Ocean Shores, Raymond/South Bend, and Westport are online at http://www.dnr.wa.gov/geology/hazards/tsunami/evac/. Printed copies will be distributed to residents of Grays Harbor County and Pacific County this spring. Brochures for communities in Clallam County are available on the EMD website at http://emd.wa.gov/3-map/mit/eq-tsunami/tsunami-idx.htm.

EMD, DGER, and San Juan County Department of Emergency Management did a field study of the coastline of San Juan, Orcas, and Lopez Islands in the summer of 2004. The data will be used to develop tsunami evacuation maps for the county and provide the needed information to develop an earthquake/tsunami risk communications program for county citizens and visitors.

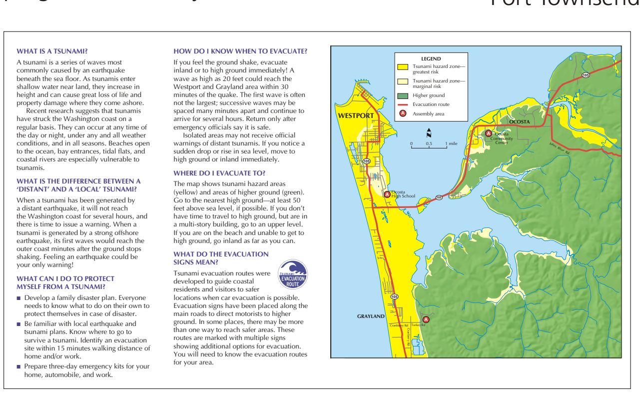


Figure 10. Map side of the tsunami evacuation brochure for Westport.

Evacuation Routes and Signs

Clallam, Grays Harbor, Island, Jefferson, and Pacific counties have posted warning signs in tsunami hazard zones. To aid in car evacuation from tsunamis generated by a distant earthquake, they have marked evacuation routes with signs to steer residents and visitors to high ground. San Juan, Skagit, Whatcom, and other saltwater counties are in the process of establishing evacuation plans, routes, and signage.

AHAB Radio

EMD, in partnership with Federal Signal, designed and developed a system that provides both tone and voice alert and notification capability for any hazardous situation. AHAB Radio can be activated via NOAA Weather Radio, the EAS system, or other communication protocols. These devices can be installed in areas that are prone to natural and manmade hazards. The system can be placed where no power is available, such as at a beach. It can be wind driven, solar driven, or use commercial electrical power. The AHAB radio won the 2004 National Earthquake Conference Award of Excellence.

Currently, all counties and tribes along the Pacific coast, Strait of Juan de Fuca, and Puget Sound rely largely on emergency broadcasting for warnings about tsunamis. Now, AHAB systems are enhancing local tsunami warning plans in several locations—Port Townsend in Jefferson County, La Push on the Quileute Indian Reservation, and Ocean Shores in Grays Harbor County.

The EMD began installing AHAB systems on the Pacific coast in 2003. The work is done in partnership with local officials and the National Weather Service. Initial funding was provided by NOAA's National Tsunami Hazard Mitigation Program (NTHMP).

Future installations are planned for Neah Bay on the Makah Indian Reservation and Westport in Grays Harbor County. Instead of an AHAB system, Pacific County uses a telephone alert system to supplement its EAS and NOAA Weather Radio warnings.

State and local officials are considering installing more AHAB systems. While AHAB was originally developed to aid tsunami warning systems, it will be used to address other hazards, too, for example, Mount Rainier lahars or mud flows—AHAB systems are located in Orting and McMillin in Pierce County, with installations planned for Sumner and Puyallup.

In 2004, EMD, in partnership with the USGS, NOAA, University of Washington, and City of Seattle, installed four AHAB systems on the Seattle waterfront. This area of multiple hazards (earthquakes, storm surges, tsunamis, major chemical spills, and possible terrorist activity) is the economic hub of the Pacific Northwest. Chemical detectors, a weather station, cameras, tide gauges, and seismometers are currently being added to enhance the basic system. This will help the city make real-time decisions for emergency response and use AHAB Radio to rapidly provide guidance to citizens and businesses in the hazard zone.

Tsunami Education

EMD and the Institute of Geological and Nuclear Sciences in New Zealand partnered to quantify the public and private sectors' understanding of earthquake and tsunami hazards on the Washington coast, their knowledge of AHAB and NOAA Weather Radio, and their preparedness to deal with an earthquake and tsunami. To fix deficiencies noted in the school assessments, EMD developed and published a book for elementary school children—*How the Smart Family Survived a Tsunami*. The book won the 2004 National Earthquake Conference Award of Excellence.

EMD and the State/Local Tsunami Workshop, in partnership with the Provincial Emergency Program, British Columbia, and the Olympic Peninsula Intertribal Cultural Advisory Committee, developed a video, *Run to High Ground*, for K–6. Elements include an imaginative animated story of a large earthquake and tsunami off the Washington coast as seen through the eyes of a young boy. Narrated by Hoh tribe storyteller Viola Riebe, the video was showcased at an Earthquake Tribal Workshop in June 2004.

Hosted by EMD, the USGS, DGER, and the Quinault Nation, this was the first Earthquake Workshop for Tribes in Washington State. The workshop educated tribal officials about earthquake and tsunami hazards and provided public education materials and training opportunities specifically for tribal officials. Many of the speakers were tribal members, ensuring that information important to them was disseminated. The tribes were able to showcase their efforts in emergency management for possible use as a template by other tribes. The workshop featured a field trip to areas of subsidence along the Washington coast that link scientific evidence to coastal Native American oral history. It has increased the understanding of tribal needs and enhanced cooperation between the tribes and state and federal government.

DGER has also participated in public education programs in coastal communities, talking about tsunamis, answering questions, and passing out informational materials.

Planning

Washington was the first state in the nation to receive FEMA approval of its enhanced hazard mitigation plan. The concept of "best available science" required by land-use planning in the state was used to develop the plan's hazard profiles for earthquakes, tsunamis, and landslides. EMD has provided these and other natural hazard profiles to all local jurisdictions around the state for use in local hazard mitigation plans. The profiles are posted on the EMD website at http://emd.wa.gov/3-map/mit/mit-pubs-forms/hazmit-plan/hazmit-plan-idx.htm.

Tsunami-Resistant Buildings

For some areas of the coast, safe evacuation areas are too far away for many citizens to reach on foot. The southern Washington coast has several long peninsulas or spits of low-lying ground. Ocean Shores peninsula is 7 miles long and Long Beach peninsula is 20 miles long with little or no high ground. Alaska, California and Oregon also have vulnerable spits. For these areas, shelter in readily accessible earthquake- and tsunami-resistant structures may be the preferred evacuation option.

The mitigation committee of NTHMP held a scoping workshop in 2002 to evaluate the feasibility of developing siting and structural engineering design guidance for buildings in both high seismic and high tsunami hazard zones (Walsh and others, 2002a). This was followed by a pilot study by Harry Yeh of Oregon State University and Ian Robertson of the University of Hawaii to evaluate forces on buildings during tsunamis and structural characteristics of buildings that survived. NTHMP and FEMA have incorporated the results of this study and contracted with the Applied Technology Council to develop the final guidance. To make these buildings economically feasible, the design guidance is for buildings that will have other uses, such as schools or community centers. This guidance will be in a building code format and will be an adjunct to FEMA's Coastal Construction Manual. Expected completion date is in 2007.

TsuInfo Alert

NTHMP also has a newsletter and information retrieval service, *TsuInfo Alert*, which is prepared and published by DGER and distributed worldwide. Current and back issues of *TsuInfo Alert* are available at http://www.dnr.wa.gov/geology/tsuinfo/.

Because DGER publishes *TsuInfo Alert*, the Geology Library collects material on the subject of tsunamis. To learn what documents are available, go to http://www.dnr.wa.gov/geology/washbib.htm, click on SEARCH THE DATABASE, and type 'tsunamis' in the SUBJECT field. For information about emergency management, mitigation and preparedness, type those terms in the SUBJECT field, either singly or together, separated by the / sign. Search tips are given on the web page cited above. For more information, contact Lee Walkling, lee.walkling@wadnr.gov or 360-902-1473.

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LINKS

All-Hazards NOAA Weather Radio – http://www.nws.noaa.gov/nwr/

All-Hazards NOAA Weather Radio in Washington:

- *National Weather Service* – http://www.wrh.noaa.gov/sew/nwr1.php
- *Washington State Emergency Management* – http://emd.wa.gov/5-prep/trng/pubed/weather/wxradio-idx.htm

Cascadia subduction zone – http://www.pnsn.org/HAZARDS/CASCADIA/cascadia_zone.html

DART tsunami detection buoys – http://www.ndbc.noaa.gov/dart.shtml

Emergency Alert System – http://www.fcc.gov/eb/eas/

Emergency Alert System in Washington – http://www.wsab.org/eas/eas.html

International Tsunami Warning Center – http://www.prh.noaa.gov/itic/

National Weather Service – http://weather.gov

National Weather Service Seattle – http://weather.gov/seattle

National Weather Service Portland – http://weather.gov/portland

NOAA – http://www.noaa.gov

Pacific Marine Environmental Lab – http://www.pmel.noaa.gov/

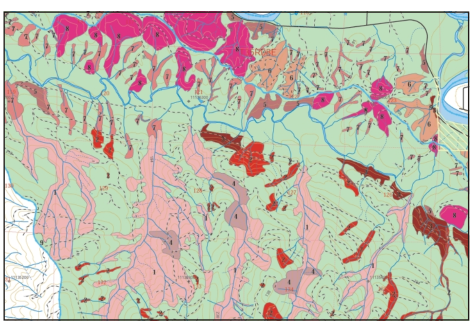
Pacific Tsunami Warning Center – http://www.prh.noaa.gov/ptwc/

Seismometer – http://interactive2.usgs.gov/faq/list_faq_by_category/get_answer.asp?id=193

West Coast/Alaska Tsunami Warning Center – http://wcatwc.arh.noaa.gov/ (responsible for coastal waters from Alaska to California, including Washington) ■

LANDSLIDE HAZARD ZONATION PROJECT

DGER geologists are working with Laura Vaugeois of the Department of Natural Resources Forest Practices Division on the Landslide Hazard Zonation (LHZ) Project, which is describing and mapping all potentially unstable slopes in priority watersheds. Under the direction of Tim Walsh, the team is preparing landslide hazard zonation maps for all private and state-owned forested lands.



The LHZ maps (excerpt shown above) will be used as a screening tool to eliminate any errors of omission in the identification of unstable landforms during both harvest layout and the permitting process. Forest Practices expects the maps to improve regulatory efficiency for permitting, land management planning, harvest unit layout, and SEPA (State Environmental Policy Act) review. For more information on the LHZ Project, go to http://www.dnr.wa.gov/forestpractices/lhzproject/. ■

DGER STAFF NEWS

In the fall of 2004, **William 'Bill' Lingley, Jr.**, transferred from DGER to DNR's Land Management Division as Chief Geologist. He is working on policy development for Habitat Conservation Plan implementation, as well as minerals and petroleum resource management. Bill joined DGER in 1985 as a geologist working on the surface mining reclamation, oil and gas, and geothermal regulatory programs. More recently, he worked with DNR's Forest Practices Division on the Landslide Hazard Zonation Project.

Geophysicist **Sammantha Magsino** has left DGER to take her dream job with the National Academy of Science in Washington, D.C. She works for the Board on Earth Sciences and Resources. Samm started with DGER in 2001. She was a prime mover on the Hazard Mitigation Grant Program, which produced liquefaction susceptibility maps and NEHRP site class maps for every county in the state [http://www.dnr.wa.gov/geology/hazards/hmgp.htm].

Geomorphologist **Karl Wegmann** is taking educational leave to pursue a Ph.D. at Lehigh University in Bethlehem, Pennsylvania. Karl is our expert on the Cowlitz County landslides. Karl's webpage is http://www.lehigh.edu/~kawc/kww.html.

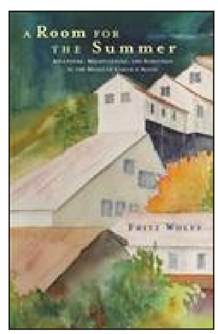
Currently working on the Surface Mining Remote Sensing Program are cartographer **Loren Baker**, Technical Coordinator **Tommy Duerr**, GIS Specialist **Rebecca Niggemann**, and Technical Assistant **Tara Salzer**. The program uses aerial photos to monitor compliance with reclamation plans and determine mining disturbance to accurately calculate the required reclamation bond.

Working on the Landslide Hazard Zonation Project with DNR's Forest Practices Division are geologists **Pat Pringle**, **Lorraine Powell**, **Eric Bilderback**, **Tom Boyd**, **Ben Cashman**, and **Belle Sarikhan**. Geomorphologist **Matt Brunengo** has returned after several years in Oregon to lend his expertise.

Geologist **John Bromley** is the new Surface Mine Inspector for the south area, and geologist **James Poelstra** is working on the Aggregate Mapping Project.

Doreen Smith is our Office Manager, and **Shannon Franks** is our new Office Assistant Senior.

Geologist **Fritz Wolff** has just published *A Room for the summer—Adventure, misadventure, and seduction in the mines of the Coeur d'Alene*, an autobiographical account of the rough-and-tumble world of hardrock mining. It recounts his experiences above and below ground as an apprentice mining engineer in the late 1950s. Fritz learned firsthand the camraderie and the dangers of working underground. Find out more at http://www.oupress.com/bookdetail.asp?isbn=0-8061-3658-8. ■



Cover watercolor is by Fritz's wife, artist Mary McCann.

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