Cascadia Earthquake and Tsunami, Pacific Coast

The Cascadia Subduction Zone, which extends 700 miles from Vancouver Island, Canada, to Cape Mendocino, California, produces destructive earthquakes and tsunamis that have the potential to cause great damage in the Pacific Northwest of the United States and in Southwest Canada. Its tsunamis will inundate not only low-lying areas along the Pacific Coast of the continental United States but also cause damage to distant shores including those of Hawaii and Japan.[1,2]

In its earthquake and tsunami potential, the Cascadia Subduction Zone resembles the Sunda Trench that produced a giant earthquake off the coast of Sumatra Island, Indonesia on December 26, 2004 (see comparison graphic, page 6). The earthquake and ensuing tsunami in the Indian Ocean killed an estimated 283,000 people, displaced 1.1 million people, with another 14,000 people still reported missing.[3]

The earth's largest earthquakes occur at subduction zones, where two pieces of the Earth's crust meet. In the Cascadia Subduction Zone, this is where the Juan de Fuca plate is gradually descending, or subducting, below the North American plate. Seismic strain accumulates when the plates stick together at their interface. The pressure eventually releases in an earthquake; the more pressure released, the larger the earthquake. A tsunami is generated when the movement of the plates creates a sudden vertical displacement of the Pacific Ocean sea floor; the greater the displacement, the larger the tsunami.

The Earthquake

- Scientific evidence shows great earthquakes of magnitude 8 to 9 or greater occur about every 500 years in the Cascadia Subduction Zone. Scientists currently estimate there is a 10 to 14 percent chance an M 9.0 earthquake will occur in this zone in the next 50 years.[4]

- Ground shaking is likely to last several minutes in an M 9.0 earthquake, somewhat less in a smaller earthquake. During the December 2004 Sumatra earthquake, the ground shook for 8 to 10 minutes in some locations.[5]

- After the earthquake, there could be months of aftershocks which have the potential to do additional damage and generate another tsunami, as was demonstrated in Sumatra in March 2005.

- The seismic waves of this earthquake could be dangerous to tall buildings, bridges, and pipelines in the Interstate 5 / U.S. Highway 99 corridor.

- Much of the land near the Pacific Coast will subside, or fall in elevation, during the earthquake. During an M 9.0 subduction zone earthquake, the elevation of land along much of the Pacific Coast is expected to subside or fall about five feet.[6] This will make coastal communities more susceptible to flooding and damage from a tsunami.

- Japanese written history pinpoints the most recent event in the Cascadia Subduction Zone to the evening of January 26, 1700. This estimated M 9.0 earthquake produced a tsunami that struck the Pacific Coast and traveled to Japan, damaging coastal communities there. In North America, the earthquake and its tsunami left abundant evidence along the Pacific Coast, and the catastrophe entered Native American oral history as well.[7, 8]

Cascadia Earthquake and Tsunami, Pacific Coast

The Tsunami

- Residents of some Pacific Coast communities will have as little as 15-20 minutes before the first tsunami wave comes onshore following the earthquake. Individuals caught in the path of a tsunami have little chance to survive; debris may crush them or they may drown. Because of subsidence, significant flooding will occur before the first tsunami wave strike.

- A tsunami comes onshore resembling a series of quickly rising tides. It withdraws with currents much like those of a river. Swift currents carrying debris commonly cause most of the damage from tsunamis. Waves can be tens of feet high. The tsunami that followed the Sumatra earthquake in December 2004 reached 100 feet in places.[9]

- Waves can travel inland a half-mile or more, depending upon the terrain. The tsunami that struck Sumatra Island traveled up to three miles inland in places.[10]

- Tsunami waves can continue for hours; later waves can be larger, more deadly, and more damaging. For example, the third and fourth waves to strike Crescent City, CA, following the 1964 Alaska earthquake killed 11 people and caused $45-96 million in damage (2005 $).

Impact of a Cascadia Subduction Zone Earthquake, Tsunami[11]

(Note: Best-available computer modeling and loss-estimation software – HAZUS-MH, developed by FEMA and the National Institute of Building Sciences – cannot predict accurately the physical and economic losses caused by subduction-zone earthquakes. Therefore, the following narrative only provides a general description of the types of damage and impacts anticipated by scientists and engineers.)

An M 9.0 earthquake on the Cascadia Subduction Zone will be catastrophic to the Pacific Northwest. The ground could shake for four minutes or more. The earthquake and its associated hazards – ground shaking, landslides, liquefaction, subsidence, tsunamis, fires, and hazardous material spills – will create significant damage and potentially thousands of deaths and injuries.

This earthquake could result in major economic losses. Help from the national level – both the United States and Canada – will be needed. Tsunami damage and trade disruptions could affect not only the United States, but also other Pacific Rim trading partners for years to come.

Coastal communities will experience strong shaking, landslides, and subsidence. Within minutes of the earthquake, a tsunami will strike. The combination of these events along with fires caused by ruptured gas and fuel lines may devastate many coastal communities just as Hurricanes Katrina and Rita recently devastated Gulf Coast communities.

Communities could be isolated for a few days, as landslides along U.S. Highway 101 and through the Coast Range temporarily sever highway travel between the coast and inland areas to the east. Destruction of roads, airport runways, ports, and rail lines will leave some cities isolated. Buildings, roads, bridges and utility lines will suffer varying amounts of damage and destruction. Extensive injuries and fatalities will occur. Public health becomes important, because of the number of casualties and the limited medical help available.

Cascadia Earthquake and Tsunami, Pacific Coast

In the early hours after the earthquake and tsunami, residents and visitors will have to do much of the work to rescue those trapped in the rubble, provide temporary shelter, conduct immediate clean-up, and organize distribution of relief supplies as they become available. Outside assistance will be unavailable or unable to reach these communities except via helicopter or air drop because of infrastructure damage.

Much of the region's population lives along ***the Interstate 5 / U.S. Highway 99 corridor*****.** At this distance from the earthquake source, there is uncertainty about the impact of ground shaking on buildings, lifelines, and transportation systems. There likely will be local areas of concentrated damage that depends upon building types and soils.

Transportation closures for any significant period along the I-5 / U.S. 99 corridor – the center of the West Coast's north-south transportation network would have far-reaching economic consequences. It could make transport of rescue workers and emergency supplies to the area difficult immediately following the earthquake.

If the earthquake causes major damage to the region's major urban centers of Seattle, WA, and Portland, OR, economic loss could reach tens of billions of dollars. Any loss of facilities at the Ports of Seattle, WA, Tacoma, WA, and Portland, OR will ripple through the regional and national economy. Ports in Seattle and Tacoma collectively moved more than $61 billion in foreign commerce in 2003; if combined, they would be the fourth largest port in the United States behind Los Angeles, New York / New Jersey, and Long Beach.[12]

East of the Cascades**,** communities can expect a much lower level of shaking and limited damage. They will feel economic effects from regional damage, and will be important staging points for recovery efforts west of the mountains.

East-west corridors such as Interstate highways 90 and 84 and parallel rail lines may experience rock falls in the mountains that close them at least temporarily; connections to cities in the I-5 / U.S. 99 corridor could be lost for a time. Because of this, farmers could have difficulty shipping grain and other agricultural products to foreign markets. The extra demand for products needed to rebuild western Oregon and Washington and northern California will overburden rail lines, trucking, and air traffic through the eastern area of this region.

Tsunami Impact on Washington State

The Washington coast and the Strait of Juan de Fuca are vulnerable to tsunamis generated by a local Cascadia Subduction Zone earthquake and by distant earthquakes elsewhere in the Pacific Ocean basin.

NOAA's National Tsunami Hazard Mitigation Program Center for Tsunami Inundation Mapping Efforts (TIME) developed tsunami models to help potentially affected communities prepare evacuation plans and maps for a future tsunami. The models use a M9.1 subduction zone earthquake off the Washington coast as the generator of the tsunami.

The first tsunami wave will arrive in coastal communities within 30 to 60 minutes of a subduction zone earthquake[13]; in the Strait of Juan de Fuca, the first wave will arrive within 90 minutes.

Projected at-risk coastal population – 43,740[14], or about one-quarter of the population of the four counties bordering the Pacific Coast. This number excludes thousands of tourists that populate at-risk beach areas at various times of the year. It does not include at-risk communities on the east end of the Strait of Juan de Fuca such as Bellingham, Anacortes and

Mount Vernon, and Island and San Juan counties; their at-risk populations have not been calculated.

Projected Tsunami Wave Heights For Several At-Risk WA Communities

Ocean Park	29 Feet
Sunset Beach	20 Feet
Grayland	19 Feet
Long Beach	18 Feet
Westport, Ocean Shores	15 Feet
Quileute	13 Feet
Port Angeles	11 Feet
Neah Bay	10 Feet
Port Townsend	10 Feet
Aberdeen, Hoquiam	4 Feet

Note: Tsunami wave height may be larger depending upon local tide conditions. [15, 16, 17, 18, 19]

A tsunami generated by a subduction-zone earthquake will inundate or overtop at-risk coastal communities. Communities at risk to complete overtopping by a tsunami include Bay Center, Ocean Park, Long Beach, Raymond, South Bend, Westport, Ocean Shores, Hoquiam, Aberdeen, and South Aberdeen. Many of these communities are popular with tourists year-round.

At-risk tribal communities include the Makah, Hoh, Quinault, Shoalwater, Quileute, and Lower Elwha Indian nations, each with small reservations in low-lying coastal areas. Most are impoverished with little to no infrastructure to support emergency planning and response.

A subduction zone earthquake and tsunami will devastate coastal communities' tourism industry, a significant fraction of their economic base. Tourism provides from 9 to 22 percent of the jobs in the four coastal counties – Pacific, Grays Harbor, Jefferson, and Clallam – compared to 4 percent statewide. Tourism-related payroll totaled more than $155 million in 2003. The same year, visitors spent more than $507 million on accommodations, food and beverage, and entertainment in these counties, with local and state tourism-related tax receipts more than $40 million. [20, 21, 22, 23]

Tsunami Impact on Oregon

Projected Tsunami Wave Heights For Several At-Risk OR Communities[24]

Gearhart	46 Feet
Garibaldi	36 Feet
Brookings	36 Feet
Lincoln City	35 Feet
Waldport	31 Feet
Newport	30 Feet
Warrenton	30 Feet
Bandon	20 Feet
Port Orford	20 Feet

Note: Tsunami wave height may be larger depending upon local tide conditions.

The Oregon Department of Geology and Mineral Industries developed inundation maps in 1995 to support legislation that limits construction of essential facilities and special occupancy structures in tsunami flooding zones. The maps depicted expected inundation from a tsunami generated from a M8.8-8.9 earthquake on the Cascadia Subduction Zone.

Projected at-risk coastal population – nearly 63,000[25] in the seven counties bordering the Pacific Coast. This number excludes thousands of tourists that populate at-risk beach areas at various times of the year.

Communities at-risk to inundation by a subduction-zone tsunami include Bandon, Brookings, Depoe Bay, Gearhart, Gold Beach, Lincoln City, Newport, Pacific City, Port Orford, Seaside, and Yachats.[26]

Cascadia Earthquake and Tsunami, Pacific Coast

Tsunami Impact on Northern California

Not available at this time.

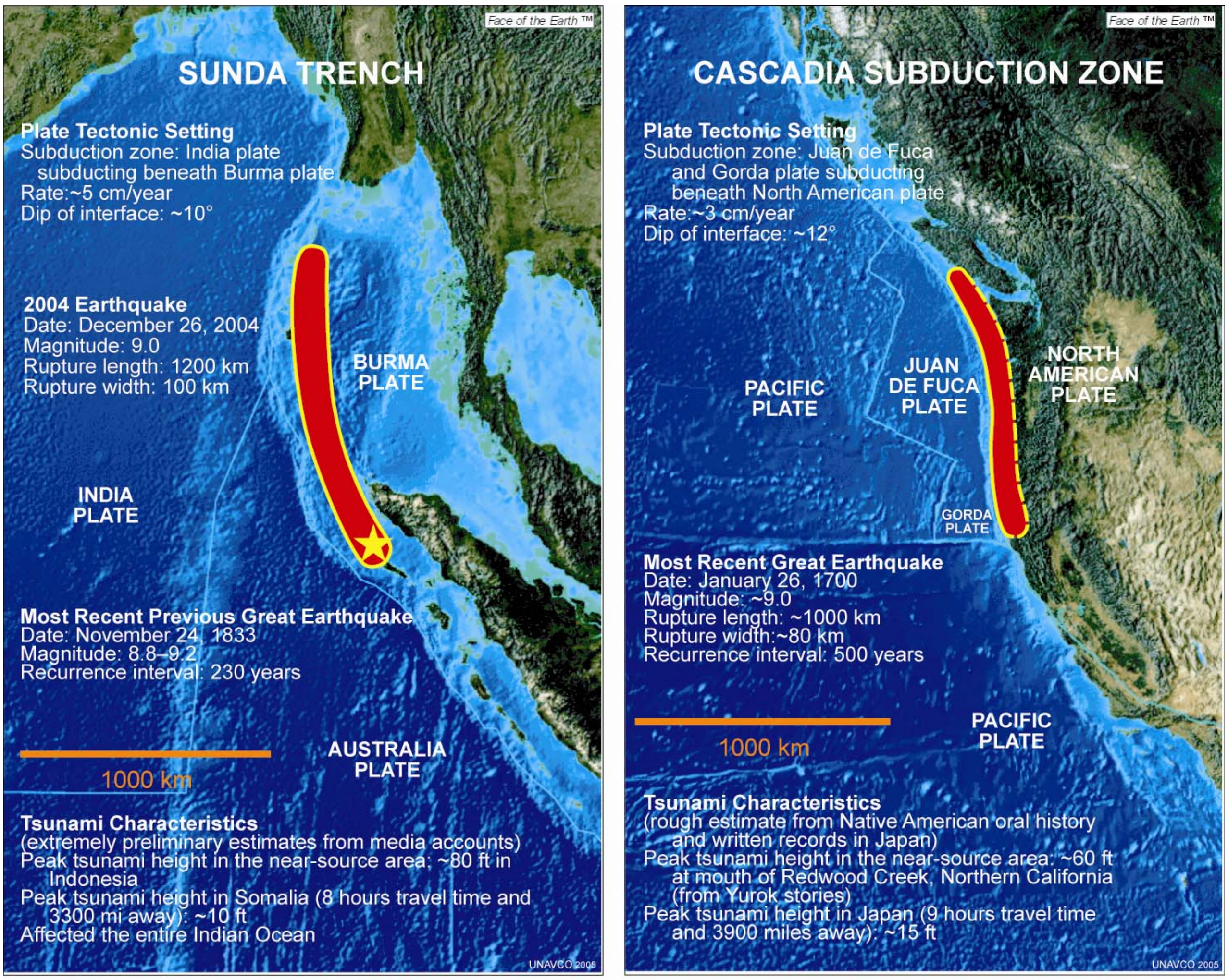
Recent Subduction Zone Earthquakes and Tsunamis Worldwide, 1960 - Present

Date	Origin	Effects	Casualties
May 22, 1960[27]	South-Central Chile EQ Magnitude 9.5	Largest earthquake recorded in the world. Damage to Chile, Hawaii (61 tsunami deaths), and Japan (118 tsunami deaths).	4,000-5,000 dead; 3,000 homeless; 2 million injured.
March 27, 1964[28]	Prince William Sound, Alaska EQ Magnitude 9.2	Second-largest earthquake in 20th century. Shaking lasted 3 minutes. Severe damage to south coast of Alaska. Wave height at Valdez Inlet estimated at 220 feet. Tsunami deaths in AK, OR, CA.	125 dead (tsunami 110, EQ 15)
Aug. 23, 1976[29]	Celebes Sea EQ Magnitude 7.9	Southwest Philippines struck, devastating Alicia, Pagadian, Cotabato and Davao.	8,000 dead
July 17, 1998[30]	Papua New Guinea EQ Magnitude 7.1	Arop, Warapu, Sissano, and Malol Papua New Guinea devastated. Wave height estimated at 33 feet.	2,200 dead; 200 missing; 9,500 homeless
Dec. 26, 2004[31,32]	Sumatra, Indonesia EQ Magnitude 9.0	Parts of Indonesia, Thailand, Malaysia, India, Sri Lanka, Maldives devastated. Wave heights reached 100 feet. Tsunami measured around the world.	283,000 dead; 14,100 missing; 1.1 million displaced
March 28, 2005[33]	Sumatra, Indonesia EQ Magnitude 8.7	Parts of Sumatra Island, Indonesia badly damaged. Wave height estimated at 10 feet.	1,400 dead

Cascadia Earthquake and Tsunami, Pacific Coast

Comparing the Sunda Trench, Cascadia Subduction Zone

The following graphic, compiled by Lori Dengler, Professor of Geology at Humboldt State University, Arcata, CA, compares the Sunda Trench subduction zone, the location of the December 2004 Indonesia earthquake and tsunami, with the Cascadia Subduction Zone off the Pacific Northwest Coast. The earthquake rupture zones are red with yellow border; the star shows the epicenter of December 2004 earthquake. As published in *DGER News*, Vol. 2, No. 1, Spring 2005, Washington Department of Natural Resources, Division of Geology and Earth Resources.



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