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Local Source (Cascadia Subduction Zone) Tsunami Inundation Map
Clatsop Spit, Oregon

2013

Introduction

The Oregon Department of Geology and Mineral Industries (DOGAMI) has been identifying and mapping the tsunami inundation hazard along the Oregon coast since 1994. In Oregon, DOGAMI manages the National Tsunami Hazard Mitigation Program, which has been administered by the National Oceanic and Atmospheric Administration (NOAA) since 1995. DOGAMI's work is designed to help cities, counties, and other sites in coastal areas reduce the potential for disastrous tsunami-related consequences by understanding and mitigating this geologic hazard. Using federal funding awarded by NOAA, DOGAMI has developed a new generation of tsunami inundation maps to help residents and visitors along the entire Oregon coast prepare for the next Cascadia Subduction Zone (CSZ) earthquake and tsunami.

The CSZ is the tectonic plate boundary between the North American Plate and the Juan de Fuca Plate (Figure 1). These plates are converging at a rate of about 1.5 inches per year, but the movement is not smooth and continuous. Rather, the plates lock in place, and unreleased energy builds over time. At intervals, this accumulated energy is violently released in the form of a megathrust earthquake rupture, where the North American Plate suddenly slips westward over the Juan de Fuca Plate. This rupture causes a vertical displacement of water that creates a tsunami (Figure 2). Similar rupture processes and tsunamis have occurred elsewhere on the planet where subduction zones exist: for example, offshore Chile in 1960 and 2010, offshore Alaska in 1964, near Sumatra in 2004, and offshore Japan in March 2011.

CSZ Frequency: Comprehensive research of the offshore geologic record indicates that at least 19 major ruptures of the full length of the CSZ have occurred off the Oregon coast over the past 10,000 years (Figure 3). All 19 of these full-rupture CSZ events were likely magnitude 8.9 to 9.2 earthquakes (Witter and others, 2011). The most recent CSZ event happened approximately 300 years ago on January 26, 1700. Sand deposits carried onshore and left by the 1700 event have been found 1.2 miles inland; older tsunami sand deposits have also been discovered in estuaries 6 miles inland. As shown in Figure 3, the range in time between these 19 events varies from 110 to 1,150 years, with a median time interval of 490 years. In 2008 the United States Geological Survey (USGS) released the results of a study announcing that the probability of a magnitude 8-9 CSZ earthquake occurring over the next 30 years is 10% and that such earthquakes occur about every 500 years (WGCEP, 2008).

CSZ Model Specifications: The sizes of the earthquake and its resultant tsunami are primarily driven by the amount and geometry of the slip that takes place when the North American Plate snaps westward over the Juan de Fuca Plate during a CSZ event. DOGAMI has modeled a wide range of earthquake and tsunami sizes that take into account different fault geometries that could amplify the amount of seawater displacement and increase tsunami inundation. Seismic geophysical profiles show that there may be a steep splay fault running nearly parallel to the CSZ but closer to the Oregon coastline (Figure 1). The effect of this splay fault moving during a full-rupture CSZ event would be an increase in the amount of vertical displacement of the Pacific Ocean, resulting in an increase of the tsunami inundation onshore in Oregon. DOGAMI has also incorporated physical evidence that suggests that portions of the coast may drop 4 to 10 feet during the earthquake; this effect is known as subsidence. Detailed information on fault geometries, subsidence, computer models, and the methodology used to create the tsunami scenarios presented on this map can be found in DOGAMI Special Papers 41 (Priest and others, 2009) and 43 (Witter and others, 2011).

Map Explanation

This tsunami inundation map displays the output of computer models representing five selected tsunami scenarios, all of which include the earthquake-produced subsidence and the tsunami-amplifying effects of the splay fault. Each scenario assumes that a tsunami occurs at Mean Higher High Water (MHHW) tide; MHHW is defined as the average height of the higher high tides observed over an 18-year period at the Astoria tide gauge (NOAA Station 9439040). To make it easier to understand this scientific material and to enhance the educational aspects of hazard mitigation and response, the five scenarios are labeled as "T-shirt sizes" ranging from Small, Medium, Large, Extra Large, to Extra Extra Large (S, M, L, XL, XXL). The map legend depicts the respective amounts of slip, the frequency of occurrence, and the earthquake magnitude for these five scenarios. Figure 4 shows the cumulative number of buildings inundated within the map area.

The computer simulation model output is provided to DOGAMI as millions of points with values that indicate whether the location of each point is wet or dry. These points are converted to wet and dry contour lines that form the extent of inundation. The transition area between the wet and dry contour lines is termed the Wet/Dry Zone, which equates to the amount of error in the model when determining the maximum inundation for each scenario. Only the XXL Wet/Dry Zone is shown on this map.

This map also shows the regulatory tsunami inundation line (Oregon Revised Statutes 455.446 and 455.447), commonly known as the Senate Bill 379 line. Senate Bill 379 (1995) instructed DOGAMI to establish the area of expected tsunami inundation based on scientific evidence and tsunami modeling in order to prohibit the construction of new essential and special occupancy structures in this tsunami inundation zone (Priest, 1995).

Time Series Graphs and Wave Elevation Profiles: In addition to the tsunami scenarios, the computer model produces time series data for "gauge" locations in the area. These points are simulated gauge stations that record the time, in seconds, of the tsunami wave arrival and the wave height observed. It is especially noteworthy that the greatest wave height and velocity observed are not necessarily associated with the first tsunami wave to arrive onshore. Therefore evacuees should not assume that the tsunami event is over until the proper authorities have sounded the all-clear signal at the end of the evacuation. Figure 5 depicts the tsunami waves as they arrive at a simulated gauge station. Figure 6 depicts the overall wave height and inundation extent for all five scenarios at the profile locations shown on this map.

Cascadia Subduction Zone Setting

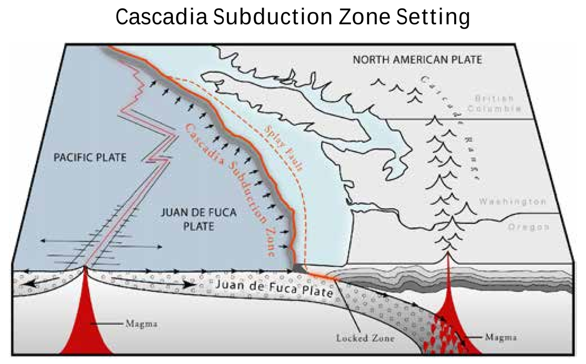
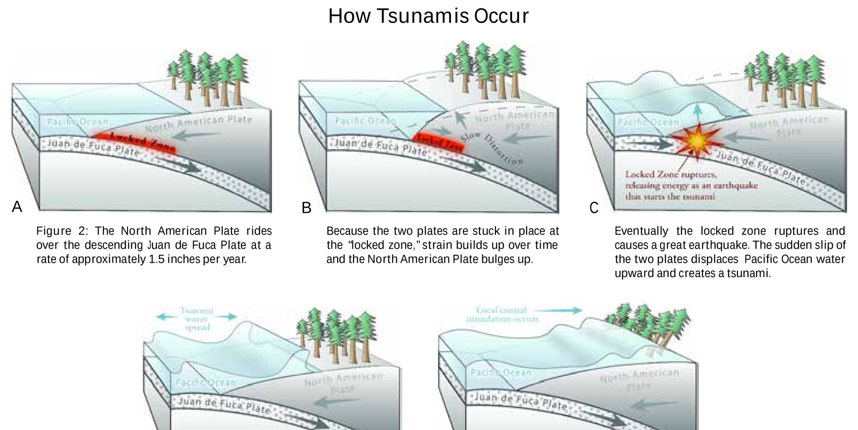


Figure 1: This block diagram depicts the tectonic setting of the region. See Figure 2 for the sequence of events that occur during a Cascadia Subduction Zone megathrust earthquake and tsunami.

How Tsunamis Occur



A: Figure 2: The North American Plate rides over the descending Juan de Fuca Plate at a rate of approximately 1.5 inches per year.

B: Because the two plates are stuck in place at the "locked zone," strain builds up over time and the North American Plate bulges up.

C: Eventually the locked zone ruptures and causes a great earthquake. The sudden slip of the two plates displaces Pacific Ocean water upward and creates a tsunami.

D: Displaced and uplifted Pacific Ocean water rushes in all directions.

E: Along the Oregon coast, tsunami waves run up onto the land for several hours.

Occurrence and Relative Size of Cascadia Subduction Zone Megathrust Earthquakes

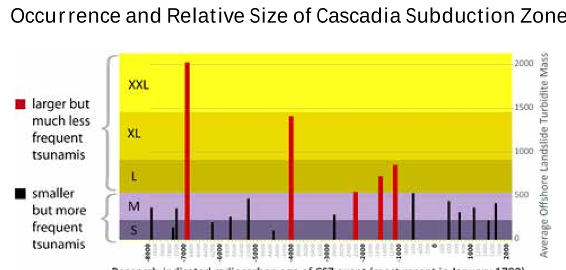


Figure 3: This chart depicts the timing, frequency, and magnitude of the last 19 great Cascadia Subduction Zone events over the past 10,000 years. The most recent event occurred on January 26, 1700. The 1700 event is considered to be a "medium sized" event. The data used to create this chart came from research that examined the many submarine landslides, known as "turbidites," that are triggered only by these great earthquakes (Witter and others, 2011). The loose correlation is "the bigger the turbidite, the bigger the earthquake."

Buildings within Tsunami Inundation Zones

	Entire Map Area	City of Warrenton	Unincorporated Areas
Total Buildings	77	65	12
Buildings within Tsunami Zones*			
Small	2	0	2
Medium	63	51	12
Large	77	65	12
Extra Large	77	65	12
Extra Extra Large	77	65	12
Percent of Buildings within Tsunami Zones			
Small	2.6%	0.0%	16.7%
Medium	81.8%	78.5%	100.0%
Large	100.0%	100.0%	100.0%
Extra Large	100.0%	100.0%	100.0%
Extra Extra Large	100.0%	100.0%	100.0%

*Building counts shown are based on polygon centroids and are cumulative within the map area.

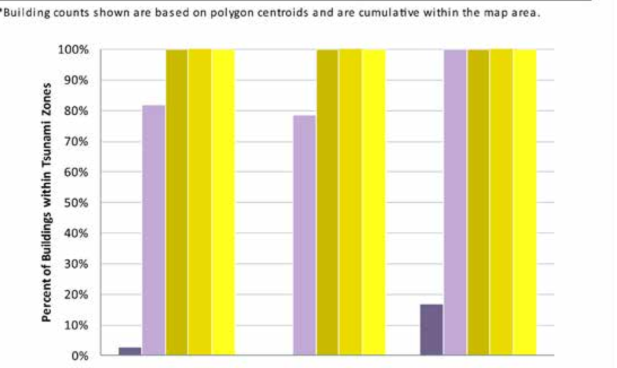


Figure 4: The table and chart show the number of buildings inundated for each "tsunami T-shirt scenario" for cities and unincorporated portions of the map.

Estimated Tsunami Wave Height through Time for Simulated Gauge Station

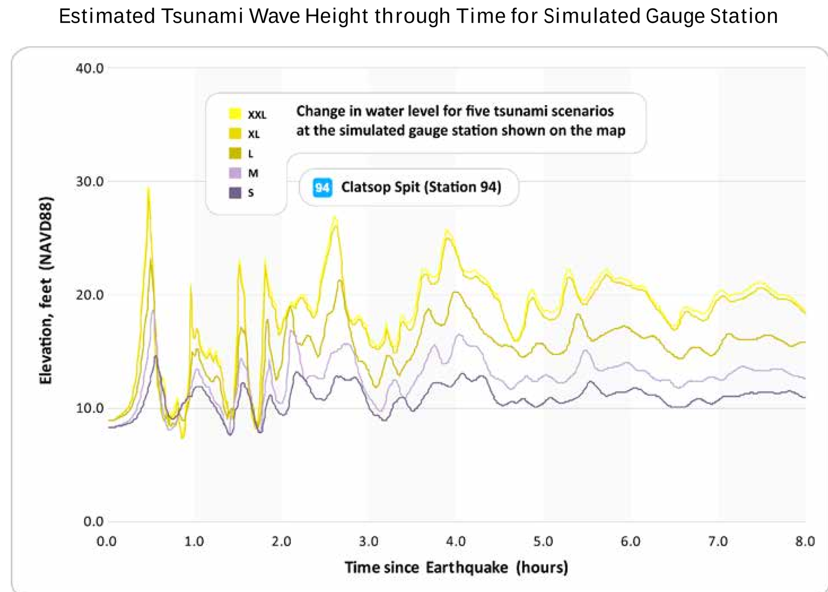


Figure 5: This chart depicts the tsunami waves as they arrive at the selected reference point (simulated gauge station). It shows the change in wave heights for all five tsunami scenarios over an 8-hour period. The starting water elevation (0.0 hour) takes into account the local land subsidence or uplift caused by the earthquake. Wave heights vary through time, and the first wave will not necessarily be the largest as waves interfere and reflect off local topography and bathymetry. Any absence of data indicates periods for which tsunami inundation has not yet reached or has receded from the station location and dry land is exposed.

Maximum Wave Elevation

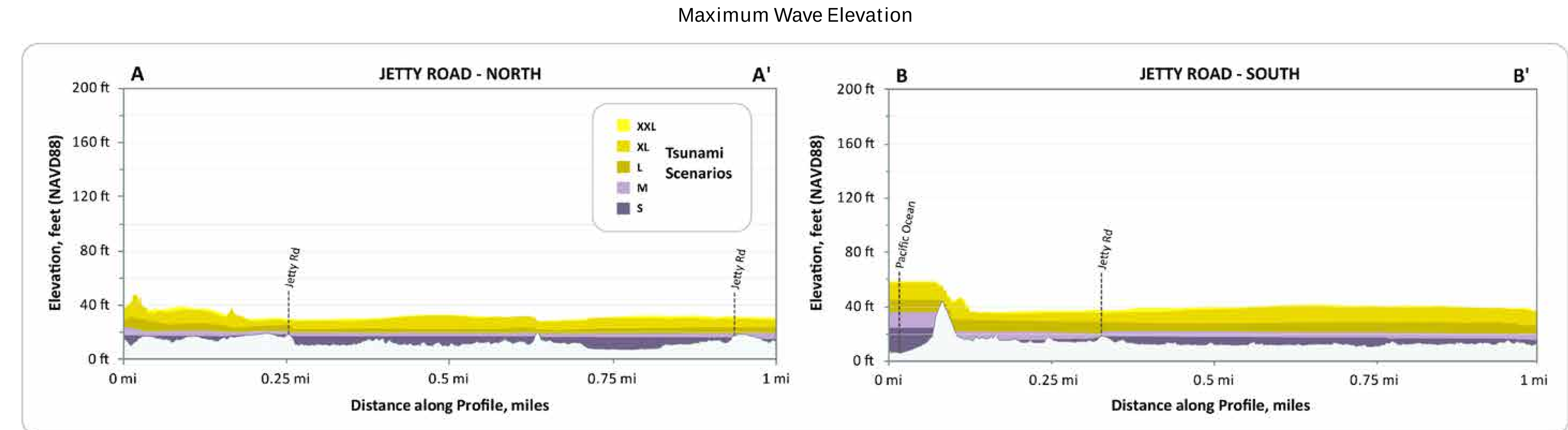


Figure 6: These profiles depict the expected maximum tsunami wave elevation for the five "tsunami T-shirt scenarios" along lines A-A' and B-B'. The tsunami scenarios are modeled to occur at high tide and to account for local subsidence or uplift of the ground surface.

APPROXIMATE MEAN MAGNETIC DECLINATION JANUARY 1, 2012

Scale 1:10,000

0 — 0.25 — 0.5 Mile

0 — 0.25 — 0.5 — 1 Kilometer

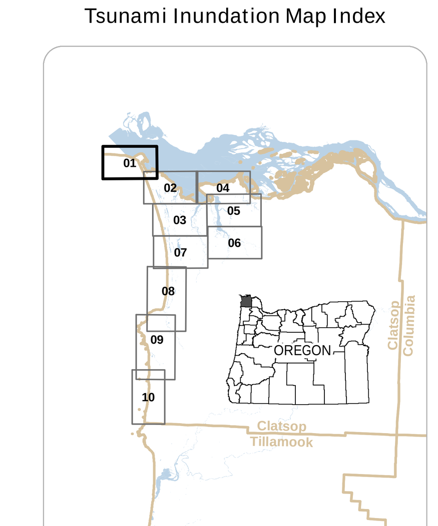
Legend

Earthquake Size		Average Slip Range (ft)	Maximum Slip Range (ft)	Time to Accumulate Slip (yrs)	Earthquake Magnitude
	XXL	59 to 72	118 to 144	1,200	~9.1
	XL	56 to 72	115 to 144	1,050 to 1,200	~9.1
	L	36 to 49	72 to 98	650 to 800	~9.0
	M	23 to 30	46 to 62	425 to 525	~8.9
	S	13 to 16	30 to 36	300	~8.7

XXL Wet/Dry Zone

Urban Growth Boundary
Building Footprint
Simulated Gauge Station
Profile Location
Senate Bill 379 Line
State Park
Elevation Contour (25 ft intervals up to 200 ft)
Fire Station
Police Station
School
Hospital/Urgent Care Clinic
U.S. Highway
State Highway
Improved Road

Tsunami Inundation Map Index



Clat-01	Clatsop Spit	Clat-06	Youngs River South
Clat-02	Warrenton North	Clat-07	Del Rey Beach
Clat-03	Warrenton South - Rilea	Clat-08	Gearhart - Seaside
Clat-04	Astoria	Clat-09	Cannon Beach
Clat-05	Youngs River North	Clat-10	Arch Cape - Falcon Cove

Data References

Source Data:
This map is based on hydrodynamic tsunami modeling by Joseph Zhang, Oregon Health and Science University, Portland, Oregon. Model data input were created by John T. English and George R. Priest, Department of Geology and Mineral Industries (DOGAMI), Portland, Oregon.

Hydrology data, contours, critical facilities, and building footprints were created by DOGAMI. Senate Bill 379 line data were redigitized by Rachel L. Smith and Sean G. Pickner, DOGAMI, in 2011 (GIS file set, in press, 2012).

Urban growth boundaries (2011) were provided by the Oregon Department of Land Conservation and Development (DLCD).

Transportation data (2011) provided by Clatsop County were edited by DOGAMI to improve the spatial accuracy of the features or to add newly constructed roads not present in the original data layer.

Lidar data are from DOGAMI Lidar Data Quadrangles LDQ-2011-46123-B8-Warrenton and LDQ-2011-46124-B1-Clatsop Spit.

Coordinate System: Oregon Statewide Lambert Conformal Conic, Unit: International Feet, Horizontal Datum: NAD 1983 HARN, Vertical Datum: NAVD 1988. Graticule shown with geographic coordinates (latitude/longitude).

Software: Esri ArcGIS® 10.1, Microsoft® Excel®, and Adobe® Illustrator®

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Editing: Don W.T. Lewis, Rachel L. Smith
Publication: Deborah A. Schueller
Map Date: 06/05/2013

References:
2007 Working Group on California Earthquake Probabilities (WGCEP), 2008, The Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2): U.S. Geological Survey Open-File Report 2007-1437 and California Geological Survey Special Report 203 [http://pubs.usgs.gov/of/2007/1437/].

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