

## 2013

## Tsunami Inundation Map Doug-09

## Tsunami Inundation Maps for Clear Lake, Douglas County, Oregon

## Plate 1

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 states 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-length 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 offshore and left by the 1700 event have been found 1.2 miles inland, where 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 slips 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 seafloor displacement and increase tsunami inundation. Seismic geophysical profiles show that there may be a steep slip fault running nearly parallel to the CSZ but closer to the Oregon coastline (Figure 1). The effect of this slip 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).

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 spillay fault. Each scenario assumes that a tsunami occurs at Menikoff High Water Line (MHWW) tide; MHWW is defined as the average height of the higher high tides observed over an 18-year period at the Yaquina Bay (Central Coast Model) tide gauge. 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.

A cross-sectional diagram of the Juan de Fuca Plate subducting beneath the North American Plate. The Pacific Plate is shown to the left, with the Juan de Fuca Plate extending from it. The Juan de Fuca Plate is shown dipping into the mantle beneath the North American Plate. A 'Locked Zone' is indicated at the interface between the plates. Magma is shown rising from the mantle at two locations: one near the subducting plate and another further inland under the North American Plate. The diagram also shows the 'Buller's Geoclone' and 'Washington Dike' features.

**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.

**A**

**B**

**C**

**D**

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

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

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.

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

Dispersed and upflung Pacific Ocean water rushes in all directions.

**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 lower categorization is "the larger the turbidite, the bigger the earthquake".

|                                                  |                   | Entire Map Area |  | Unincorporated Areas |  |
|--------------------------------------------------|-------------------|-----------------|--|----------------------|--|
|                                                  |                   | 199             |  | 199                  |  |
| <b>Total Buildings</b>                           |                   |                 |  |                      |  |
| <b>Buildings within Tsunami Zones*</b>           |                   |                 |  |                      |  |
|                                                  | Small             | 19              |  | 19                   |  |
|                                                  | Medium            | 26              |  | 26                   |  |
|                                                  | Large             | 27              |  | 27                   |  |
|                                                  | Extra Large       | 31              |  | 31                   |  |
|                                                  | Extra Extra Large | 31              |  | 31                   |  |
| <b>Percent of Buildings within Tsunami Zones</b> |                   |                 |  |                      |  |
|                                                  | Small             | 9.5%            |  | 9.5%                 |  |
|                                                  | Medium            | 13.1%           |  | 13.1%                |  |
|                                                  | Large             | 13.6%           |  | 13.6%                |  |
|                                                  | Extra Large       | 15.6%           |  | 15.6%                |  |
|                                                  | Extra Extra Large | 15.6%           |  | 15.6%                |  |

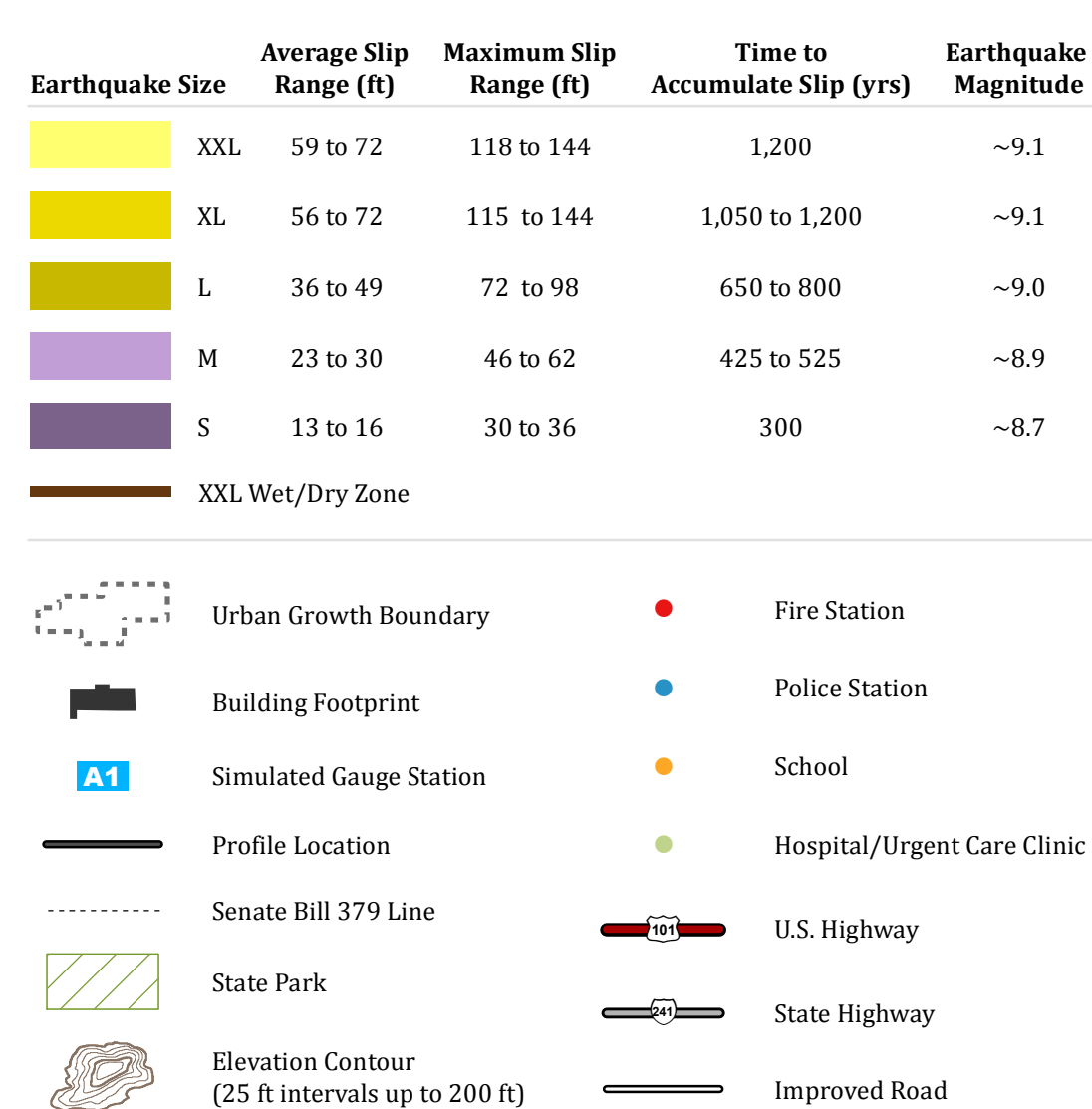
\*Building counts shown are based on polygon centroids and are cumulative within the map area.

| Area                 | Dark Purple Bar (%) | Medium Purple Bar (%) | Yellow Bar (%) |
|----------------------|---------------------|-----------------------|----------------|
| Entire Map Area      | ~10                 | ~12                   | ~15            |
| Unincorporated Areas | ~10                 | ~12                   | ~15            |

**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.



**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.



The map displays the Klamath River watershed with 10 sampling sites marked by numbered boxes. The river flows from the north (top) towards the south (bottom). Lake Douglas is located to the east of the river. The Oregon-California border is indicated by a dashed line. An inset map of Oregon shows the study area's location in the northwest corner of the state.

| Site Number | Location          |
|-------------|-------------------|
| 01          | Slitteen Lake     |
| 02          | Taklamakan Lake   |
| 03          | Gardiner          |
| 04          | East Gardner      |
| 05          | Brusport          |
| 06          | Impewa River West |
| 07          | Sulphur Springs   |
| 08          | Impewa River East |
| 09          | Clear Lake        |
| 10          | Clear Lake        |

[illegible]