Modeling Crustal Fault Earthquakes and Tsunamis to the Sequim Dungeness River Marsh

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What do we know?

- 7 Cascadia events have occurred in the last 3,000 years (Atwater et al, 2004).
- 3 Cascadia events have been positively identified in tsunami deposits found in the Waatch Valley and Neah Bay, Washington (Peterson et al., 2013).
- 6 to 8 additional tsunami deposits have been found in the Puget Sound that have yet to be correlated to Cascadia, the Seattle Fault, or other known sources (Williams and Hutchinson, 2000; Williams et al., 2005).
- To date, no field studies have been completed at the Dungeness River Marsh.

Aerial view of the Dungeness River Marsh looking east. Source: Washington State Department of Ecology, 2006

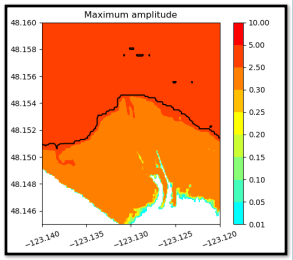
Site Background

Vicinity Map showing the location of the Dungeness River Marsh on the Olympic Peninsula. Source: Google Earth, 2018

- The Dungeness River Marsh is located on the Olympic Peninsula in Sequim, Washington.
- The marsh surrounding the river mouth covers an area 0.7 square km in size.
- Northwest of the marsh lies the Dungeness Spit, an 11 km long sand spit that acts as a barrier to westerly waves.

Methods

- GeoClaw tsunami modeling code was used to simulate different earthquake scenarios and to create inundation maps.
- Standard earthquake source models of hypothetical Cascadia events from Witter et al. (2013) were used to predict the possibility of inundation at the site.
- 14 hypothetical earthquakes were created from Leech River and Utsalady Point estimated fault parameters.
- ArcGIS software was used to create composite inundation hazard maps to show the maximum flood distance for each of the earthquake scenarios relative to one another.

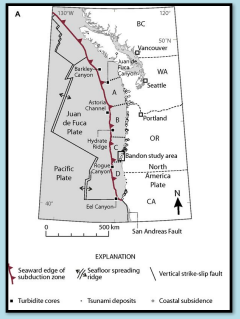


Plot from GeoClaw showing extent of flooding for Cascadia L1 scenario. Source: GeoCLAW, 2018

Cascadia earthquakes

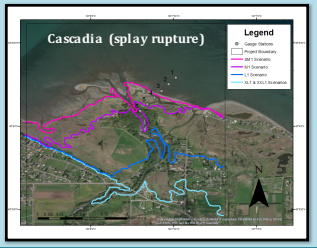
Cascadia megathrust earthquakes were based on scenarios constructed by Witter et al. (2013). These scenarios are divided into four general earthquake size classes based on 19 Holocene turbidite deposits that have been discovered along the Cascadia subduction zone (Goldfinger et al., 2012). The most recent 1700 AD event is categorized as an M.

Earthquake Size Class	Average Recurrence Interval	# of Cascadia-Correlated Turbidite Events
Small (SM)	300 years	5
Medium (M)	525 years	10
Large (L)	800 years	3
Extra-Large (XL)	1,200 years	1



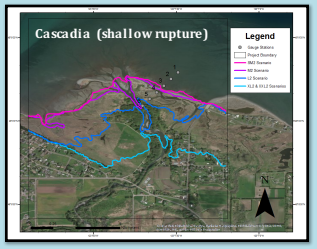
Cascadia Subduction Zone. Source: Witter et al. (2013)

Inundation Maps

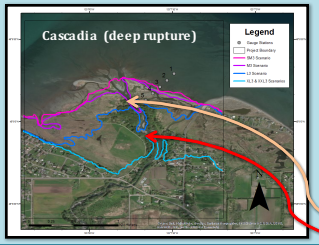


Cascadia earthquakes with splay ruptures cause greater inundation than shallow or deep ruptures.

Cascadia Fault Type	Numerical Designation
Splay fault	1
Shallow buried Rupture	2
Deep Buried Rupture	3

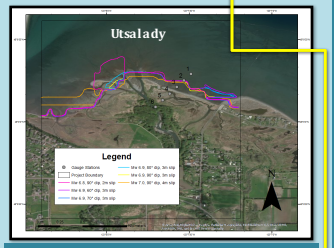


Small (S) Cascadia earthquakes are unlikely to cause significant inundation of the Dungeness River marsh.



Extra-large (XL) Cascadia earthquakes are capable of inundating most of the Dungeness River Marsh.

Tsunami deposits from Leech River earthquakes could potentially be found on the east side of the Dungeness River marsh.

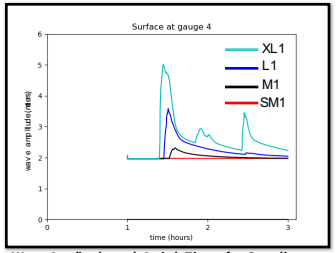


Simulations of Utsalady fault earthquakes indicate limited inundation potential at this site.

Where to dig?
XL Cascadia L+ Cascadia
Small local events

Wave Amplitude & Arrival Times for Cascadia

- **The first major wave** will strike the Dungeness River Marsh in **90 minutes**, regardless of size or rupture style.
- After the first wave inundates, at least **two more waves** are expected to occur at **30 minute intervals.**
- A **M1** size earthquake is capable of generating tsunami waves **over 2 meters** in height.
- A **XL1** size earthquake is capable of generating tsunami waves **5 meters** in height.

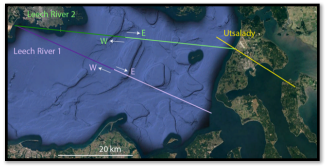


Wave Amplitude and Arrival Times for Cascadia earthquakes.

Local Crustal Faults

Leech River fault

- Two known ruptures of the Leech River fault have occurred in the last 12,000 years. The magnitude of these quakes is estimated to be 6.5 to 7.0. (Morell, 2017)
- Two suspected locations for the Leech River fault were modeled in this study.
- For each location, 4 unique rupture scenarios were simulated to determine a range of tsunami inundation potential at the Dungeness River marsh site.
- The extent of inundation is similar for both locations.
- East side ruptures have greater inundation at the Dungeness River marsh site.



Location of Leech River fault and Utsalady Point fault. Source: Google Earth, 2018

Utsalady Point fault

- Two ruptures of the Utsalady fault have occurred in the last 2,200 years (Johnson et al. 2004).
- For this earthquake source, 6 unique rupture scenarios were simulated.
- Little offshore deformation produced a small tsunami.
- Little offshore deformation produced a small tsunami.

Conclusions

- Small (S) Cascadia source earthquakes appear unlikely to have left tsunami deposits at this site.
- Medium (M) to extra-large (XL) Cascadia source earthquakes appear likely to have caused significant inundation of the Dungeness River marsh area.
- Utsalady fault source earthquakes appear unlikely to have left tsunami deposits at this site.
- Leech River fault source earthquakes may have left tsunami deposits on the eastern side of the Dungeness River.

Why We Care

- Only the Seattle fault and Cascadia L1 scenario are considered for hazard planning purposes in the Puget Sound, thus highlighting the need for a more extensive analysis of other local crustal fault sources to accurately assess tsunami hazard.
- Just east of the Dungeness River marsh there are many residences located near the shoreline that are at risk of flooding from tsunamis. Verifying the presence of historic tsunami deposits at Dungeness River marsh helps clarify the risk of inundation to these homes.

What's Next?

- Model other local, upper crustal faults such as: the San Juan fault, the South Whidbey Island fault, Strawberry Point fault, Darrington-Devils Mountain fault, Sandy Point fault, Birch Bay fault, Boulder Creek fault, and the Lake Creek-Boundary fault.
- Dig at key locations in the Sequim Dungeness River Marsh site where the preservation potential of tsunami deposits is high.

Acknowledgements

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