NACIS 2019 TACOMA

WASHINGTON STATE DEPT OF NATURAL RESOURCES
WASHINGTON GEOLOGICAL SURVEY

Daniel Coe
Washington Geological Survey

MAPPING THE WAVE

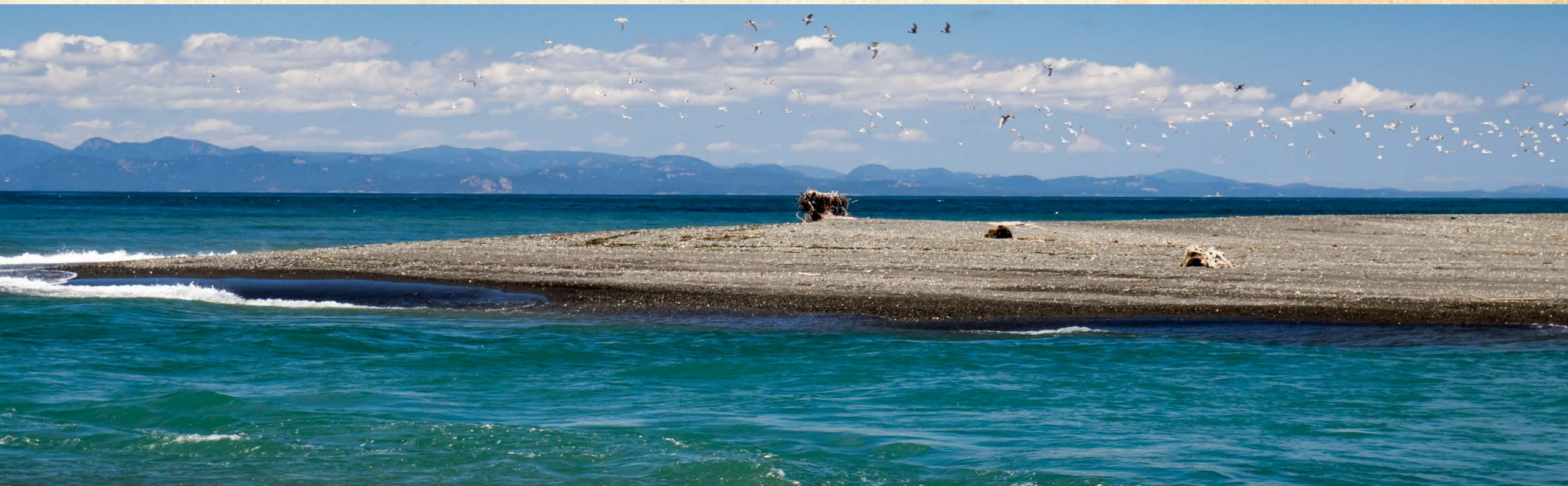
Depicting Tsunami Hazards in Washington State

image modified from: The Great Wave (Kanagawa Oki Nami Ura) by Hokusai Katsushika

Washington Geological Survey

WASHINGTON STATE DEPT OF NATURAL RESOURCES
WASHINGTON GEOLOGICAL SURVEY

MISSION: To collect, develop, use, distribute, and preserve geologic information to promote the safety, health, and welfare of the residents of Washington, protect the environment, and support its economy.



Tsunamis in the Pacific Northwest

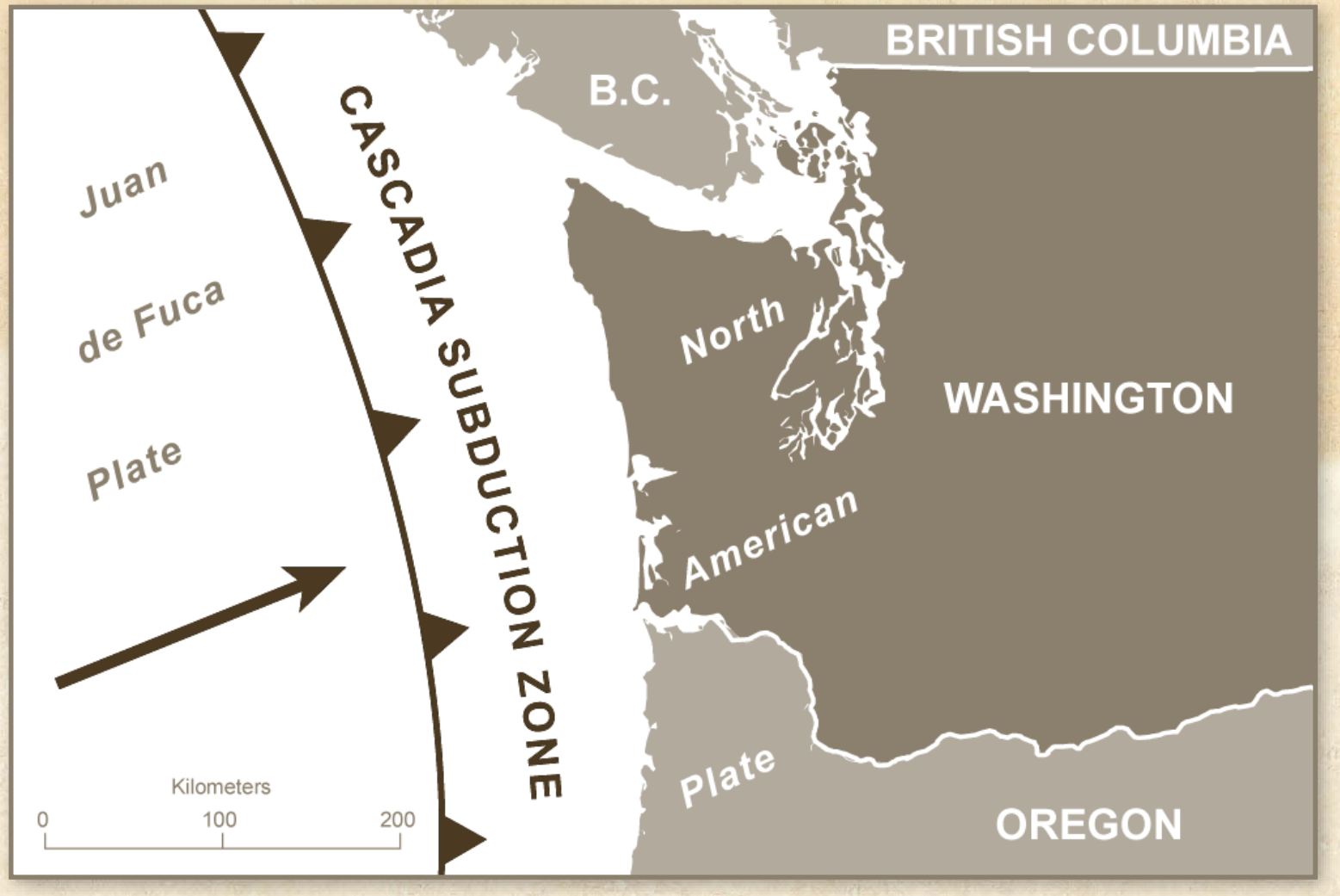
- Distant and Local Sources
- Local Cascadia-induced tsunami
  - < 15 minutes before tsunami reaches coast
  - potential for inundation up to 60 feet

Tsunamis in the Pacific Northwest

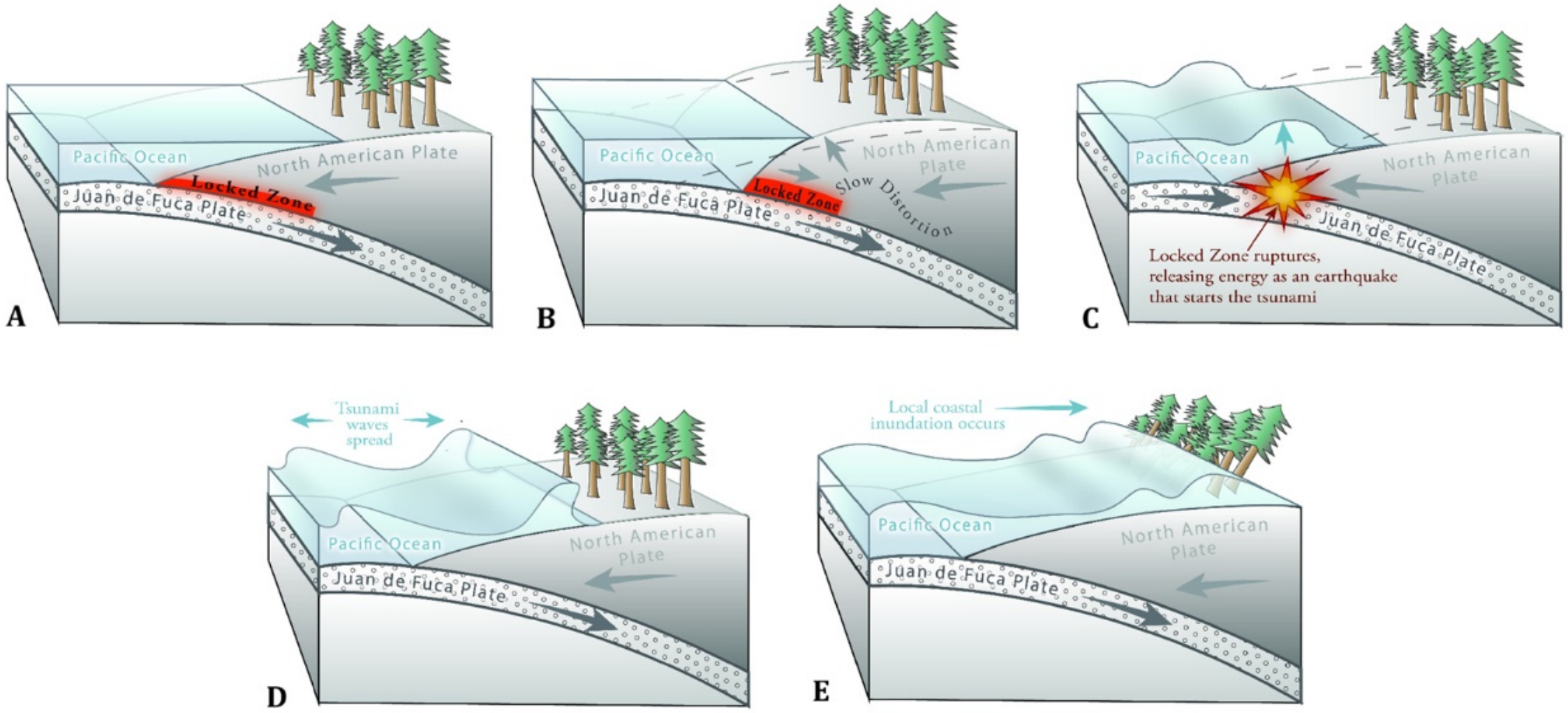
- Many communities in tsunami inundation zones
- 31,000 WA students attend schools in tsunami inundation zones
  (Doughton and Gilbert, 2016)
- Summer tourism greatly increases coastal population

Cascadia Subduction Zone (CSZ)

- Average interval between earthquakes: 240 years
- Average interval between large (>8.5 M_w) earthquakes: 500–600 years
- Last large CSZ earthquake: January 26, 1700

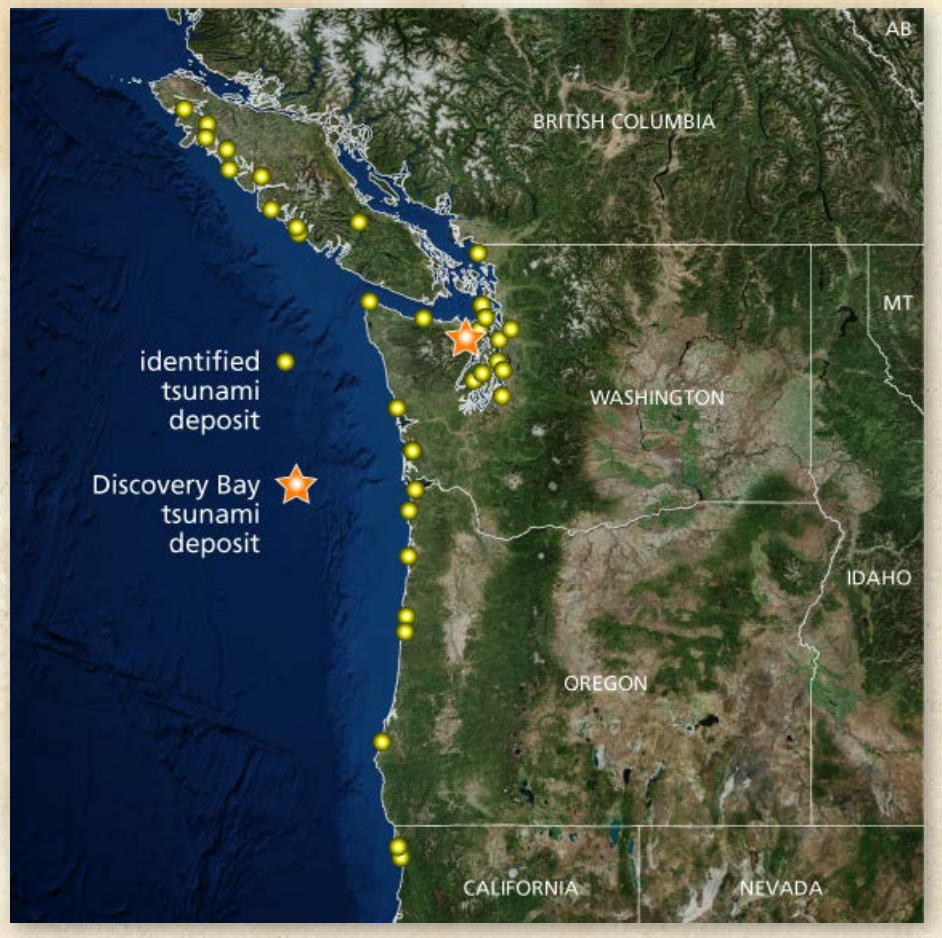


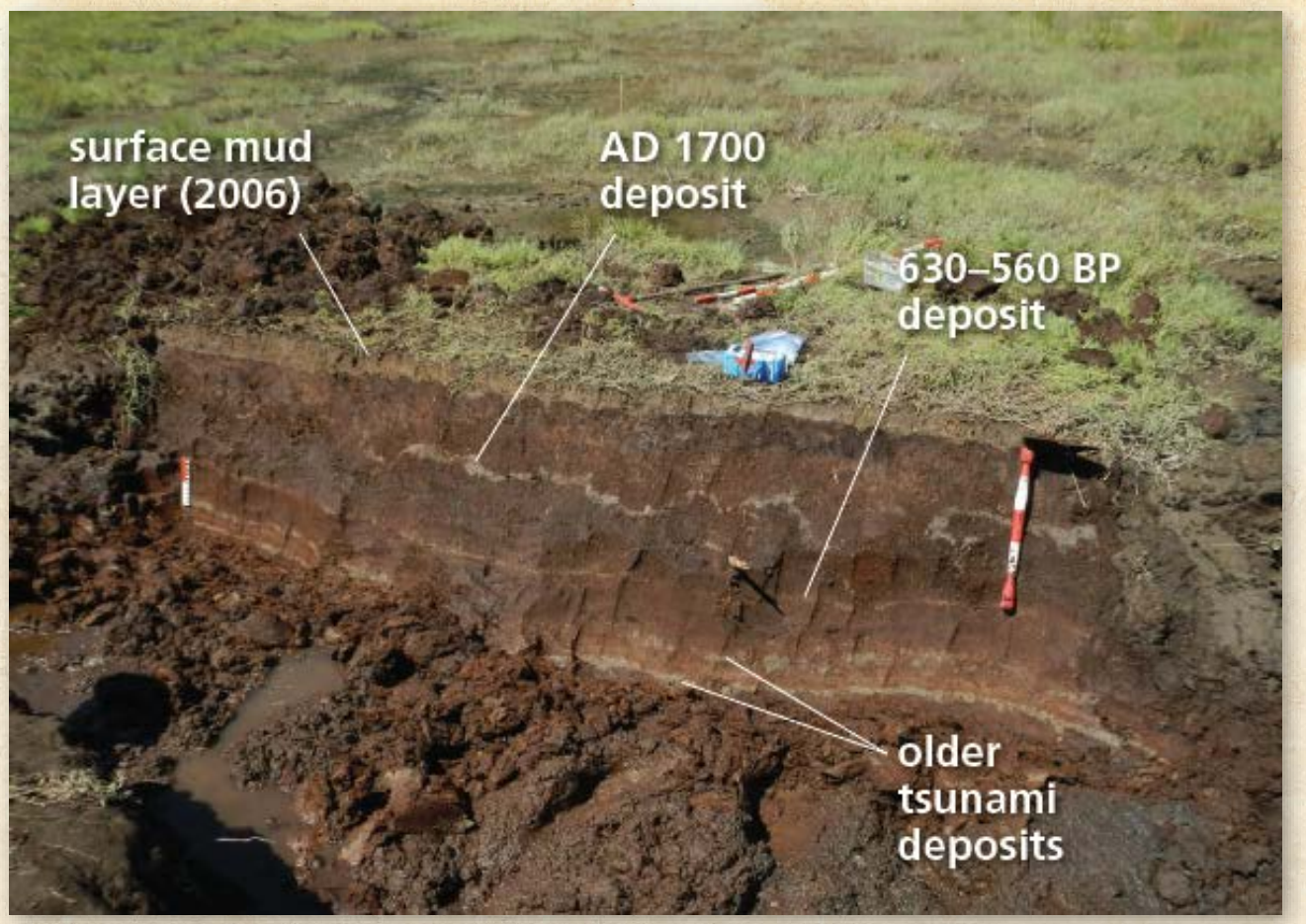
CSZ Earthquake and Tsunami



Source: DOGAMI

CSZ Earthquake and Tsunami





Images: Carrie Garrison-Laney (WA SeaGrant)

2011 Tōhoku Earthquake and Tsunami

- Magnitude 9.0–9.1 ($\mathbf{M_w}$) earthquake
- Massive tsunami inundation multiple stories high
- Hundreds of billions of dollars in damage
- Over 15,000 deaths

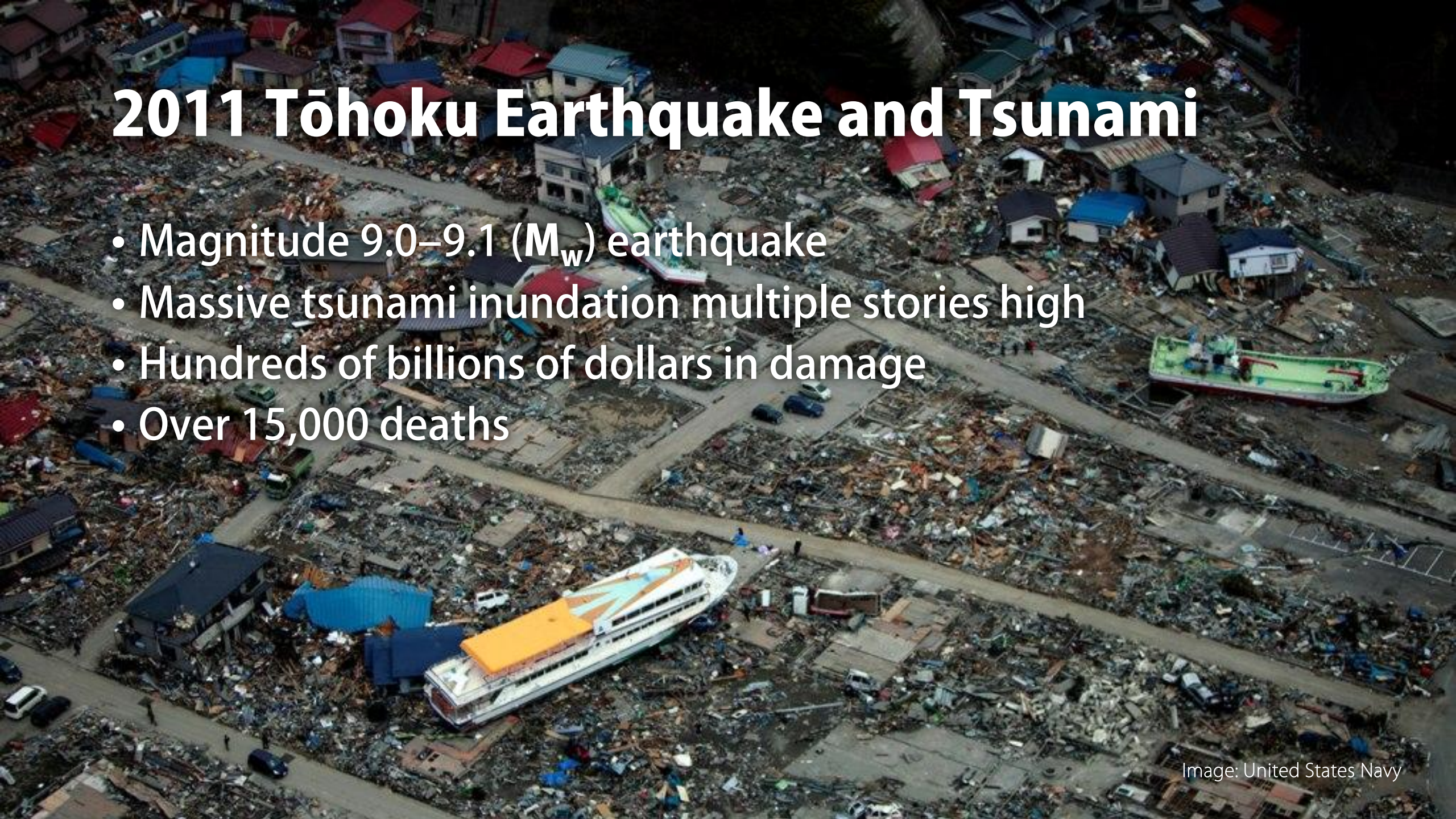
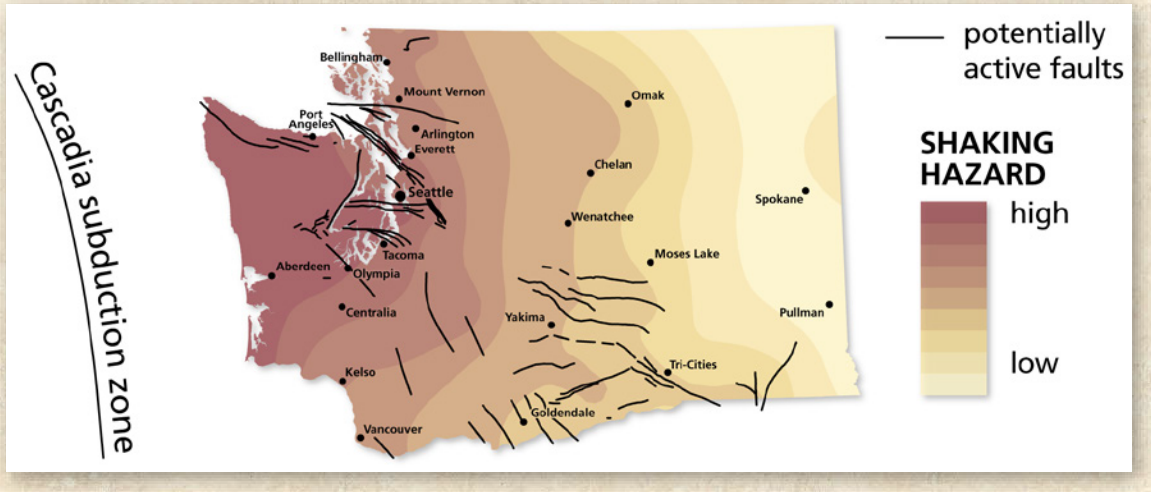


Image: United States Navy

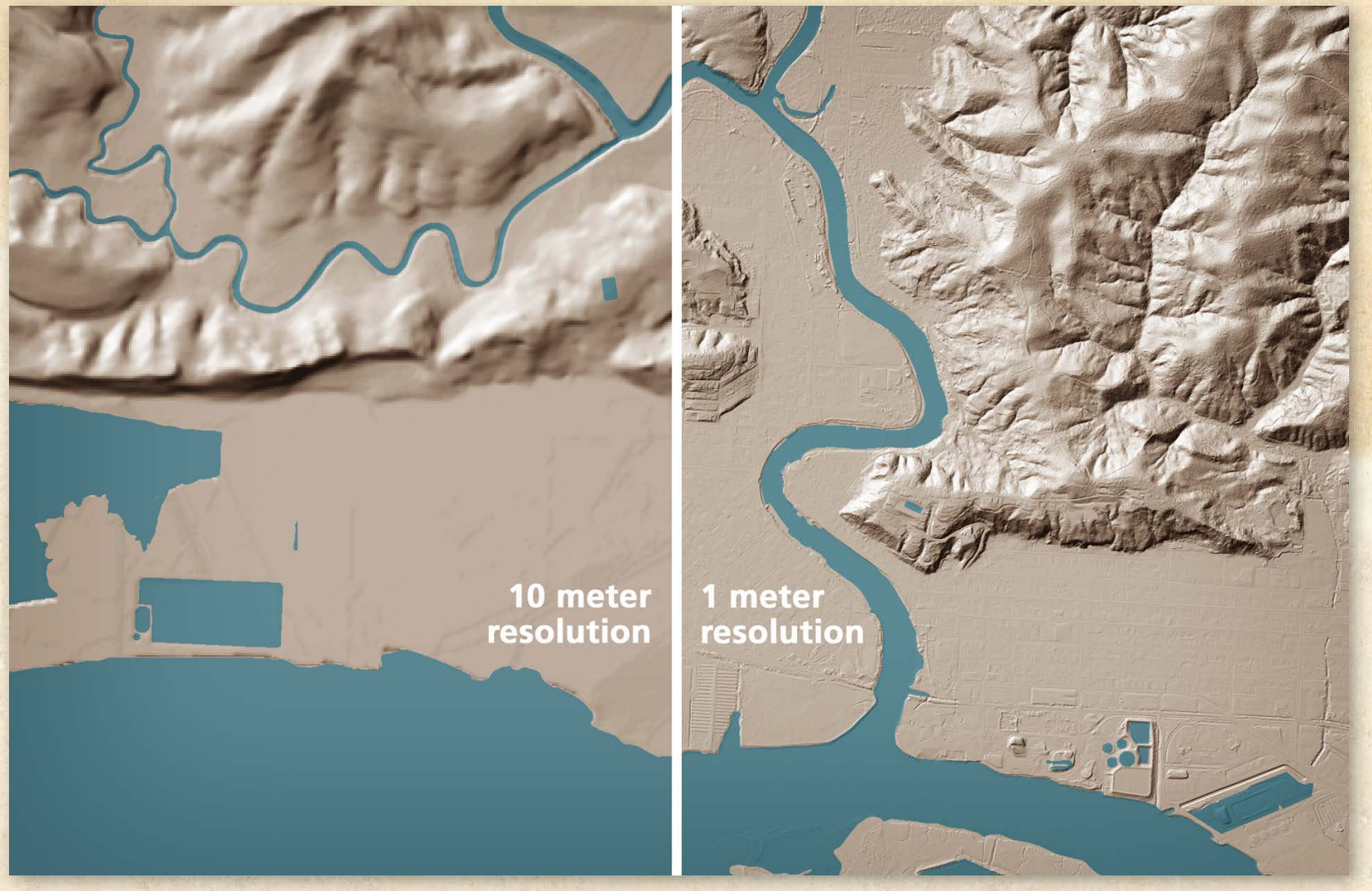
Tsunami Mapping Challenges

- Multiple earthquake scenarios



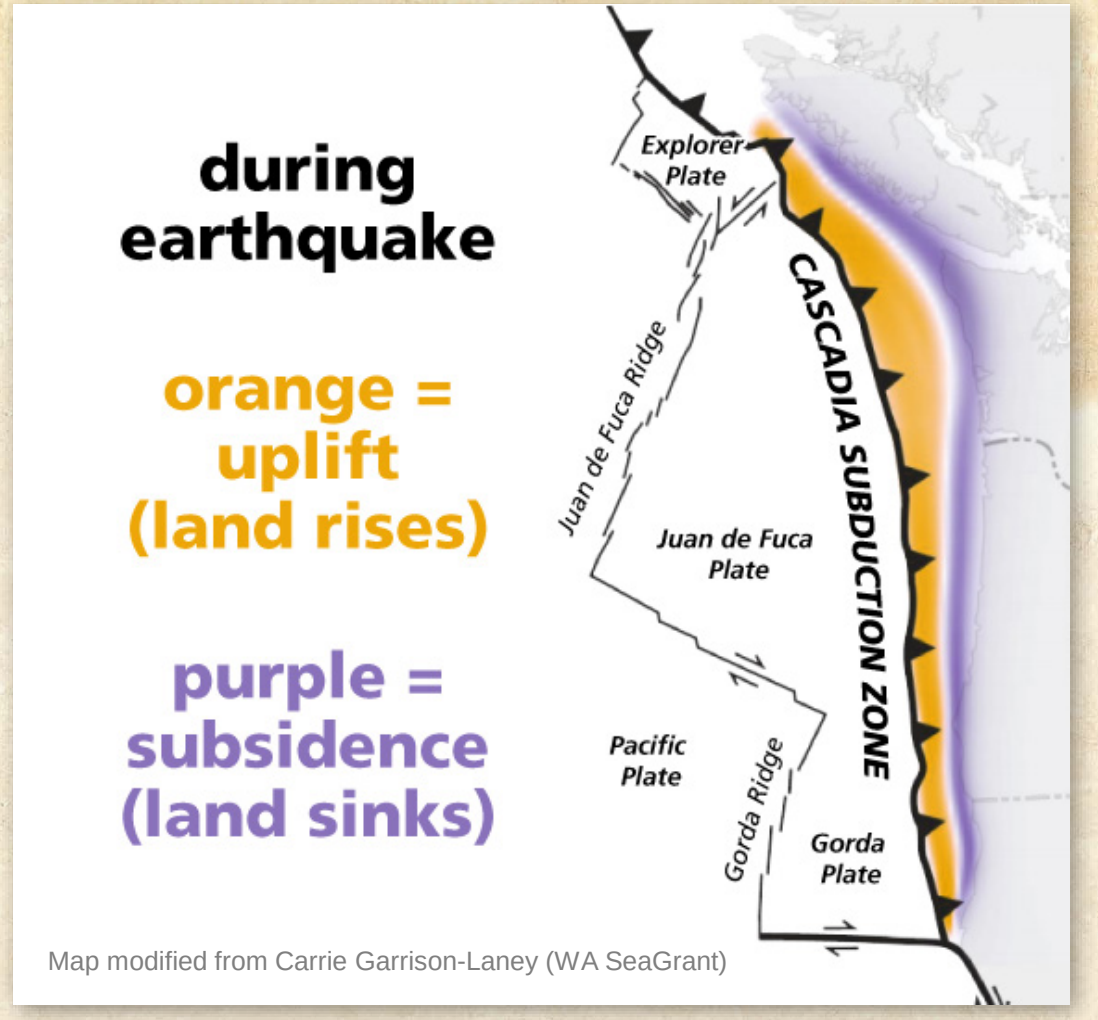
Tsunami Mapping Challenges

- Multiple earthquake scenarios
- Data inconsistencies / updates



Tsunami Mapping Challenges

- Multiple earthquake scenarios
- Data inconsistencies / updates
- Earthquake uplift and subsidence



Map modified from Carrie Garrison-Laney (WA SeaGrant)

Tsunami Mapping Challenges

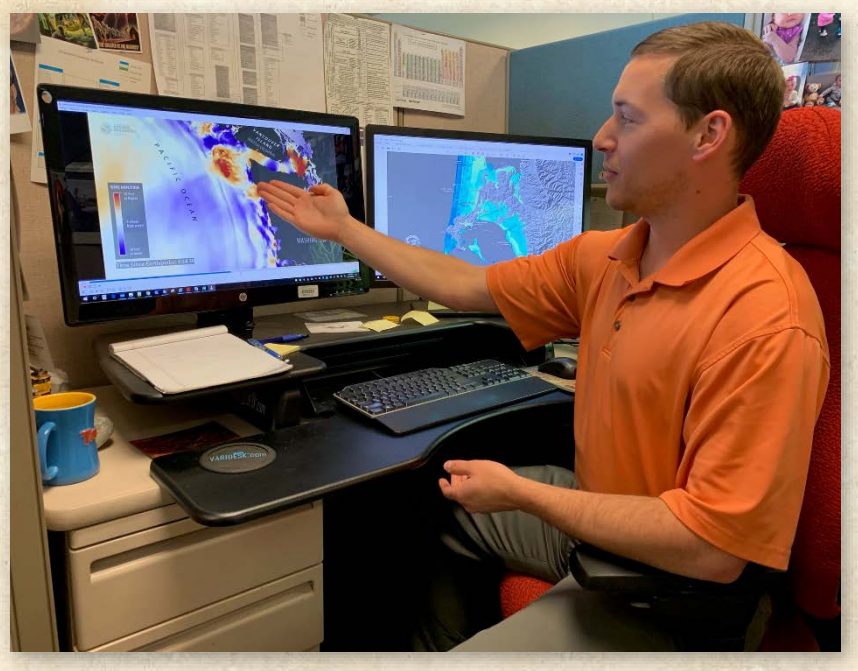
- Multiple earthquake scenarios
- Data inconsistencies / updates
- Earthquake uplift and subsidence
- Long and complicated coastline (3,026 miles)

Tsunami Mapping Challenges

- Multiple earthquake scenarios
- Data inconsistencies / updates
- Earthquake uplift and subsidence
- Long and complicated coastline (3,026 miles
- Bureaucracy

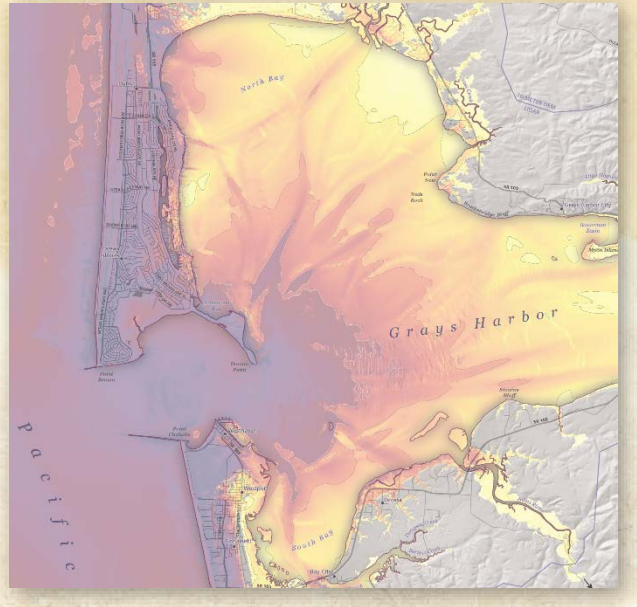
WGS Tsunami Team

- **Chief Hazards Geologist**–Corina Forson
- **Tsunami Hazards Geologist**–Daniel Eungard
- **Tsunami Hazards Geologist**–Alex Dolcimascolo



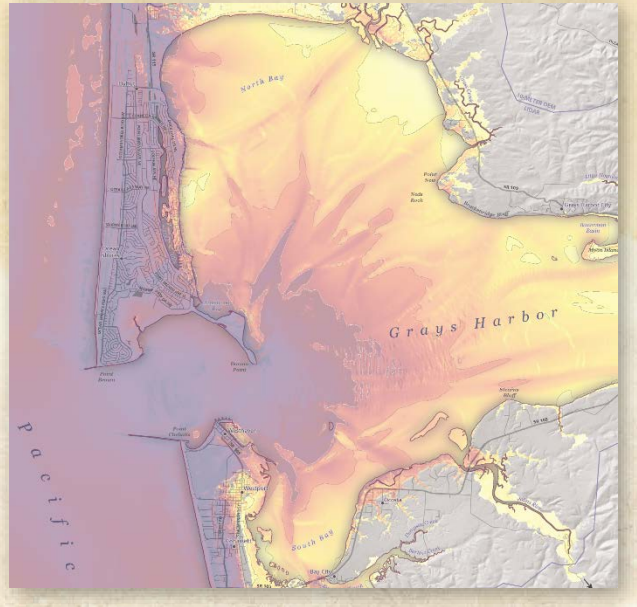
Recent WGS Tsunami Mapping

- Inundation and current velocity



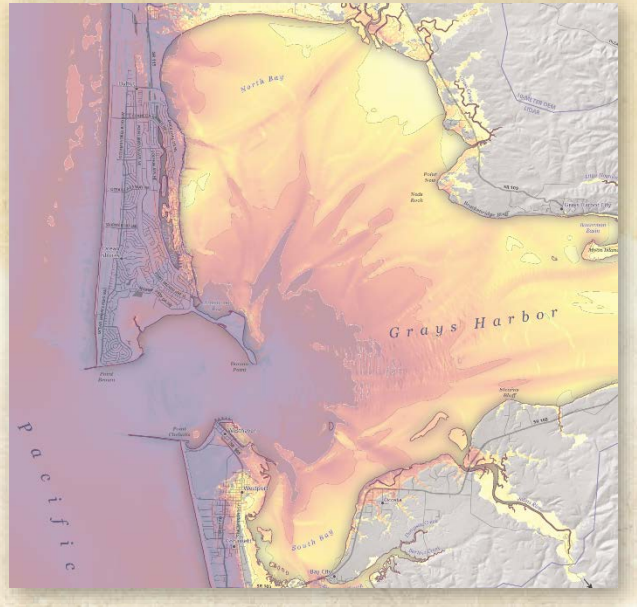
Recent WGS Tsunami Mapping

- Inundation and current velocity
- Evacuation walk times



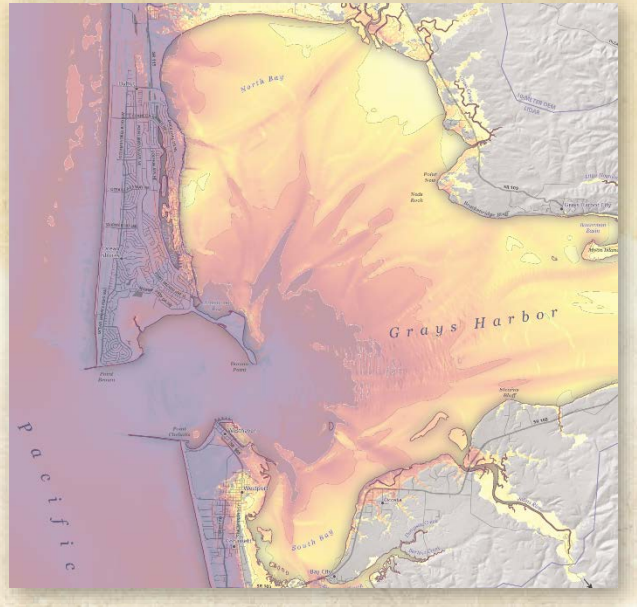
Recent WGS Tsunami Mapping

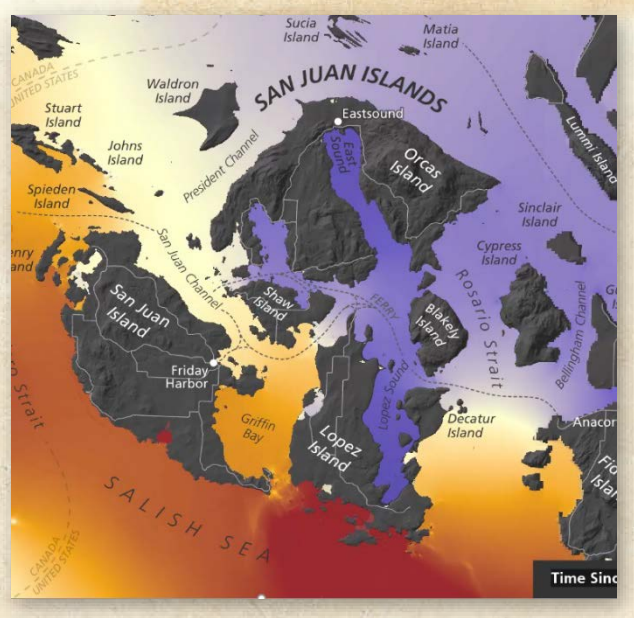
- Inundation and current velocity
- Evacuation walk times
- WGS website—interpretive graphics and data



Recent WGS Tsunami Mapping

- Inundation and current velocity
- Evacuation walk times
- WGS website—interpretive graphics and data
- Amplitude and velocity simulations

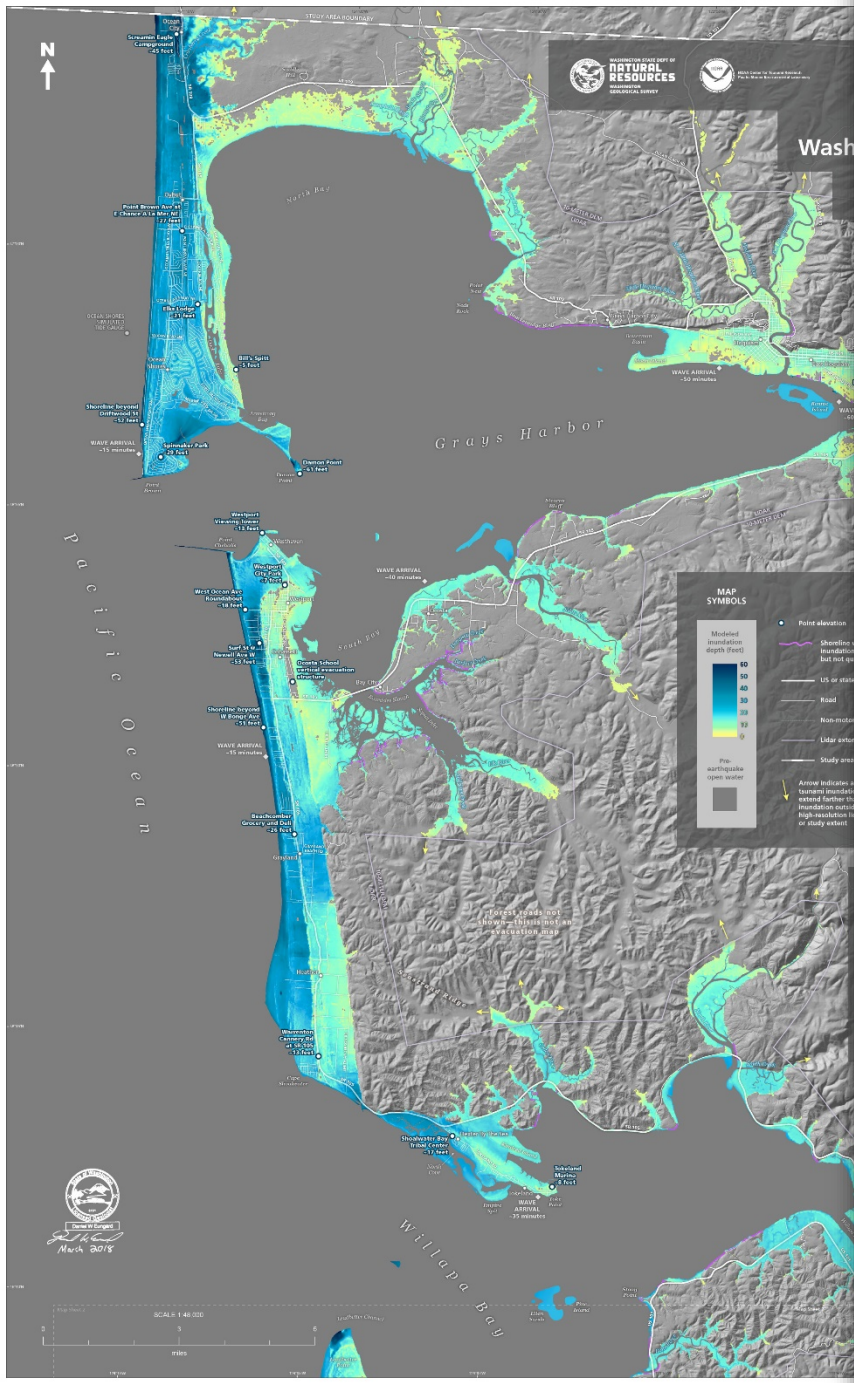




Inundation and Current Velocity

- Modeled magnitude 9.0 Cascadia-induced tsunami
- 2 inundation maps (binned / continuous data) and current velocity (speed)
- 6 coastal regions mapped thus far
- Modeling Software, ArcGIS Desktop and Adobe Photoshop/Illustrator


N
Grays Harbor
Pacific Ocean
Willapa Bay
North Bay
South Bay
Westport
Aberdeen
Hoquiam
MAP SYMBOLS
Modeled inundation depth (feet)
>6
2.5–6
0–2.5
Pre-earthquake open water
Forest roads not shown—this is not an evacuation map
March 2018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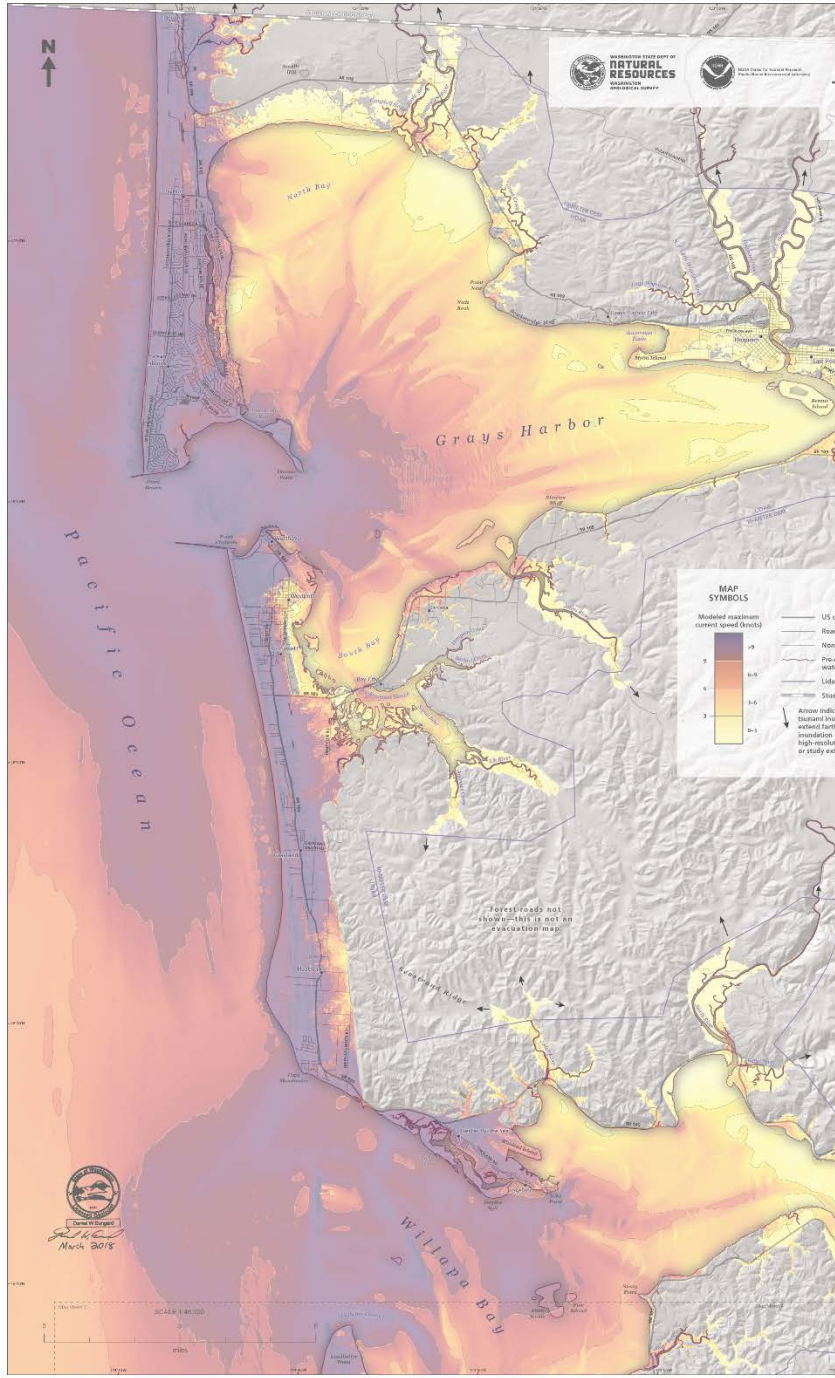
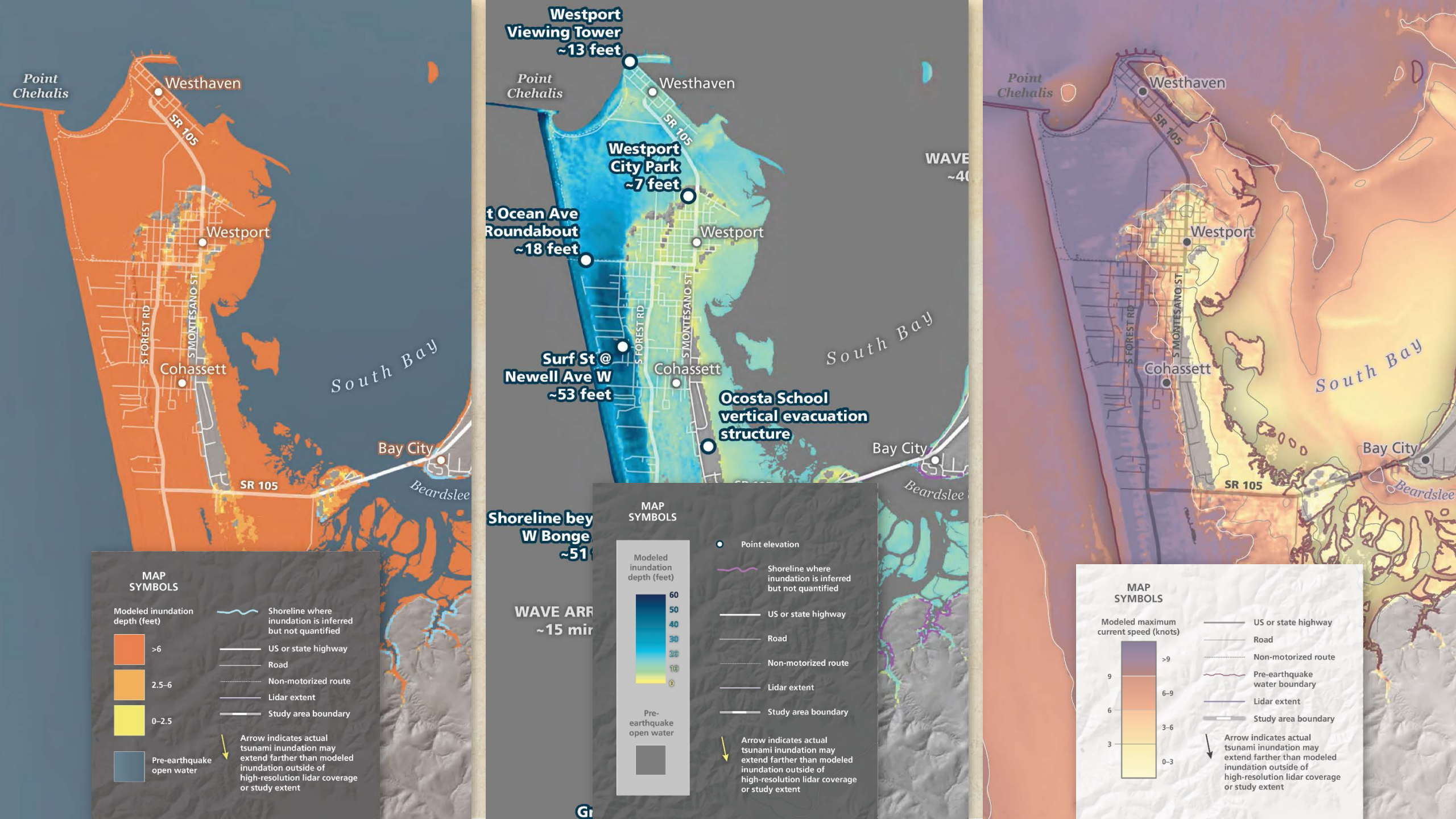
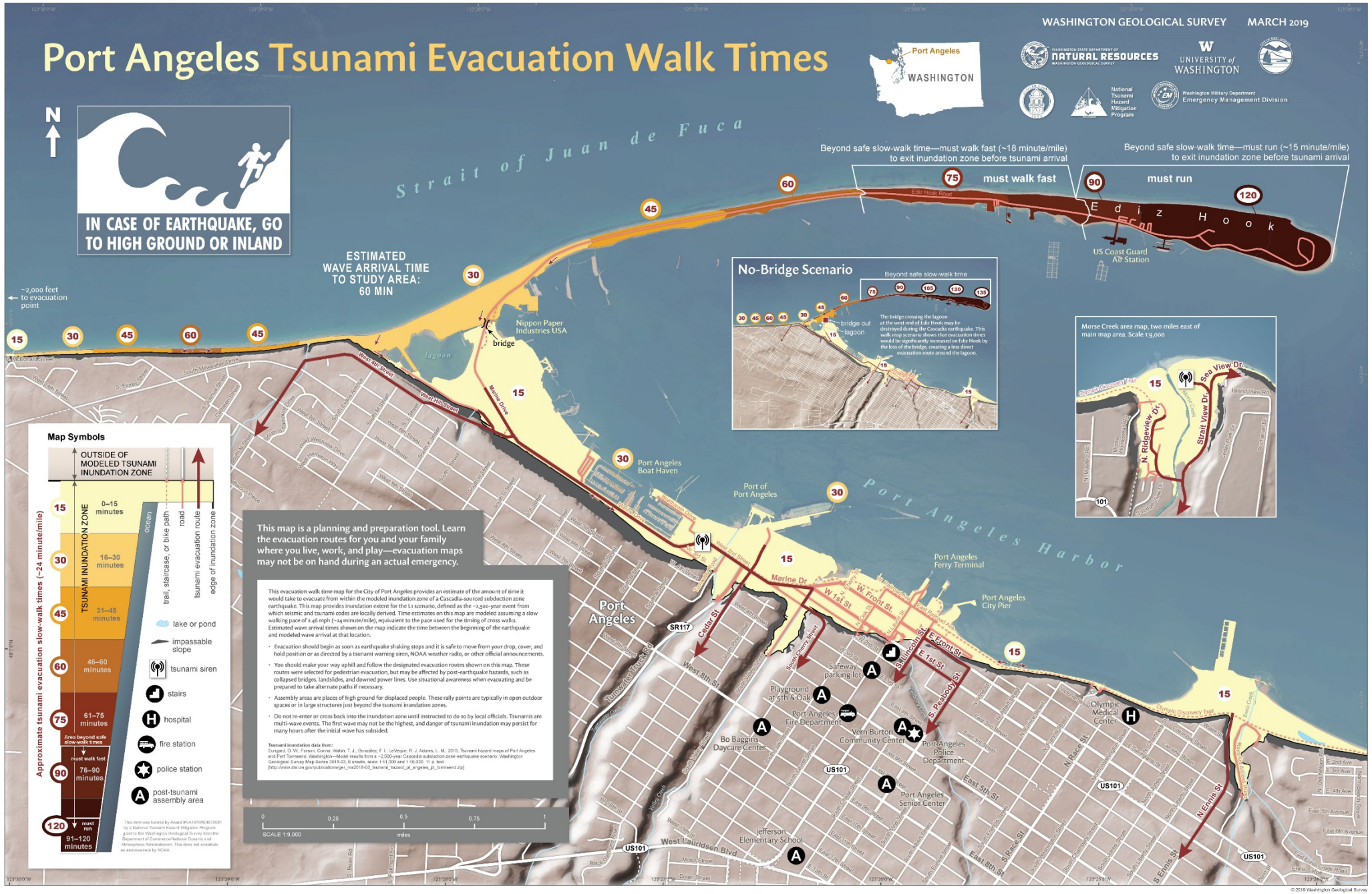

N
Grays Harbor
Pacific Ocean
Willapa Bay
North Bay
South Bay
Westport
Aberdeen
Hoquiam
MAP SYMBOLS
Modeled maximum current speed (knots)
Forest roads not shown—this is not an evacuation map
March 2018


Point Chehalis
Westhaven
SR 105
Westport
S MONTESANO ST
S FOREST RD
Cohassett
South Bay
Bay City
SR 105
Beardslee
MAP SYMBOLS
Modeled inundation depth (feet)
>6
2.5–6
0–2.5
Pre-earthquake open water
Shoreline where inundation is inferred but not quantified
US or state highway
Road
Non-motorized route
Lidar extent
Study area boundary
Arrow indicates actual tsunami inundation may extend farther than modeled inundation outside of high-resolution lidar coverage or study extent
Westport Viewing Tower ~13 feet
Westport City Park ~7 feet
t Ocean Ave Roundabout ~18 feet
Surf St @ Newell Ave W ~53 feet
Ocosta School vertical evacuation structure
Shoreline bey
W Bonge
~51
WAVE ARR
~15 mi
WAVE
~40
Modeled inundation depth (feet)
60
50
40
30
20
10
0
Pre-earthquake open water
Point elevation
Modeled maximum current speed (knots)
9
6
3
>9
6–9
3–6
0–3

Evacuation Walk Time Modeling

- Modeled slow walk pace (~2.5 mph) to exit tsunami zone
- 10 communities mapped thus far
- Vertical evacuation structures needed for several locations
- ArcGIS Desktop, Pedestrian Evacuation Analyst Toolkit (PEAT), Adobe Photoshop and Illustrator


Port Angeles Tsunami Evacuation Walk Times
WASHINGTON GEOLOGICAL SURVEY MARCH 2019
Port Angeles
WASHINGTON
N
IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND
Strait of Juan de Fuca
Beyond safe slow-walk time—must walk fast (~18 minute/mile) to exit inundation zone before tsunami arrival
must walk fast
Beyond safe slow-walk time—must run (~15 minute/mile) to exit inundation zone before tsunami arrival
must run
Ediz Hook
US Coast Guard Air Station
ESTIMATED WAVE ARRIVAL TIME TO STUDY AREA: 60 MIN
~2,000 feet to evacuation point
Nippon Paper Industries USA
bridge
lagoon
No-Bridge Scenario
Beyond safe slow-walk time
bridge out
lagoon
The bridge crossing the lagoon at the west end of Ediz Hook may be destroyed during the Cascadia earthquake. This walk map scenario shows that evacuation times would be significantly increased on Ediz Hook by the loss of the bridge, creating a less direct evacuation route around the lagoon.
Morse Creek area map, two miles east of main map area. Scale 1:9,000
Port Angeles Boat Haven
Port of Port Angeles
Port Angeles Harbor
Port Angeles Ferry Terminal
Port Angeles City Pier
Port Angeles
Marine Dr
West 8th Street
Cedar St
SR117
Tumwater Truck Rd
US101
Safeway parking lot
Playground at 5th & Oak
Port Angeles Fire Department
Vern Burton Community Center
Port Angeles Police Department
Port Angeles Senior Center
Bo Baggins Daycare Center
Jefferson Elementary School
West Laurideen Blvd
East 5th St
East 8th St
N Ennis St
S Ennis St
N Race St
S Race St
Olympic Medical Center
Olympic Discovery Trail
Sea View Dr
Strait View Dr
N. Ridgeview Dr
Map Symbols
OUTSIDE OF MODELED TSUNAMI INUNDATION ZONE
TSUNAMI INUNDATION ZONE
Approximate tsunami evacuation slow-walk times (~24 minute/mile)
0–15 minutes
16–30 minutes
31–45 minutes
46–60 minutes
61–75 minutes
Area beyond safe slow-walk times
must walk fast
76–90 minutes
must run
91–120 minutes
Ocean
trail, staircase, or bike path
road
tsunami evacuation route
edge of inundation zone
lake or pond
impassable slope
tsunami siren
stairs
hospital
fire station
police station
post-tsunami assembly area
This item was funded by Award #NA16NWS4670041 by a National Tsunami Hazard Mitigation Program grant to the Washington Geological Survey from the Department of Commerce/National Oceanic and Atmospheric Administration. This does not constitute an endorsement by NOAA.
This map is a planning and preparation tool. Learn the evacuation routes for you and your family where you live, work, and play—evacuation maps may not be on hand during an actual emergency.
This evacuation walk time map for the City of Port Angeles provides an estimate of the amount of time it would take to evacuate from within the modeled inundation zone of a Cascadia-sourced subduction zone earthquake. This map provides inundation extent for the L1 scenario, defined as the ~2,500-year event from which seismic and tsunami codes are locally derived. Time estimates on this map are modeled assuming a slow walking pace of 2.46 mph (~24 minute/mile), equivalent to the pace used for the timing of cross walks. Estimated wave arrival times shown on the map indicate the time between the beginning of the earthquake and modeled wave arrival at that location.
Evacuation should begin as soon as earthquake shaking stops and it is safe to move from your drop, cover, and hold position or as directed by a tsunami warning siren, NOAA weather radio, or other official announcements.
You should make your way uphill and follow the designated evacuation routes shown on this map. These routes were selected for pedestrian evacuation, but may be affected by post-earthquake hazards, such as collapsed bridges, landslides, and downed power lines. Use situational awareness when evacuating and be prepared to take alternate paths if necessary.
Assembly areas are places of high ground for displaced people. These rally points are typically in open outdoor spaces or in large structures just beyond the tsunami inundation zones.
Do not re-enter or cross back into the inundation zone until instructed to do so by local officials. Tsunamis are multi-wave events. The first wave may not be the highest, and danger of tsunami inundation may persist for many hours after the initial wave has subsided.
Tsunami inundation data from:
Eungard, D. W.; Forson, Corina; Walsh, T. J.; Gonzalez, F. I.; LeVeque, R. J.; Adams, L. M., 2016, Tsunami hazard maps of Port Angeles and Port Townsend, Washington—Model results from a ~2,500-year Cascadia subduction zone earthquake scenario: Washington Geological Survey Map Series 2016-03, 6 sheets, scale 1:11,200 and 1:16,000. 11 p. text. [http://www.dnr.wa.gov/publicationsger_ms2016-03_tsunami_hazard_pt_angeles_pt_townsend.zip]
SCALE 1:9,000
0 0.25 0.5 0.75 1
miles
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Bellingham Tsunami Evacuation Walk Times

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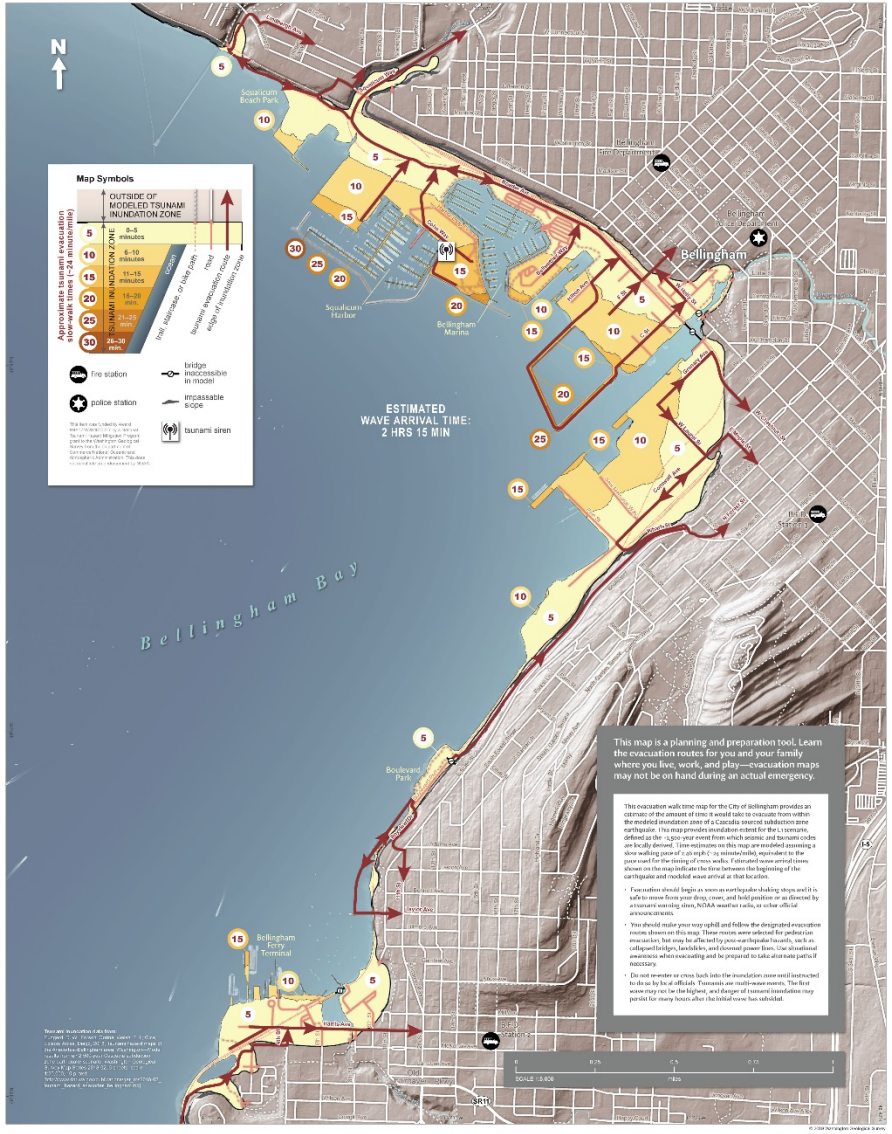
MARCH 2019

Map Location
WASHINGTON

IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND

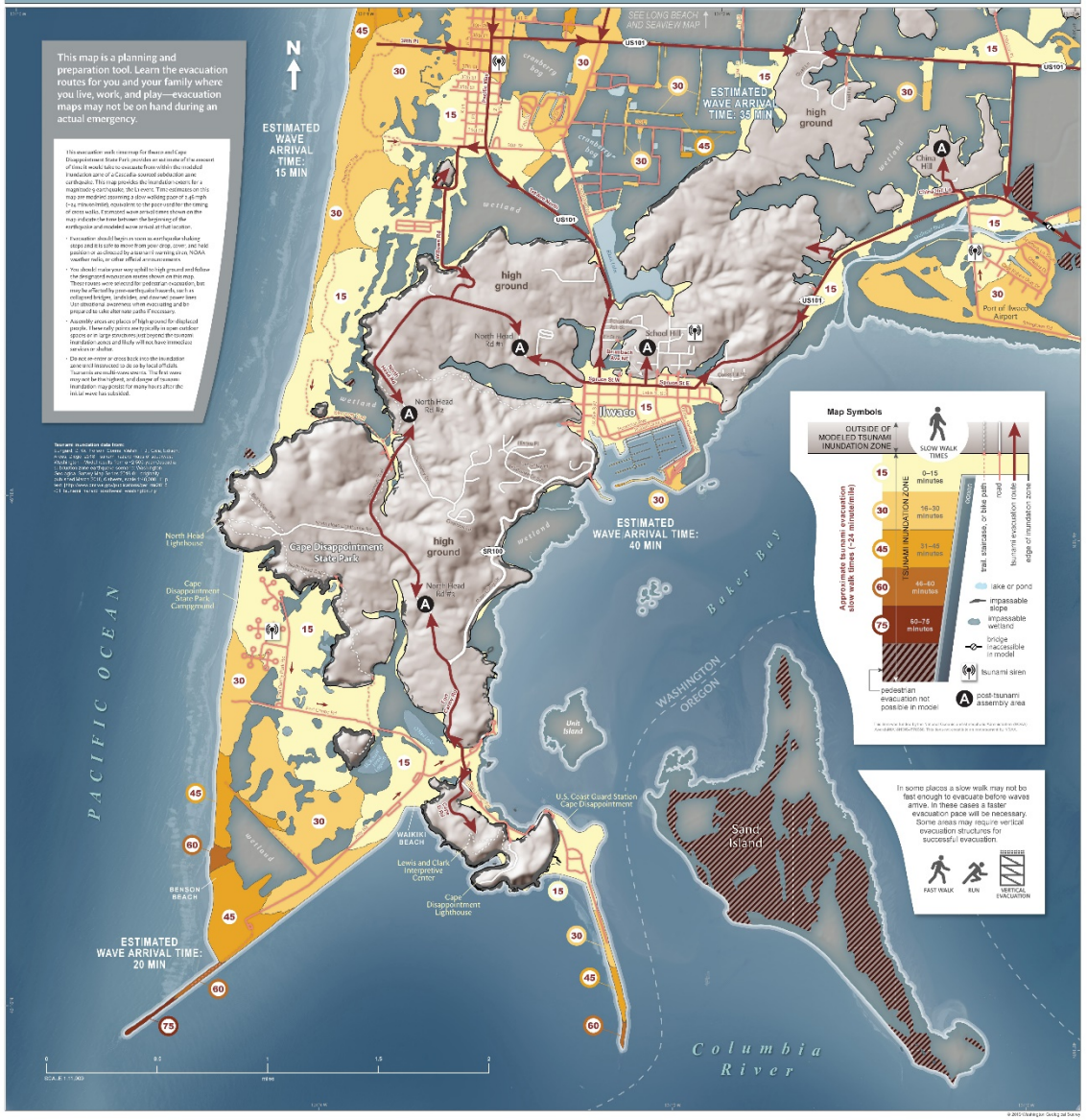


Ilwaco and Cape Disappointment Tsunami Evacuation Walk Times

WASHINGTON GEOLOGICAL SURVEY
SEPTEMBER 2019

WASHINGTON
Map Location

IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND



Ocosta School vertical evacuation structure

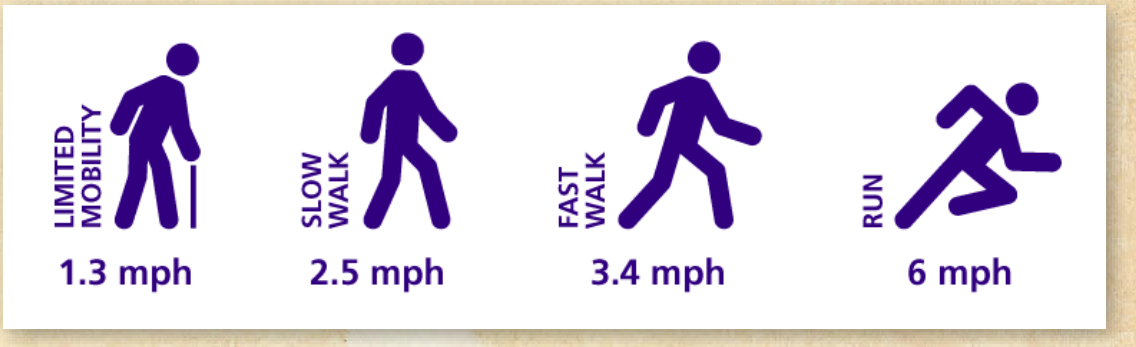
Community Events

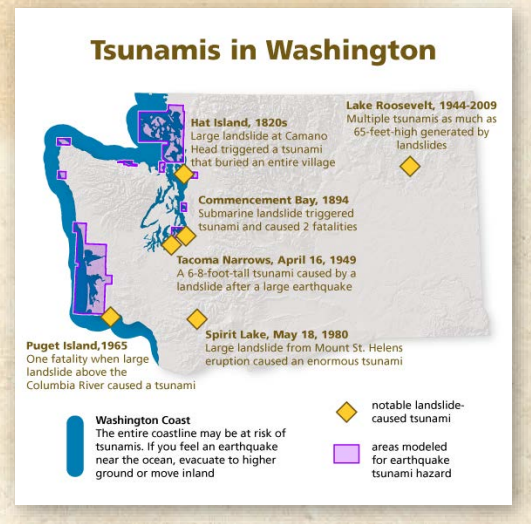
- Tsunami Road Show
- Stakeholder workgroup meetings ~10 times per year
- Presentations on request to various community groups

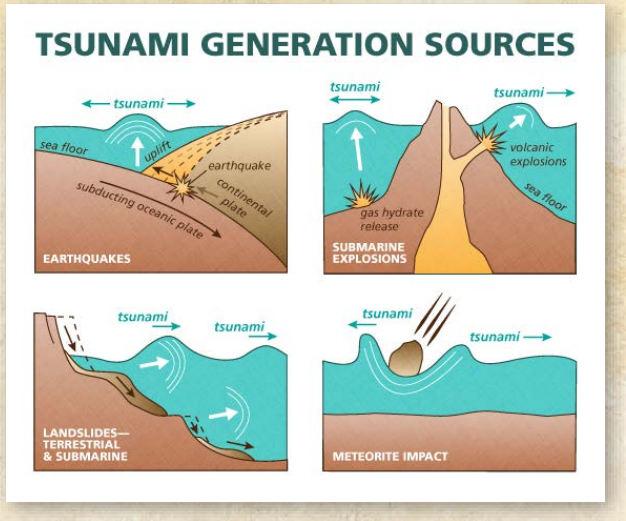
WGS Tsunami Webpage

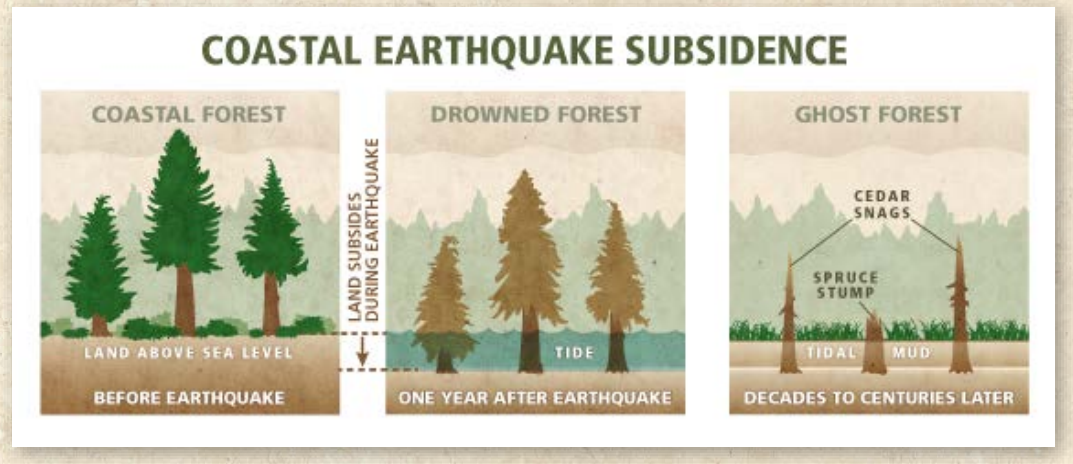
- Tsunami science
- Tsunami history
- Tsunami resources

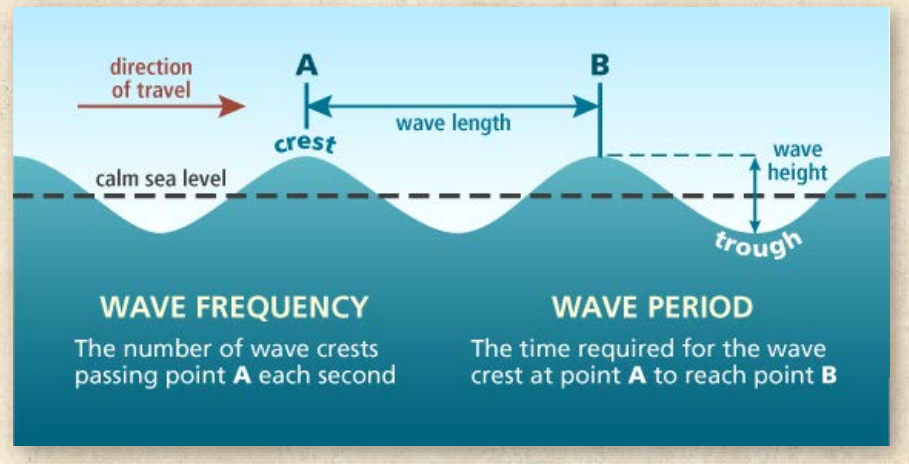
Website Maps and Graphics

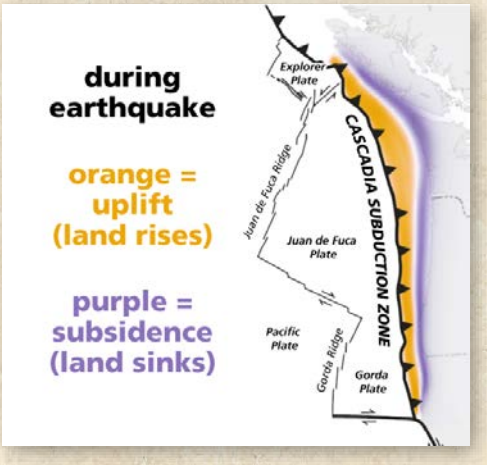










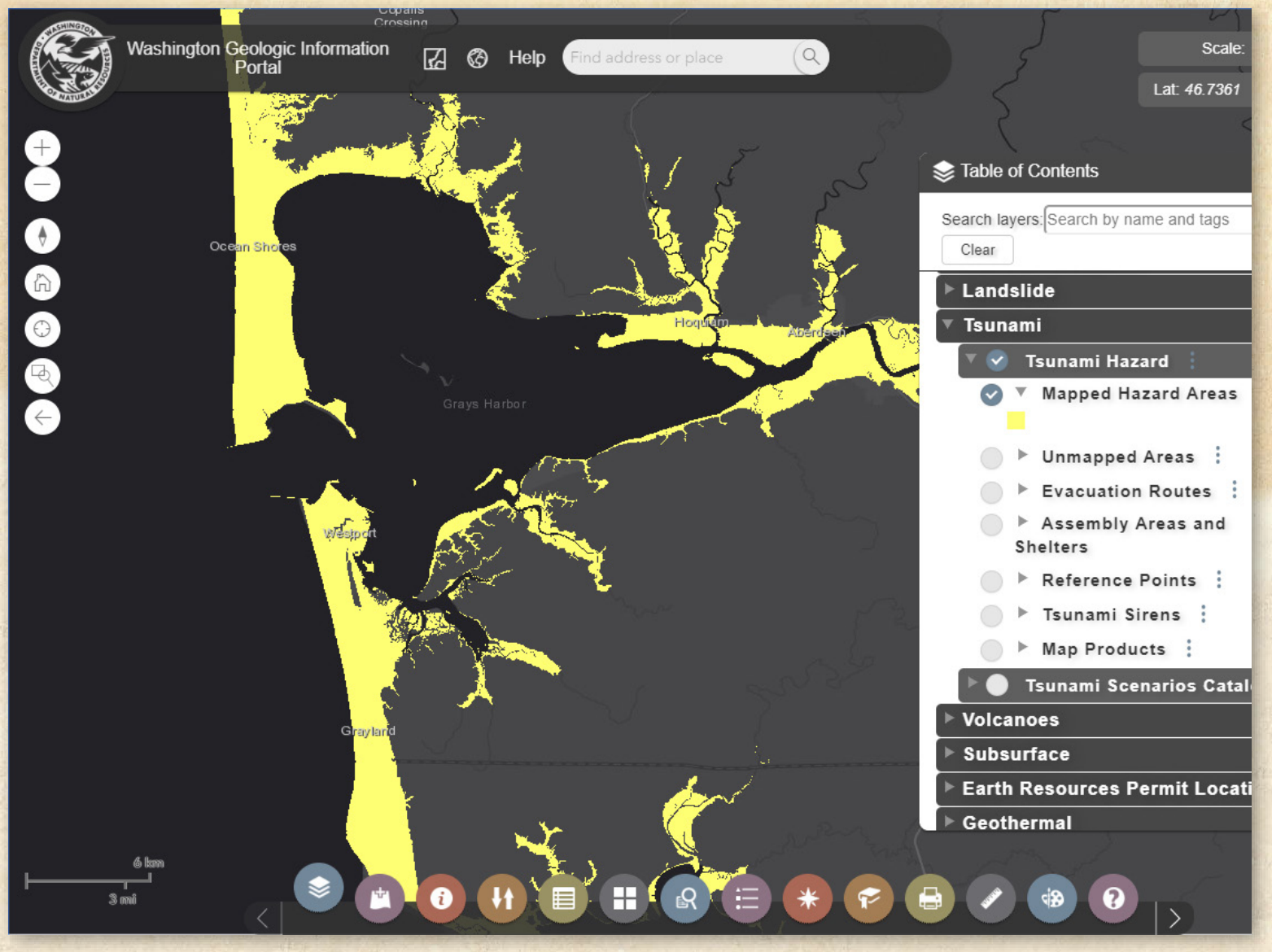



PACIFIC OCEAN
LONG BEACH PENINSULA
North Head Lighthouse
Ilwaco
Cape Disappointment State Park Campground
CAPE DISAPPOINTMENT
Baker Bay
US Coast Guard Station
Cape Disappointment Lighthouse
Columbia River
Sand Island


PACIFIC OCEAN
LONG BEACH PENINSULA
High Ground — above a modeled tsunami inundation scenario
North Head Lighthouse
Ilwaco
Cape Disappointment State Park Campground
CAPE DISAPPOINTMENT
Baker Bay
US Coast Guard Station
Cape Disappointment Lighthouse
Columbia River
Sand Island

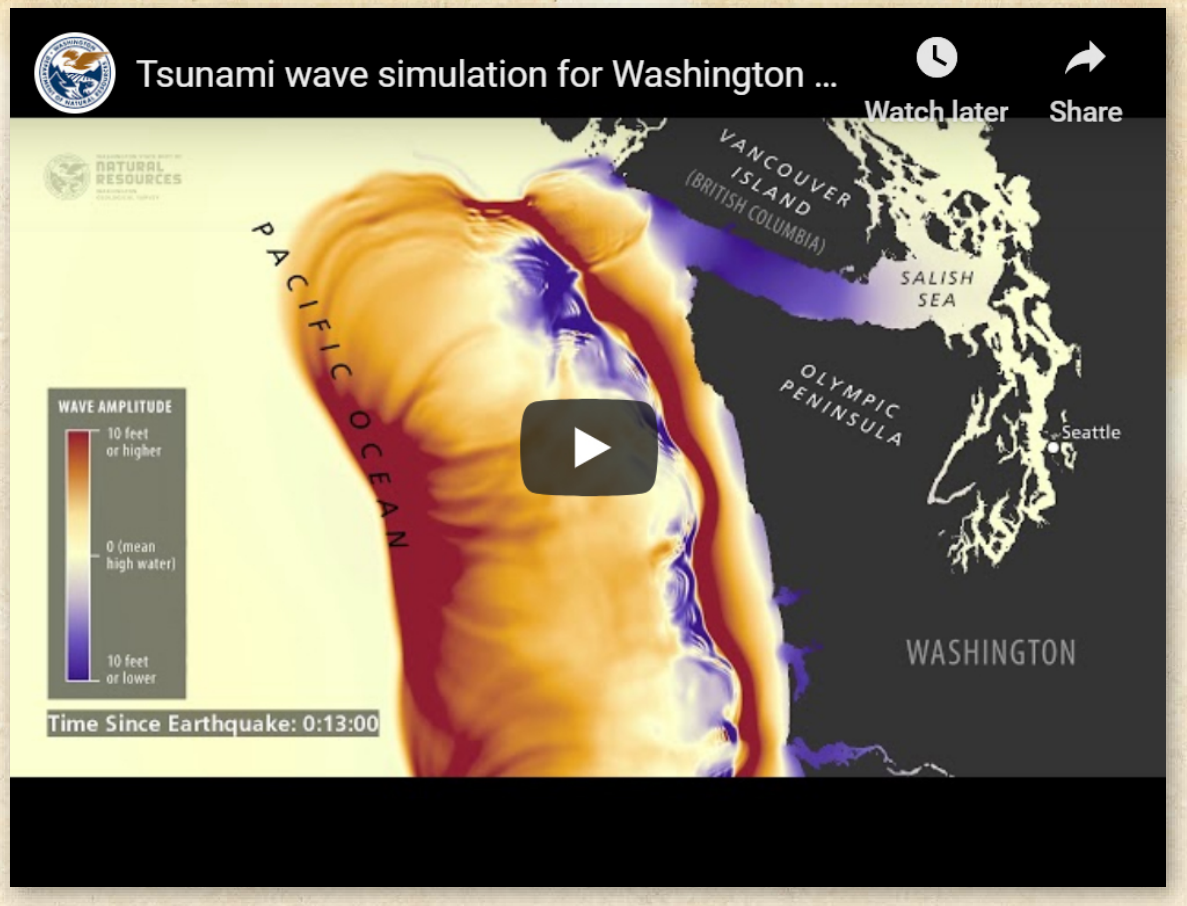
Washington Geologic Information Portal

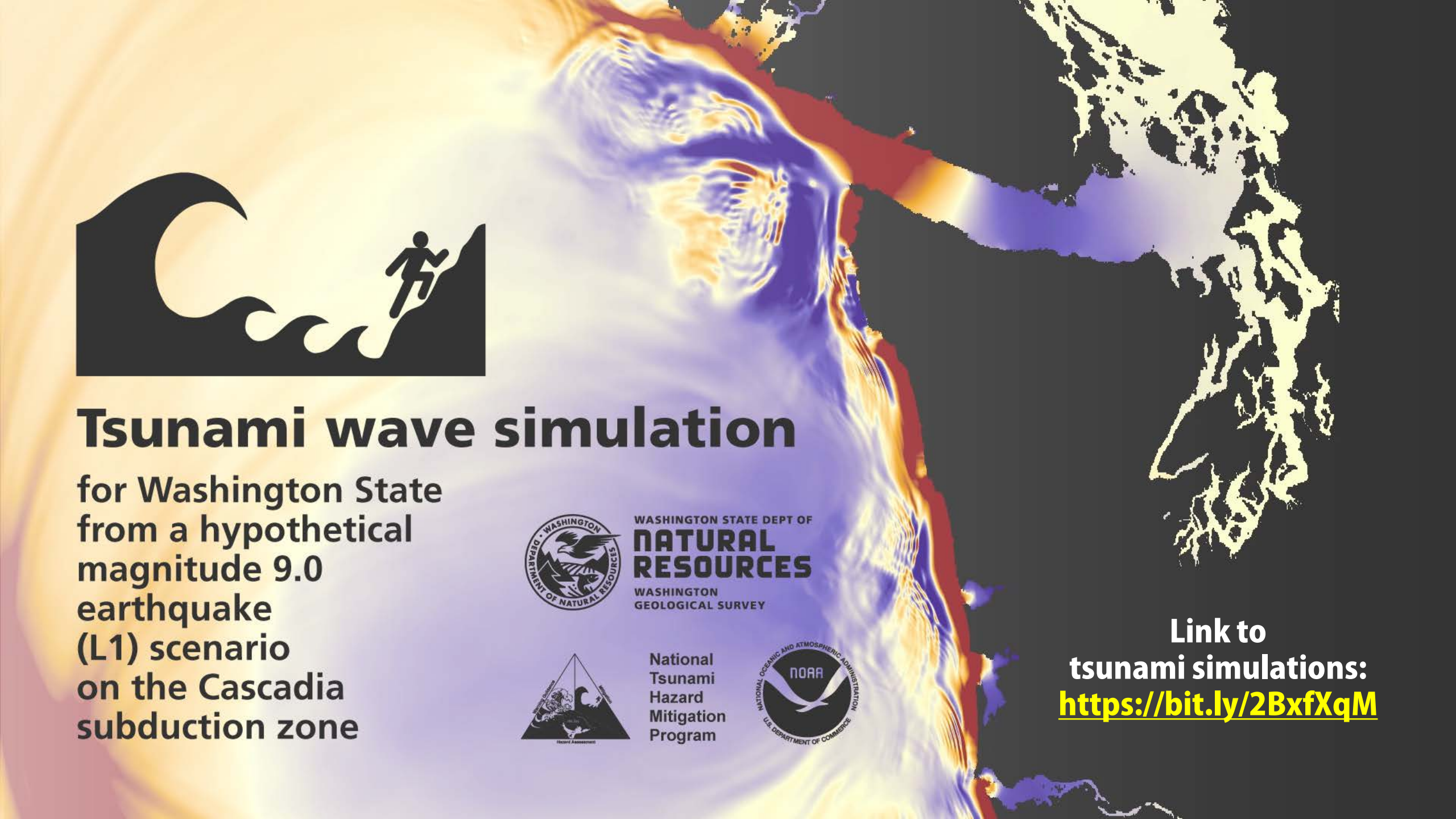
- Publication and data downloads
- Tsunami hazard areas
- Evacuation routes
- Assembly areas
- Tsunami sirens



Amplitude and Velocity Simulations

- 9 simulations
- Wave amplitude (peaks and troughs)
- Current velocity (speed)
- YouTube and direct MP4 download
- Modeling Software (M.O.S.T.)—NetCDF files, ArcGIS Pro, Adobe After Effects and Illustrator
- More in the next month





Tsunami wave simulation

for Washington State
from a hypothetical
magnitude 9.0
earthquake
(L1) scenario
on the Cascadia
subduction zone

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NATURAL RESOURCES
WASHINGTON
GEOLOGICAL SURVEY

National
Tsunami
Hazard
Mitigation
Program

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

**Link to
tsunami simulations:
https://bit.ly/2BxfXqM**

Thanks!

contact: Dan Coe
daniel.coe@dnr.wa.gov