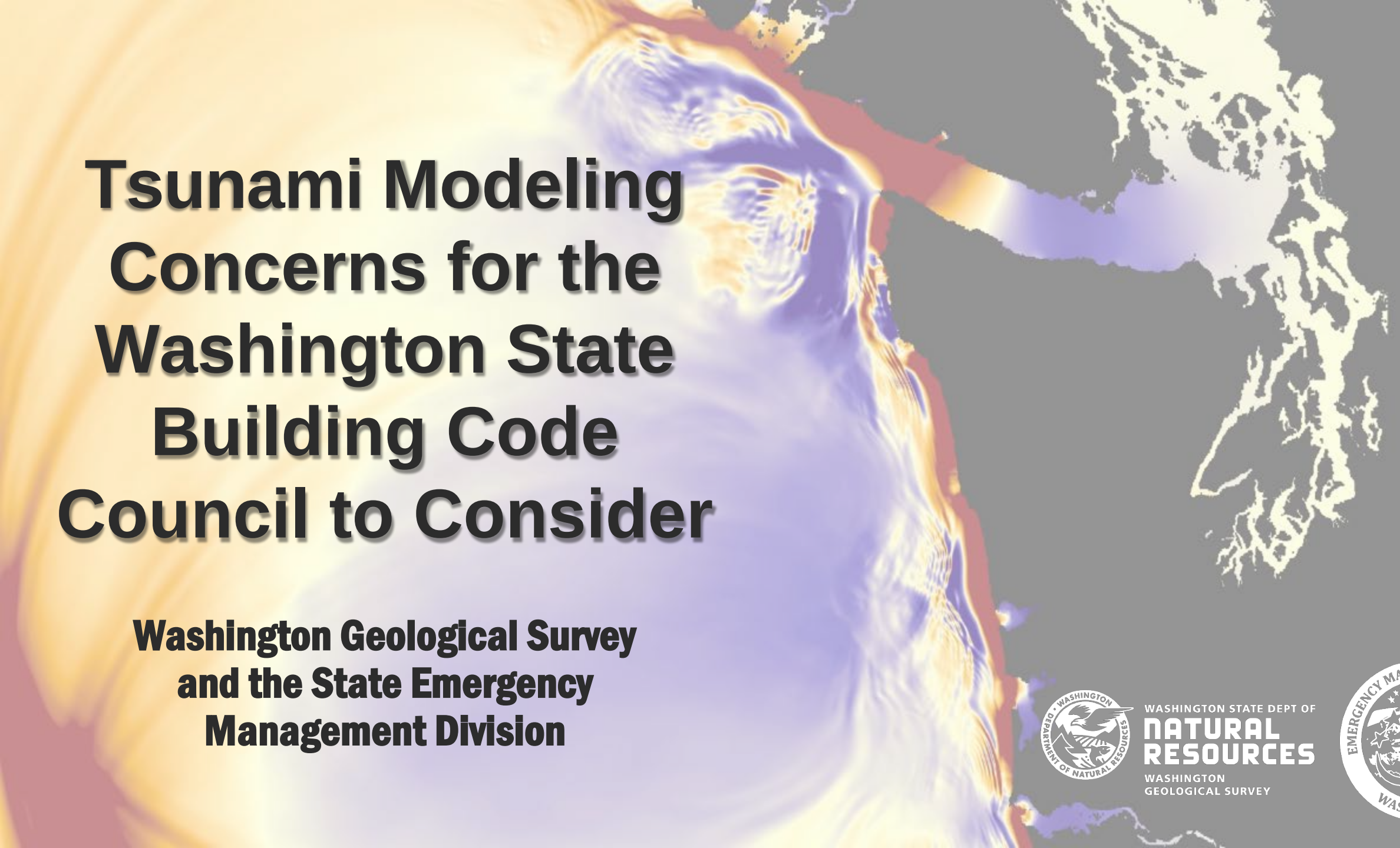
Tsunami Modeling Concerns for the Washington State Building Code Council to Consider



Washington Geological Survey and the State Emergency Management Division

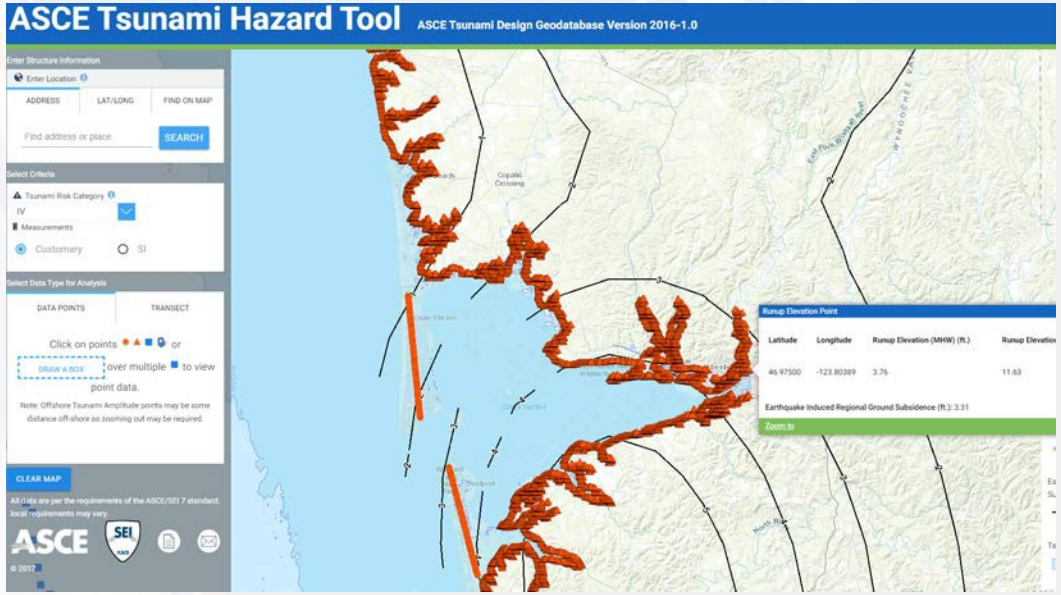
WASHINGTON STATE DEPT OF NATURAL RESOURCES
WASHINGTON GEOLOGICAL SURVEY

EMERGENCY MANAGEMENT DIVISION
WASHINGTON

2011 Tohoku Japan: Why we need to understand the hazard and prepare

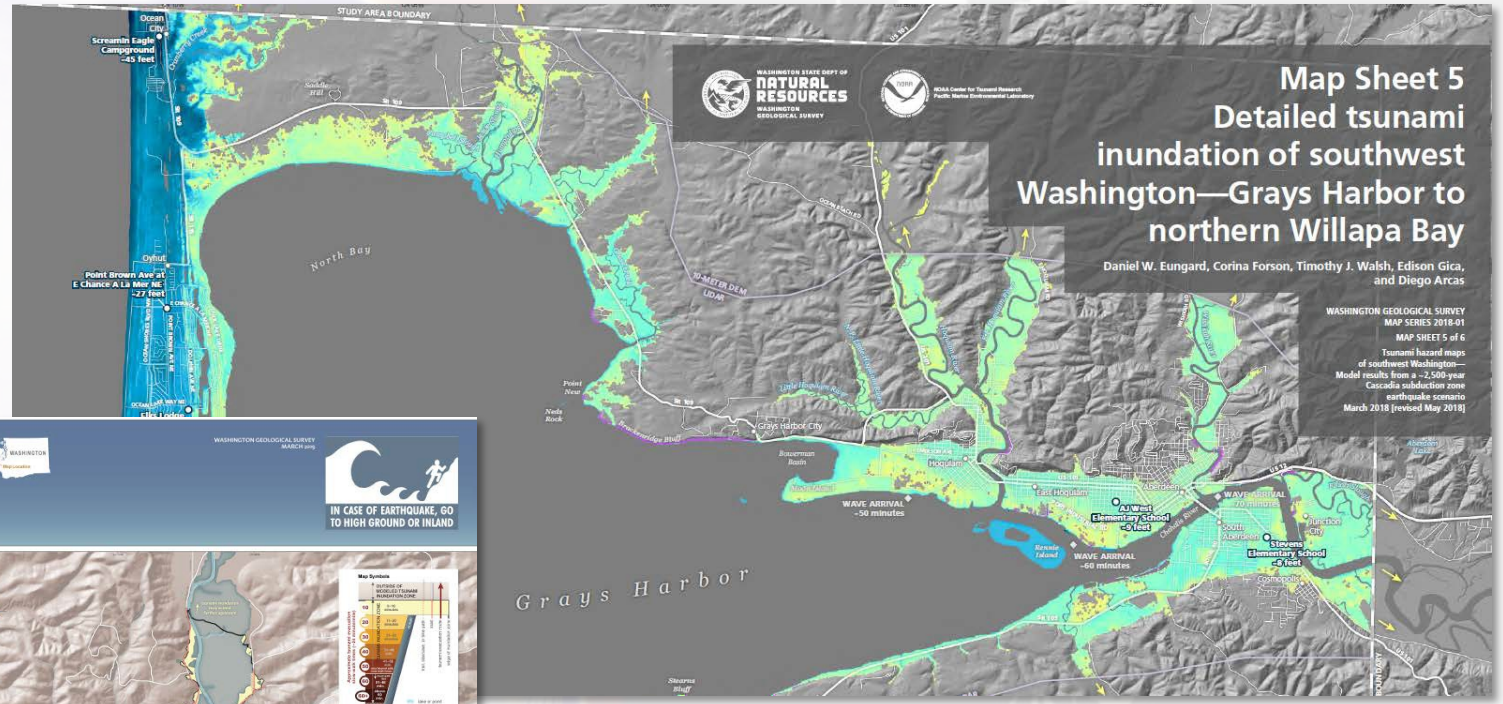
The tsunami loads chapter of the building code (ASCE)

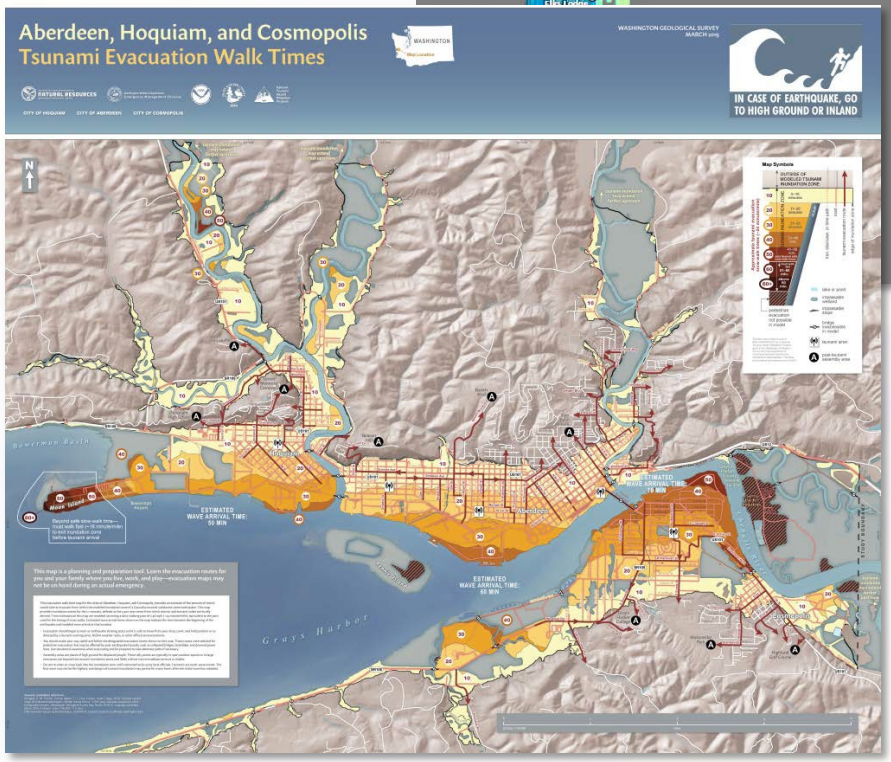
- ASCE 7-16 (a tsunami resilient design code) requires engineers to incorporate tsunami forces and flow depths when designing and building structures >Risk Category II buildings (especially essential and critical facilities, e.g. vertical evacuation, schools, hospitals, etc). ***<u>This part of the code is good and we agree with it.</u>***
- However, the code is guided by a Tsunami Design Zone (TDZ) that is modeled based on a 2,475-year event, determined from probabilistic tsunami hazard analysis. **<u>The maps which are part of the code are controversial.</u>**



Current Washington tsunami modeling

Hazard and evacuation products for Washington and Oregon are based on a seminal peer-reviewed study examining Cascadia earthquake events and recurrence intervals (Witter and others, 2011).

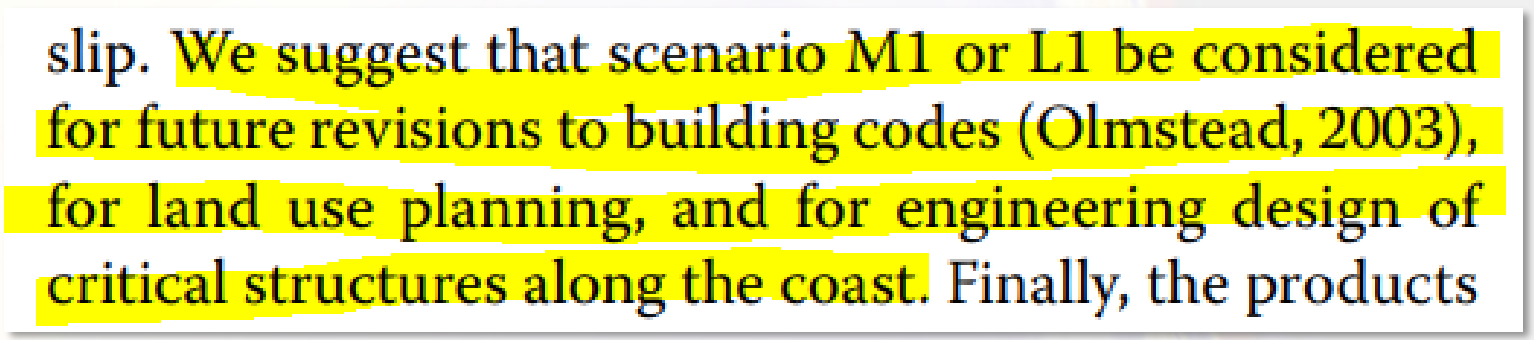




These products are widely used and accepted by local emergency managers and land-use planners.

Current Washington tsunami modeling

The earthquake source that is used on the outer coast and in much of Puget Sound is a magnitude 9.0 Cascadia subduction zone earthquake along a splay fault. This event encompasses 95% of the hazard, including the more likely smaller events that have happened in the past 10,000 years. This scenario is called the “L1” and is recommended by Witter and others (2011).


slip. We suggest that scenario M1 or L1 be considered for future revisions to building codes (Olmstead, 2003), for land use planning, and for engineering design of critical structures along the coast. Finally, the products

The deterministic L1 CSZ modeling cannot be equated to the probabilistic modeling used to develop the TDZ.

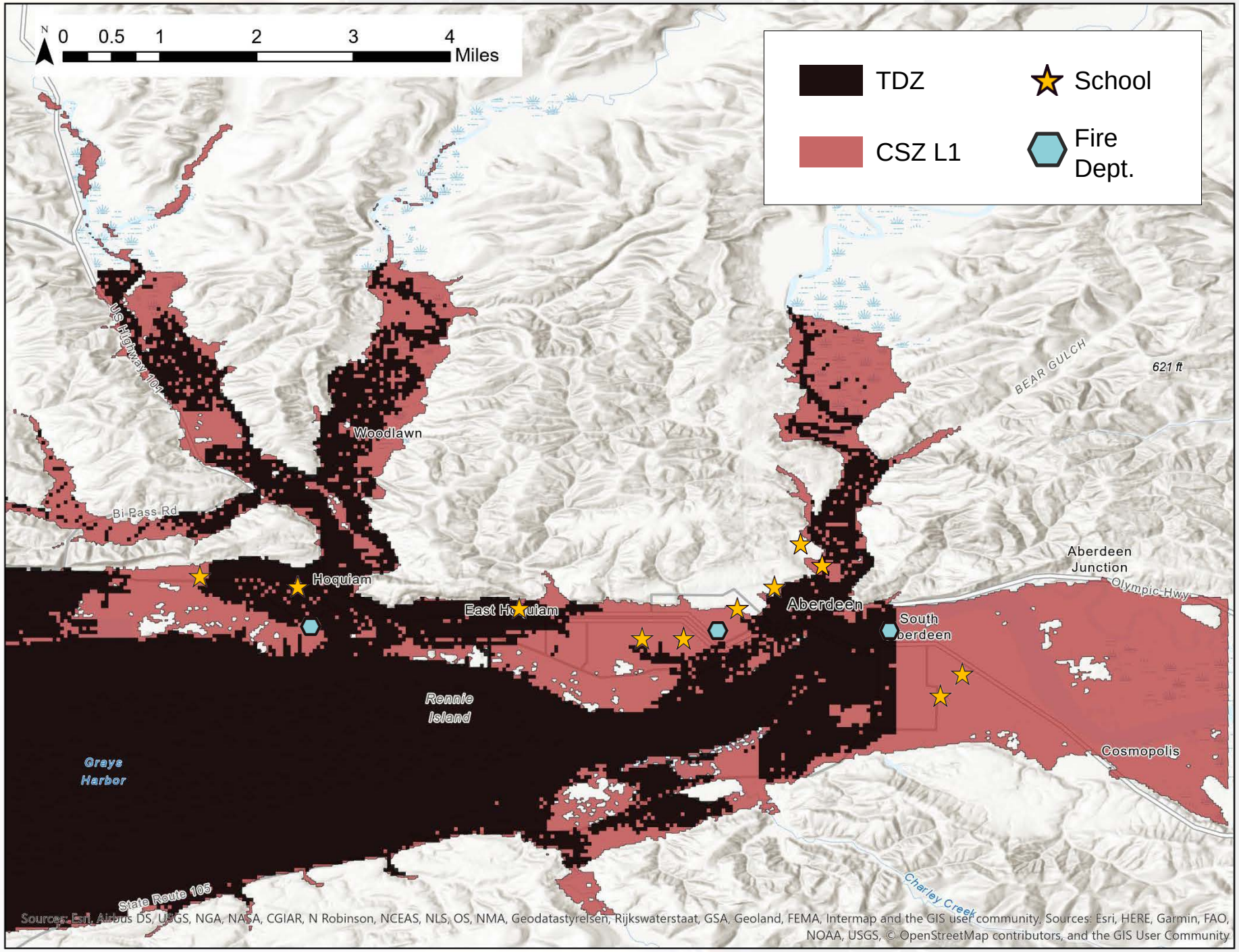
5 Concerns with ASCE tsunami modeling of the Tsunami Design Zone (TDZ)

1. The tsunami modeling process used to develop the TDZ went through scientific review. **However, consensus on the tsunami source characterization is still needed, and the process was not well documented, publicly available, or reproducible**.

2. The TDZ is largely acceptable in terms of extent. **However, there are some significant discrepancies between extent, flow depth, and the 100-m bathymetry line in the TDZ, and in the published Cascadia data. These differences could lead to under-designed structures and/or the construction of critical facilities in unmapped tsunami hazard zones.** Until discrepancies in the sources can be better understood, Washington could adopt a more conservative approach for design and construction of critical facilities.

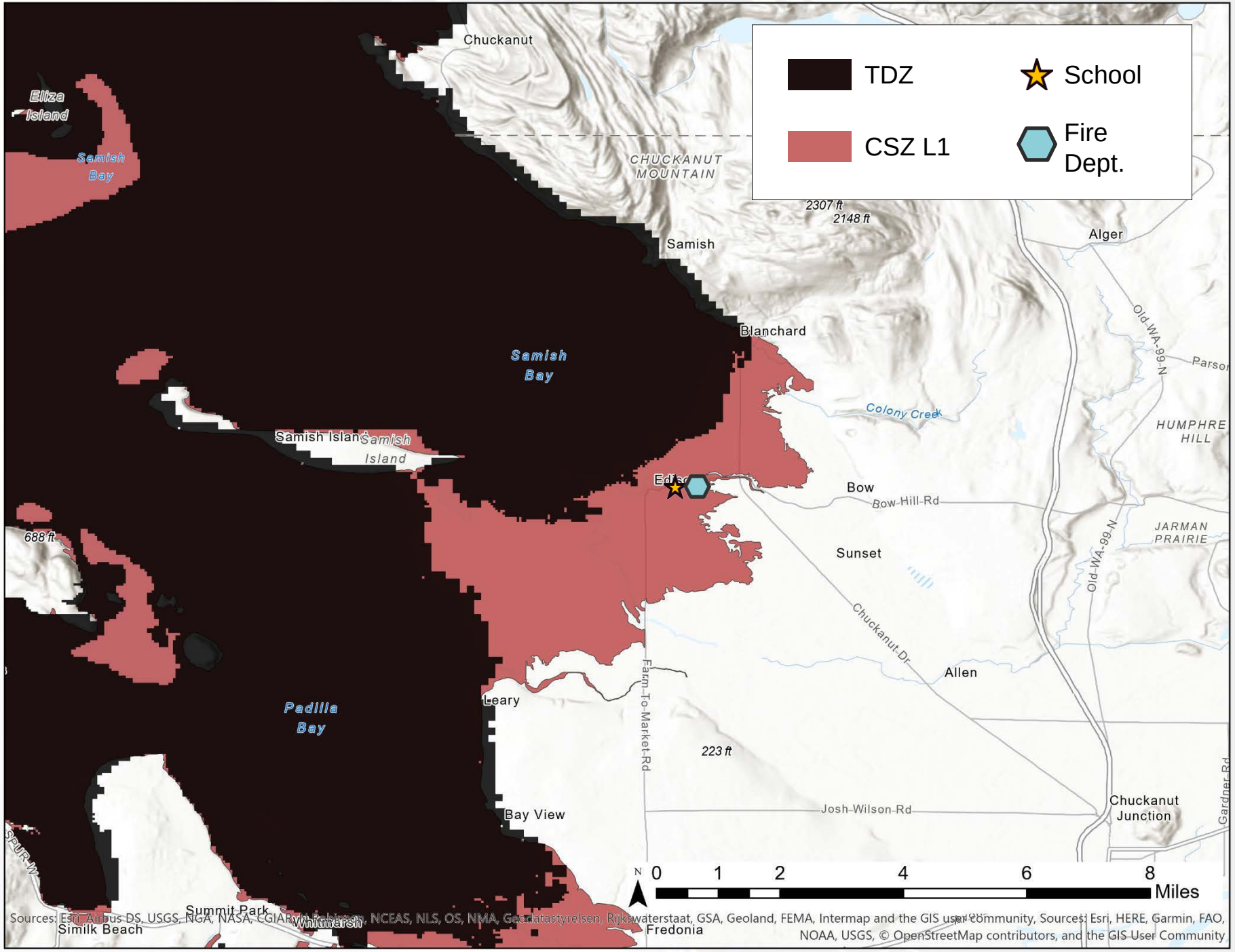
Outer coast example

Comparison of **state tsunami modeling** vs. **ASCE tsunami design zone** modeling in Aberdeen, WA



Puget Sound example

Comparison of **state tsunami modeling** vs. **ASCE tsunami design zone** modeling in Bow-Edison, WA



5 Concerns with ASCE tsunami modeling of the Tsunami Design Zone (TDZ) (cont.)

3. The **resolution of TDZ modeling is very poor (~60 m onshore),** whereas **Oregon, California, and Washington tsunami modeling is done at no greater than 10 m resolution**. This is critical for capturing topography onshore and bathymetry offshore which both have a significant impact on tsunami inundation and run-up.

4. ASCE TDZ source models relied more on global averages than geologic, geophysical, or geodetic data from Cascadia to define locking patterns. This means that **the earthquake source model used in the tsunami modeling may not reflect what is happening in Cascadia.**

5. The slip amounts along the CSZ for the TDZ is in question. Extremely high and low slip patches are included in the ASCE TDZ as part of the logic-tree/PTHA approach. **If slip is underestimated, this could result in errors and underestimations in the inundation. Overestimated, it can be unnecessarily conservative.**

Concerns with ASCE site-specific tsunami modeling for vertical evacuation structures

1. The ASCE site-specific modeling requirements for vertical evacuation structures (VES) are complex and poorly documented. **Modelers on projects may be forced to use unrealistic inputs in order to meet code requirements.**

2. Site-specific modeling is required to match the ASCE wave amplitude within +/-20 % at the 100 m bathymetry line. **Even if site-specific inundation modeling is more conservative onshore than the flow depth data provided by ASCE, it requires that modelers increase the earthquake source to meet the 100 m bathymetry line, thus overestimating inundation.** This has led to over-conservatism in some areas, resulting in significant increases in project costs. The Long Beach Berm was not feasible because of these issues.

What other states do

Oregon

Oregon decided not to adopt the ASCE-7-16 tsunami chapter statewide. They did decide that it's fine for local municipalities to use the engineering calculations as desired for specific projects, such as vertical evacuation structures.

This means that the engineering calculations may be used, but not the map zoning based on ASCE modeling.

California

The California Building Standards Commission adopted the tsunami loads and effects section created by ASCE, with the following caveat: When discussing the maps, the Division of the State Architects (DSA) office include the following language changes in RED: **"**…*1617.10 Tsunami Loads. The design and construction of Risk Category III or IV buildings and structures located in the Tsunami Design Zones defined in the ASCE Tsunami Design Geodatabase, or other data determined applicable by the enforcement agency (Division of the State Architect), shall be in accordance with Section 1615.1 except as modified by this code. …***"**

A path forward

Short term

- Locals can elect to use State modeling where it is more conservative for both TDZ and for site-specific modeling for critical facilities

Long term

- WA could develop high-resolution statewide/regional probabilistic tsunami modeling and replace the ASCE TDZ in the future
- Collaborate to ensure best-available science and modeling are used in Washington building codes

Thank you for letting me share our concerns

Questions?

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Supplementary Slides

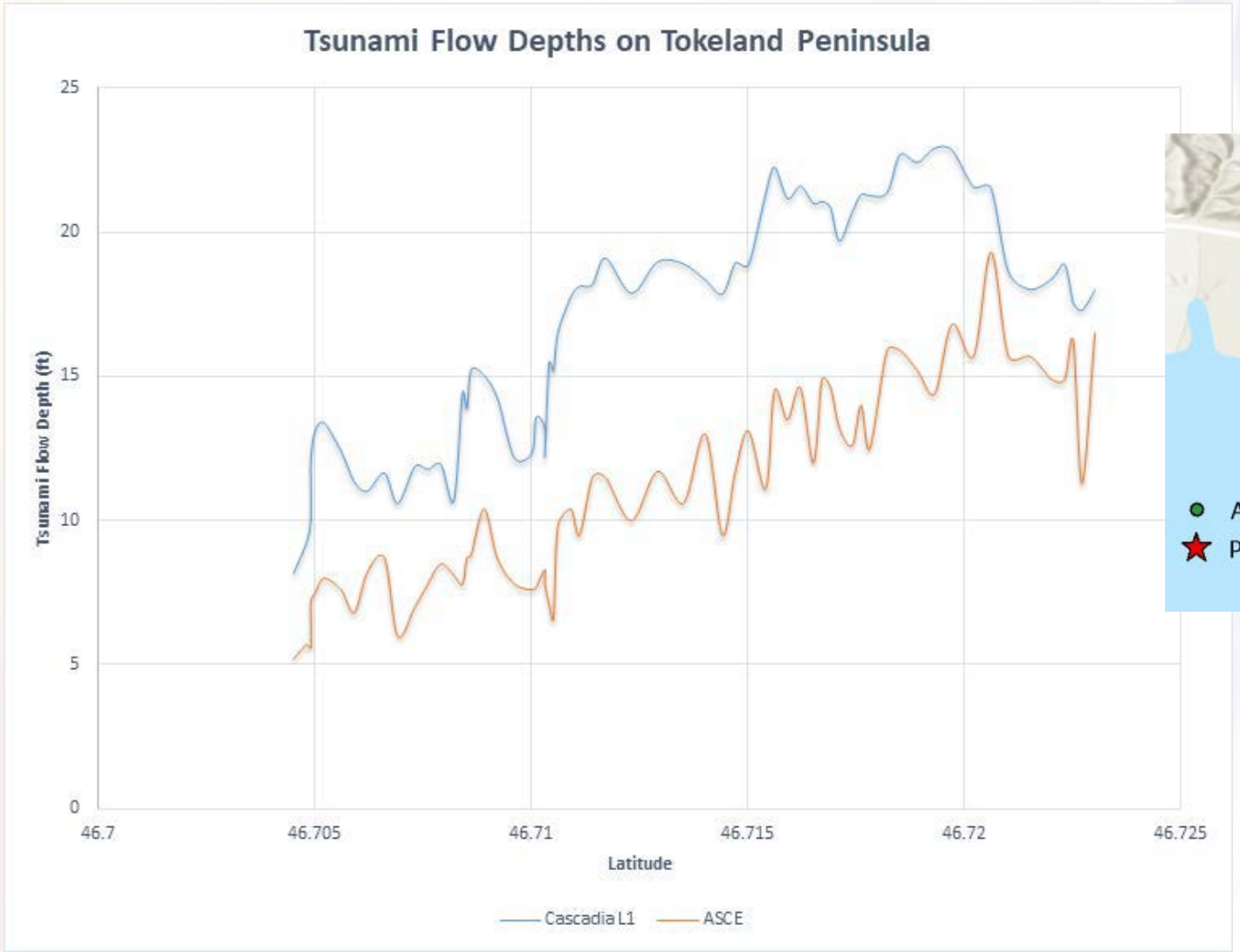
Why use deterministic when ASCE uses probabilistic?

“The PTHA analysis indicates that the 2500-year tsunami hazards along the coastal regions of Washington, Oregon and northern California are dominated by tsunamis generated in the Cascadia Subduction Zone (CSZ).” – Wei, 2017 (methods on tsunami modeling for the ASCE)

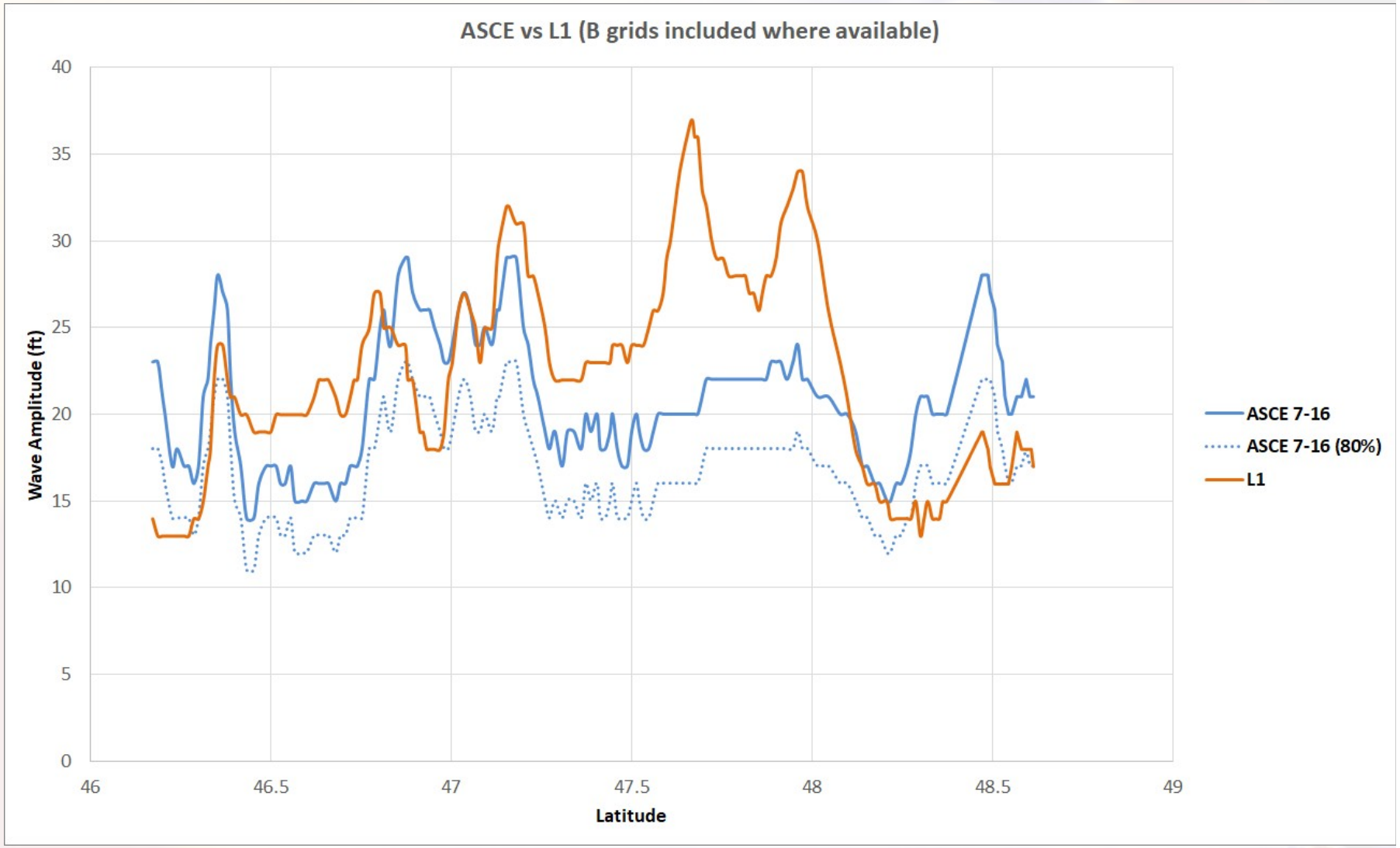
In the Puget Sound, the Seattle Fault dominates, and our modeling for this earthquake source closely matches the TDZ.

<u>Deterministic vs. Probabilistic</u>
Probabilistic modeling is preferred. However, the probabilistic modeling that was presented in the ASCE code has never been subject to a peer review by a broad group of scientists, especially in the Pacific Northwest. Cascadia modeling (deterministic) has been peer reviewed, adopted by OR and WA scientists and emergency managers.

Onshore WA tsunami modeling is more conservative – Tokeland WA



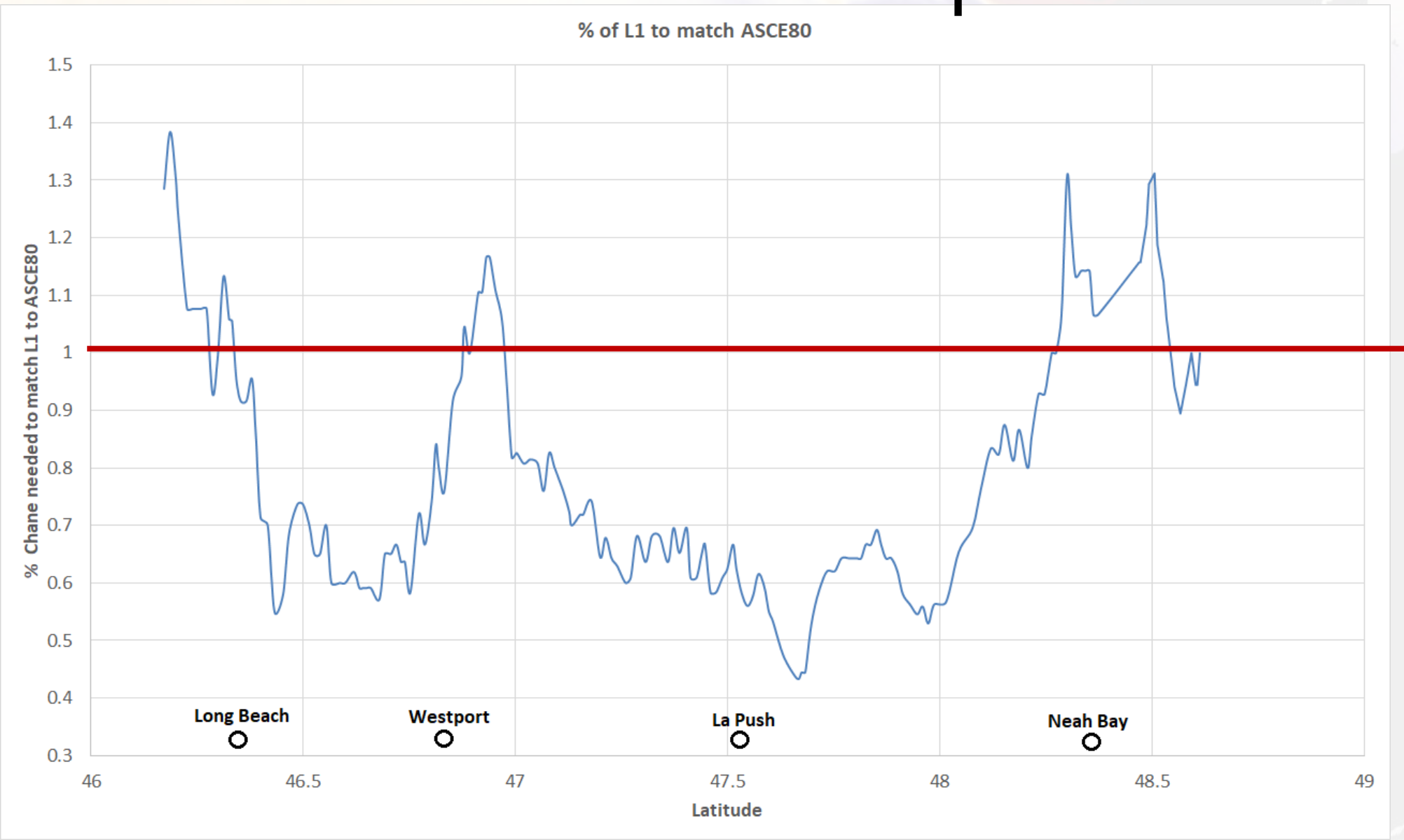
Washington modeling vs. ASCE offshore at 100 m



It is important to point out that most of WA tsunami modeling along the outer coast is "compliant" and MORE CONSERVATIVE than ASCE requirements at the 100 m bathymetry line. However, there are significant exceptions.

This is largely due to the low-resolution data used and likely from unrealistic source models.

Washington CSZ modeling compared to ASCE tsunami code requirements offshore



Locations **not compliant** with ASCE tsunami modeling requirements

Locations **compliant** with ASCE tsunami modeling requirements