Practical Risk Reduction – The Tsunami Provisions in ASCE 7 (and the International Building Code)

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Tohoku Tsunami photograph at Minami Soma by Sadatsugu Tomizawa

USA Codes and Standards

- **International Building Code (IBC)**
- **ASCE 7 Minimum Design Loads for Buildings and Other Structures (ASCE 7) developed in an ANSI-accredited consensus process**

- Other Standards:
  - Material specific design specifications
  - Non-structural installation standards
  - Testing and qualification standards

ASCE 7-16 Minimum Design Tsunami in the Five Western States

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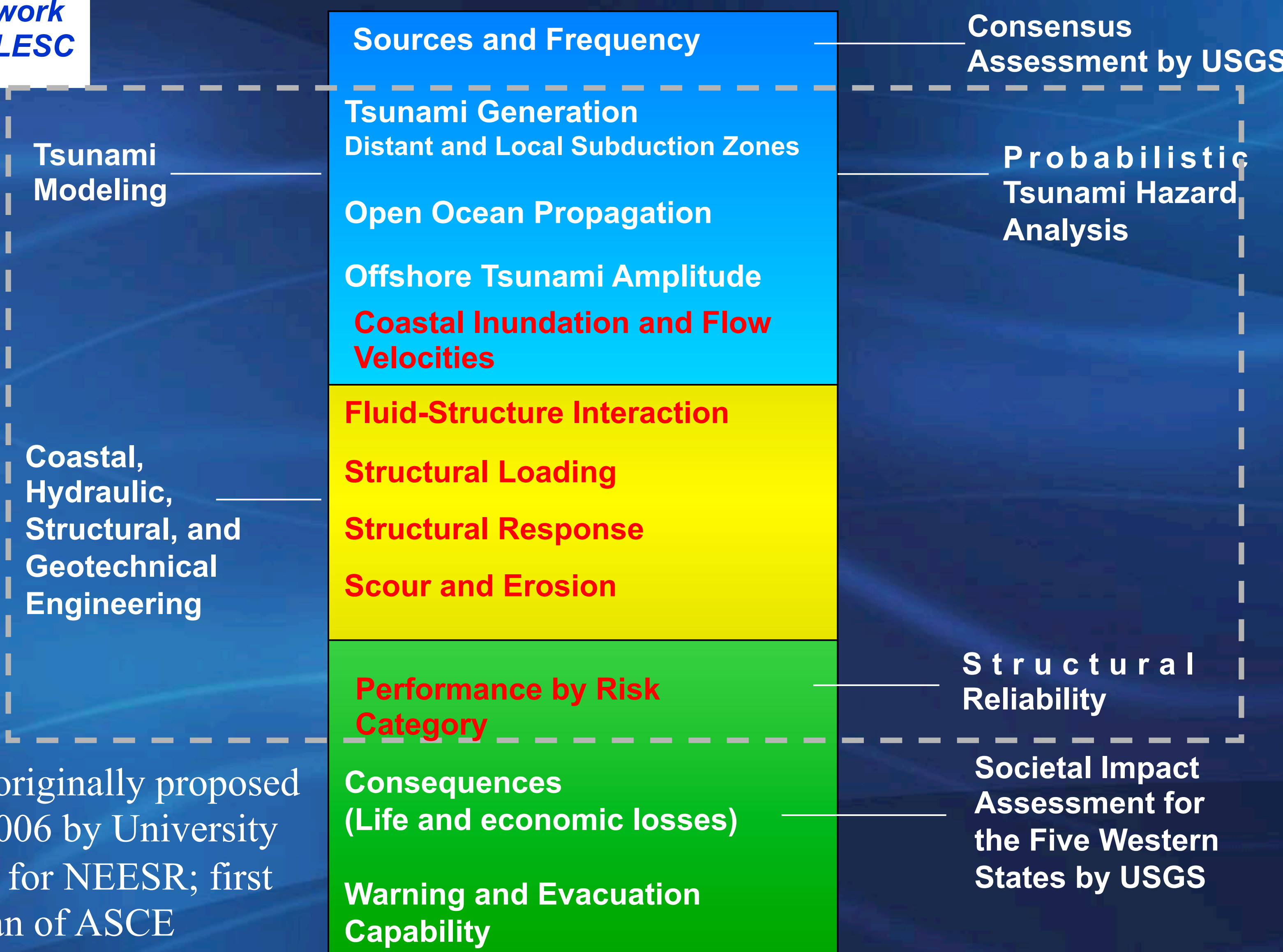
- A U.S. national standard for engineering design for tsunami effects does not exist. As a result, tsunami risk to coastal zone construction is not explicitly addressed in design.
- The Tsunami Loads and Effects Subcommittee has developed a new Chapter 6 - Tsunami Loads and Effects for the ASCE 7-16 Standard, which has been passed and is approaching approval.
- ASCE 7-16 to be published by March 2016
- Tsunami Provisions would then be referenced in IBC 2018
- State Building Codes of AK, WA, OR, CA, and HI ~ 2020
- ASCE will be publishing a design guide in 2015 with several types of design examples, and offering seminars.

Implementation of Tsunami-Resilient Engineering Design

Scope of work
ASCE 7 TLESC



Concept originally proposed in 2005-2006 by University of Hawaii for NEESR; first master plan of ASCE provisions written in 2011

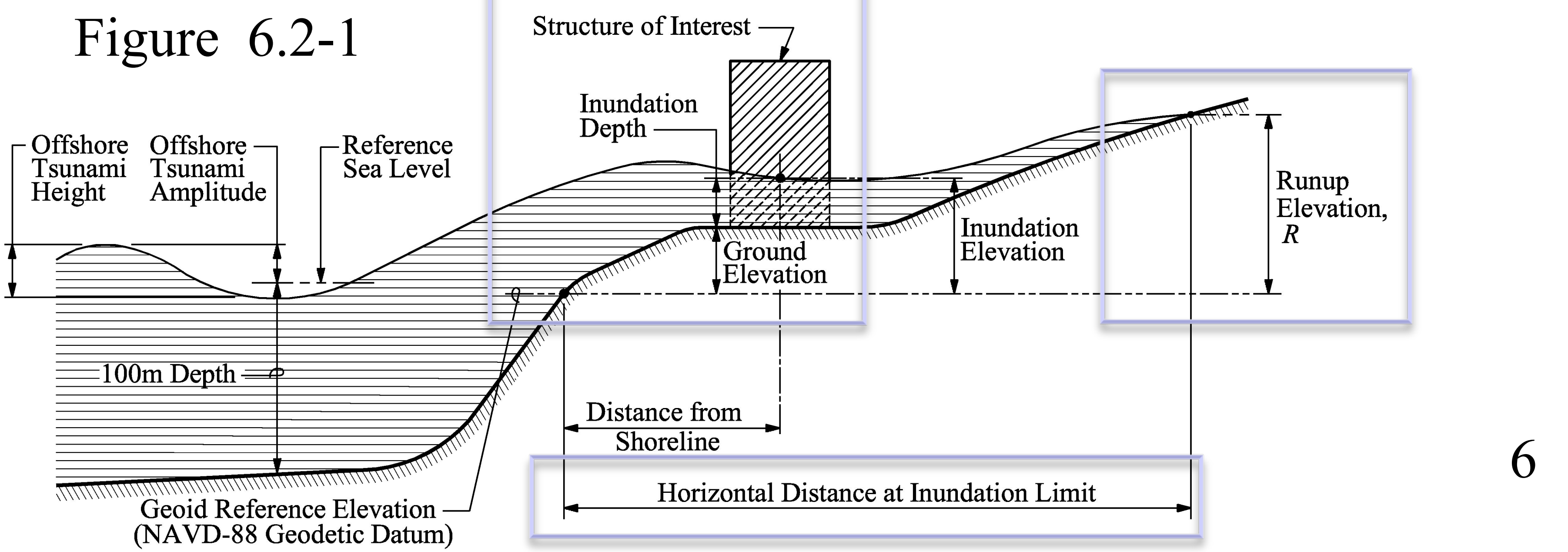
MCT and Tsunami Design Zone

- The Maximum Considered Tsunami (MCT) has a 2% probability of being exceeded in a 50-year period, or a ~2500 year average return period.
- The Maximum Considered Tsunami is the design basis event, characterized by the inundation depths and flow velocities at the stages of in-flow and outflow most critical to the structure.
- The Tsunami Design Zone is the area vulnerable to being flooded or inundated by the Maximum Considered Tsunami. The runup for this hazard probability is used to define a Tsunami Design Zone map.

Terminology

- RUNUP ELEVATION: Difference between the elevation of maximum tsunami inundation limit and the (NAVD-88) reference datum
- INUNDATION DEPTH: The depth of design tsunami water level with respect to the grade plane at the structure
- INUNDATION LIMIT: The horizontal inland distance from the shoreline inundated by the tsunami

Figure 6.2-1



Tsunami Design Zone: Lessons from the Tohoku, Chile, and Sumatra Tsunamis

- Recorded history may not provide a sufficient measure of the potential heights of great tsunamis.
- Design must consider the occurrence of events greater than in the historical record
- Therefore, probabilistic physics-based Tsunami Hazard Analysis should be performed in addition to historical event scenarios
- The PTHA procedure accounts for uncertainty

ASCE Database of PTHA Offshore Tsunami Amplitudes and Inundation Limit and Runup Points

Probabilistic Tsunami Hazard Analysis (ASCE)

- Integration over a broad range of seismic sources with varying sizes and recurrence rates
- Formal inclusion of uncertainties through logic trees and distribution functions
- Probabilistic hazard is primary expressed in the Offshore Tsunami Amplitude at 100m bathymetry offshore from the site of interest
- Source disaggregation of hazard for sites both near and far from those sources
- Source model characterization for probabilistic tsunami events

PTHA determines the Max. Considered Tsunami

- The ASCE PTHA procedure was peer reviewed by a broad stakeholder group convened by the NOAA National Tsunami Hazard Mitigation Program, and included independent comparative pilot studies. Subduction Zone Earthquake Sources are consistent with USGS Probabilistic Seismic Hazard model.

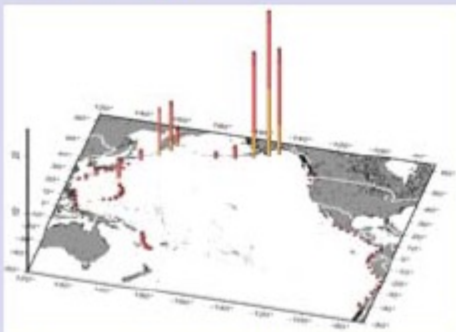
Probabilistic Tsunami Hazard Analysis

SOURCE	Moment Magnitude and Slip, Source Locations, and Recurrence based on Seismology
PROPAGATION	Propagation per long wave equations in deep ocean to determine amplitude and period at offshore locations
SITE ANALYSIS of DESIGN	Inundation limit and Runup determined by nonlinear wave propagation models
DESIGN MAPS	Probabilistic Maps of Offshore Amplitude, Inundation Limit and Runup for 5 states

2,500-year Inundation Zone Using PTHA Maps & Forecast Tools

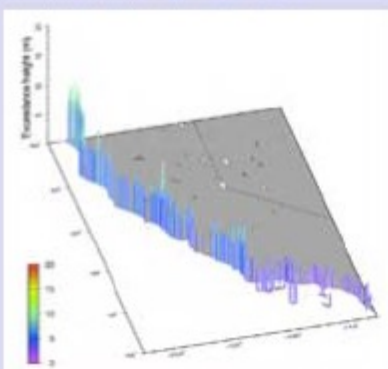
URS PTHA maps

– Source disaggregation and selection



Courtesy of Thio et al. (2010)

– Offshore tsunami height for an ARP level



Courtesy of Thio et al. (2010)

ComMIT

Reconstruct disaggregated scenarios using a combination of PMEL "unit tsunami sources":

- source location
- magnitude
- rupture area
- slip

Tsunami inundation modeling for reconstructed sources

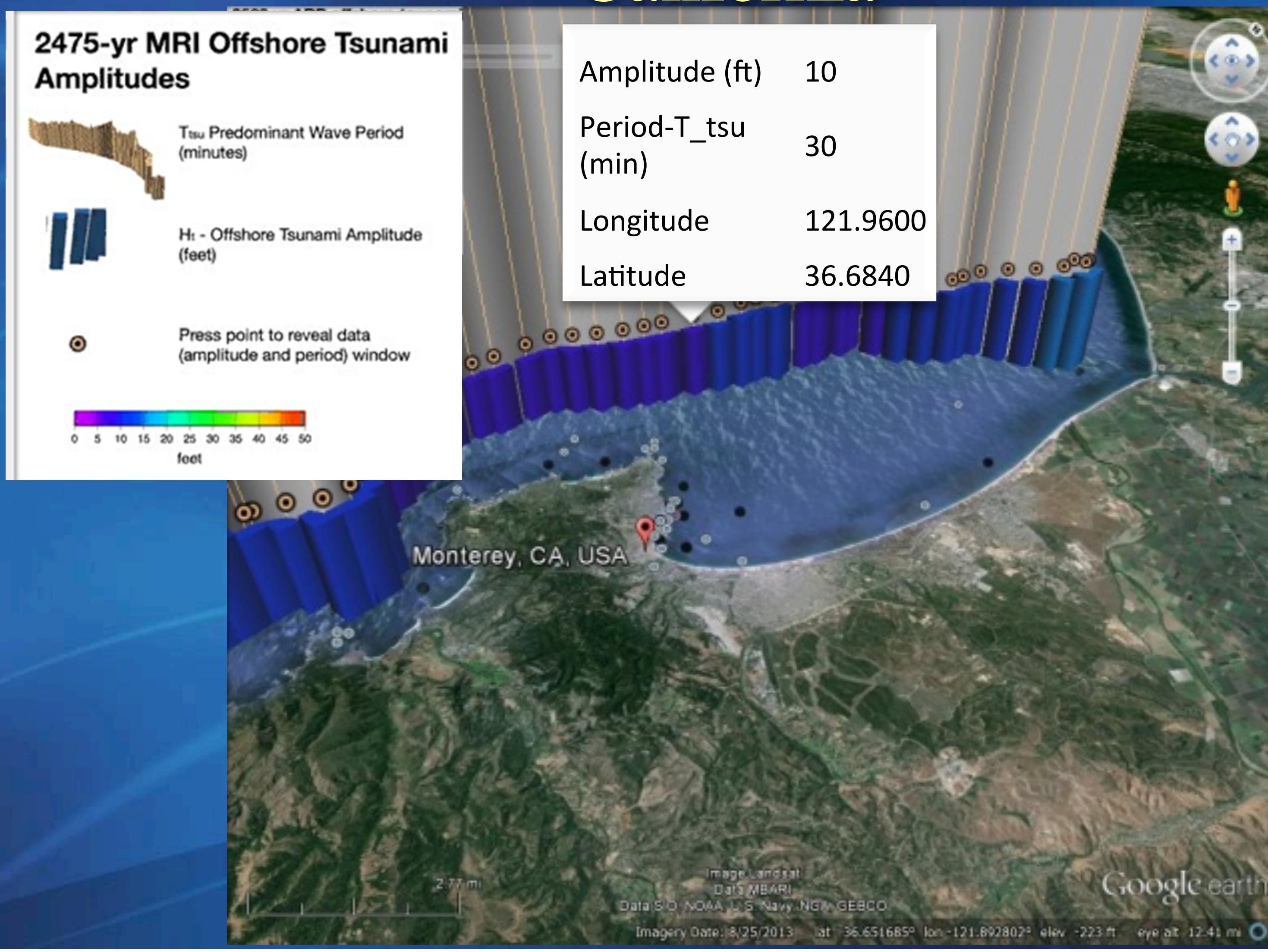
Tuning for PTHA tsunami height using unit tsunami sources

Derive probabilistic flooding hazard maps using an envelop of inundation lines obtained from above steps

Summary of Design Basis

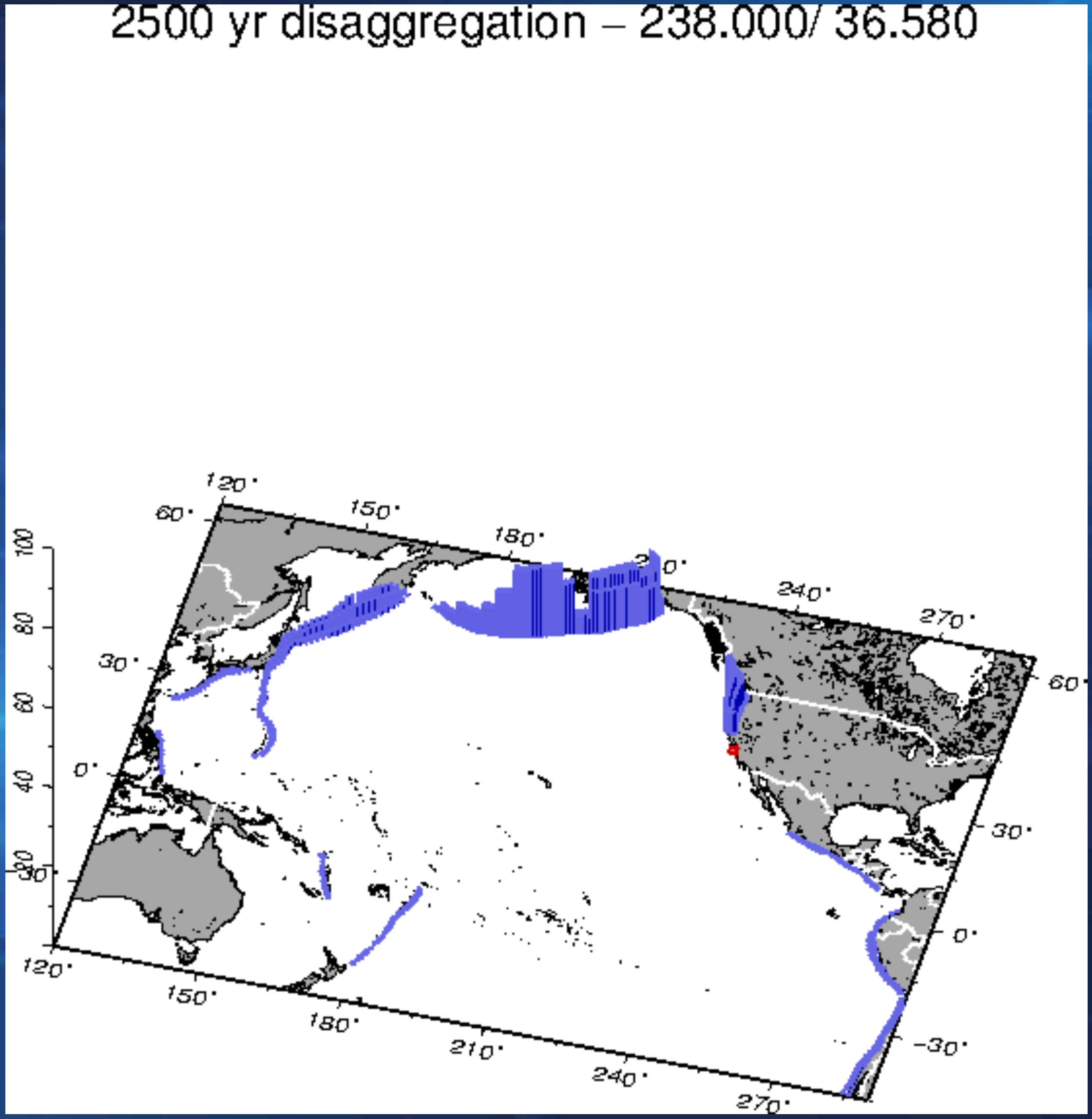
- PTHA-based design criteria - The method of Probabilistic Tsunami Hazard Analysis is consistent with probabilistic seismic hazard analysis in the treatment of uncertainty.
- Maximum Considered Tsunami – 2500-year MRI
- The tsunami design provisions utilize probabilistic Offshore Tsunami Amplitude maps and Tsunami Design Zone inundation maps
- Procedures for tsunami inundation mapping are based on using these probabilistic values of Offshore Tsunami Amplitude
- Hydraulic analysis or site-specific inundation analysis to determine site design flow conditions: velocity, depth for at least three critical loading stages
- Design includes fluid loads, debris loads, and foundation

Offshore Tsunami Amplitude and Period for the Maximum Considered Tsunami at Monterey California



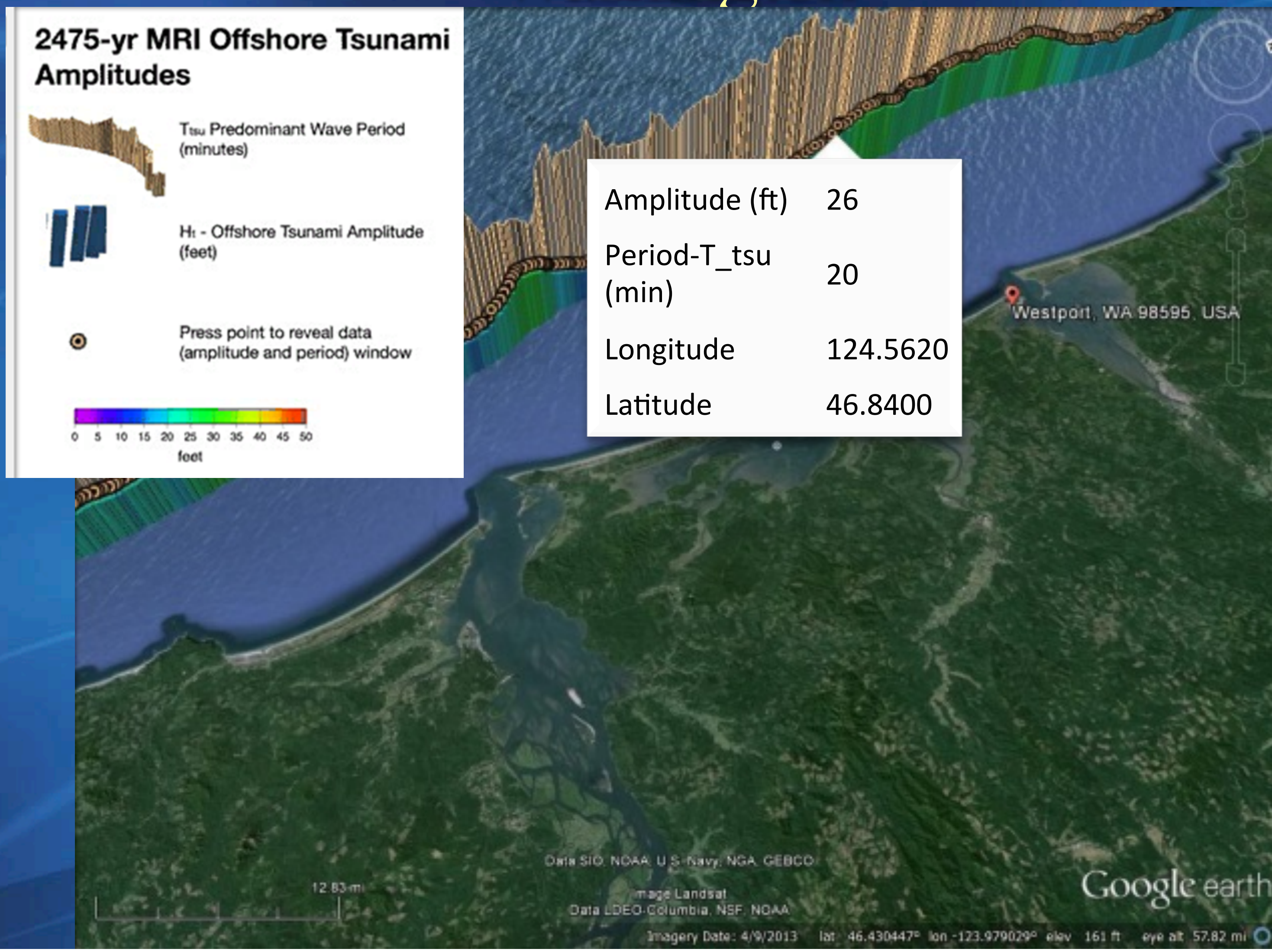
Predominant Probabilistic Sources for Monterey, CA

- sources are primarily Alaska, East Aleutian, and Kuriles



Tsunami Design Zone - Monterey

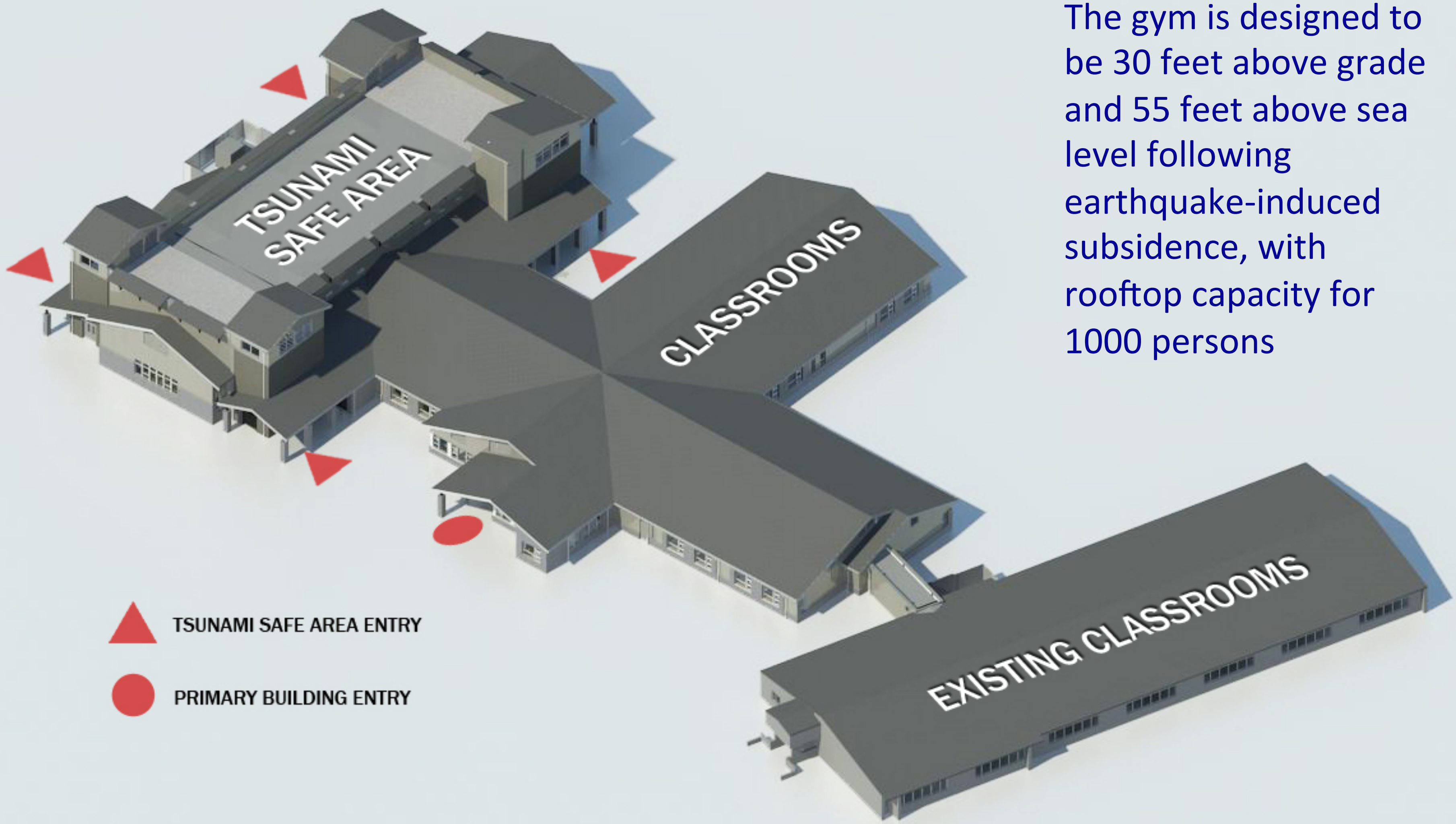
Offshore Tsunami Amplitude$_{\varepsilon}$ and Period for the Maximum Considered Tsunami at Westport, Washington



Tsunami Design Zone – Vicinity of Ocosta, WA

- At sites with overwash, reference points of inundation depth are given

Ocosta Elementary School
Westport, Washington
America's first tsunami refuge just broke ground



The gym is designed to be 30 feet above grade and 55 feet above sea level following earthquake-induced subsidence, with rooftop capacity for 1000 persons

ASCE 7 Chapter 6- Tsunami Loads and Effects

- 6.1 General Requirements
- 6.2-6.3 Definitions, Symbols and Notation
- 6.4 Tsunami Risk Categories
- 6.5 Analysis of Design Inundation Depth and Velocity
- 6.6 Inundation Depth and Flow Velocity Based on Runup
- 6.7 Inundation Depth and Flow Velocity Based on Site-Specific Probabilistic Tsunami Hazard Analysis
- 6.8 Structural Design Procedures for Tsunami Effects
- 6.9 Hydrostatic Loads
- 6.10 Hydrodynamic Loads
- 6.11 Debris Impact Loads
- 6.12 Foundation Design
- 6.13 Structural Countermeasures for Tsunami Loading
- 6.14 Tsunami Vertical Evacuation Refuge Structures
- 6.15 Designated Nonstructural Systems
- 6.16 Non-Building Structures

Risk Categories of Buildings and Other Structures per ASCE 7

Not all structures within the TDZ are subject to the provisions

Risk Category I	**Buildings and other structures that represent a low risk to humans**
Risk Category II	**All buildings and other structures except those listed in Risk Categories I, III, IV**
Risk Category III	**Buildings and other structures, the failure of which could pose a substantial risk to human life.** **Buildings and other structures with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.**
Risk Category IV	**Buildings and other structures designated as essential facilities** **Buildings and other structures, the failure of which could pose a substantial hazard to the community.**

- **The scope of the tsunami provisions targets the performance of Risk Category III and IV buildings and critical infrastructure**

Tsunami Disaster Resilience by Design

- Maps and design criteria in the ASCE 7 design standard are based on engineering risk analysis and reliability targets, rather than deterministic scenarios
- The ASCE 7 tsunami provisions applies to design for community planning and resilience before a tsunami event.
- After a tsunami, it will have even more significance as means to plan, site, and design what (and where) is appropriate and necessary in reconstruction, to enable Building Back Better.
- This is a new accomplishment that directly provides a means to effectively influence community resilience and the reliability of critical infrastructure.

Recommendations

- The ASCE 7 provisions constitute a comprehensive means of improving tsunami resilience when adopted as part of a mandatory building code. It then makes tsunamis a required consideration in planning, siting, and design.
- The ASCE 7 tsunami provisions have general applicability and can be adapted elsewhere as a standardized methodology for risk-based engineering.
- In order to achieve the appropriate reliabilities for community resilience, Probabilistic Tsunami Hazard Analysis should be the basis for the development of Tsunami Design Zone maps.
- Higher-resolution bathy-topographic data should be used with a validated inundation model to produce the Tsunami Design Zone maps for a region.