# ASCE 7-16 Tsunami Provisions – Engineering Design

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# ASCE 7-16 Tsunami Part III: Engineering Design

- Part 1: ASCE 7 overview, ASCE consensus process
- Part 2: Probabilistically generated inundation hazard
- Part 3: Using hazard values from part 2 and design a building to resist the forces while meeting the basic requirements
  - Collapse Prevention at MCE (2,500yr) Event

# ASCE 7-16: Engineering Design

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

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GENERAL INFORMATION – WHAT BUILDINGS ARE REQUIRED

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HAZARD DETERMINATION AT BUILDING SITE (I.E. DEPTH/VELOCITY)

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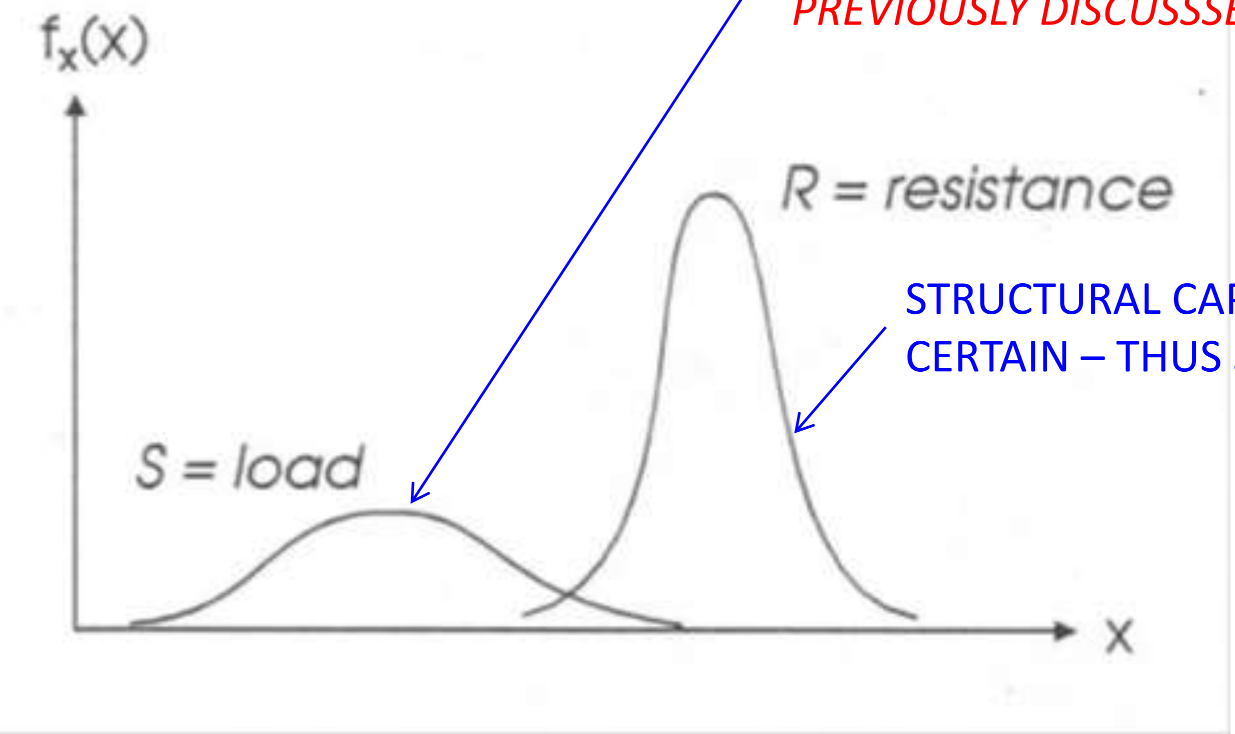
BUILDING DESIGN FORCES & REQUIREMENTS

# Recap Resilience based design

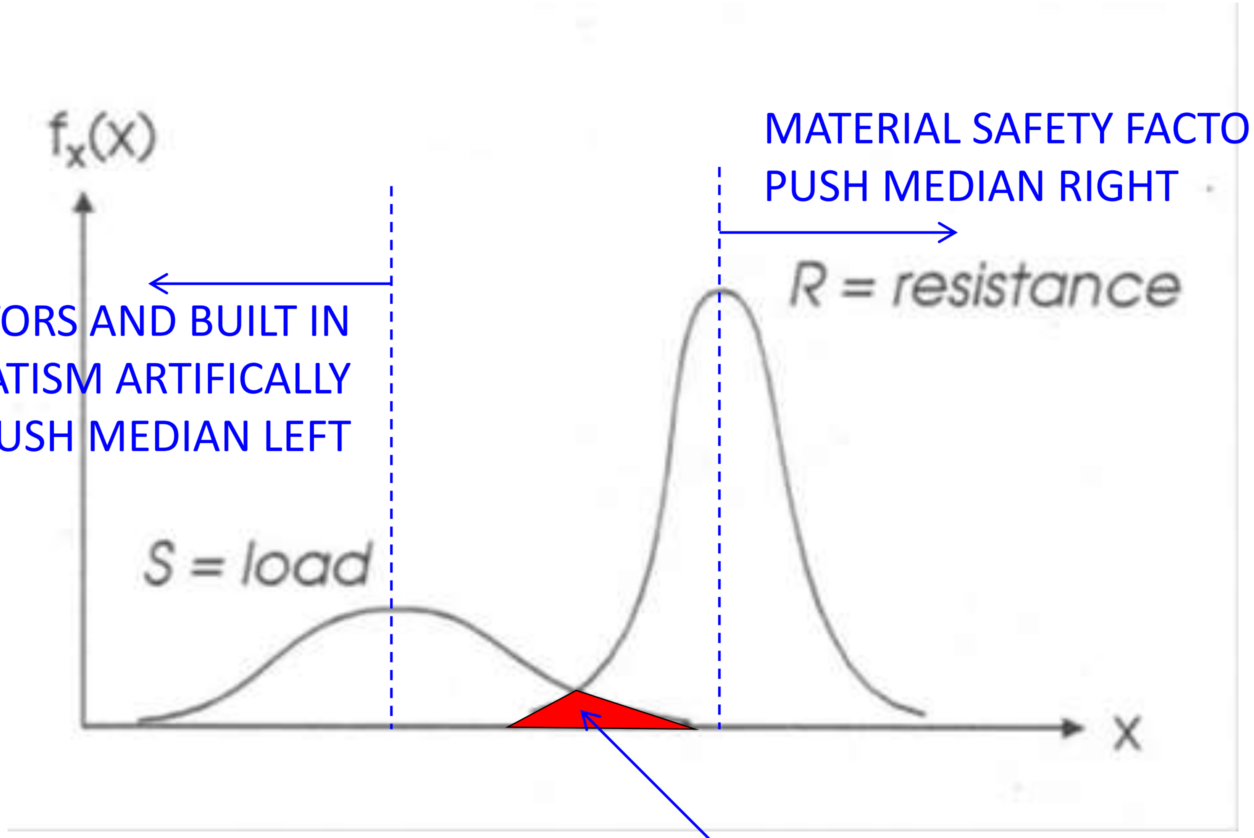


TSUNAMI LOADING – HIGHLY UNCERTIAN – THUS LARGE SPREAD IN PROBABLISTIC LOAD

*PREVIOUSLY DISCUSSSED*

STRUCTURAL CAPACITY – MORE CERTAIN – THUS SMALLER SPREAD

# How does ASCE 7/IBC ensure safety



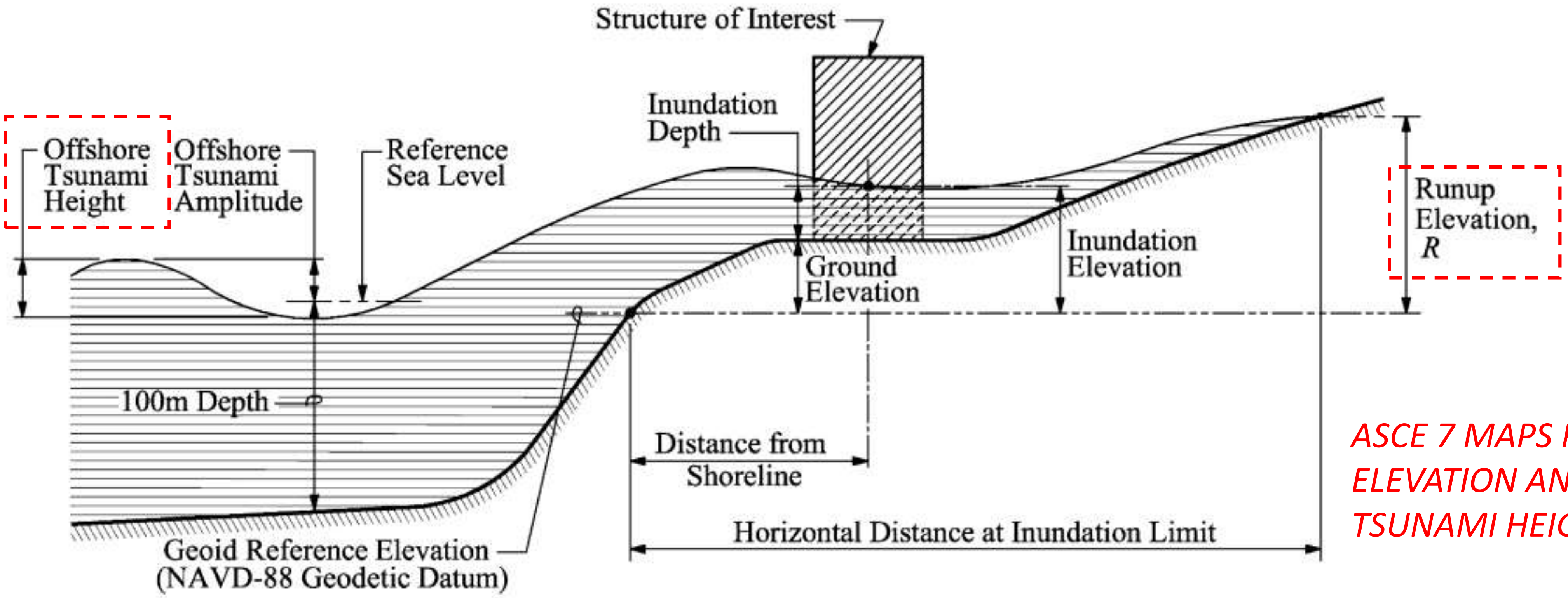
MATERIAL SAFETY FACTORS ARTIFICALLY PUSH MEDIAN RIGHT

LOAD FACTORS AND BUILT IN CONSERVATISM ARTIFICALLY PUSH MEDIAN LEFT

GOAL: MINIMIZE OVERLAP = I.E. PROBABLITY OF FAILURE

# Design with ASCE 7 Chapter 6

- Sections 6.5-6.7 take mapped values and turn them into the required design parameters (depth & velocity)



*ASCE 7 MAPS PROVIDE RUNUP ELEVATION AND OFFSHORE TSUNAMI HEIGHT*

# Design with ASCE 7 Chapter 6

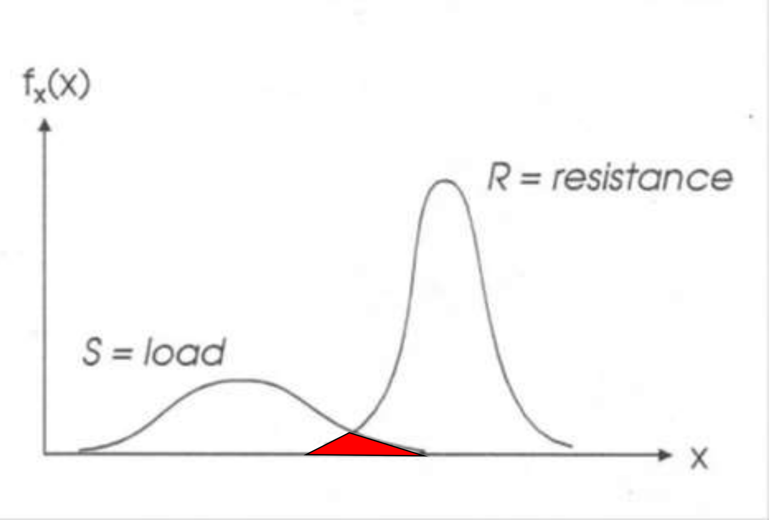
- Sections 6.5-6.7 take mapped values and turn them into the required design parameters
  - Maps provide runup line/elevation and offshore wave height
  - Maps do not provide depth & velocity directly

- Sections 6.8-6.11 provide the tools to take the design parameters (depth & velocity) and turn them into forces

# Structural Design for Tsunami Loads (Section 6.8)

- 6.8 defines 3 load cases for designer to consider
- Reliability analysis was performed based on ASCE 7 target reliabilities discussed in chapter 2
  - From this importance factors were calibrated.
    - RC II = 1.0
    - RC III = 1.25
    - RC IV = 1.25

PER ASCE 7 CHAPTER 1 – RC III & IV BUILDINGS NEED TO HAVE LOWER COLLAPSE PROBIBILITIES – THUS LOADS ARE AMPLIFIED



# Structural Loads (Section 6.9 – 6.11)

# Section 6.9: Hydrostatic Forces

- Hydrostatic pressure on outside walls
- Unbalanced Lateral Forces (larger buildings)
- Buoyant Uplift based on displaced volume
- Trapped air in voids below elevated slab
- Residual Water Surcharge Loads on Elevated Floors

# Section 6.10 – Hydrodynamic Forces

- Global Building Drag Forces
    - w/ Debris Damming 6.10.2.4
- Individual Component Evaluation
    - Columns: 6.10.2.2
    - Walls 6.10.2.3
    - Entrapped bore
    - Perforated Walls: 6.10.2.4
    - Non-Perpendicular Elements: 6.10.2.5
    - Flow Stagnation on Walls & Slabs: 6.10.3
    - 50% Increase for bore effects where $F_r > 1.0$

# Section 6.10 – Hydrodynamic Forces

- Global lateral force Check
  - Compare $V_{TSU}$ to 75% of the over strength capacity of the seismic lateral system
  - Not adequate for better than collapse prevention
- Evaluate individual components using conventional strength design
  - Load considered as sustained static load
  - Include appropriate load combinations and factors
  - Include material strength reduction factors ($\phi$)

# Section 6.11 – Debris Impact Loads

- Waterborne Debris Loads
  - Utility poles/logs
  - Passenger vehicles
  - Tumbling boulders and concrete masses
  - Shipping containers only where near ports and harbors
  - Large vessels considered for Critical Facilities and Risk Category IV only where near such ports and harbors

Shipping Containers

Power poles / tree trunks

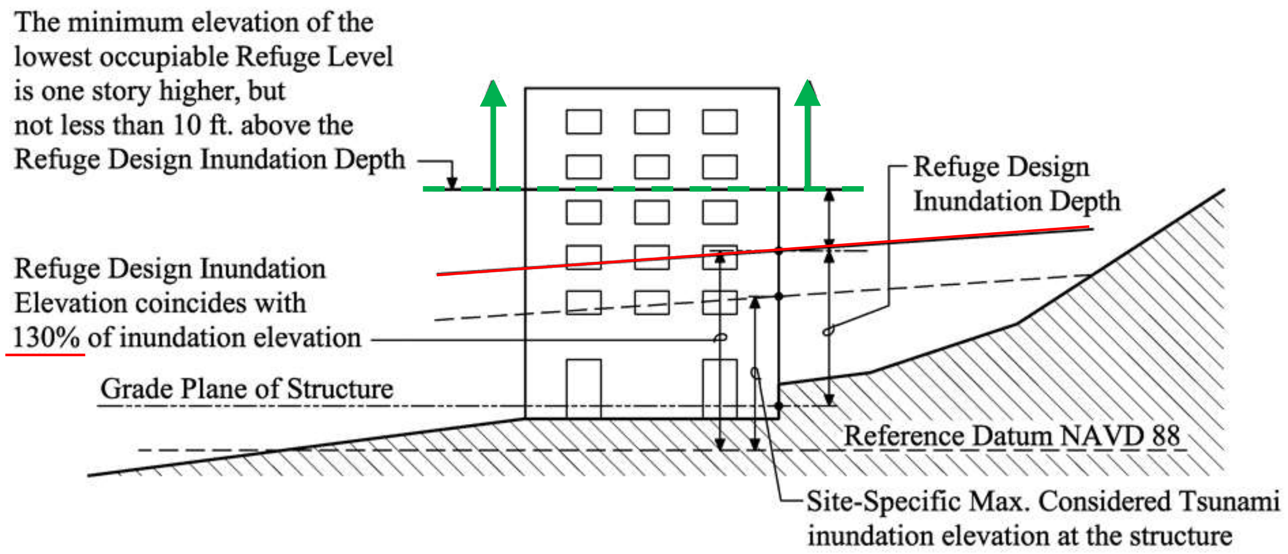
Medium Bolder

# Section 6.12 – Foundation Design

- Foundation Issues
  - Scour (global/local)
  - Bearing Capacity (pour pressure softening)
  - Uplift capacity (buoyancy/overturning)

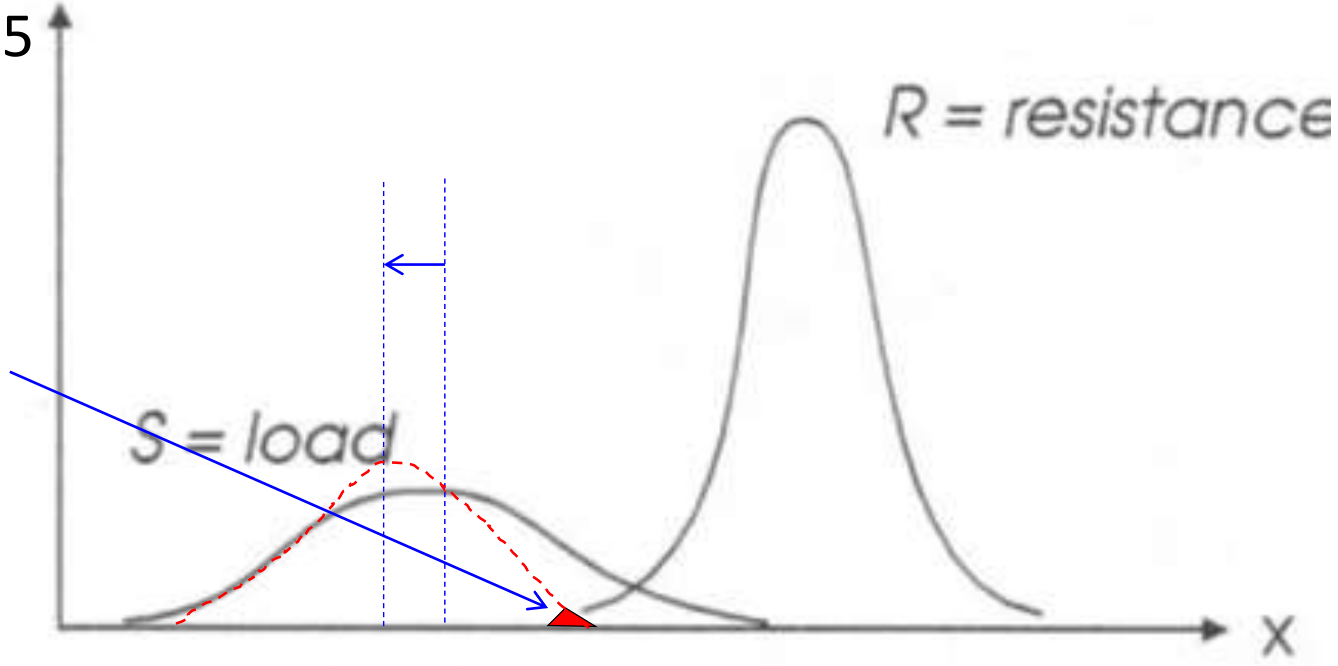
# Section 6.14 – Tsunami Vertical Evacuation

- Designated vertical evacuation structures
  - Tsunami Vertical Evacuation Refuge Structures - ASCE 7 Chapter 6 is intended to supersede both FEMA P646 structural guidelines and IBC Appendix M
  - Peer Review Required



# Section 6.14 – Tsunami Vertical Evacuation

- Additional reliability (99%) is achieved through site-specific inundation analysis and an increase in the design inundation elevation
  - Site specific modeling required (less uncertainty)
  - 30% + 10ft increase in flow depth
  - RC IV – so loads multiplied by I = 1.25



REDUCED PROBABLITY OF FAILURE BY ADDITIONAL REQUIREMENTS

# Project Examples

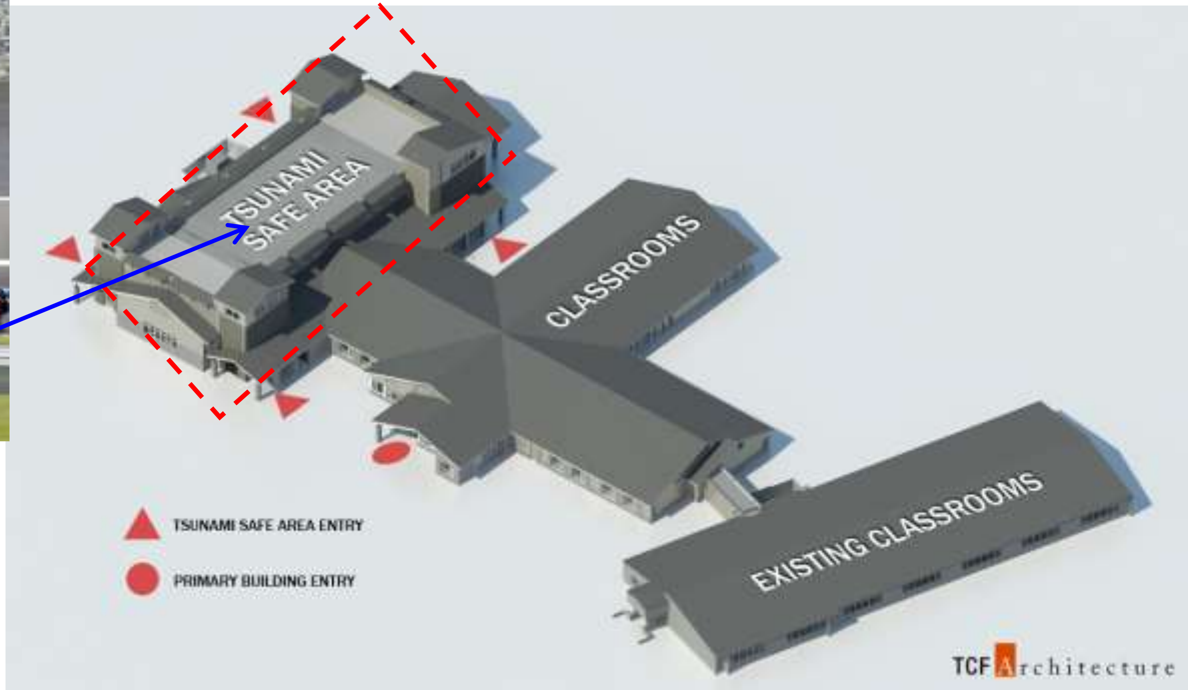
- Ocosta Elementary School
  - Ocosta WA
- Oregon State Marine Sciences Initiative Building
  - Newport OR

# Ocosta Elementary School - Requirements

- Project Requirements
  - New classrooms (23)
    - Ideal to be one level for elementary students
  - Office, kitchen, music room, cafeteria, and gym
  - Evacuation Space for ~1,000 people set above DOGAMI $L_1$ event
    - ASCE 7 draft provisions used (before mapping complete)

- Solution was to use tall volume spaces (Gym, cafeteria & music room) to create evacuation area
  - Minimized the impact of having tall roof area

# Ocosta Elementary School - Building

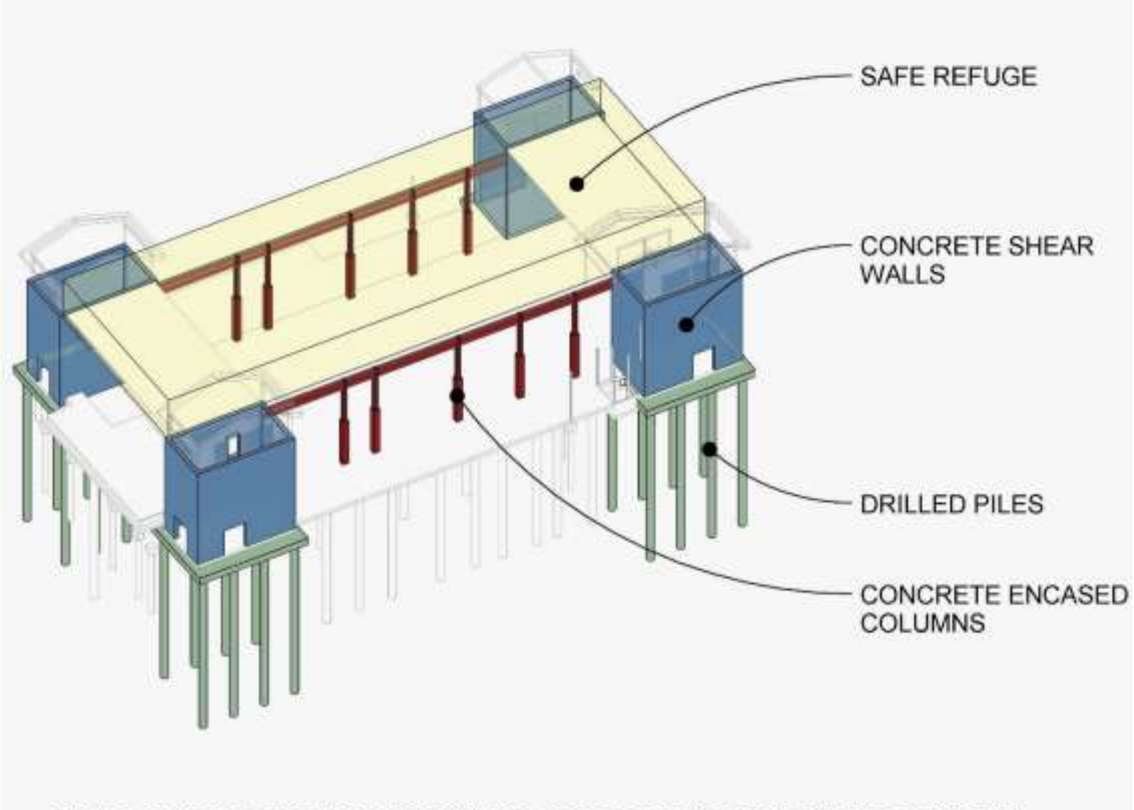


REFUGE AREA

Images courtesy of TCF Architecture

# Ocosta Elementary School – Structural System

- Gym building (Evacuation Space)
  - 4 concrete cores in each corner (stairs)
  - Pile foundation under cores
  - Steel truss w/ steel columns
  - Structural steel & composite deck roof



NOTE: CLASSROOMS AND EXISTING CLASSROOMS NOT SHOWN FOR CLARITY.

# Ocosta Elementary School

School opened in 2016

Images courtesy of TCF Architecture

# Vertical Evacuation Projects #2 :
# Oregon State University
# Marine Sciences Initiative Building

Newport, OR

# OSU Marine Sciences Building –Project Team

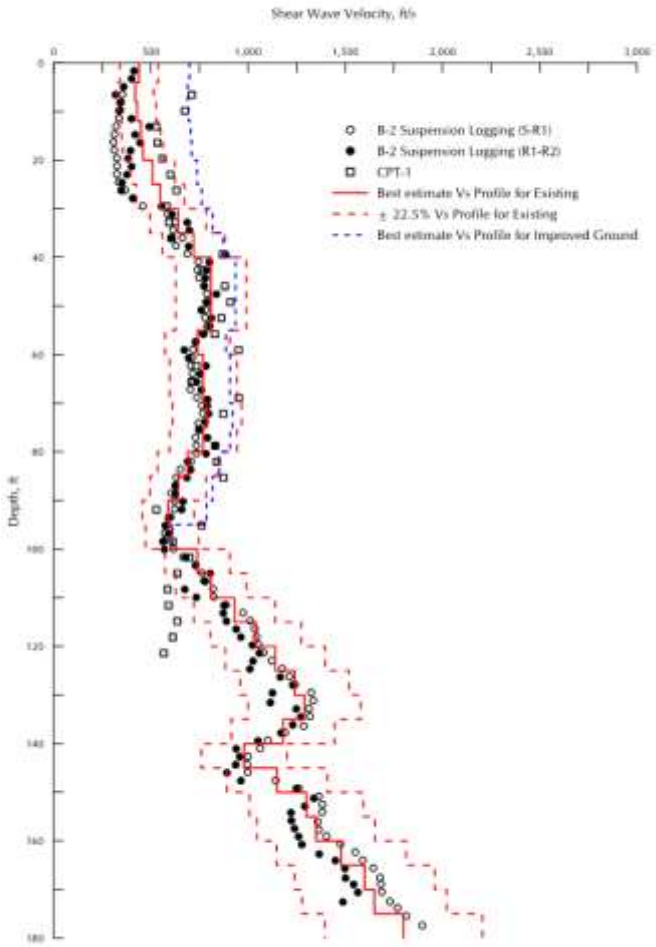
| | |
|---|---|
| Owner: | Oregon State University |
| Architect: | Yost Grube Hall Architects |
| Structural Engineer: | KPFF Consulting Engineers |
| Geotechnical Engineer: | GRI |
| Tsunami Modeler: | Yong Wei (NOAA/University of Washington) |
| Contractor: | Anderson Construction |

# OSU Marine Sciences Building – Design Criteria

- Design Criteria set by presidents message announcing the project
- Guiding principles
  - Demonstration Project
  - Intuitive Evacuation
  - Promote Collaboration
  - Iconic Building
- Building program/space requirements
  - Natural Light
  - Auditorium
  - Educational lab space
  - Research lab space w/ faculty office
  - Enclosed MEP space to combat environmental conditions

# OSU Marine Sciences Building - Hazards

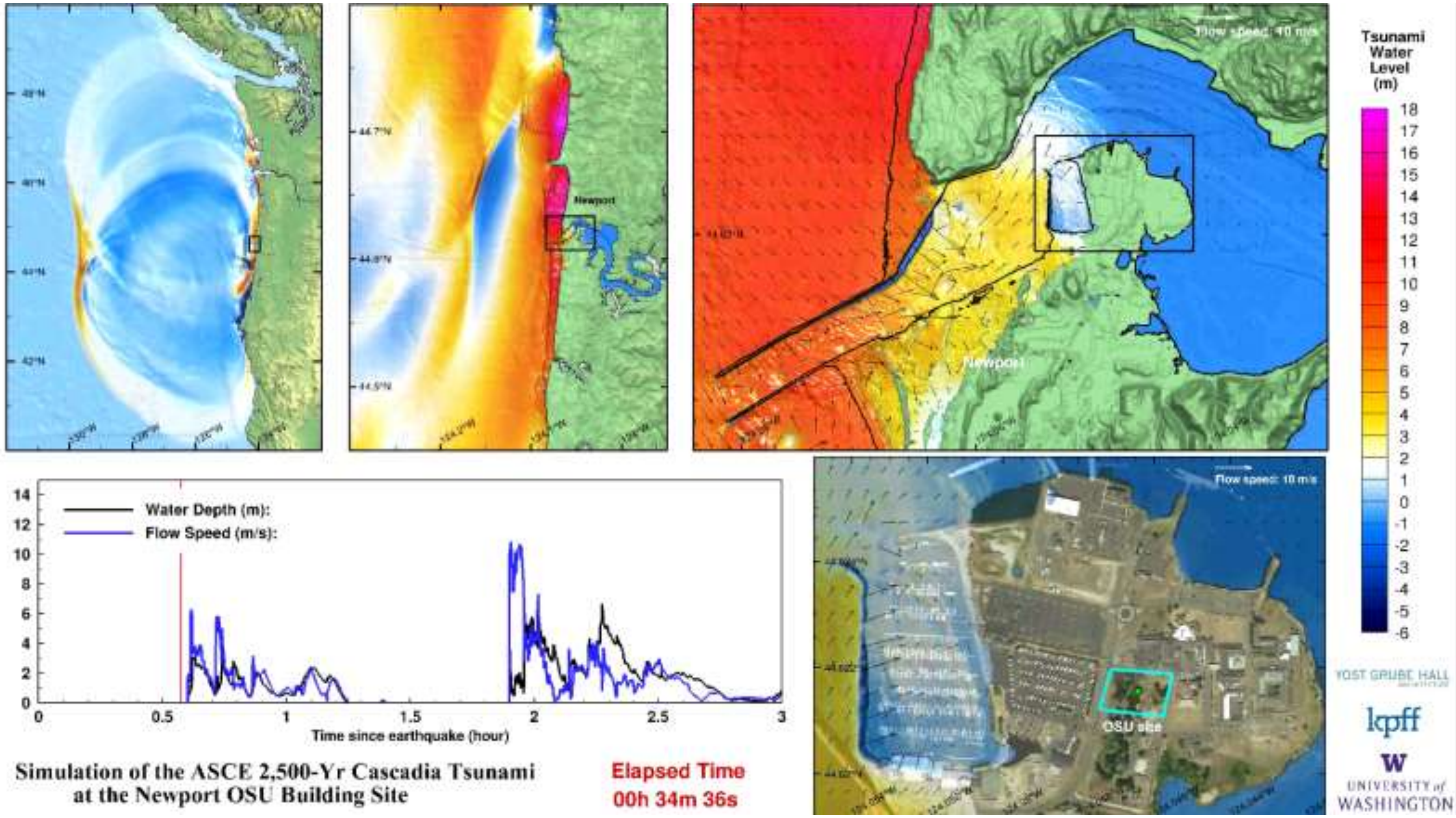
- Seismic hazard
    - Site located on liquefiable soil at multiple layers to 95ft
        - Considered cyclic degradation below 100ft
    - High water table
    - Close proximity to Cascadia subduction zone leads to high site specific spectra
    - Considered near source effects from local fault (<1km)



# OSU Marine Sciences Building - Hazards

- Site Specific Tsunami Modeling done by Dr. Yong Wei (NOAA/UW)
  - Hi-RES DEM (5m Grid)

- Results:
  - ASCE 7 MCT (2,500yr)
    - D = 21ft
    - V = 32ft/s

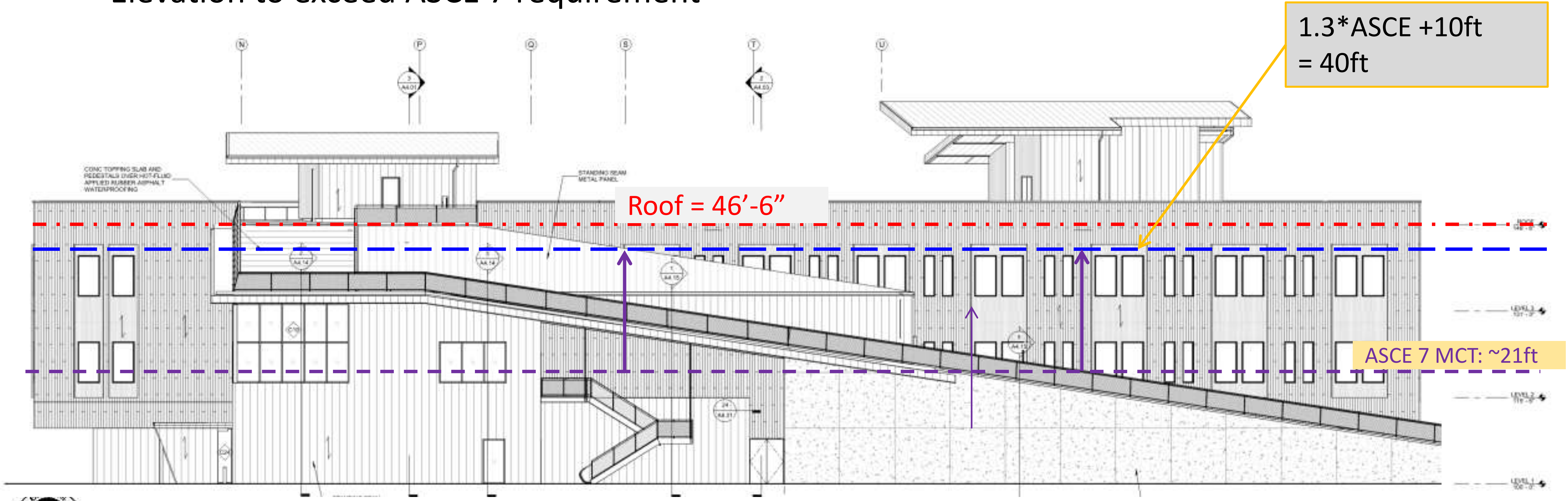


# OSU Marine Sciences Building – Debris

- Per ASCE 7 debris analysis is required
    - Logs
    - Cars/trucks
    - Boulders
    - Ships (if required)
    - Shipping containers (if required)

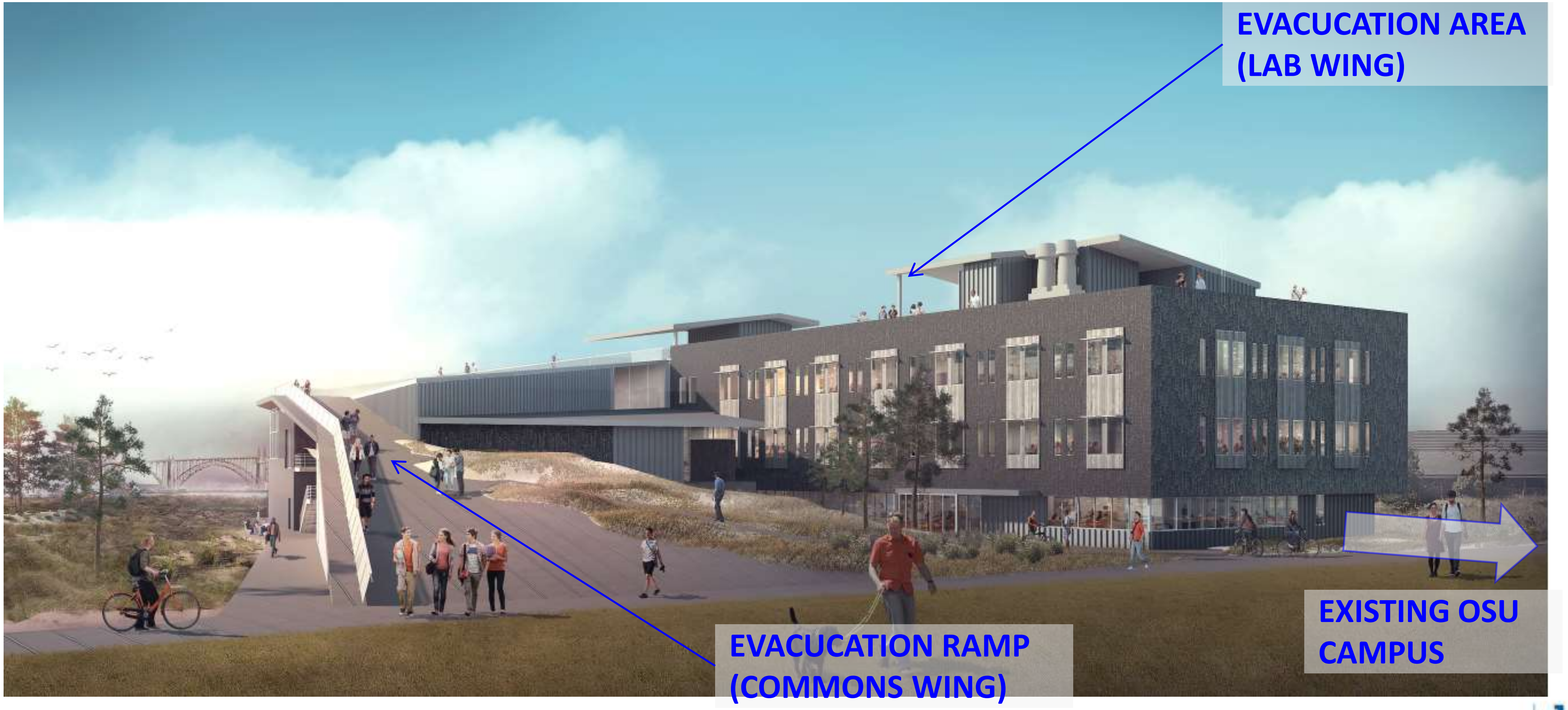
*ASCE 7-16 Tsunami Provisions – Engineering Design*

- Lab roof serves as evacuation space
    - Min 1,000 occupants
- Elevation to exceed ASCE 7 requirement



ELEVATION FROM SOUTH

# OSU Marine Sciences Building


**EVACUCATION AREA (LAB WING)**

**EVACUCATION RAMP (COMMONS WING)**

**EXISTING OSU CAMPUS**

# OSU Marine Sciences Building - Construction

**Construction Camera (9/9/2019)**

**Pre-Construction Rendering**

# Questions?