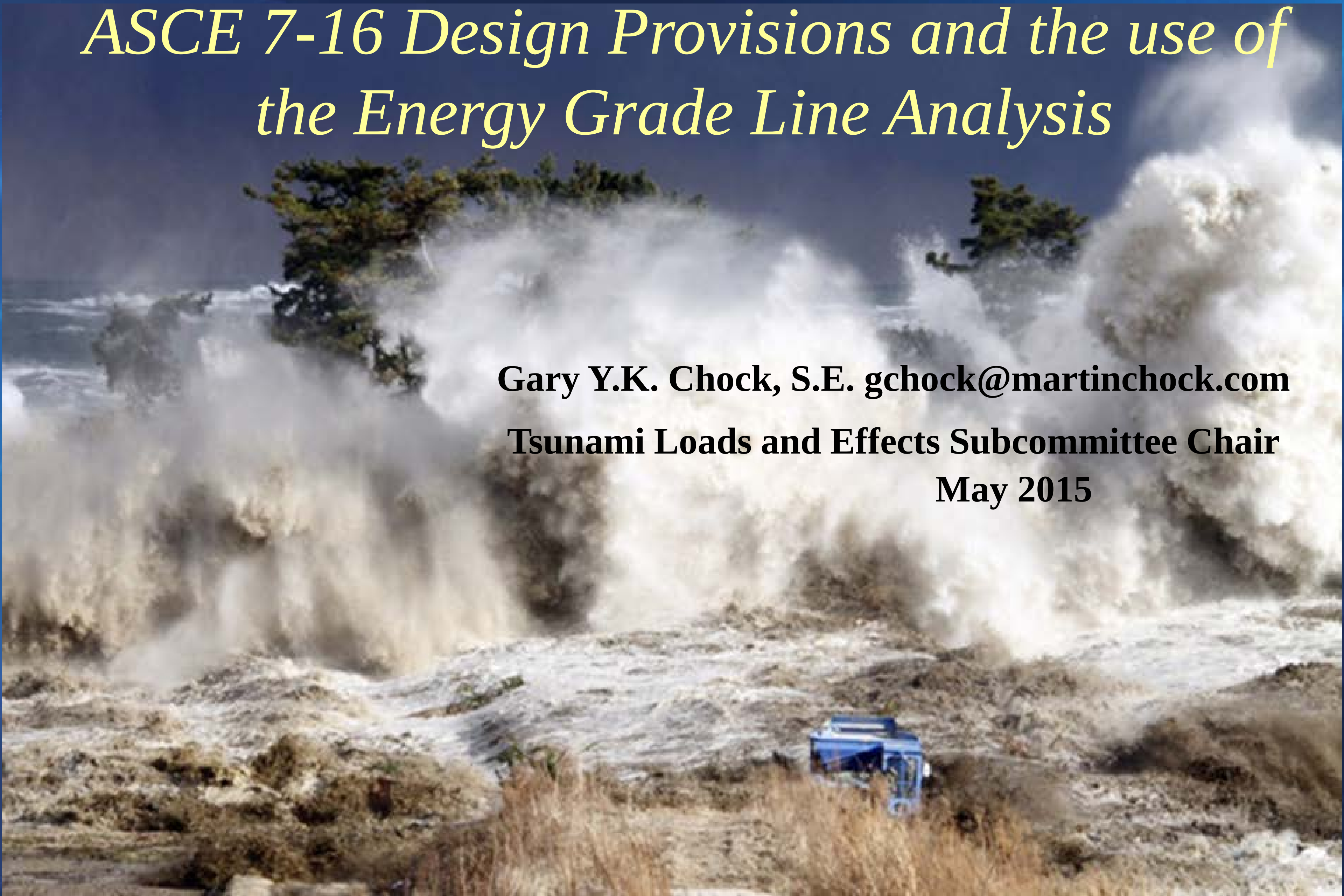
Chapter 6 on Tsunami Loads and Effects in ASCE 7-16 Design Provisions and the use of the Energy Grade Line Analysis



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Tsunami Loads and Effects Subcommittee Chair

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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
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- 6.14 Tsunami Vertical Evacuation Refuge Structures
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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.

Basic Lessons for Design of Buildings from Past Tsunami

- While structures of all material types can be subject to general and progressive collapse during tsunami, but it is feasible to design certain buildings to withstand tsunami events
- Mid-rise and larger buildings with robust structural systems survive.
- Seismic design has significant benefits to tsunami resistance of the lateral-force-resisting system.
- Local structural components may need local “enhanced resistance
- Foundation system should consider uplift and scour effects particularly at corners.

Target Reliabilities of the ASCE Tsunami Design Provisions

		Tsunami Risk Category II I = 1.0	Tsunami Risk Category III I = 1.25	Tsunami Risk Category IV I = 1.25	Tsunami Vertical Evacuation Refuge RC IV I = 1.25 & 1.3h_n
Average Reliabilities	Reliability index, β	2.74	2.87	3.03	3.68
	$P_{f\ 50\text{-year}}$	0.31%	0.21%	0.13%	0.05%
Component Failure, conditional given the MCT	Reliability index, β	1.44	1.65	1.92	2.43
	Probability of initiating a life-endangering failure	7.5%	5.0%	2.5%	0.75%

Tsunami Flow Characteristics

- Near constant velocity over land, top to bottom, with very rapidly rising depth; Unlike a storm surge; there is no stillwater
- Wave period ranges between 30 minutes to 45 minutes for *each* wave in a series; shoaling leads to nearshore amplitude typically being amplified to several times the offshore amplitude; fluid forces must be considered force-sustained actions
- Flow reversal
- Two approaches to determine depth and flow velocity
  - **Flow parameters based on pre-calculated runup from the maps (the Energy Grade Line Analysis)**
  - **Flow parameters based on a Site-Specific Probabilistic Hazard Analysis**

Inundation Depth and Flow Velocity Analysis Procedures where Runup is mapped

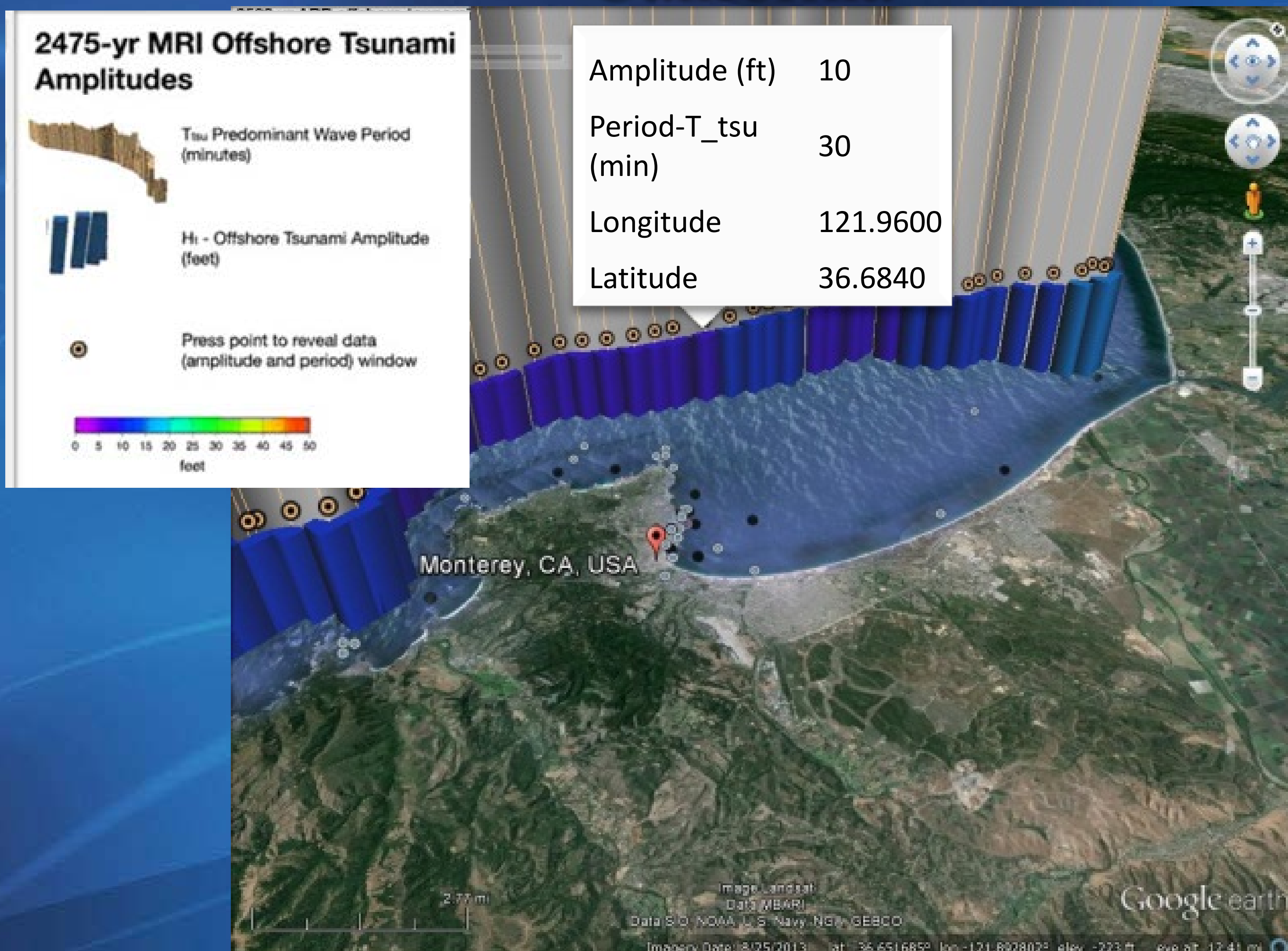
Analysis Procedure using the Tsunami Design Zone Map	Tsunami Risk Category (TRC) Structure Classification			
	TRC II	TRC III	TRC IV (excluding TVERS)	TRC IV - Tsunami Vertical Evacuation Refuge Shelter (TVERS)
Energy Grade Line Analysis	✔	✔	✔	✔
Site-Specific Analysis	Permitted;	Permitted;	✔ Required if EGLA inundation depth $\geq$ 12 ft (3.7 m)*	✔

✔ indicates a required procedure

* MCT inundation depth including sea level rise component

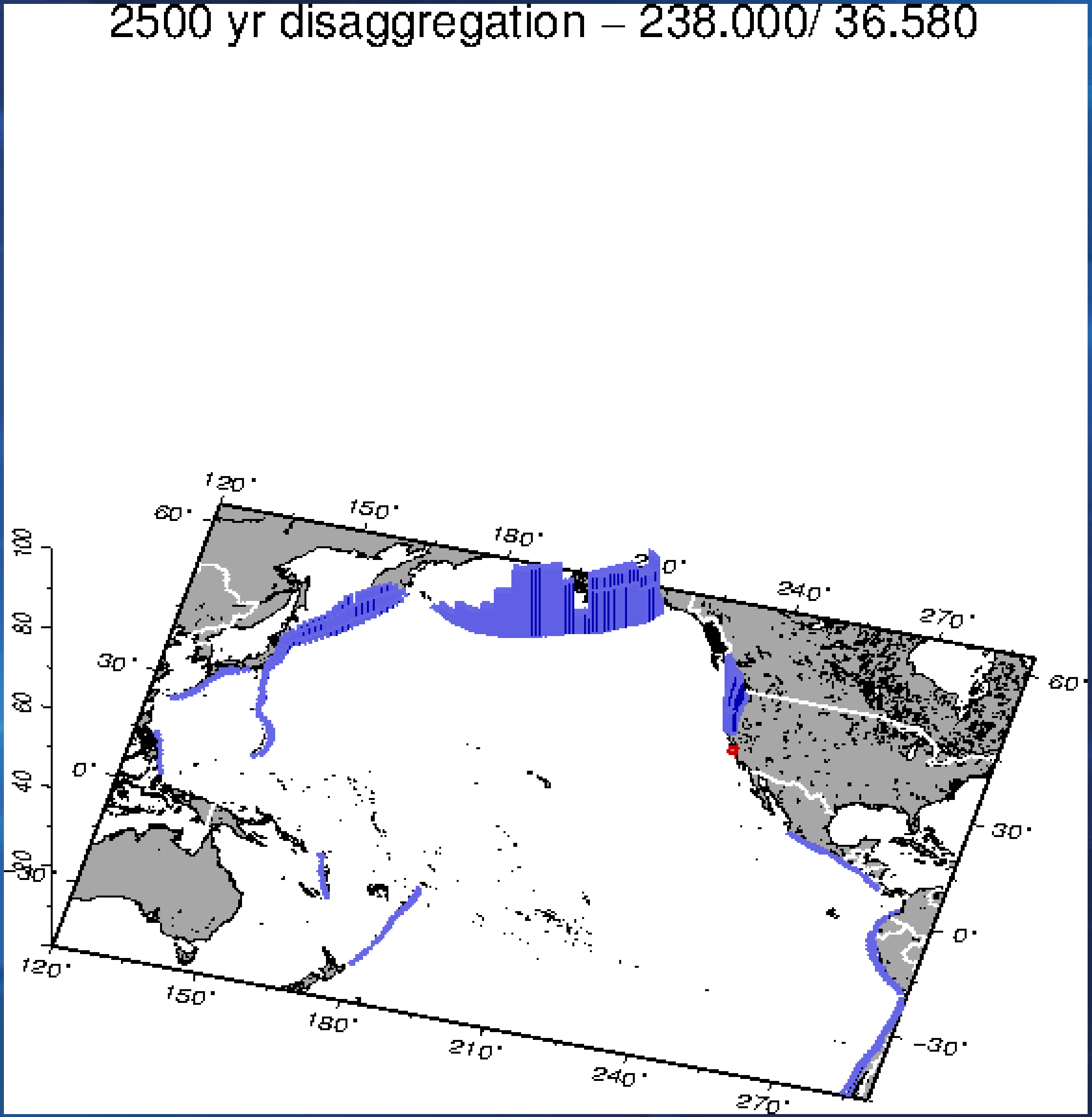
- A "floor value" of either 90% or 75% of the Energy Grade Line calculated from the runup is maintained based on terrain roughness (urban - 90%, other roughnesses – 75%)
-

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

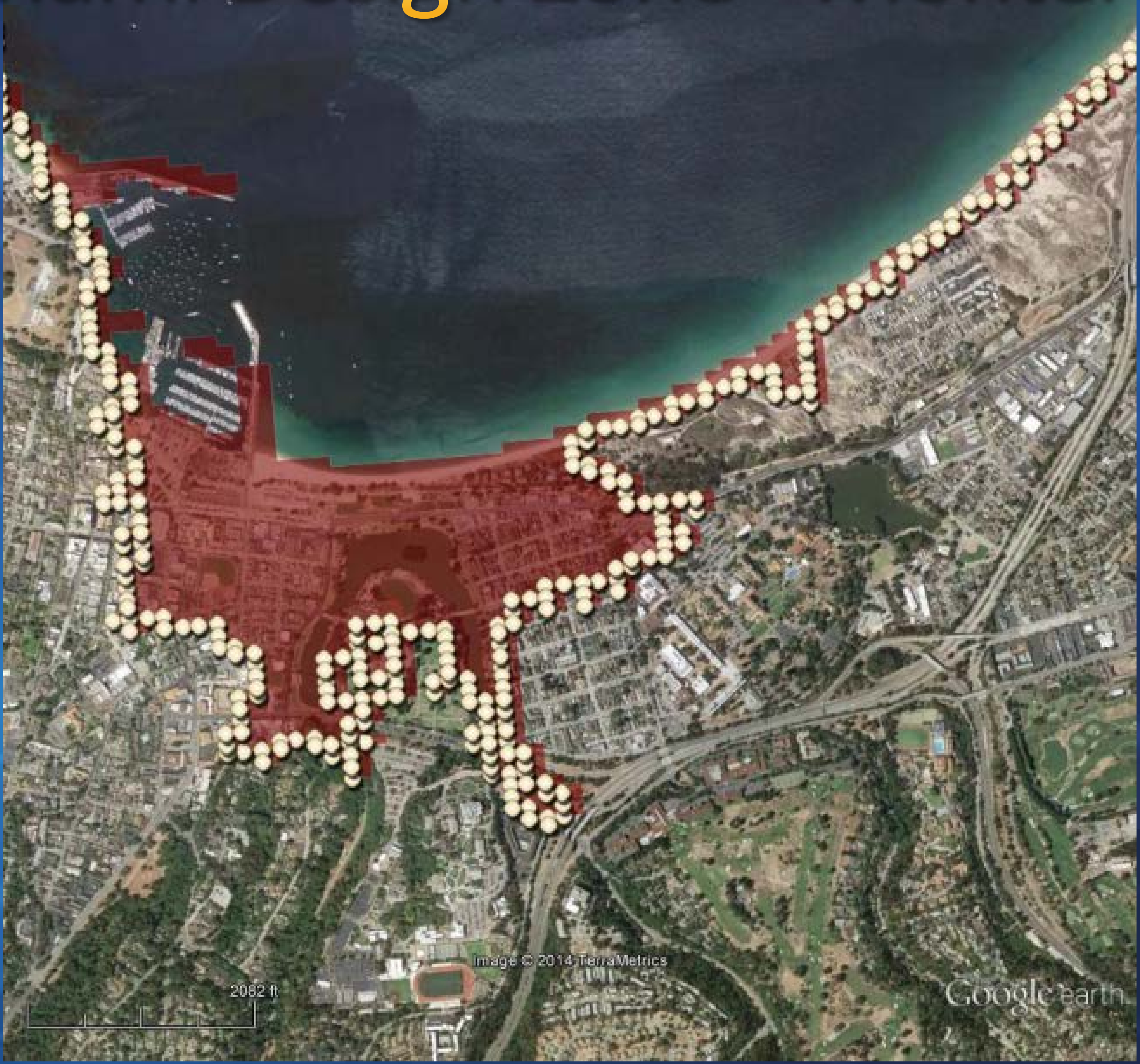


Predominant Probabilistic Sources for Monterey, CA

- sources are primarily Alaska, East Aleutian, and Kuriles



Tsunami Design Zone - Monterey

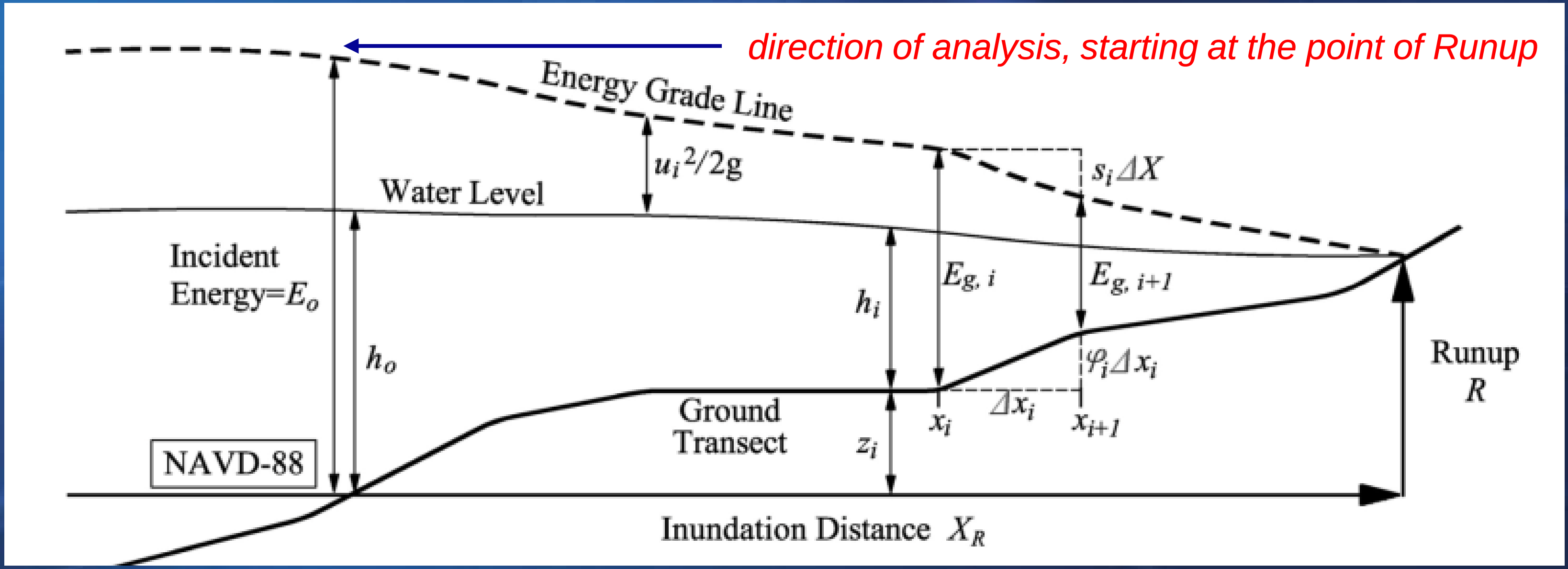


Inundation Depth and Flow Velocity Based on Runup

- Energy Grade Line Analysis
  - Incremental analysis of hydraulic head starting from runup point
  - Calculation based on simple hydraulics using Manning's roughness coefficients

$$E_{g,i+1} = E_{g,i} - \left(\phi_i + s_i\right)\Delta X_i$$

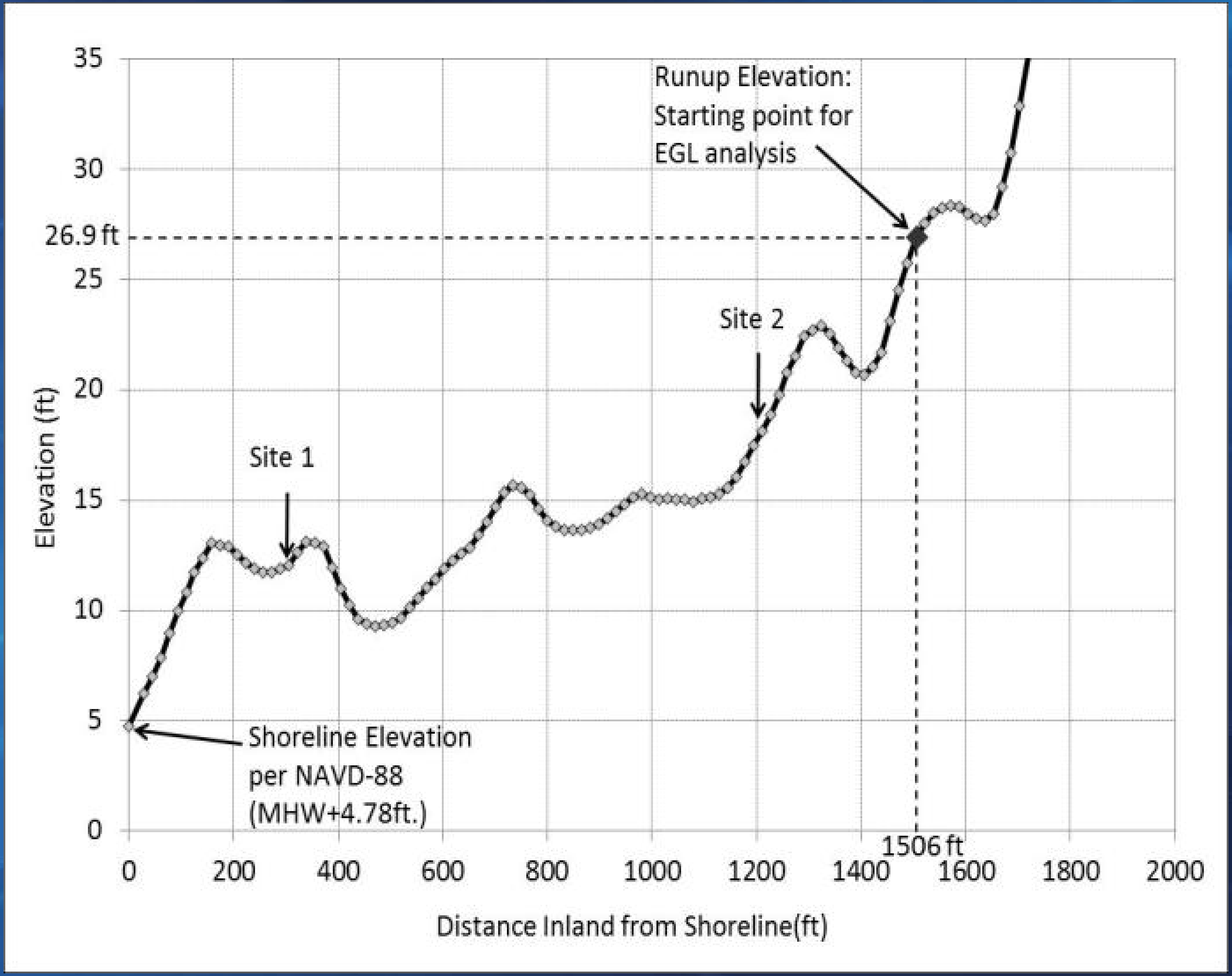
  - Validated to be conservative through field data & 36,000 numerical simulations yielding 700,000 data points



Monterey, California – Example Transect

Obtain topographic elevation profile from a Digital Elevation Model (not GE!)

- Use the transect data to compute the slope and distance along incremental segments
- Assign Manning's n



Energy Grade Line Analysis done on a Spreadsheet

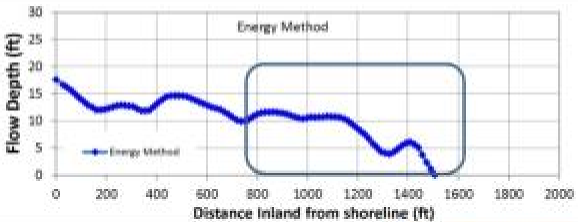
Manning's Roughness, *n*, for Energy Grade Line Analysis

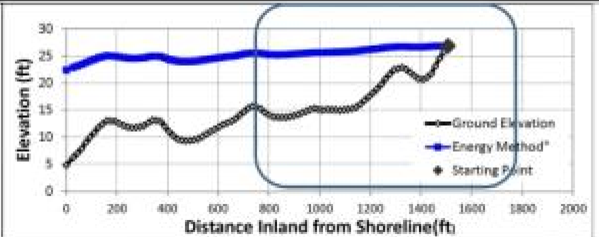
Description of Frictional Surface	n
Coastal water nearshore bottom friction	0.025 to 0.03
Open land / field	0.025
All other cases	0.03
Buildings of at least urban density	0.04

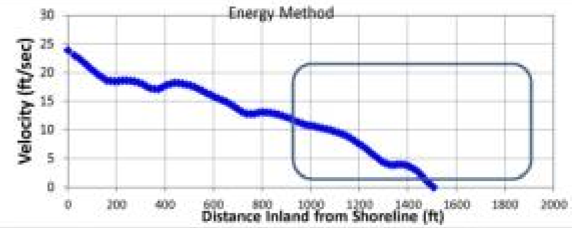
Transect Profile				STEP 3	STEP 1	STEP 4	STEP 5	STEP 6 →	Calculate				
STEP 2		STEP 3		Calculate	Input	Calculate	Calculate	Eq. 6.6.2-2	Solution for Energy Head, Depth, Velocity, and Inundation Elevation				
Input		Calculate		Ground slope	Manning Coefficient		Froude number Eq. 6.6.2-3	Friction Slope					
x_i (ft)	z_i (ft)	Δx	Δz	φi	n_i	x/x_R	F_{ri}	s_i	E_{gi} Energy Head (ft)	h_i inundation depth (ft)	u_i (ft/sec)	Check Section 6.6.1 u_{min} for hydrodynamic forces	Inundation Elevation h_i+z_i (ft)
Obtain Transect Points from a Topographic Digital Elevation Model		Determine the slope increments of the segment in the direction of incoming flow		Based on Δz/Δx	Based on Table 6.6-1	For determining Froude Number along the transect	Based on proportion of distance along the transect to the inundation limit	$g F_{ri}^2/((1.49/n)^2 h_{i-1}^{1/3})$	Hydraulic Head at point	Inundation depth at point i	Maximum overland flow velocity at point *i*	min. flow velocity shall not be taken less than 10 ft/s and ≤ the lessor of: $1.5 (gh_i)^{1/2}$ and 50 ft/s	Water Elevation
		$\Delta x_i = x_i - x_{i+1}$	$\Delta z_i = z_i - z_{i+1}$		input by segment		$(1 - x_i/x_R)^{1/2}$	or $(u_i)^2/((1.49/n_i)^2 h_{i-1}^{4/3})$	$E_{g,i-1} + (\varphi i + si)\Delta xi$	$h_i = E_{g,i}/(1+0.5 F_{ri}^2)$	$= F_{ri}\sqrt{(gh_i)}$		add the ground elevation and the inundation depth

The Energy Grade Line Analysis stepwise procedure consists of the following steps:

1. Obtain the Runup and Inundation Limit values from the Tsunami Design Map
2. Approximate the principal topographic transect by a series of x-z grid coordinates defining a series of segmented slopes;
   x is the distance inland from the shoreline to the point and z is the ground elevation of the point
3. Compute the topographic slope ,φ_i, of each segment as the ratio of the increments of elevation and distance from point to point in the direction of the incoming flow.
4. Obtain the Manning's Coefficient, n , from Table 6.6-1 for each segment based on terrain analysis.
5. Compute the Froude number at each point on the transect using **Equation 6.6.2-3**.
6. Start at the point of Runup with a boundary condition of E_R =0 at the point of Runup and
7. Select a nominally small value of inundation depth (~0.1 ft.) h_R at the point of Runup
8. Calculate the hydraulic friction slope , s_i , using **Equation 6.6.2-2**
9. Compute the hydraulic energy head E_{i+1} from **Equation 6.6.2-1** at successive points towards the shoreline
10. Calculate the inundation depth h_{i+1} from the hydraulic energy E_{i+1}
11. Using the definition of Froude number, determine the velocity u_{i+1}. Check against the minimum flow velocity required by **Section 6.6.1.**
12. Repeat through the transect until the h and u are calculated at the site. These are used as the maximum inundation depth , h_{max} , and maximum velocity , u_{max} , at the site.







EXAMPLE

Input ------> ------>

Coordinates x_R and z_R of Runup Point

At this location

NAVD-88 4.78 = MHW

Notes:

1. Structures located entirely within inundation depths of 3 ft or less need not be designed for tsunamis

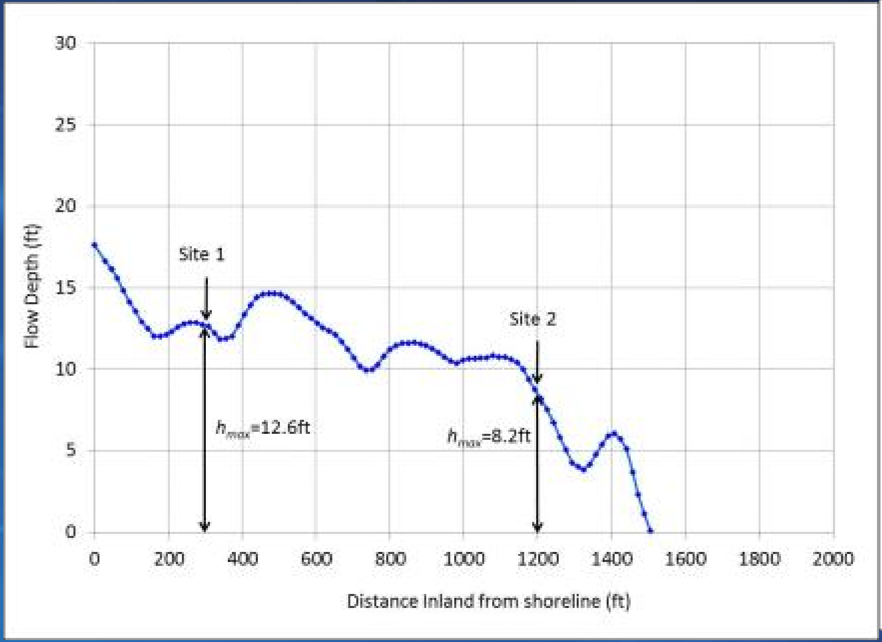
2. Scour depth is permitted to be reduced per Section 6.12.2.5.1, where the calculated Froude number is less than 0.5

Calculate from Runup Point along the transect towards the ocean

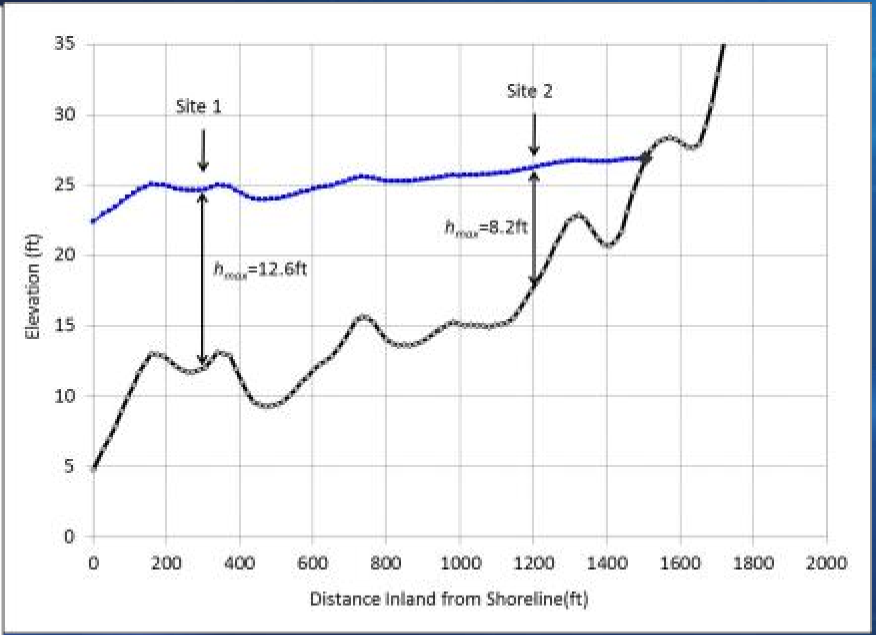
Transect points, i, toward ocean starting at the Runup Point	Enter Transect Profile x_i (ft)	z_i (ft)	Δx_i (ft)	Δz_i (ft)	Ground slope φi	Manning n_i	x/x_R	Froude number F_{ri} (see note 2)	Friction Slope s_i	Solution for Energy Head, Depth, Velocity: E_{gi} Energy Head (ft)	h_i inundation depth (see note 1) (ft)	u_i (ft/sec)	u_{min} for hydrodynamic forces §6.6.1 (ft/sec)	Inundation Elevation h+z (ft)
0	1505.5	26.87				0.030	1.000	0.000	0.000000	0.0	0.10	0.0		26.87
1	1489.1	25.73	16.4	1.14	0.0694	0.030	0.989	0.104	0.000305	1.15	1.14	0.6	10.0	26.87
2	1472.7	24.53	16.4	1.20	0.0731	0.030	0.978	0.148	0.000273	2.35	2.32	1.3	10.0	26.85
3	1456.2	23.11	16.4	1.42	0.0865	0.030	0.967	0.181	0.000323	3.77	3.71	2.0	10.0	26.82
4	1439.8	21.69	16.4	1.42	0.0865	0.030	0.956	0.209	0.000369	5.20	5.09	2.7	10.0	26.78
5	1423.4	21.03	16.4	0.66	0.0402	0.030	0.945	0.234	0.000416	5.87	5.71	3.2	10.0	26.74
6	1407.0	20.66	16.4	0.37	0.0225	0.030	0.935	0.256	0.000481	6.25	6.05	3.6	10.0	26.71
7	1390.6	20.79	16.4	-0.13	-0.0079	0.030	0.924	0.276	0.000550	6.12	5.90	3.8	10.0	26.69
8	1374.1	21.29	16.4	-0.50	-0.0305	0.030	0.913	0.295	0.000634	5.64	5.40	3.9	10.0	26.69
9	1357.7	21.92	16.4	-0.63	-0.0383	0.030	0.902	0.313	0.000735	5.02	4.78	3.9	10.0	26.70
10	1341.3	22.55	16.4	-0.63	-0.0384	0.030	0.891	0.330	0.000850	4.40	4.17	3.8	10.0	26.72
11	1324.9	22.89	16.4	-0.34	-0.0207	0.030	0.880	0.346	0.000977	4.08	3.85	3.9	10.0	26.74
12	1308.5	22.67	16.4	0.22	0.0134	0.030	0.869	0.362	0.001096	4.32	4.05	4.1	10.0	26.72
13	1292.0	22.42	16.4	0.25	0.0152	0.030	0.858	0.377	0.001167	4.58	4.28	4.4	10.0	26.70
14	1275.6	21.55	16.4	0.87	0.0530	0.030	0.847	0.391	0.001234	5.47	5.09	5.0	10.0	26.64
15	1259.2	20.76	16.4	0.79	0.0481	0.030	0.836	0.404	0.001249	6.29	5.81	5.5	10.0	26.57
16	1242.8	19.76	16.4	1.00	0.0609	0.030	0.825	0.418	0.001275	7.31	6.72	6.1	10.0	26.48
17	1226.4	18.87	16.4	0.89	0.0542	0.030	0.815	0.431	0.001291	8.22	7.52	6.7	10.0	26.39
18	1209.9	18.13	16.4	0.74	0.0451	0.030	0.804	0.443	0.001317	8.98	8.18	7.2	10.0	26.31
19	1193.5	17.47	16.4	0.66	0.0402	0.030	0.793	0.455	0.001352	9.66	8.75	7.6	10.0	26.22
20	1177.1	16.76	16.4	0.71	0.0432	0.030	0.782	0.467	0.001392	10.39	9.37	8.1	10.0	26.13
21	1160.7	16.06	16.4	0.70	0.0426	0.030	0.771	0.479	0.001429	11.12	9.97	8.6	10.0	26.03
22	1144.2	15.56	16.4	0.50	0.0305	0.030	0.760	0.490	0.001466	11.64	10.39	9.0	10.0	25.95
23	1127.8	15.27	16.4	0.29	0.0177	0.030	0.749	0.501	0.001512	11.96	10.62	9.3	10.0	25.89
24	1111.4	15.11	16.4	0.16	0.0097	0.030	0.738	0.512	0.001567	12.14	10.74	9.5	10.0	25.85
25	1095.0	15.07	16.4	0.04	0.0024	0.030	0.727	0.522	0.001626	12.21	10.74	9.7	10.0	25.81
26	1078.6	14.93	16.4	0.14	0.0085	0.030	0.716	0.533	0.001691	12.38	10.84	9.9	10.0	25.77
27	1062.1	15.04	16.4	-0.11	-0.0067	0.030	0.706	0.543	0.001751	12.30	10.72	10.1	10.1	25.76
28	1045.7	15.05	16.4	-0.01	-0.0006	0.030	0.695	0.553	0.001823	12.32	10.68	10.3	10.3	25.73
29	1029.3	15.09	16.4	-0.04	-0.0024	0.030	0.684	0.562	0.001890	12.31	10.63	10.4	10.4	25.72
30	1012.9	15.01	16.4	0.08	0.0049	0.030	0.673	0.572	0.001958	12.42	10.67	10.6	10.6	25.68
31	996.5	15.12	16.4	-0.11	-0.0067	0.030	0.662	0.581	0.002021	12.34	10.56	10.7	10.7	25.68
32	980.0	15.30	16.4	-0.18	-0.0110	0.030	0.651	0.591	0.002093	12.20	10.38	10.8	10.8	25.68
33	963.6	15.11	16.4	0.19	0.0116	0.030	0.640	0.600	0.002171	12.42	10.53	11.0	11.0	25.64
34	947.2	14.81	16.4	0.30	0.0183	0.030	0.629	0.609	0.002226	12.76	10.76	11.3	11.3	25.57
35	930.8	14.49	16.4	0.32	0.0195	0.030	0.618	0.618	0.002275	13.12	11.01	11.6	11.6	25.50
36	914.4	14.16	16.4	0.33	0.0201	0.030	0.607	0.627	0.002322	13.48	11.27	11.9	11.9	25.43
37	897.9	13.91	16.4	0.25	0.0152	0.030	0.596	0.635	0.002369	13.77	11.46	12.2	12.2	25.37
38	881.5	13.76	16.4	0.15	0.0091	0.030	0.586	0.644	0.002419	13.96	11.57	12.4	12.4	25.33
39	865.1	13.65	16.4	0.11	0.0067	0.030	0.575	0.652	0.002476	14.11	11.64	12.6	12.6	25.29
40	848.7	13.67	16.4	-0.02	-0.0012	0.030	0.564	0.661	0.002534	14.13	11.60	12.8	12.8	25.27
41	832.3	13.64	16.4	0.03	0.0018	0.030	0.553	0.669	0.002600	14.21	11.61	12.9	12.9	25.25
42	815.8	13.79	16.4	-0.15	-0.0091	0.030	0.542	0.677	0.002662	14.10	11.47	13.0	13.0	25.26
43	799.4	14.06	16.4	-0.27	-0.0164	0.030	0.531	0.685	0.002737	13.88	11.24	13.0	13.0	25.30

EGLA results

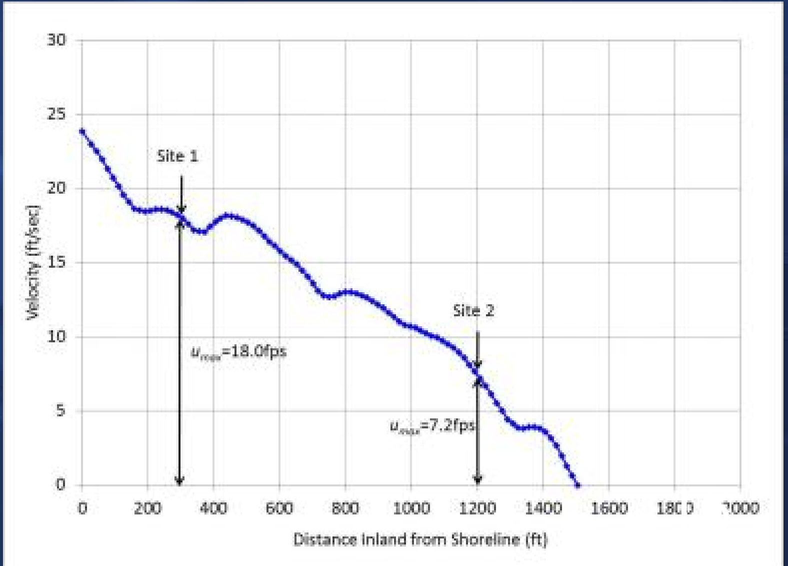
Inundation depth (h_i) profile from Energy Grade Line analysis



Inundation elevation ($h_i + z_i$) profile from Energy Grade Line analysis

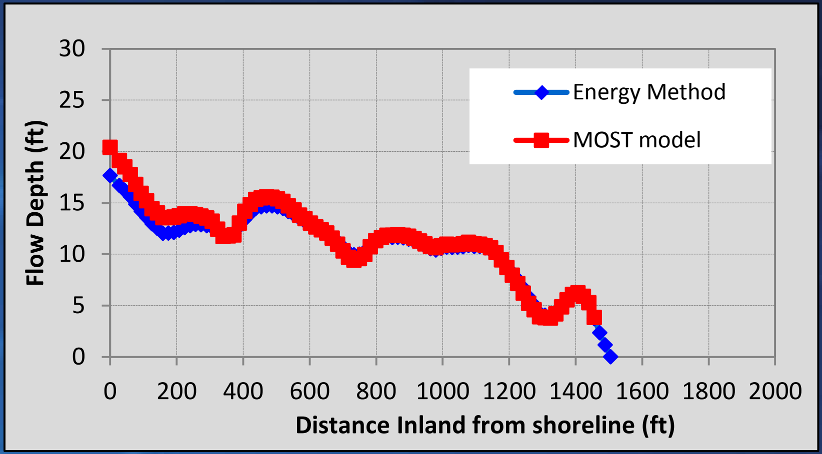


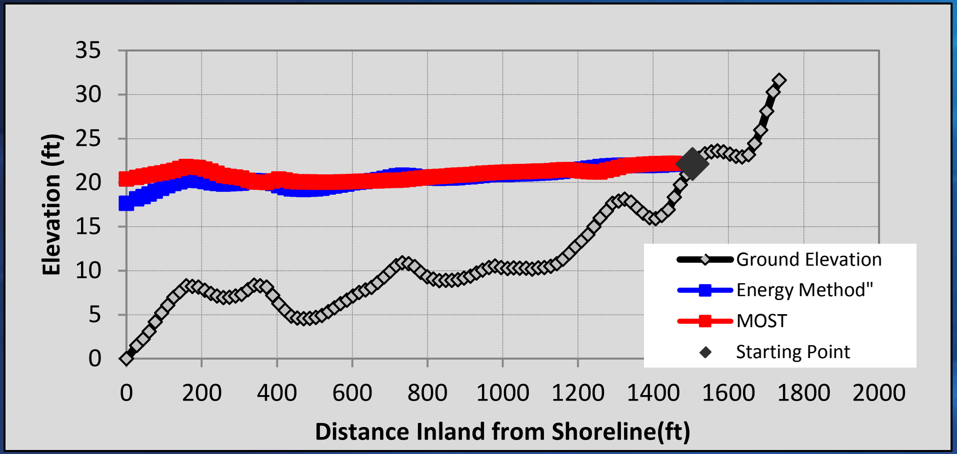
Flow velocity (u_i) profile from Energy Grade Line analysis

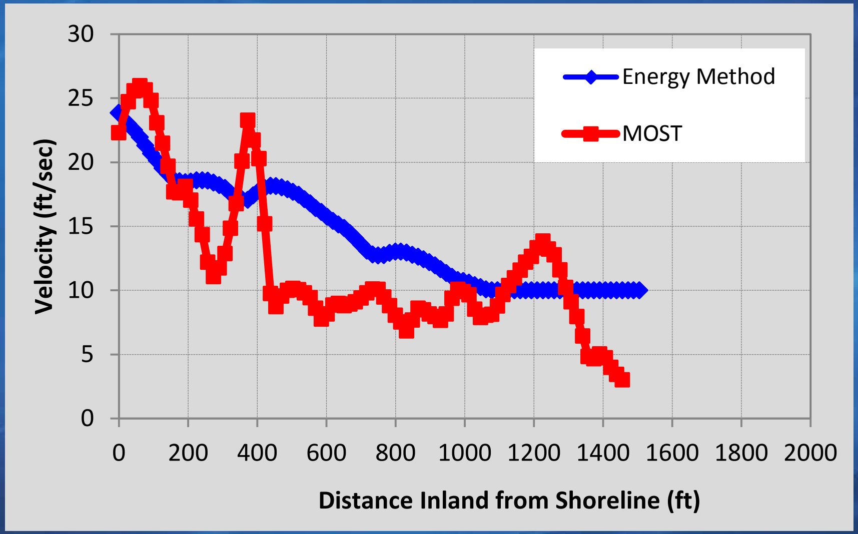


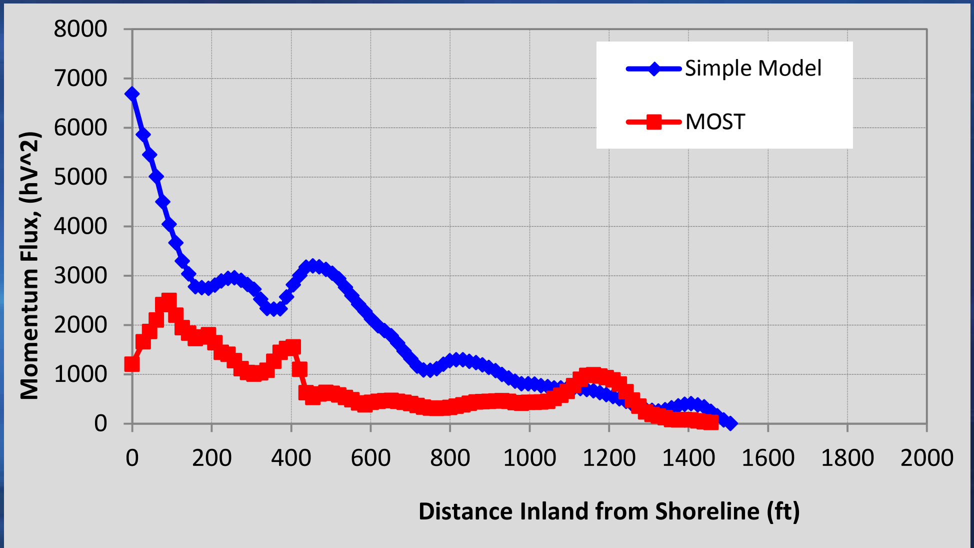
- Also see Robertson,I.N. (2016) Tsunami Loads and Effects: Guide to the Tsunami Design Provisions of ASCE 7-16, ASCE Publications

Energy Grade Line Analysis comparisons









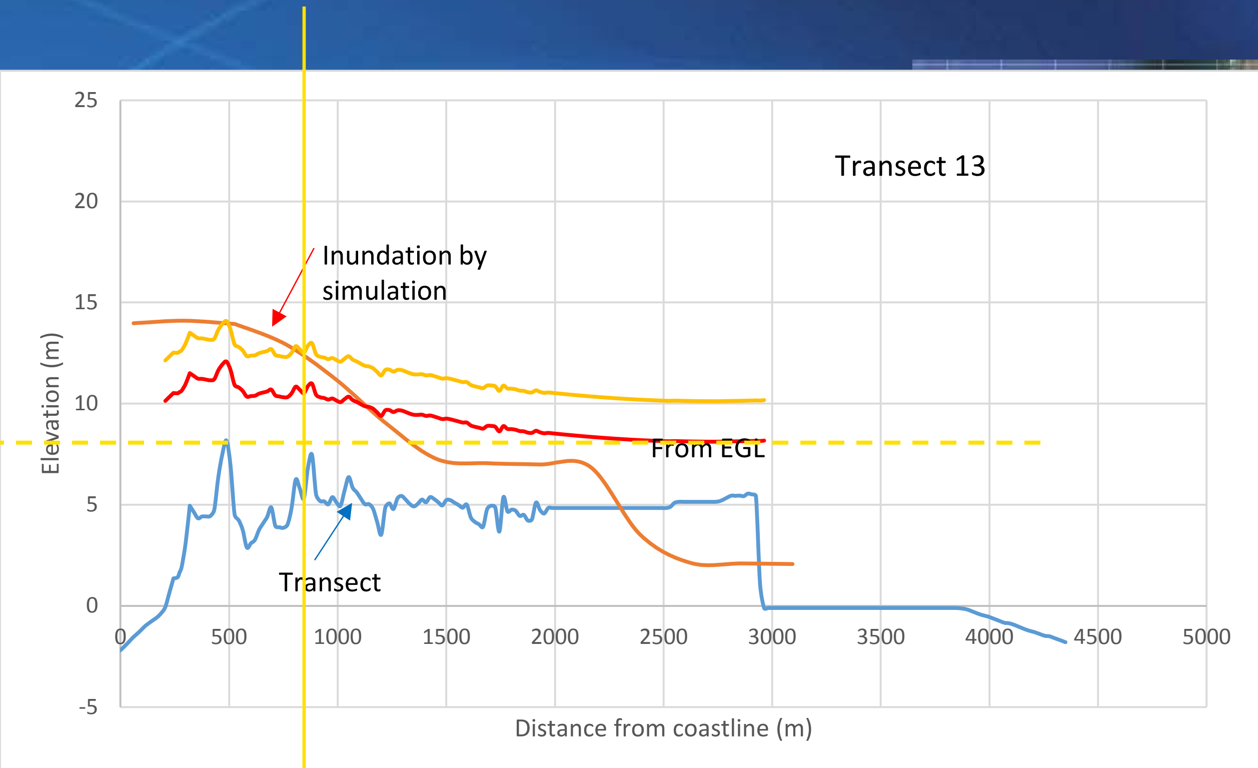
Per Section 6.6.1, calculated flow velocity shall not be taken less than 10 ft/s (3.0 m/s) and need not be taken greater than the lesser of 1.5 (ghmax)1/2 and 50 ft/s (15.2 m/s).

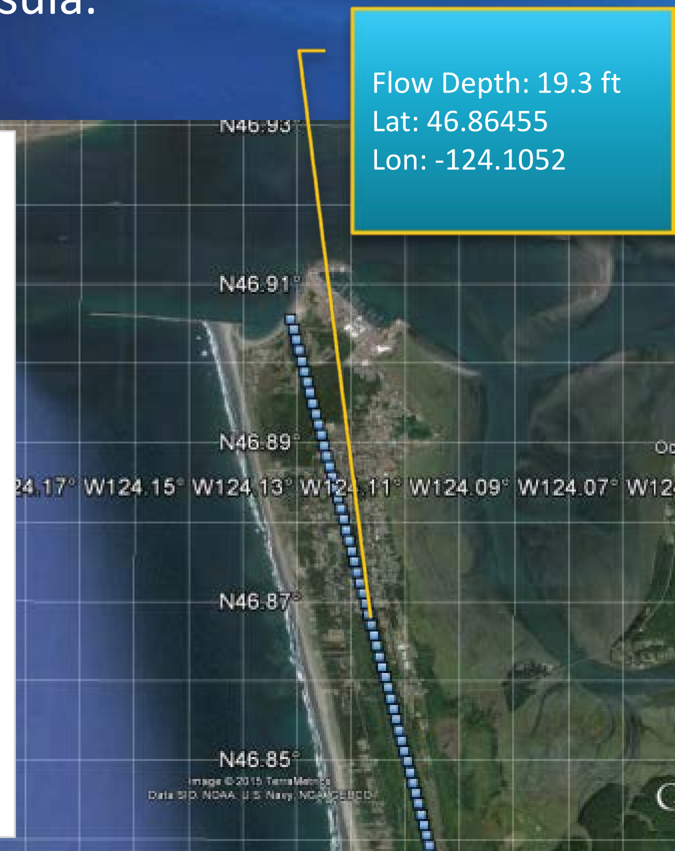
Tsunami Design Zone – Vicinity of Ocosta, WA

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

"Where the maximum topographic elevation along the topographic transect between the shoreline and the inundation limit is greater than the runup elevation, "

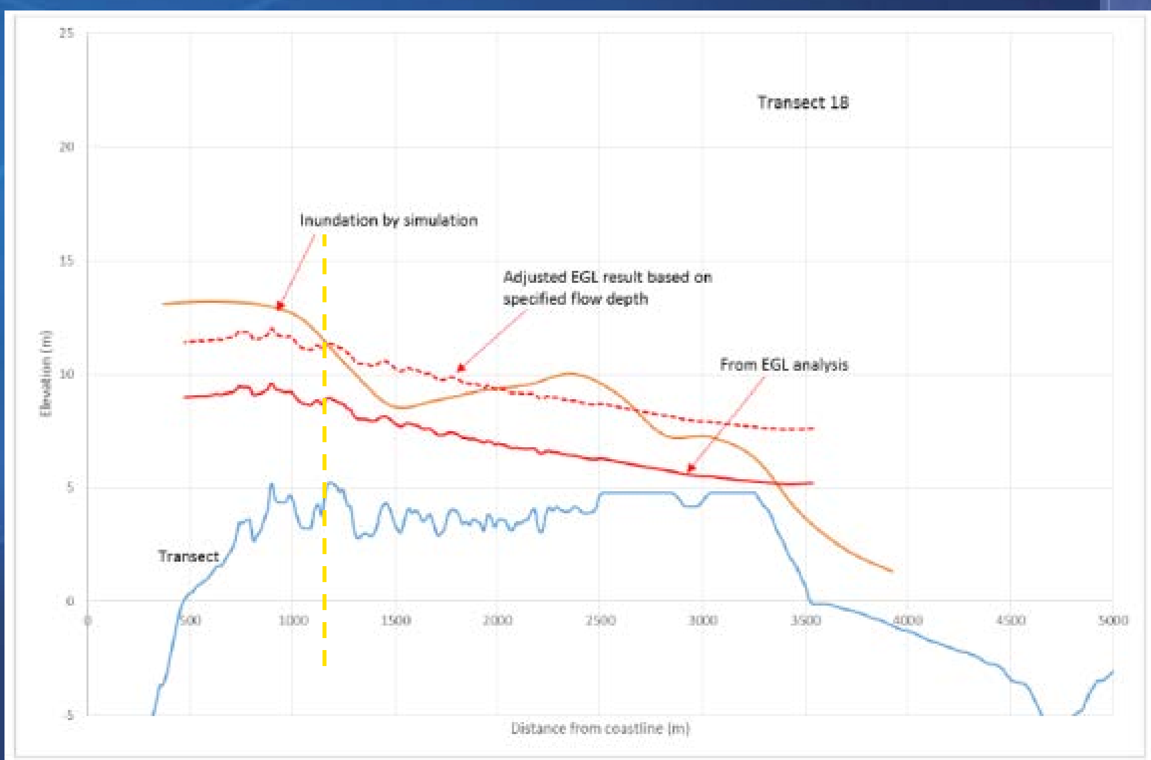
- Energy Grade Line Analysis "shall assume a runup elevation and horizontal inundation limit having at least 100% of the maximum topographic elevation along the topographic transect."
- At sites with overwash, final reference points of inundation depth may be placed on the axis of the higher terrain of the peninsula.

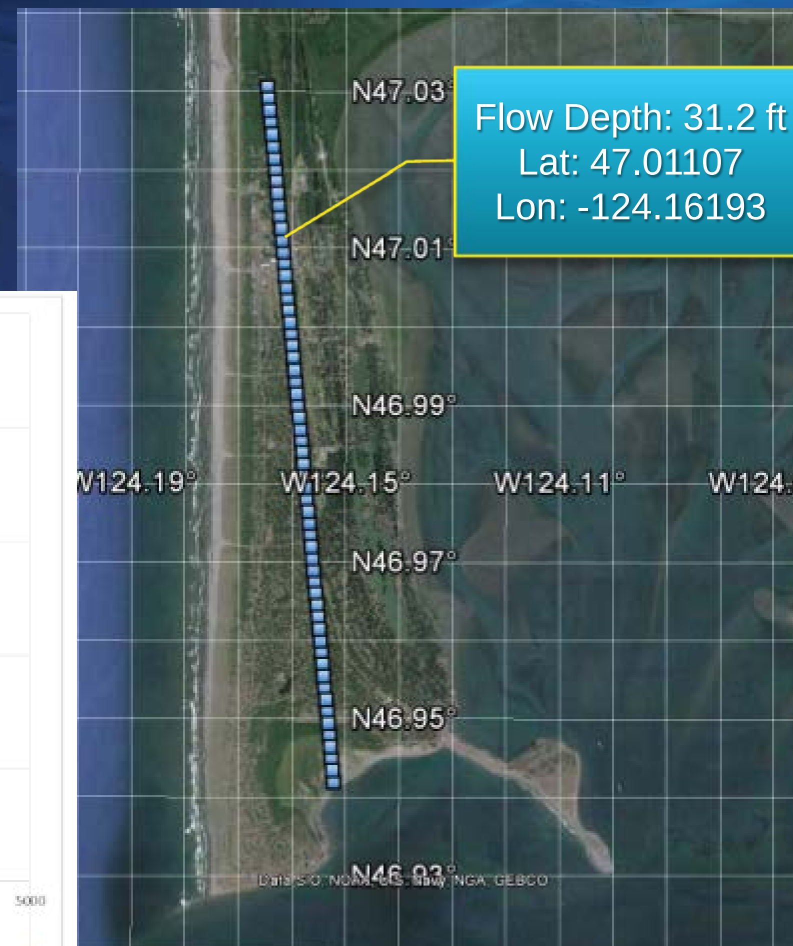




"Overwashed Peninsulas - Where the maximum topographic elevation along the topographic transect between the shoreline and the inundation limit is greater than the runup elevation, "

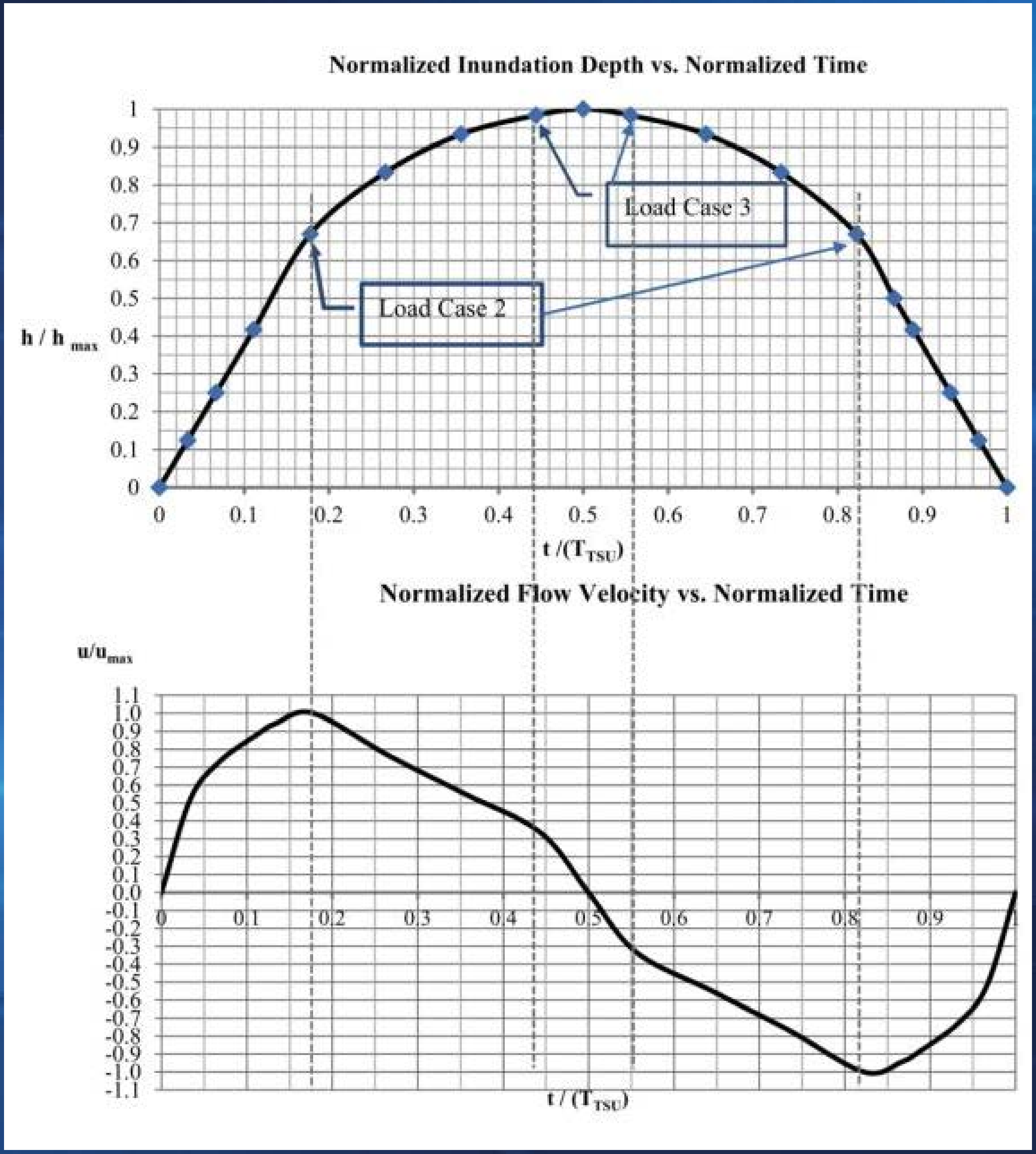
- Energy Grade Line Analysis shall assume a runup elevation and horizontal inundation limit having at least 100% of the maximum topographic elevation along the topographic transect.





Load Cases

- Based on a prototypical time history of depth and flow velocity as a function of the maximum values determined from the Energy Grade Line Analysis
- Check 3 discrete governing stages of flow
- Load Case 1 is a maximum buoyancy check during initial flow



Tsunami-Specific Design Conditions

- Minimum Fluid Density – prescribed with 10% increase accounting for debris-laden seawater
- Flow Amplification – the Energy Grade Line Analysis includes an internal allowance for this, but a Site-Specific Analysis needs to include this effect explicitly
- Directionality of Flow – variation of flow shall be considered +-22.5 degrees off the principal transect
- Minimum Closure Ratio – accounts for the “piling-on” effect of copious tsunami debris to create more obstruction to flow than just the bare structure

Section 6.8.3.3 Load Combinations [Strength Design]

Principal Tsunami Forces and Effects shall be combined with other specified loads in accordance with the load combinations of Eq. 6.8.3.3-1:

$0.9D + \mathbf{F_{TSU}} + 1.0\ H_{TSU}$ (Eq. 6.8.3.3-1a)

$1.2D + \mathbf{F_{TSU}} + 0.5L + 0.2S + 1.0\ H_{TSU}$ (Eq. 6.3.3.3-1b)

where,

F_{TSU} =tsunami load effect for incoming and receding directions of flow

H_{TSU} = load due to tsunami-induced lateral foundation pressures developed under submerged conditions. Where the net effect of H_{TSU} counteracts the principal load effect, the load factor for H_{TSU} shall be 0.9.

Tsunami Loads and Effects

- Hydrostatic Forces (equations of the form $k_s \rho_{sw} g h$)
  - Unbalanced Lateral Forces at initial flooding
  - Buoyant Uplift based on displaced volume
  - Residual Water Surcharge Loads on Elevated Floors
- Hydrodynamc Forces (equations of the form $\frac{1}{2} k_s \rho_{sw} (hu^2)$)
  - Drag Forces – per drag coefficient C_d based on size and element
  - Lateral Impulsive Forces of Tsunami Bores or Broad Walls: Factor of 1.5
  - Hydrodynamic Pressurization by Stagnated Flow – per Benoulli
  - Shock pressure effect of entrapped bore – (this is a special case)
- Waterborne Debris Impact Forces (flow speed and √mass)
  - Poles, passenger vehicles, medium boulders always applied
  - Shipping containers, boats if structure is in proximity to hazard zone
  - Extraordinary impacts of ships only where in proximity to Risk Category III & IV structures
- Scour Effects (mostly prescriptive based on flow depth)

Tsunami Design

- Overall Lateral Force Resisting System
  - Drag on entire structure
  - Closure coefficient based on projected area of all structural elements below flow level, but not less than 0.7
  - For SDC D, if $V_{Tsu} \leq 0.75\Omega_o E_h$, then system okay

Tsunami Design

- Component Design
  - Exterior Columns and Shear Walls
    - Hydrodynamic drag including effects of debris damming (C_{cx} = 0.7)
    - Debris Impact including orientation factor (C_o = 0.65)
  - Interior Columns and Shear Walls
    - Hydrodynamic drag *without* debris damming (therefore, interior shear walls are favorable)
    - No debris impact loads

Buoyancy

- At an exterior inundation depth not exceeding the maximum inundation depth nor the lesser of one-story or the height of the top of the first story windows, evaluate uplift conditions.
- Buoyancy shall also include the effect of air trapped below floors. All windows, except those designed for large missile wind-borne debris impact or blast loading, shall be permitted to be considered openings when the inundation depth reaches the top of the windows or the expected strength of the glazing, whichever is less.
- Exception: Load Case 1 need not be applied to Open Structures nor to structures where the soil properties or foundation and structural design prevents detrimental hydrostatic pressurization on the underside of the foundation and lowest structural slab.

Hydrodynamic Loads

- Formulations for detailed calculations on the building and for loads on components
  - Typically of the standard form drag (h- inundation depth and u – flow velocity for each load case)

$$f_{dx} = \frac{1}{2}\rho_s C_d C_{cx} B\left(hu^2\right)$$

  - Adjustments for perforated and angled walls
- Uplift pressure equations for wall-slab recesses

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
- Can be considered a DUCTILITY-GOVERNED ACTION: Any action on a structural component characterized by post-elastic force versus deformation curve that has 1) sufficient ductility and 2) results from an impulsive short-term force that is not sustained

Types of Floating Debris
Logs and Shipping Containers

Power poles and tree trunks become floating logs

Shipping containers float even when fully loaded

Conditions for which Design for Debris Impact are Evaluated

Debris	Buildings and Other Structures	Threshold Inundation depth
Poles, logs, passenger vehicles	All	3 ft (0.91 m)
Boulders and Concrete Debris	All	6 ft (1.8 m)
Shipping Containers	All	3 ft (0.91 m)
Ships and/or barges	Tsunami Risk Category III Critical Facilities and Category IV	12 ft (3.6 m)

Debris Impact Force

- Nominal maximum impact force

$$F_{ni} = u_{\max} \sqrt{k m_d}$$

- Design force based on the importance factor and an orientation factor

$$\boldsymbol{F_i = I_{TSU} C_o F_{ni}}$$

- Impact duration

$$t_d = \frac{2 m_d u_{\max}}{F_{ni}}$$

  - Typical durations are about 5 milli-sec
- Dynamic force capped based on yielding or crushing strength of debris (about 140k for shipping containers, 110 kips for logs and poles)

Site Hazard Assessment for Shipping Containers and Boats or Ships

- Point source of debris
  - Shipping container yards
  - Ports with barges/ships

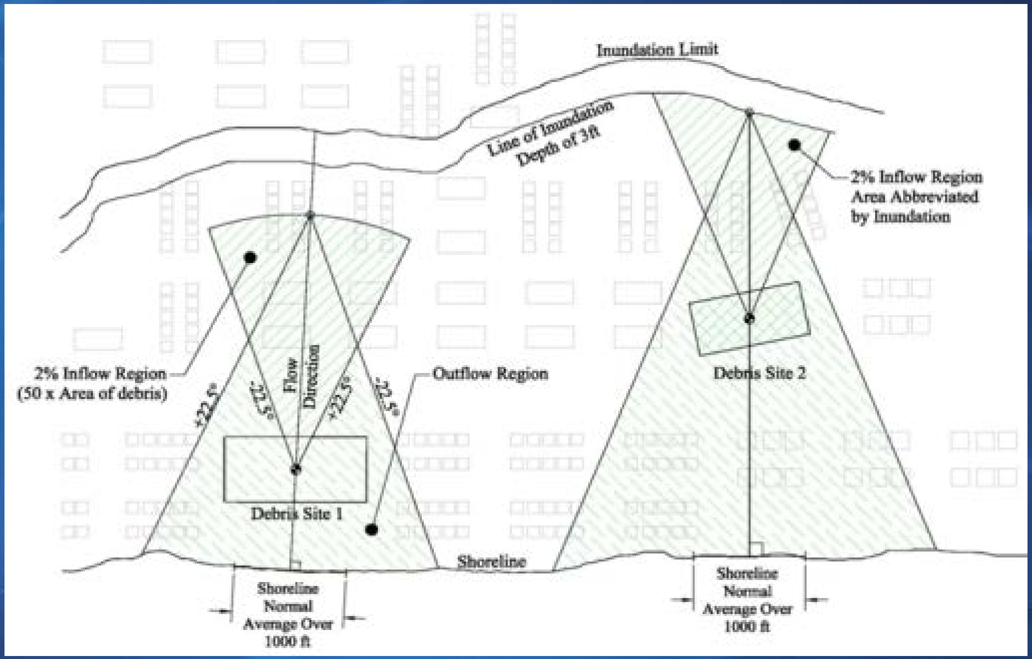


Figure 6.11-1

- Approximate probabilistic site assessment procedure based on proximity and amount of potential floating objects
  - Determine potential debris plan area
    - Number of containers * area of a container
  - Determine concentration: area of debris/land area
  - 2% concentration defines debris dispersion zone

Foundation Design

- Under-seepage Forces
- Loss of Strength
- Erosion
- Local Scour
- Plunging Scour (i.e., overtopping a wall)

- Design solutions involve scour protection or perimeter deep foundations

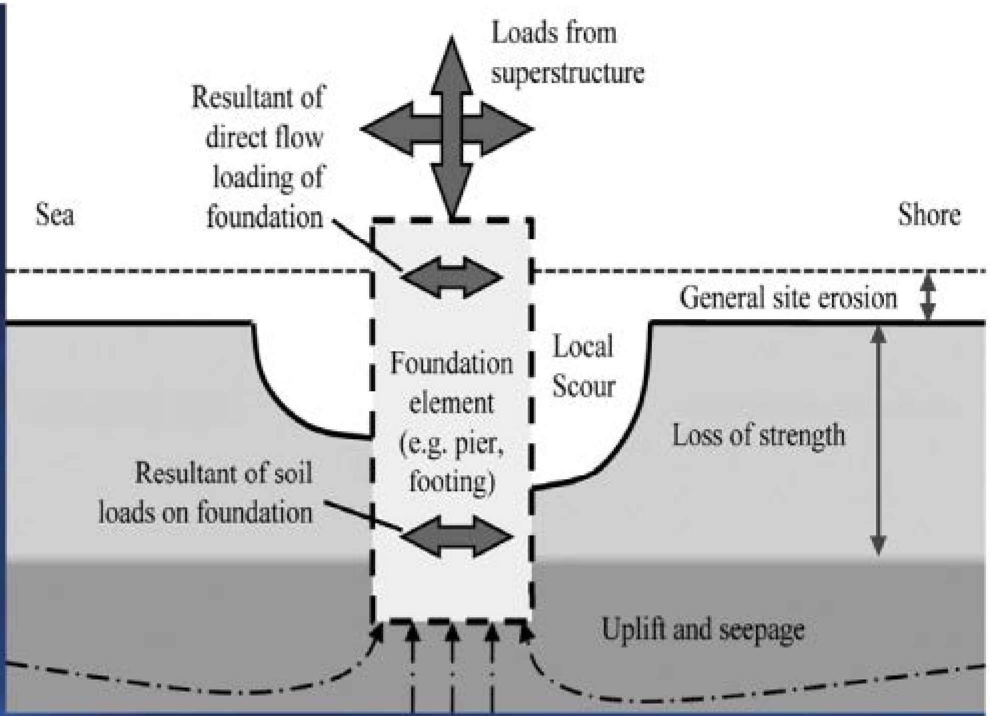


Figure C6.12-1. Schematic of tsunami loading condition for a foundation element

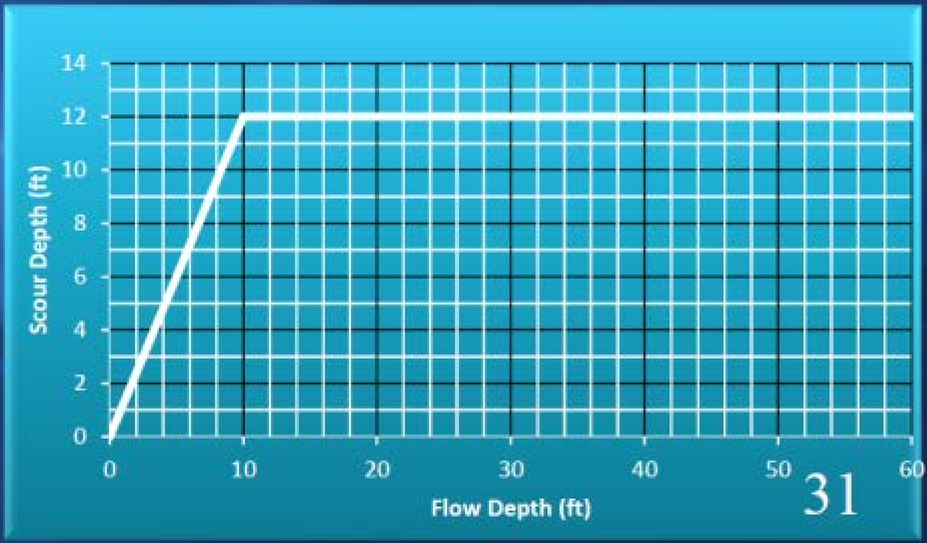
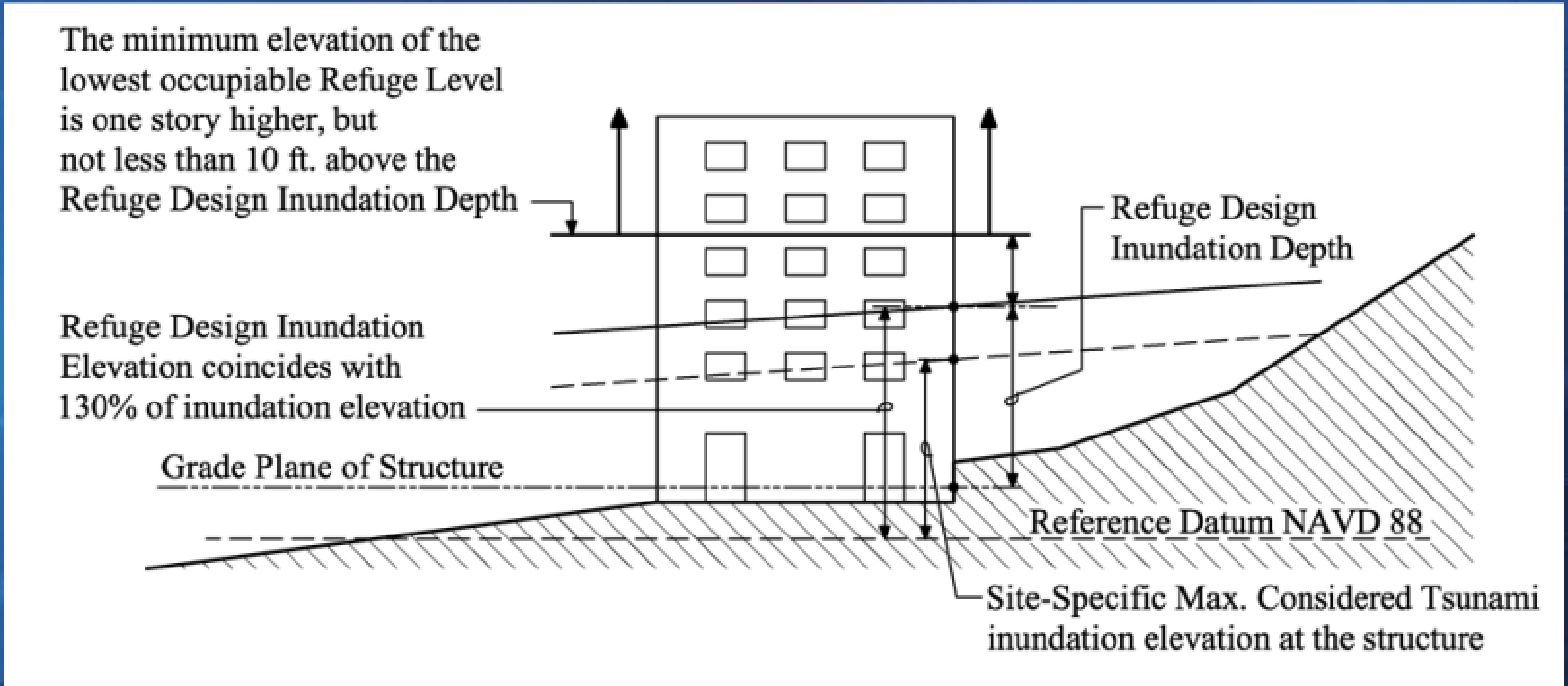


Figure 6.12-1 Local Scour Depth due to Sustained Flow and Pore Pressure Softening

Tsunami Vertical Evacuation Refuge Structures

- Tsunami Vertical Evacuation Refuge Structures - ASCE 7 Chapter 6 is intended to supersede both FEMA P646 structural guidelines and IBC Appendix M

Figure 6.14-1. Minimum Refuge Elevation



Follow-up activities in 2015

- ASCE will be publishing *Tsunami Loads and Effects: Guide to the Tsunami Design Provisions of ASCE 7-16* ,with many worked examples for RC II buildings (by Ian Robertson) and a subsequent second volume of design examples emphasizing RC III, RC IV, and nonbuilding critical facility structures (by Seth Thomas)
  - RC II buildings at various locations
  - Port Operations Facility
  - Protective Barrier for Fuel Tank Farm
  - Hospital for an isolated coastal community
  - Facility with Chemical Storage
  - Tsunami Vertical Evacuation Refuge Structure
  - Podium structure for a light-frame superstructure
- Webinars and Seminars will also be provided through ASCE

Summary

- 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
- Fluid loads, debris loads, foundation demands

The ASCE Tsunami Loads and Effects Subcommittee

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