PORT OF PORT TOWNSEND

Point Hudson Marina Breakwater Preliminary Design

PORT OF PORT TOWNSEND

COAST & HARBOR ENGINEERING

December 5, 2014

Outline

- Project Status (Scopes of Work, To-Do List from Conceptual Design)
- Existing Conditions
- Alternative Evaluation
- Preliminary Design - Coastal Engineering Refinement
- Conclusions, Results, Recommendations
- Next Steps

Project Status (Scopes of Work)

- Previous Pre-Feasibility Assessment – 100%
- Task 100 – Data Collection – 100%
- Task 200 – Alternatives Evaluation & Preferred Concept – 100%
- Task 300 – Preliminary Design – 85%
- Task 400 – Permitting Support (no work performed)

Conceptual Design – Port Feedback

- Possible construction cost threshold of around $4 million, dependent on grant funding.
- Wave protection of marina more important than entrance channel wave environment
- Summer construction possible, construction may not need to be sequenced to provide uninterrupted breakwater protection
- Provision for future walkway along S. breakwater would be a nice feature, but shouldn't drive design

Preliminary Design Refinement To-Do List

- Further investigate the benefit of partially-reflective structures
- Feasibility of floating breakwater for N. breakwater leg
- Top-of-breakwater elevation with consideration for sea-level rise
- Breakwater alignment refinement

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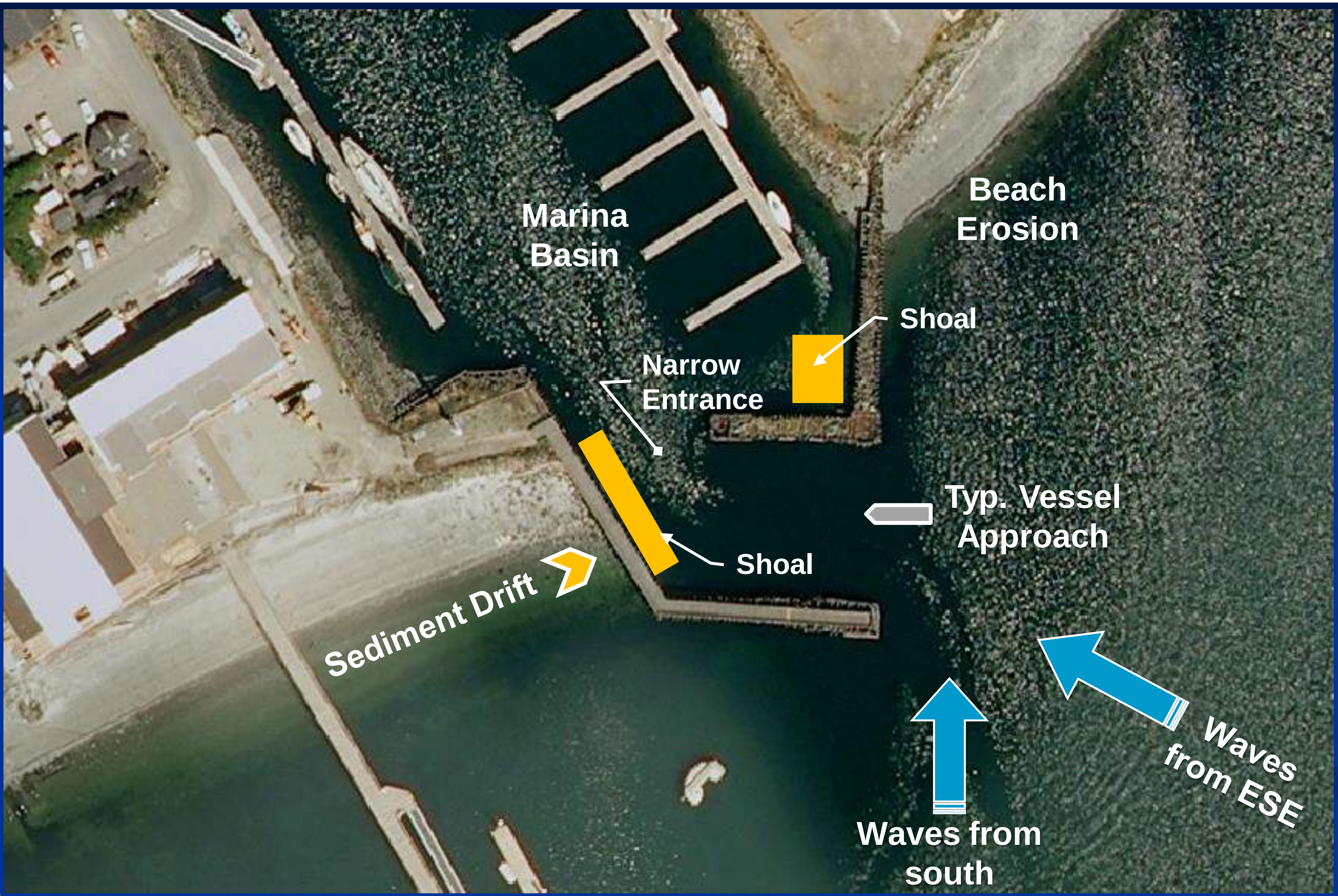
Existing Site Conditions



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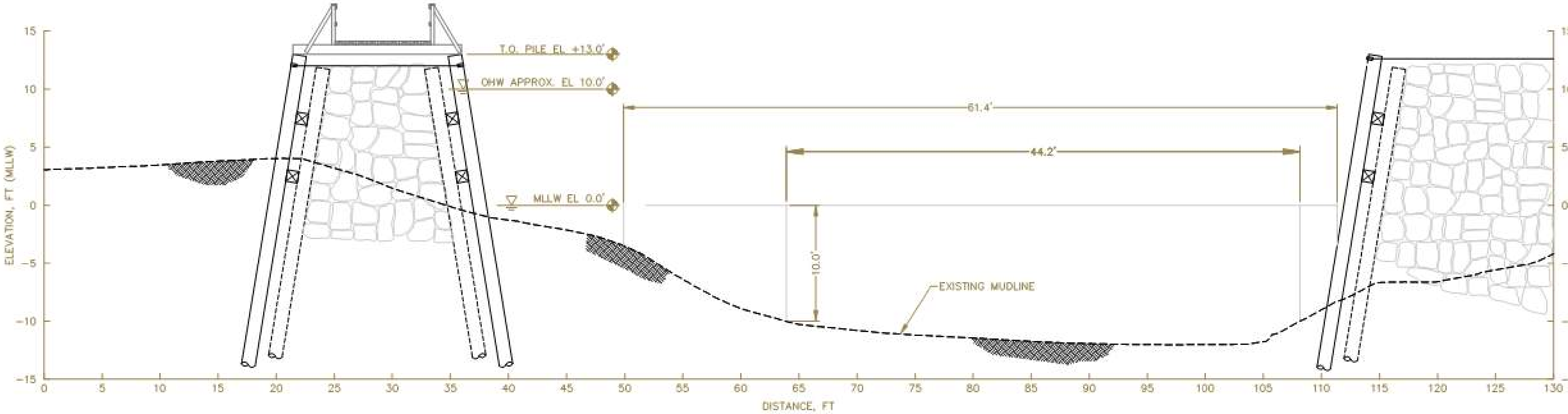
Existing Conditions - Navigation

- Primary Design Vessel Large Sailboat
  - One-way Traffic
    - LOA = 90 ft
    - Beam = 22 ft
    - Draft = 8 ft
- Secondary Design Vessel Large Powerboat
  - One-way Traffic
    - LOA = 90 ft
    - Beam = 24 ft
    - Draft = 7 ft
- Typical Powerboat (50 ft x 16)
  - Two-way Traffic
    - LOA = 50 ft
    - Beam = 16 ft
    - Draft = 5 ft
- Special Case - Adventuress
  - Assisted vessel under good weather and a high tide
    - LOA = 133 ft
    - Beam = 21 ft
    - Draft = 12 ft

Existing Conditions - Navigation



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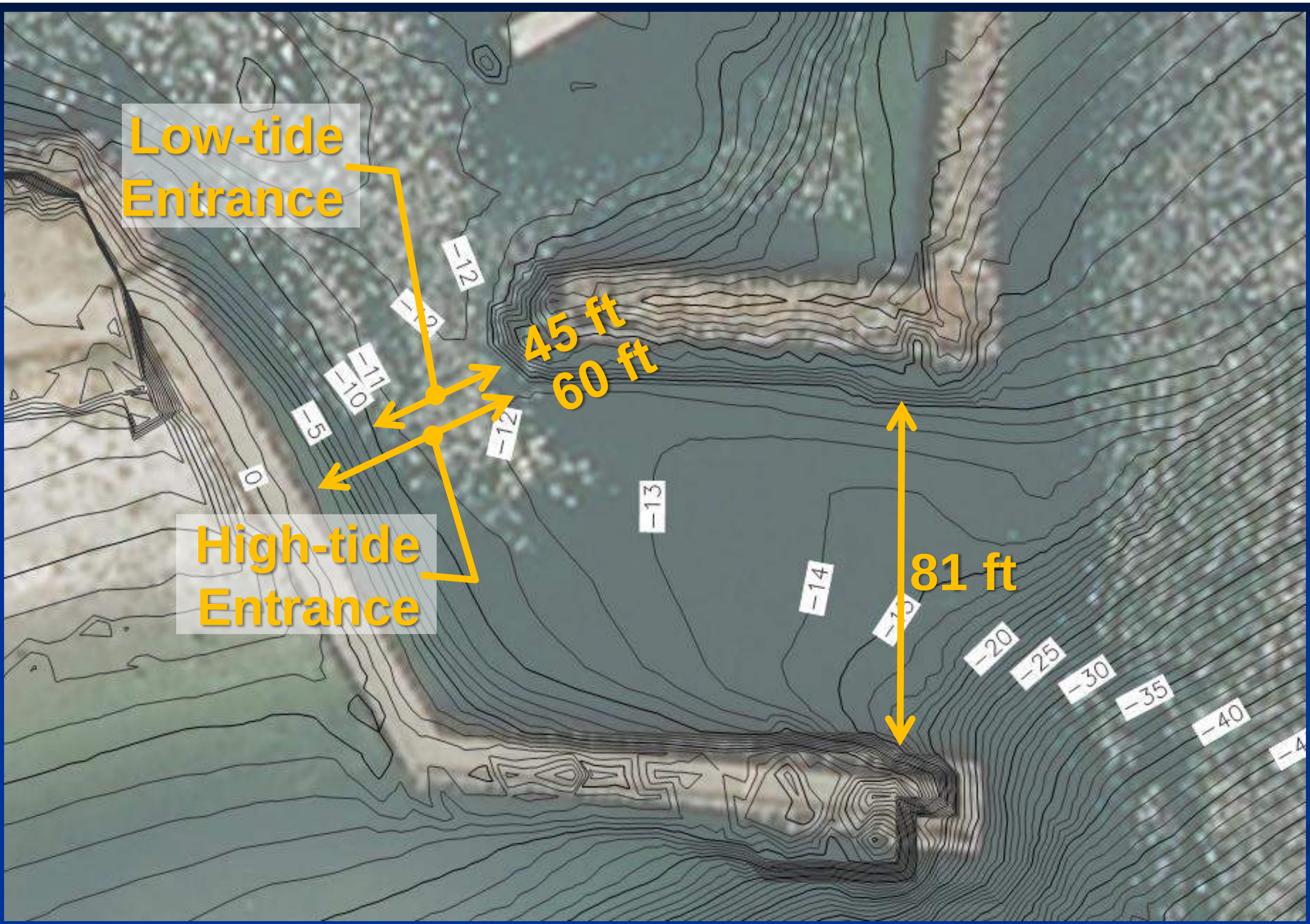
Existing Conditions - Navigation



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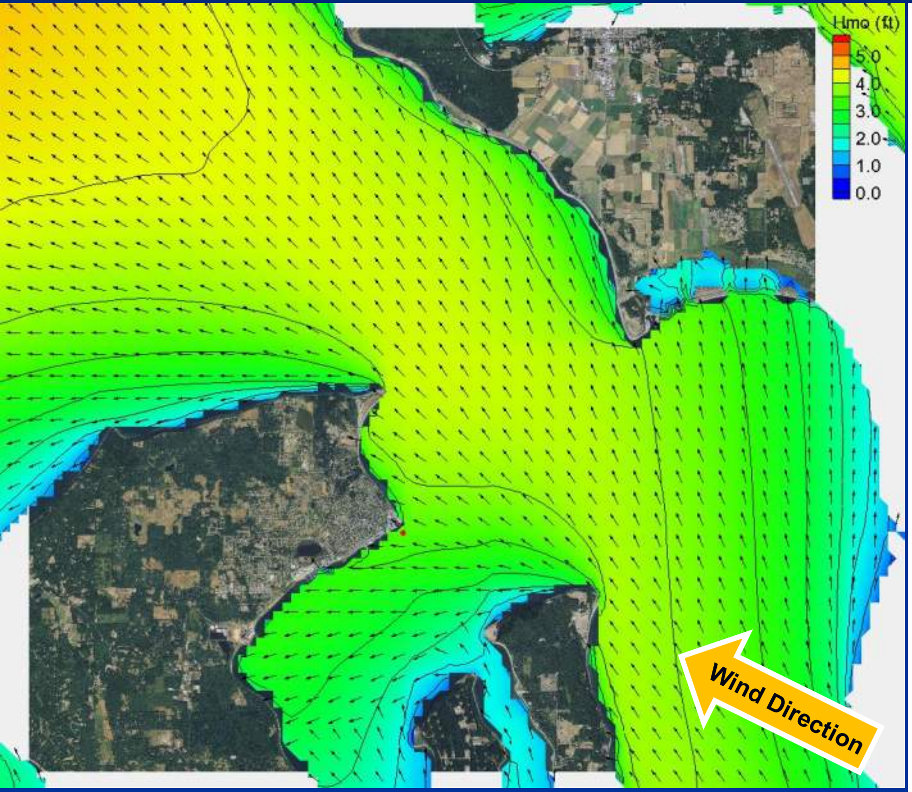
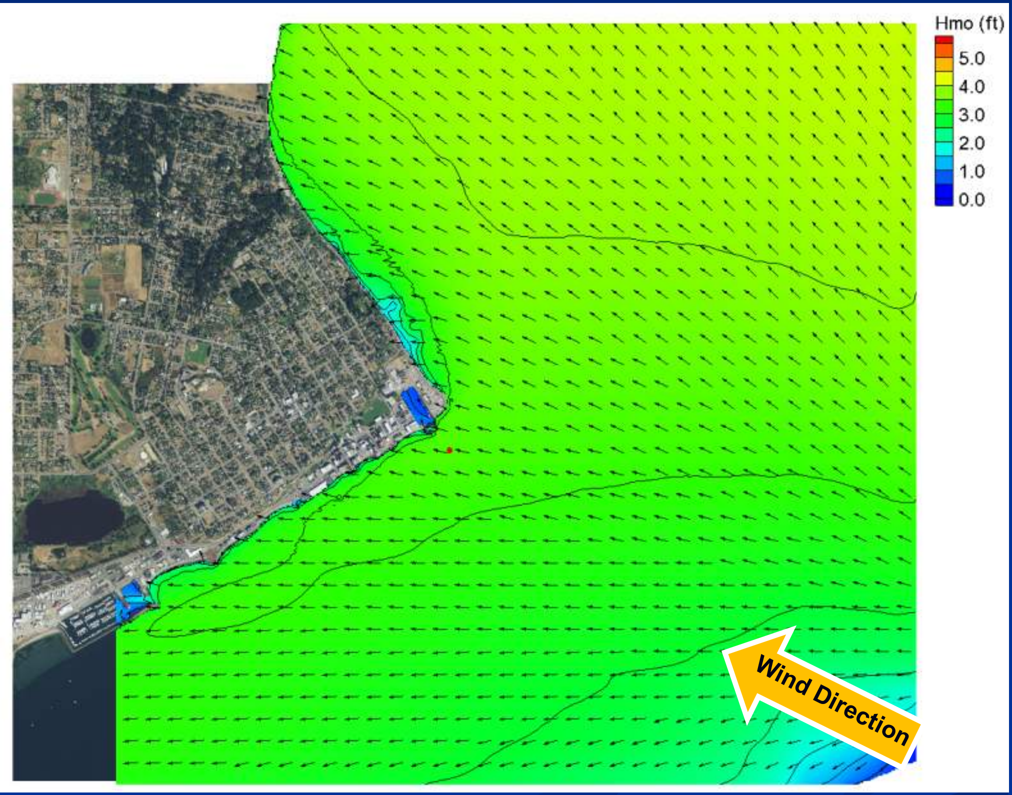
Existing Facility – Waves (Oct. 13, 2014 Storm)

Wind Speed = 37 mph (16.54 m/s), Wind Dir = 120° TN, Water Level = MHHW



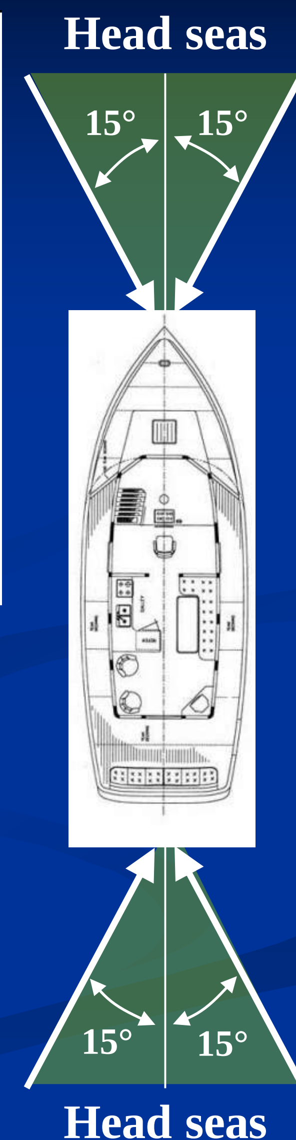


Extracted Results Hmo = 3.14 ft, Tp = 3.80 s, Pdir = 105° TN

Existing Facility – (Oct 13, 2014 Storm)

WAVE CRITERIA FOR MOORING BASIN (State of Alaska ADOT&PF)

Recurrance Interval: Once per	50 years	1 Year	Week
For Wave Heights (inches):			
Head Sea,T<2	12	12	12
Head Sea,2<T<6	24	12	6
Head Sea,T>6	24	12	6
Beam Sea,T<2	9	12	12
Beam Sea,2<T<6	9	6	3
Beam Sea,T>6	9	6	3
For Horizontal Motion (inches):			
Head Sea,T<2			
Head Sea,2<T<6			
Head Sea,T>6	48	24	18
Beam Sea,T<2			
Beam Sea,2<T<6			
Beam Sea,T>6	24	12	9



Wave height (ft)	Existing	Criteria (ft)
Pt#1	No Moorage	NA
Pt#2	No Moorage	NA
Pt#3	0.5	✓ 0.5 Marginal
Pt#4	0.4	✓ 1.0
Pt#5	0.4	✓ 1.0

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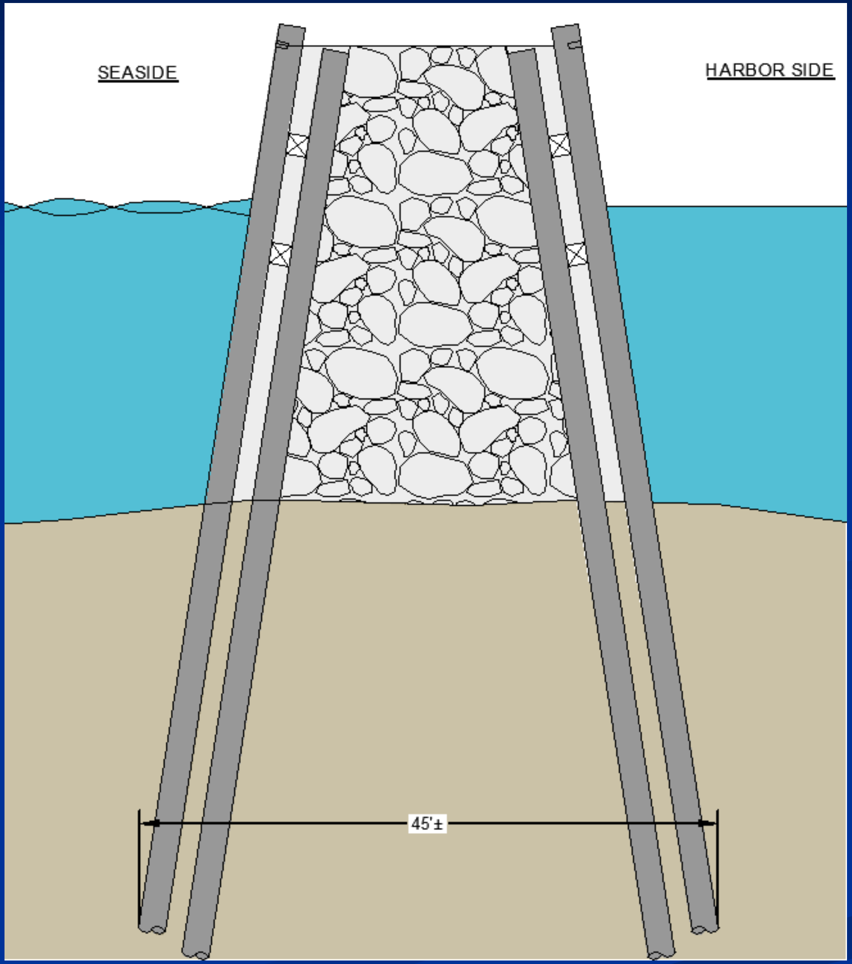
Site Considerations – Sand Abrasion

- Accelerated deterioration of unprotected structures due to sand abrasion

Site Considerations – Existing Piles

- Pile driving obstructions: existing battered timber piles of unknown embedment depth (assumed 25’)



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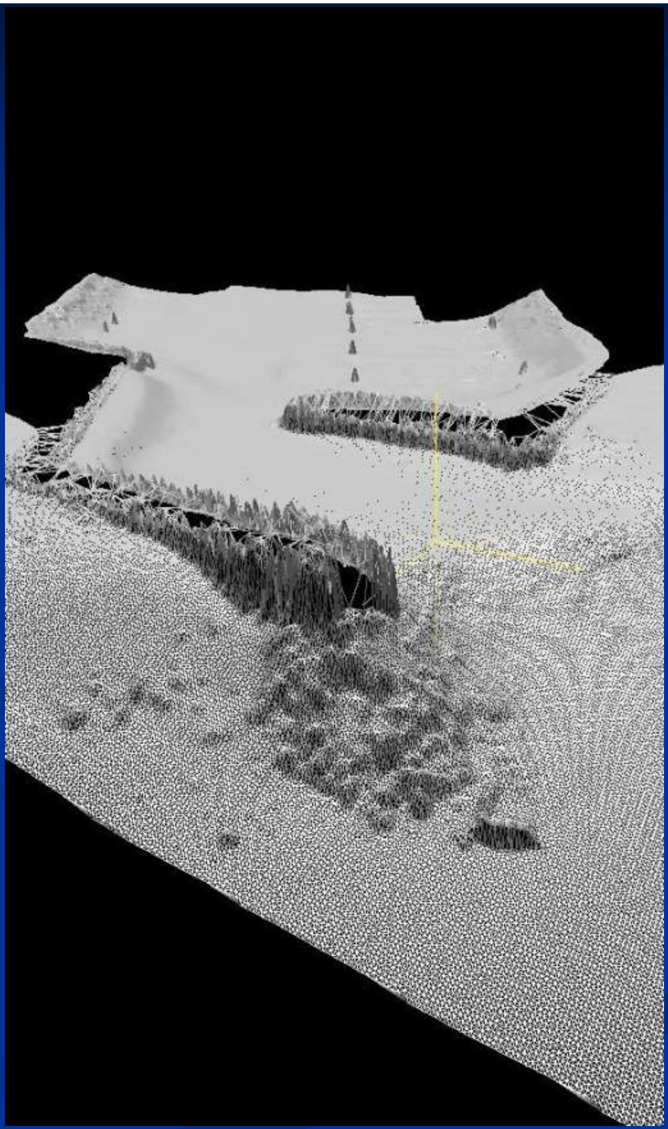
Site Considerations – Armor Rock

- Armor rock has leaked out of existing structure, potential pile driving obstruction



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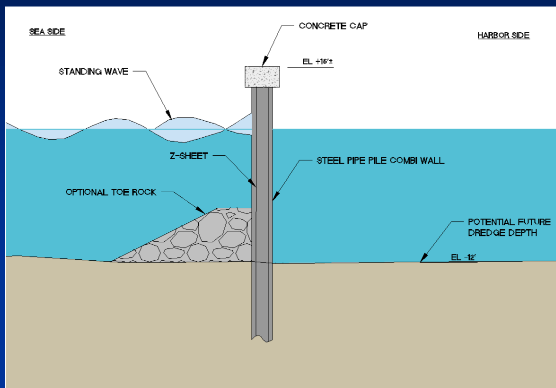
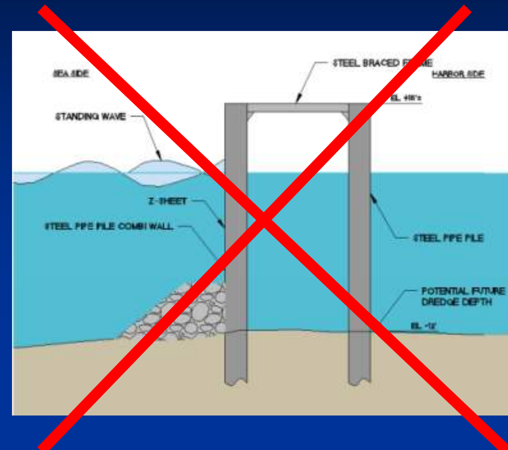
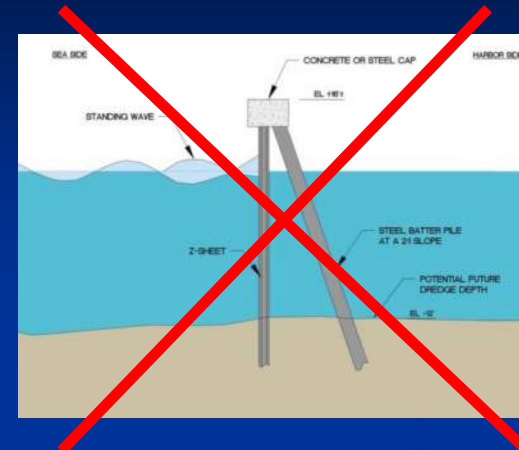
Site Considerations – Demolition

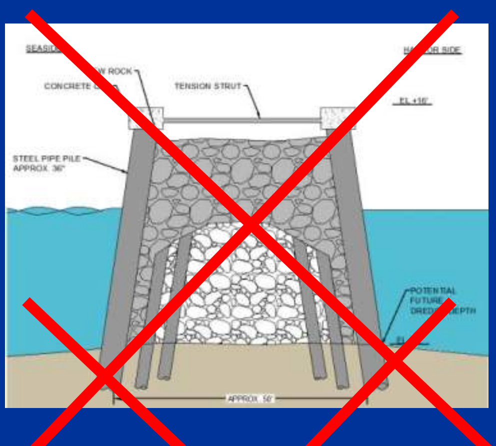
- Remnant piles may be problem for pile driving
- Areas for pile driving will need to be cleaned of any armor rock debris
- Structural systems only requiring partial demolition considered
- Demolition could be staged to avoid the winter storm season
- Continued operations of the marina during construction hours may increase construction costs
- July 16th to Feb 15th (outer portion
- July 16th to Oct 15th (beach areas)

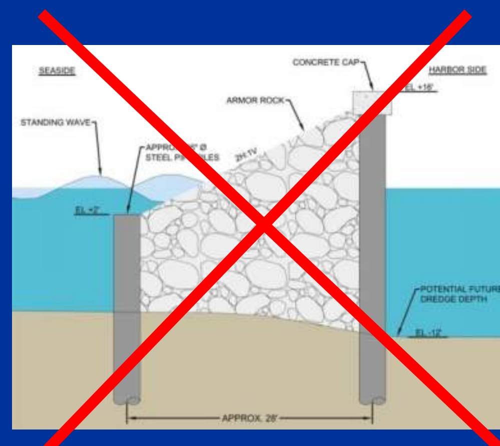
Structure Types Considered

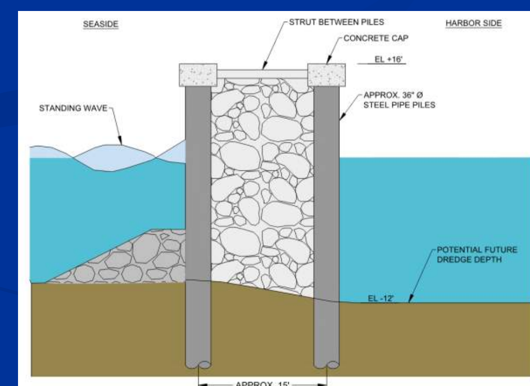


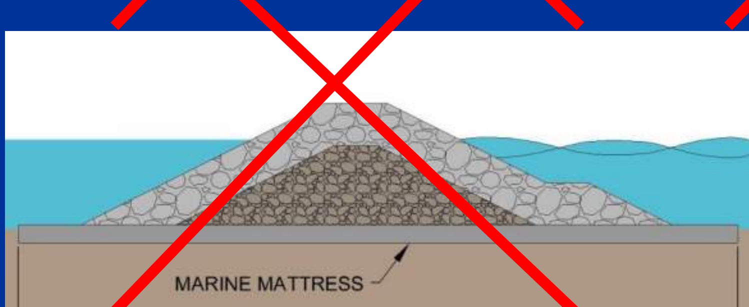


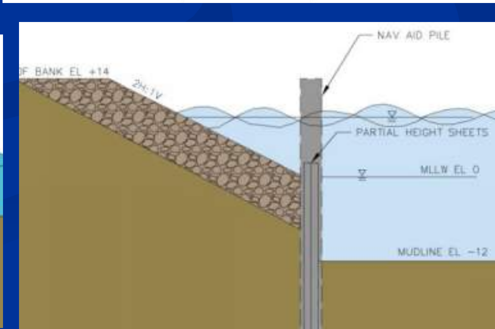






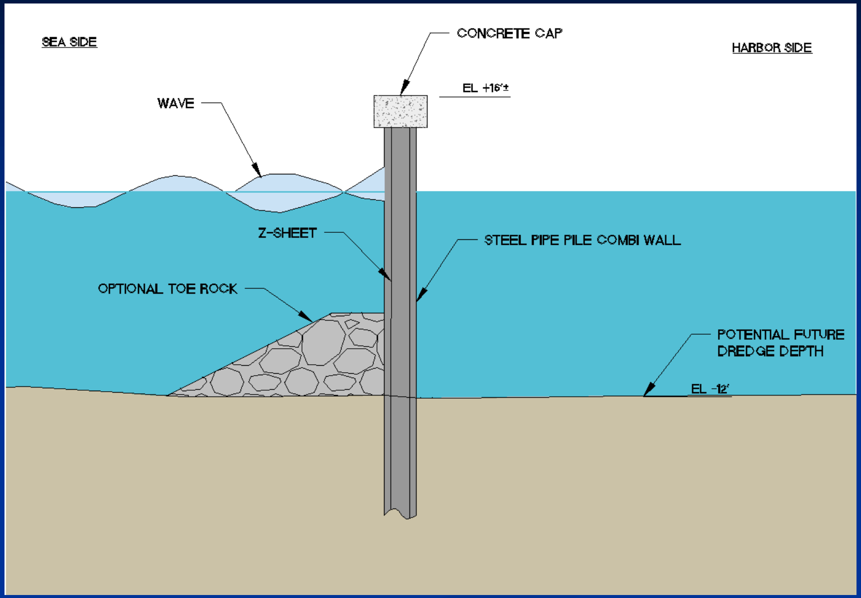






Cantilever Breakwater and Retaining Wall

- Combi Wall with vertical pile
- Reinforced concrete cap
- Optional Toe Rock
- Advantages
  - Cost-effective system
  - Easily constructed
  - Small footprint
  - Easy to convert to walkway (add rails)
- Limitations
  - Not practical in deep water
  - Reflective
  - Requires full demo of existing



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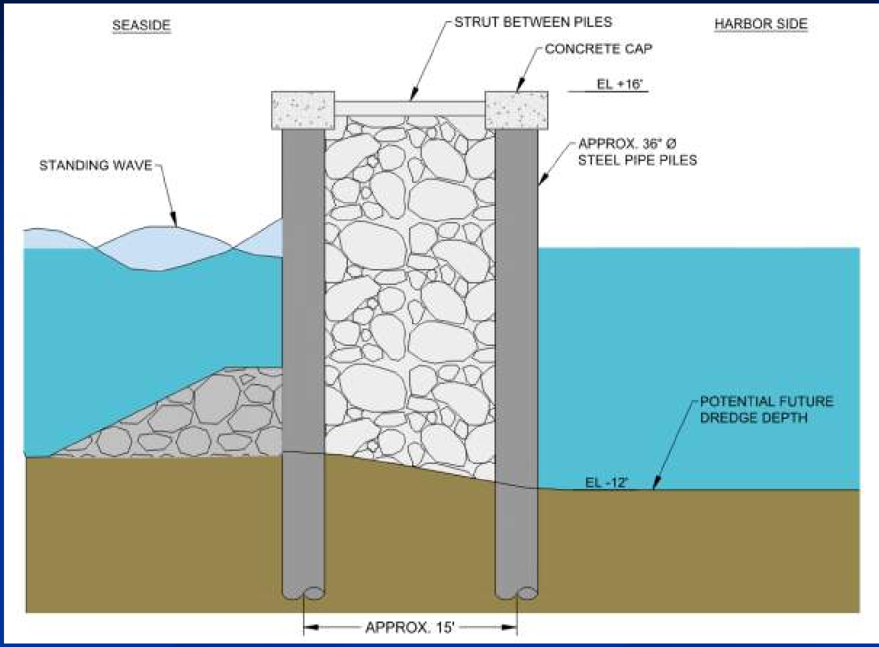
Vertical Piles and Rock Core

- Vertical Pile on front and back face
- Strut at top connecting piles
- Narrower footprint – less impact to navigation
- Advantages
  - Absorbs wave energy
  - Not as large as rubble mound structure
  - Similar to existing breakwater performance
- Limitations
  - More expensive
  - Requires full demo of existing



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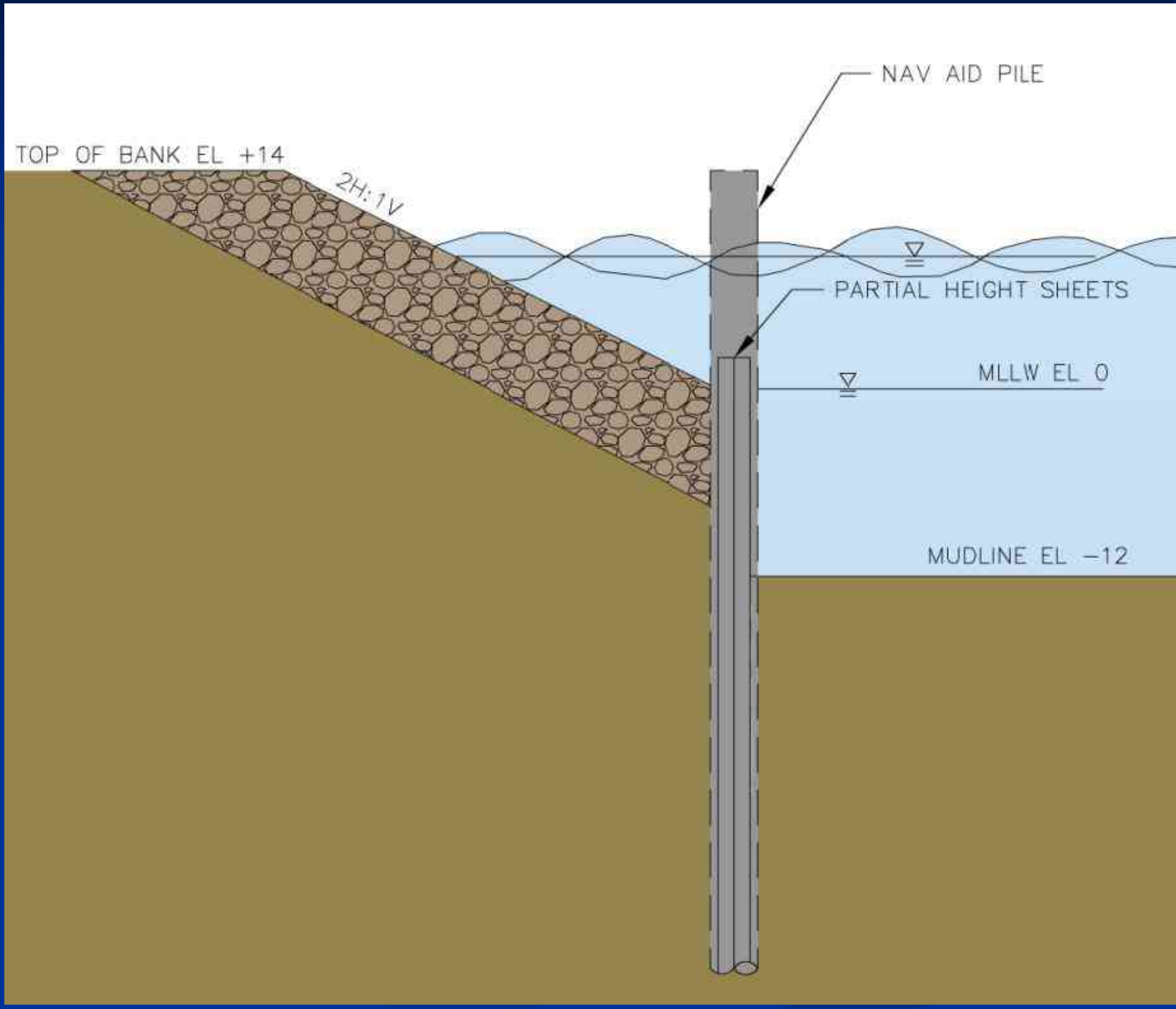
Partial-Height Retaining Wall

- Partial Height Wall to reduce cost
- 2:1 Slope Protection
- Provides a 12 ft wide drive lane to access breakwater
- NAV AID piles required



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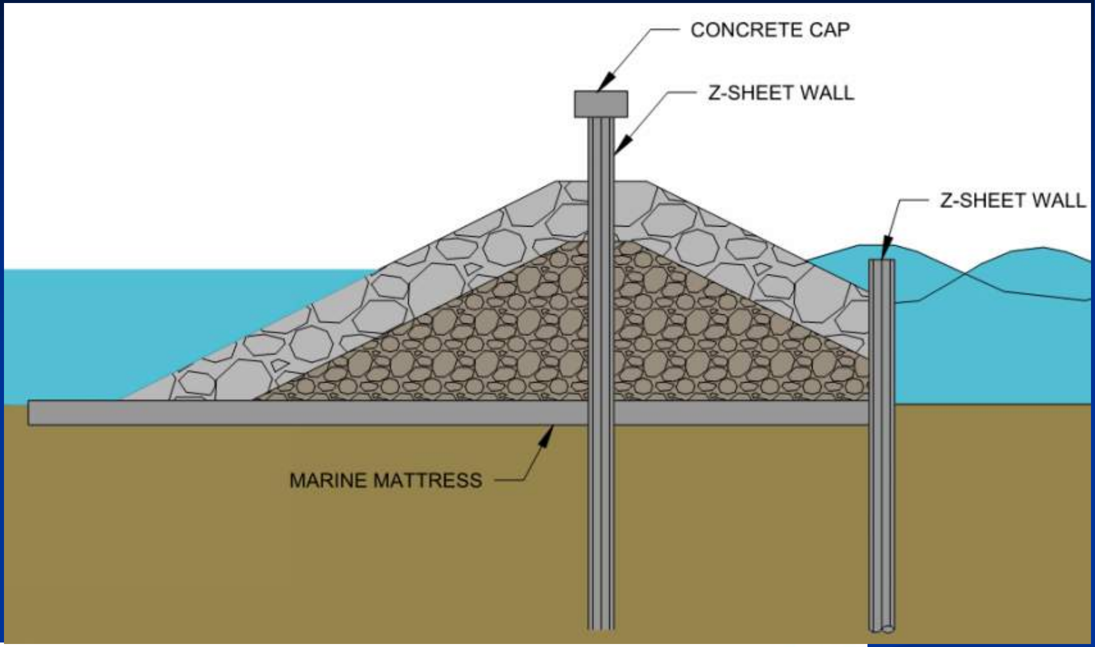
Rubble-Mound Structure

- Long design life
- Resistant to sand abrasion
- Advantages
  - Less wave reflection
  - Cost effective system
  - Reuse of some existing armor rock possible as fill
  - Partially Reflective
- Limitations
  - Large Footprint
  - Not economical in deep water



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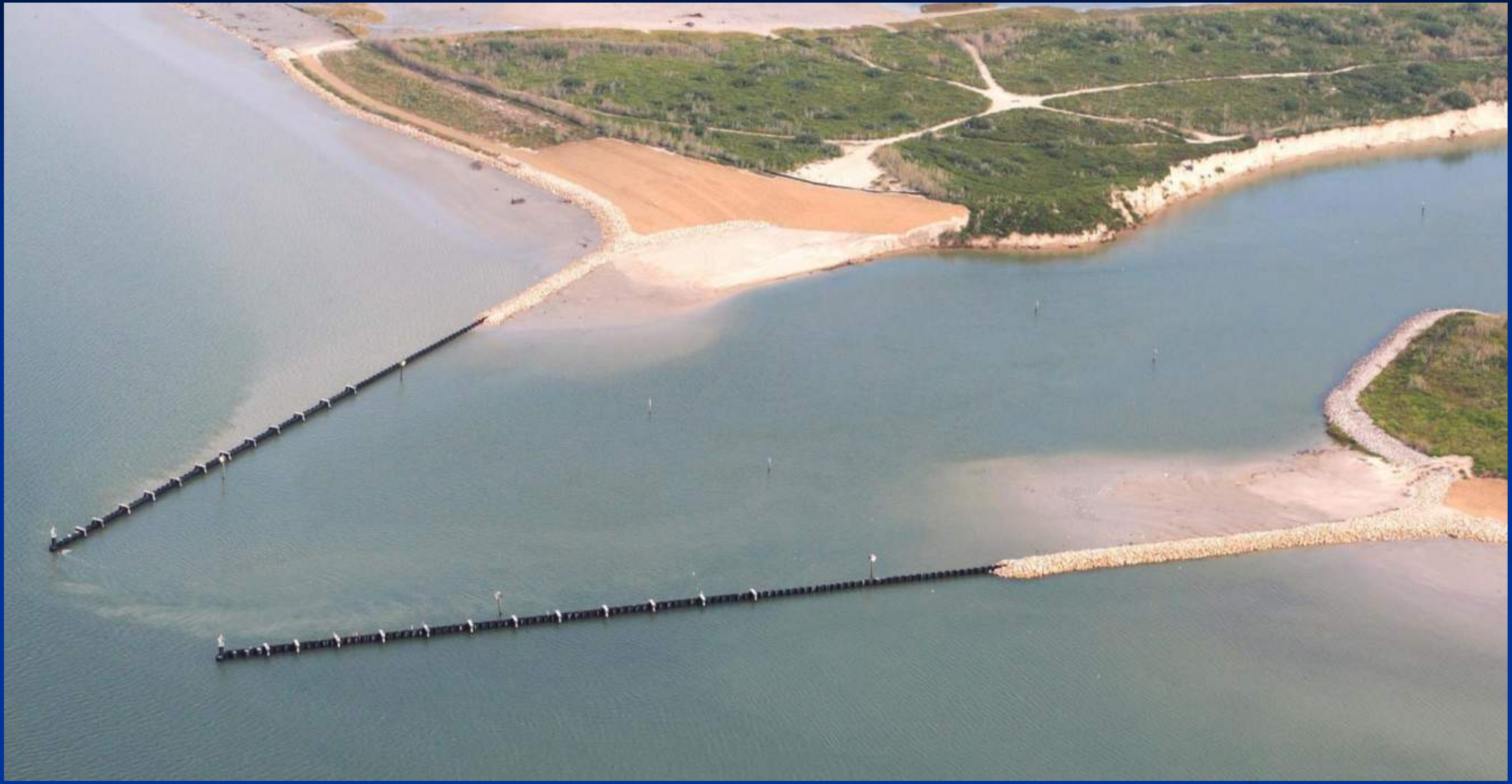
Rubble-Mound Structure – CHE Project



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Alternative Assessment Criteria

- Construction Cost
- Life-Cycle Cost
- Marina Wave Environment
- Entrance Channel Navigation
- Marina Protection During Construction
- Constructability
- Environmental Impacts/Permitting
- Phased Construction Possibility

Cost

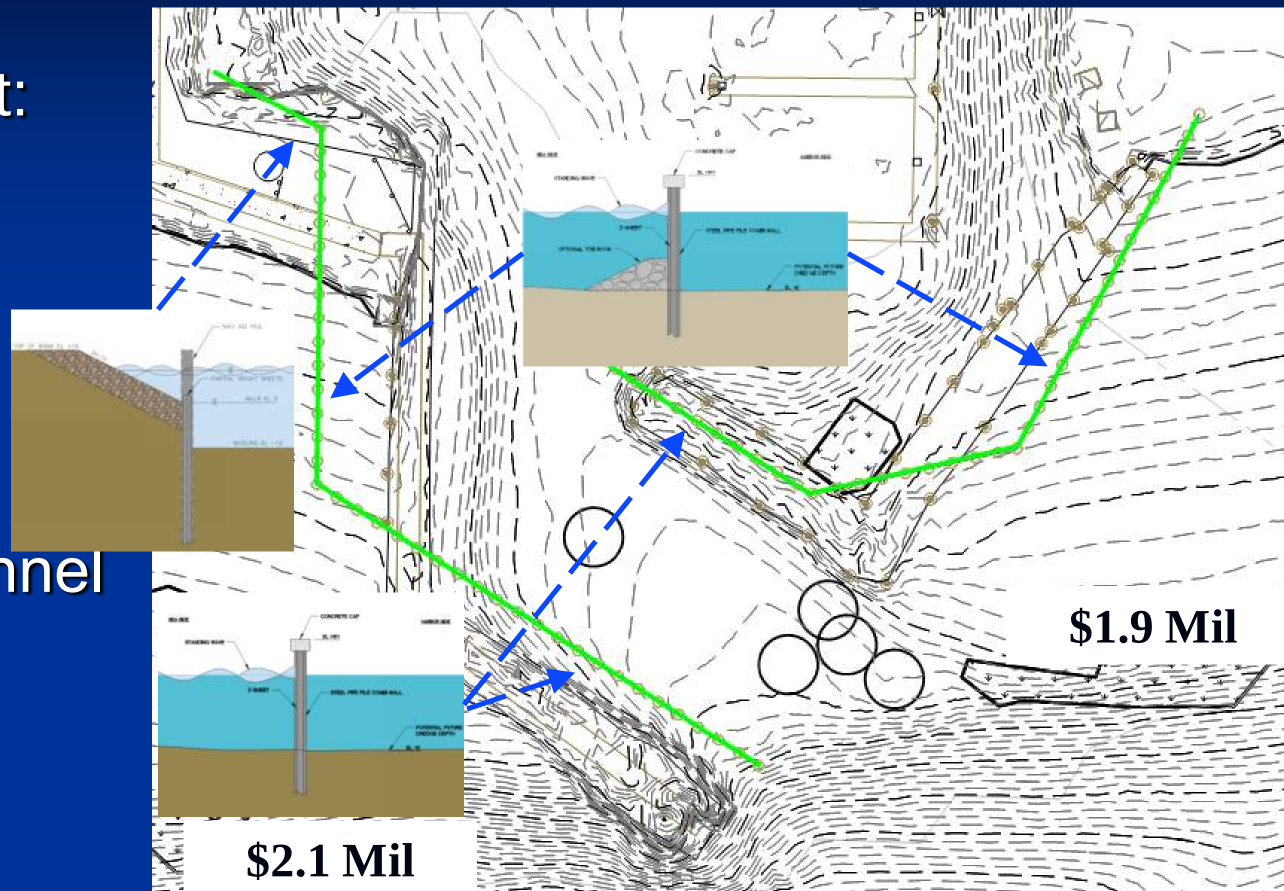
- Port currently has approx. 4 million construction budget
- CHE prioritized cost-savings and accuracy of cost-estimates, life-cycle costs considered
  - Discussed project with local contractors/material suppliers
  - Refined the structural analysis – components sized for each breakwater leg
  - Steel vs. concrete pile cap
  - Coating/cathodic protection system
- Cost includes contingency for phase of design and tax
- Cost does not include:
  - Engineering
  - Permitting fees
  - Future data acquisition
  - Mitigation/ monitoring

Cost Sensitivities

- Demolition & New Wall Construction Coordination
- Marina Vessel Access Requirements During Construction
- Time of Year Construction Occurs

Preliminary Design – Alternative 1

- Estimated Construction Cost: $4.0 Million
- Marina Wave Climate
  - Beam Seas
  - Head Seas
- 85‘ Entrance channel



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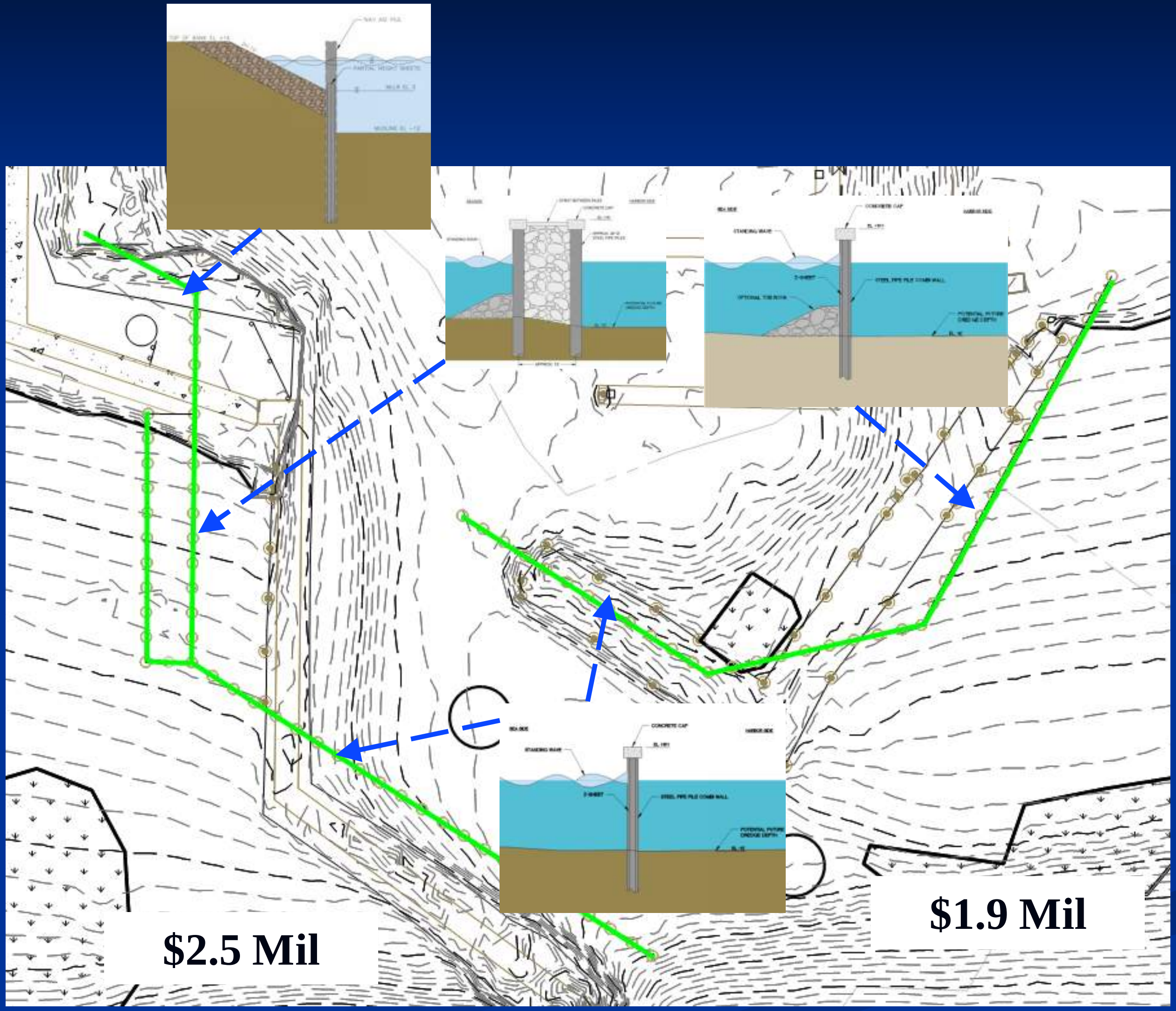
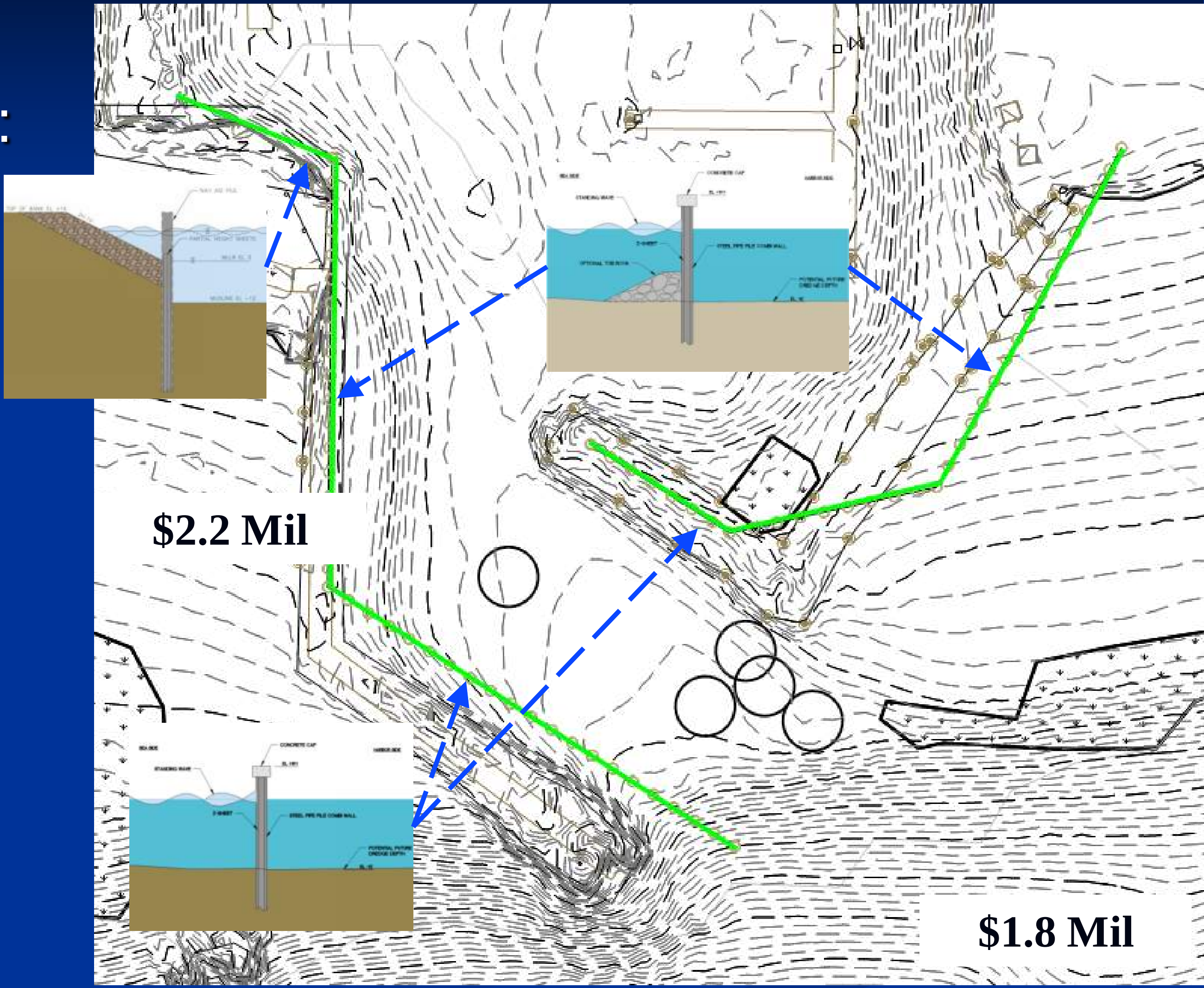
Alternative 1 With Partially Reflective Structure

- Base Cost: $4.0 Million
- Additional $400k cost for partially reflective option
- Marina Wave Climate
  - Beam Seas
  - Head Seas
- 85' Entrance Channel



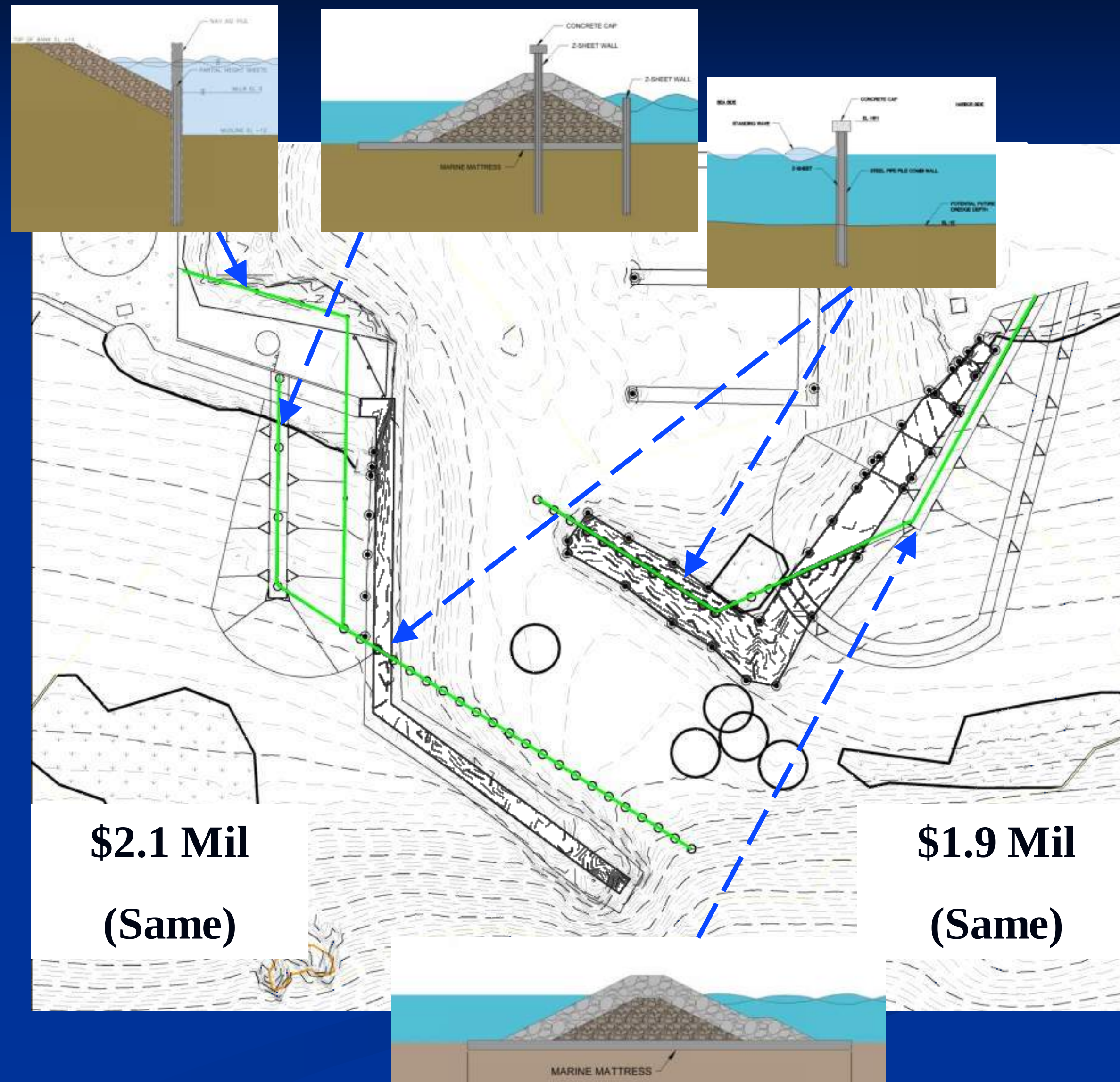
Preliminary Design – Alternative 2

- Estimated Construction Cost: $4.0 Million
- Marina Wave Climate
  - Beam Seas
  - Head Seas
- 85' Entrance Channel



Preliminary Design – Alternative 3

- Estimated Construction Cost: $4.0 Million
- Marina Wave Climate
  - Beam Seas
  - Head Seas
- Larger footprint but less pile driving
- 77’ Entrance Channel



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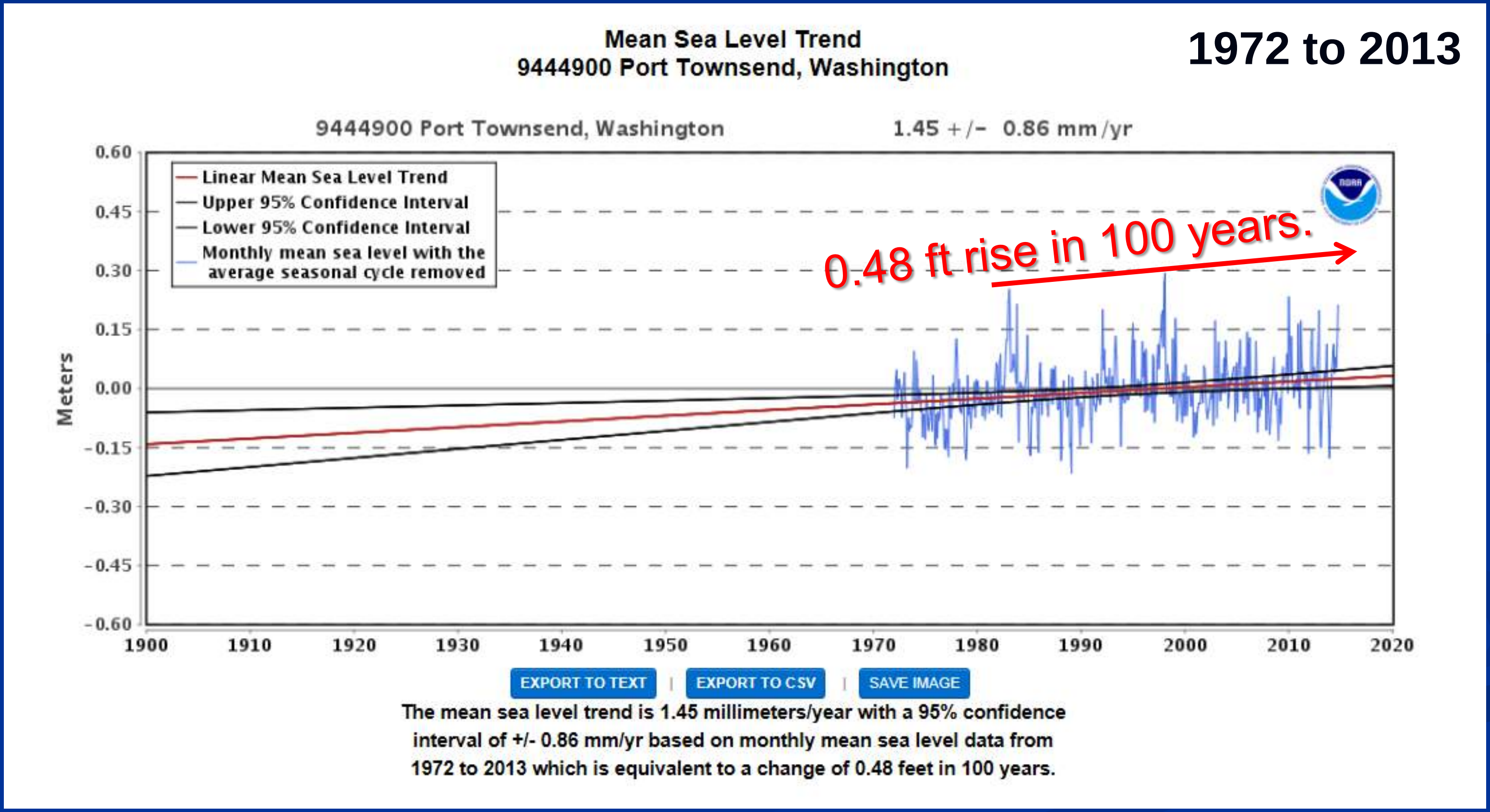
Additional Coastal Engineering Analysis

- Previous Findings
  - E/SE wave direction controls
  - Entrance channel width effects wave penetration
  - Cost/benefit of partially reflective structure not yet determined
- Sea Level Rise Summary
- Floating Breakwater Feasibility Assessment
- Breakwater overtopping and crest height
- Wave Model Parameter Tuning
- Wave Modeling for Alternative 1 & 2
  - Fully reflective structures
  - Partially reflecting Structures
  - Focused on 50-year & 1-year storm from ESE
  - Reanalysis of existing condition

Considerations for Sea Level Rise – Real Data

- Rising sea levels are a reality in Puget Sound; sea level rise relative to land elevation changes must be considered locally (see next slide)
- Long term SLR trend of 0.48 ft in 100 years ± 0.25 ft



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Considerations for Sea Level Rise - Estimates

- Future climate conditions may change.
- SLR Low estimate of 0.57 ft/100 years up to Medium estimate of 1.2 ft/100 years

Table III. Calculation of very low, medium, and very high estimates of Washington sea level change for 2050 and 2100, in cm (and, for totals, inches). VLM and and Total (the sum of factors used to calculate the total relative SLR value) are reported for NW Olympic Peninsula, the central and southern Washington coast, and Puget Sound. Negative VLM values represent vertical uplift of the land and a negative Total represents an apparent or relative sea level drop. Both the very low and very high SLR estimates are considered low probability scenarios.

SLR Estimate	Components	2050			2100		
		NW Olympic Peninsula	Central & Southern Coast	Puget Sound	NW Olympic Peninsula	Central & Southern Coast	Puget Sound
Very Low	Global SLR	9 cm			18 cm		
	Atm. Dynamics	-1 cm			- 2 cm		
	VLM	-20 cm	- 5cm	0 cm	- 40 cm	-10 cm	0 cm
	Total	**-12 cm (-5")**	**3 cm (1")**	**8 cm (3")**	**-24 cm (-9")**	**6 cm (2")**	**16 cm (6")**
Medium	Global SLR	15 cm			34 cm		
	Atm. Dynamics	0 cm			0 cm		
	VLM	- 15 cm	- 2.5 cm	0 cm	-30 cm	- 5 cm	0 cm
	Total	**0 cm (0")**	**12.5 cm (5")**	**15 cm (6")**	**4 cm (2")**	**29 cm (11")**	**34 cm (13")**
Very High	Global SLR	38 cm			93 cm		
	Atm. Dynamics	7 cm			15 cm		
	VLM	-10 cm	0 cm	10 cm	- 20 cm	0 cm	20 cm
	Total	**35 cm (14")**	**45 cm (18")**	**55 cm (22")**	**88 cm (35")**	**108 cm (43")**	**128 cm (50")**

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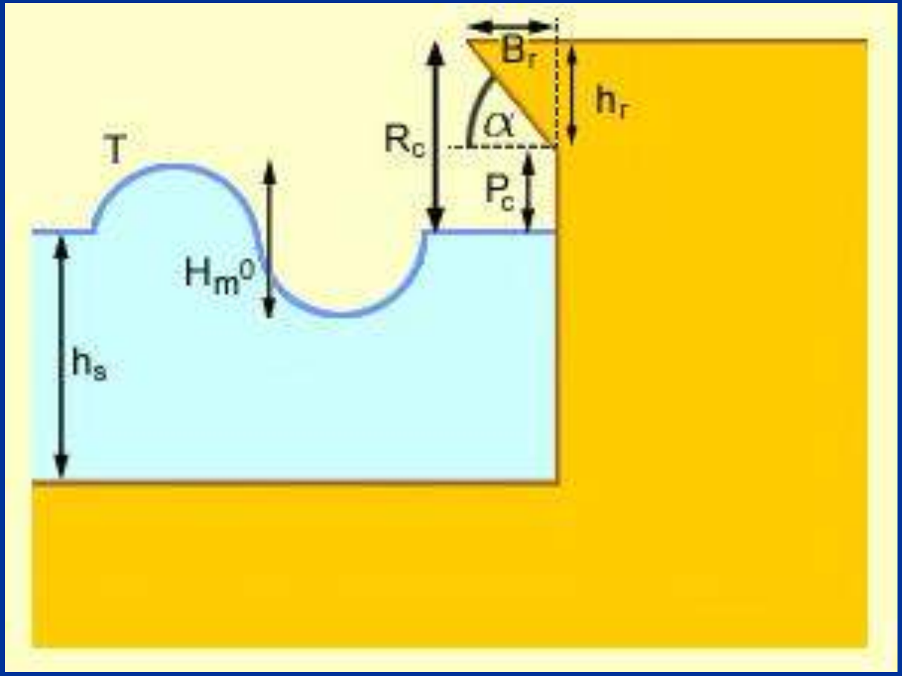
UW Climate Impacts Group (2008)

Floating Breakwater Feasibility

- Not feasible for segments along beach due to shallow water (grounding), breaking wave conditions, and resulting sedimentation issues in the marina
- Not feasible for North BW due to potential sedimentation and shallow water depths.
- Long wave periods (4 to 5 seconds) requires wide and deep structure to attenuate wave energy.
- Offshore segment of South BW would require large floating breakwater system (approx. 12 ft draft 30 ft beam) at minimum.
- Cost and maintenance would be prohibitive.

Breakwater Crest Height Analysis

- Evaluated for 50-yr wave at 2-year water level
- Top elevation of +16 selected for Preliminary Design
- Target less than 10 l/s/m



Top Elevation ft MLLW	Prob. Overtopping l/s/m	Deterministic Overtopping l/s/m
15 ft	17.0	33.7
16 ft	3.0 ✓	7.0 ✓

Breakwater crest elevation of 16 ft (min) achieves overtopping goal.

Consider adding additional 0.5 ft of height to account for future sea level rise

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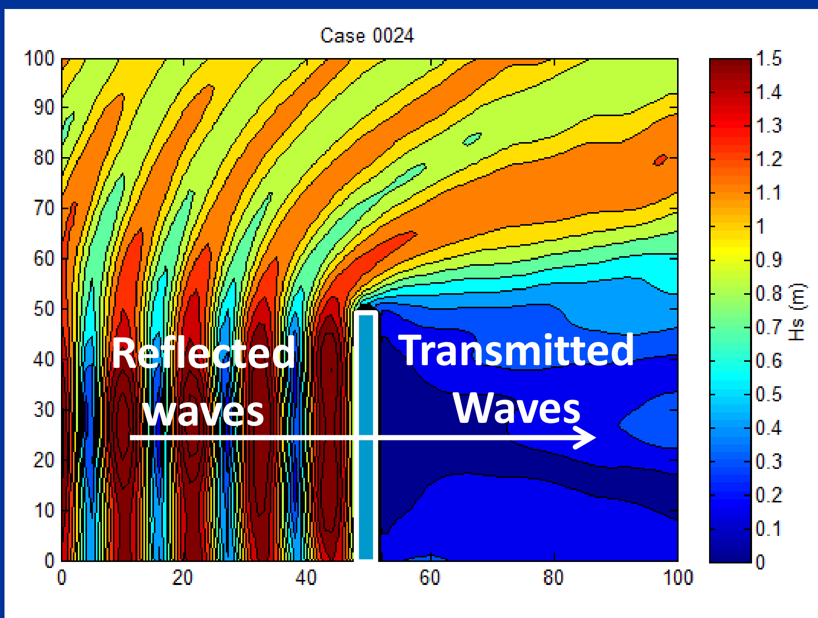
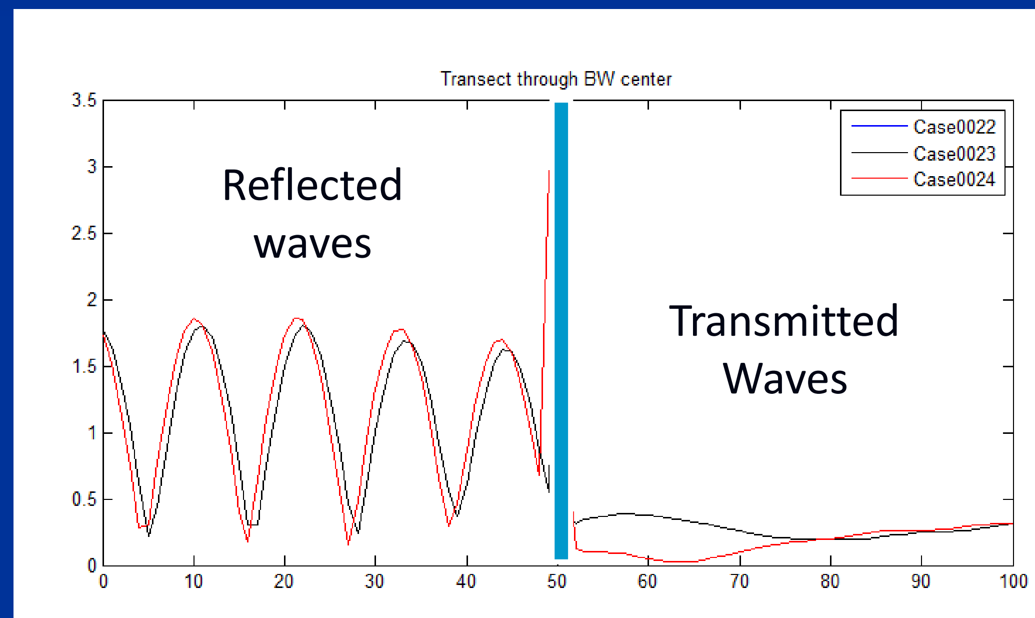
Wave Model Parameter Tuning

- Performed detailed model testing and calibration of model parameters (approximately 30 cases run)
- Selected refined model parameters for use in analysis of revised breakwater alternative layouts.



Example Case 24 Plan View



Example Cross Section

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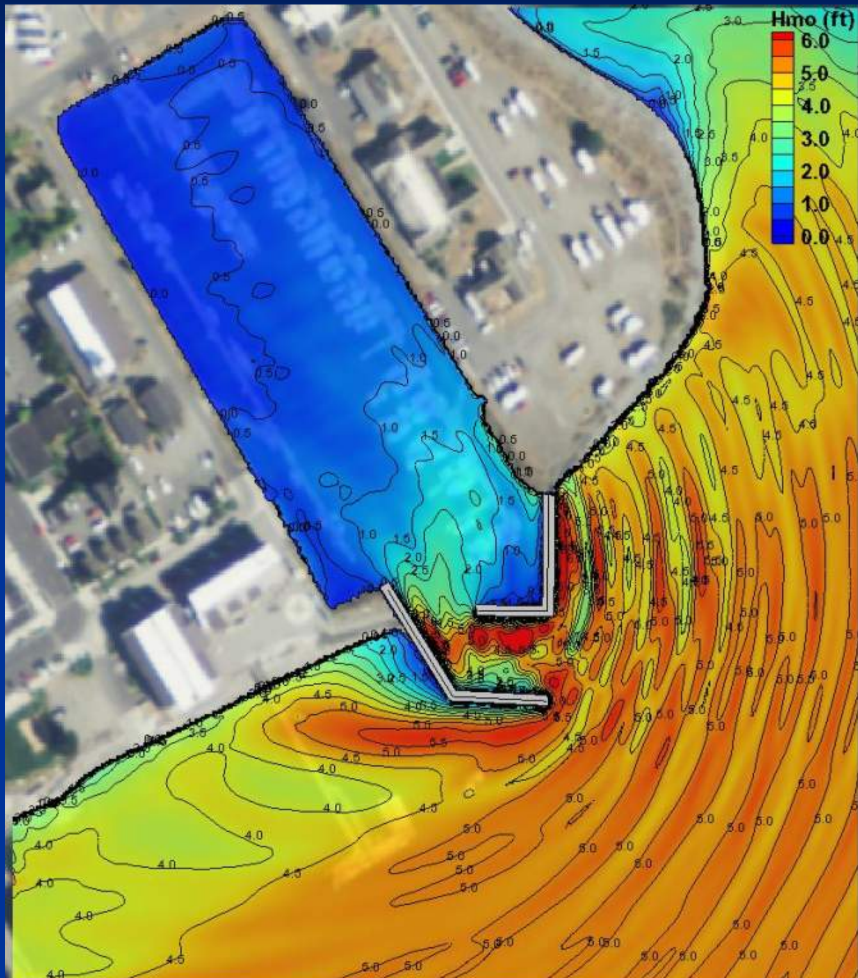
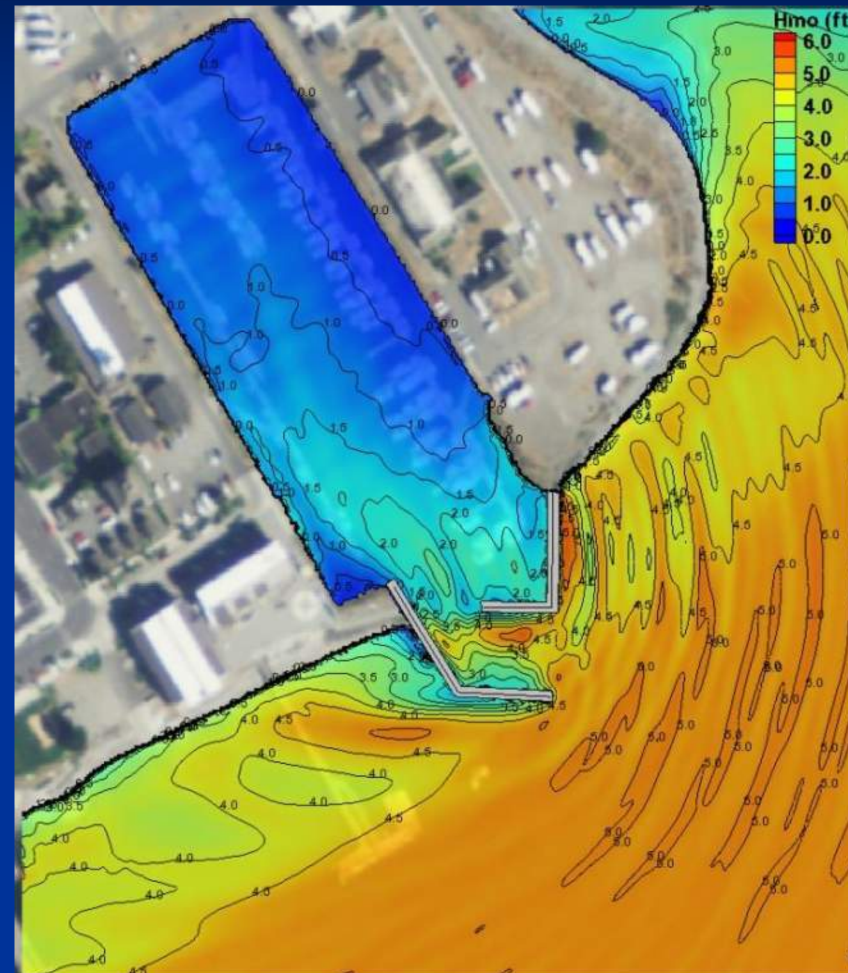
Compare Existing With - 50 Year Storm MHHW

Existing, 100% Reflective



Existing, 50% Reflective



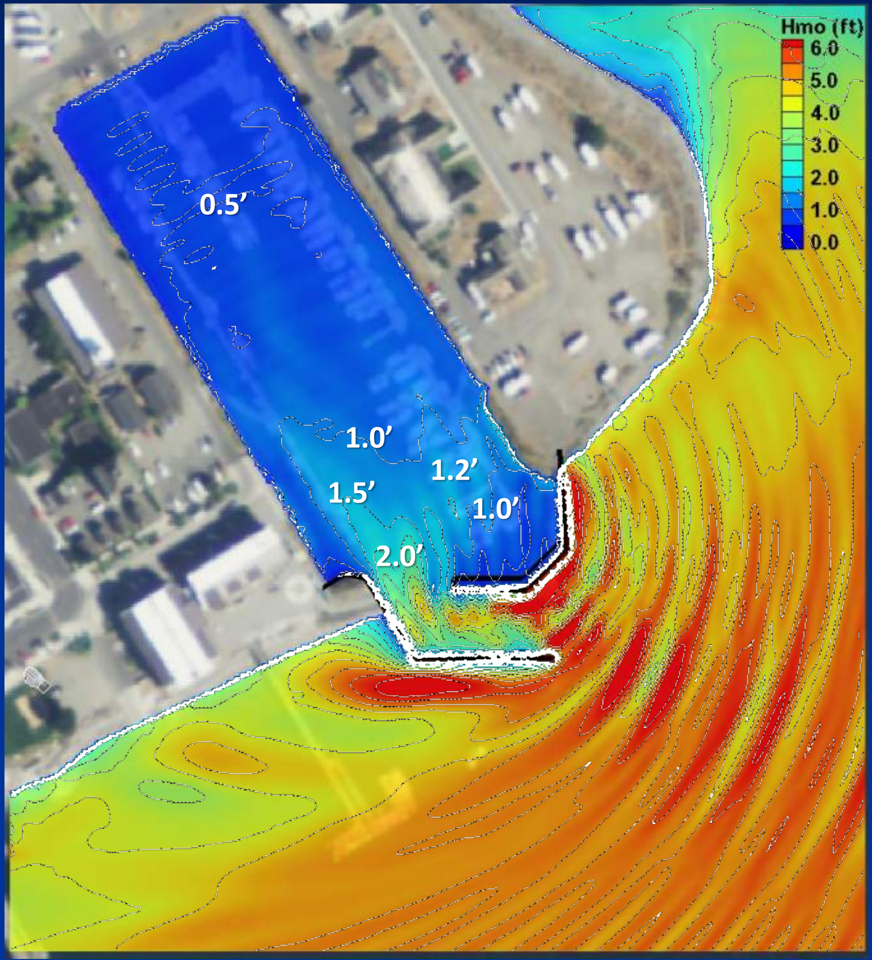
Spectral

Hmo = 4.99 ft (1.52 m),

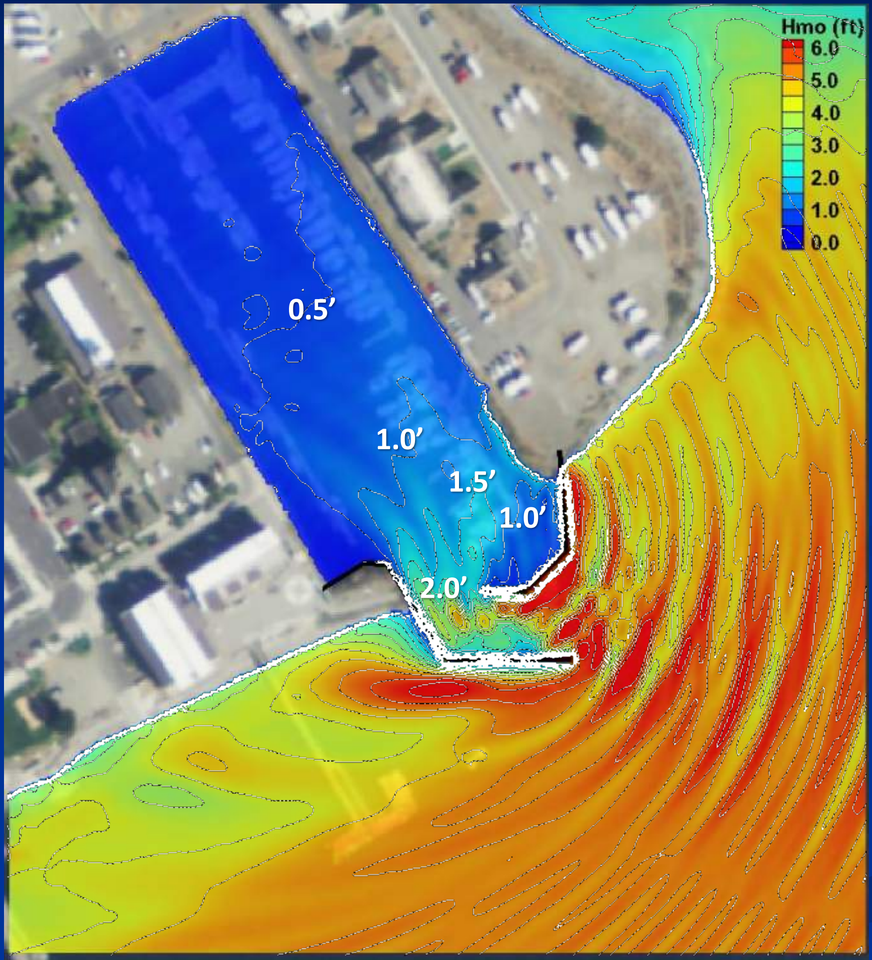
Tp = 4.5, Hdir = 105°, TN (165°, CART), Wdir = 110°, TN

HWAVE Model Results – 50 Year Storm MHHW

Alternative 1, Fully Reflective



Alternative 2, Fully Reflective



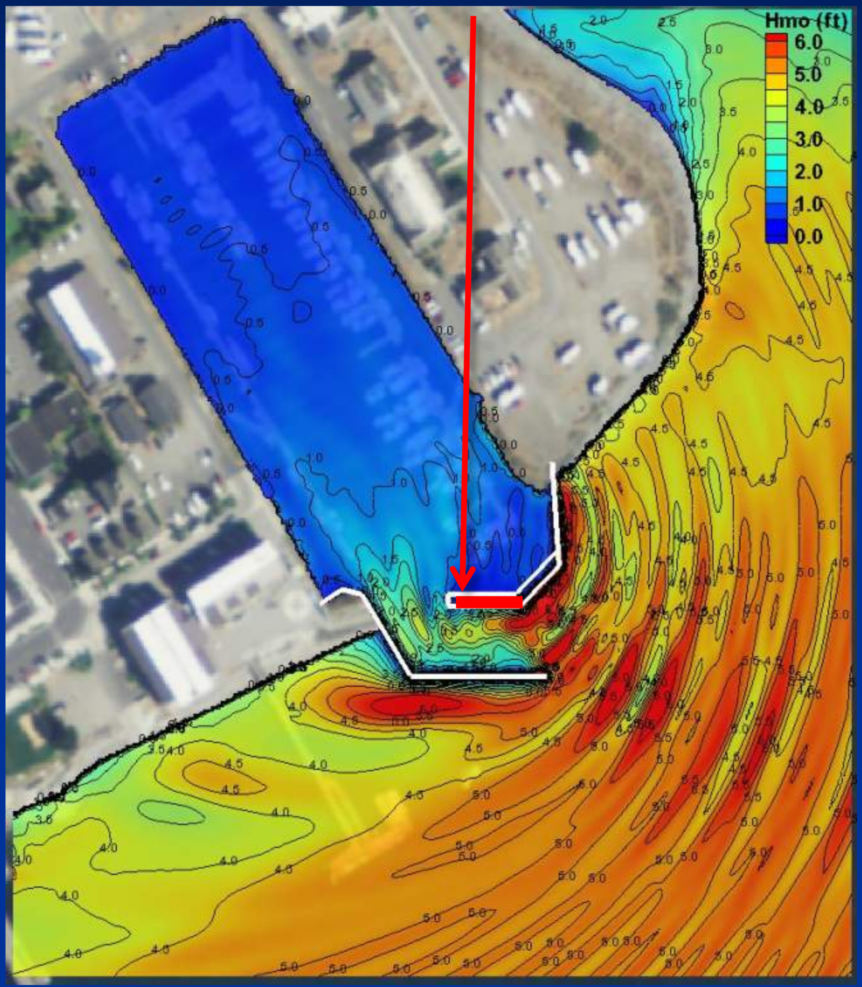
Spectral

Hmo = 4.99 ft (1.52 m),

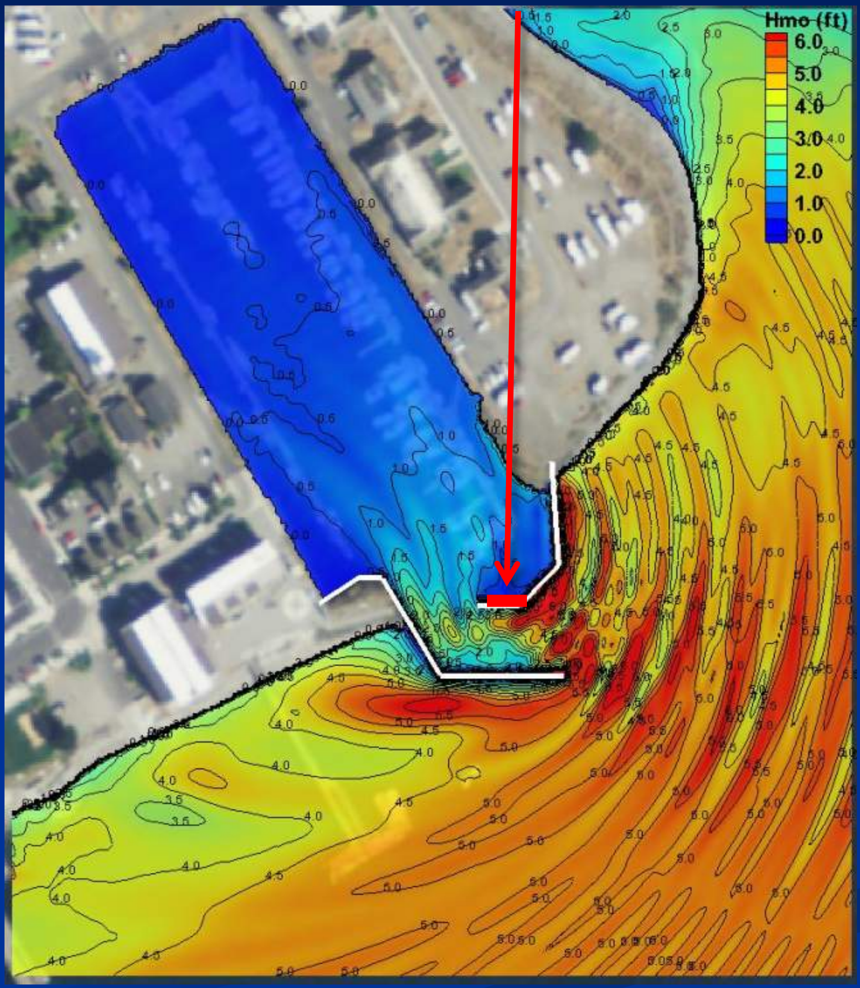
Tp = 4.5, Hdir = 105°, TN (165°, CART), Wdir = 110°, TN

HWAVE Model Results – 50 Year Storm MHHW

Alternative 1a, 50% Reflective



Alternative 2a, 50% Reflective



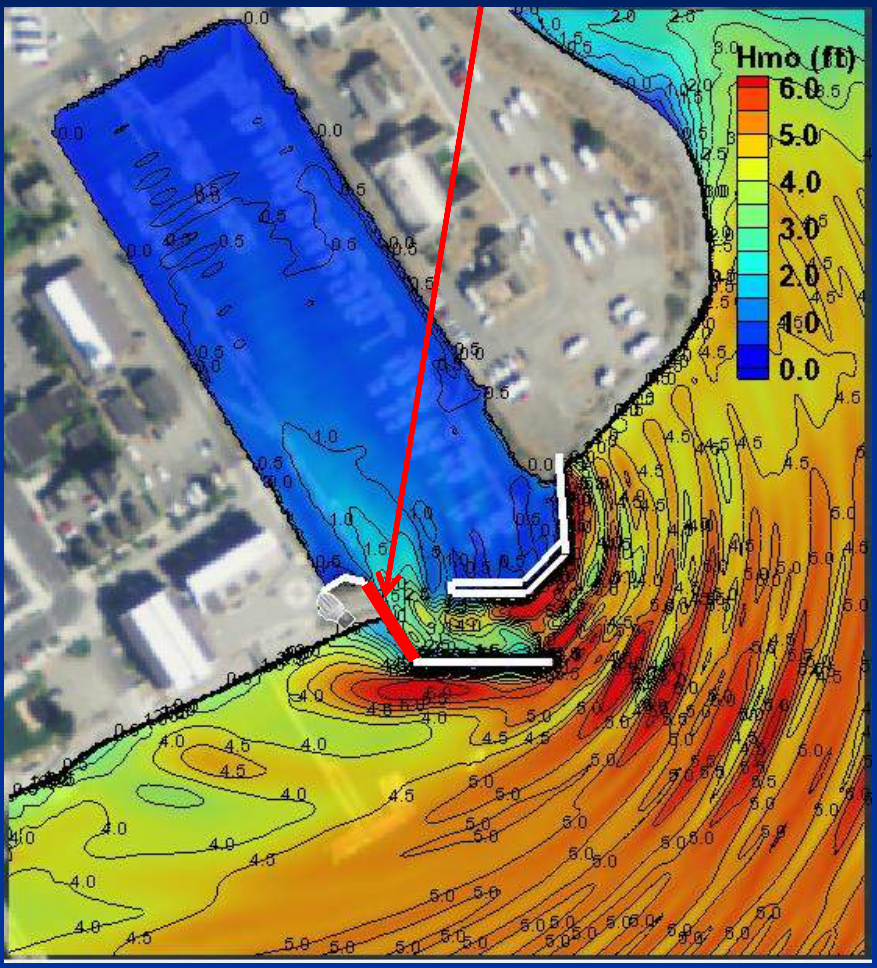
Spectral

Hmo = 4.99 ft (1.52 m),

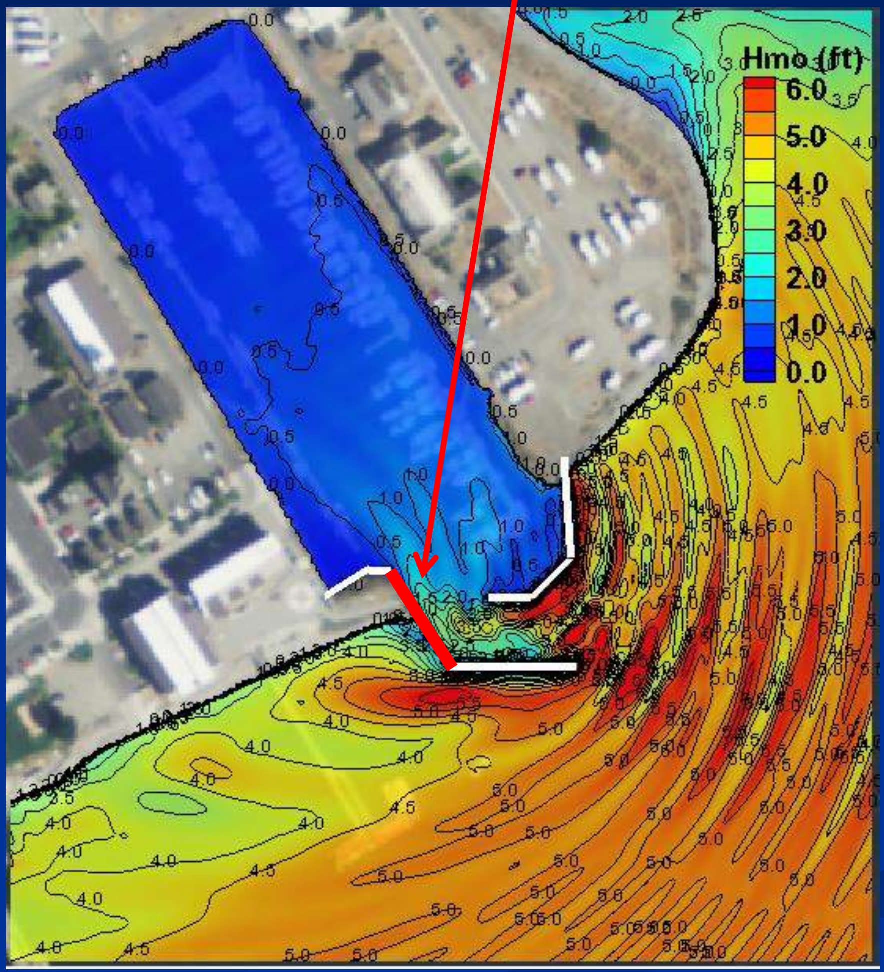
Tp = 4.5, Hdir = 105°, TN (165°, CART), Wdir = 110°, TN

HWAVE Model Results – 50 Year Storm MHHW

Alternative 1b, 50% Reflective



Alternative 2b, 50% Reflective



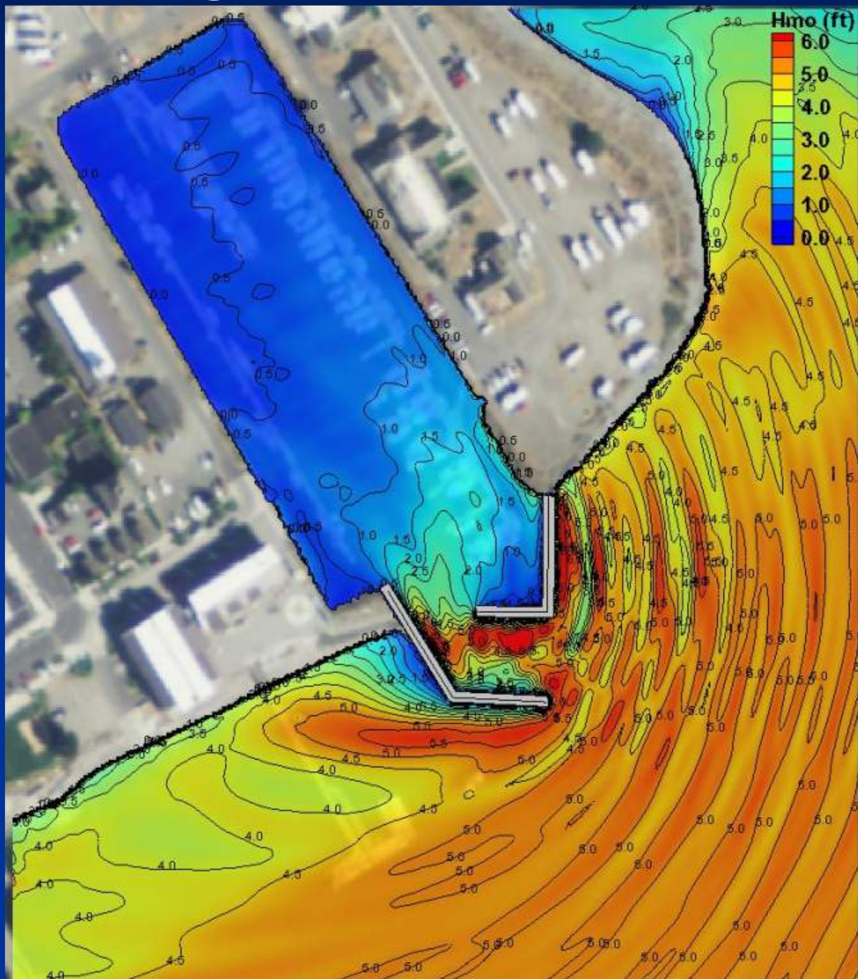
Spectral

Hmo = 4.99 ft (1.52 m),

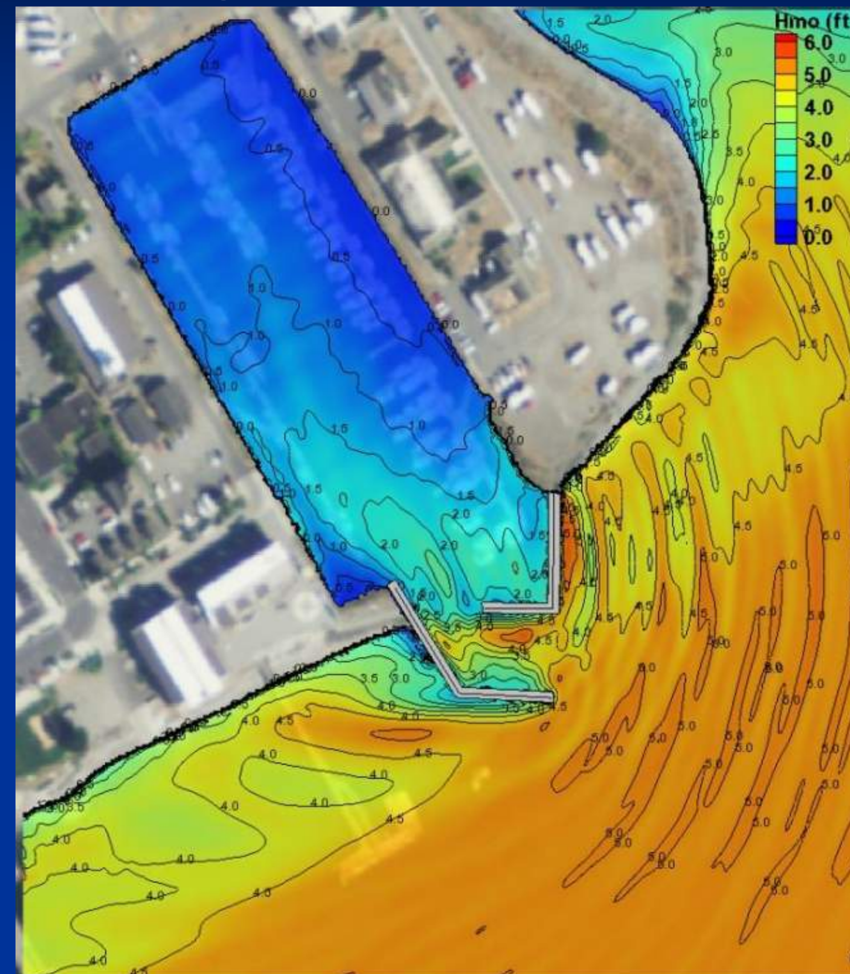
Tp = 4.5, Hdir = 105°, TN (165°, CART), Wdir = 110°, TN

Compare Existing With - 50 Year Storm MHHW

Existing, 100% Reflective



Existing, 50% Reflective



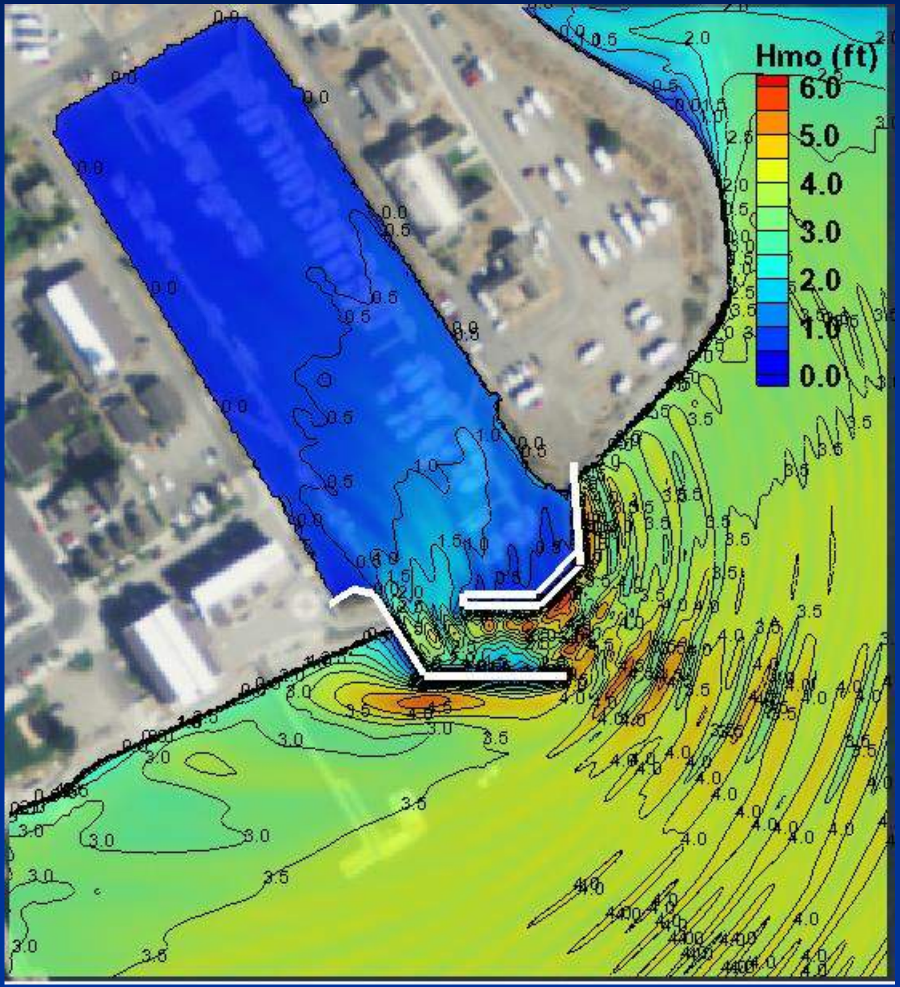
Spectral

Hmo = 4.99 ft (1.52 m),

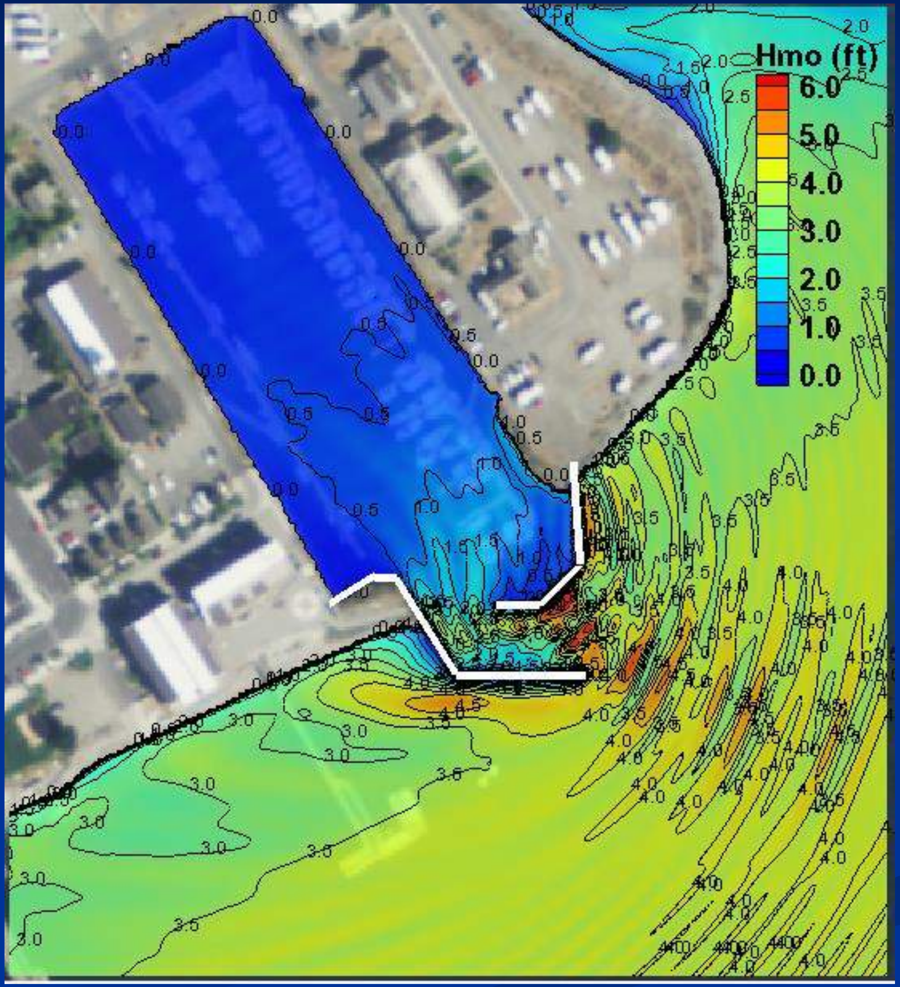
Tp = 4.5, Hdir = 105°, TN (165°, CART), Wdir = 110°, TN

HWAVE Model Results – 1 Year Storm MHHW

Alternative 1, Fully Reflective



Alternative 2, Fully Reflective



Spectral

Hmo = 3.83 ft (1.17 m),

Tp = 4.01, Hdir = 105°, TN (165 CART), Wdir = 110°, TN

Design wave criteria for small craft moorage

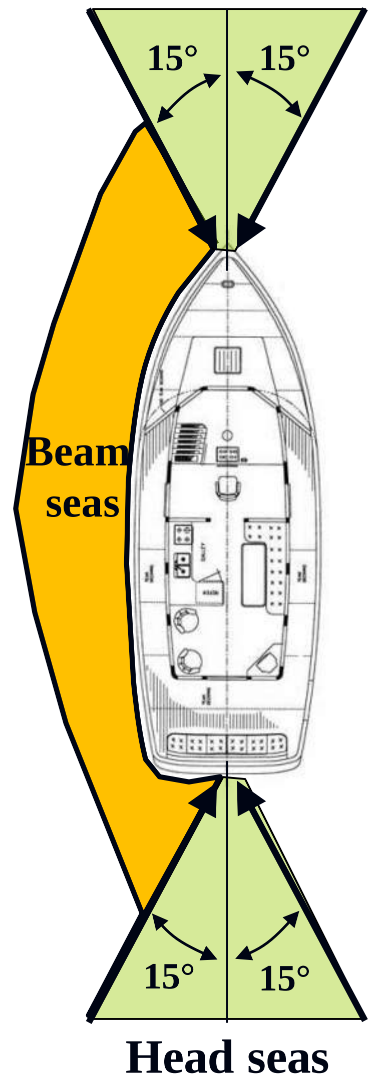
WAVE CRITERIA FOR MOORING BASIN (State of Alaska ADOT&PF)

Recurrance Interval: Once per	50 years	1 Year	Week
For Wave Heights (inches):			
Head Sea,T<2	12	12	12
Head Sea,2<T<6	24	12	6
Head Sea,T>6	24	12	6
Beam Sea,T<2	9	12	12
Beam Sea,2<T<6	9	6	3
Beam Sea,T>6	9	6	3
For Horizontal Motion (inches):			
Head Sea,T<2			
Head Sea,2<T<6			
Head Sea,T>6	48	24	18
Beam Sea,T<2			
Beam Sea,2<T<6			
Beam Sea,T>6	24	12	9

From "*Study to Determine Acceptable Wave Climate in Small Craft Harbours*"
Canadian Manuscript report of Fisheries and Aquatic Sciences - No. 1581

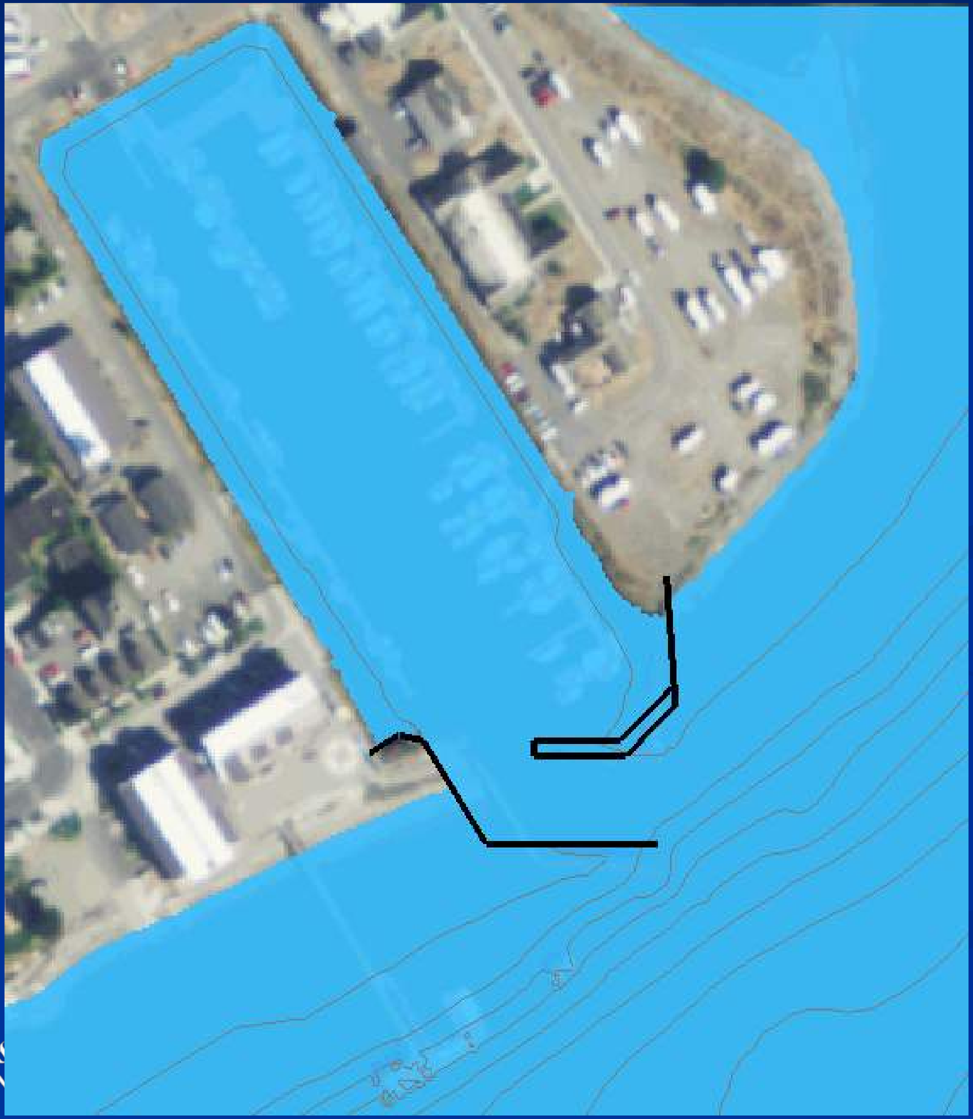
Note: **"head sea"** only applys to vessels that are aligned within **+ or - 15 degrees** of the wave direction

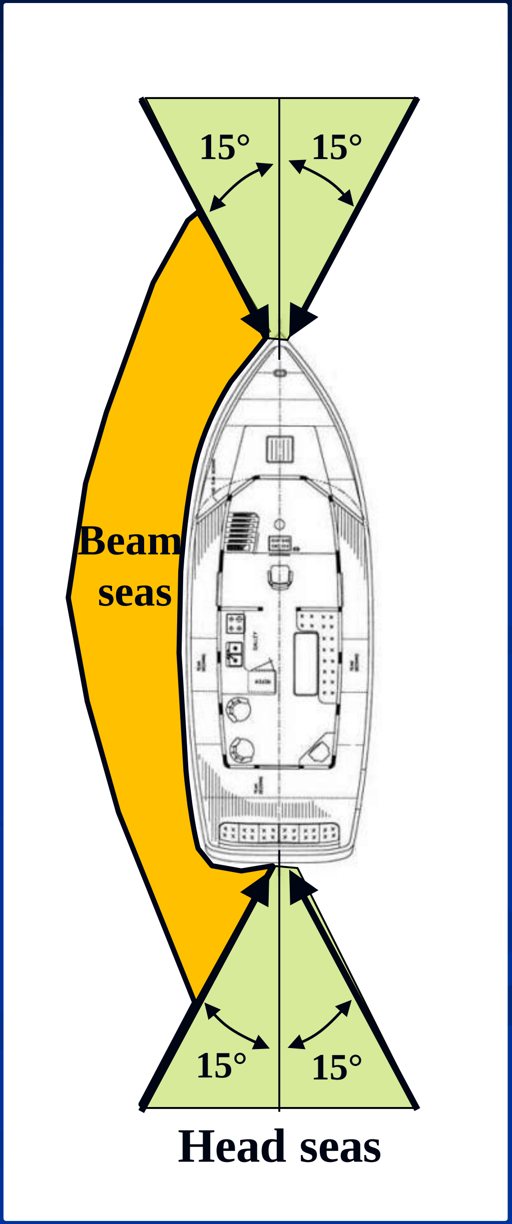
Above criteria are for a "good" wave climate. Multiply by .75 for "excellent" wave climate and 1.25 for "moderate" wave climate.



HWAVE Direction for 50-year storm at MHHW

Alternative 1, Fully Reflective





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HWAVE Direction for 50-year storm at MHHW

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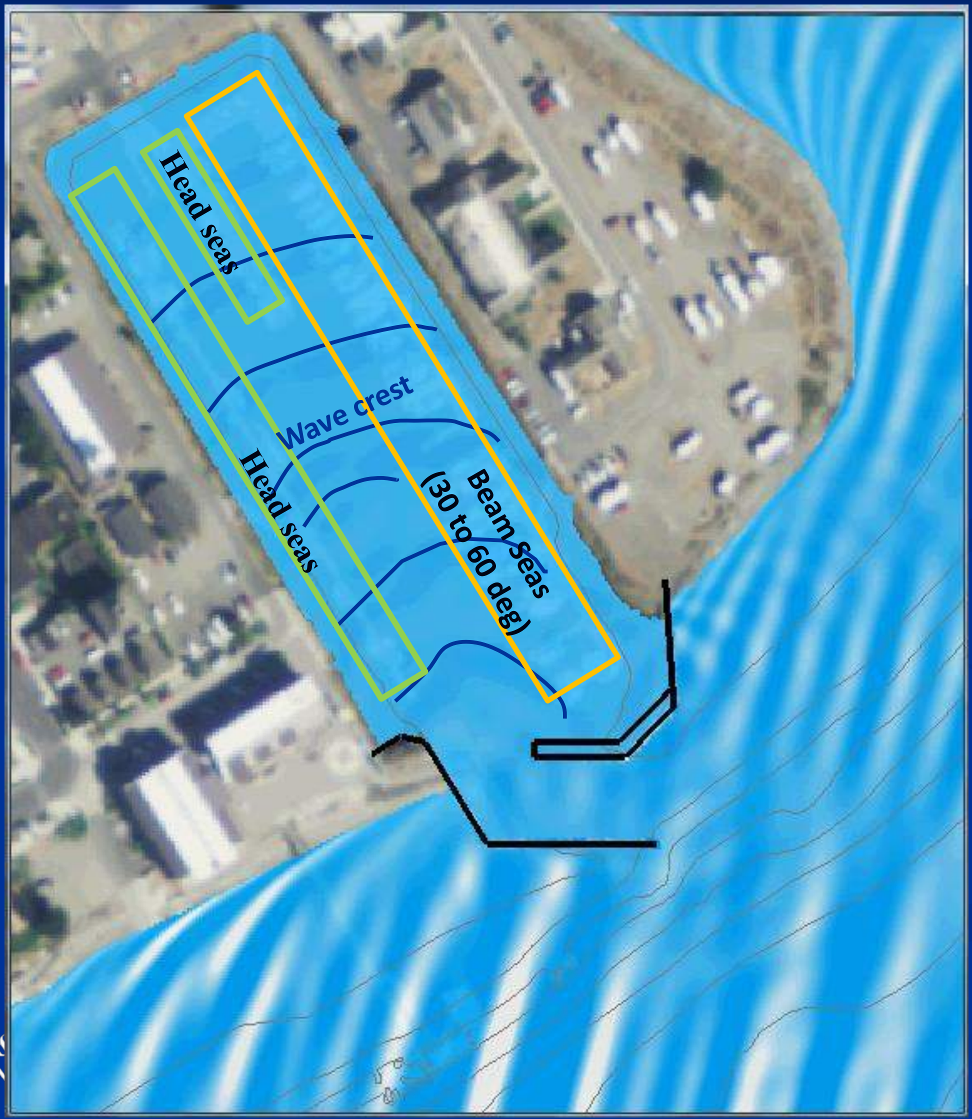

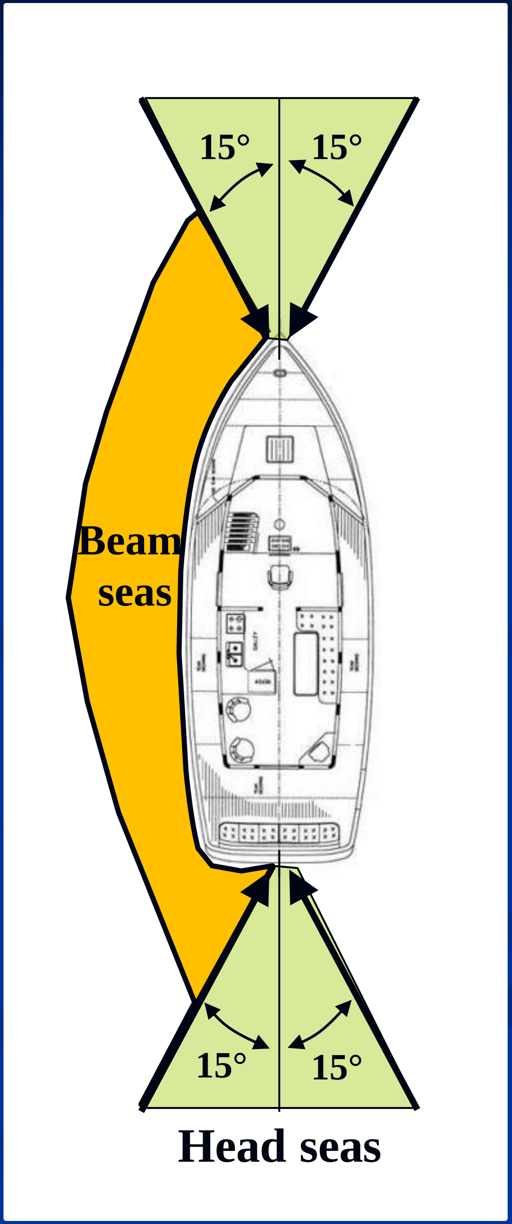

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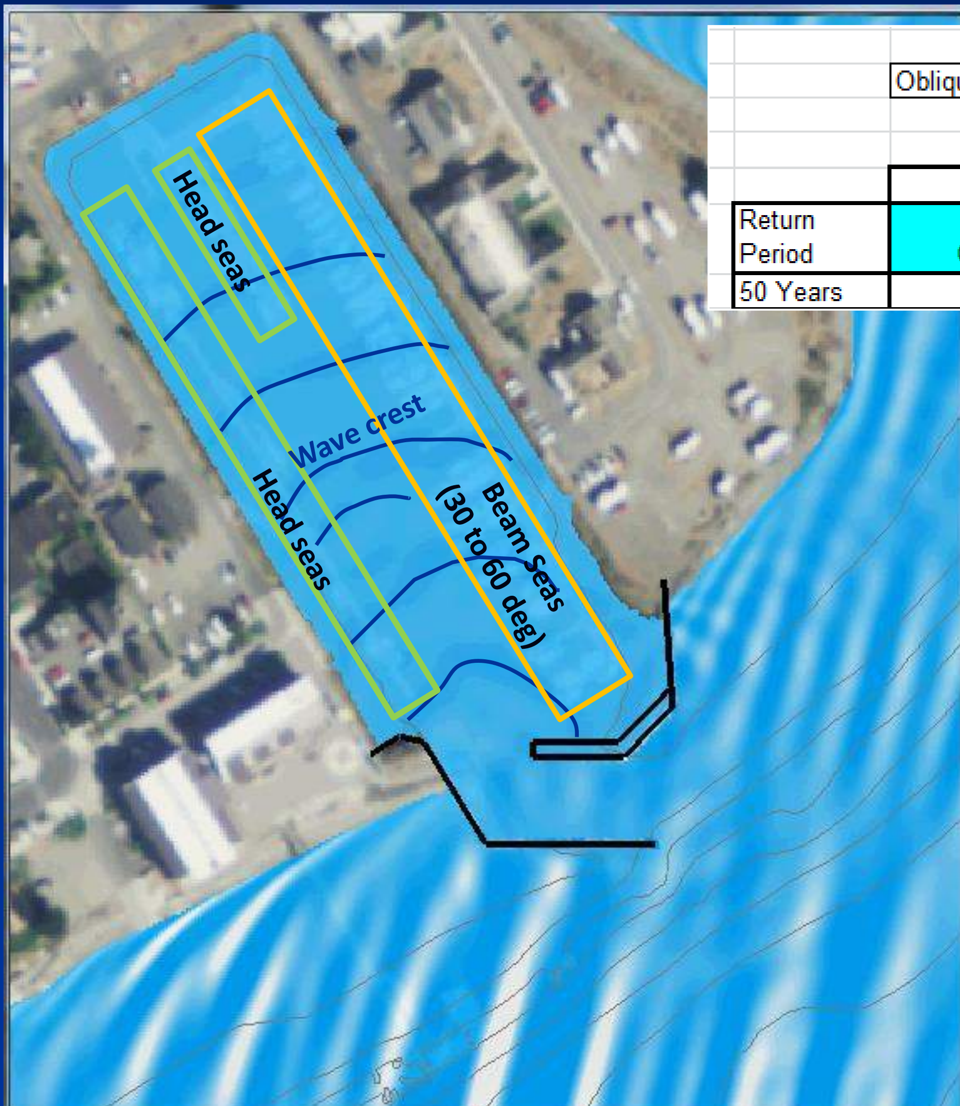


Consider Beam Wave Direction 45 Deg.

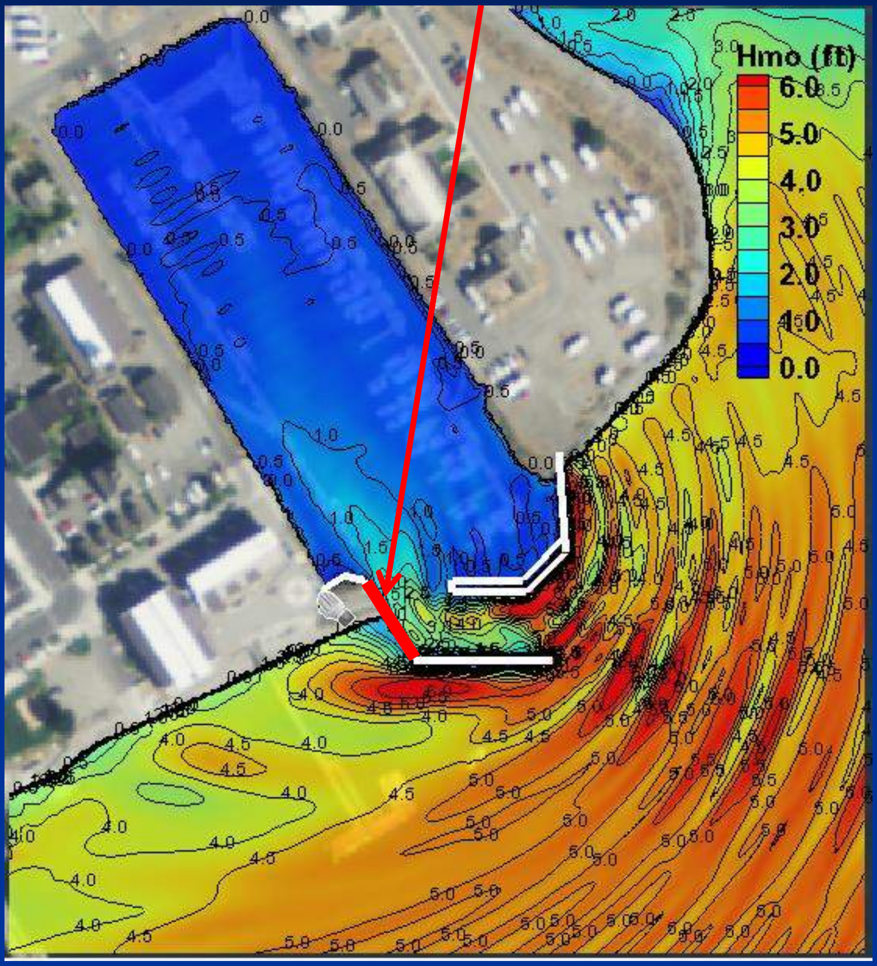
	Input	
Oblique Angle (deg)	45	Angle from Head Sea

	Recommended Maximum Agitation Height (ft) for Oblique Seas		
Return Period	"Excellent" Classification	"Good" Classification	"Moderate" Classification
50 Years	0.84	1.12	1.40

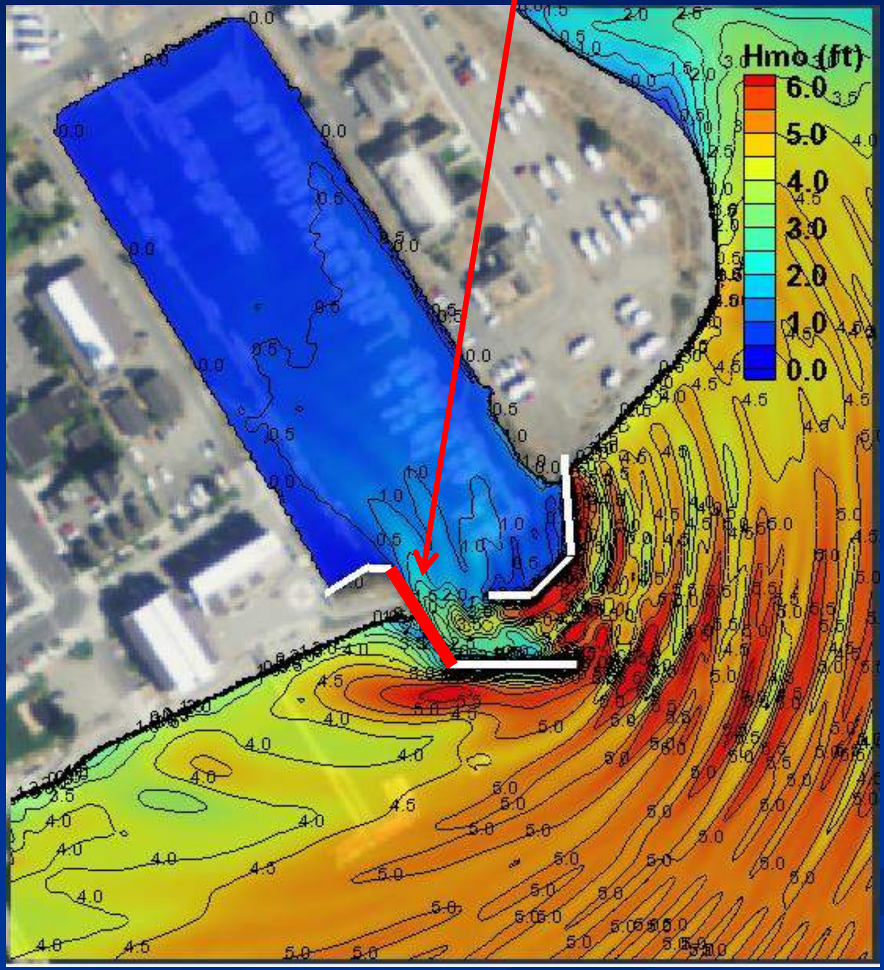
Alt.	Head Sea	Beam Sea
Existing	Good/ Moderate	Moderate
1	Good	Moderate
1a	Good	Moderate
1b	Excellent	Good
2	Excellent	FAIL
2a	Excellent	FAIL
2b	Excellent	Moderate

HWAVE Model Results – 50 Year Storm MHHW

Alternative 1b, 50% Reflective



Alternative 2b, 50% Reflective



Spectral

Hmo = 4.99 ft (1.52 m),

Tp = 4.5, Hdir = 105°, TN (165°, CART), Wdir = 110°, TN

Coastal Engineering Analysis – Summary of Results

- Existing conditions wave penetrate marina primarily from the ESE direction. Existing marina basin provides overall “Moderate” to “Good” wave climate.
- If existing navigation width is adequate for Port, replacing existing configuration with vertical wall solutions provides poor wave climate in marina basin, with increased waves at entrance due to reflections (about 10 to 20% increase).
- Opening the marina entrance (by 20 ft) would allow more wave penetration requiring extension(shift) of the outer breakwater.
- Selective use of partially reflective structures can help improve harbor tranquility, particularly for the S. Breakwater.

Outline

- Project Status (Scopes of Work, To-Do List from Conceptual Design)
- Existing Conditions
- Alternative Evaluation
- Preliminary Design - Coastal Engineering Refinement
- Conclusions, Results, Recommendations
- Next Steps

What’s New?

- Sensitivity of Alignment/Structure Type on Anticipated Wave Climate
- Refined Construction Considerations
- Chamfered Alignment
  - Shorter distance
  - Reduces wave reflection into entrance channel/marina
- Precast cap -> Economical walkway

Key Decisions

- Entrance Opening Width
- Entrance Corner Width
- Nearshore Rubble Mound Structure vs. Combi-Wall
- Partially Reflective Structures
- Rock Toe for Sand Abrasion
- Env/Regulatory Considerations

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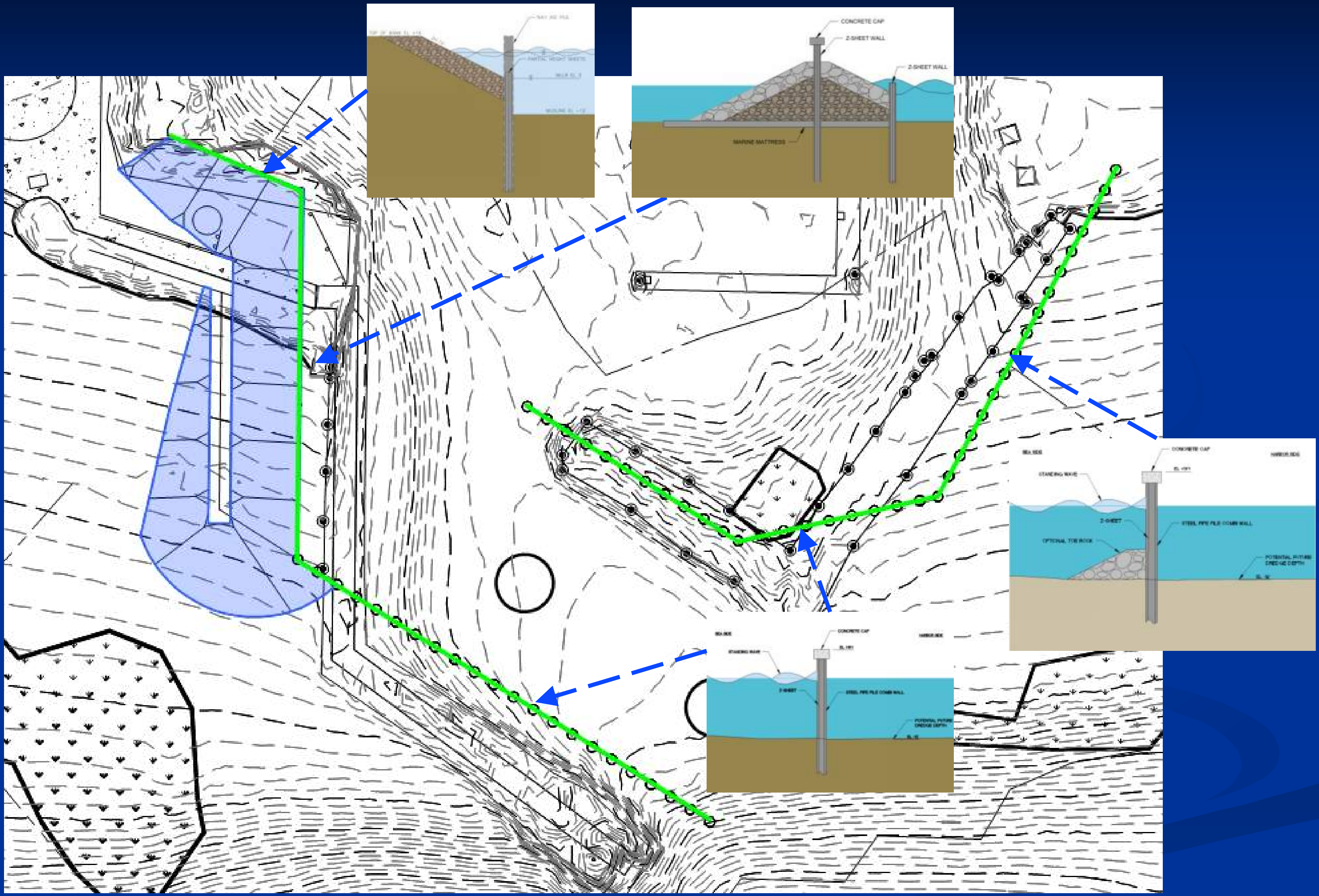
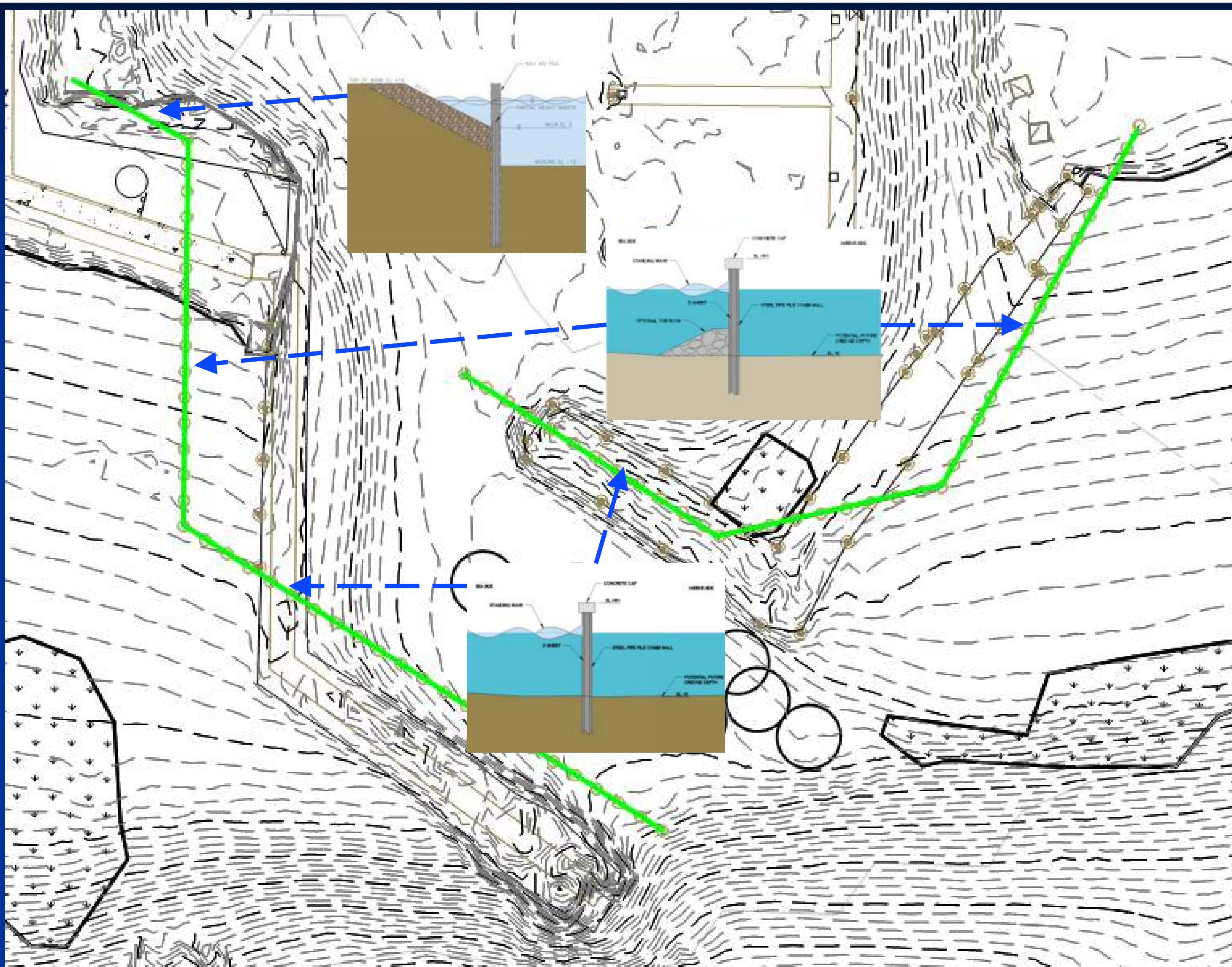
CHE Recommendations



CHE Recommendations



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Grant Funding

- Potential to fund portions of the project with grant funding
  - Conc cap = walkway
  - Creosote Pile Removal

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Design – Build

- Requires an approach to permitting that allows contractor some flexibility in the final design
  - Description of work
  - Impacts (footprints, pile driving)
  - Work sequencing and equipment

COAST & HARBOR ENGINEERING

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Next Steps

- Create permit strategy for project components
  - Partially reflective structures
  - CIP Conc vs. steel pile cap
  - Design-build layout flexibility?

PORT OF PORT TOWNSEND
Point Hudson Marina Breakwater Alternatives Analysis

COAST & HARBOR ENGINEERING