Green-Gray Alternative to Stabilize Lola Road in Cedar Island, North Carolina

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UNCW Coastal Engineering

Agenda

Problem Area of Interest

Background

Solution Design

Cost Estimates

Problem Area of Interest

- Lola Road
- Increased Erosion in Area
- Road Importance
- Current Revetment

Problem Area of Interest

Background

Previous Engineering

Revetment

- Deteriorating
- Likely minimal design
- Between 250 and 265 ft
- NCDOT Class 2 Rip Rap

Breakwater

- Designed by Quibble and Associates
- Funded by TNC
- Effective in a matching wave climate
- Four 90 ft sections of marl stone
- Visual oyster growth
- Accretion

Google Earth

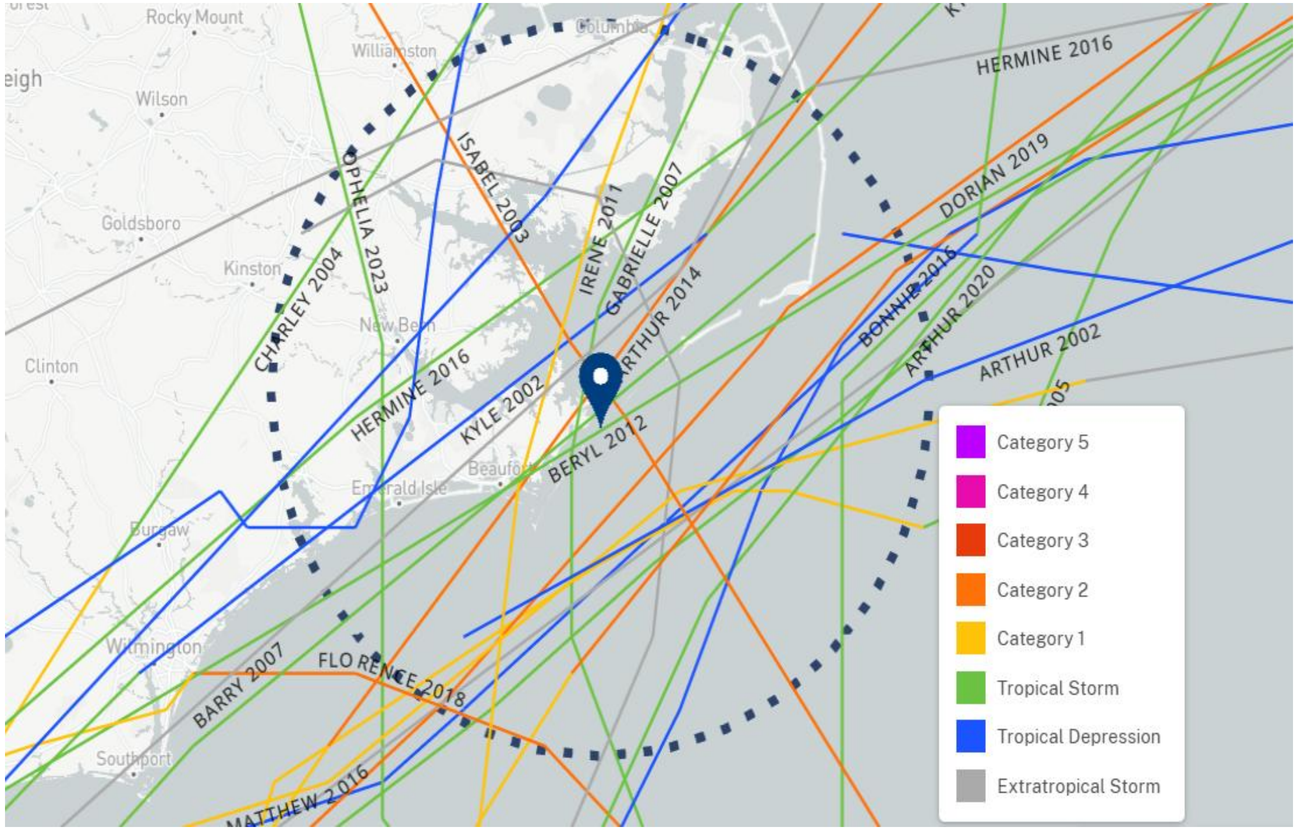
Background

Erosion

- Consistent erosion
- About 2.5-3 ft/year

Background

Storm & Floods



NOAA Historical Hurricane Tracks

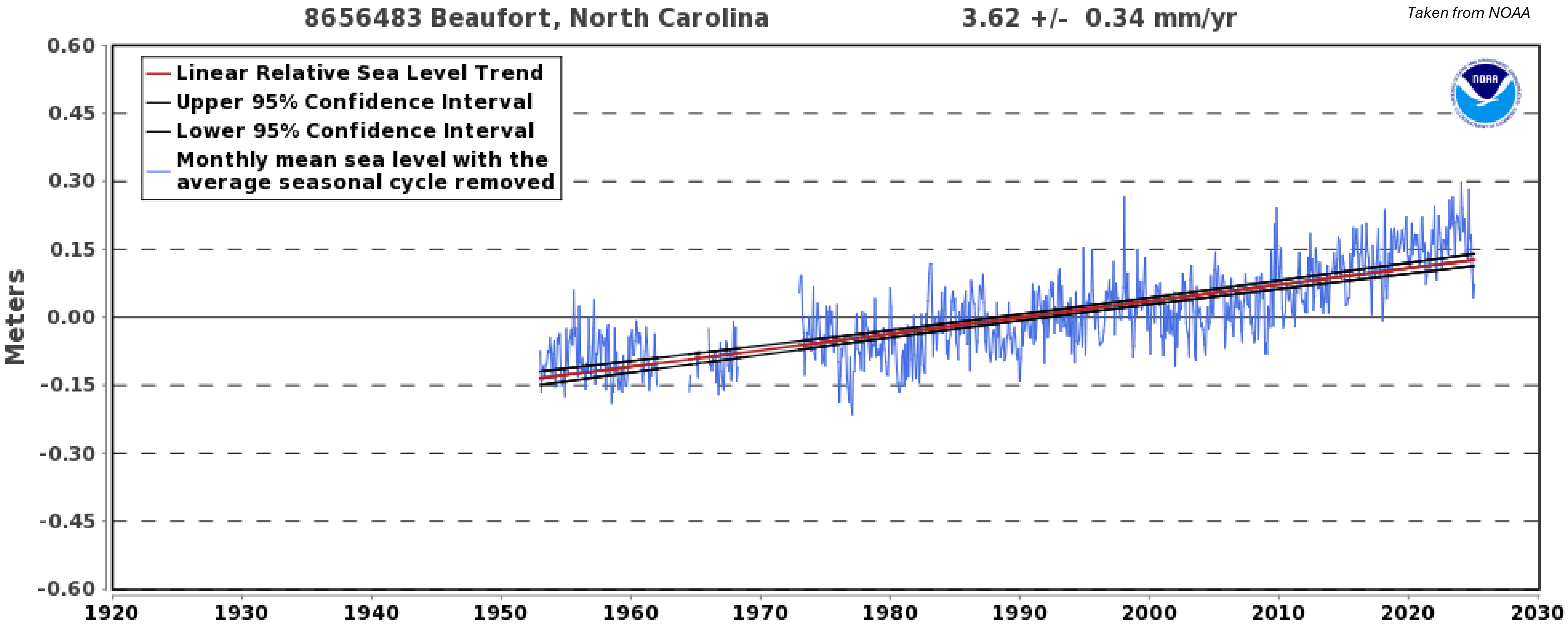
= Areas impacted by high tide flooding

High tide flooding from NOAA Sea level rise

Background

Sea Level Rise

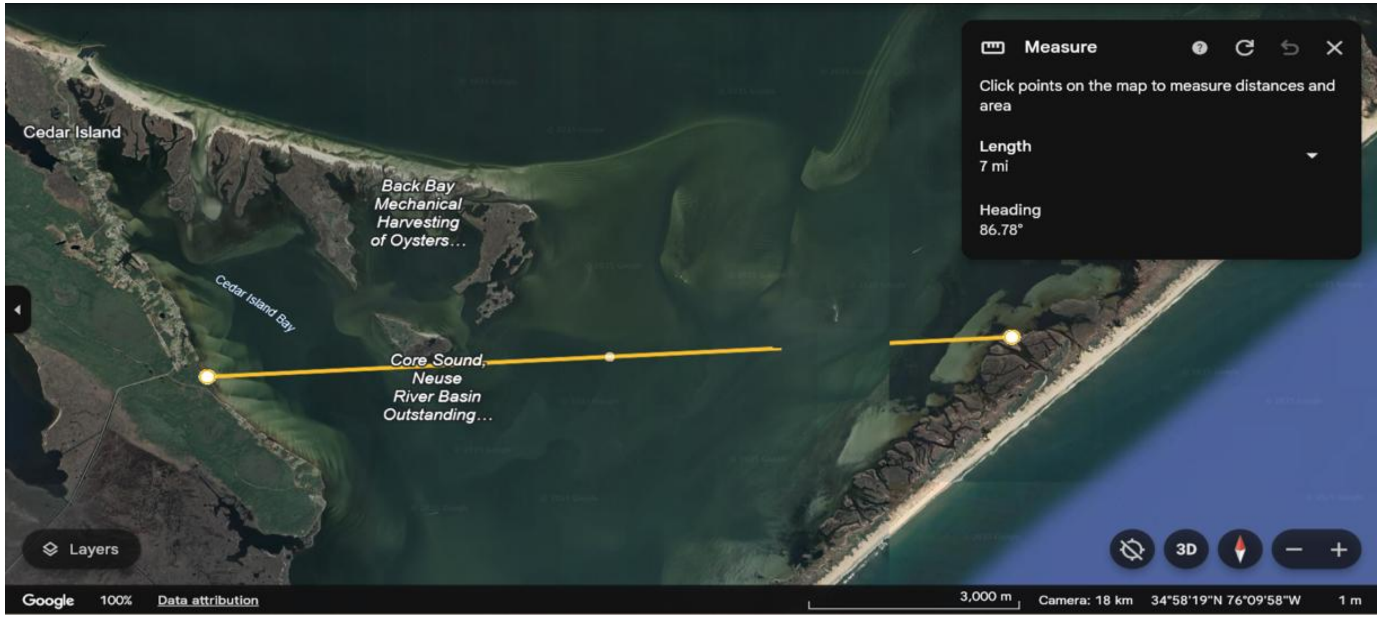
Taken from NOAA



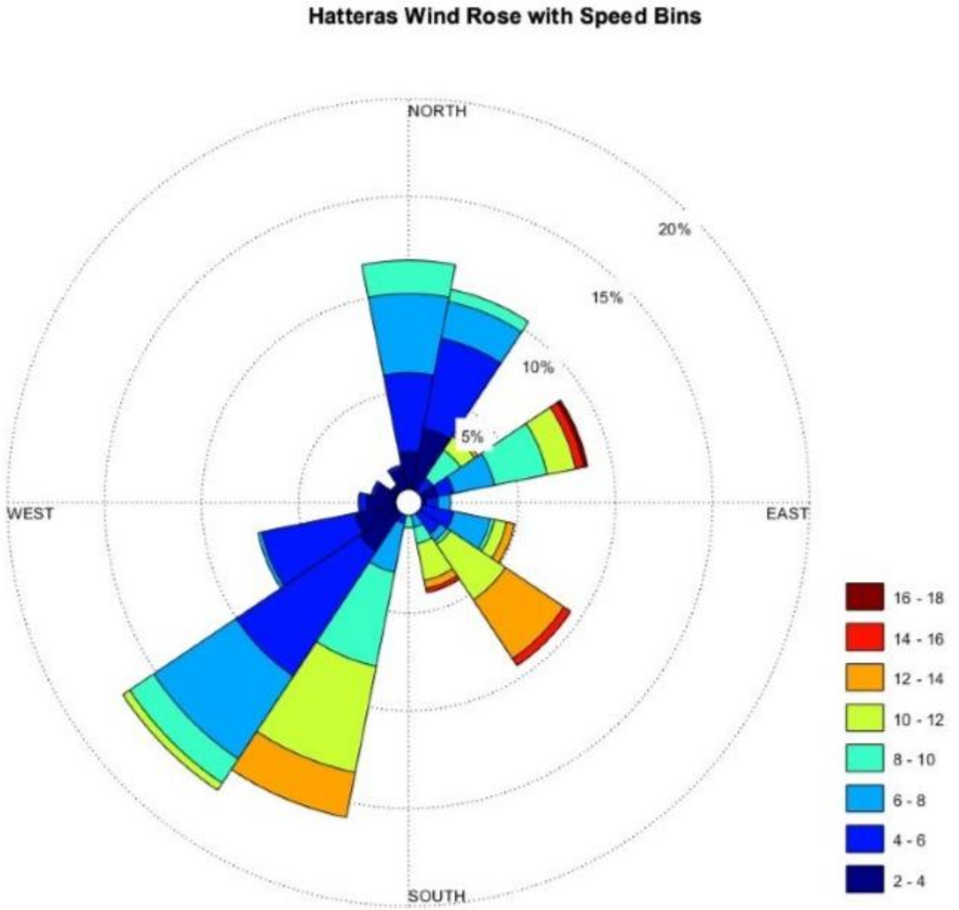
Background

Tidal Range & Winds

- Mean Tidal Range
  - Cedar Island 0.28-0.34 ft (NOAA, 8655151)
  - Hatteras 0.47-0.65ft (NOAA, 8654467)



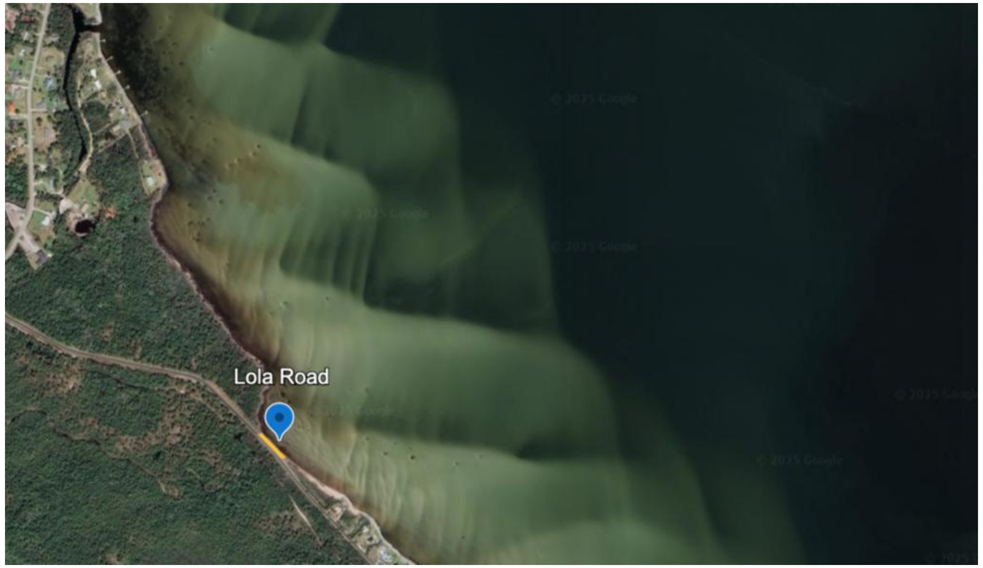
Google Earth



Background

Coastal Processes

- Flooding of lowlands
- Northwest to Southeast littoral drift
- Scarping

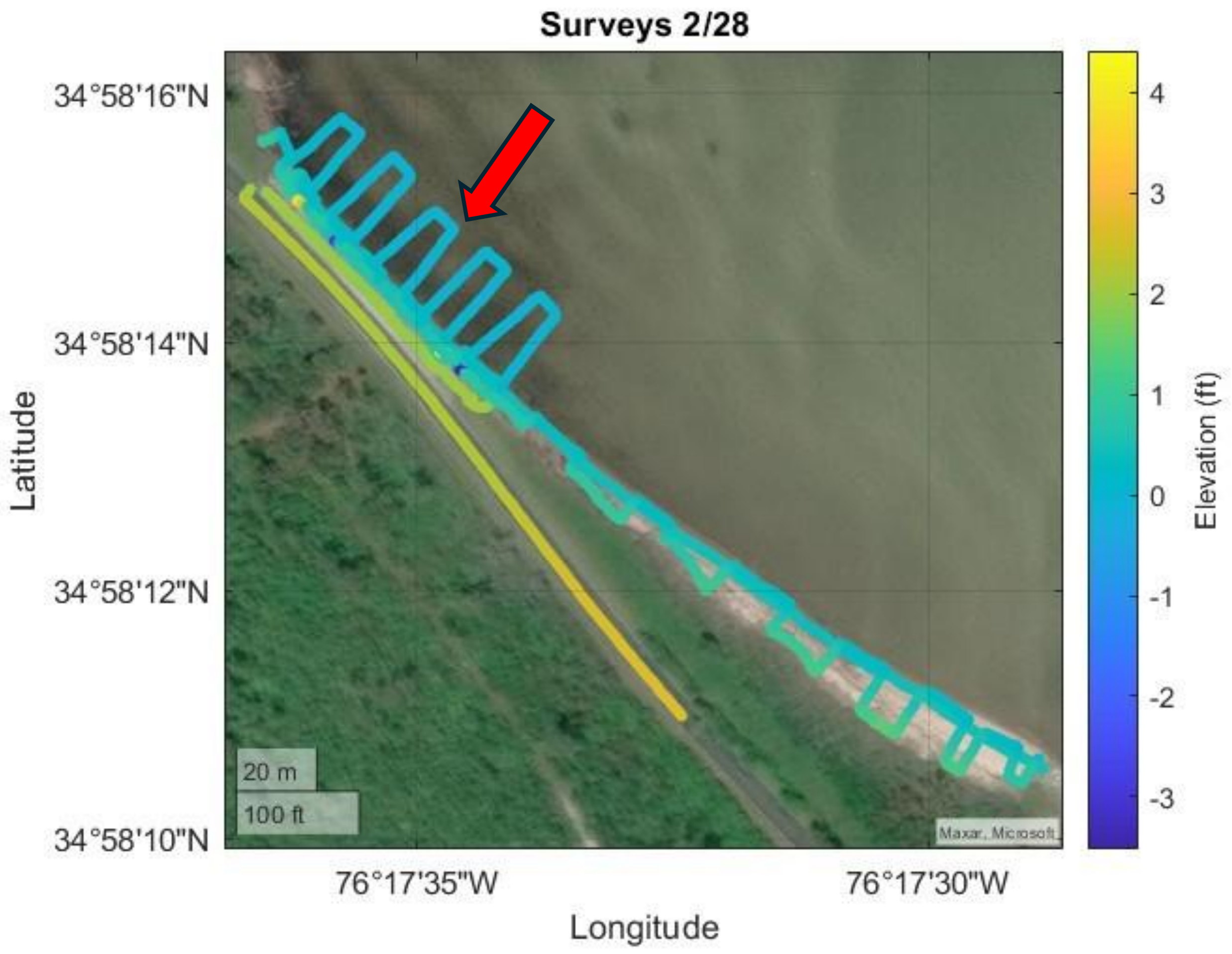


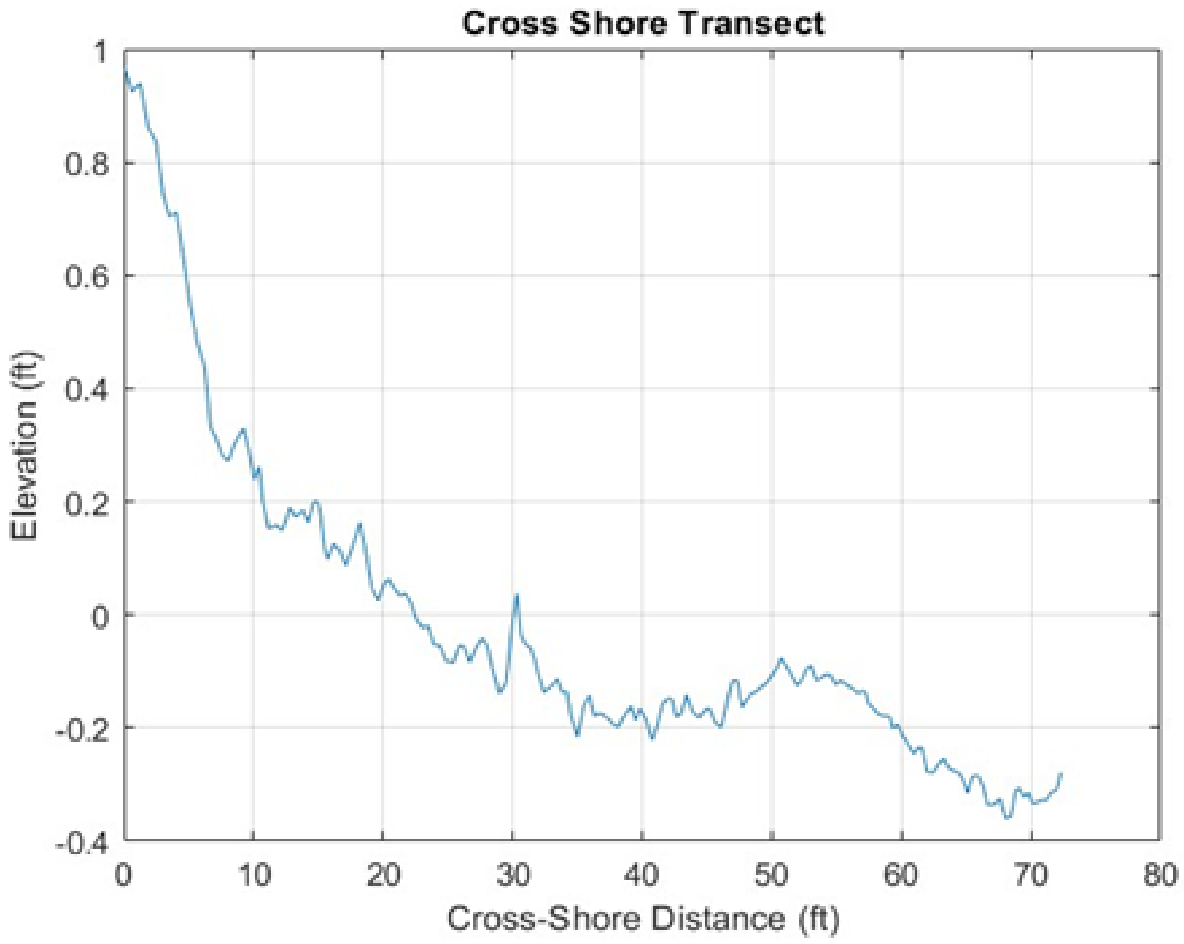
Google Earth

Christine Voss (UNC Institute of Marine Sciences)

Field Data Collection

Walking Surveys

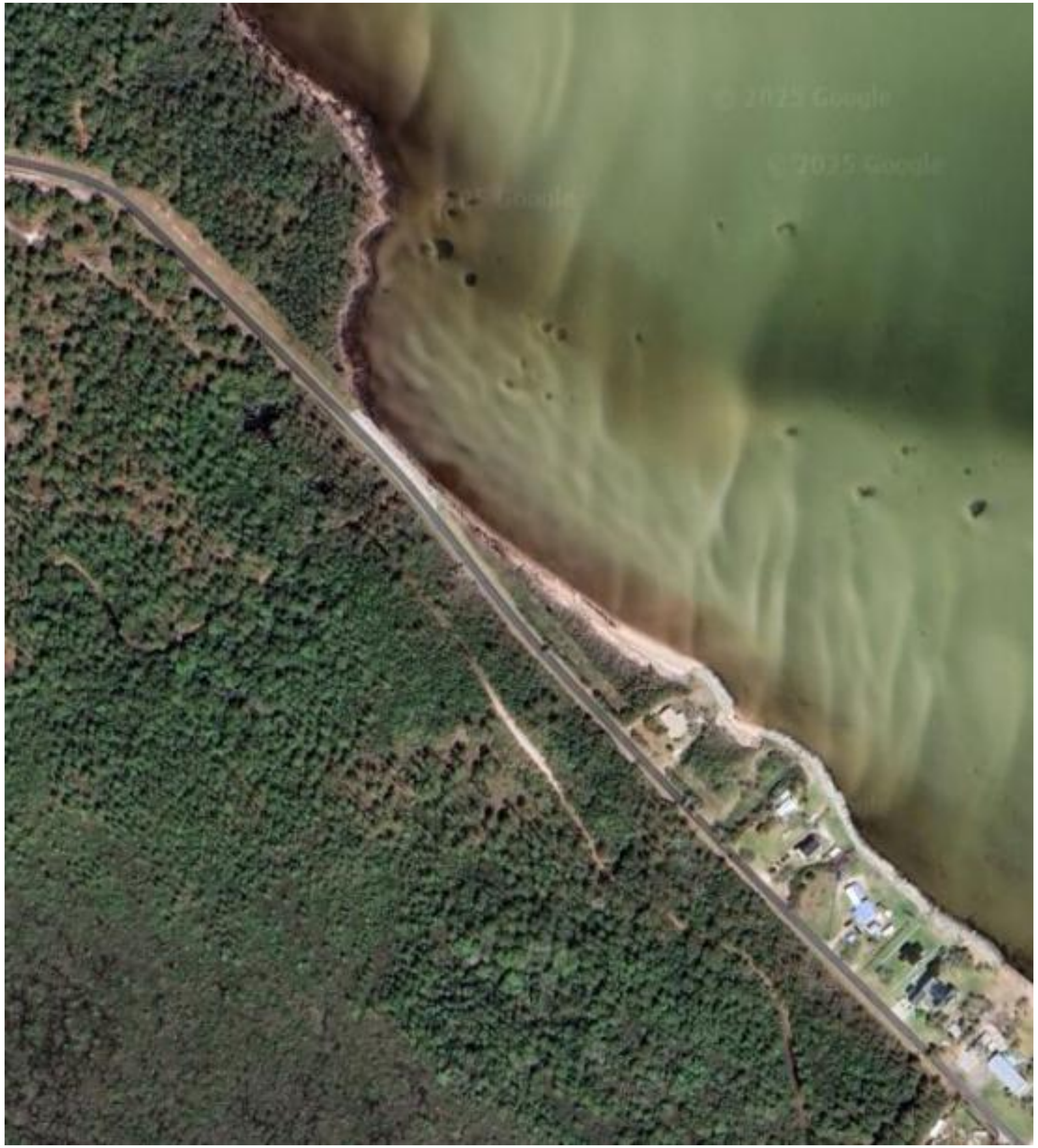




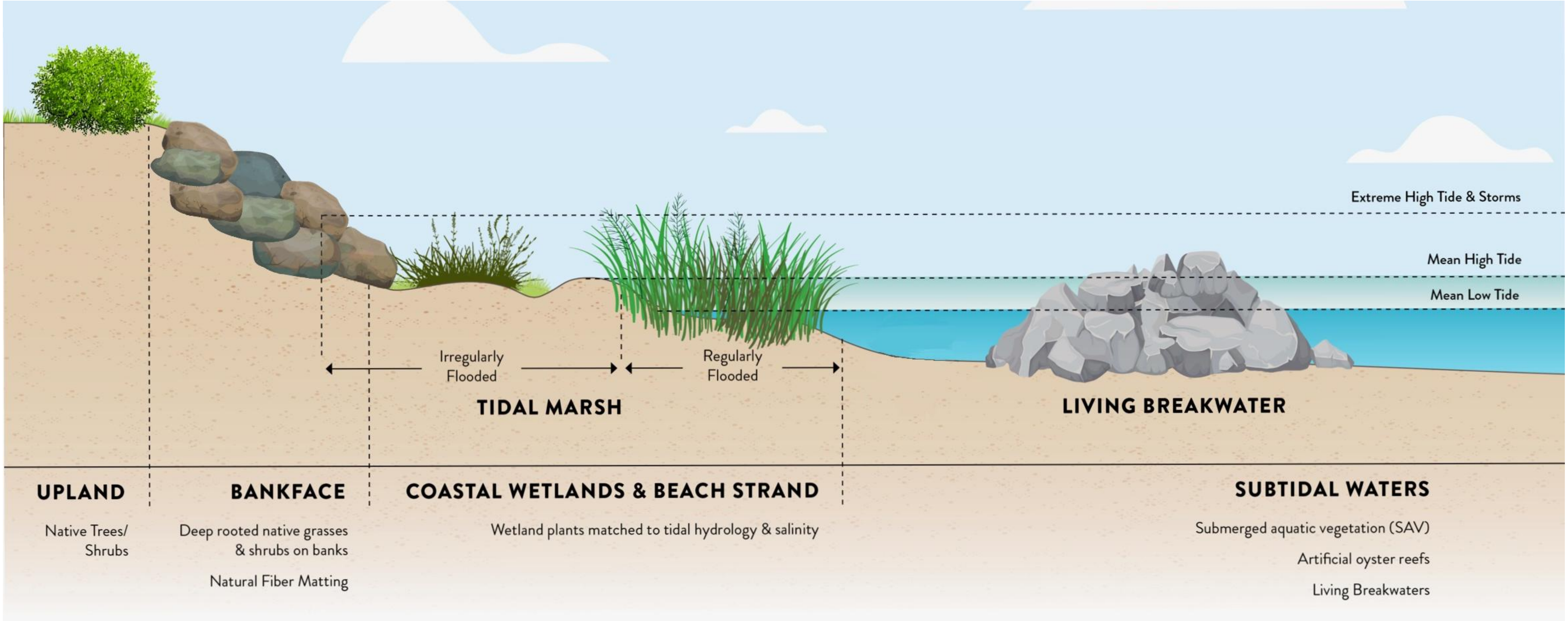
NAVD88

Design Objectives

- Road stabilization
- Dissipate wave energy
- Partner interests



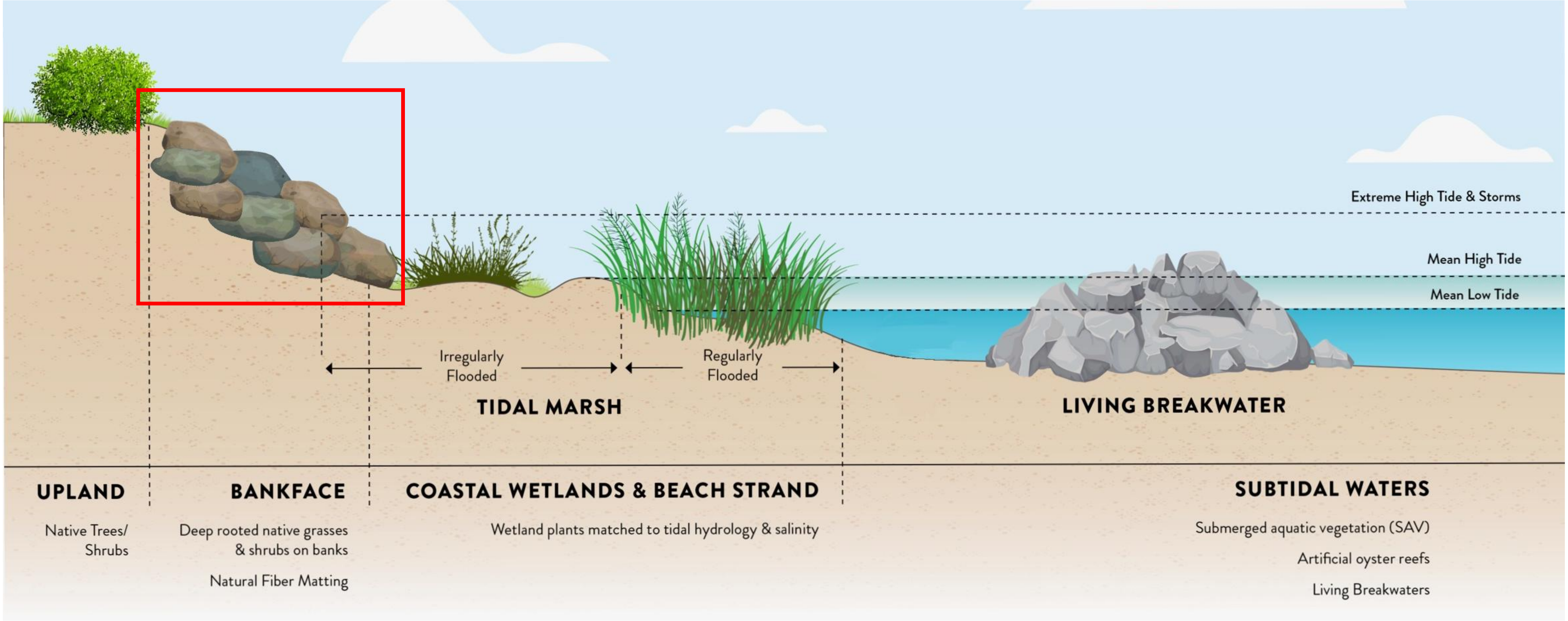

HOW GREEN OR GRAY SHOULD YOUR SHORELINE SOLUTION BE?
GREEN - SOFTER TECHNIQUES
GRAY - HARDER TECHNIQUES
Living Shorelines
Coastal Structures
VEGETATION ONLY - Provides a buffer to upland areas and breaks small waves. Suitable for low wave energy environments.
EDGING - Added structure holds the toe of existing or vegetated slope in place. Suitable for most areas except high wave energy environments.
SILLS - Parallel to vegetated shoreline, reduces wave energy, and prevents erosion. Suitable for most areas except high wave energy environments.
BREAKWATER - (vegetation optional) - Offshore structures intended to break waves, reducing the force of wave action, and encourage sediment accretion. Suitable for most areas.
REVETMENT - Lays over the slope of the shoreline and protects it from erosion and waves. Suitable for sites with existing hardened shoreline structures.
BULKHEAD - Vertical wall parallel to the shoreline intended to hold soil in place. Suitable for high energy settings and sites with existing hard shoreline structures.



Texas General Land Office


LEGEND
Oyster Castle Breakwater
Spartina Alterniflora
Spartina Patens
Existing Revetment
Yaupon Holly
Lola Road
Reference Shoreline
(0 ft NAVD88)
N
0
100
200
Feet
250
37
40
35
38
100
11
10
9

Revetment



Texas General Land Office

Revetment Repairs

- Advantages
- Design Considerations
- Modifications

Revetment Design Calculations

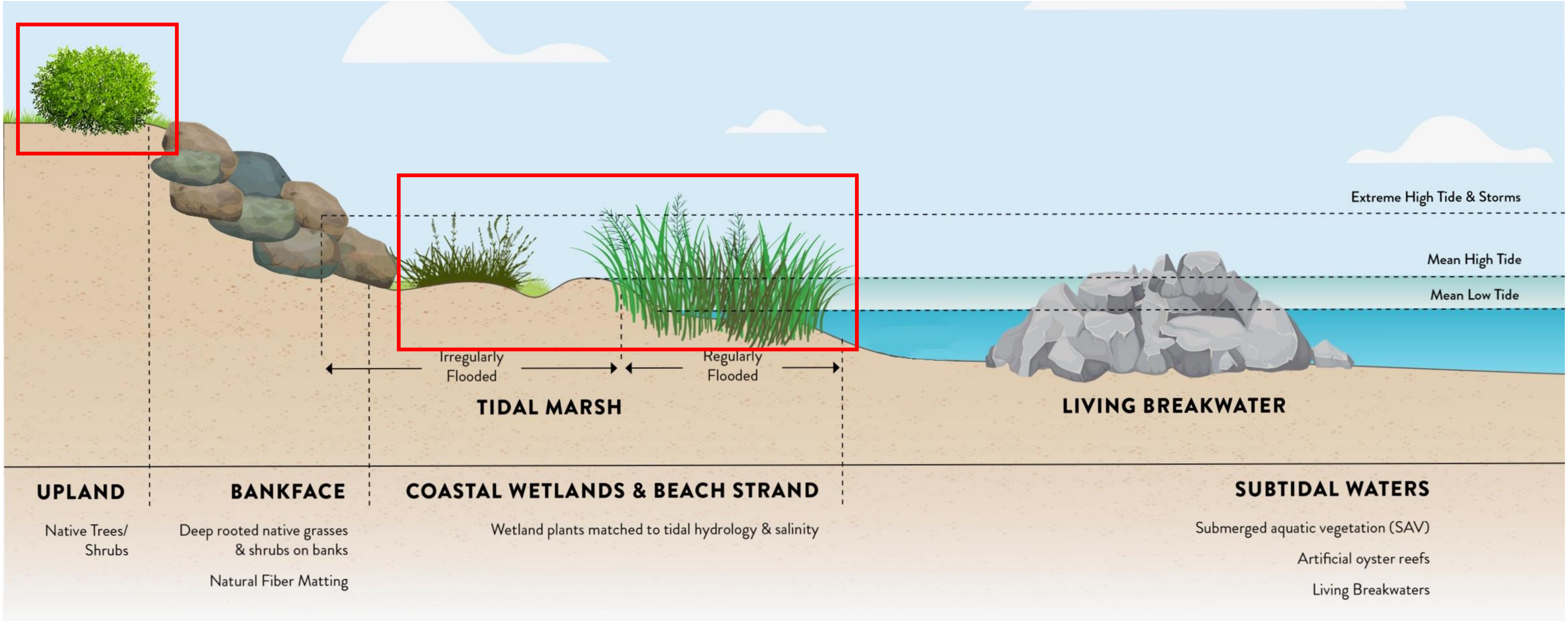
- Slope: 1V:1.15H
- Wave Height: 5.24 ft
- Median Stone Size: 1.28 ft

Revetment Modification

TABLE 1042-1 ACCEPTANCE CRITERIA FOR RIP RAP AND STONE FOR EROSION CONTROL			
Class	Required Stone Sizes, inches		
	Minimum	Midrange	Maximum
A	2	4	6
B	5	8	12
1	5	10	17
2	9	14	23

- Our minimum D_{n50} of 1.28 ft (15 inches), allows us to fill holes with minimum class 2 of normal quarry stone

Vegetation



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Plant Compatibility

- pH range of 3.7 - 7.9
- Flooding tolerance
- USDA Hardiness Zone of 6-9
- Fine to coarse-grain size
- Salinity range of 0 – 35 ppt
    - Cedar Island typical range is 15-20 ppt (USGS Water Data for the Nation)

CWEM Site	pH	OM%	PBS	Clay%	Silt%	Sand%
ACE Basin NWR - Grove Marsh/Edisto River	4.8	18	44	17	30	53
Alligator River NWR - Koehring Road Pocosin	3.6	70	21	3	21	77
Alligator River NWR - Long Shoal River	6.8	12	92	3	24	73
Blackbeard Island NWR - Blackbeard Creek	6.0	11	81	12	17	72
Cape Romain NWR - Horsehead Creek	3.2	11	17	22	28	50
Cape Romain NWR - Raccoon Key	3.4	11	18	14	38	48
Cedar Island NWR - Wet Marsh	5.8	65	75	4	17	79
Currituck NWR - Swan Island	5.5	21	65	3	5	93
Harris Neck NWR - Harris Neck Creek	5.7	39	72	14	18	68
Lower Suwannee NWR - Shired Creek	5.8	6	75	2	5	93

Site Averages from USFWS "Vegetation of Coastal Wetland Elevation Monitoring Sites on National Wildlife Refuges in the South Atlantic Geography"

Vegetation Types

Spartina Alterniflora:

- Smooth cordgrass
- Thrives in regularly flooded area

Spartina Patens:

- Salt meadow cordgrass
- Thrives in irregularly flooded areas

Yaupon:

- Tolerant species
- Dense root system

Marsh Species

Texas A&M-Master Gardener Program

Planting Approach

Spartina Alterniflora:
- Space about 1-2 inches apart
- Use staggered or triangular spacing
- Plant between April 1 and September 30
- Plant by hand using common garden tools

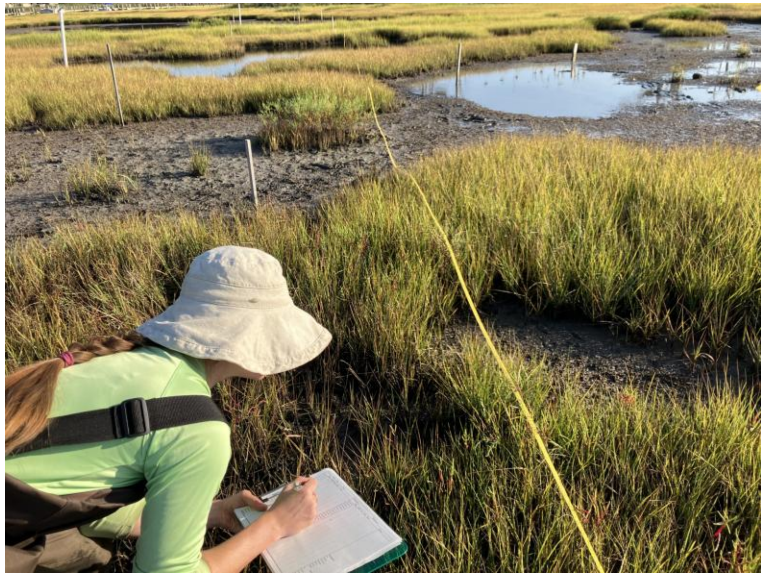
Spartina Patens:
- Space units 1-2 inches apart
- Use common garden hand tools
- Plant in late winter to early spring

Yaupon:
- Offset on 10-inch spacing
- Transplant in late winter or early spring

Maintenance

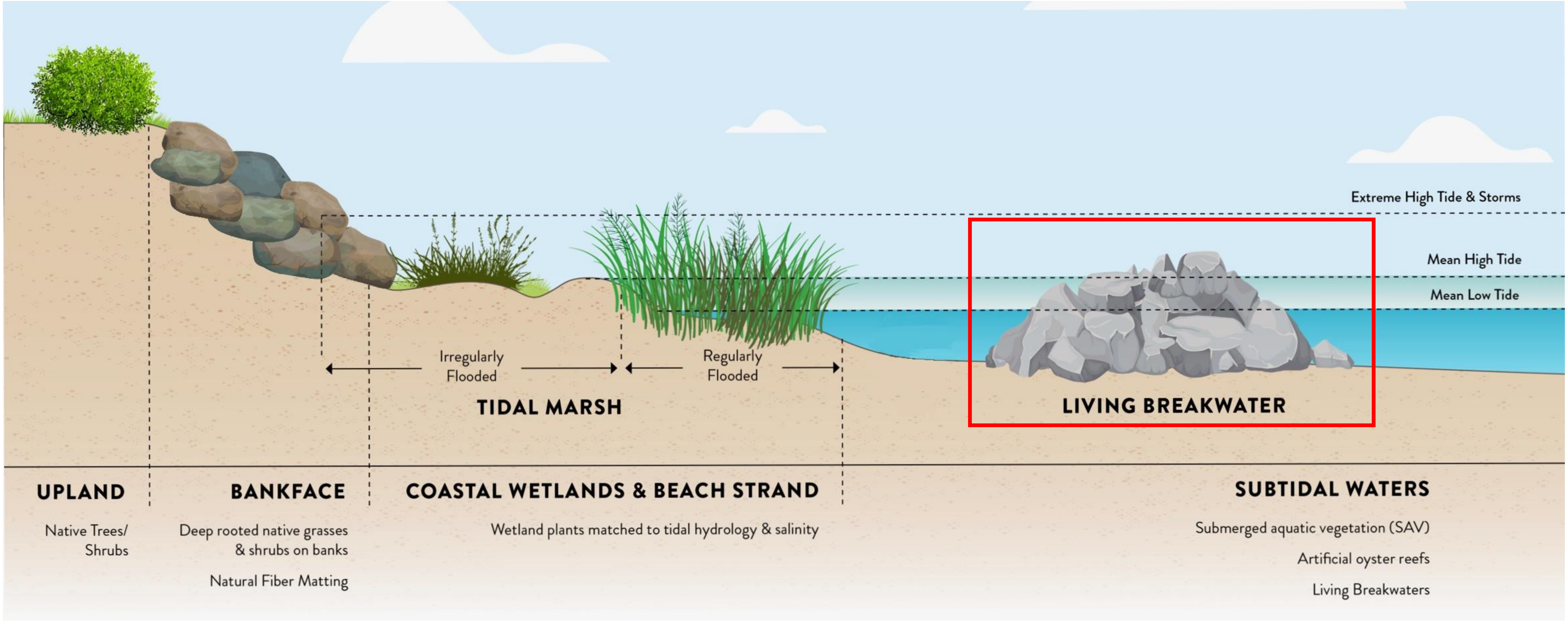
- Revisit the site after 90 days and then 180 days
- Look for dead patches, 25%-30% of plant failure
- Watch for weather
- 2 growing seasons = stability

Coastal Transplants



USFWS

Oyster Castle Breakwaters



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Oyster Castle Breakwaters

- Dissipate wave energy
- Eco-friendly and sustainable
- Cost-effective
- Adaptable and flexible

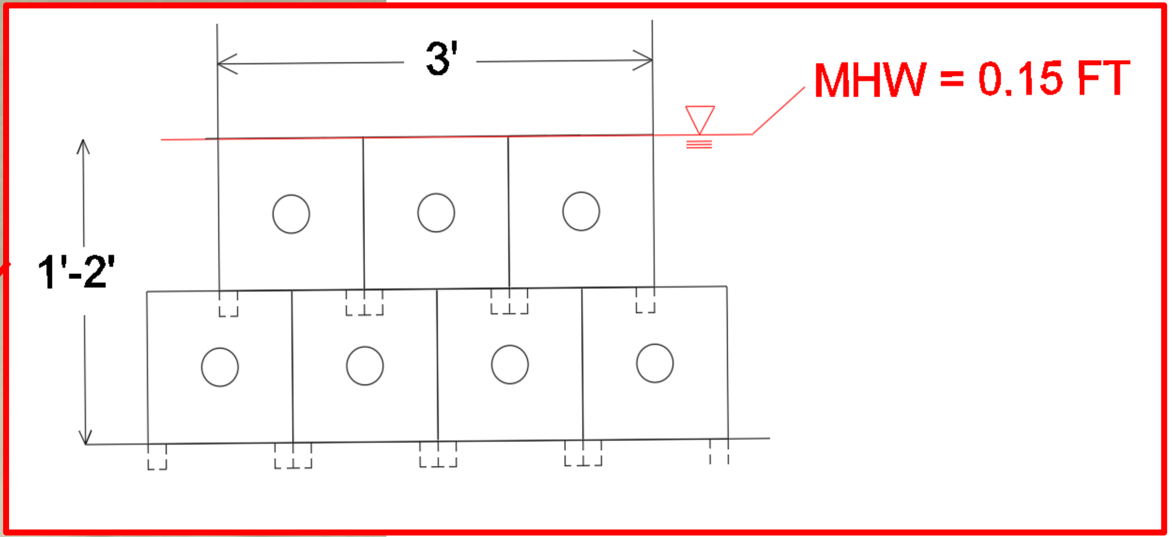
Rutgers: Marine and Coastal Sciences

Oyster Castle Breakwater: Design Considerations

- Bathymetry
- Stability of offshore sediment
- Wave environment
- Oyster growth

Chesapeake Bay Journal

Oyster Castle Breakwater Design



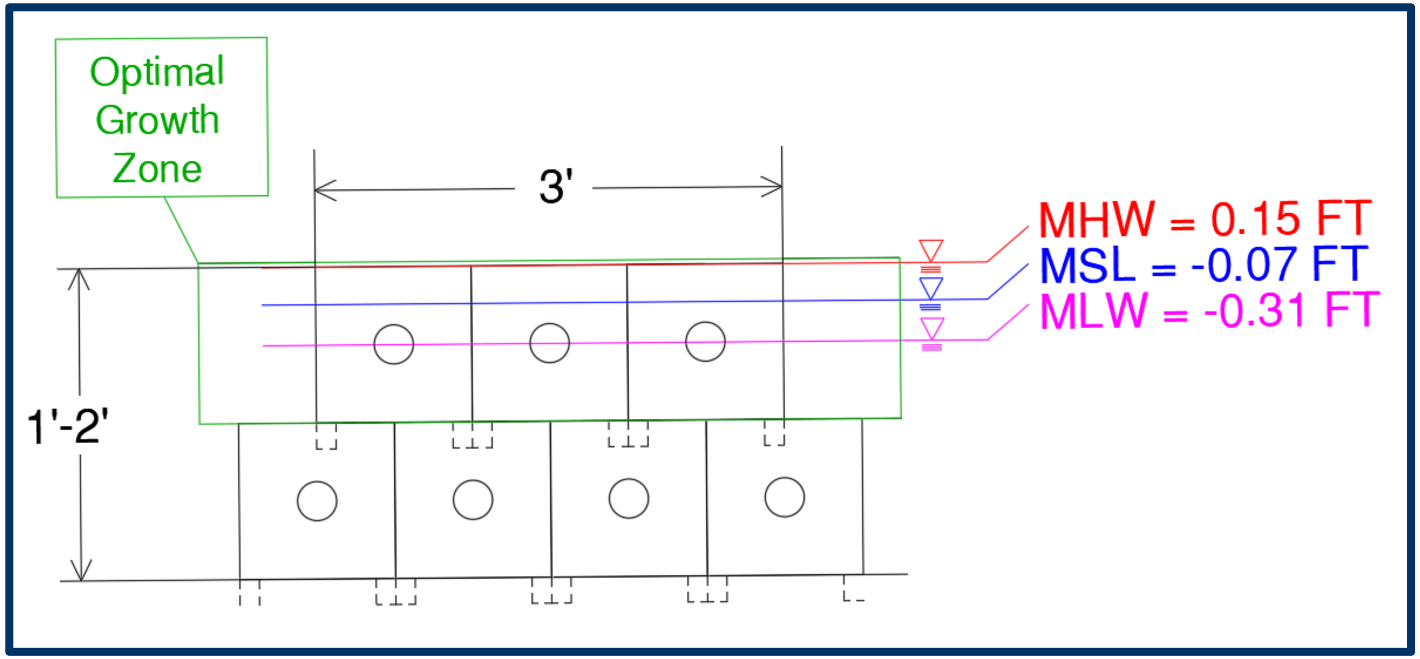
- Segment and gap lengths
- Alignment offshore
- Crest height and width
- Base width
- Geotextile fabric

Oyster Castle Breakwater Effectiveness

- Wave transmission coefficient

Wave Condition	50-year Storm	25-year Storm	Conditions Derived from RBR Data
% Energy Dissipated	52%	49%	17%-48%

Oyster Growth Zone



CROSS SECTION VIEW (NAVD88)

- Short-term protection
- Long-term protection

Lafyette Wetlands Partnership

Construction/ Maintenance

Key Takeaways:
1. Low cost
2. Lightweight
3. Enhanced Biodiversity

Fabricate Concrete Blocks

Place Oyster Breakwater

Lafyette Wetlands Partnership

Seed Oyster Breakwater

SANDBAR
OYSTER COMPANY

Phases of Construction

Phase 1	• Construction of oyster castle breakwaters • Seed castles with oyster spat
Phase 2	• Shoreline clean up • Revetment repair
Phase 3	• Planting of intertidal vegetation • Planting of upland vegetation
Phase 4	• Routine monitoring • Maintenance

Cost Estimates

Vegetation		
Plants	Yaupon	$4,800
	Spartina Alterniflora	$12,500
	Spartina Patens	$6,250
		$23,550
Maintenance	Site vists ($885 per visit)	$1,700
	Watering ($1,000 per visit)	$2,000
	Weed Control ($500 per visit)	$1,000
	Fencing/protection	$750
		$5,450
Potential Replant and Damages	Replanting yaupon	$1,500
	Replanting S.A.	$3,800
	Replanting S.P.	$1,900
		$7,200
	Total	**$36,200**

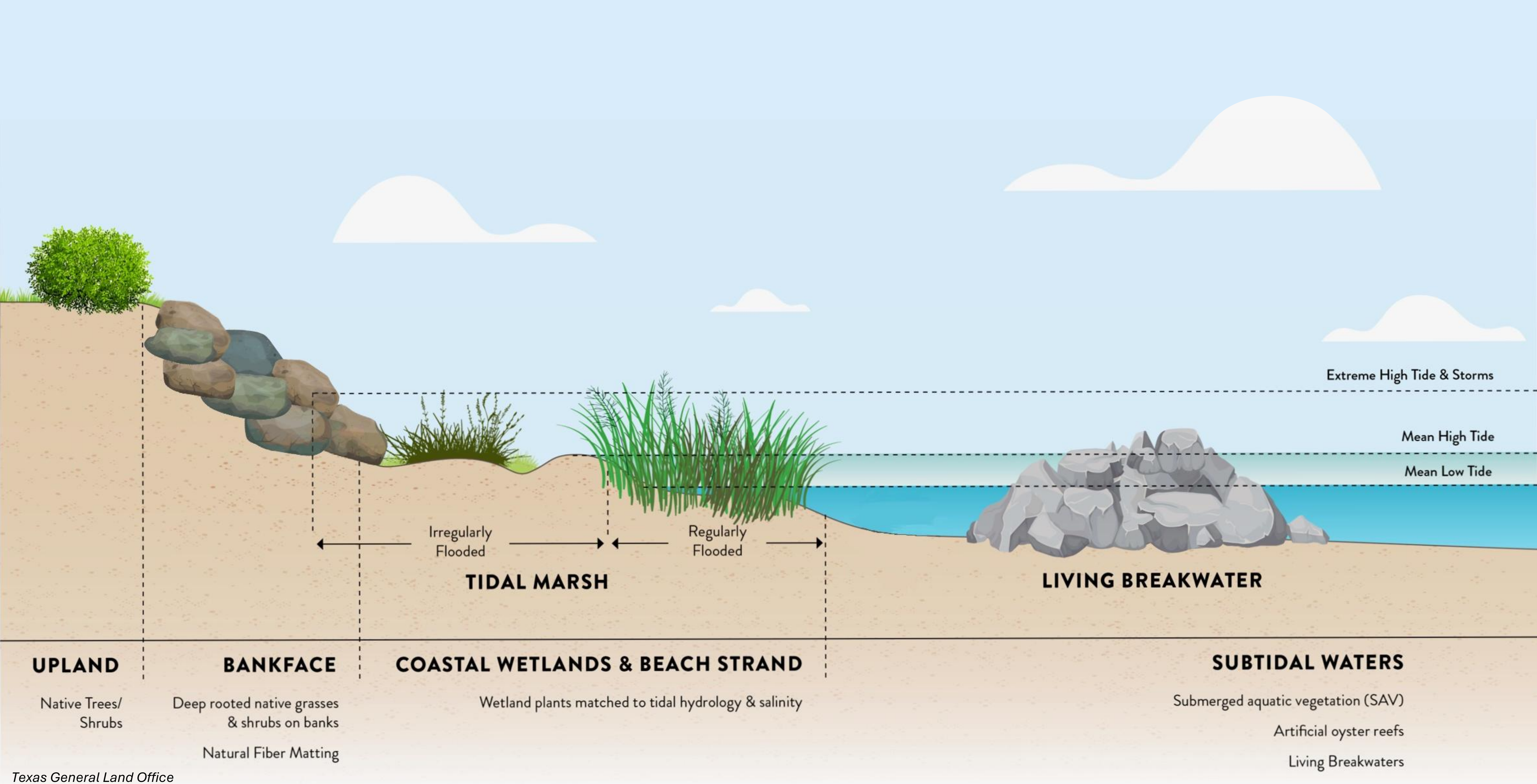
Revetment	
Size 2 Rip Rap	$25,000
Equipment	$6,000
Mobilization	$5,000
Labor	$24,000
Total	**$60,000**

Oyster Breakwaters		
Materials	Cement Block Fabrication (1,728 total)	$17,280
	Geotextile Fabric ($0.92 per sqft)	$5,600
	Oyster Bushel (8 needed)	$900
Labor	Oyster Breakwater Construction	$8,700
	Seeding	$500
	Monitoring (first 12 months)	$2,200
	Monitoring (Annual and Post Storm)	$800
	Mobilization	$5,000
	Total	**$41.000**

15% contingency = $42,000

Cost Estimates

Total cost of $180,000



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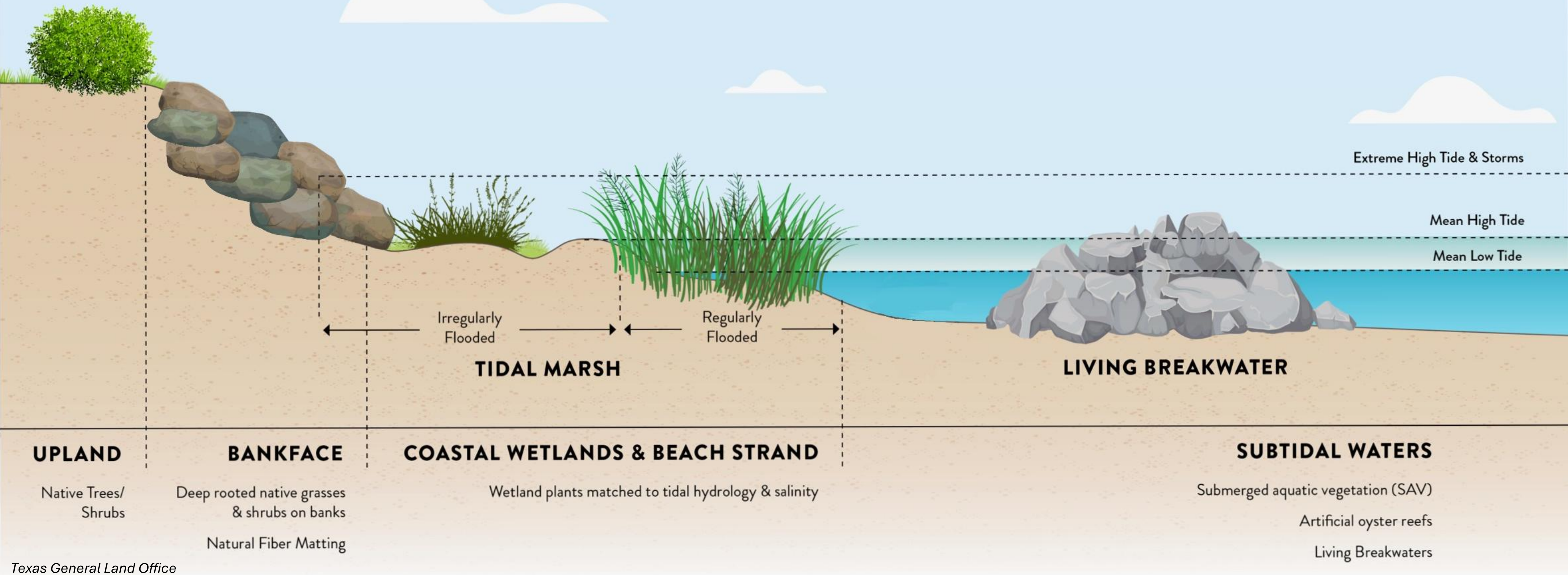
'Legendary Shoreline'



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Acknowledgements

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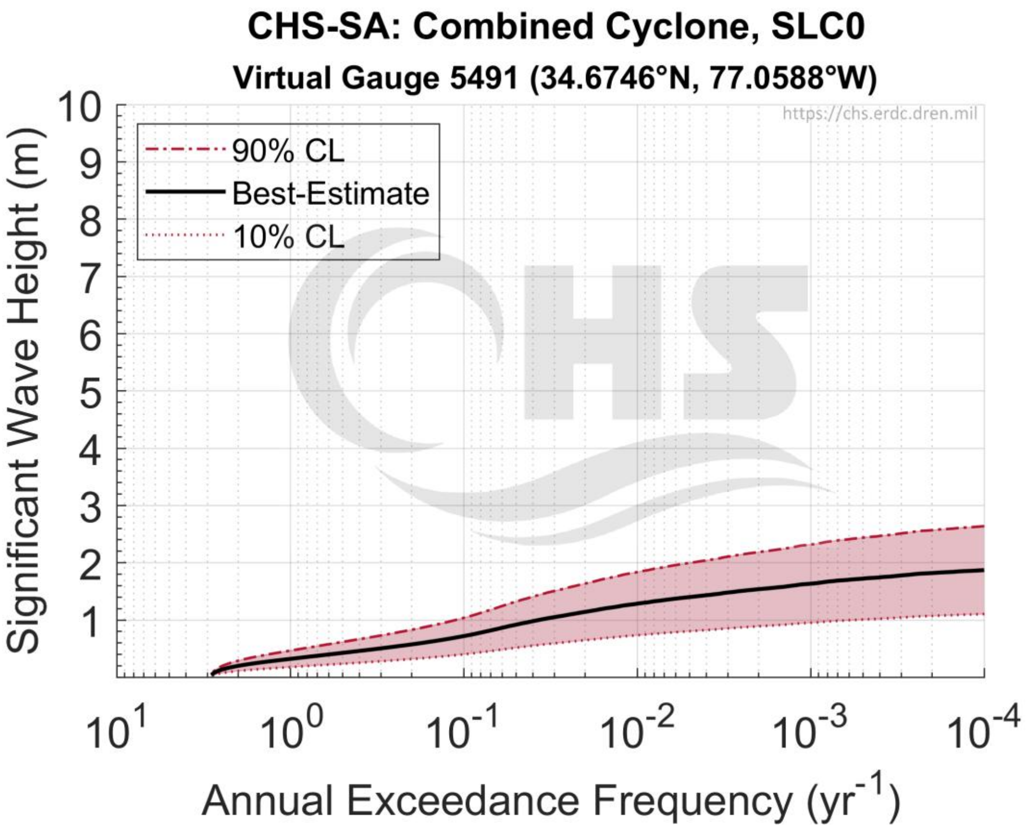
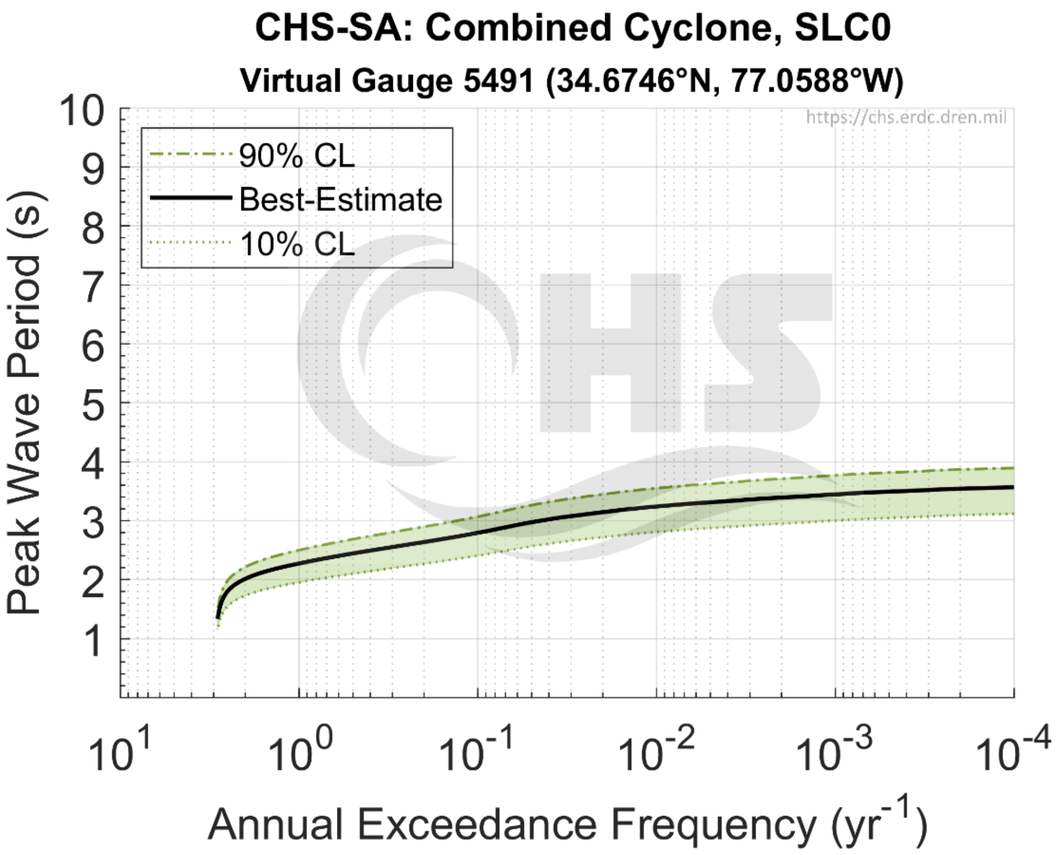
Danielle Szimanski – EA Engineering

Cal Novelli – Ecotone

Questions/Discussion

Coastal Engineering


CHS-SA: Combined Cyclone, SLC0
Virtual Gauge 5491 (34.6746°N, 77.0588°W)
https://chs.erdc.dren.mil
90% CL
Best-Estimate
10% CL
Significant Wave Height (m)
Annual Exceedance Frequency (yr^{-1})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https://chs.erdc.dren.mil
90% CL
Best-Estimate
10% CL
Peak Wave Period (s)
Annual Exceedance Frequency (yr^{-1})

Permitting

Federal Regulation

- Nationwide Permit for Living Shorelines
- Section 404 Permit (Clean Water Act)

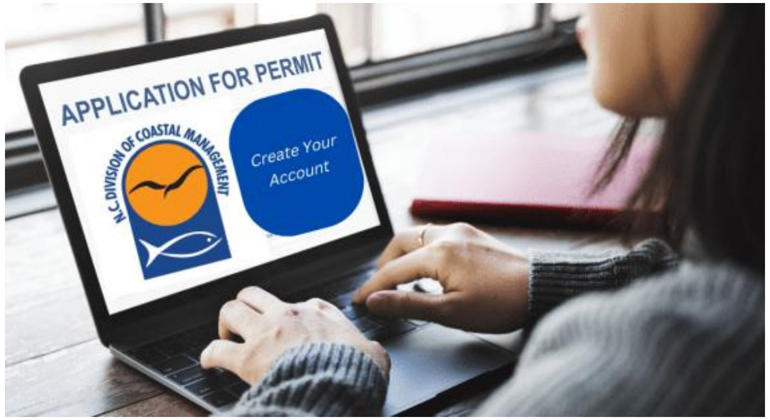
State Regulation

- CAMA Major Permit through NCDEQ

Local Regulation

- Carteret County Building Permit

Oyster/ Plant Growth Permits



Mobilization Site

Oyster Castle Breakwater Equations

Wave Transmission Formula by van der Meer and d'Angremond (1991) for Rock Armored Low-Crested, Submerged, and Reef Breakwaters

$$C_t = \left(0.031 \frac{H_s}{D_{n50}} - 0.24\right) \frac{R_c}{D_{n50}} + b$$

maximum $C_t = 0.75$, minimum $C_t = 0.075$ conventional structure

maximum $C_t = 0.60$, minimum $C_t = 0.15$ reef type structure

where

$$b = \begin{cases} -5.42\, s_{op} + 0.0323 \frac{H_s}{D_{n50}} - 0.0017 \left(\frac{B}{D_{n50}}\right)^{1.84} + 0.51 & \text{conventional structure} \\ -2.6\, s_{op} - 0.05 \frac{H_s}{D_{n50}} + 0.85 & \text{reef type structure} \end{cases}$$

H_s – significant wave height of incident waves

D_{n50} – median of nominal diameter of rocks for design conditions

R_c – freeboard, negative for submerged breakwater

B – width of the crest

s_{op} – deepwater wave steepness corresponding to peak period.

$$E_{dissipated} = E_{incident} - E_{transmitted}$$

where

$$E_{incident} = \frac{1}{8}\rho g {H_s}^2$$

$$E_{transmitted} = K_t(E_{incident})$$

Oyster Castle Breakwater Equations

50-year Storm Wave Conditions

- $H_s = 5.28\ ft, T_p = 5.1\ s$
- $K_t = 0.476$
- $E_{dissipated} = 3669\ ft - lbf/ft^2$

Maximum Recorded Wave Conditions

- $H_s = 0.3\ ft, T_p = 2.29\ s$
- $K_t = 0.523$
- $E_{dissipated} = 11\ ft - lbf/ft^2$

25-year Storm Wave Conditions

- $H_s = 4.54\ ft, T_p = 4.8\ s$
- $K_t = 0.514$
- $E_{dissipated} = 2516\ ft - lbf/ft^2$

Minimum Recorded Wave Conditions

- $H_s = 0.011\ ft, T_p = 1.81\ s$
- $K_t = 0.826$
- $E_{dissipated} = 0.005\ ft - lbf/ft^2$

Calculations

Median Stone Size Formula

Van der Meer (1988)

Calculating Surf Stability Parameter ξ_m			**wave steepness**		**Δ**	
wave stepness (no dimensions) s_{om}	0.401732179		wave height (ft)	6.03	mass density of rocks (lb/ft^3)	165
slope angle (radians) α	0.5805		wave length (ft)	15.01	mass density of water (lb/ft^3)	64.36
surf stability parameter (no dimensions) ξ_m	1.034804401					
Calculating Surf Stability Parameter ξ_{mc}						
notional permability (no dimensions) P	0.6					
surf stability parameter (no dimensions) ξ_{mc}	2.48324698	Since ξm is less than ξmc we will use equation 1				
Calculating Median Stone Size (m^3) D_{n50}						
relative eroded area (no dimensions) S	4					
number of waves (no dimensions) N_z	7500					
(no dimensions) Δ	1.563704164					
significant wave height (ft) H_s	6.035					
D_{n50} (1)	3.005630942					
median stone size (ft) D_{n50}	1.28406506					