Living Shorelines in Coastal New Hampshire

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University of New Hampshire
COASTAL HABITAT
CHART

University of New Hampshire

Risks at the Coast

- Sea Level
- Surge
- Waves

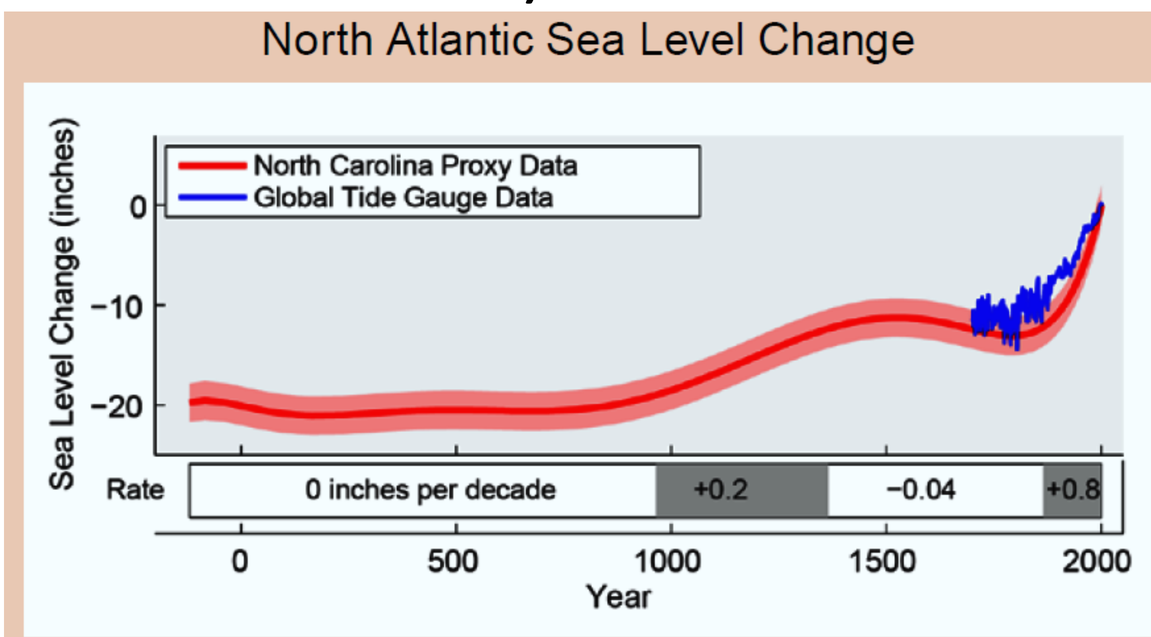
Will Brown, 2017

Sea Level

- Humans evolved societies and infrastructure in locations that by trial and error were situated to present acceptable environmental risks (sea level, flooding, landslides, fire, earthquake, etc.). Unfortunately the full variability of environmental processes have not been well understood, even to this day.

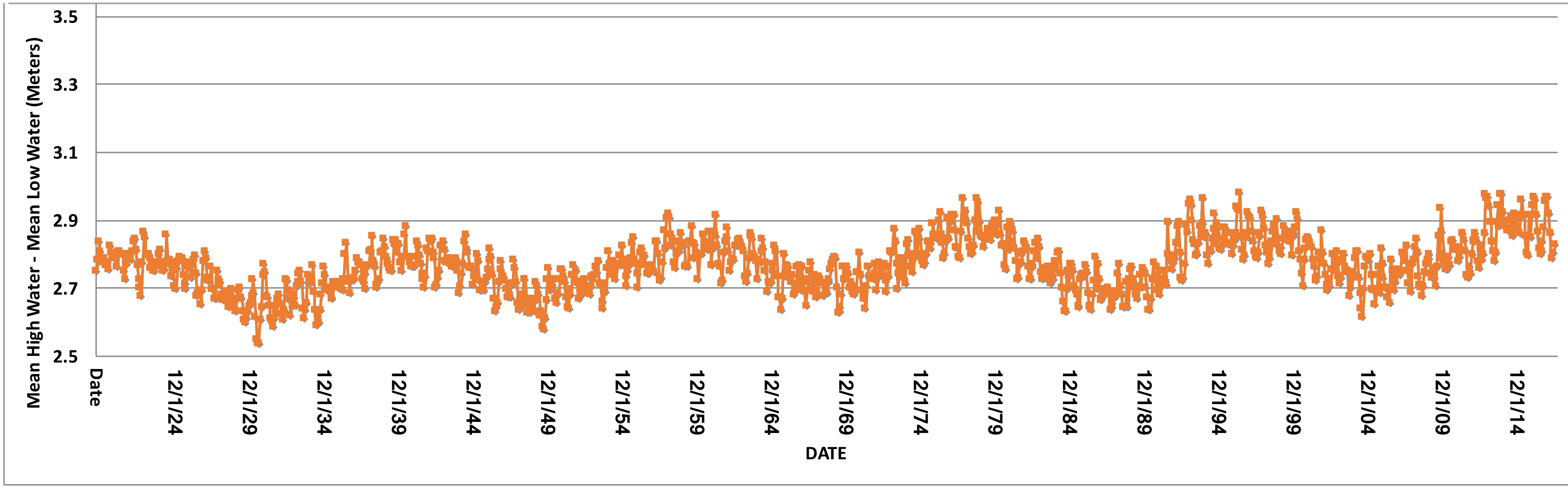
Sea Level Rise

- *Global sea level has risen by about 8 inches since reliable record keeping began in 1880. It is projected to rise another 1 to 4 feet by 2100* (4-15 mm/yr) (National Climate Assessment)
- New England experienced a 5” rise 2009-2010 (Goddard et al. 2015)



Kemp, et al, 2011

Diurnal Tide Range
Metonic 19 year Cycle – Portland ME



Wikipedia

The tide range is substantially greater every 19 years due to a pattern first identified by Menton, active in the 5th century BC., who provided the basis for the Antikythera Mechanism (an astronomical clock) pulled from a shipwreck in 1901.

Change in Greater Diurnal Tide Range - Boston

Tide
Range (m)

1900 1920 1940 1960 1980 2000

Year

On the order of 1 mm/year increase

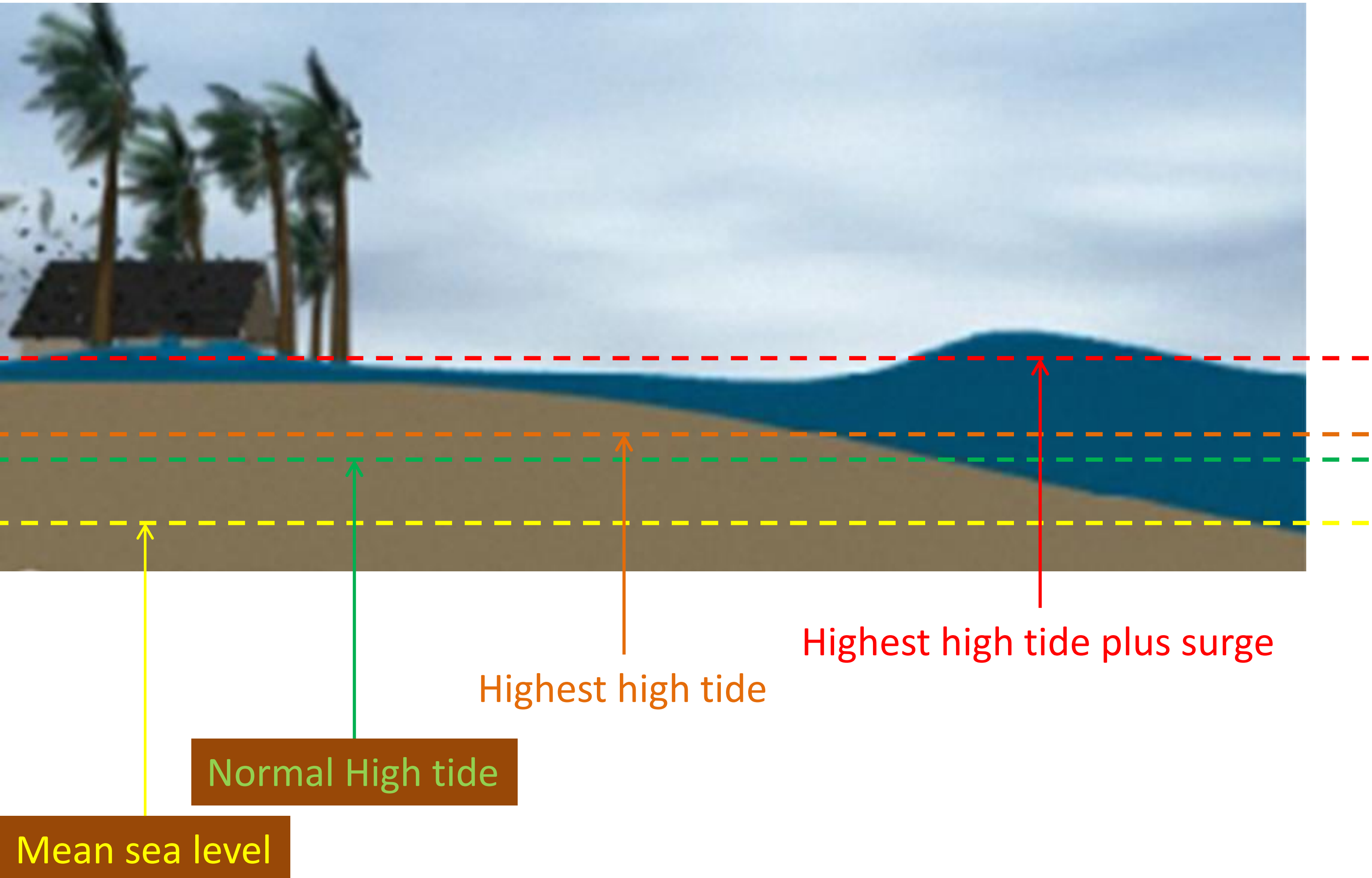
Mawdsley, et al, 2015

What Causes Surge?

- Difference in atmospheric pressure over the ocean
- Wind driving water to the coast


Wind and Pressure Components of Hurricane Storm Surge
Storm motion
Eye
Wind-driven Surge
Pressure-driven Surge (5% of total)
Water on ocean-side
flows away without
raising sea level much
As water approaches land
it "piles up" creating storm surge
©The COMET Program

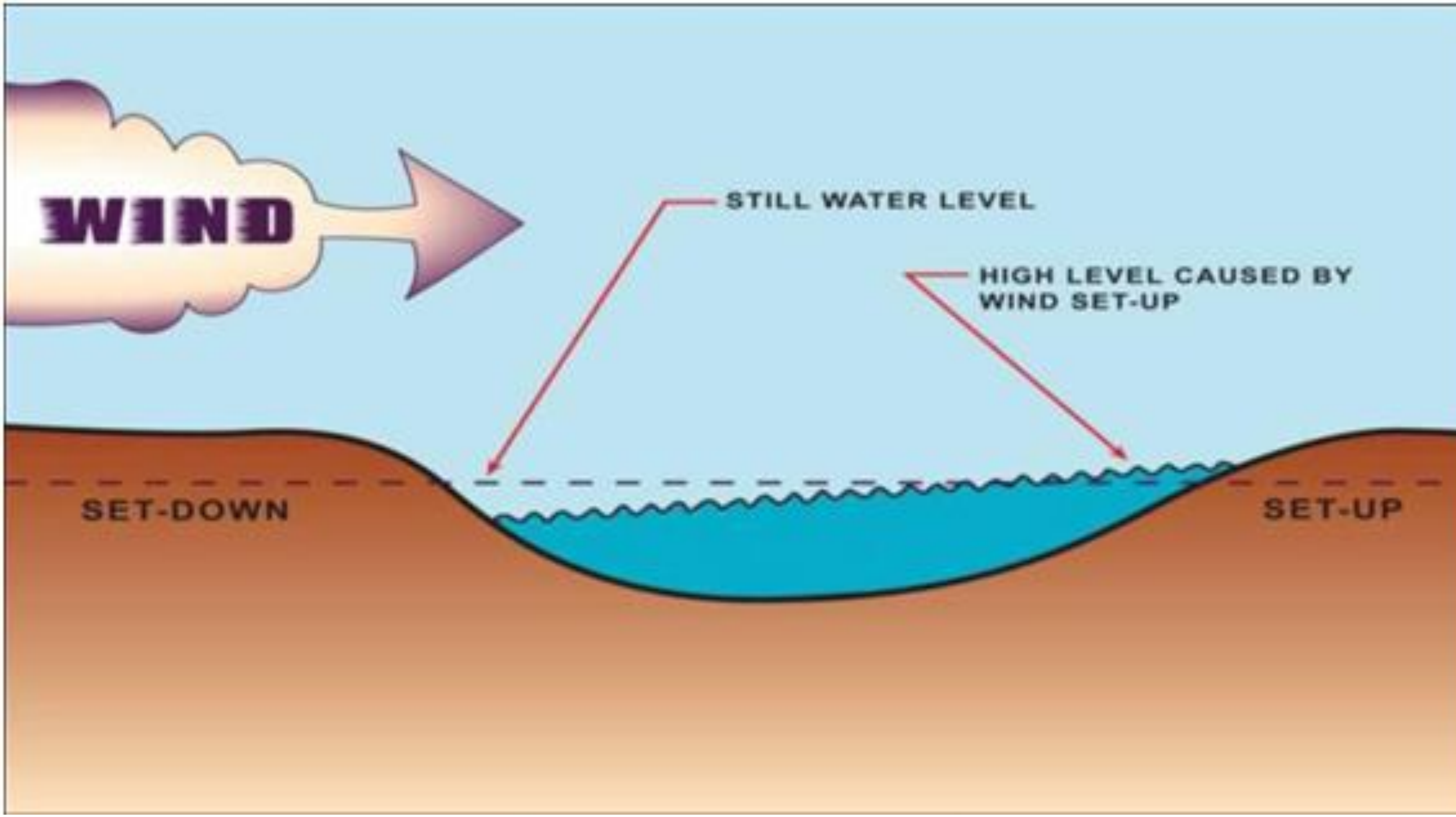
Surge and Tides



Surge Vulnerability Statistics

- From 1990-2008, coastal population density increased by 32% in Gulf coastal counties, 17% in Atlantic coastal counties, and 16% in Hawaii (U.S. Census Bureau 2010)
- Much of the United States' densely populated Atlantic and Gulf Coast coastlines lie less than 10 feet above mean sea level
- Over half of the Nation's economic productivity is located within coastal zones
- 72% of ports, 27% of major roads, and 9% of rail lines within the Gulf Coast region are at or below 4 ft elevation (CCSP, SAP 4-7)
- A storm surge of 23 ft has the ability to inundate 67% of interstates, 57% of arterials, almost half of rail miles, 29 airports, and virtually all ports in the Gulf Coast area (CCSP SAP 4-7)

Smaller Water Bodies - Setup



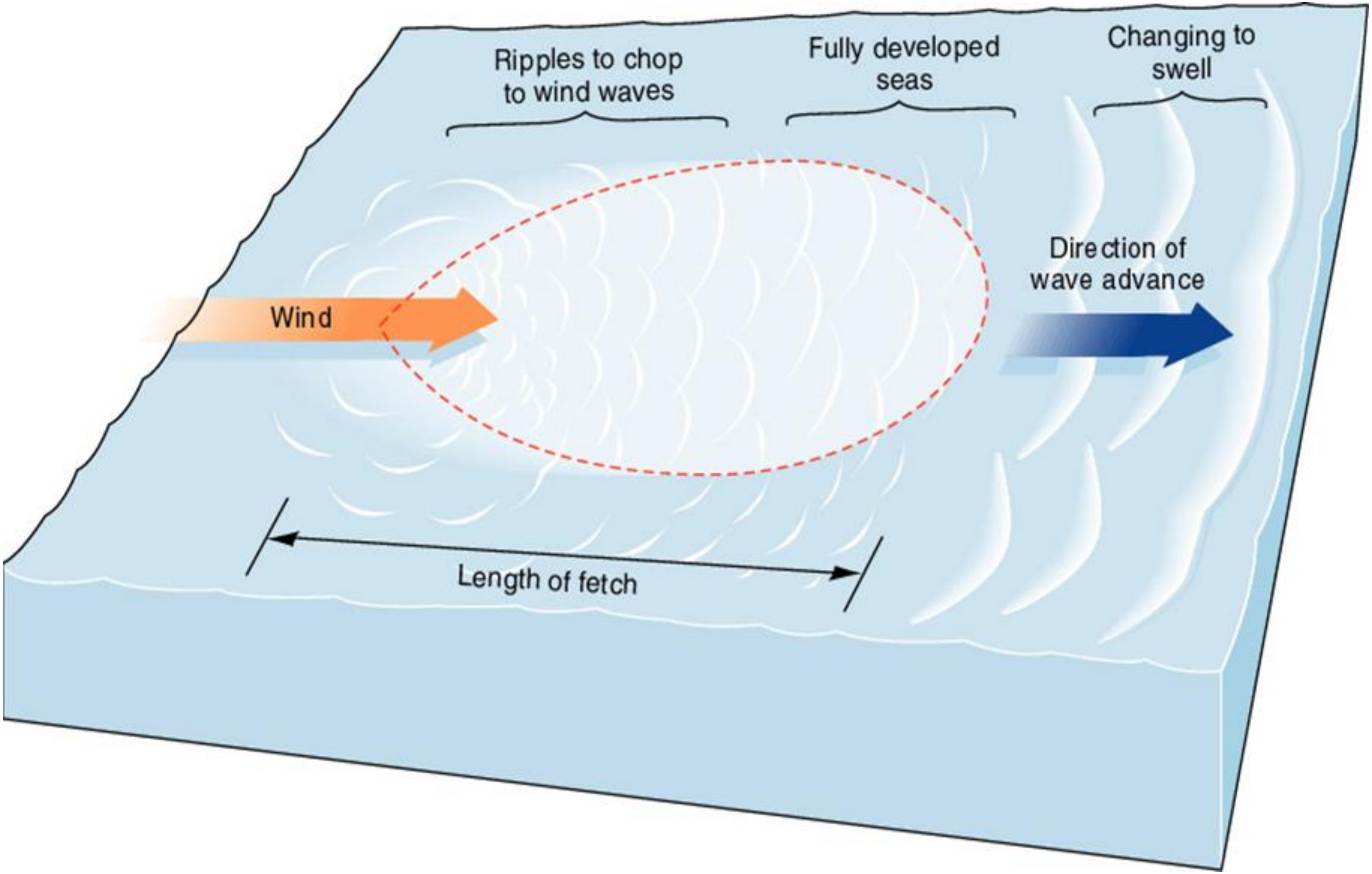
A problem identified in the Hampton - Seabrook Estuary

What Causes Water Waves?

- Wind
- Disturbances
  - Objects
  - Earthquakes
  - Landslides
    - Unsubmerged
    - Submerged

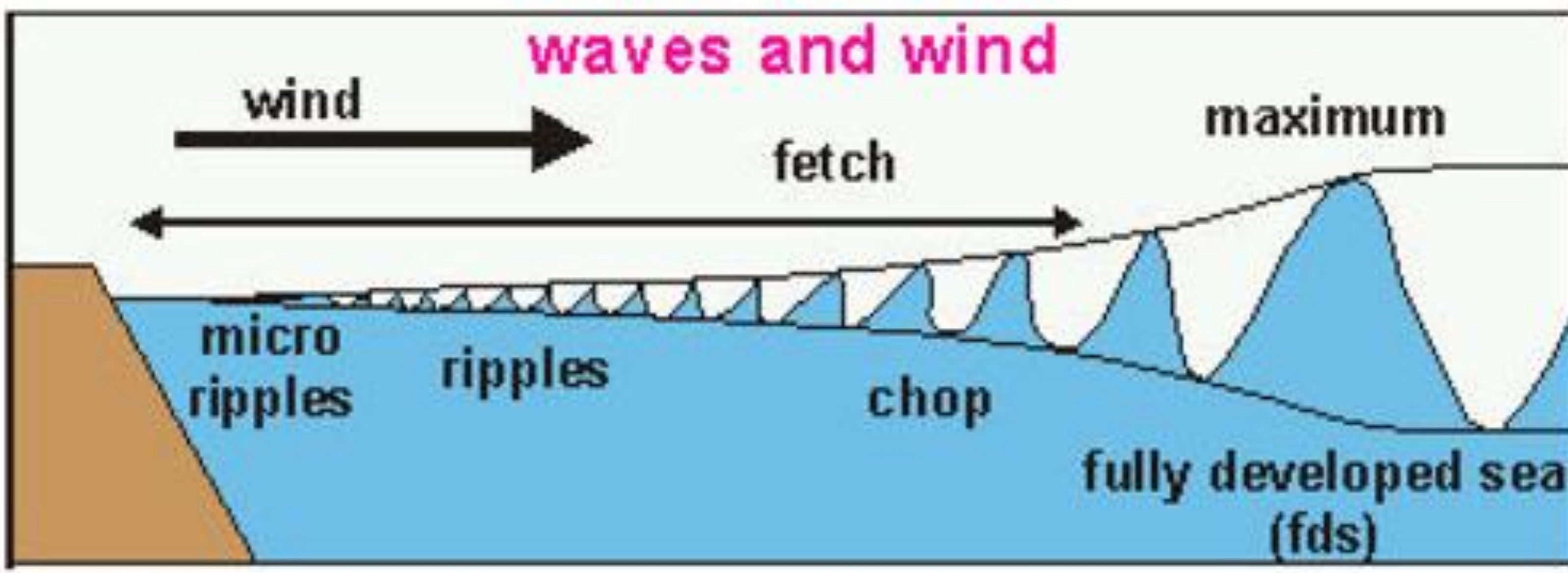
Wind-Generated Waves

- Wind strength (velocity, shear)
- Duration of wind
- Continuous distance (fetch) over which wind exists

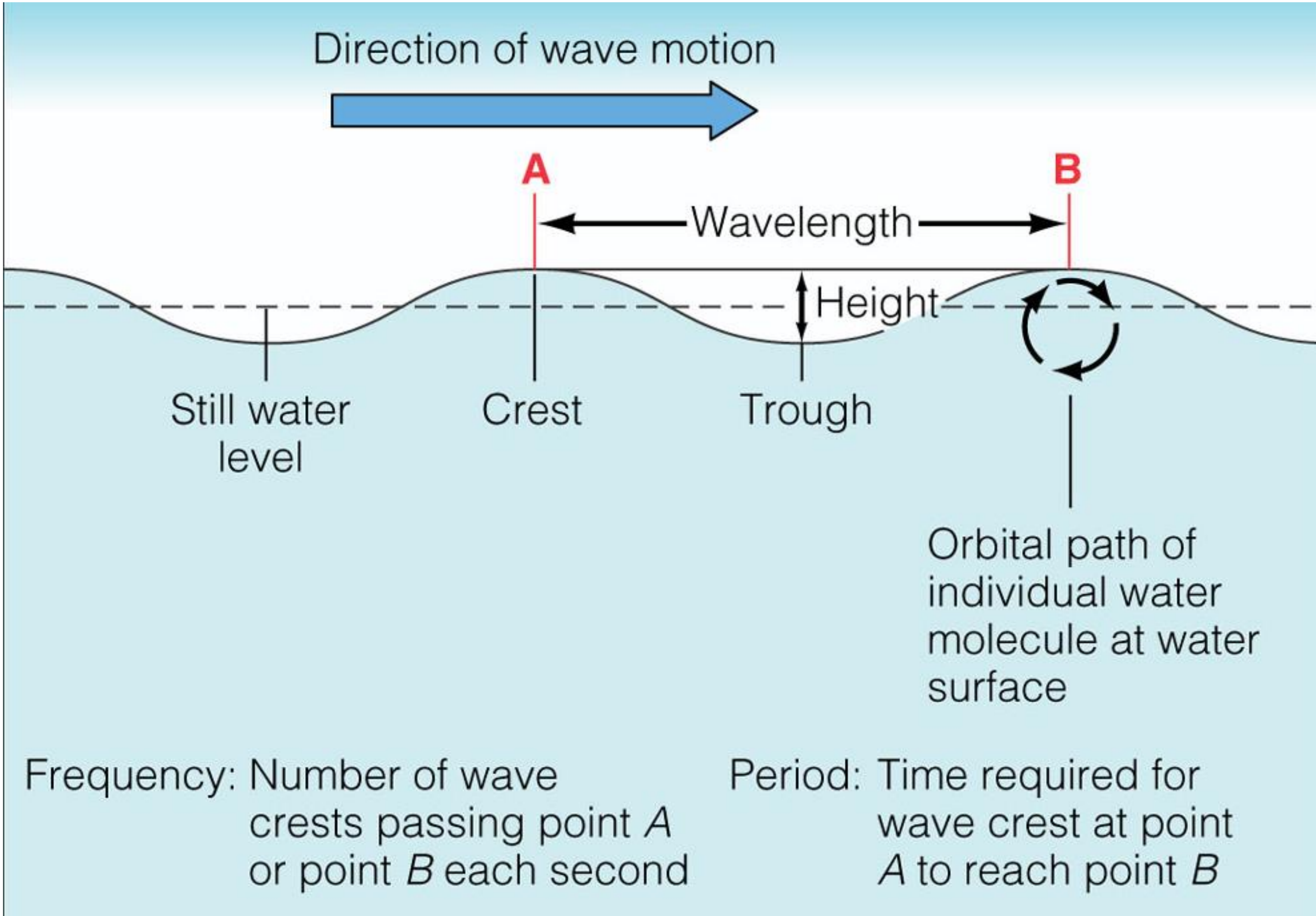

Ripples to chop
to wind waves
Fully developed
seas
Changing to
swell
Direction of
wave advance
Wind
Length of fetch

Wave Growth

- The wind energy is continually transferred to the waves causing the ripples to increase in size



Describing the Wave



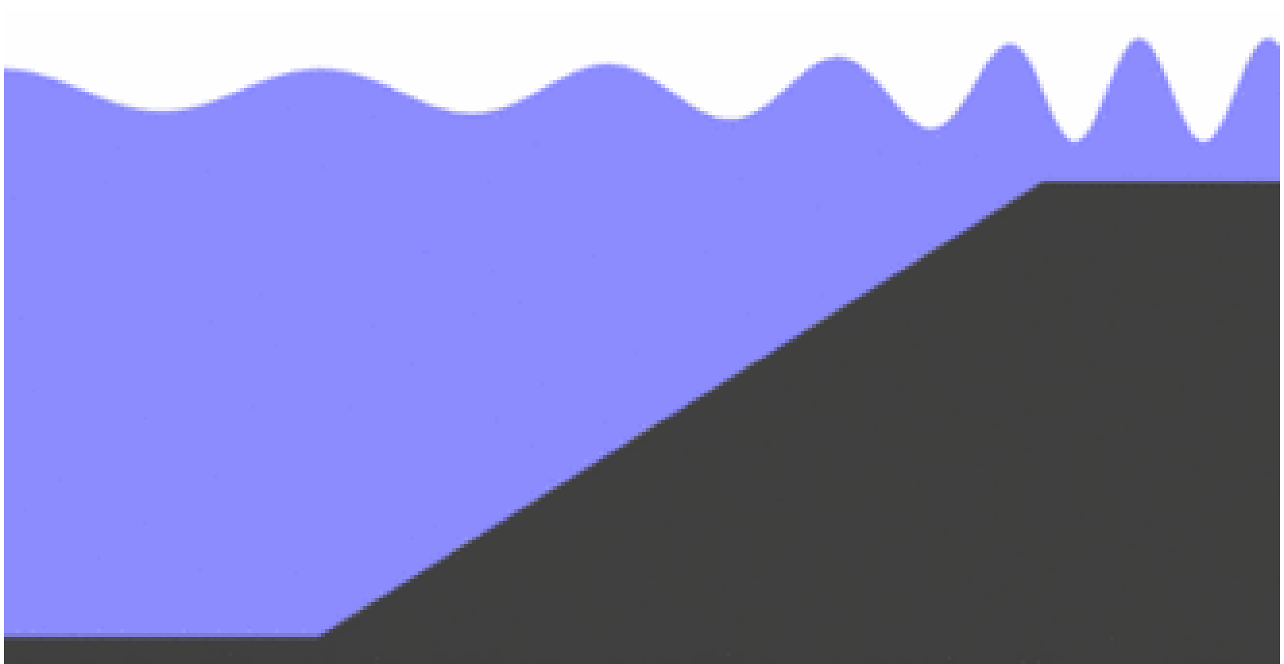
Measuring Wave Energy

- Wave height – H
- Wave period – T
- Wave energy flux on a coastline

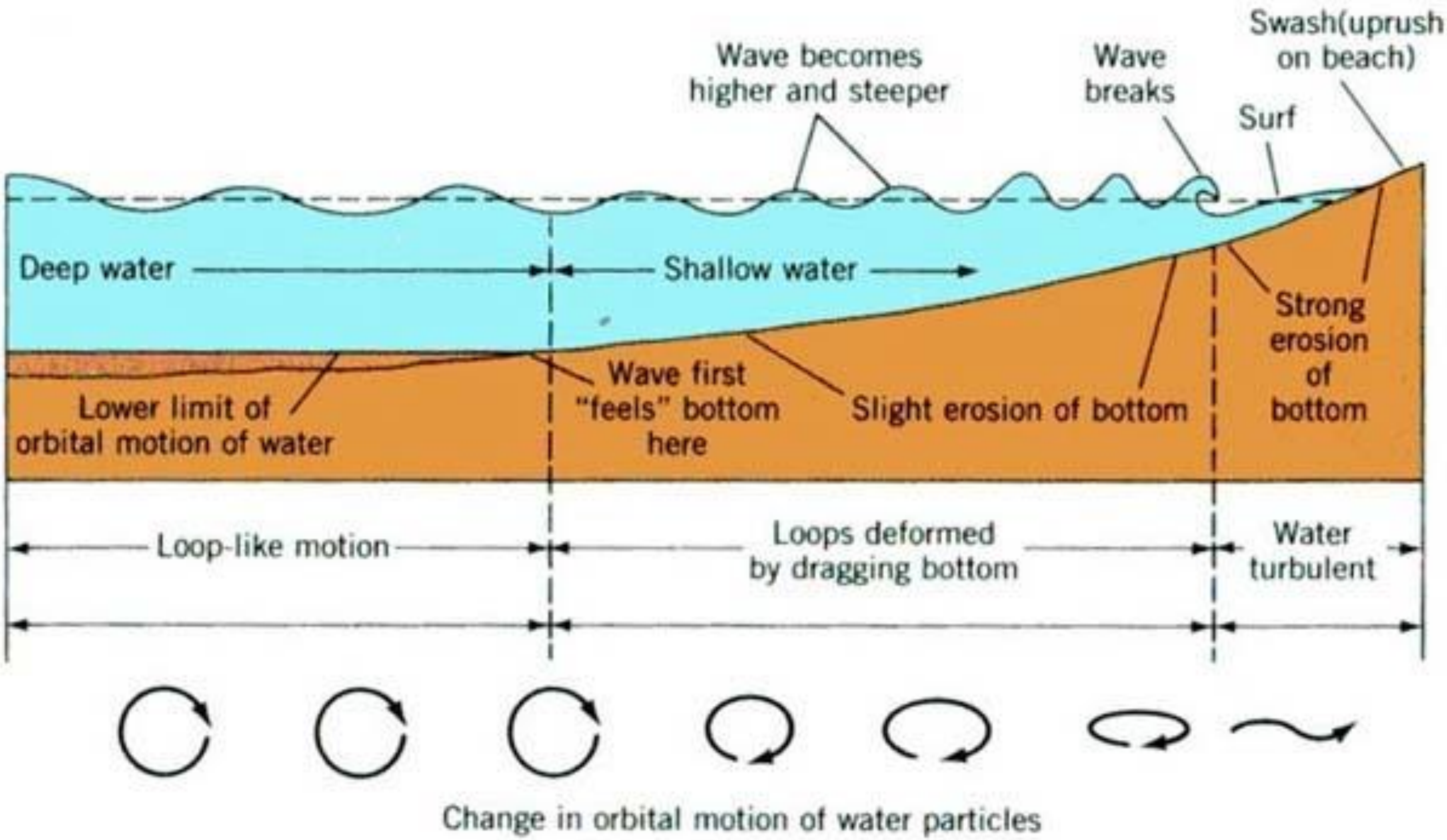
  proportional to H^2T

Wave Shoaling

- When waves enter shallow water they slow down. The wave length is reduced. The energy flux must remain constant and the reduction in wave speed is compensated by an increase in wave height.



Breaking Waves



Bed Friction

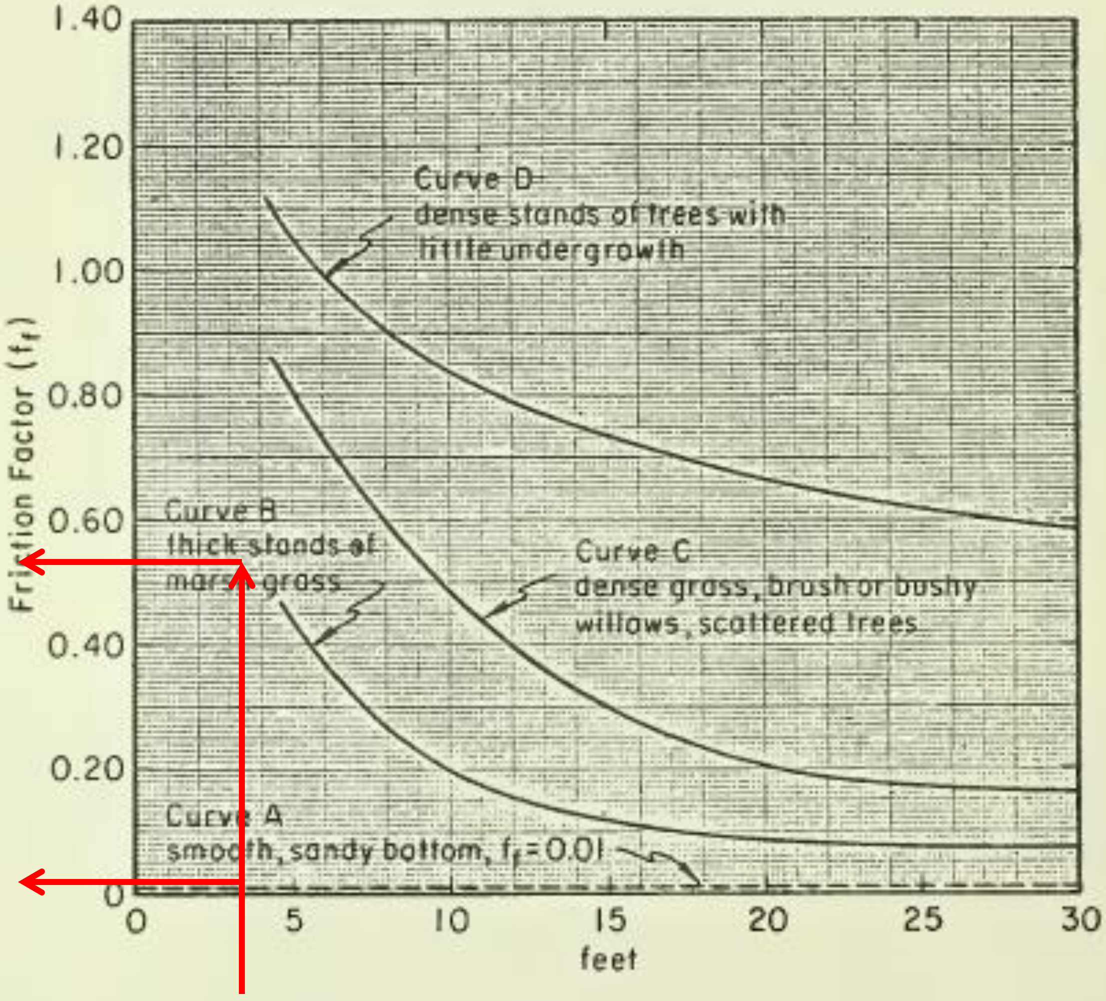
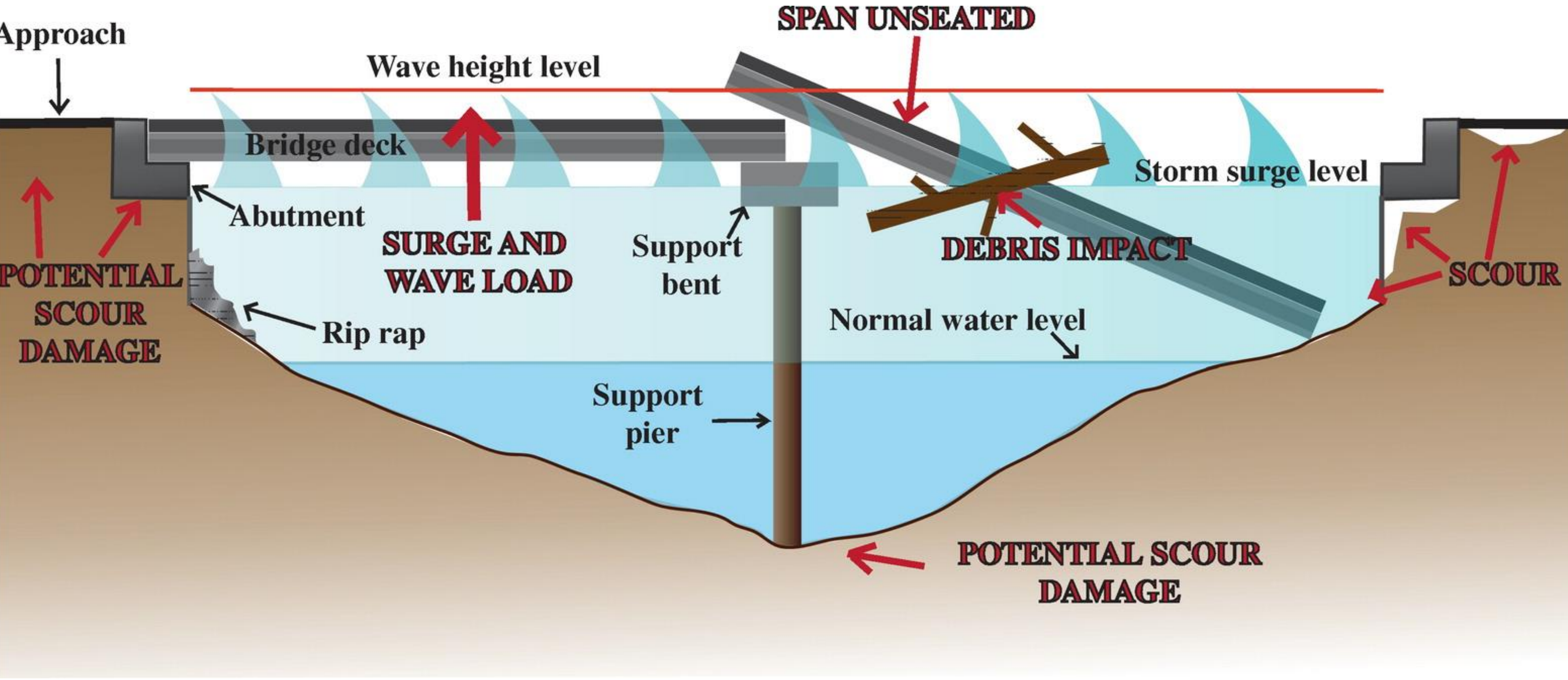


Figure 13. Bottom-friction factors.

The salt marsh vegetation increases frictional resistance by almost 2 orders of magnitude

Effect on Infrastructure



Bay St. Louis, Mississippi, after hurricane Katrina

Adaptation

- Sea level
- Surge
- Waves

Where water is moving, we have the potential to mitigate the environmental forces

Where do the Living Shorelines Fit In?

- Vegetation
  - Causes wave/surge energy losses
    - Lower wave height
    - Lower velocity
    - Lower erosion
  - **Provides habitat**
- Salt marsh bench
  - Shallow water depth
    - Minimizes maximum wave height
    - Could break waves
    - Small wave height reduced 63% by 7 m marsh width (Morgan et al. 2009)
  - Longer distance of energy loss

Living Shoreline Definition

- *Living shorelines maintain continuity of the natural land–water interface and reduce erosion while providing habitat value and enhancing coastal resilience.* (NOAA, Guidance for Considering the Use of Living Shorelines, 2015)
- *Living shorelines maintain the continuity of natural land-water interface and provide ecological benefits which hard bank stabilization structures do not, such as improved water quality, resilience to storms, and habitat for fish and wildlife.* (COE NWP, 2016) – Focus is EROSION

Critical Living Shoreline Components

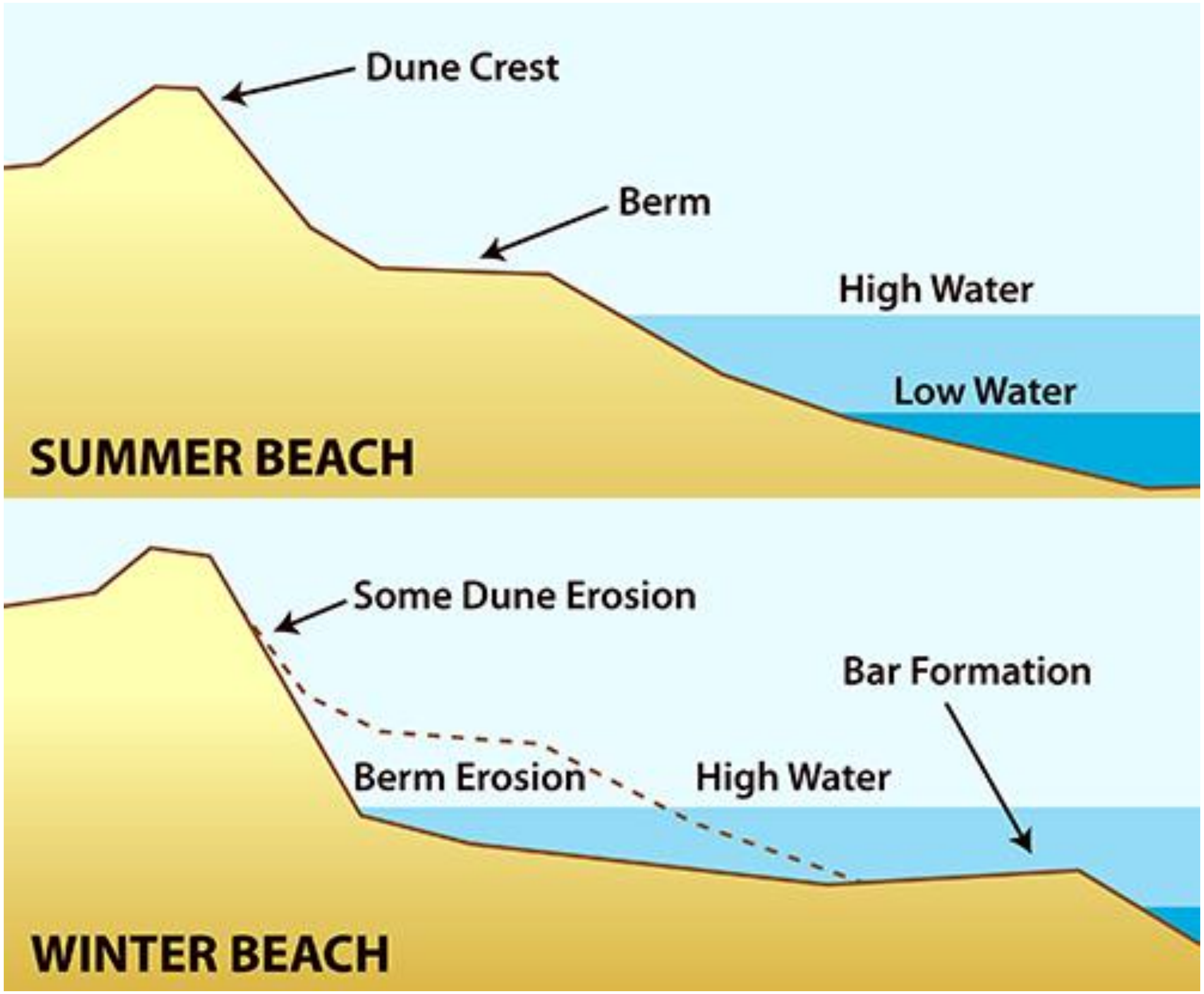
- Continuity of shoreline water-sediment characteristics
- Habitat
  - Aquatic
  - Riparian

Does not necessarily include plants, but "*Living shorelines must have a substantial biological component*…" (COE, NWP, 2016)

Why Living Shorelines?

Living shorelines provide ecosystem services to society, shoreline stabilization, storm attenuation, food production, nutrient and sediment removal, water quality improvement and carbon sequestration (Barbier et al. 2011).

Warning



- *"…shorelines are dynamic environments and the core function of stabilization is not static, but changes over time…"* (COE NWP, 2016)

What are some of the dominant coastal habitats?

Salt Marshes
Seagrass Beds
Coral Reefs
Mudflats

Rocky Intertidal Shore
Shellfish Reef
Mangrove Swamp
Barrier Beach/Dunes

Why?

1) **Physical forces (wind, tides) interact with internal process to support a negative feedback system.**

2) **The result is a recognizable ecosystem that has ecological functions and human values.**

Salt MarshVegetation

- Low Marsh:
  - *Spartina alterniflora* (smooth cordgrass
- High Marsh:
  - *Spartina patens* (salt hay)
  - *Puccinellia americana* (alkali grass)
  - *Distichlis spicata* (spike grass)
  - *Juncus gerardii* (black grass)
- Tidal Buffer Zone:
  - *Panicum virgatum* (switchgrass)
  - *Solidago sempervirens* (seaside goldenr

Spartina alterniflora

Ecozones

- Low Marsh - Near the MSL; (McKee and Patrick 1988). *Spartina alterniflora* is the only important plant.
- High Marsh - Begins at MHW and extends up to high tide line – A reasonable lower limit for a built/planted marsh might be 10 cm higher than that. Practically, it is best to plant *S. alterniflora* as much as 25 cm above MHW – it will do fine at these elevations; high marsh plants should be planted too and may replace *S. alterniflora* .
- Tidal Buffer Zone - Begins at or above the spring high tide but certainly below the highest observable tide (HOT) and extends as much as two feet higher, depending on exposure. - A transition from the highest of the high marsh plants (like seaside goldenrod and high tide bush) to quackgrass and then shrubs at even higher levels (beach plum, shad bush, bayberry, etc.)

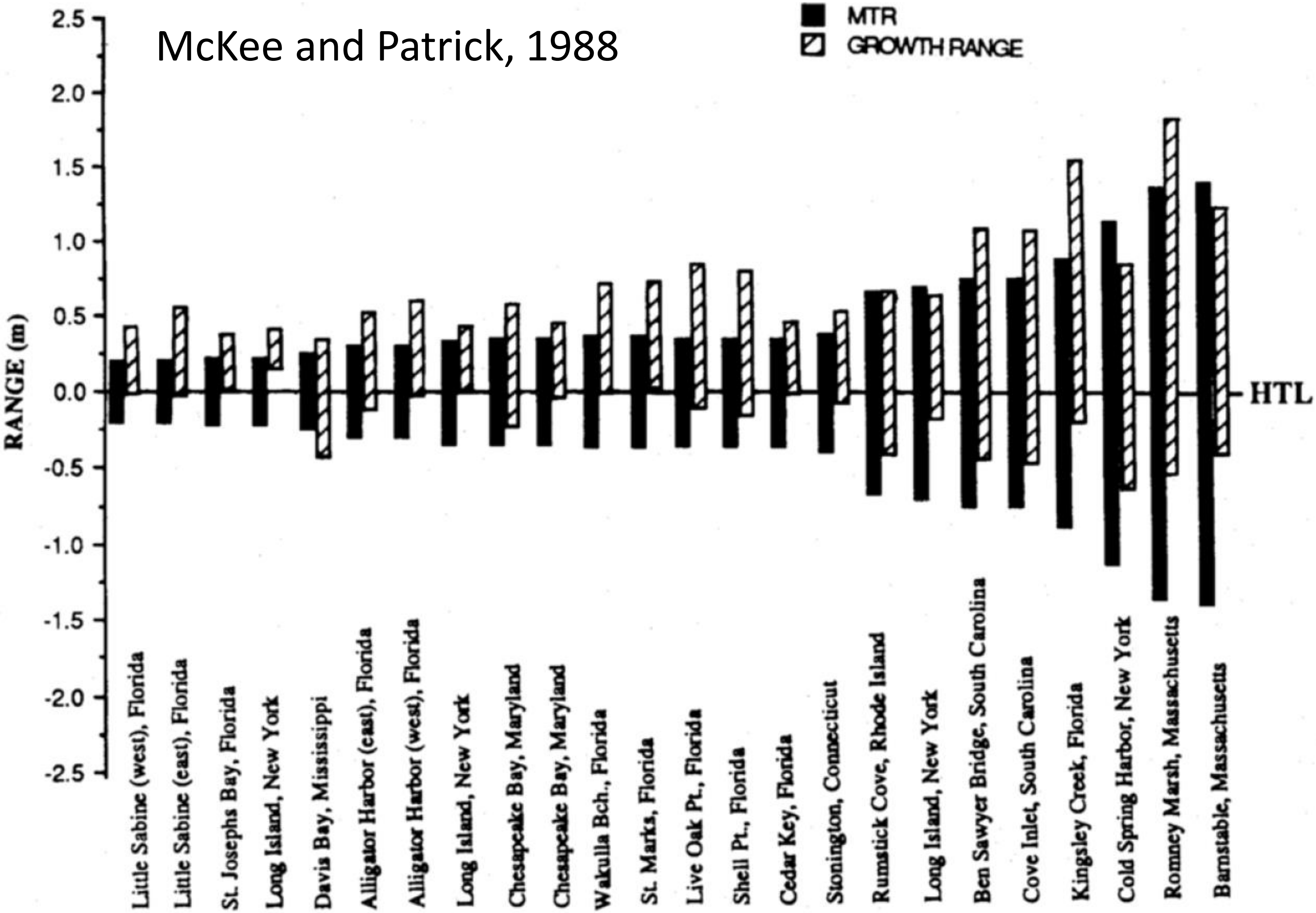
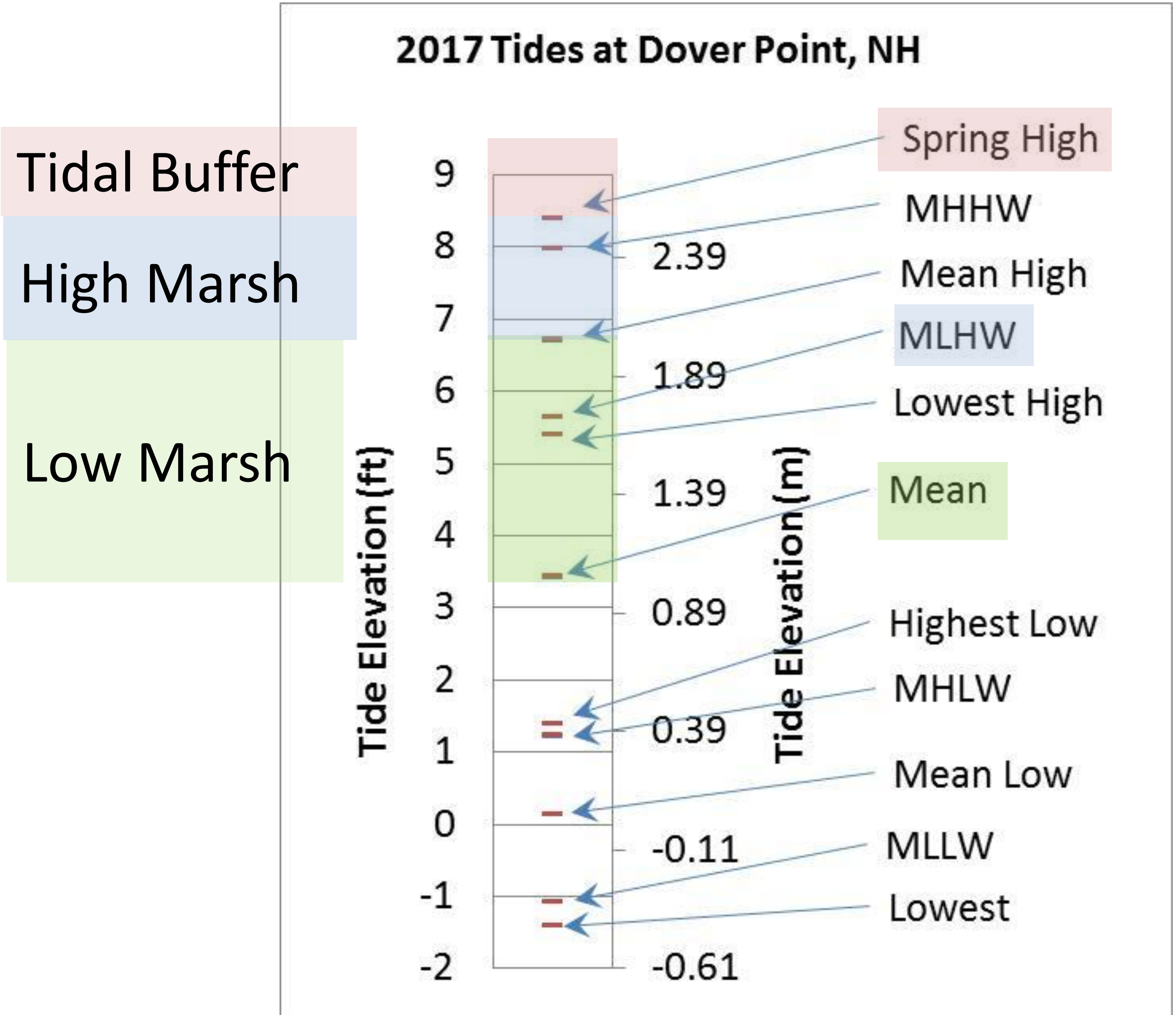


Fig. 2. The elevational range of growth of *Spartina alterniflora* relative to mean tide range (MTR) at selected locations along the Atlantic and Gulf coasts (arranged in order of increasing tidal amplitude). The half tide level (HTL) is the plane midway between mean high water (MHW) and mean low water (MLW).

The Zones


Tidal Buffer
High Marsh
Low Marsh
2017 Tides at Dover Point, NH
Tide Elevation (ft)
9
8
7
6
5
4
3
2
1
0
-1
-2
Tide Elevation (m)
2.39
1.89
1.39
0.89
0.39
-0.11
-0.61
Spring High
MHHW
Mean High
MLHW
Lowest High
Mean
Highest Low
MHLW
Mean Low
MLLW
Lowest

Conceptual Model of Salt Marsh Processes

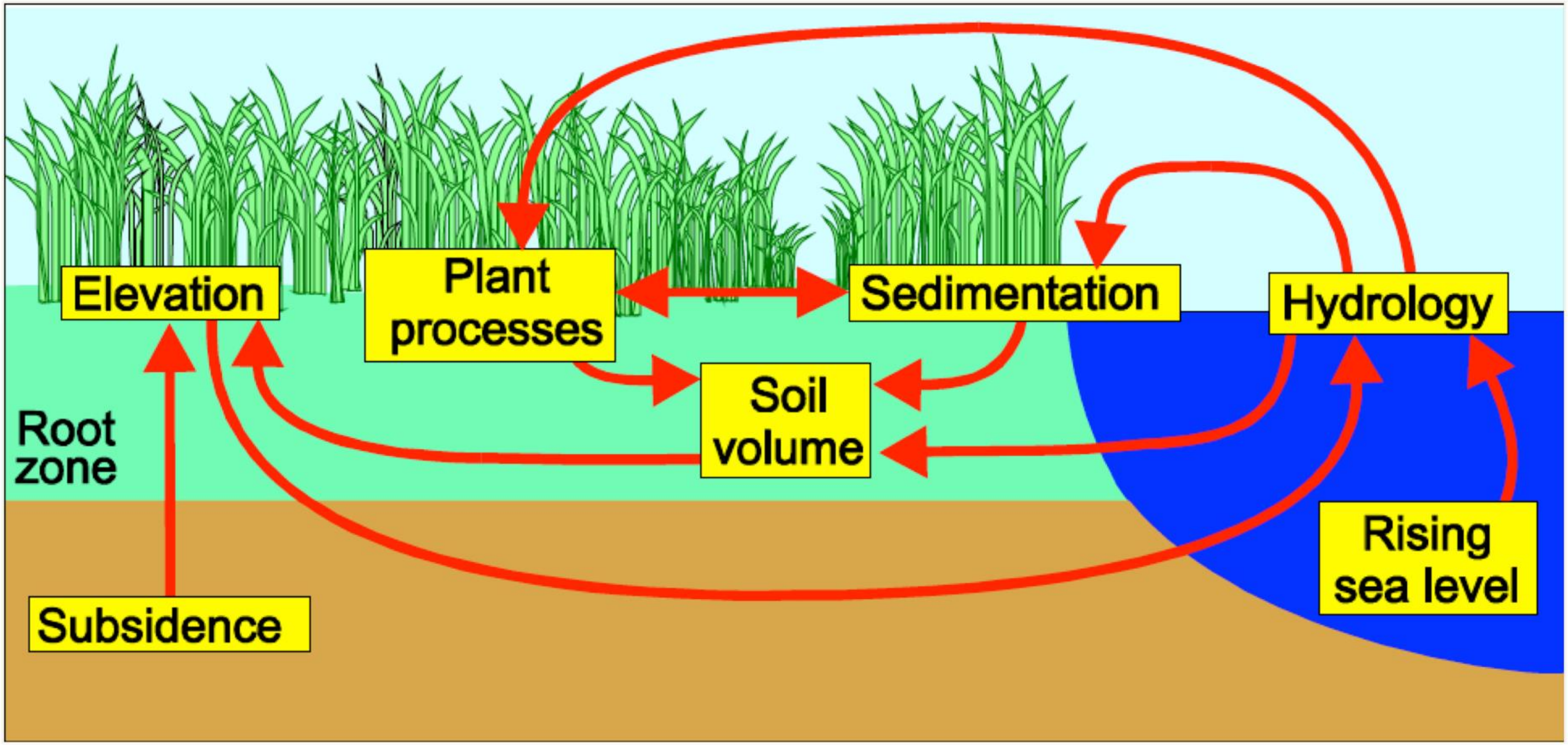
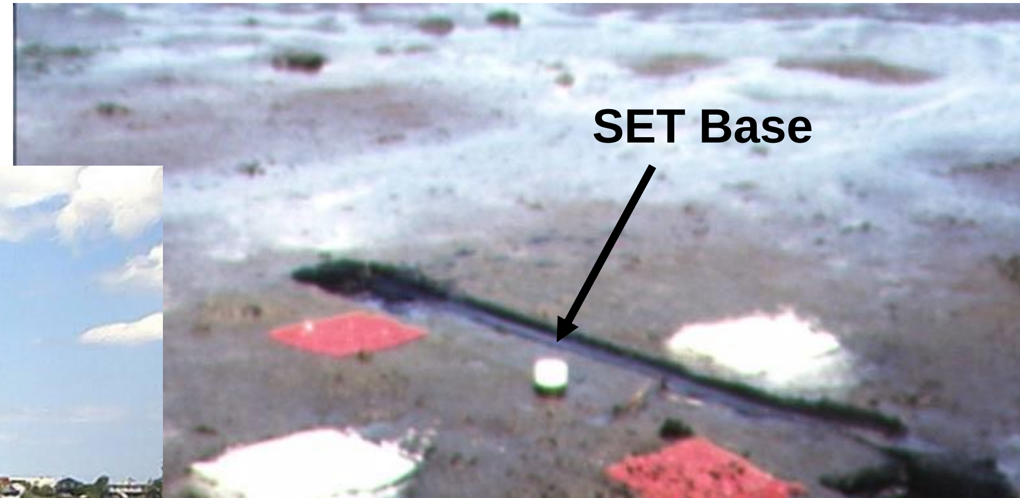


Figure 4. Conceptual model of salt marsh (Cahoon and Lynch http://www.pwrc.usgs.gov/set/).

Surface Elevation Tables (SETs) and Marker Horizons Established . . . and Measured



Salt marshes are among our most productive and valuable ecosystems

- Plants support food webs
- Secondary production
- Plant structure for habitat
- Support of biodiversity
- Protection from flooding
- Protection from coastal erosion
- Removal of sediments & excess nutrients
- Aesthetic, Recreational & Educational values
- Self-sustaining ecosystems
- Long term carbon storage

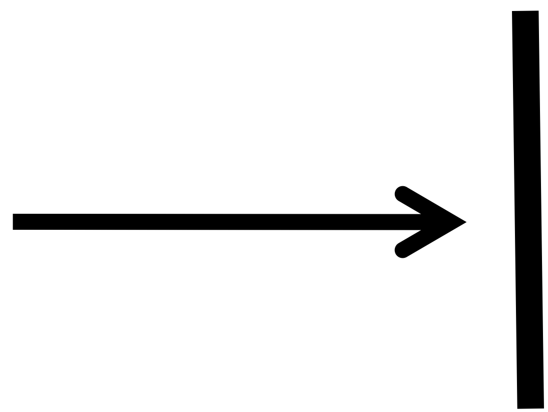
The Case for Building Salt Marshes into Living Shorelines

- Loss of 30% of historical salt marshes
- Future for marshes is not bright - SLR/CC
- Salt marshes and peat develop slowly as sea levels rise – most marshes are over 1,000 years old
- Created marshes erode EVEN if shoreline protected
  - 1993 salt marsh creation lost 20% of area in five years in North Mill Pond
- Salt marshes protect, survive and heal following storms
  - Gittman et al. 2014

THE SALT MARSH SQUEEZE

From Kirsten Howard, NHCP

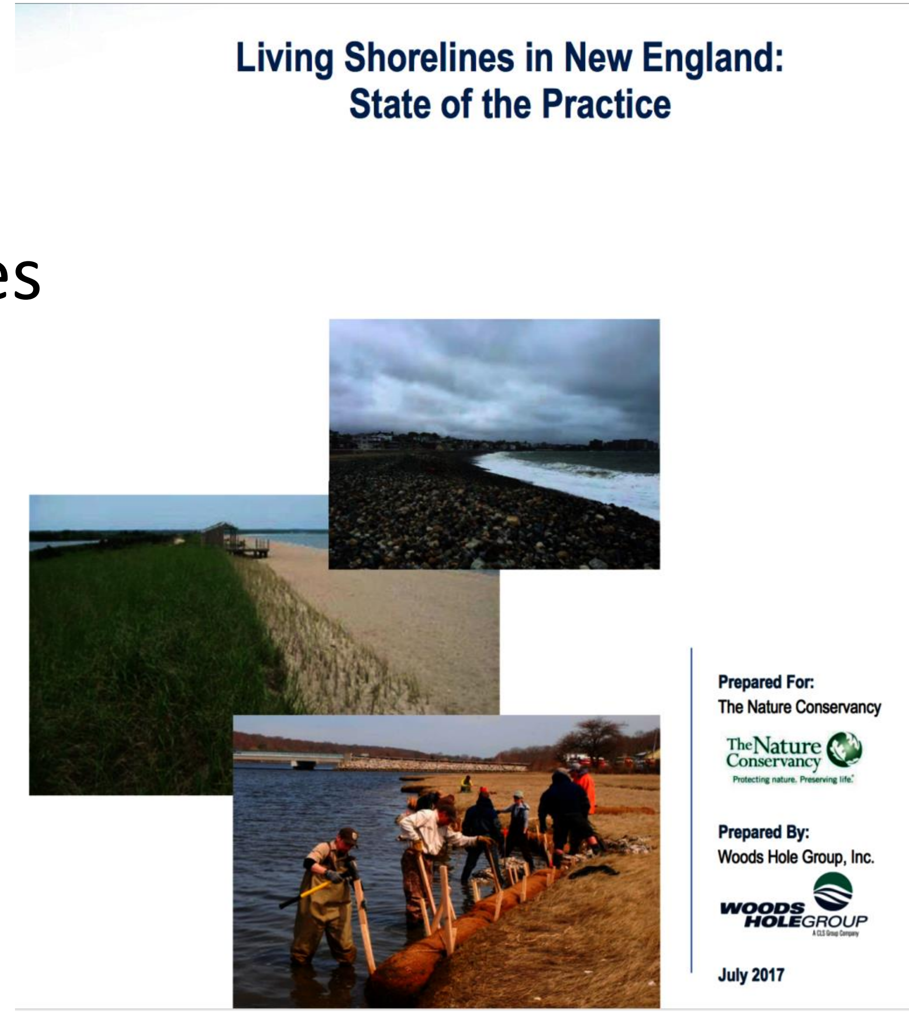
Marsh migration
+
Shoreline stabilization
=
salt marsh squeeze



Regional Efforts

- Define the range of Living
  Shorelines
- Identify New England Issues
- Monitoring Protocols

- The Nature Conservancy, Woods Hole Group, NH Coastal Program, UNH, ME Coastal Survey and others


Living Shorelines in New England:
State of the Practice

Prepared For:
The Nature Conservancy

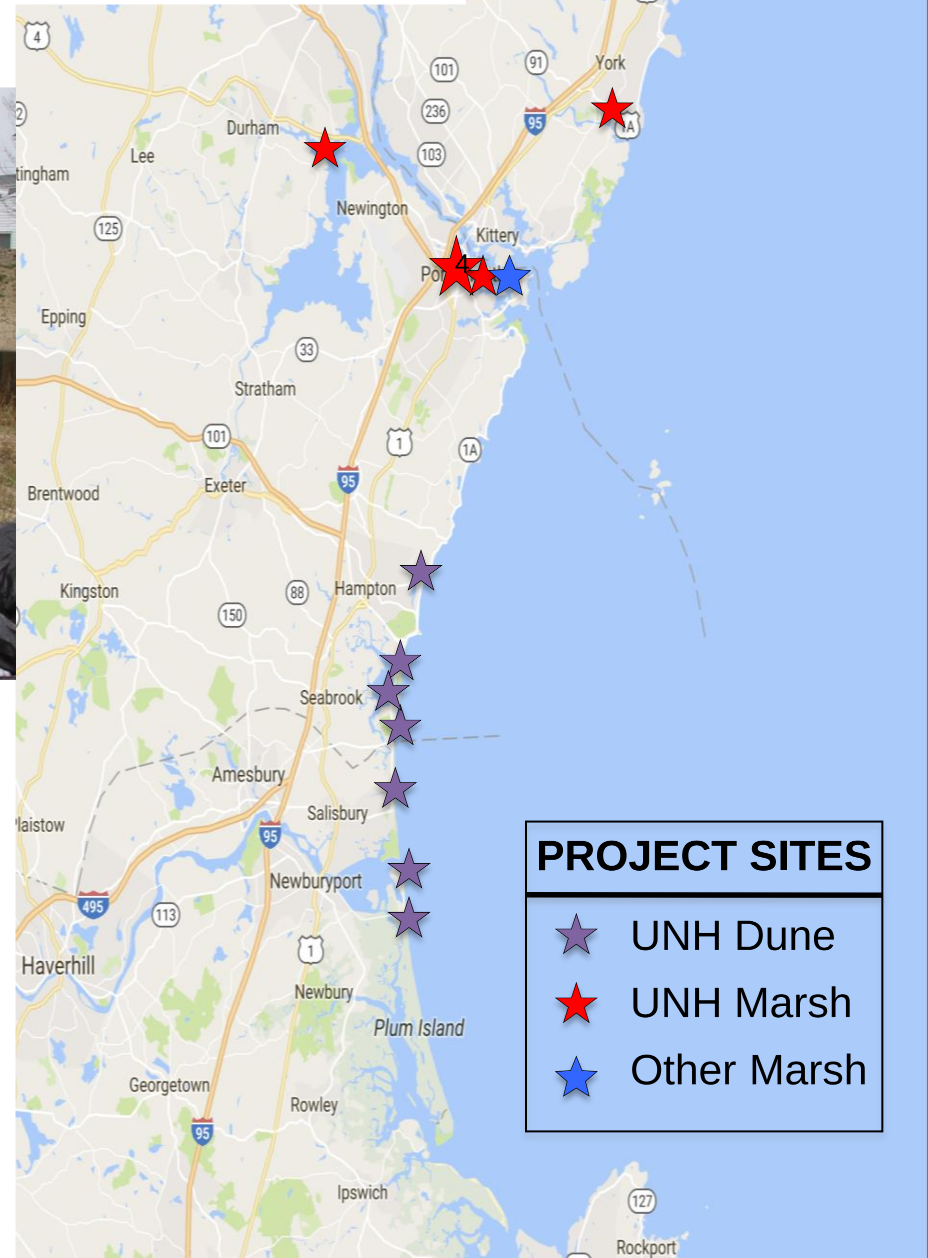
Prepared By:
Woods Hole Group, Inc.

July 2017

Local Living Shoreline Projects

Coastal Habitat Restoration Team:
Burdick, Moore, Grizzle,
Eberhardt, Ashcraft, Ballestero
and Technicians
and Students

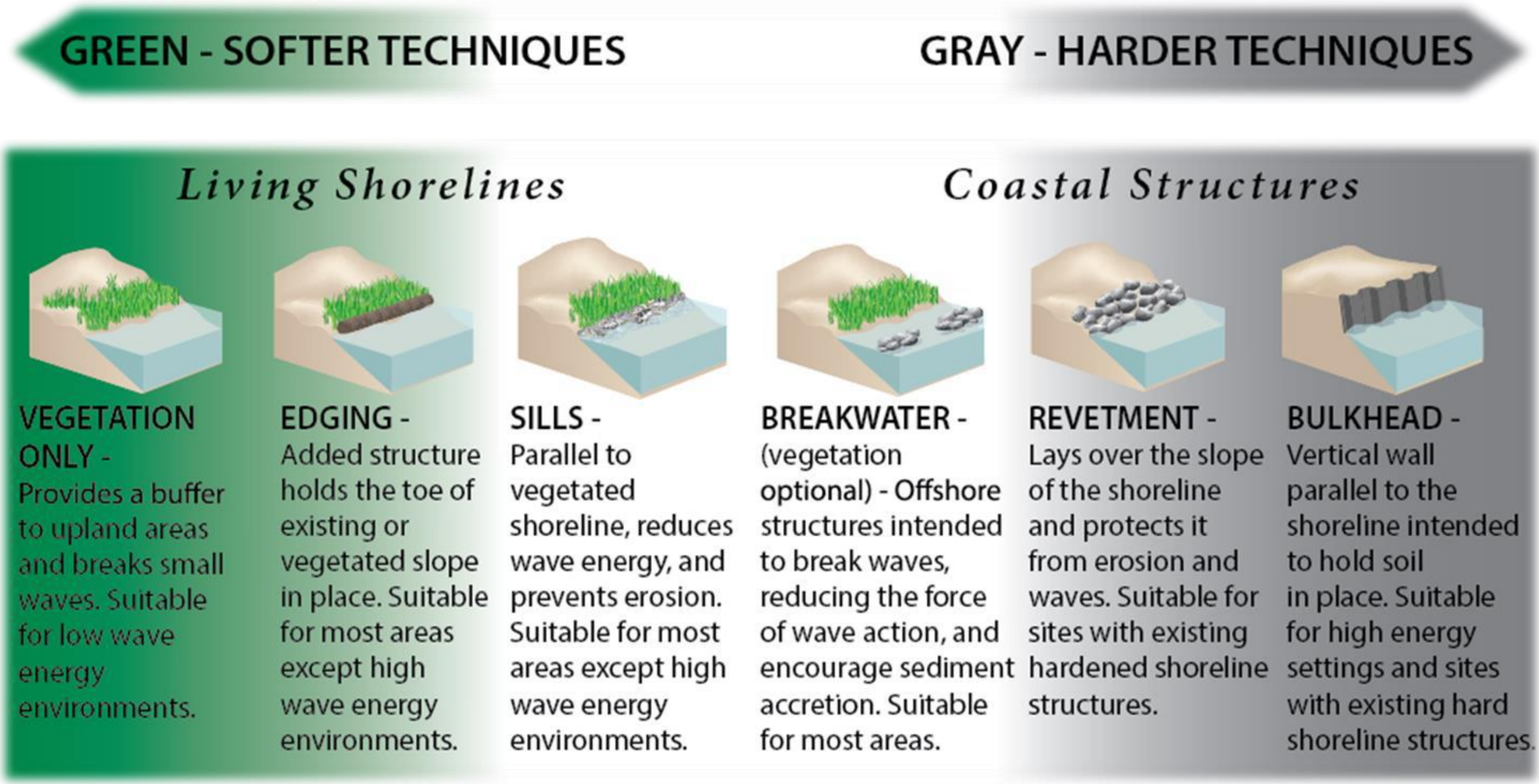
University of New Hampshire
COASTAL HABITAT
CHART



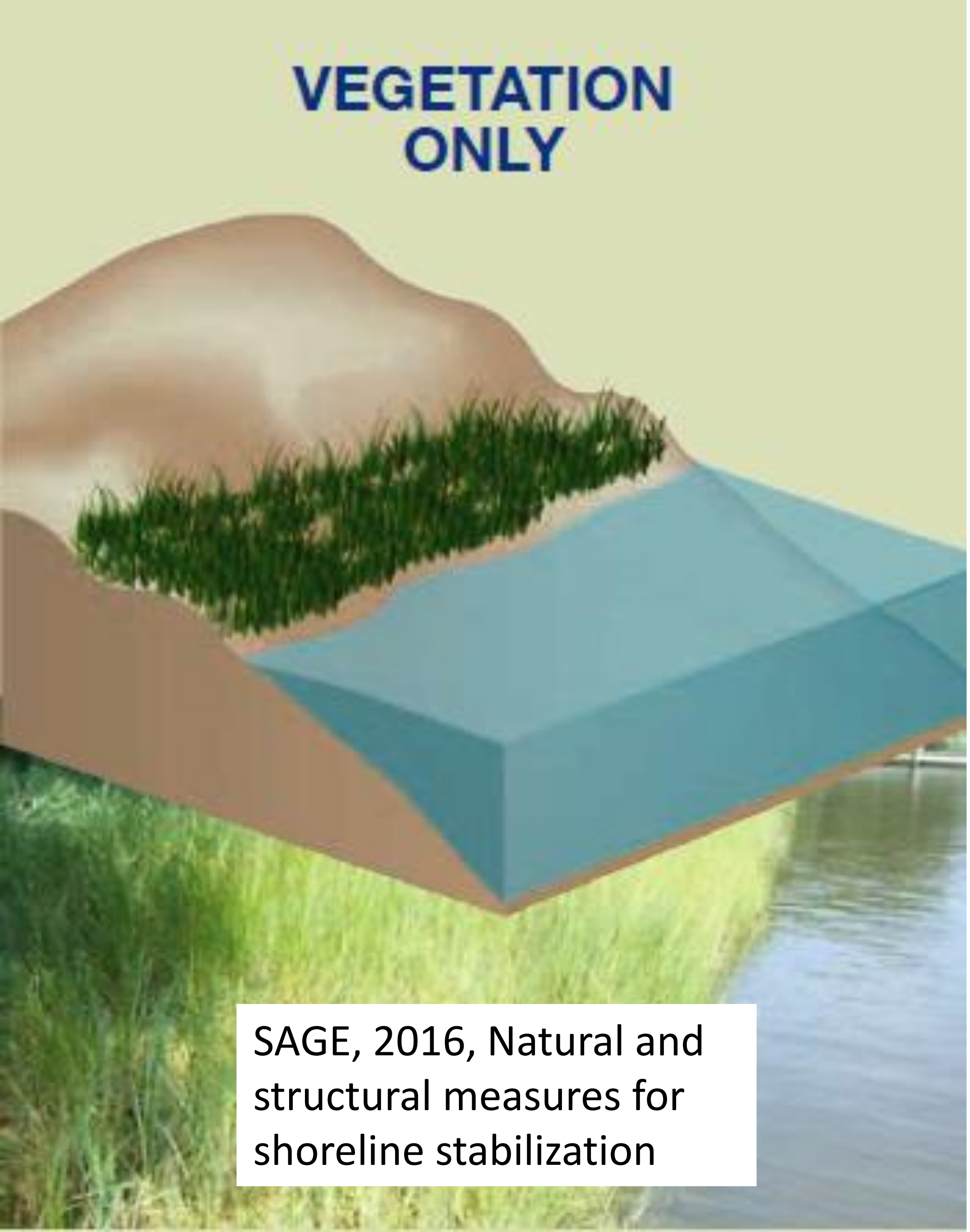
Challenges of northern shoreline projects

- Low light
- Short growing season
- Large tidal range
- Ice
- Zone between -2 ft MSL and 3.5 ft MSL

Ranges of Options

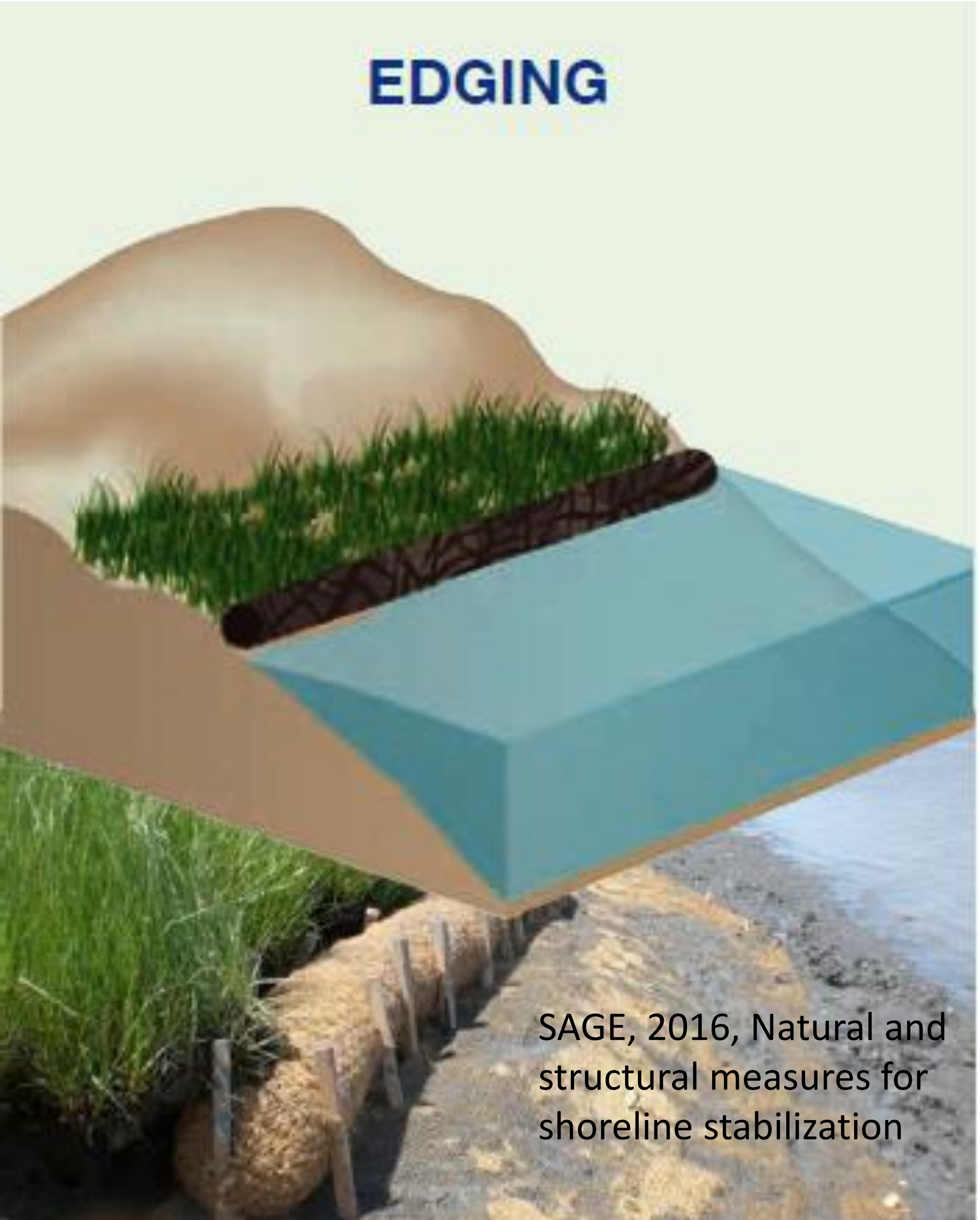


Guidance for Considering Use of Living Shorelines, NOAA 2015



SAGE, 2016, Natural and structural measures for shoreline stabilization

Mill Pond Way berm removal, North Mill Pond, Portsmouth, NH



SAGE, 2016, Natural and structural measures for shoreline stabilization

Brewster Street Mitigation on North Mill Pond (Stantec)

North Mill Pond at Brewster St. Mitigation 2016

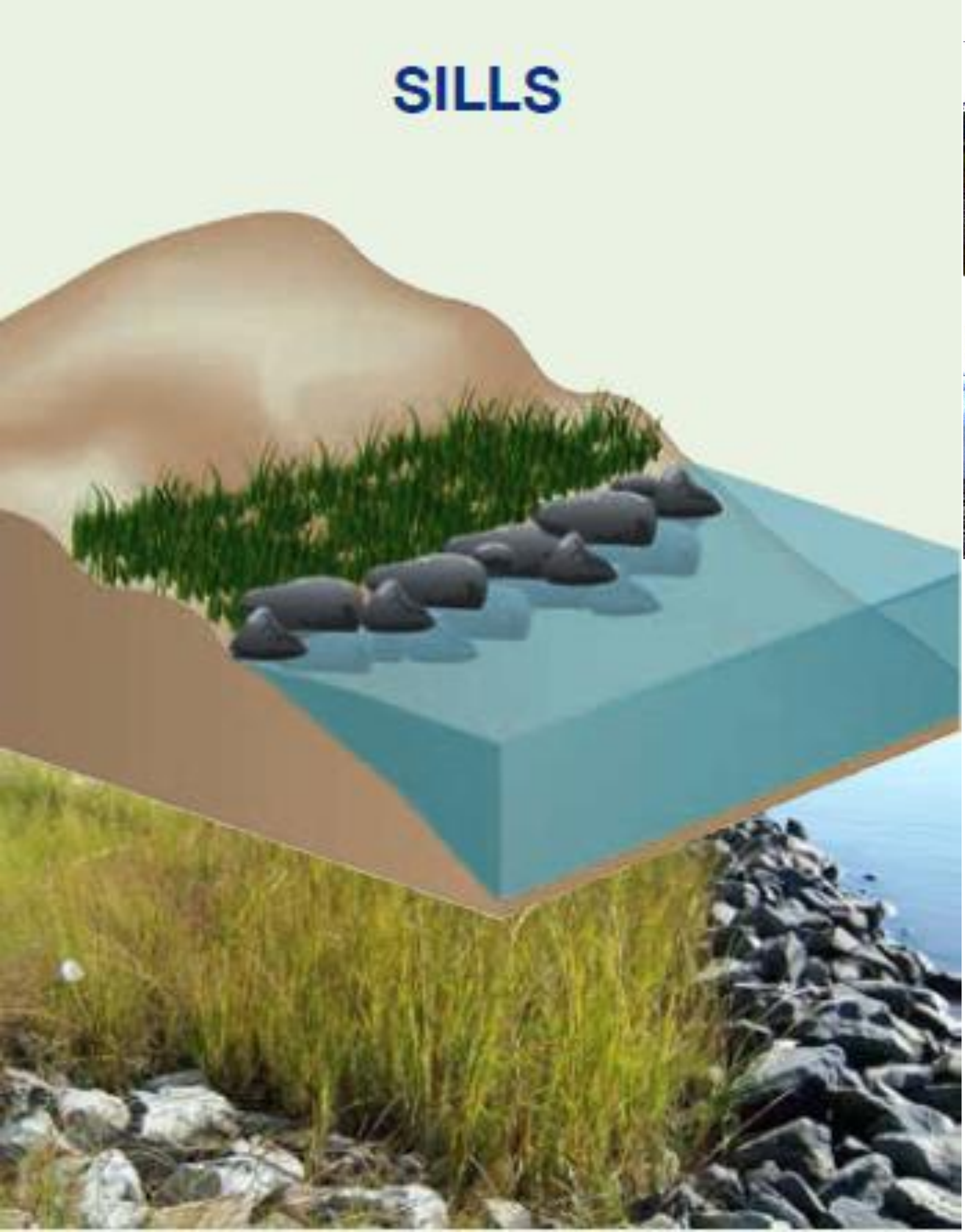
Pre-existing

Fill to Designs Grades

Plant With Plugs . . .

and boulders to break up ice

Final Product



Marsh built in South Mill Pond 2001, Portsmouth, in front of seawall and behind sill constructed from existing rocks on site.

SAGE, 2016, Natural and structural measures for shoreline stabilization

Two More Case Studies: Living Shoreline Marshes with Sills

1) Cutts Cove, Portsmouth

– Designed as restoration of salt marsh

– Approach is to partially remove rip-rap wall

– Sill provides a ‘climate ready’ feature for 2060

2) Wagon Hill Farm, Durham

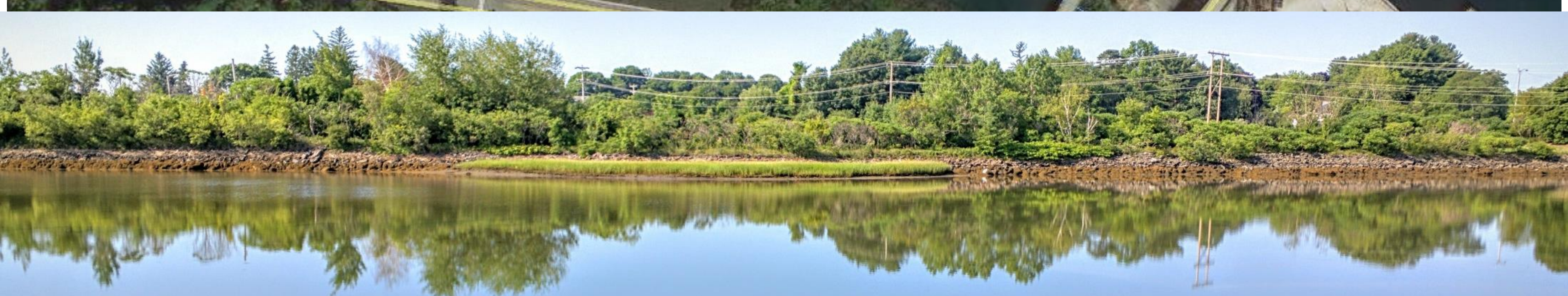
– Designed to stop erosion

– Also restores damaged salt marsh

– Sill provides erosion resistant edge and ‘climate ready’ feature; TBZ allows for marsh migration

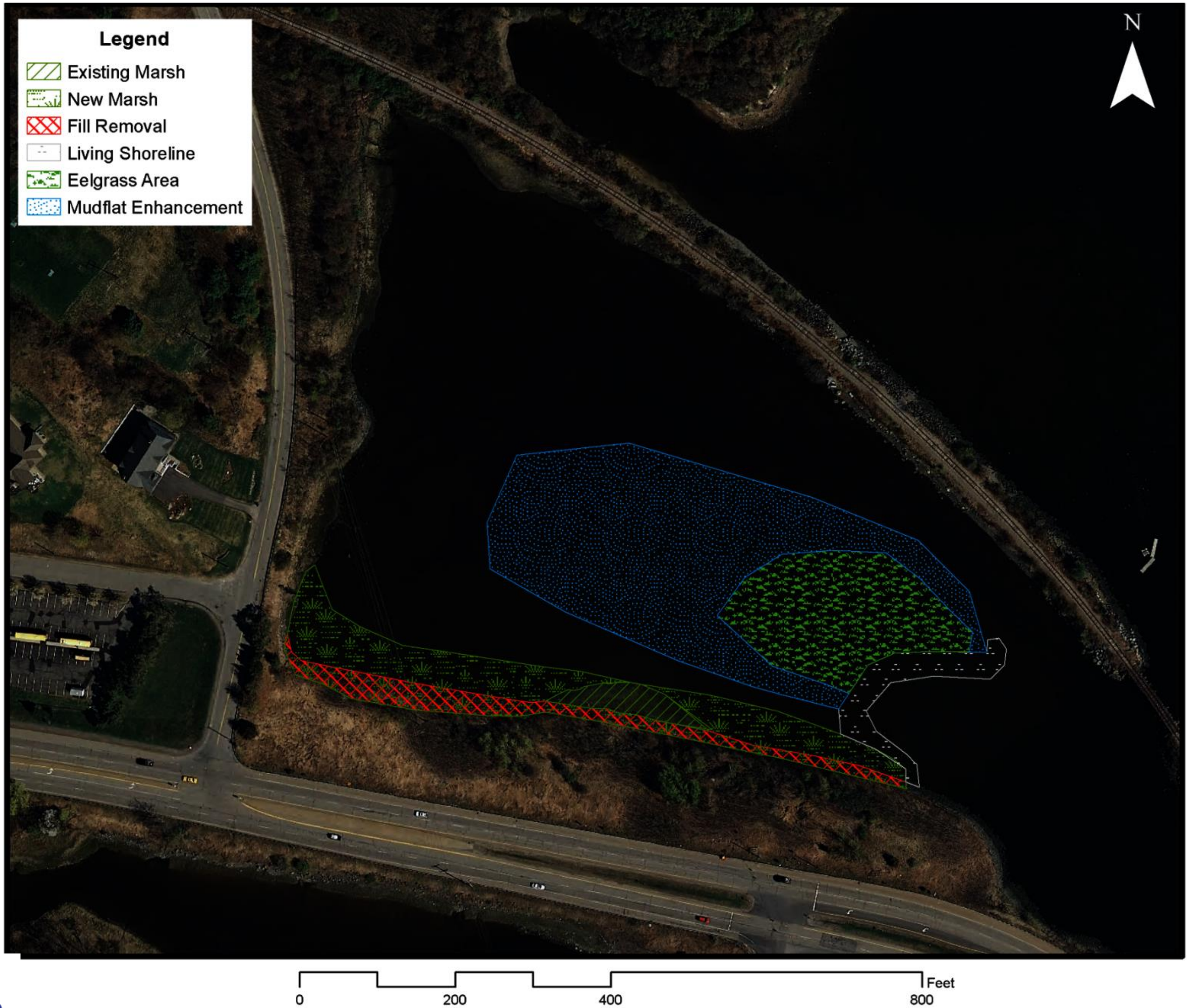
Cutts Cove


95
Forrest St
Cutts Ave
Brigham Ln
Chase Dr
Michael Succi Dr
Sarah Mildred Long Bridge
1



Rip Rap Armor at Cutts Cove

Sarah Mildred Long Bridge Replacement Mitigation Plan January 2014



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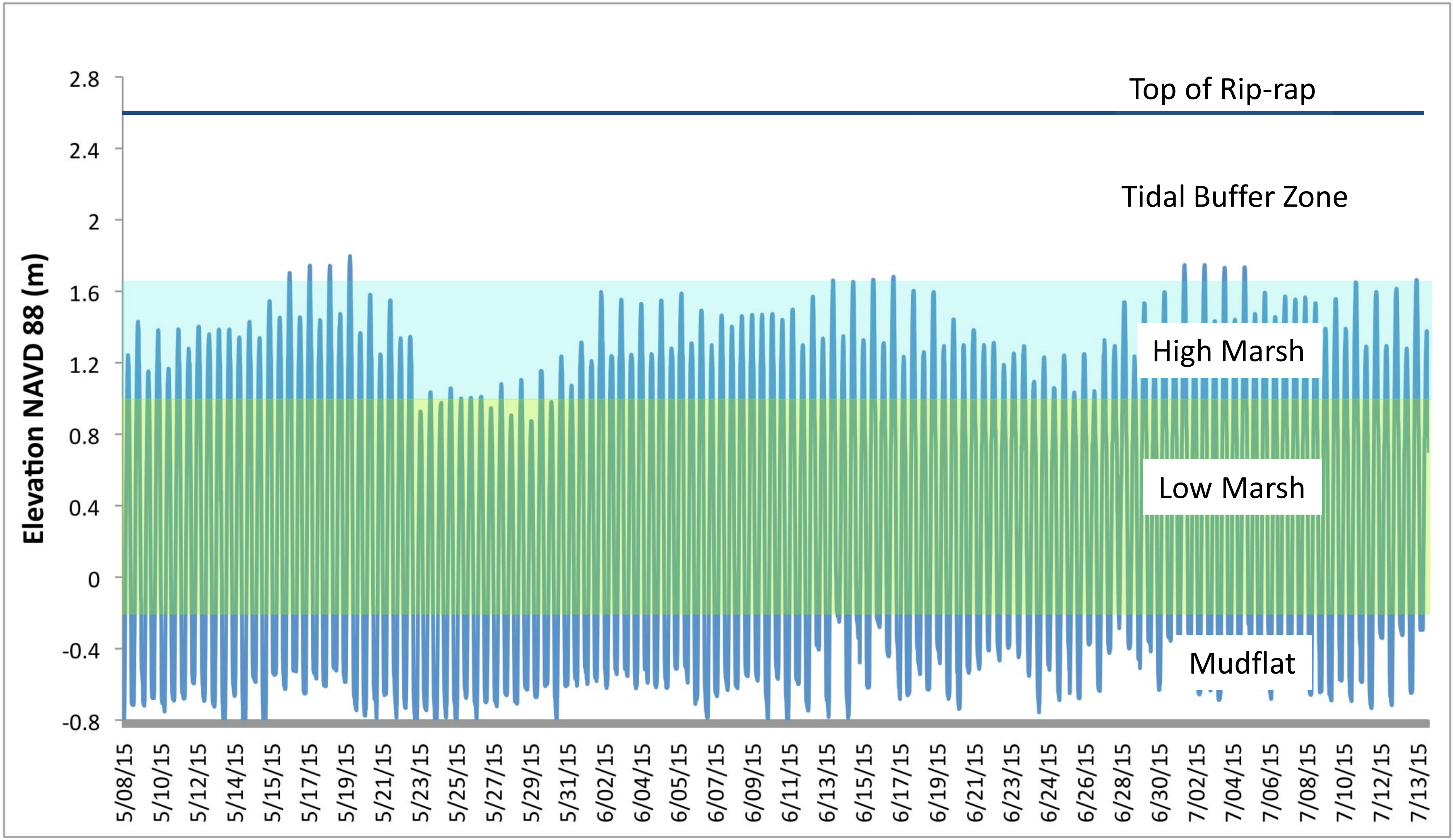
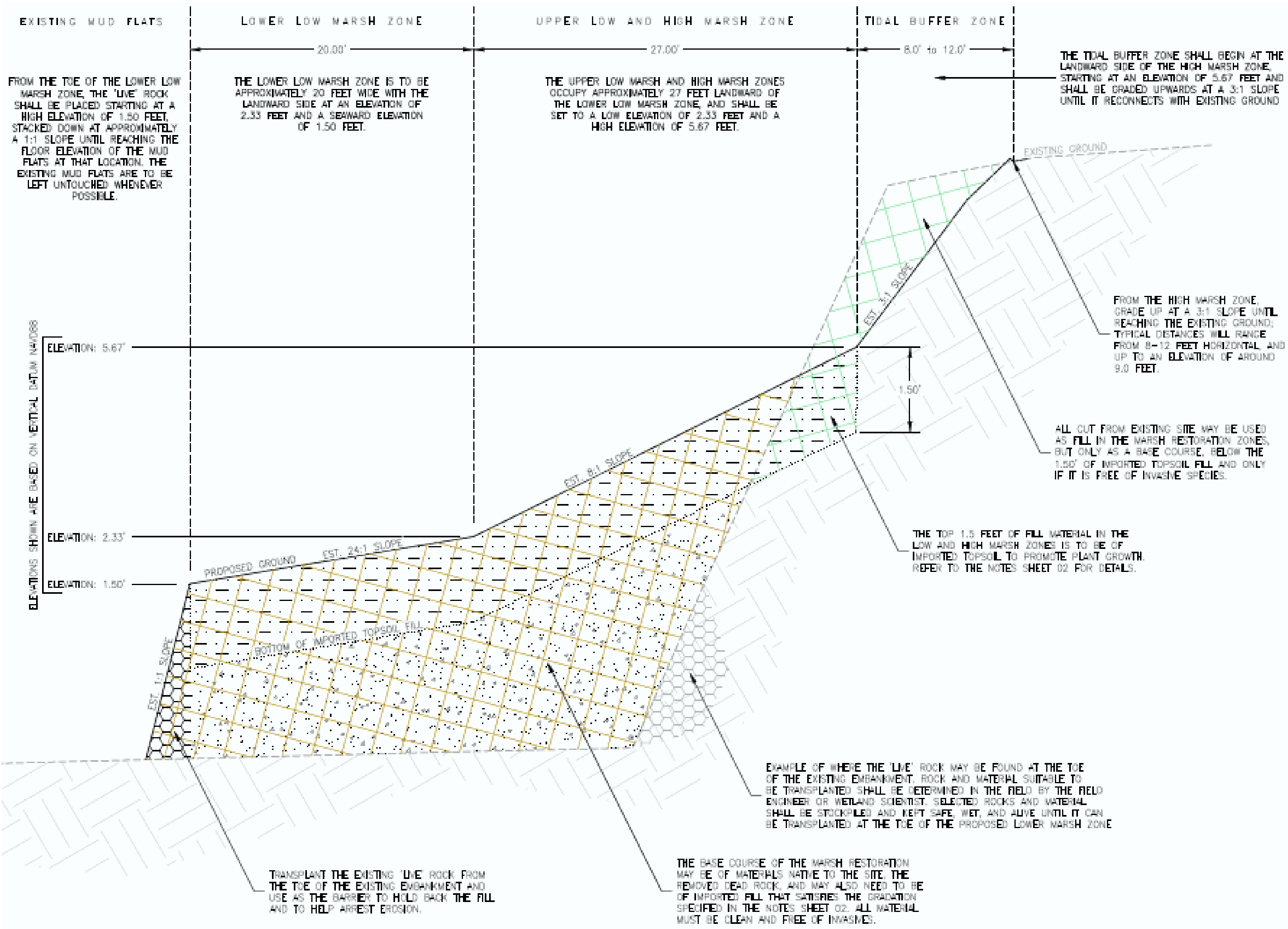
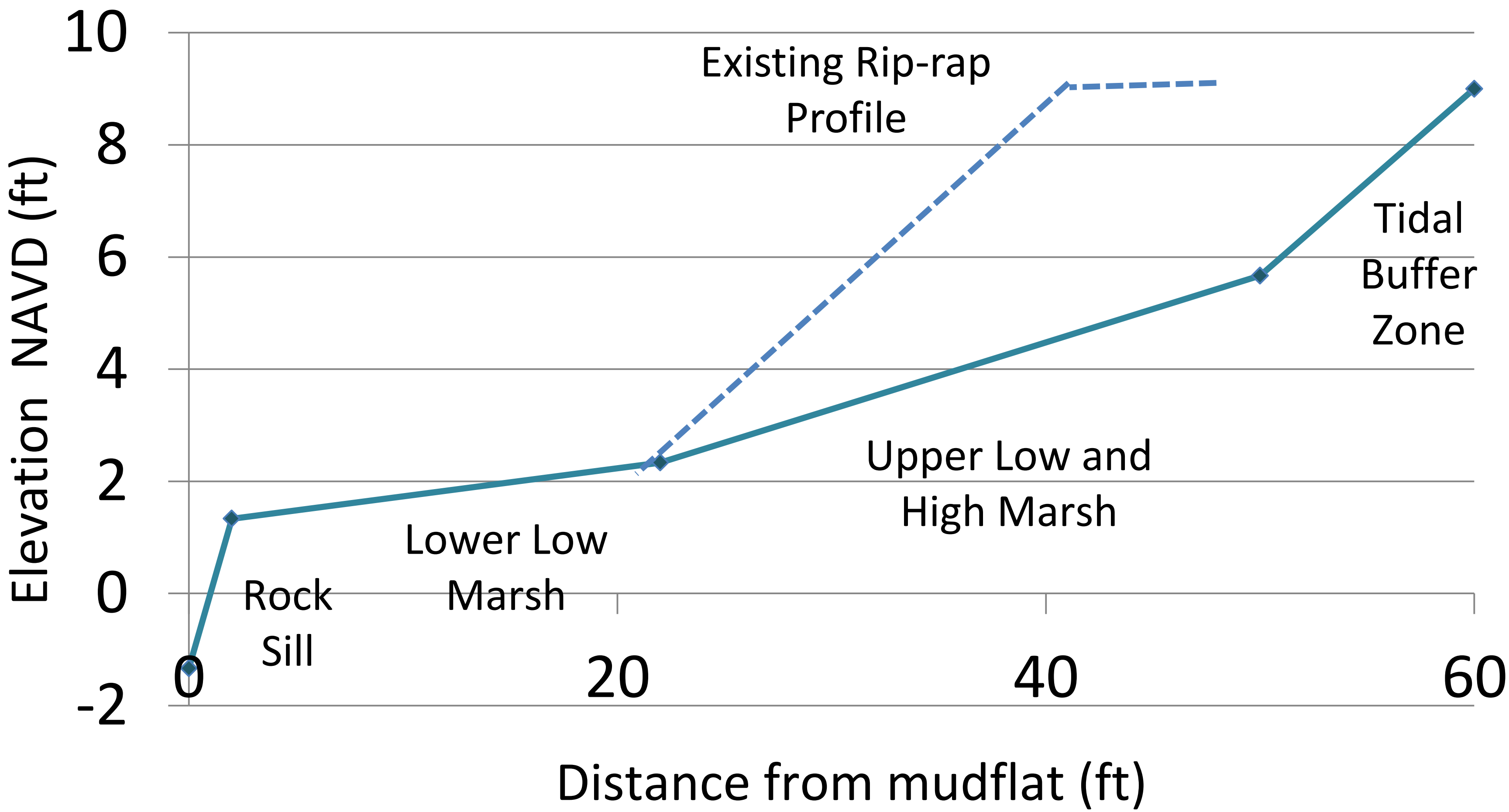
Tides and existing marshes in Cutts Cove



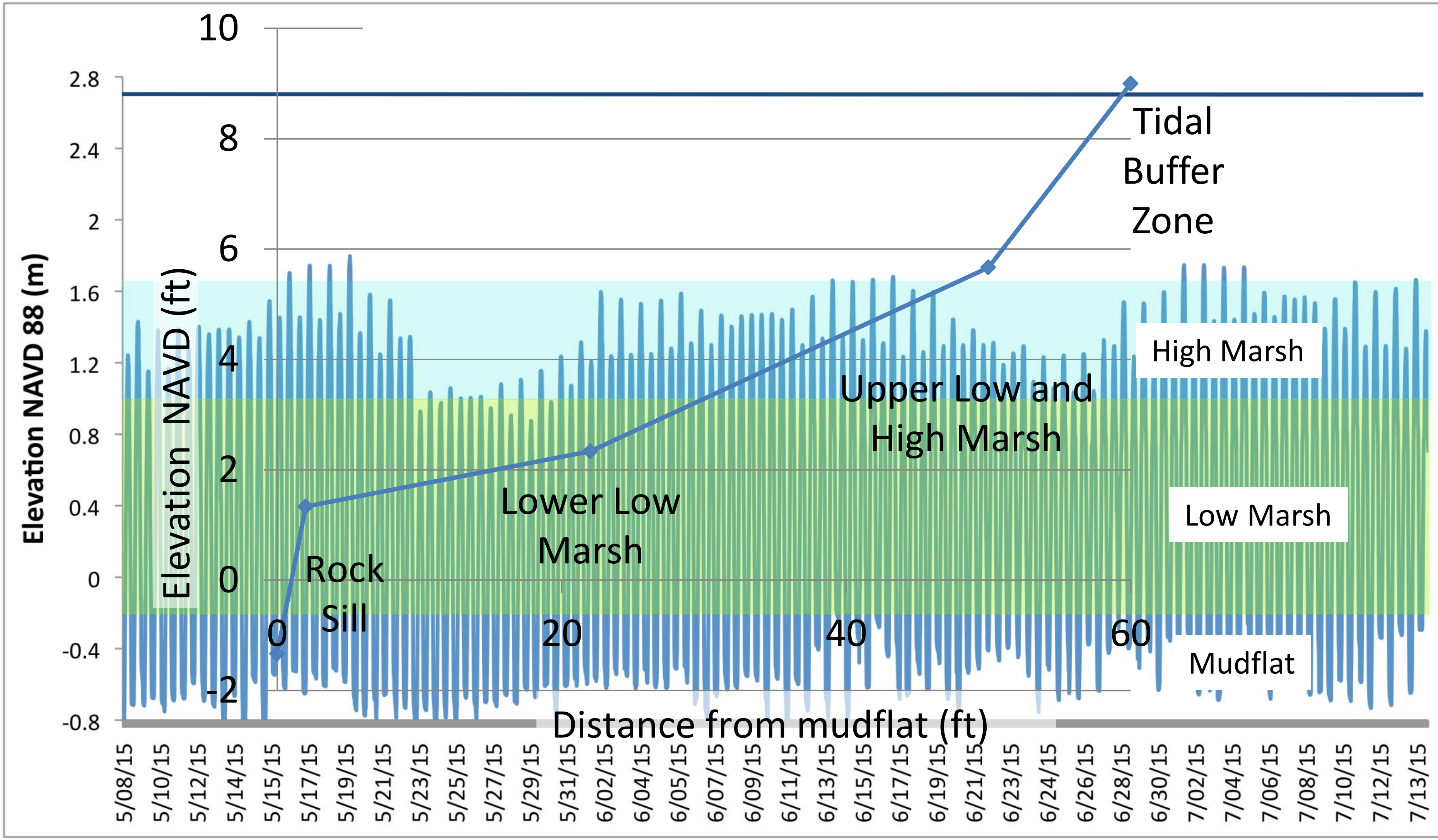
Proposed Cutts Profile



Cutts Profiles and Ecosystems



Tides and existing marshes in Cutts Cove



Construction Sequence

Clear and Grub

Flatten rip-rap wall and build stone edge

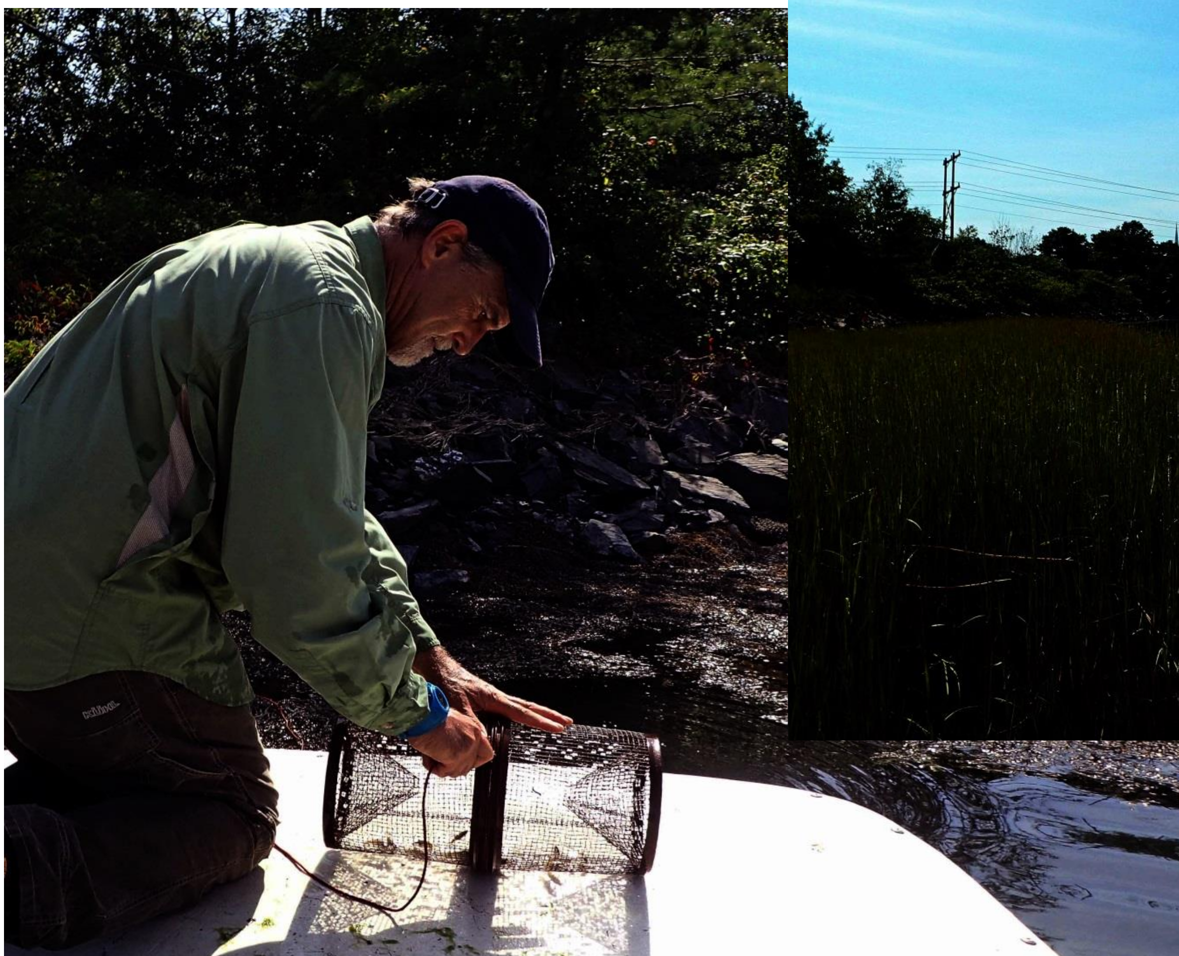
Backfill with sandy silt to elevation

Planting and Maintenance

Measures of Success

- Monitoring
  - Erosion
  - Plant establishment and growth
  - Animal use of habitat
- Maintenance

Pre-restoration Fish Sampling



Case Study #2: Wagon Hill Farm

University of New Hampshire

Change from 1992 to 2015

Wagon Hill Farm Issues and Data Collection

Potential Causes of Erosion

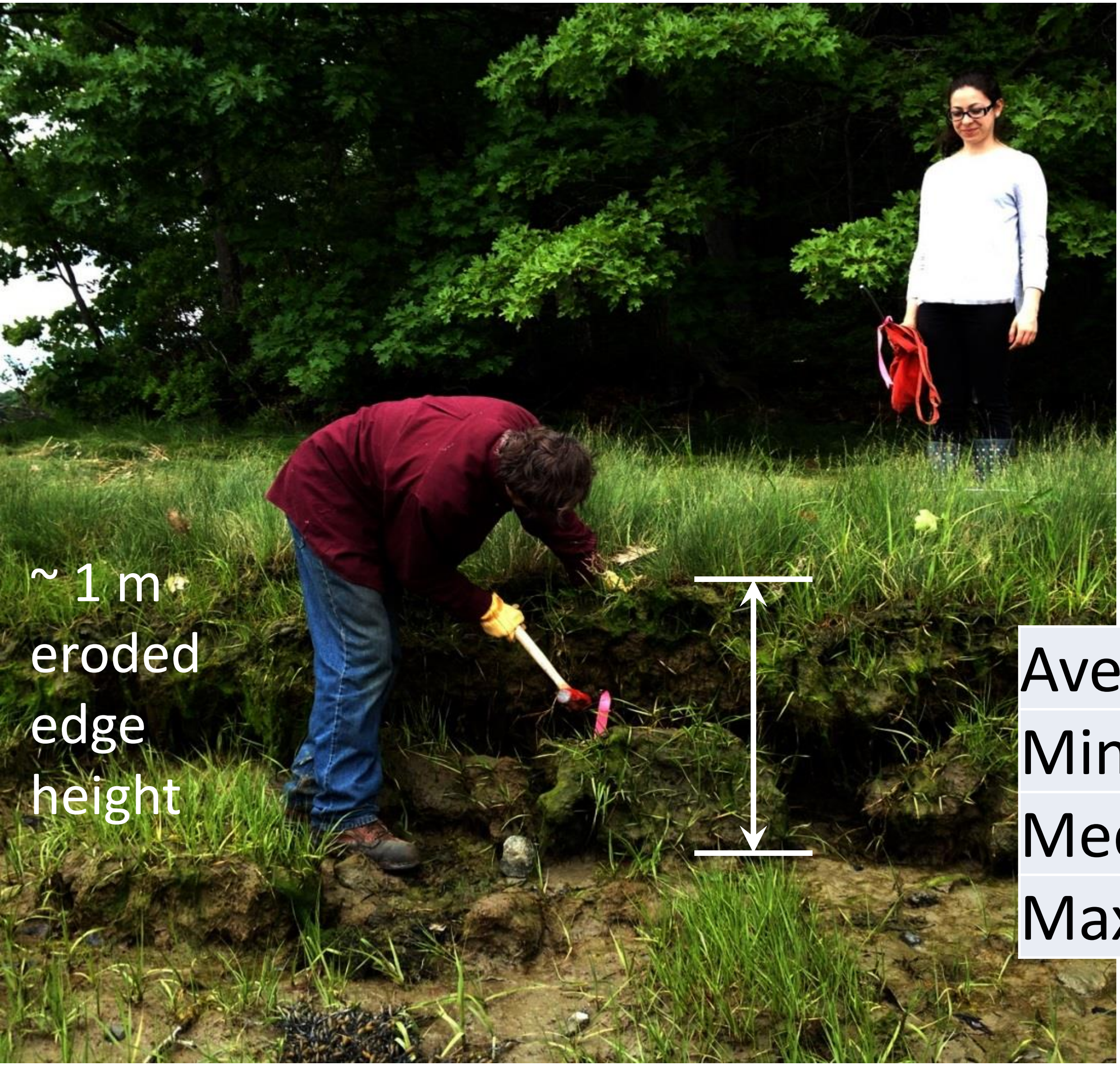
- Waves
- Increased foot /pet traffic
- Decreased light
- Increased Sea Level
- Ice Damage
- Plant disease or herbivory
- Lack of Sediment supply
- Eroded shoreline promotes erosion cycle
- Stormwater

Data Collection

[to eliminate potential causes and inform design]

- High intensity water levels
- Wildlife cameras
- Light meters
- Water level recorders
- Wildlife cameras
- Observations
- Trial structure
- Erosion pins

Setting Erosion Pins

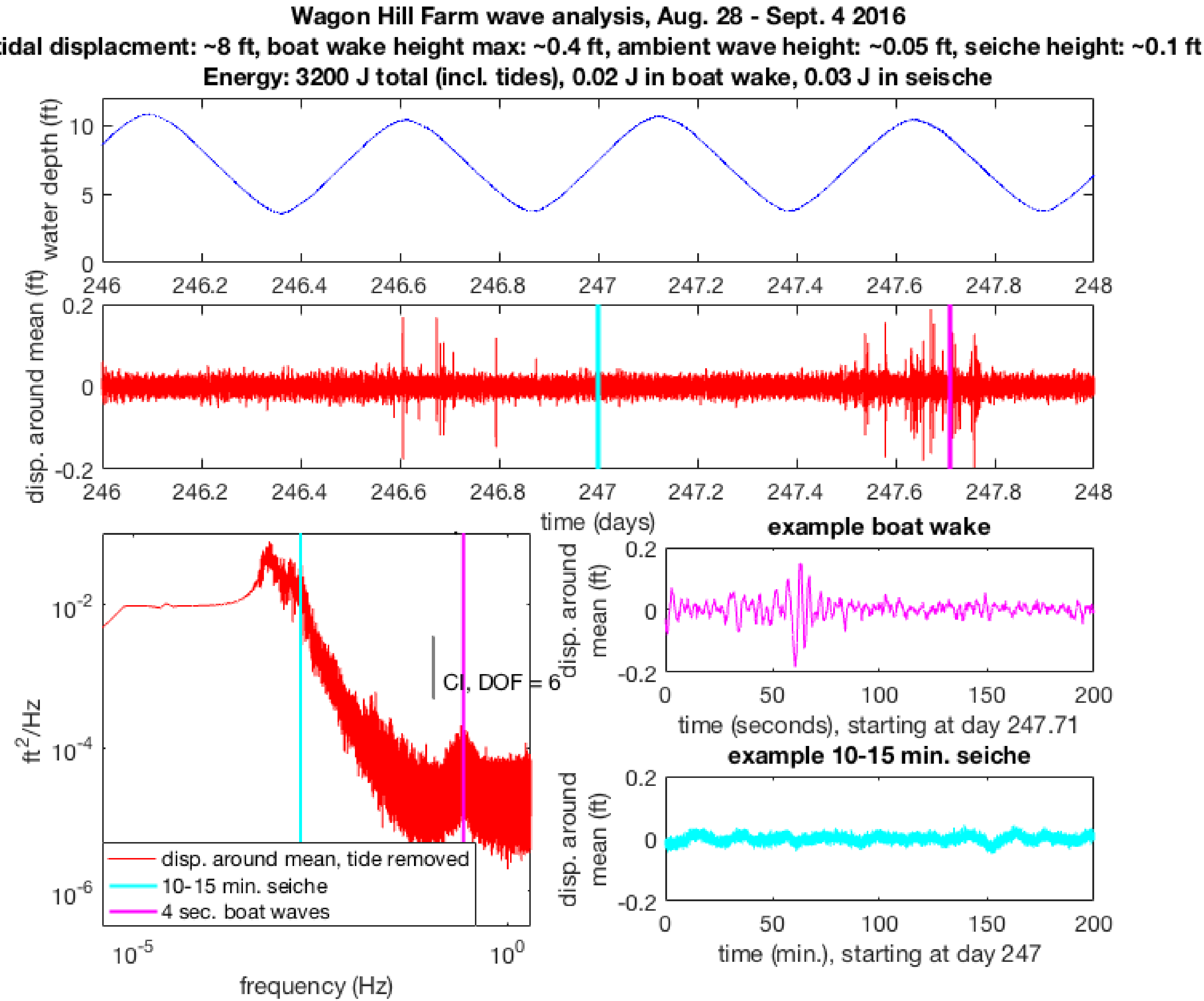


Erosion Rate (ft/yr)

	upper	lower
Average	0.208	0.148
Minimum	0.000	0.000
Median	0.129	0.054
Maximum	0.875	0.930

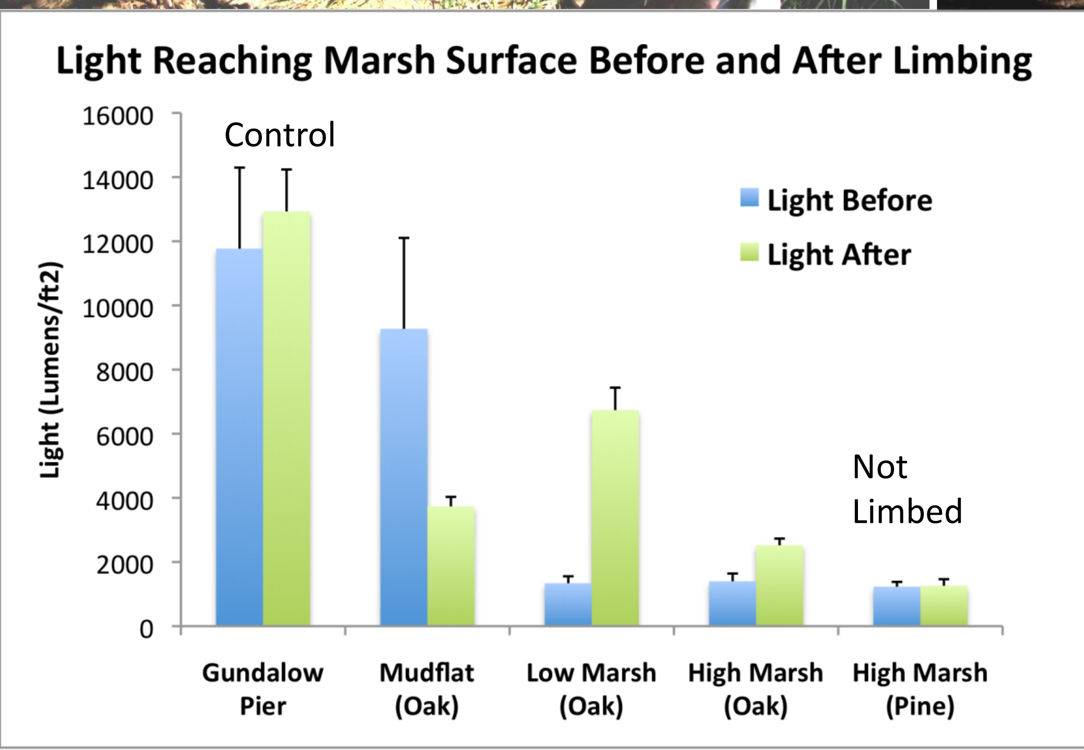
Foot Traffic and Boat Waves

Observed Erosion Most Tidal Cycles

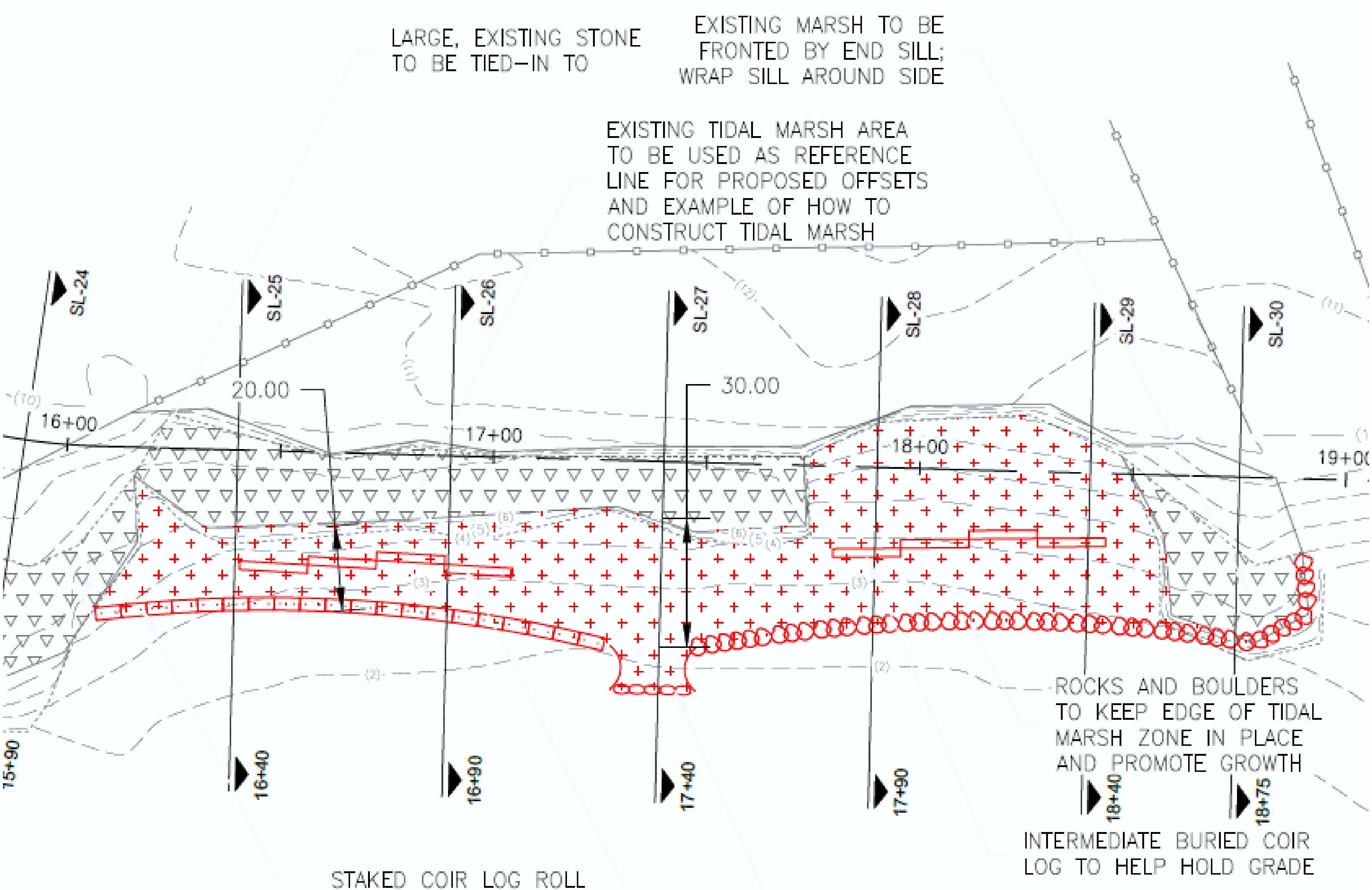


Wagon Hill Farm wave analysis, Aug. 28 - Sept. 4 2016
tidal displacment: ~8 ft, boat wake height max: ~0.4 ft, ambient wave height: ~0.05 ft, seiche height: ~0.1 ft
Energy: 3200 J total (incl. tides), 0.02 J in boat wake, 0.03 J in seische
water depth (ft)
disp. around mean (ft)
time (days)
example boat wake
disp. around mean (ft)
time (seconds), starting at day 247.71
example 10-15 min. seiche
time (min.), starting at day 247
ft^2/Hz
CI, DOF = 6
disp. around mean, tide removed
10-15 min. seiche
4 sec. boat waves
frequency (Hz)

Light can be a big issue for plants



Potential First Phase - Plan



Present Profile Concept

Conclusions

- Recognize limited growing season
- Difficulty increases with tidal range and physical exposure to shear stress from waves ***and ice***
- Be aware of conditions that can reduce success: shade and animals (geese, crabs, snails, people)
- Consider management (including people management) at the landscape scale

Thank You!