Living Shorelines 201

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NROC ENGINEERING LIVING SHORELINES IN NH WORKSHOP
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Overview of Talk

- Definitions
- Shoreline issues addressed by living shoreline solutions
- Driving forces resulting in erosion
- Erosion resisting forces
- Vegetation
- Shoreline ecosystems
- Regulations
- Challenges of northern shoreline projects
- Where to Use
- WHF data to date
- Measures of success
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)
What Is Not “Living” Shoreline?

- Bulkhead
- Seawall
- Revetment
- Groins
- Breakwater
- Sills
- Composite

  However some may be components of living shoreline systems
Definitions of nearshore zones and legal ownership for a typical coastal zone

NRC, 2007, Mitigating Shore Erosion Along Sheltered Coasts

G. WILLIAM PURDIE & a.
v. NH ATTORNEY GENERAL,
1999 - MHW
Common Sheltered Coasts

1. Beach

2. Marsh

NRC, 2007, Mitigating Shore Erosion Along Sheltered Coasts

3. Beach/Dune

4. Beach

5. Marsh

6. Beach/Dune
Shoreline Issues Addressed by Living Shoreline Solutions

- Erosion (from waves, currents—longshore drift, ice)
- Habitat loss (historic and recent losses of oyster reefs, salt marshes, tidal buffer zone)
- Sea level rise (salt marshes build with sea level rise—up to a point)
- Infrastructure protection (bridge abutments, roads, pipelines, sewers, etc.)
Elements leading to Erosion

- Waves
- Currents
- Exposed soils
- Tidal range
- Ice
- Foot traffic
- Pollution
- Subsidence
- Sea level rise
- Loss of sediment supply
- Loss of vegetation

Velocity
Shear stress
Erosion Resisting Elements

- Particle size and composition
- Vegetation (above and below ground)
- Slope
- Enhanced sediment supply
The Tide

NOAA/NOS/CO-OPS
Preliminary Water Level (A1) vs. Predicted Plot
8518750 The Battery, NY
from 2007/04/15 - 2007/04/16

Date/Time (Local)

Predicted WL
Observed WL
(Obs-Pred)
Tidal Definitions

- Mean Tide – average of high and low tide observations over a long time period
- Mean High Tide – average of just all the high tides over a long time period
- Mean Higher High Tide - the average of the higher high water height of each tidal day observed over a long time period
- National Tidal Datum Epoch – 19 years. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years
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).
Vegetation

- **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 goldenrod)
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.)
The Zones

Tidal Buffer

High Marsh

Low Marsh

2017 Tides at Dover Point, NH

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- Spring High
- MHHW
- Mean High
- MLHW
- Lowest High
- Mean
- Highest Low
- MHLW
- Mean Low
- MLLW
- Lowest
Shoreline Mudflat Ecosystems

Importance and Features

Mudflats provide habitat for invertebrates, crustaceans and birds. Microalgae on mudflats are important primary producers. Seagrass may occur on mudflats. Mudflats support a detrital food web.

Icon Key
- Molluscs
- Worms
- Phytoplankton
- Shrimp
- Wading birds
- Crabs
- Mud
- Sand

NRC, 2007, Mitigating Shore Erosion Along Sheltered Coasts
Shoreline Salt Marsh Ecosystems

**Importance and Features**

- Salt marshes provide important nursery habitat for crabs and fishes.
- Salt marshes act as a nutrient filter and are the site of nutrient cycle.
- Salt marshes support high primary production.

- Seagrasses may or may not occur adjacent to marshes.
- Kelp and their associated organisms may occur offshore of salt marshes.

**Icon Key**

- Native marsh grass
- Birds and waterfowl
- Kelp
- Sea otter
- Kelp associated fauna

NRC, 2007, Mitigating Shore Erosion Along Sheltered Coasts
Shoreline Bluff Ecosystems

Importance and Features

Sediment breaks off the cliff. As a result, bluffs are an important source of sediment. Groundwater seepage undermines the integrity of the bluff.

Bluffs provide habitat for burrowing organisms such as rabbits and insects. Flats adjacent to bluffs serve as habitat for molluscs, worms, birds and crustaceans.

Icon Key

- phytoplankton
- grasses
- rabbits
- insects
- birds
- molluscs
- worms
- shrimp
- crabs
- soil
- sand

NRC, 2007, Mitigating Shore Erosion Along Sheltered Coasts
Where to Use Living Shorelines

- Living shorelines are effective primarily in sheltered, low- to mid-energy coasts (see the 2007 National Research Council Report entitled “Mitigating Shore Erosion along Sheltered Coasts”). (COE NWP, 2016)
  - Marshes
  - Mangroves
  - Nearshore coral reefs
  - Seagrass beds
  - Oyster reefs
  - Sand beaches
  - Dunes
Laws and Regulations

- Public Trust Doctrine (Martin v. Lessees of Waddell, 41 U.S. 367 (1842) and Shivley v. Bowlby, 152 U.S. 48 (1894)).
- Rivers and Harbors Act of 1899
- Federal Water Pollution Control Act (FWPCA; Clean Water Act) of 1972
Challenges of northern shoreline projects

- Low light
- Short growing season
- Large tidal range
- Ice
The Constructed Shoreline Spectrum

NATURE-BASED
NON-STRUCTURAL

HYBRID
NON-STRUCTURAL + STRUCTURAL

HARD
STRUCTURAL MAJORITY

MARSH PLANTING
OYSTER BREAKWATER
MARSH TOE REVETMENT
LIVE CRIB WALL
Case Study – Salt Marsh Restoration

- Wagon Hill Farm, Durham, NH
Ellen Snyder ponders erosion at a site visit
Change from 1992 to 2015
Low Tide
Observed Erosion Most Tidal Cycles
Erosion Pins Monitored Quarterly
The Groundwater Well Installed in 2000
The 2009 Tree
Wagon Hill Farm wave analysis, Aug. 28 - Sept. 4 2016

Tidal displacement: ~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 seiche
“Softer” Edge

Can extend the sediment to avoid hard edge, but cannot grow anything over most of the fill. Would most likely erode.
Potential First Phase - Plan

Anchored logs
Root wads
Coir logs
Crib wall
Rock
Profile Type 1 – Coir Log

- Bank to be slightly cut back where large undercut trees are felled.
- Intermediate, buried coir log roll at grade break to help prevent against erosion.
- Existing tidal marsh.
- Proposed coir mat pillows – coir mat rolled around sediment, staked into place, set top of coir pillows at 1.70'.
- Backfill with specified marsh fill top 1.5' will be of loam, and all lands will be planted and/or seeded with specified species.
Profile Type 2 – Root wads

Bank to be slightly cut back where large undercut trees are felled.

Intermediate, buried coin log roll at grade break to help prevent against erosion.

Proposed root wad toe protection; top of root wad shall be placed at 1.70'.

Backfill with specified marsh fill; top 1.5' will be of loan, and all lands will be planted and/or seeded with specified species.

Existing ground.
Profile Type 3 – Crib wall

Bank to be slightly cut back where large, undercut trees are felled.

Intermediate, buried coir log roll at grade break to help prevent against erosion.

Proposed log cribbing toe protection; top of log crib shall be placed at 1.79'.

Backfill with specified marsh fill. Top 1.5 will be of loam, and all lands will be planted and/or seeded with specified species.
Profile Type 4 - Rock
Coir Logs and Root Wad
Living Shorelines for Engineers

David “Flotsam” Burdick and Gregg “Mudflat” Moore, Jackson Estuarine Lab, Tom “Klondike” Ballestero, Civil and Environmental Engineering, University of New Hampshire
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)
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
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
Figure 4. Conceptual model of salt marsh (Cahoon and Lynch http://www.pwrc.usgs.gov/set/).
The Case for Building Salt Marshes into Living Shorelines

- What functions and values are lost?
  - Plant productivity, food web support, 2° aquatic production, biodiversity
  - Nutrient and sediment removal from water
  - Ability to grow with sea level rise
  - Ability to reduce wave energy and heal following storms
  - Carbon storage
  - Aesthetic value
The Case for Building Salt Marshes into Living Shorelines

- Loss of 30% of historical salt marshes
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- Salt marshes protect, survive and heal following storms
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- SO . . . living shorelines are needed if we are to:
  - 1) Protect existing marsh where needed
  - 2) Create new marsh to replace historic and new losses
  - 3) Protect eroding shorelines
SEAWALL

SAGE, 2016, Natural and structural measures for shoreline stabilization
The Case for Living Shorelines along Beaches (and Dunes)

- Loss of most beach/dune systems
- Future for valuable beaches, businesses, residences, uncertain
- Potential losses from storms high
- The wider and taller the dune, the greater protection
- Dunes are needed to store sand onshore for the loss/rebuilding cycle
Dune Restoration

Fences and plants collect sand for onshore storage

- Sacrificial
- Reduce need for $$ nourishment
- Rip-rap / seawalls cannot store sand
The Case for Building Dunes

What functions / values are lost Compared to Seawall?

- High value recreational areas (beaches)
- Plant productivity, food web support, $2^\circ$ ary production, biodiversity (ESA – plovers)
- Ability to grow with sea level rise
- Ability to reduce wave energy and heal following storms
- Aesthetic value

What functions lost Compared to Nourishment Alone?

- Plant productivity, food web support, $2^\circ$ ary production, biodiversity (ESA – plovers)
- Ability to reduce wave energy and heal following storms
- Aesthetic value
Monitoring

- Survey
- Erosion pins
- Plant density and abundance by species
- Soil particle size distribution
- Soil carbon and accretion
- Wildlife
Inspection

- Gullyng and other signs of erosion
- Invasive species
- Nuisance species
- Plant mortality
- Wrack
- Ice damage
Maintenance

- Repair gullies
- Improve/enhance drainage
- Sill repair
- Replant/reseed
What do we still need to find out about LS and how can engineers help us?

How much light is needed for ‘healthy’ salt marsh to grow?

What is the best plant density to use in New England?

What species of plants should be used in the tidal buffer to enhance marsh migration?
Cutts Cove
Rip Rap Armor at Cutts Cove
Cutts Cove Concept
Enhanced Mudflat -shell from oyster conservationist and recycling program
Proposed Cutts Profile

- **Existing Mud Flats**
  - From the toe of the lower low marsh zone, the dune rock shall be placed starting at a high elevation of 1.00 feet, stacked down at approximately 4:1 slope until reaching the floor elevation of the mud flats at that location. The existing mud flats are to be left undisturbed whenever possible.

- **Lower Low Marsh Zone**
  - The lower low marsh zone is to be approximately 20 feet wide with the landward toe at an elevation of 2.33 feet and a seaboard elevation of 1.50 feet.

- **Upper Low and High Marsh Zone**
  - The upper low and high marsh zones occupy approximately 27 feet landward of the lower low marsh zone and shall be set to a low elevation of 2.33 feet and a high elevation of 5.67 feet.

- **Tidal Buffer Zone**
  - The tidal buffer zone shall look at the landward side of the high marsh zone, starting at an elevation of 5.67 feet and shall be graded upwards at a 3:1 slope until it reconnected with existing ground.

- From the high marsh zone, grade up at a 3:1 slope until reaching the existing ground.
- Typical elevated fill grade from 8'-0" feet horizontal and up to an elevation of around 90'-0".
- All cut from existing site may be used as fill in the marsh occupation zone, cut fill as a base course below the 1.50' of imported topsoil fill and only if free of invasive species.

- The top 1.5' of fill material in the low and high marsh zones is to be of imported topsoil to promote plant growth. Refer to the notes sheet 20 for details.

- Example of where the dune rock may be found at the toe of the existing vegetation zone. The dune rock shall be placed in the fill of the low marsh zone. The dune rock shall be placed in the fill of the low marsh zone.

- Transplant the existing dune rock from the toe of the existing vegetation and toe of the proposed lower marsh toe to help arrest erosion.

- The same course of the marsh vegetation, native to the site, the removed dune rock and native to the site of imported fill that contains the objection specified in the notes sheet 20. All material must be clean and free of invasive species.
Cutts Profiles and Ecosystems

![Graph showing elevation against distance from mudflat](image)

- Elevation NAVD (ft)
- Distance from mudflat (ft)

- Existing Rip-rap Profile
- Tidal Buffer Zone
- Upper Low and High Marsh
- Lower Low Marsh
- Rock Sill
Tides and existing marshes in Cutts Cove

[Graph showing tides and marsh elevations with labels for Rock Sill, Lower Low Marsh, Upper Low and High Marsh, Low Marsh, and High Marsh.]

- Mudflat
- Low Marsh
- High Marsh
- Tidal Buffer Zone
- Distance from mudflat (ft)
- Elevation NAVD (ft)
Measures of Success

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

- **Maintenance**
Winter Can Be Cruel