STATE OF SCIENCE & ENGINEERING FOR NATURAL AND NATURE-BASED FEATURES

Julie Rosati
Jane Smith
Mary Bryant

US Army Corps of Engineers
Engineer Research & Development Center
Coastal & Hydraulics Laboratory

Julie.D.Rosati@usace.army.mil
Jane.M.Smith@usace.army.mil
Mary.A.Bryant@usace.army.mil

ERDC
Engineer Research and Development Center

US Army Corps of Engineers ®

U.S.ARMY

OUTLINE

Motivation

Discuss each type of NNBF

- Provide examples with summary information about each type
- Describe ongoing USACE Research
- Summarize needs & what we know about each type

Next steps

- Identify priority gaps; obtain your perspective on needs & gaps; discuss collaboration opportunities

NATURAL AND NATURE-BASED FEATURES AT A GLANCE

Dunes and Beaches

Vegetated Features (e.g., Marshes)

Oyster and Coral Reefs

Barrier Islands

Maritime Forests/Shrub Communities

MOTIVATION – WHY STUDY NNBF?

Coastal communities are vulnerable to coastal hazards

NNBF are desired components of coastal risk reduction projects

Engineering performance of NNBF must be quantified

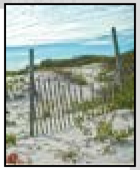
- Design, inter-annual maintenance, and adaptation
- Temporally: seasons…years…decades

USACE, 2013. *Coastal risk reduction and resilience: Using the full array of measures.* CWTS 2013-3. Washington, DC: U.S. Army Corps of Engineers, Directorate of Civil Works.

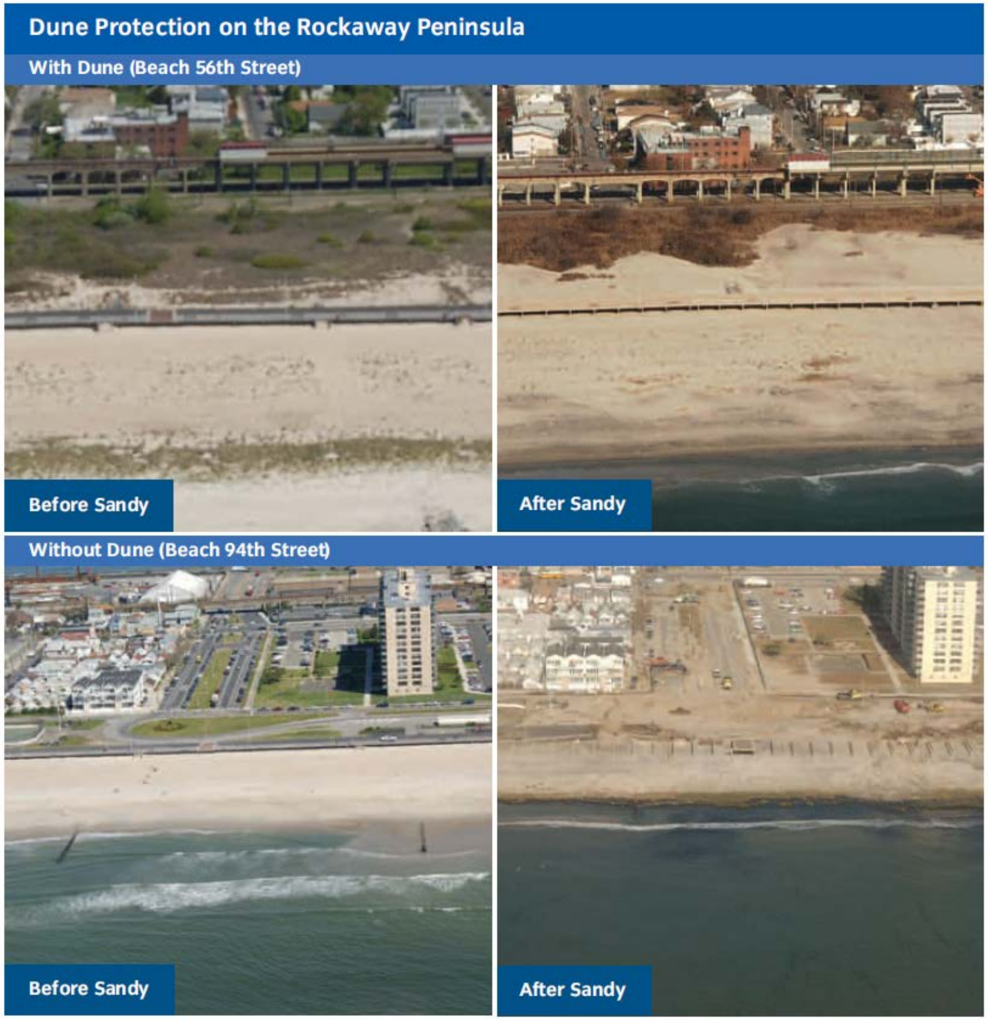
Bridges et al., 2015. *Use of Natural and Nature-Based Features (NNBF) for Coastal Resilience*. ERDC SR-15-1. U.S. Army Engineering Research and Development Center, Vicksburg, MS. 479 pp.

US Army Corps of Engineers ® ERDC INNOVATIVE SOLUTIONS for a safer, better world

DUNES AND BEACHES: EXAMPLES



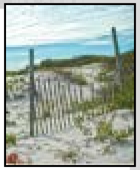
- Recognized as the first line of defense for reducing storm impacts to landward infrastructure
- Qualitative (and in some cases quantitative) performance documented (e.g., Post-Sandy Performance Evaluation Study USACE, 2013)
- Performance governed by dune height/volume and beach width; vegetation reinforces stability



Credit: NOAA

POCs: USACE New York District, http://www.nan.usace.army.mil/Missions/Civil-Works/Projects-in-New-York/East-Rockaway-Inlet-to-Rockaway-inlet-Rockaway-Beach/

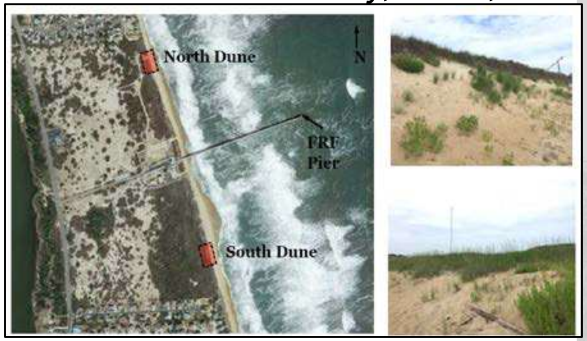
DUNES AND BEACHES: RESEARCH



Integrating dune ecological & morphological processes

- Morphology evolves during erosional events such as tropical and extratropical cyclones
- Coastal vegetation (above and below-ground biomass) reduces erosion during storms, and enhances recovery
- Over long periods, vegetation can accelerate beach and dune accretion through feedback mechanisms

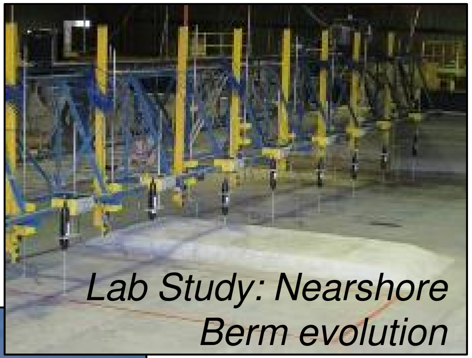
Monitoring Dune Evolution, Field Research Facility, Duck, NC



POC: Katherine.L.Brodie@usace.army.mil

Beneficial use of dredged material

- Monitoring sediment placed in the nearshore through laboratory/field studies (e.g., Ft. Myers and Vilano Beach, FL)
- Documenting separation of fines during the dredging process for on-beach placement

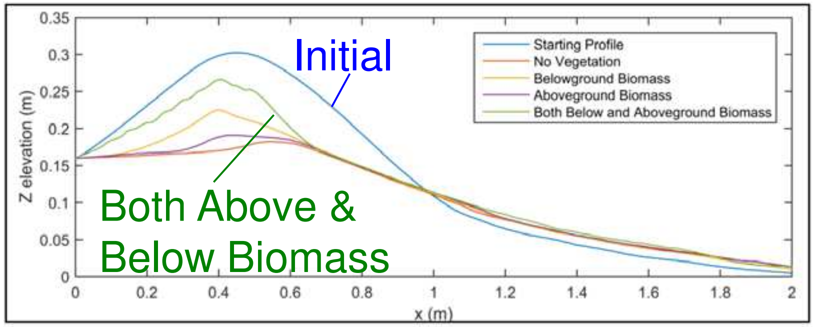


Lab Study: Nearshore Berm evolution

POC: Duncan.B.Bryant@usace.army.mil

Laboratory, field, and numerical studies ongoing

Lab Study: Benefits of Above- and Below-Ground Dune Biomass



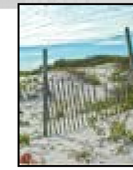
POC: Duncan.B.Bryant@usace.army.mil

Monitoring Nearshore Berm, FL

POC: Katherine.E.Brutsche@usace.army.mil

ERDC
INNOVATIVE SOLUTIONS for a safer, better world

DUNES AND BEACHES: NEEDS AND WHAT WE KNOW

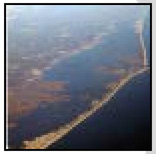


- Benefits are documented in site-specific examples; many are anecdotal
  - Would there be benefit in synthesizing performance in a summary document?
- Performance is governed by dune height/volume & beach width
  - Role of vegetative cover?
- Analytical relationships exist for x-shore & planview evolution
  - Improve to account for vegetative characteristics
- Dune vegetation decreases erodibility and ultimately likelihood for overwash and breaching
- USACE models being adapted to account for vegetation and improve representation of **recovery**; open-source models are being validated
- Needs:
  - Link cross-shore and longshore processes
  - Field verification of laboratory findings on benefits of below-ground biomass, different types of vegetation and seasonal/multi-season variability

US Army Corps of Engineers®

ERDC INNOVATIVE SOLUTIONS for a safer, better world

ISLANDS & EMERGENT BERMS: EXAMPLES (1/2)



Mississippi Coastal Improvement Program (MsCIP): Barrier Island Restoration of Ship Island, MS

USACE Mobile District's comprehensive study:

– Barrier island restoration for island stability, wave, surge, and shoaling reduction, preservation of Mississippi Sound salinity, and habitat (subaerial & subaqueous)

MsCIP Restoration of Ship Island, MS

Nearshore sand placement, Assateague Island, MD

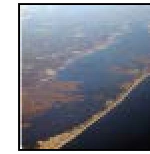
Assateague Island, MD

USACE Baltimore district mines Ocean City Inlet ebb shoal and places sediment in the nearshore

- Provides habitat & reduces potential for breaching

US Army Corps of Engineers
ERDC INNOVATIVE SOLUTIONS for a safer, better world

ISLANDS & EMERGENT BERMS: EXAMPLES (2/2)



Horseshoe Bend, Atchafalaya River, LA

USACE New Orleans District regularly dredges navigation channel, but options to place sediment have become limited

- Placed sediment such that river flow created ~ 35 ha island over 3 years
- Reduced shoaling in navigation channel and created habitat

Island Creation, Horseshoe Bend, LA

26 Terra et Aqua | Number 140 | September 2015

BURTON SUEDEL, JACOB BERKOWITZ, SUNG-CHAN KIM, NATHAN BEANE, ELIZABETH SUMMERS, DARRELL EVANS AND JEFFREY CORBINO

CREATING HORSESHOE BEND ISLAND, ATCHAFALAYA RIVER, LOUISIANA

ABSTRACT

The capacity for the placement of shoal material dredged from Horseshoe Bend at eight wetland development sites located along the river's bank lines adjacent to the channel was nearly exhausted in 1999. To meet the anticipated disposal requirements for future channel maintenance, several alternatives were examined. The choice was made for strategic placement of dredged sediment mid-river and beginning in 2002, strategic placement of the sediment dredged from Horseshoe Bend occurred at the mid-river open water placement area. This contributed to the development of an approximately 35 ha island mid-river. This practice of strategically placing dredged sediments upriver of a naturally occurring island aided the island's growth and produced greater environmental benefits than otherwise would be present using more conventional placement practices.

This article originally was presented at the Western Dredging Association and Texas A&M University Center for Dredging Studies' "Dredging Summit and Expo 2015", Houston, Texas, USA, June 22-25, 2015 and received an award for the best project on an environmental topic. It appears here in a revised form with permission.

INTRODUCTION

During the 1990s, placement of shoal material dredged from Horseshoe Bend occurred at eight wetland development sites located along the river's banklines adjacent to the channel. Capacity of these placement sites was nearly exhausted by 1999. Thus, to meet the anticipated disposal requirements for future channel maintenance, the US Army Corps of Engineers New Orleans District evaluated three placement alternatives:

1. convert the wetland development sites into upland disposal areas;
2. open water placement of dredged material via a long-distance pipeline into the open waters of Atchafalaya Bay; and
3. mounding of material at mid-river open water placement sites within a 350-acre (142 ha) area immediately adjacent to the navigation channel and upriver of a small naturally forming island.

The third alternative was selected on a demonstration basis to investigate the impacts of mid-river placement on shoaling trends downriver of the site. Beginning in 2002, strategic placement of the sediment dredged from Horseshoe Bend occurred at the mid-river open water placement area. Placement of between 0.5 to 1.8 million cubic yards of sediment was conducted every 1 to 3 years which influenced and contributed to the development of an approximately 35 ha island mid-river. The practice of strategically placing dredged sediments upriver of a naturally occurring island was conducted to aid the island's growth to produce greater environmental benefits than otherwise would be present using more conventional placement practices.

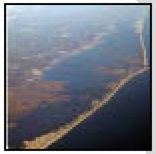
Above: The river island at Horseshoe Bend on the lower Atchafalaya River, Louisiana is being self-designed by dredged sediment strategically placed upriver (lower right), allowing the river's energy to disperse the sediment, which contributes to the natural growth of the island (Photography by Wings of Angles).

GOALS AND OBJECTIVES

To help understand how and why the island was formed over the last 12 years, the USACE conducted studies to better understand the hydrology of the river used to transfer the mounded material onto the island. Information regarding ecosystem classification and mapping and floral and faunal composition of the island were conducted to document environmental and other benefits being realised. In addition, multiple moderate and high resolution aerial photographs available from prior to 2002 to the present clearly documented the growth of the island. In Figure 1 the changes from 2010, 2011 and 2012 can be seen.

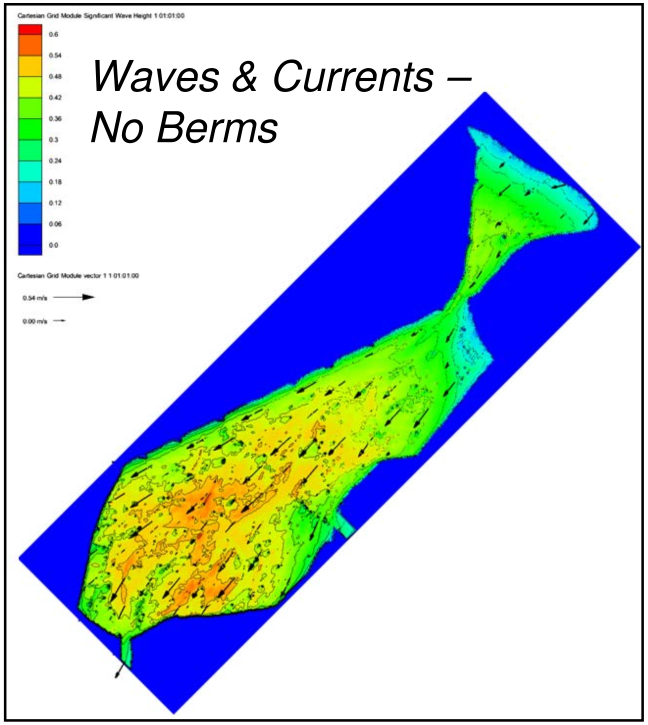
https://ewn.el.erdc.dren.mil/pub/Pub_2_Terra_et_Aqua_September2015.pdf

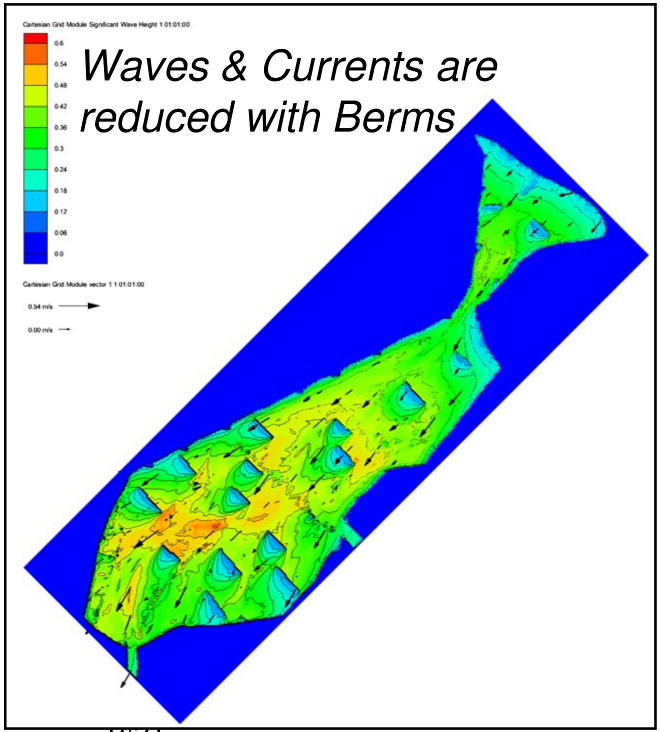
ISLANDS AND EMERGENT BERMS: RESEARCH



Hamilton and Sears Point, San Pablo Bay, CA

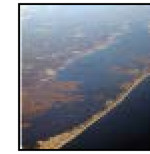
- Constructed emergent berms to accelerate wetland sedimentation during tidal inundation
- Ongoing monitoring
- Numerical modeling to evaluate berm/mound designs





POC: Joe.Z.Gailani@usace.army.mil

ISLANDS AND EMERGENT BERMS: NEEDS AND WHAT WE KNOW

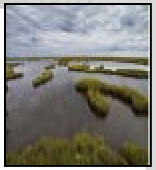


Barrier islands widely accepted as ‘first line of defense’ and can reduce waves & water levels by 10-25% in some cases; smaller islands and emergent berms to lesser degrees

Needs:

- Criteria for engineering performance
  - Propensity for barrier & berm breaching and overwash as a function of elevation, width, land use, vegetative cover & episodic forcing
- Natural morphology change of islands/berms over decadal-scales
- Validation for sediment trapping and vegetation succession
- Scalability to, and recovery from extreme events

VEGETATED FEATURES: EXAMPLES



Natural & restored marshes, seagrasses, vegetated shores

Studies indicate:

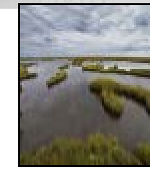
- Surge reduction (submerged)
- Wave attenuation (emergent)
- Velocity reduction
- Net trapping of sediment

Well documented compared to other features (over 70+ papers)

US Army Corps of Engineers®

ERDC INNOVATIVE SOLUTIONS for a safer, better world

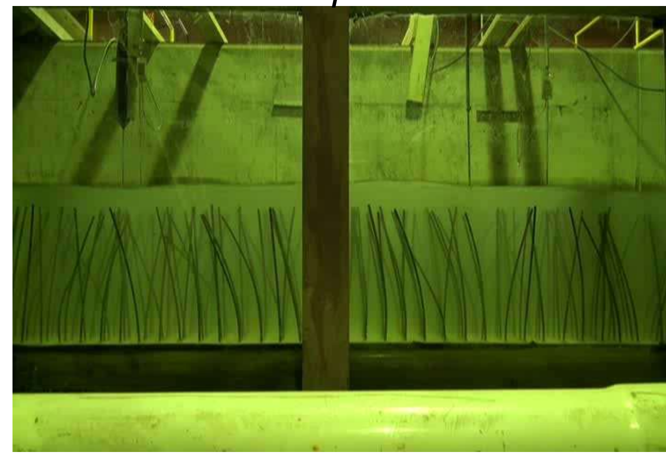
VEGETATED FEATURES: RESEARCH



Laboratory study

- Quantify wave attenuation of wetland plants
- Focus on idealized smooth cordgrass (polyolefin tubing)
- Stem density and plant submergence related to degree of wave attenuation
- Application of vegetation in spectral wave model STWAVE shows significant reductions in wave height on project scales

Lab: Quantify wave attenuation from plants

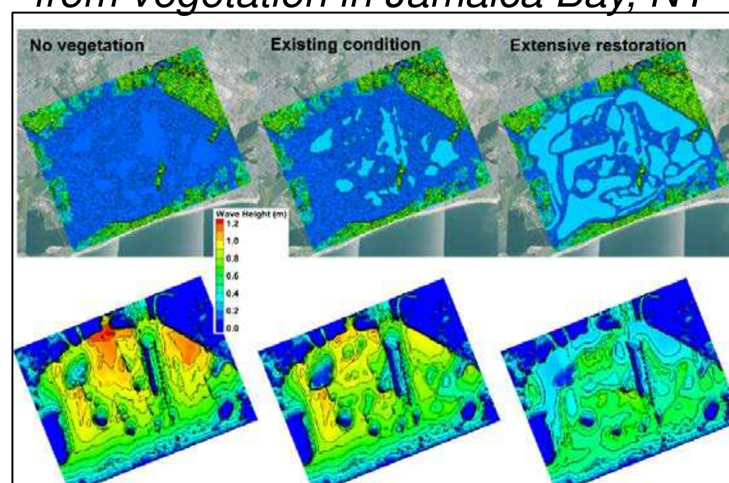


Collaboration with Northeastern Univ,, Louisiana State Univ., and Univ. of South Alabama

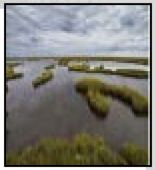
- Literature review of knowledge gaps on wave and surge-vegetation interactions, and marsh edge erosion
- Monitoring wetland erosion, Terrebonne Bay, LA
- Implementing vegetation energy dissipation model in CSHORE

[POCs: Jane.M.Smith@usace.army.mil; Mary.A.Bryant@usace.army.mil](mailto:Jane.M.Smith@usace.army.mil)

STWAVE: Wave height reduction from vegetation in Jamaica Bay, NY



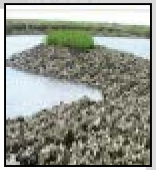
VEGETATED FEATURES: NEEDS AND WHAT WE KNOW



- Unclear how plant mimics relate to live vegetation
- Scalability to extreme events
- Seasonal/multi-seasonal variability of vegetation, e.g.,
  - *S. alterniflora* causes twice the reduction at maximum height in early fall compared to shorter height in early summer
- Wetlands
  - Violent storms contribute less than 1% to long-term salt marsh erosion rates
  - More susceptible to variations in mean wave energy rather than changes in extremes
  - Constructed wetlands can provide similar benefits to natural features; time scales differ
  - Emergent vegetation more effective at reducing waves as compared to submerged
- Time scales of recovery after storms
- Improvement to simplified/empirical model physics
- Criteria for engineering performance
- Change in functionality due to sea level rise
  - Fate of marsh is dependent on the ability of lower marshes on sediment trapping
  - Reduced sediments may be more deleterious to marsh health than sea level change

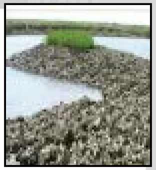
US Army Corps of Engineers® ERDC INNOVATIVE SOLUTIONS for a safer, better world

OYSTER AND CORAL REEFS: EXAMPLES



- Natural and constructed
- Reduce wave runup
- Provide habitat
- Wave dissipation
- Shoreline protection

OYSTER AND CORAL REEFS: NEEDS AND WHAT WE KNOW



Can dissipate waves, reduce runup, and provide habitat

Can out-perform comparable mud-flat, and keep pace with sea level rise

Numerical models can characterize engineering performance

Needs:

- Design guidance for placement of oyster/coral balls for maximizing both ecological and engineering benefits
  - Criteria for engineering performance (capacity to reduce waves, water levels as function of environmental forcing & reef parameters)
- Understand ability to main functionality as function of sea level change, water quality, sedimentation, etc.
- Greater collaboration among ecologists, engineers, geologists and oceanographers

US Army Corps of Engineers ® ERDC INNOVATIVE SOLUTIONS for a safer, better world

MARITIME FORESTS & SHRUB COMMUNITIES: EXAMPLES

- Attenuation of waves, storm surge, small to medium tsunamis
- Bind and build soils through extensive root systems

MARITIME FORESTS & SHRUB COMMUNITIES: NEEDS AND WHAT WE KNOW

Majority of wave attenuation occurs over narrow band; e.g., doubling width ≠ double attenuation

Most effective in reducing water depth & velocities for fast-moving storms/tsunamis

Needs:

- Establish criteria for engineering performance
- Understand seasonal variability & permanence considering long-term climate variations and human impacts
- Quantify time scales of establishment and recovery after storms
- Improvements to simplified/empirical model physics

US Army Corps of Engineers®

ERDC INNOVATIVE SOLUTIONS for a safer, better world

ADDITIONAL ONGOING SUMMARIES OF NNBF

- **International NNBF Guidelines** (planned for 2020)

https://ewn.el.erdc.dren.mil/nnbf-guidelines.html International NNBF Guidelines Project

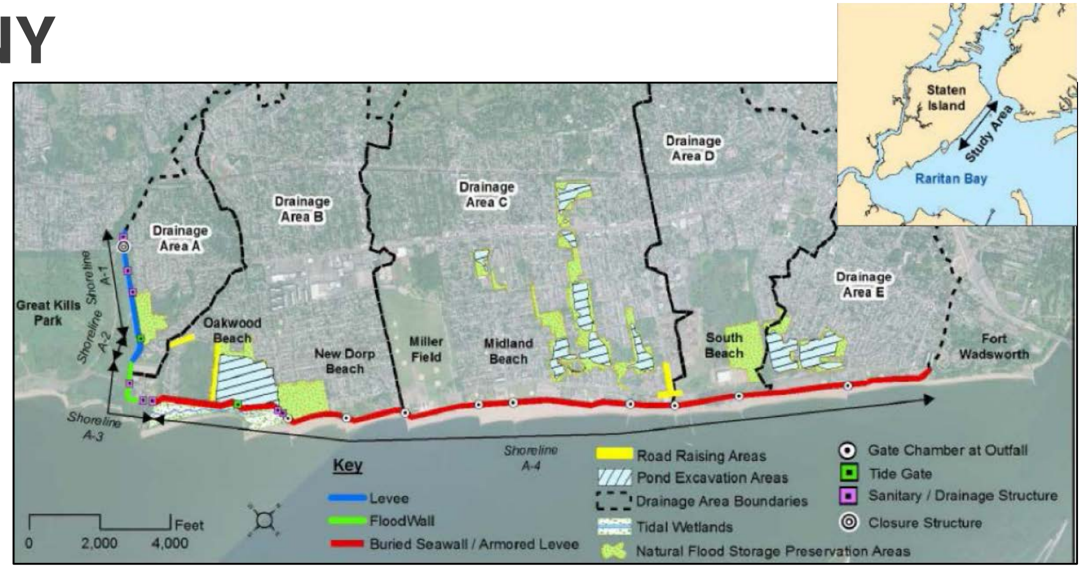
- **Electronic repository** of NNBF references in APAN (Public Access Network) (Fall 2018+)
  - *Organized by project phase & NNBF type; including keywords & summary*

Project Phase	NNBF Type
Planning	*Reference 1, 7*
Design	*Reference 2,6*
Construction	*Reference 2, 3*
Maintenance	*Reference 4*
Regulatory	*Reference 5,9*

- **USACE NNBF Roadmap** for R&D (Fall 2018+)
  - ✓ Purpose: provide a guide to focus future USACE research & development investments
    - *What do we know about each NNBF type?*
    - *What are gaps?*
    - *What are priorities for future research?*

US Army Corps of Engineers ERDC INNOVATIVE SOLUTIONS for a safer, better world

SYSTEMS APPROACH: HYBRID* PROJECT PLANNED FOR STATEN ISLAND, NY



Traditional structures:
Buried seawall, floodwall, coastal levee, floodwall, tidal gate

NNBF: *Natural storage, tidal wetlands, beach & dune system*

Other: *Raised roads, evacuated storage areas, drainage structures*

Designed to be flexible to adapt with sea level rise

**Hybrid: NNBF, traditional, and non-structural measures*

Future Adaptability of Recommended Plan for SLC Considerations

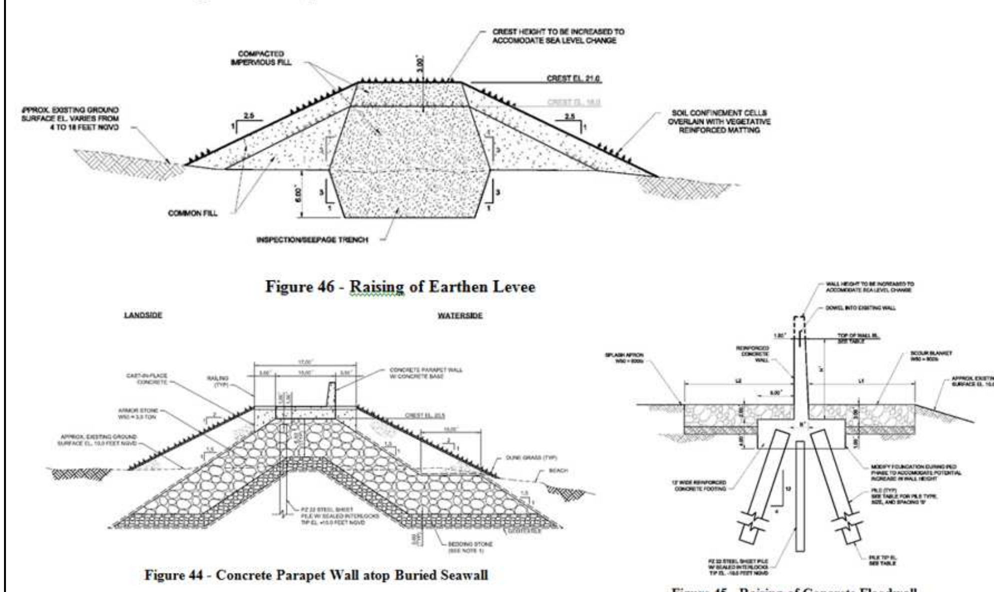


Figure 46 - Raising of Earthen Levee

Figure 44 - Concrete Parapet Wall atop Buried Seawall

Figure 45 - Raising of Concrete Floodwall

POCs: USACE New York District,
http://www.nan.usace.army.mil/Missions/Civil-Works/Projects-in-New-York/South-Shore-of-Staten-Island/

US Army Corps of Engineers® INNOVATIVE SOLUTIONS for a safer, better world

SUMMARY: RESEARCH NEEDS FOR NNBF

1. Document coastal engineering & ecosystem performance: seasons-years-decades; expand low-cost remote monitoring techniques
   a) Which types of NNBF are priority gaps and greatest need?
2. Develop Guidance
   a) Design, construction and environmental forcing criteria for successful performance (seasons to years)
   b) Long-term maintenance to sustain NNBF (years to decades) – consider changing precipitation, sea level, human infrastructure and usage
   c) Hybrid (combination traditional gray and NNBF) infrastructure
   d) Several types of NNBF in a “multiple lines of defense”, systems-approach
3. Develop methods to quantify social-economic benefits of NNBF
4. Validate predictions via integrated laboratory, field & numerical studies; Develop guidance for accurate representation of NNBF in lab/numerical
5. Communicate advances to research, state, local communities regularly
6. Quantify uncertainty associated with NNBF performance and predictive methods

Are there other needs and gaps?
Are these in approximate order of priority?
What are collaboration opportunities?

US Army Corps of Engineers® ERDC INNOVATIVE SOLUTIONS for a safer, better world

COLLABORATION OPPORTUNITIES

Long-term data documenting NNBF performance & maintenance requirements as a function of coastal forcing

- Seasonal to annual performance data also of interest
- Synthesis of beach & dune performance over decadal-scales

New collaborative monitoring opportunities

- Especially projects utilizing hybrid (“gray-green”) and combination-types of NNBF

Methods to quantify socio-economic benefits

- How are others monetizing these benefits?

What are some other opportunities?

US Army Corps of Engineers ® ERDC INNOVATIVE SOLUTIONS for a safer, better world