Engineering With Nature™

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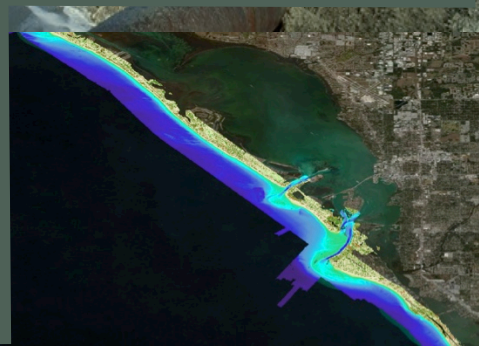
15 February, 2018



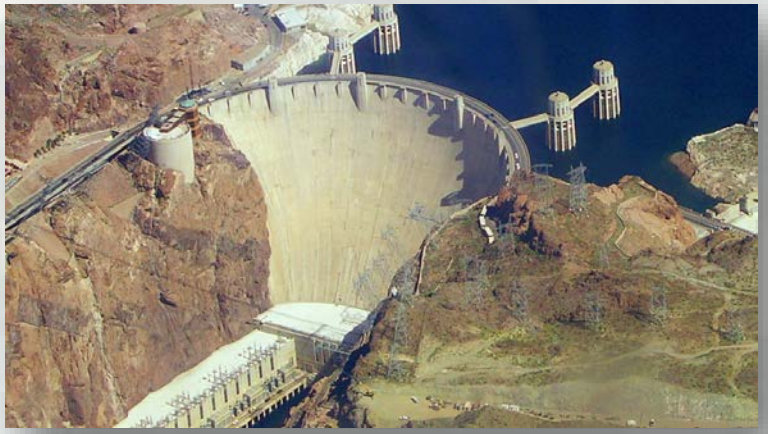
U.S. ARMY

US Army Corps of Engineers®

ERDC
Engineer Research and Development Center

1900-2000:
The Century of Infrastructure (US)

- 4,071,000 miles of roadway
  - 47,182 miles in the Interstate system
- 614,387 bridges
- 84,000 dams
- 30,000 miles of levee
- 25,000 miles of navigation channel
- >300 ports



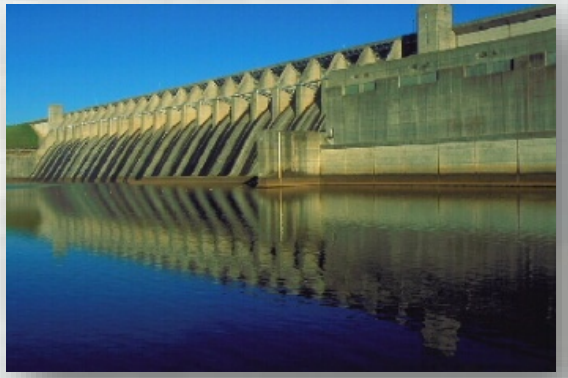
Cuyahoga River; Cleveland, OH

The 1970's: The Decade of Environmental Law and Regulation

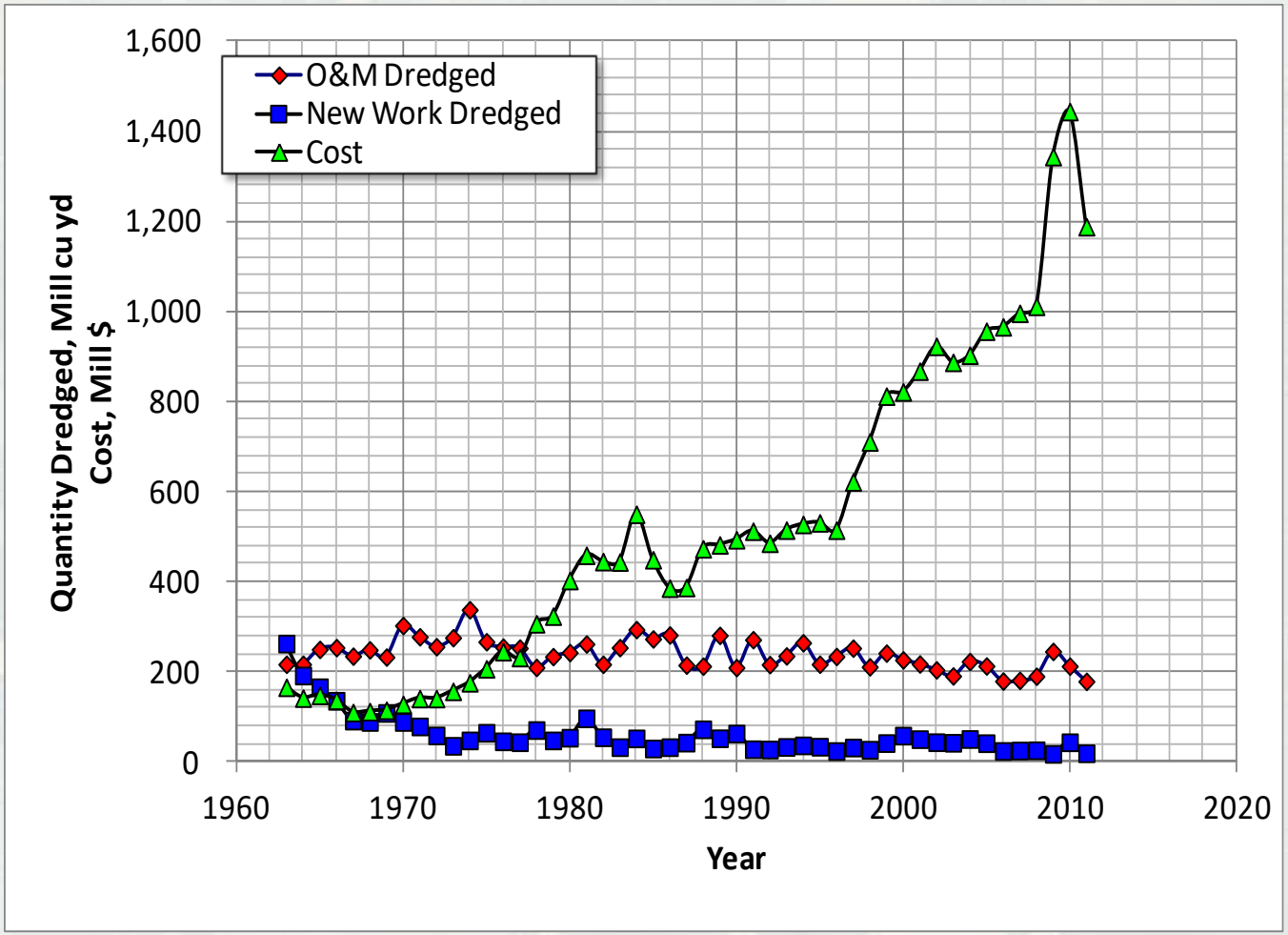
- National Environmental Policy Act of 1969
- Clean Water Act 1972
- Marine Protection, Research, and Sanctuaries Act of 1972
- Coastal Zone Management Act of 1972
- Endangered Species Act of 1973
- Resource Conservation and Recovery Act of 1976
- Comprehensive Environmental Response, Compensation and Liability Act of 1980

USACE Navigation Program: The Need for Efficiency

- USACE operates a lot of navigation projects
  - 1,067 coastal navigation projects
  - 13,000 miles of coastal navigation channels
  - 27 inland river systems with 12,000 miles of channels
  - 236 lock chambers at 192 lock sites
  - 929 navigation structures
  - 844 bridges
- Hundreds of projects in maintenance backlog



The Escalating Costs of Dredging



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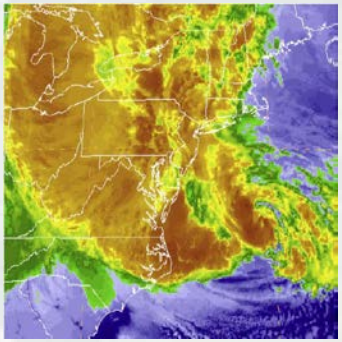
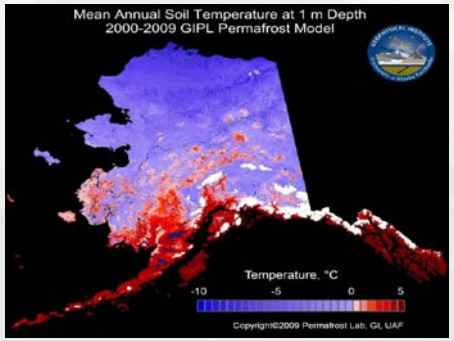
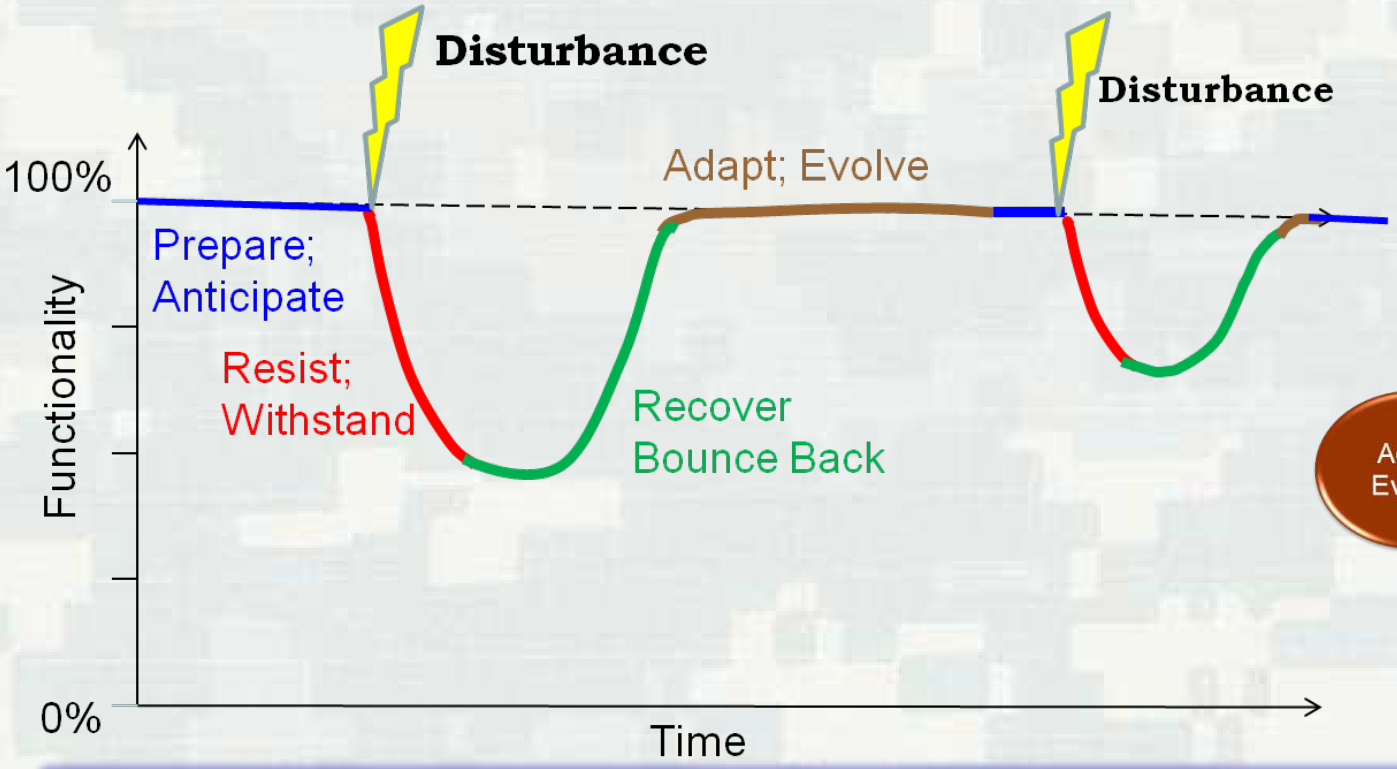
ERDC

BUILDING STRONG®

Innovative solutions for a safer, better world



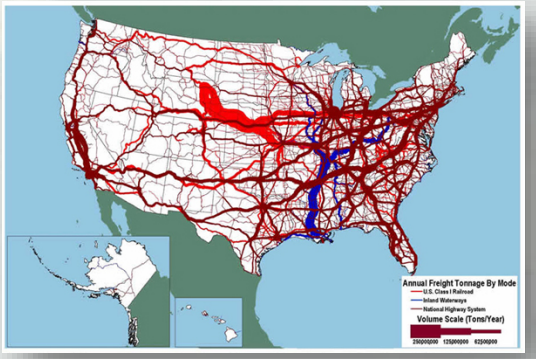




Resilience: the ability of a ***system*** to **Prepare for**, **Resist**, **Recover**, and **Adapt** to achieve functional performance under the stress of disturbances through time.

Domains of Resilience

Infrastructure / Engineering



Environment

Community

Creating Value through Alignment…

- What opportunities are there for achieving better alignment of natural and engineered systems?
  - Can improved alignment reduce risks to life, property and ecosystems?
  - What range of services can be produced through such alignment?
  - What are the science and engineering needs in order to achieve better alignment?

Sustainable Solutions Vision: "Contribute to the strength of the Nation through innovative and environmentally sustainable solutions to the Nation's water resources challenges."

Value and Use of Natural Systems

Following Hurricane Sandy:

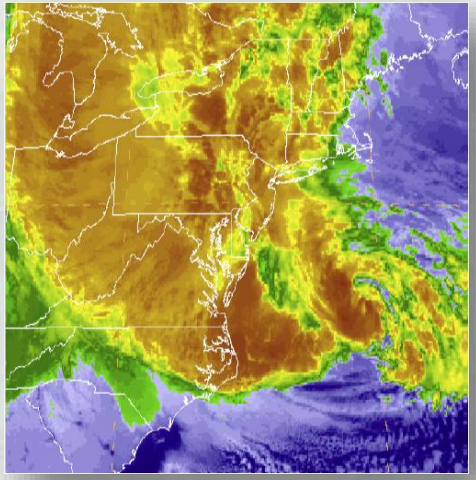
- Risk industry-based tools used to quantify the economic benefits of coastal wetlands
  - Temperate coastal wetlands saved more than $625 million in flood damages.
  - In Ocean County, New Jersey, salt marsh conservation can significantly reduce average annual flood losses by more than 20%.

COASTAL WETLANDS AND FLOOD DAMAGE REDUCTION

Using Risk Industry-based Models
to Assess Natural Defenses in the Northeastern USA

October 2016

UNIVERSITY OF CALIFORNIA SANTA CRUZ · The Nature Conservancy · Wildlife Conservation Society · LLOYD'S TERCENTENARY RESEARCH FOUNDATION

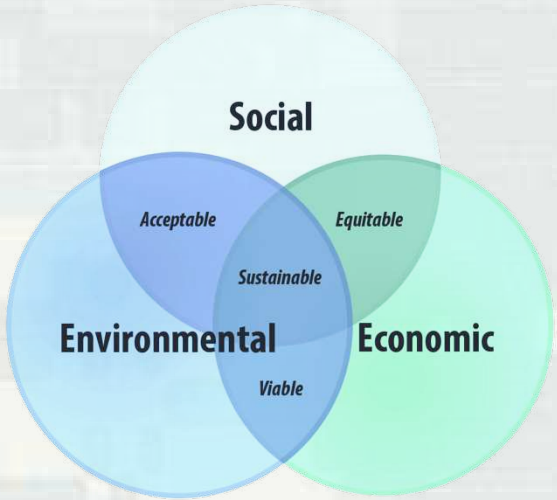


Engineering With Nature™…

…the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes.

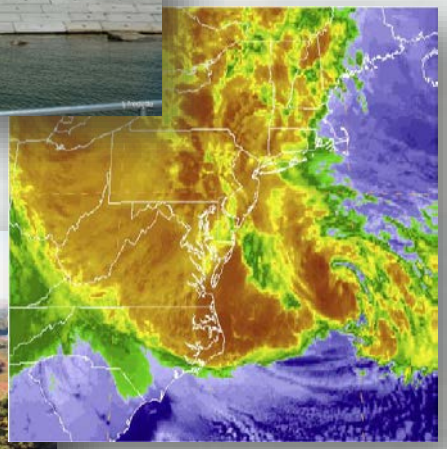
Key Elements:

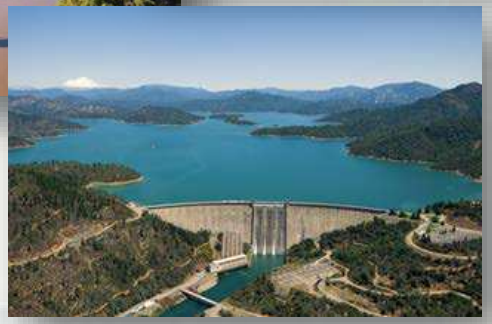
- Science and engineering that produces operational efficiencies
- Using natural process to maximum benefit
- Broaden and extend the benefits provided by projects
- Science-based collaborative processes to organize and focus interests, stakeholders, and partners



EWN Across USACE Mission Space

- Navigation
  - Strategic placement of dredged material supporting habitat development
  - Habitat integrated into structures
  - Enhanced Natural Recovery
- Flood Risk Management
  - Natural and Nature-Based Features to support coastal resilience
  - Levee setbacks
- Ecosystem Restoration
  - Ecosystem services supporting engineering function
  - “Natural” development of designed features
- Water Operations
  - Shoreline stabilization using native plants
  - Environmental flows and connectivity





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EWN Status

- *Engineering With Nature* initiative started within USACE Civil Works program in 2010.
  - Engaging across USACE Districts (23), Divisions, HQ; other agencies, NGOs, academia, private sector, international collaborators
    - Workshops (>20), dialogue sessions, project development teams, etc.
  - Guided by a strategic plan
  - Informed by focused R&D
  - Demonstrated with field projects
  - Advanced through partnering
  - Shared by strategic communications
  - Marking progress
    - 2013 Chief of Engineers Environmental Award in Natural Resources Conservation
    - 2014 USACE National Award-Green Innovation

www.engineeringwithnature.org

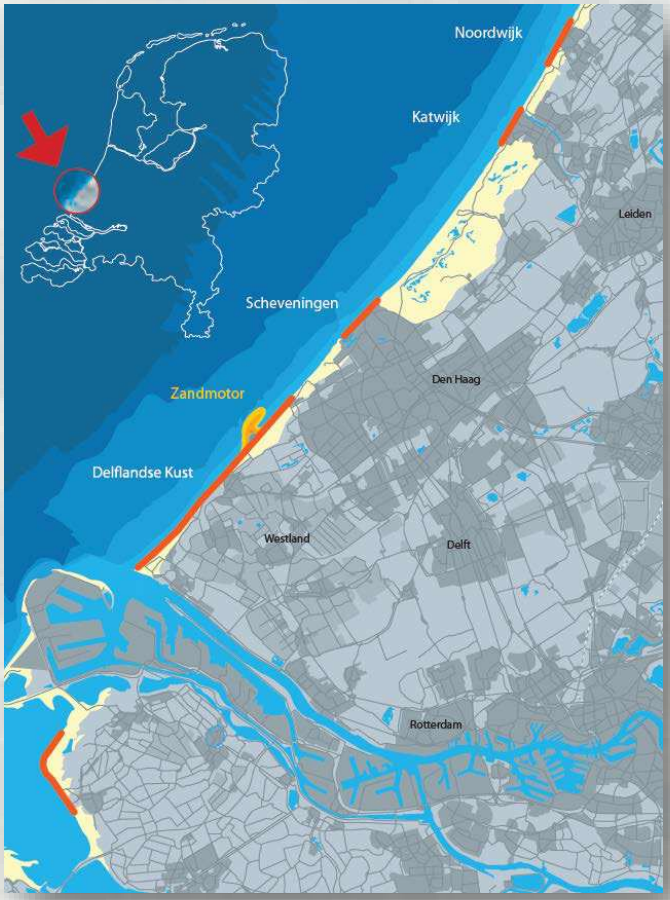
USACE Galveston, Buffalo, Philadelphia Districts: EWN "Proving Grounds"

- EWN Proving Ground Kick-Off Workshops
  - October (SWG) and December (LRB) 2014; June 2016 (NAP)
  - District, Division, EWN Leadership Team
- Identify opportunities to implement EWN across current and future programs and projects
- Emphasis on solution co-development

Noordwaard

Onehunga Bay Foreshore Restoration
Auckland, New Zealand

Dutch Sand Motor



- 2011 construction
- 21.5 mcm of sand

Chehalis Basin Floodplain Restoration

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BUILDING STRONG®

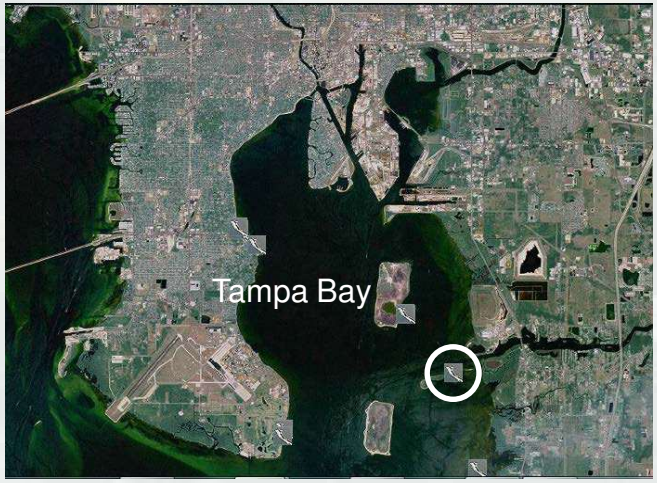
RAMBOLL ENVIRON

THE CHEHALIS TRIBE

Fort Pierce City Marina, Florida

Alafia Banks Bird Sanctuary, FL

- 8000 lb reef module breakwaters (930 ft)
- Shore protection for Audubon bird sanctuary islands
- Help restore oyster populations
- Provide habitat



www.reefball.org

Enhancing Ecosystem Value

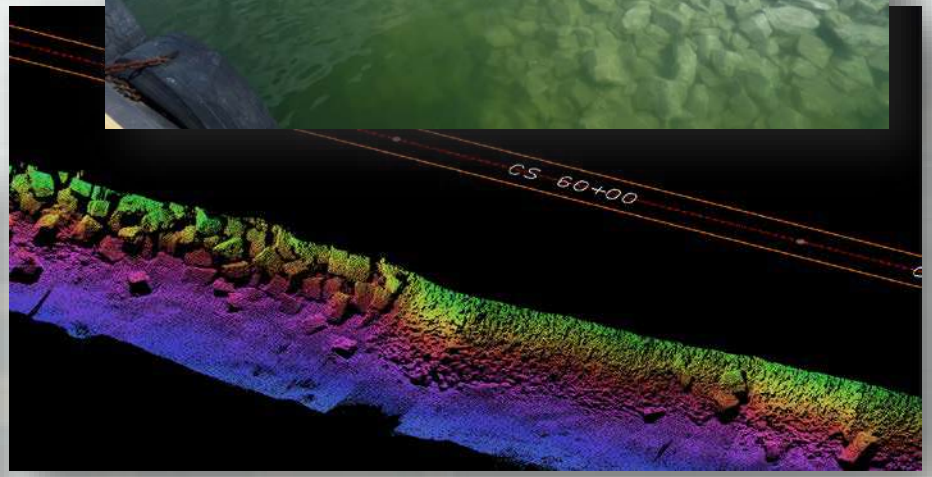
Upper Mississippi River Training Structures: Chevrons

Loosahatchie Bar, Memphis

Enhancing Existing Infrastructure

Ashtabula Harbor

Milwaukee Harbor



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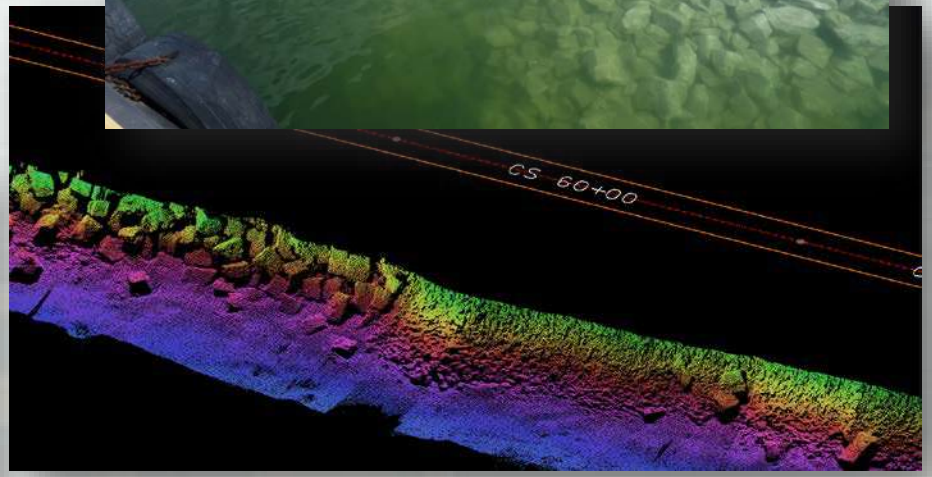

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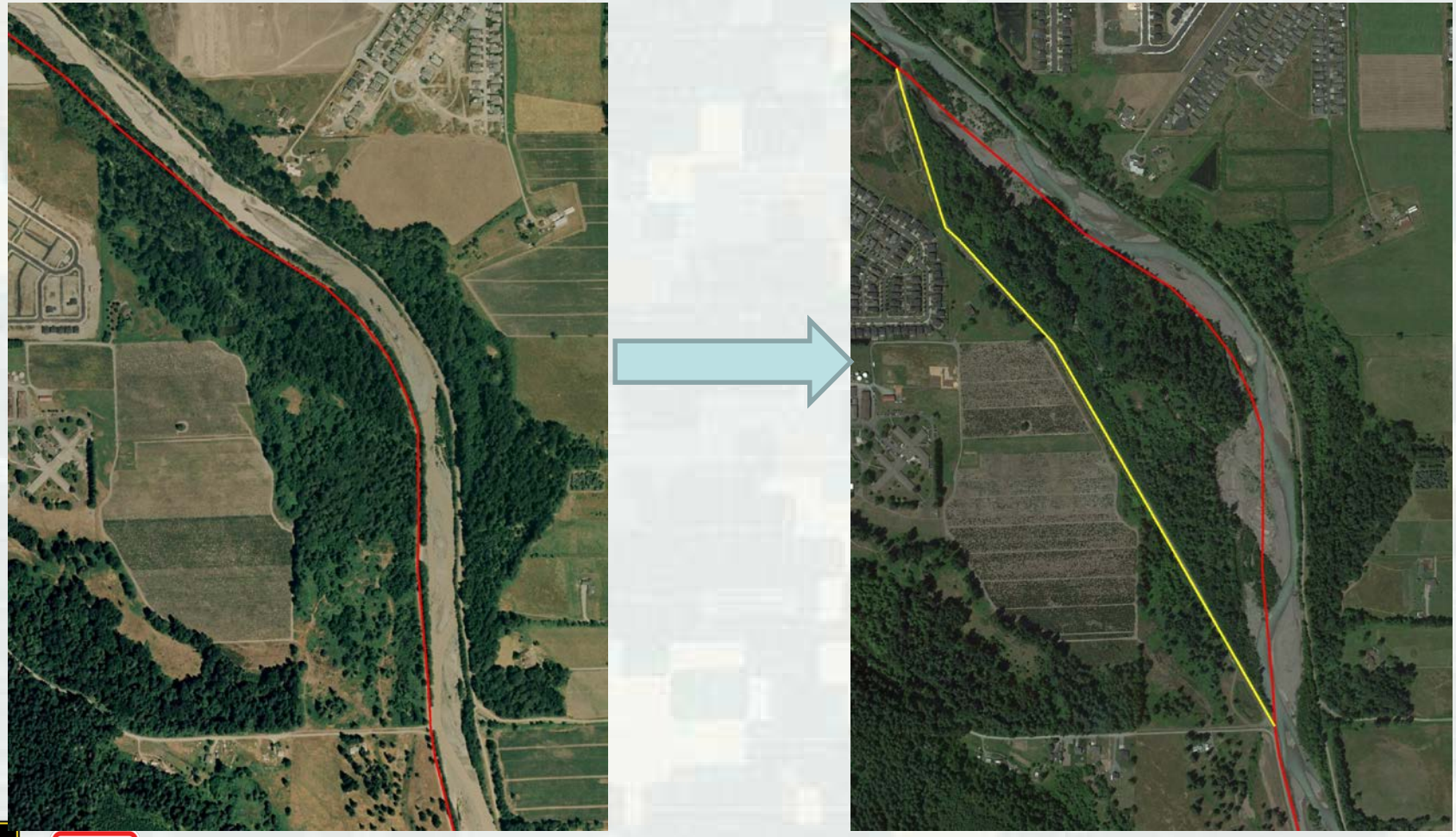
Soldier's Home Levee Setback

April 2006

June 2016



Original Levee

Setback Levee

Vegetation on Levees

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, D.C. 20314-1000

CECW-ZB

JUN 2 1 2017

MEMORANDUM FOR MAJOR SUBORDINATE COMMANDS, AND DISTRICTS

SUBJECT: Further Advancing Project Delivery Efficiency and Effectiveness of USACE Civil Works

1. Beginning 1 July 2017, this office will embark on a comprehensive organizational review of current authorities, policies, regulations, and procedures. The desired outcome is to identify opportunities for enhanced project delivery and increased organizational efficiency and effectiveness by reducing redundancies and delegating authority for decision making to the most practical and appropriate level. As a world class organization, we are committed to reliably delivering the best quality projects and services on time, and within budget. To do so, we must fully implement our Project Management doctrine, recognize risk and uncertainties, and develop mitigation strategies that allow us to accept appropriate levels of risk to improve project delivery. As part of the Civil Works strategy, I intend to operationalize risk-informed decision making at all levels in the organization, and then I expect discipline in documenting these decisions at the appropriate level. The following five paragraphs capture the key lines of effort that I expect us all to advance.

2. **Embrace and Operationalize Risk-Informed Decision Making**. We must change our behavior regarding risk management across Civil Works and in our policies, analytical approaches and models, priorities, and dialogue with sponsors and communities. Civil Works will undertake the following steps to develop a more comprehensive understanding and application of risk-informed decision making and project delivery across the agency:

a. Publish an Engineer Circular entitled *USACE Risk Framework*. This document will establish common principles for assessing, managing, and communicating risk. It

c. Levee Safety is working with the Engineer Research and Development Center Engineering with Nature effort and natural resources interests to design a risk-informed decision-making process for consideration of endangered species habitat needs as they relate to vegetation on levees.

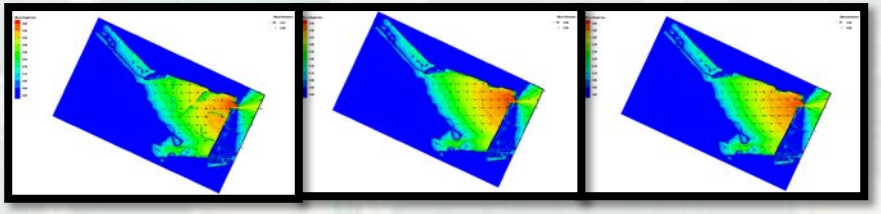
7. I look forward to getting your feedback on these ideas and actions and advancing Civil Works policies, procedures, and operations.

JAMES C. DALTON, P.E.
Director of Civil Works

ERDC

EWN Research at Hamilton and Sears Point Wetland Development, San Pablo Bay

- Accelerate wetland development using berms to support sedimentation during tidal inundation
- Remotely monitoring physical processes: wind, waves, currents suspended sediments, settling velocities, etc.
- Modeling wave generation and dissipation, testing different shapes/configurations of berms

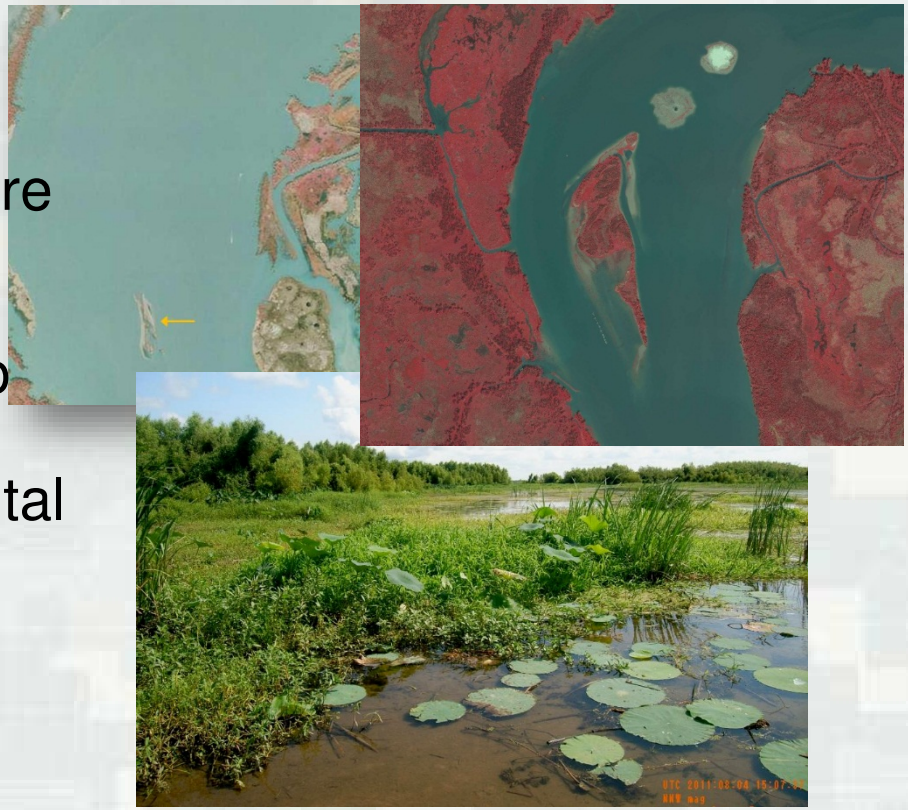


Linear Berms (As-Built) | No Berms (Control) | Mounds (ala Sears Pt.)

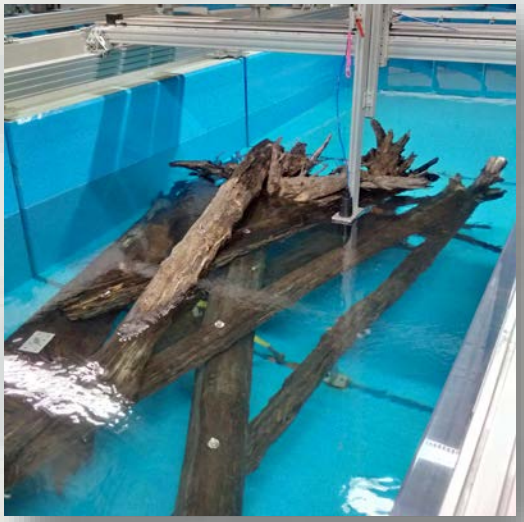
Duluth Harbor Thin-Layer Placement

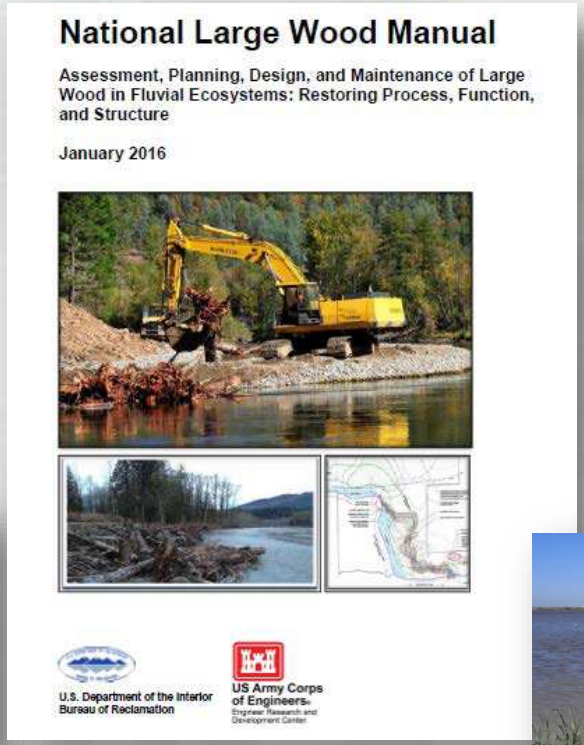
Horseshoe Bend Island, Atchafalaya River

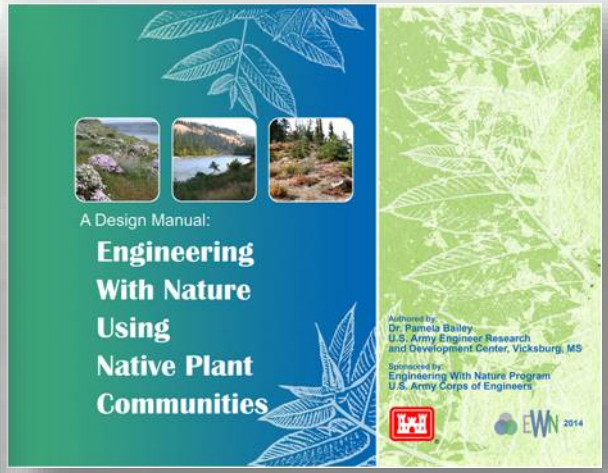
- Options for managing DM via shore-based wetland creation were exhausted
- Strategic placement of sediment (0.5-1.8 mcy/1-3 yrs) was used to create a ~35 ha island
- Producing significant environmental and engineering benefits
- Project Awards:
  - 2015 WEDA Award for Environmental Excellence
  - 2017 WEDA Award for CC Adaption
  - 2017 DPC Award for Working, Building, and Engineering with Nature



Engineering with Natural Materials







www.engineeringwithnature.org

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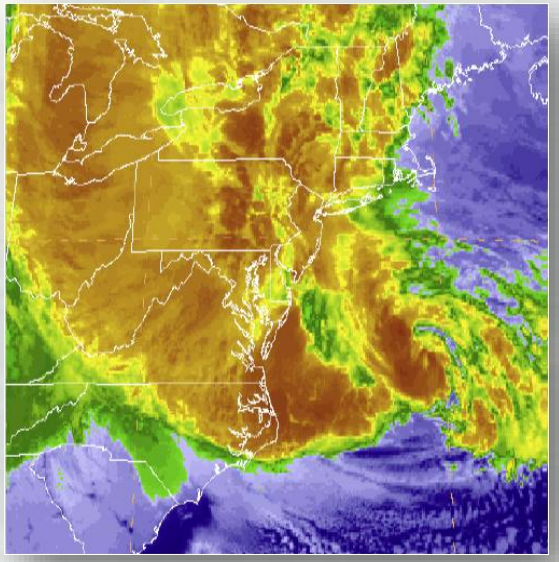
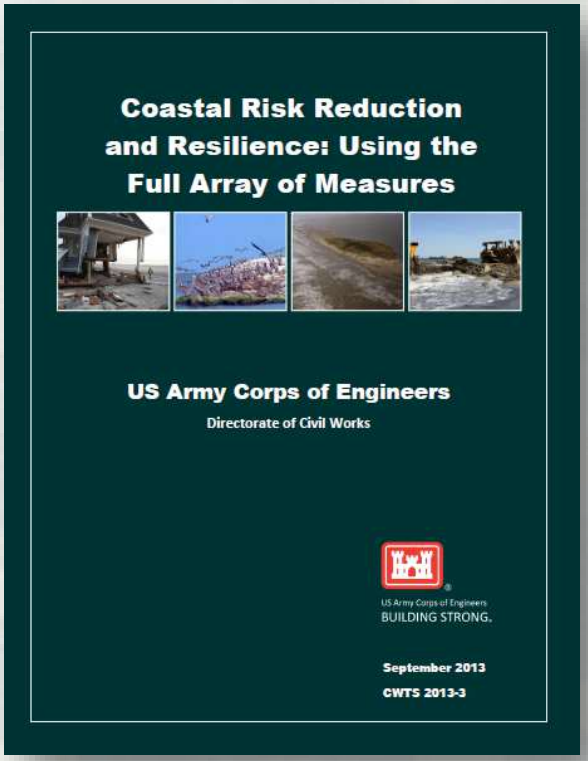
Hurricane Sandy

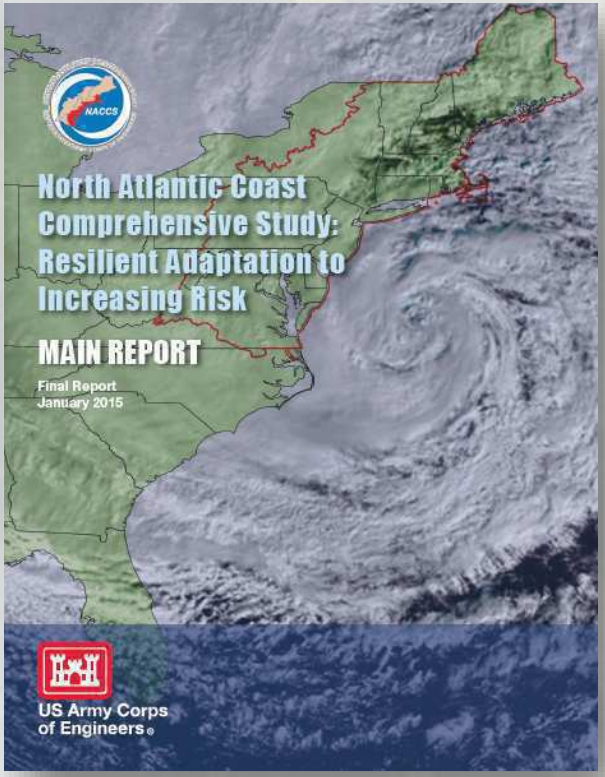
Storm Impacts and Damages: 22-29 October 2012

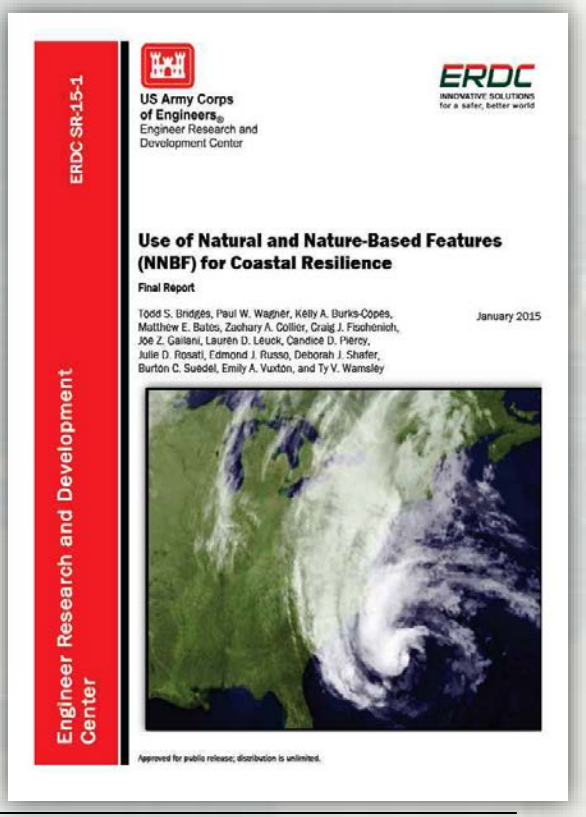
- **Human**
  - 286 people killed (159 in the US)
  - 500,000 people affected by mandatory evacuations
  - 20,000 people required temporary shelter
  - Extensive community dislocations – continuing today in some areas
- **Economic**
  - $65B in damages in the U.S.
  - 26 states affected (10 states and D.C are in the NACCS study area)
  - 650,000 houses damaged or destroyed



The North Atlantic Coast Comprehensive Study







http://www.nad.usace.army.mil/CompStudy

Engineering Performance: Nature-Based Features Work in Different Ways

Natural and Nature-Based Infrastructure at a Glance

GENERAL COASTAL RISK REDUCTION PERFORMANCE FACTORS:
STORM INTENSITY, TRACK, AND FORWARD SPEED, AND SURROUNDING LOCAL BATHYMETRY AND TOPOGRAPHY

Dunes and Beaches

Benefits/Processes

Break offshore waves

Attenuate wave energy

Slow inland water transfer

Performance Factors

Berm height and width

Beach Slope

Sediment grain size and supply

Dune height, crest, width

Presence of vegetation

Vegetated Features: Salt Marshes, Wetlands, Submerged Aquatic Vegetation (SAV)

Benefits/Processes

Break offshore waves

Attenuate wave energy

Slow inland water transfer

Increase infiltration

Performance Factors

Marsh, wetland, or SAV elevation and continuity

Vegetation type and density

Oyster and Coral Reefs

Benefits/Processes

Break offshore waves

Attenuate wave energy

Slow inland water transfer

Performance Factors

Reef width, elevation and roughness

Barrier Islands

Benefits/Processes

Wave attenuation and/or dissipation

Sediment stabilization

Performance Factors

Island elevation, length, and width

Land cover

Breach susceptibility

Proximity to mainland shore

Maritime Forests/Shrub Communities

Benefits/Processes

Wave attenuation and/or dissipation

Shoreline erosion stabilization

Soil retention

Performance Factors

Vegetation height and density

Forest dimension

Sediment composition

Platform elevation

USACE Philadelphia District: Back Bay EWN

Mordecai Island

Stone Harbor

Avalon

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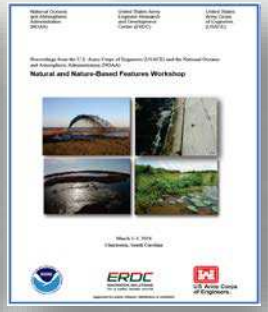
Collaboration with Federal Agencies

USACE – NOAA Collaboration Workshop: Natural and Nature-Based Features, Charleston, SC; 1-3 March 2016

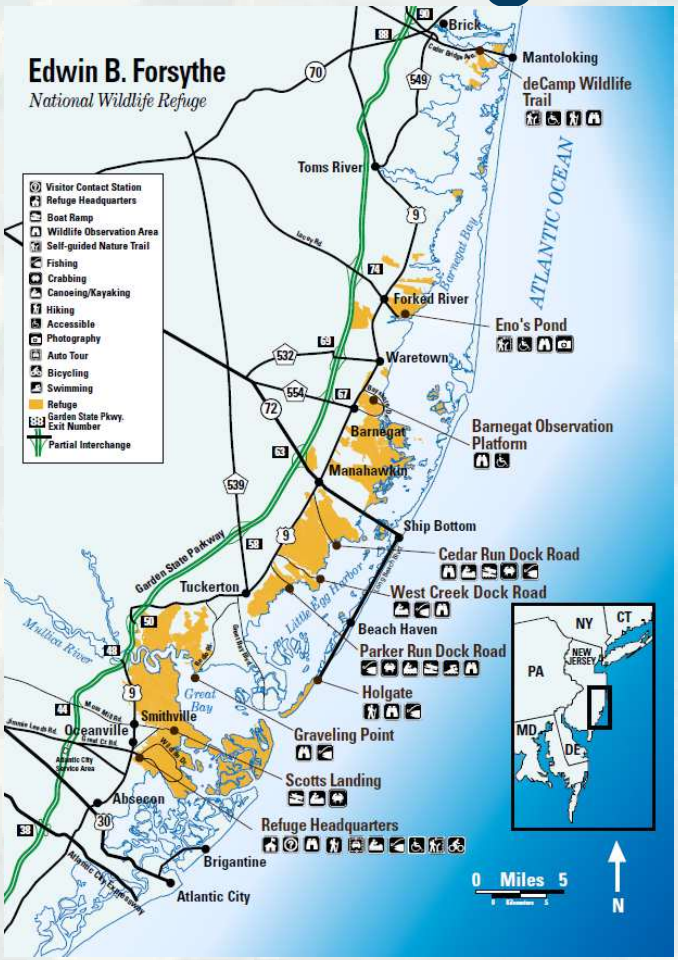


USACE/NOAA-NMFS Collaboration Workshop Engineering With Nature, Gloucester, MA; October 5-6, 2016

www.engineeringwithnature.org (NNBF)

US Fish and Wildlife Service
Forsythe National Wildlife Refuge

- Forsythe NWR: >40,000 acres of wetlands and other habitat in coastal NJ
- Collaboration objective: Enhance ecosystem resilience through engineering and restoration
- Means: Smart use of sediment resources and EWN principles and practices



Collaboration with the Private Sector: Caterpillar Inc.

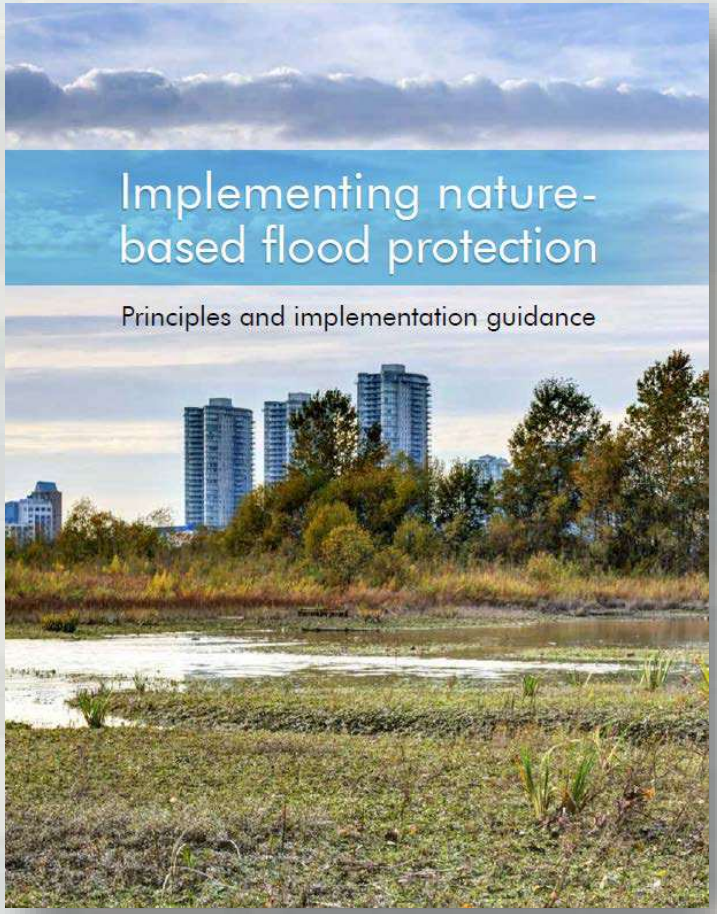
- Restoring Natural Infrastructure Summit; November 4th, 2015; New York City
- Natural Infrastructure Initiative – USACE Collaboration Work Streams
  1. NI Opportunity Evaluation Tool. Capitalizing on enterprise-level capability: CE Dredge DST
  2. Evaluation and Decision Making
  3. Field Application and Demonstration

ERDC

http://www.caterpillar.com/en/company/sustainability/natural-infrastructure.html

World Bank Principles and Implementation Guidance for Nature-Based Flood Protection

NBFP Workshop, 11-13 April 2017



https://www.gfdrr.org/sites/default/files/documents/Brochure%20Implementing%20nature-based%20flood%20protection_voor%20web.pdf

International Guidelines on the Use of Natural and Nature-Based Features for Sustainable Coastal and Fluvial Systems

Purpose: Develop guidelines for using NNBF to provide engineering functions relevant to flood risk management while producing additional economic, environmental and social benefits.

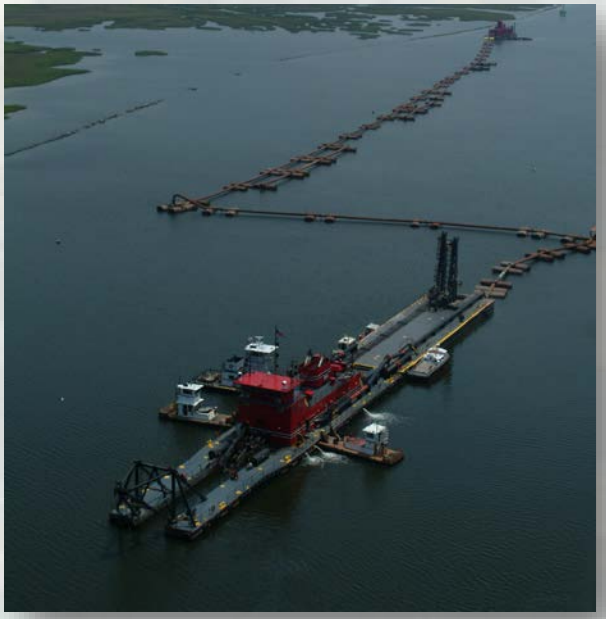
- Publish NNBF technical guidelines by 2020:
  - Multi-author: government, academia, NGOs, engineering firms, construction companies, etc.
  - Addressing the full project life cycle
  - Guidelines in 4 Parts
    - Overarching
    - Coastal Applications
    - Fluvial Applications
    - Conclusions

Needs, Challenges, Opportunities: High Level

- What are the priority opportunities to scale-up progress?
- What strategic partnerships should we pursue?
- How do we stimulate and focus the action of other key organizations?
- What are the key elements of our communication strategy?
- How should we “institutionalize” progress?

Needs, Challenges, Opportunities: Mid Level

- What are the key policy needs and actions relative to advancing practice?
- What form of guidance is needed to support decision making in different functional areas: Planning, Engineering, Operations, Regulatory?
- How do we engage across the federal government (e.g., ASA(CW), OMB, Congress, etc.), states, and internationally?



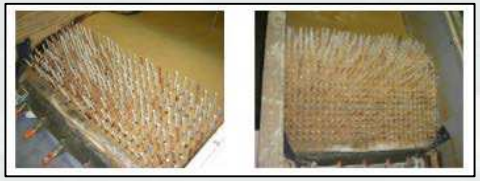
Needs, Challenges, and Opportunities: Low Level

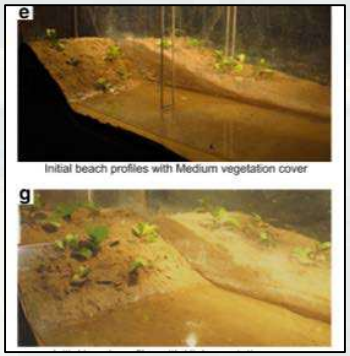
- How should we evaluate the diverse benefits produced by EWN projects?
  - How do we factor economic, engineering, environmental and social benefits into decision making?
- How do we evaluate the engineering performance of projects?
  - How do the dynamics of NI support their adaptive capacity?
  - How do we inform the integration of NI with conventional I, i.e., what is the "right" blend for a project/system?
- How do we adaptively management projects through our Operations?

Erosion of Coastal Dunes: A Focus on Dune Vegetation

Dr. Duncan Bryant

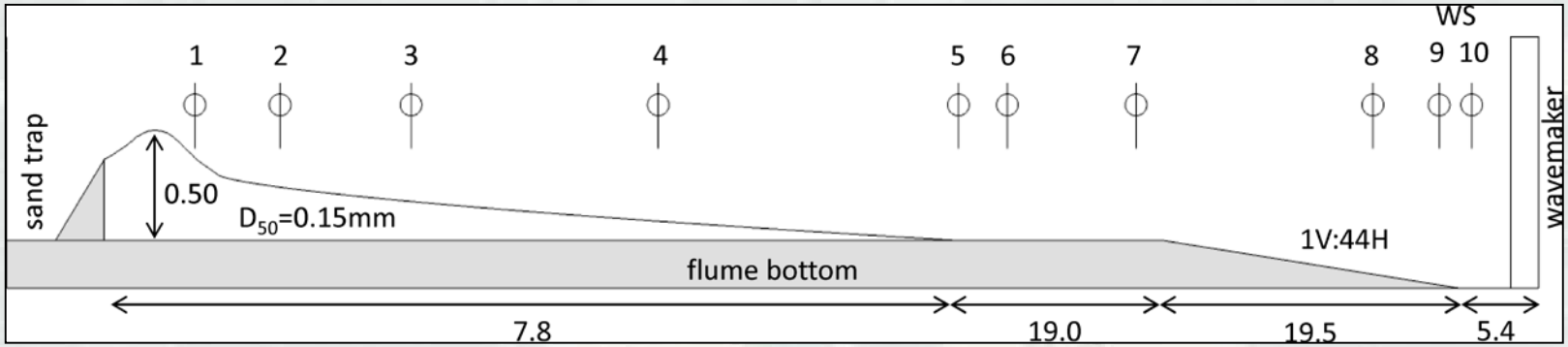
- Identify primary plant species of Atlantic and Gulf of Mexico
- Identify modes of dune erosion and impact/feedbacks between the dune and vegetation
- Previous research efforts
  - rely largely on anecdotal evidence, post-hoc observational studies, and analogous studies of other land features (e.g., river bank stabilization)
  - few studies - Kobayashi et al. (2013), Figlus et al. (2014), Silva et al. (2016)
- Identify mechanisms by which vegetation aids in reducing dune erosion under wave attack
  - aboveground and belowground plant structure





Physical Model Overview

- Systemically isolate and measure the response of a dune under wave attack considering both aboveground and belowground biomass
- 63-m long, 1.5-m wide, 1.5-m deep wave flume
- 1:15 Froude scale
- Instrumented with capacitance gauges and LiDAR



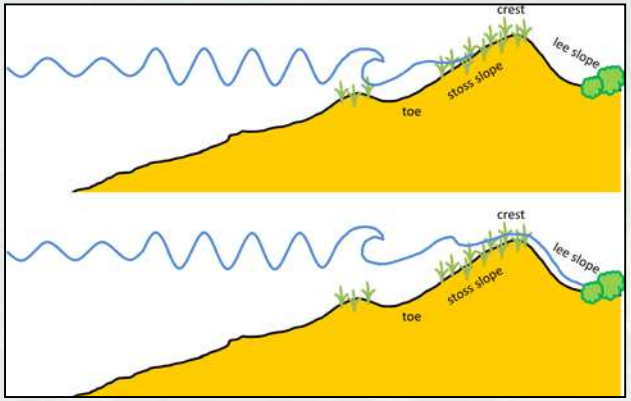
Wave Conditions

- TMA spectrum based on Sandy observations

	h (cm)	H_{m0} (cm)	T_p (s)	Number of Wave Burst	Duration of Wave Burst (s)
SC1	30	7.4	3.69	3	1200
SC2	30	8.4	2	3	1200
SO	30	12.8	3.69	3	400
DC	35	4.3	3.69	3	1200
DO	35	13.2	3.69	1*	400

*Note: The DO-AB number of runs was expanded to 3.

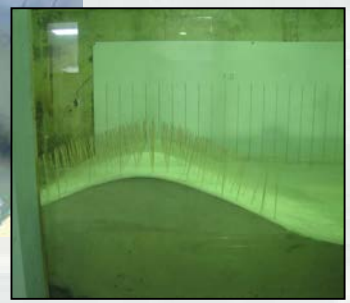
  - collision and overwash regimes



Dune Vegetation

- Plant metrics obtained from Dr. Rusty Feagin
- Aboveground biomass (A) represented by wood dowels and scaled based on void fraction
- Belowground biomass (B) represented by coir

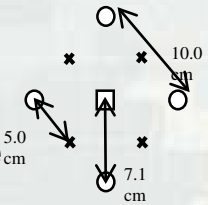
	Aboveground	Belowground
Control	None	None
A	153 stems/m^2	None
B	None	230 g/m^2
AB	153 stem/m^2	230 g/m^2

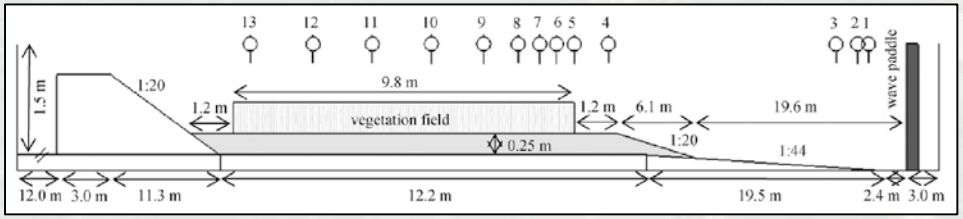


Wave Attenuation by Vegetation

- Quantify wave attenuation of wetland plants
  - Focus on smooth cordgrass
- Polyolefin tubing served as idealized vegetation
  - Readily available
  - Modulus of elasticity and diameter close to literature values
  - Flexible under wave action yet remains upright
- Investigated water depth, significant wave height, peak period, and stem density
- Modeled in CHL's 5ft flume
- Water level measured with 13 capacitance wave gauges

Ms. Mary Bryant



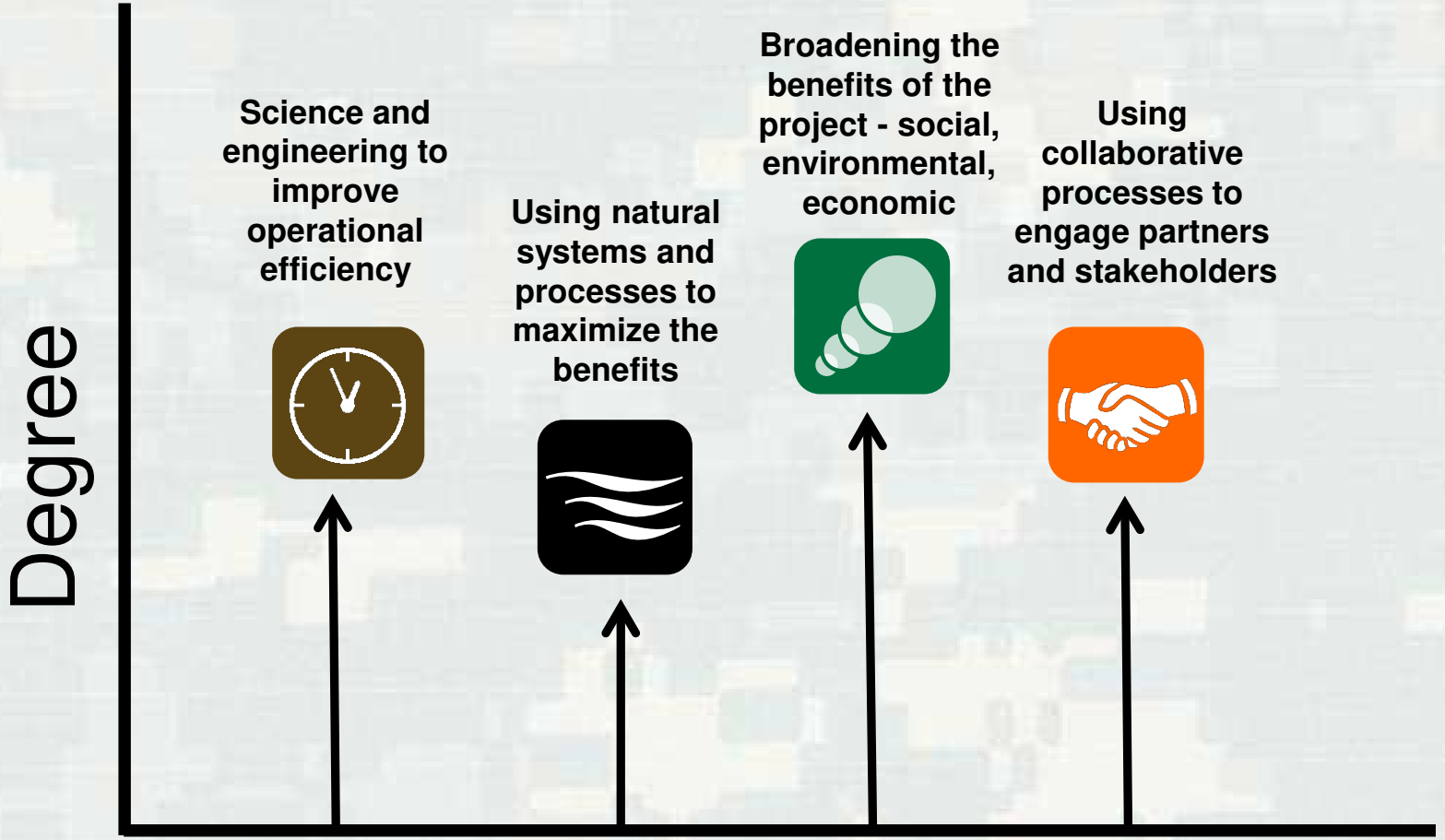


Science, Engineering, Technology Research Targets

- Fundamental processes
  - Sediment transport through and around NNBF
  - Long-term engineering and environmental performance of features
  - Environmental Services provided by engineered features and structures
  - Processes contributing to system-scale resilience
- Modeling systems that support broad-scale application
  - Planners, stakeholders and decision-makers
  - Engineering design
  - Operations and maintenance
- Reliable, cost-efficient monitoring technologies
  - Measuring system evolution
  - Infrastructure/feature performance
- Demonstration/pilot projects to innovate, evaluate, and learn at relevant field scales
  - Facilitate necessary collaboration
  - Evolve organizational culture and practice
  - Produce credible evidence of success
  - Fuel the “power of the story”

Engineering With Nature

Elements



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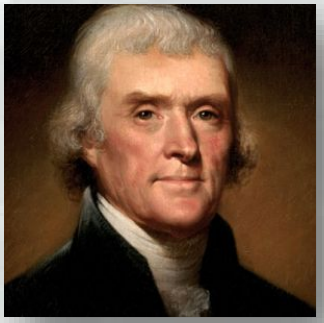

The Pursuit of Resilience…

“I endeavor to keep their attention fixed on the main objects of all science, the freedom & happiness of man.”

Thomas Jefferson to Tadeusz Kosciuszko, 1810

The Battlefield at Saratoga

"The great tacticians of the campaign were hills and forests, which a young Polish engineer was skillful enough to select for my encampment.” Major General Horatio Gates