# Engineering With Nature for Sustainable Systems: The Role of Integrated Modeling and Monitoring

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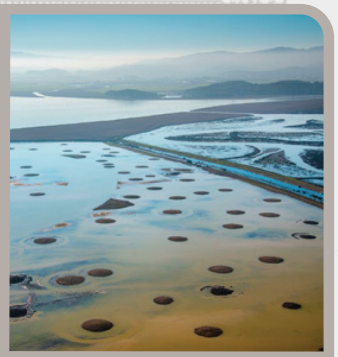
ICEMM

March 17, 2020



US Army Corps of Engineers

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

# THE SAN JOAQUIN VALLEY, CALIFORNIA

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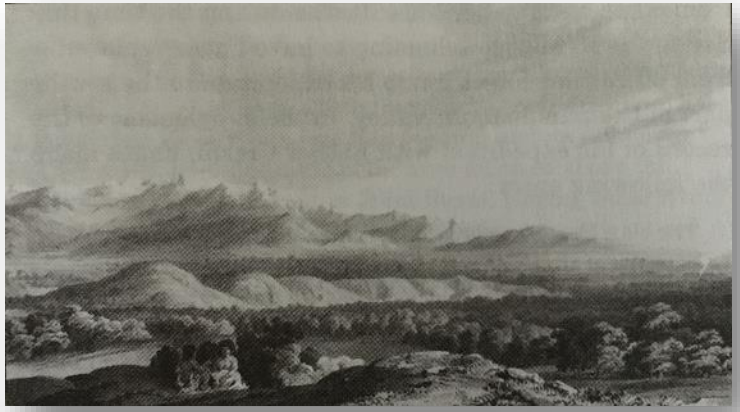
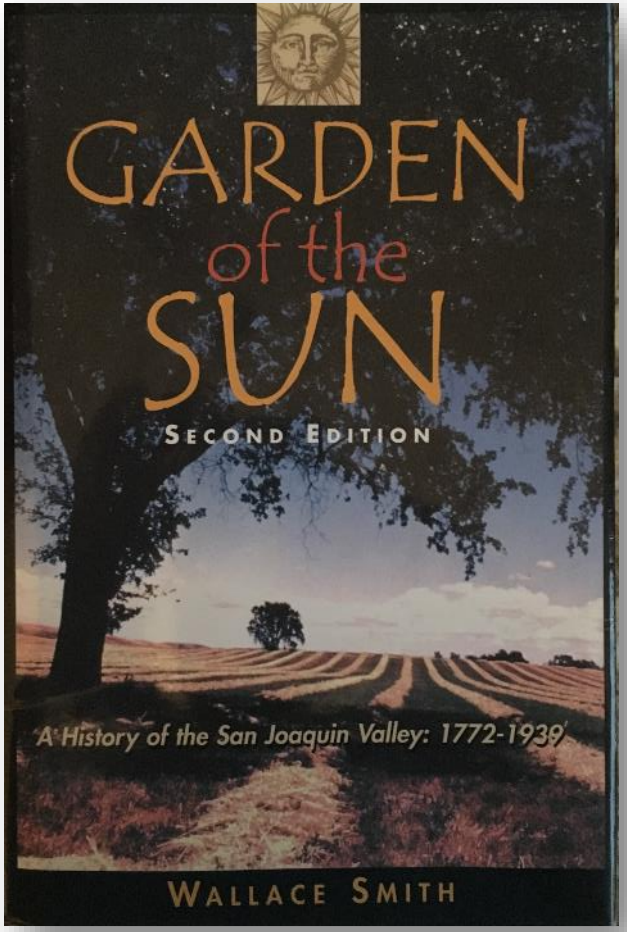
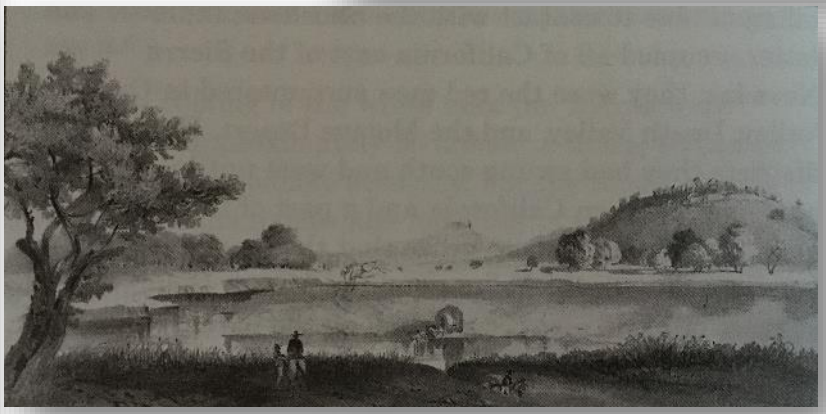
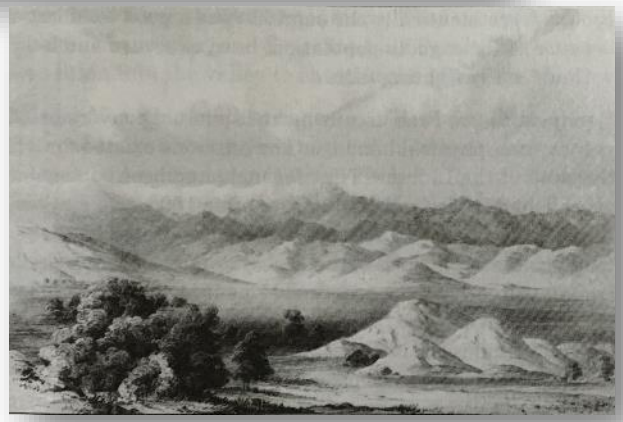
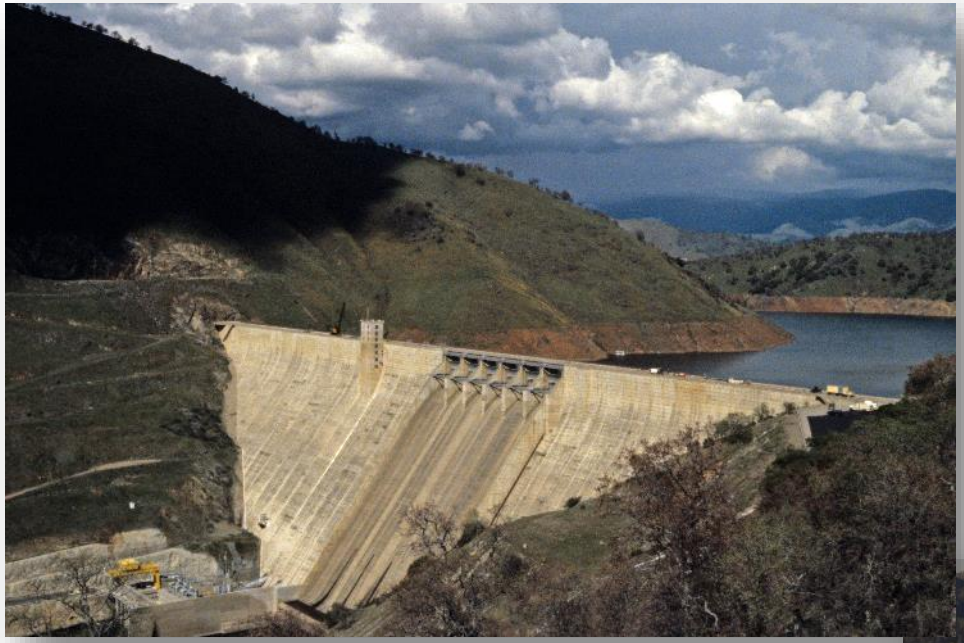


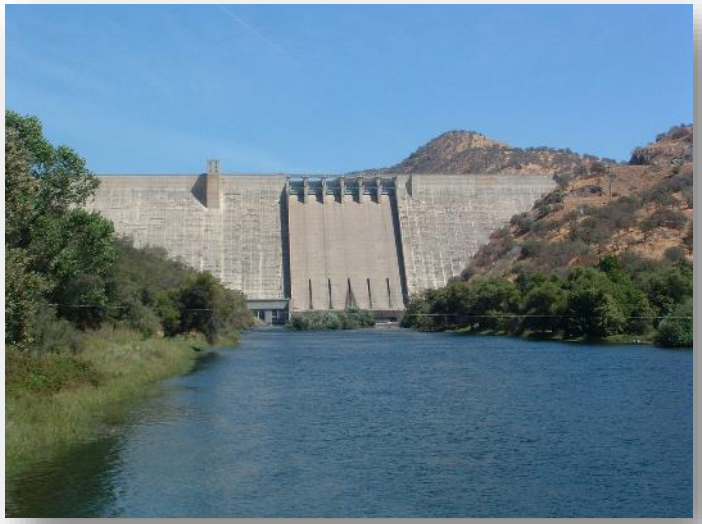




# PINE FLAT DAM; KINGS RIVER, CA





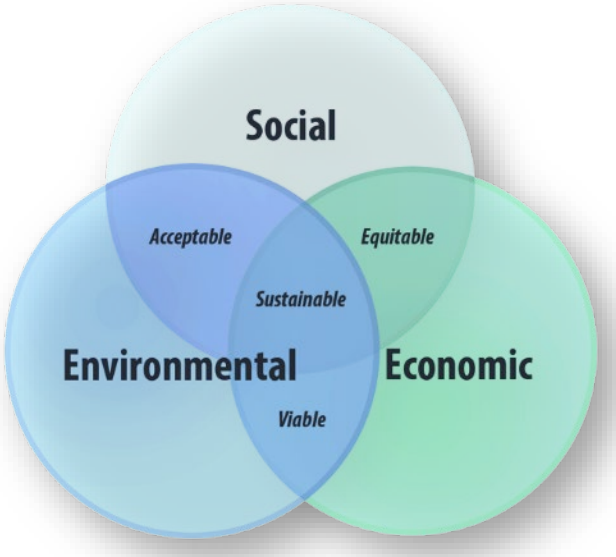
# THE SAN JOAQUIN VALLEY, CALIFORNIA

# 1900-2000: THE CENTURY OF INFRASTRUCTURE (US)

- 4,071,000 miles of roadway
  - 47,182 miles in the Interstate system
- 149,136 miles of mainline rail
- 640,000 miles of high-voltage transmission lines
- 614,387 bridges
- 90,580 dams
- 155,000 public drinking water systems
- 4,500 military installations
- 926 ports

# SUSTAINABILITY

Sustainability is achieved by efficiently investing resources to create present and future value



# ECOSYSTEM SERVICES: THE VALUE OF TREES

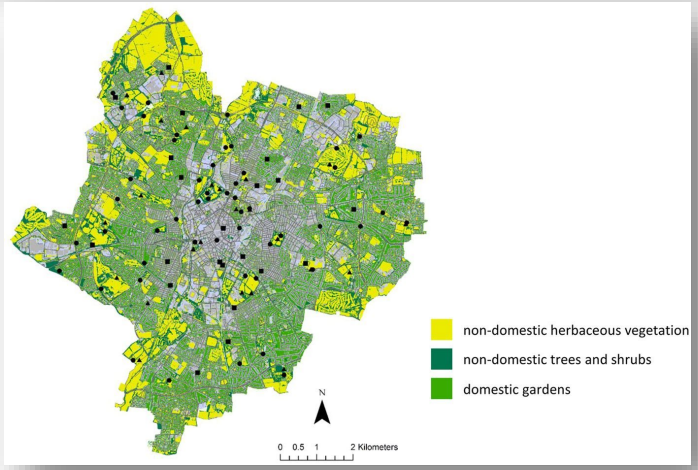
- Shaded surfaces can be 20-45ºF cooler
- Evapotranspiration plus shading can reduce peak summer temperatures by 2-9ºF
- Reduce wind speed and winter heat loss from buildings by 10-50%
- Improve local air quality
- Increase water infiltration, reducing surface water run-off

Soil surface temperatures reveal moderation of the urban heat island effect by trees and shrubs

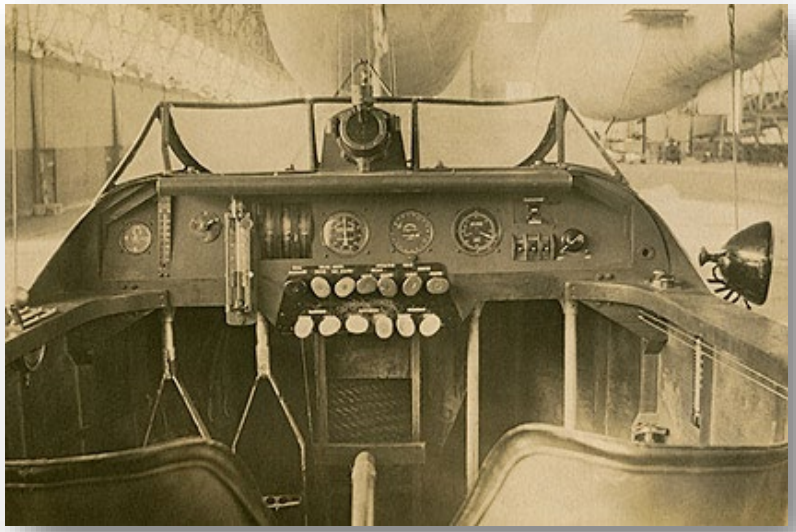
J. L. Edmondson, I. Stott, Z. G. Davies, K. J. Gaston & J. R. Leake

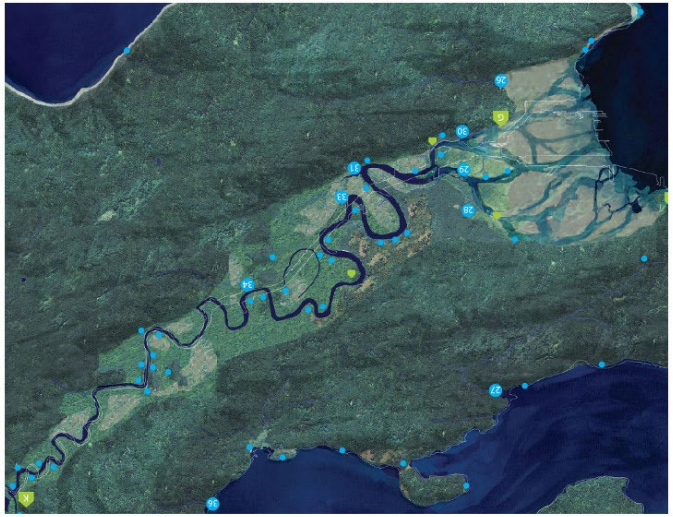
*Scientific Reports* 6, Article number: 33708 (2016) | Download Citation

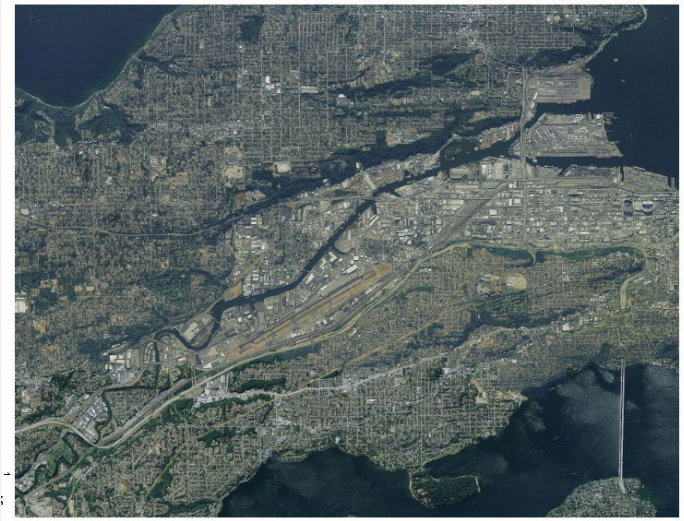
1398 Accesses | 20 Citations | 17 Altmetric | Metrics



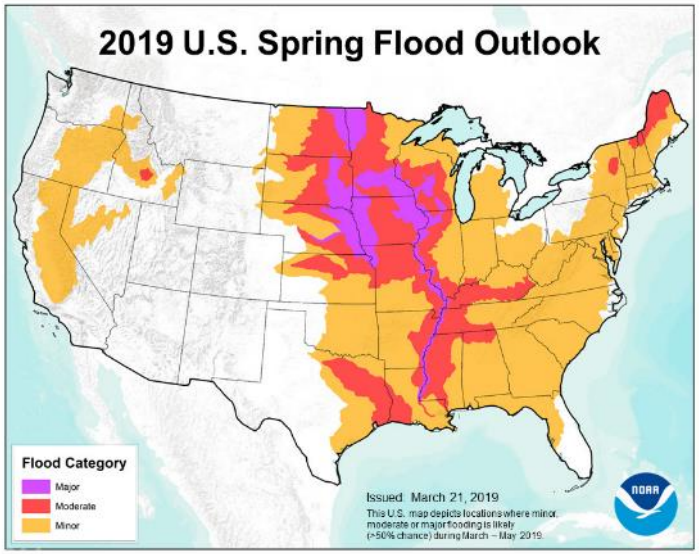
# ENGINEERING TRENDS

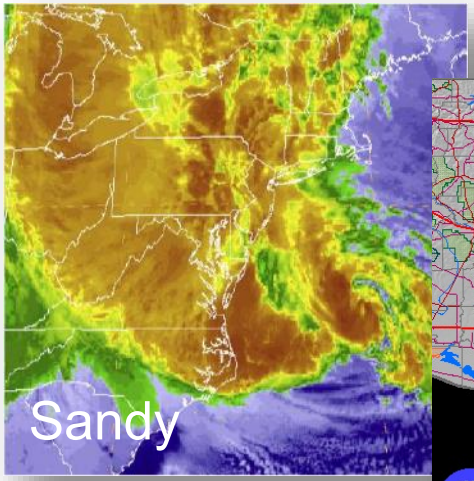




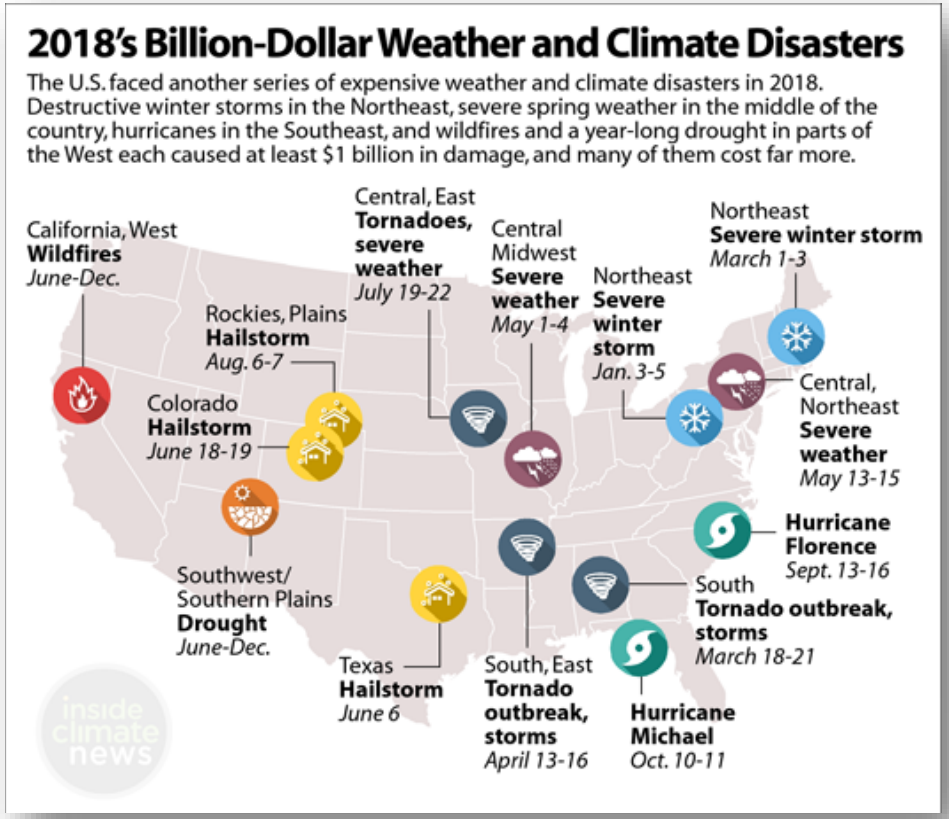


# EVIDENCE SUPPORTING THE NEED FOR INNOVATION



# NATURAL HAZARDS: IMPLICATIONS FOR ECONOMICS AND NATIONAL SECURITY

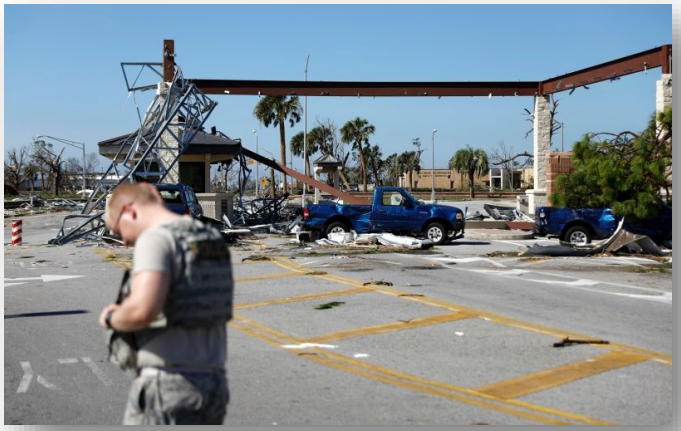


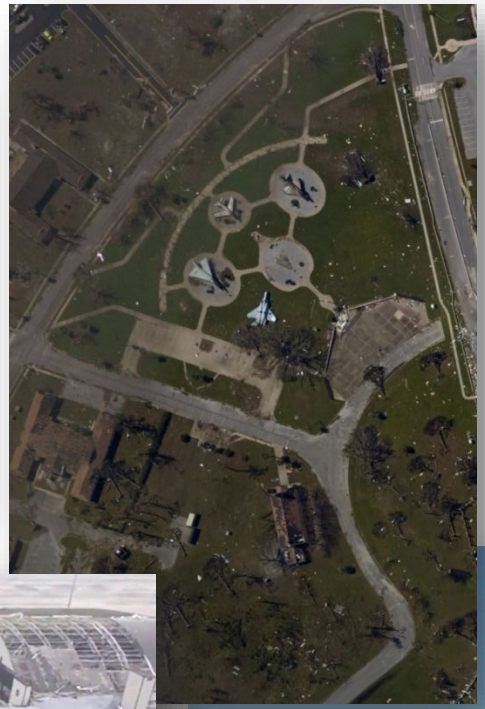

| EVENT | DATES | COST ESTIMATE | DEATHS |
|---|---|---|---|
| Northeast severe winter storm | Jan. 3-5 | $1.1B | 22 |
| Northeast severe winter storm | March 1-3 | $2.2B | 9 |
| Southern tornadoes, storms | March 18-21 | $1.5B | 0 |
| South & East tornadoes, storms | April 13-16 | $1.3B | 3 |
| Central Midwest severe weather | May 1-4 | $1.4B | 0 |
| Central & Northeast severe weather | May 13-15 | $1.4B | 5 |
| Texas hailstorm | June 6 | $1.3B | 0 |
| Colorado hailstorm | June 18-19 | $2.2B | 0 |
| Central & East tornadoes, severe weather | July 19-22 | $1.6B | 0 |
| Rockies & Plains hailstorms | Aug. 6-7 | $1.0B | 0 |
| Hurricane Florence | Sept. 13-16 | $24.0B | 53 |
| Hurricane Michael | Oct. 10-11 | $25.0B | 49 |
| Southwest & Southern Plains drought | June 1-Dec. 30 | $3.0B | 0 |
| California & Western wildfires | June 1-Dec. 31 | $24.0B | 106 |

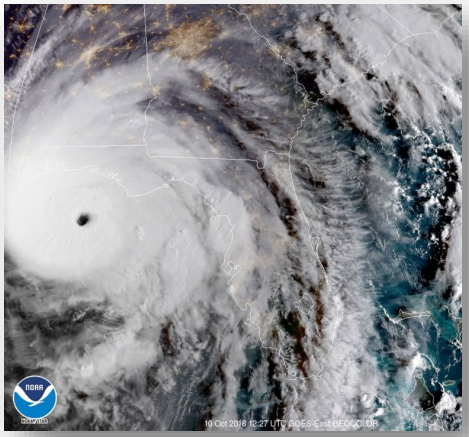
SOURCE: NOAA

PAUL HORN / InsideClimate News

# TYNDALL AIR FORCE BASE: HURRICANE MICHAEL, 10-11 OCTOBER, 2018





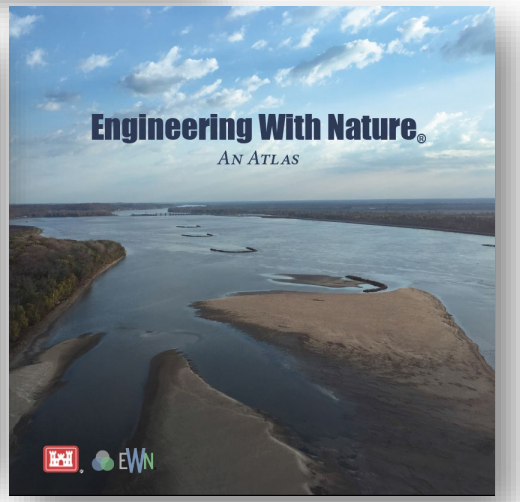


# Engineering With Nature®

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

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

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# 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 FRM
- 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

# ENGINEERING WITH NATURE® OVERVIEW

*Engineering With Nature*® began in 2010

- Engaging across USACE, other agencies, NGOs, academia, private sector, international collaborators
- Guided by a strategic plan
- Established through Proving Grounds
  - Galveston, Buffalo, Philadelphia
- 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
  - 2015, 2017 WEDA Awards; 2017 DPC Award, 2019 RNRF

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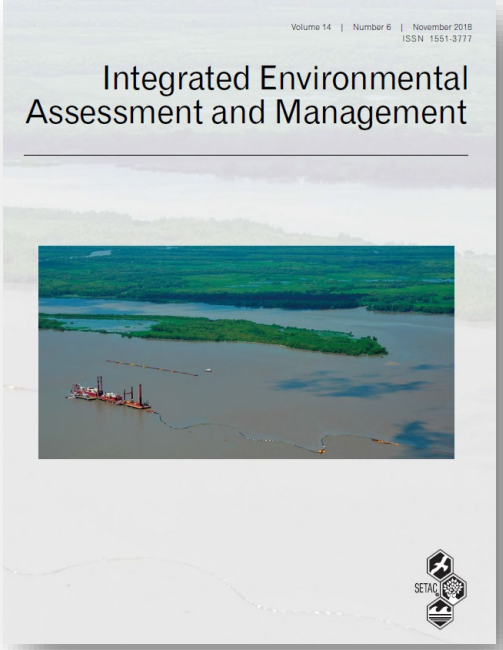
# USACE ENGINEERING WITH NATURE® RECEIVES *Renewable Natural Resources Foundation* 2019 Award for Outstanding Achievement

www.rnrf.org

## RNRF

- Founded in 1972, 501(c)(3)
- Mission: advancing science, application, and public education in managing and conserving renewable natural resources
- Member organizations: ASCE, AGU, AMS, AWRA, ASLA, GSA, SETAC
- BoD composed of reps of member organizations
- 3 annual awards

# HORSESHOE BEND ISLAND, ATCHAFALAYA RIVER




**Quantifying Wildlife and Navigation Benefits of a Dredging Beneficial-Use Project in the Lower Atchafalaya River: A Demonstration of Engineering with Nature®**

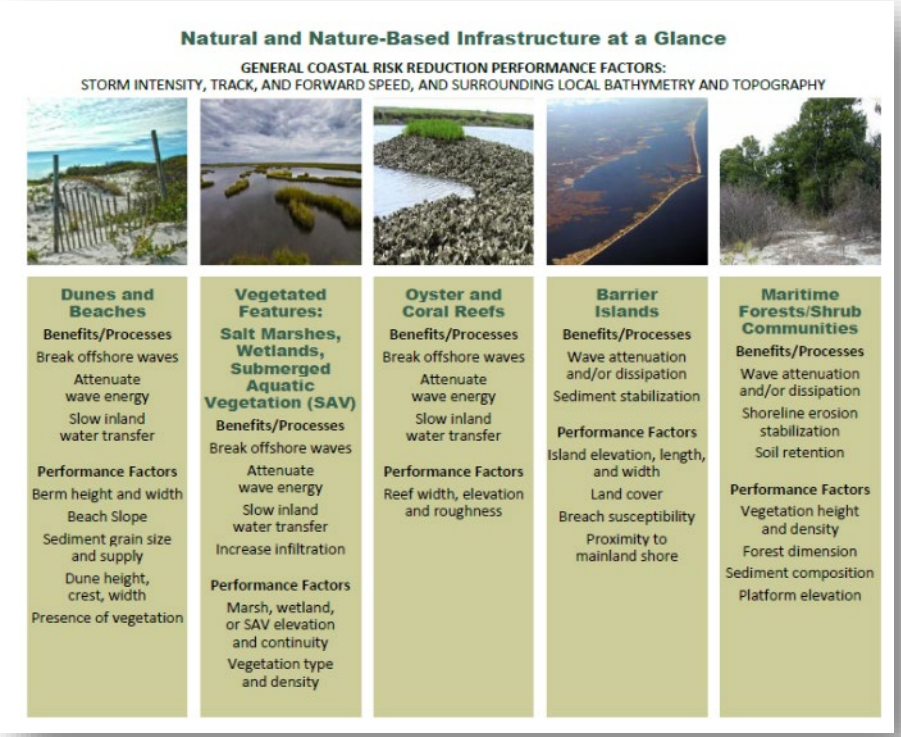
*Christy M Foran,† Kelly A Burks-Copes,‡ Jacob Berkowitz,‡ Jeffrey Corbino,§ and Burton C Suedel*‡*

Project Awards:

- 2015 WEDA Award for Environmental Excellence
- 2017 WEDA Award for CC Adaption
- 2017 DPC Award for Working, Building, and Engineering with Nature

# NATURAL AND NATURE-BASED FEATURES

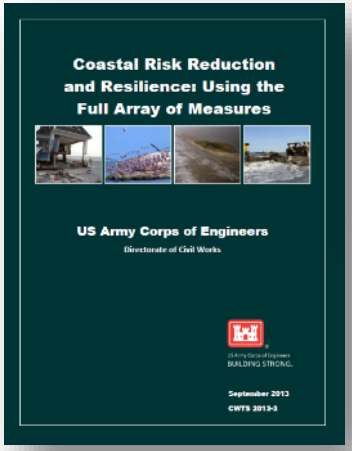
NNBF are landscape features that are developed to provide engineering functions relevant to flood risk management while producing additional economic, environmental and social benefits.

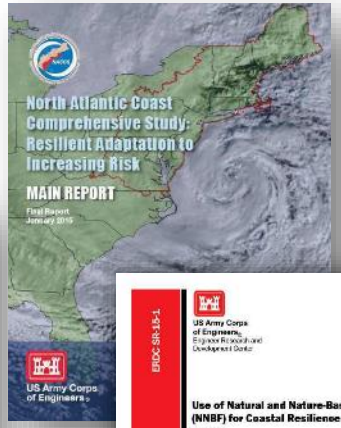


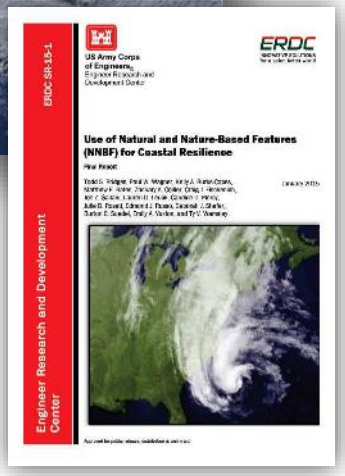
**Natural and Nature-Based Infrastructure at a Glance**

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

| Dunes and Beaches | Vegetated Features: Salt Marshes, Wetlands, Submerged Aquatic Vegetation (SAV) | Oyster and Coral Reefs | Barrier Islands | Maritime Forests/Shrub Communities |
|---|---|---|---|---|
| **Benefits/Processes** | **Benefits/Processes** | **Benefits/Processes** | **Benefits/Processes** | **Benefits/Processes** |
| Break offshore waves | Break offshore waves | Break offshore waves | Wave attenuation and/or dissipation | Wave attenuation and/or dissipation |
| Attenuate wave energy | Attenuate wave energy | Attenuate wave energy | Sediment stabilization | Shoreline erosion stabilization |
| Slow inland water transfer | Slow inland water transfer | Slow inland water transfer | **Performance Factors** | Soil retention |
| **Performance Factors** | Increase infiltration | **Performance Factors** | Island elevation, length, and width | **Performance Factors** |
| Berm height and width | **Performance Factors** | Reef width, elevation and roughness | Land cover | Vegetation height and density |
| Beach Slope | Marsh, wetland, or SAV elevation and continuity | | Breach susceptibility | Forest dimension |
| Sediment grain size and supply | Vegetation type and density | | Proximity to mainland shore | Sediment composition |
| Dune height, crest, width | | | | Platform elevation |
| Presence of vegetation | | | | |



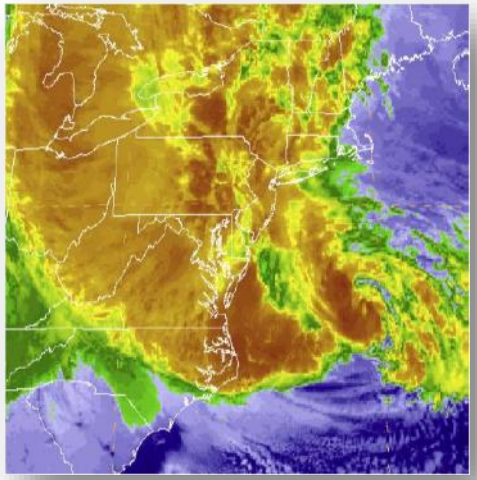



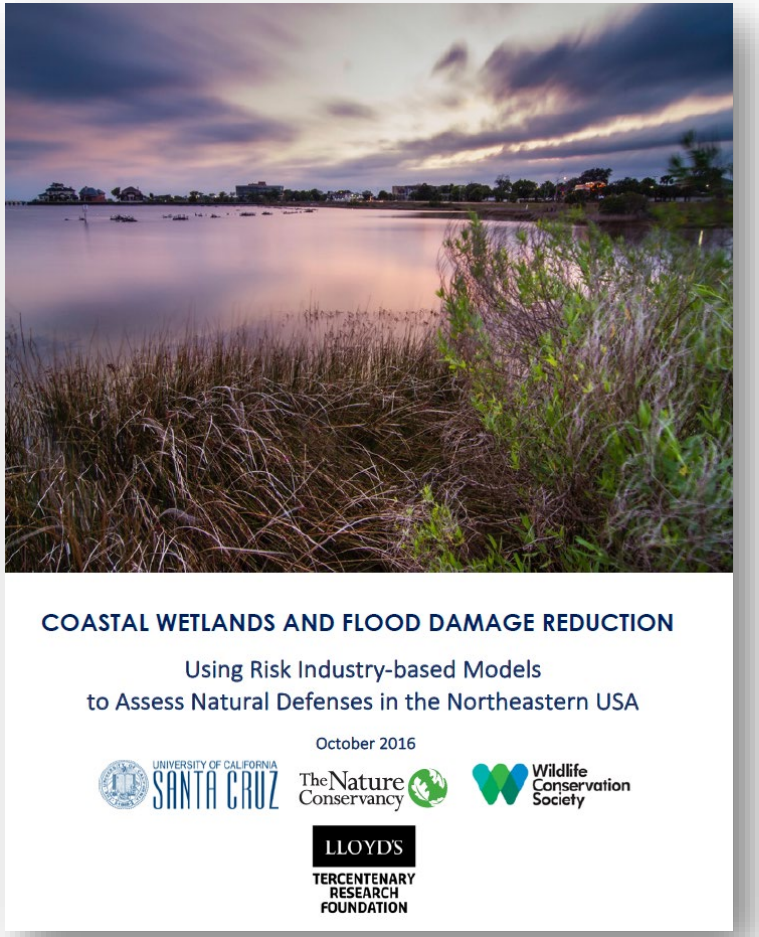



# LEVERAGING NATURE FOR ENGINEERING VALUE: *WETLANDS*

## 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%.

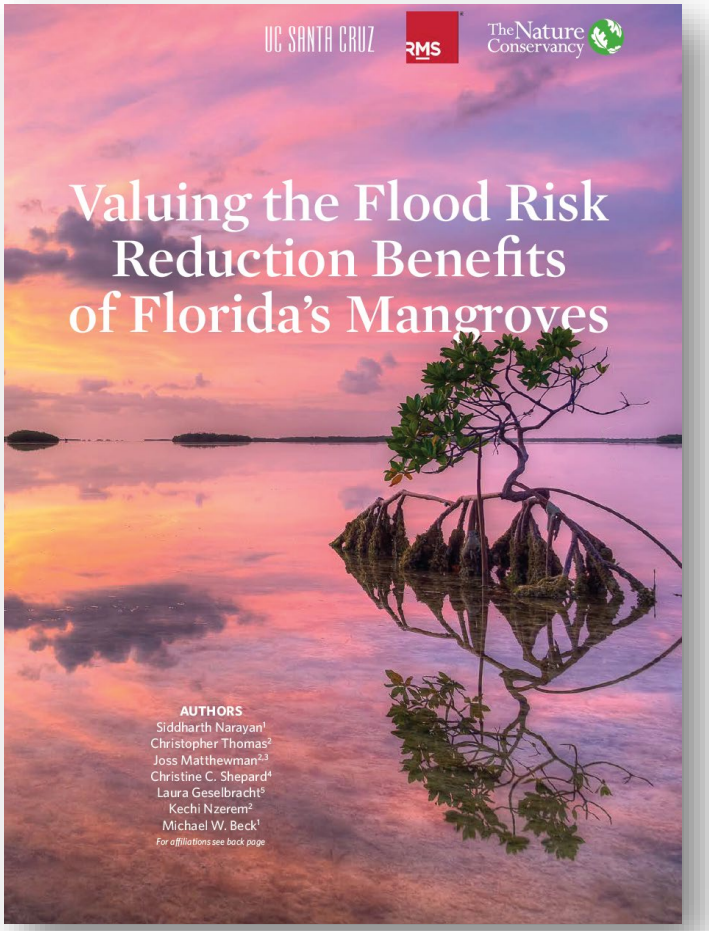




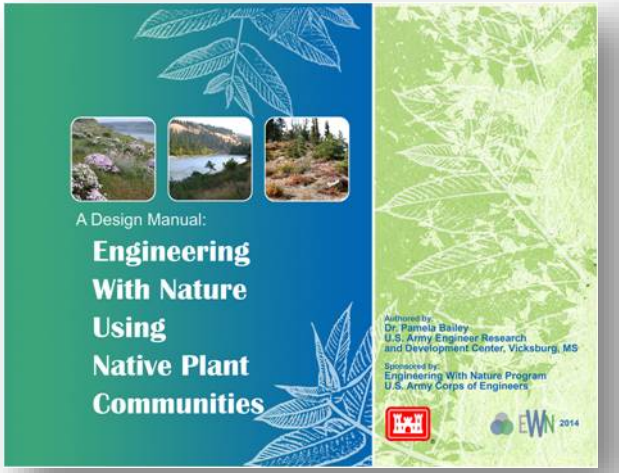
# LEVERAGING NATURE FOR ENGINEERING VALUE: *MANGROVES*

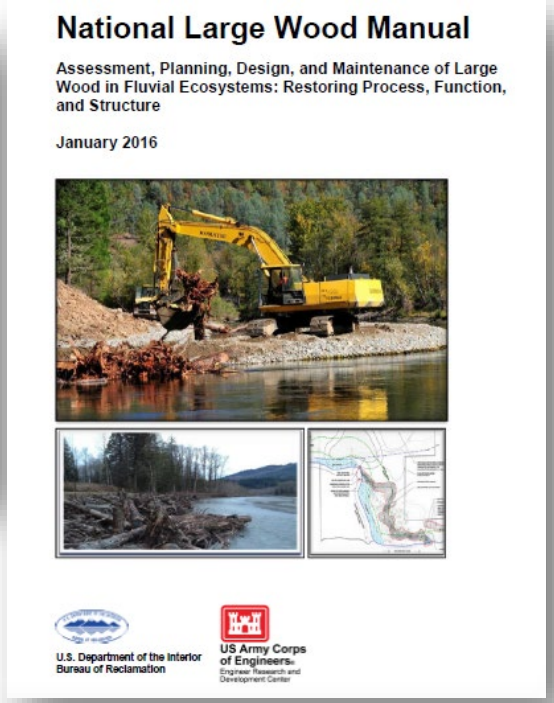
Following Hurricane Irma:

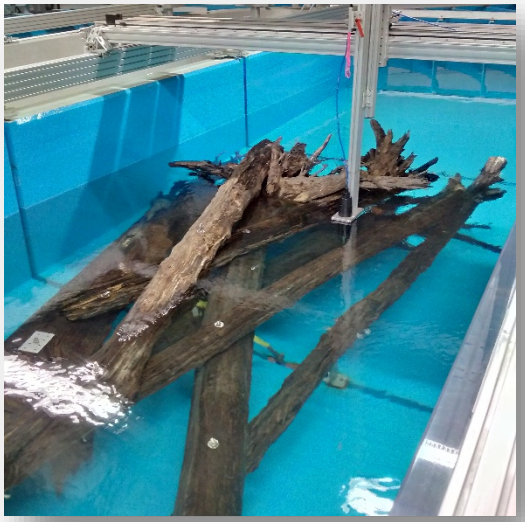
- Used an insurance industry catastrophe model from RMS to quantify the flood reduction benefits of mangroves across Florida
- During Hurricane Irma:
  - Mangroves averted $1.5 billion dollars in surge-related flood damages to properties; which represents a 25% savings in counties with mangroves.
  - Over 626,000 people living behind mangrove forests saw reduced flooding across Florida.
- Annually, across 100+ storms, mangroves reduce flood damages by 25.5% to properties in Collier County.



# ENGINEERING WITH NATURAL MATERIALS



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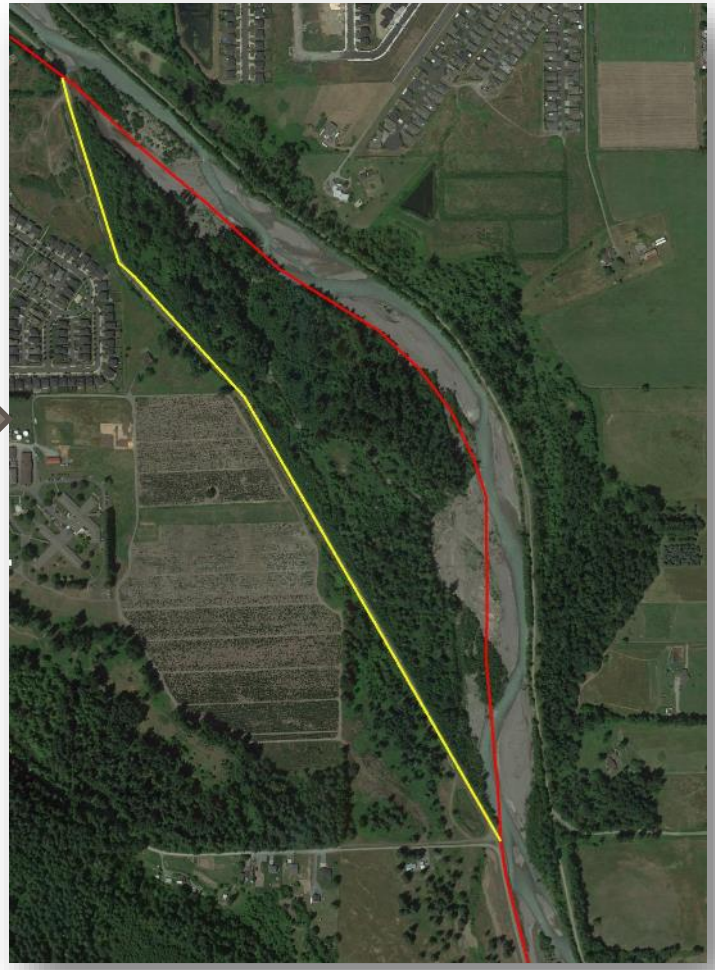
# SOLDIER'S HOME LEVEE SETBACK

April 2006

June 2016



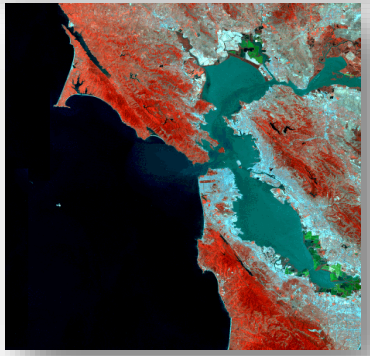
# USACE PHILADELPHIA DISTRICT: EWN IN BACK BAY NEW JERSEY

Mordecai Island

Stone Harbor

Avalon

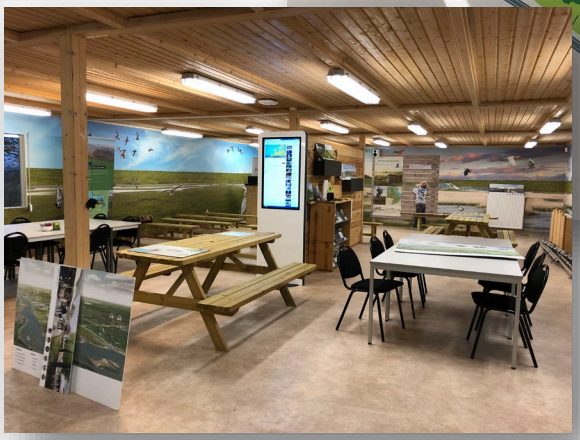
# HAMILTON AND SEARS POINT WETLANDS SAN PABLO BAY, CA



# NOORDWAARD, THE NETHERLANDS

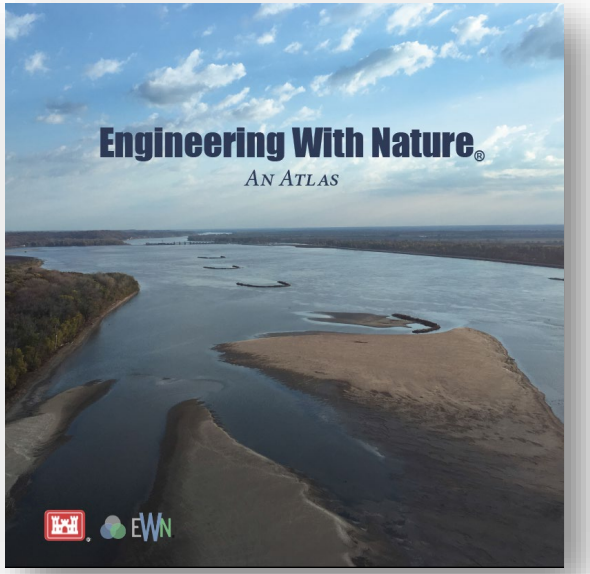
# THE BELGIAN SIGMAPLAN

# SOCIAL ENGAGEMENT: FACILITATING CHANGE



# *ENGINEERING WITH NATURE®*: BRINGING PEOPLE TOGETHER FOR INSPIRATION

# EWN ATLAS LAUNCH EVENT




10:30-12:00
January 16, 2019
National Building Museum
Washington, D.C.

"Engineering With Nature is an important initiative for the U.S. Army Corps of Engineers." James Dalton, USACE Director Civil Works

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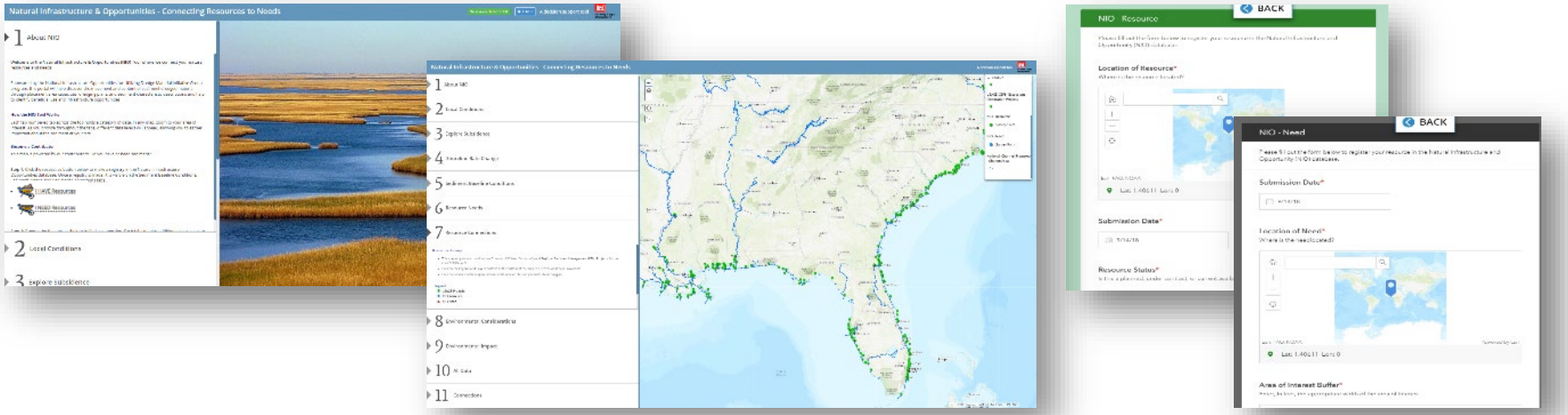
# *ENGINEERING WITH NATURE®*: BRINGING PEOPLE AND ORGANIZATIONS TOGETHER TO INNOVATE

# NATURAL INFRASTRUCTURE OPPORTUNITIES TOOL

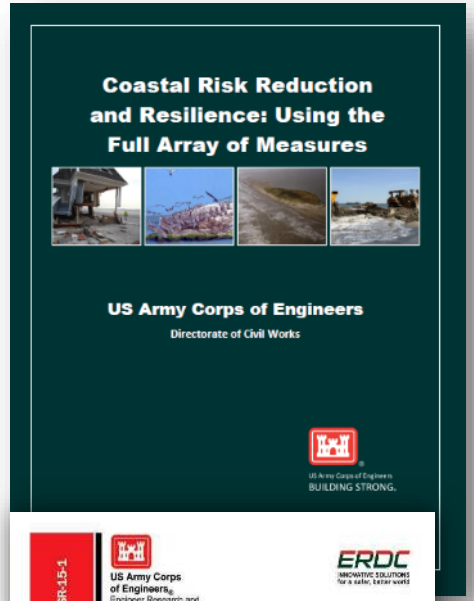
The public facing *Natural Infrastructure Opportunities Tool*, developed in collaboration with the Natural Infrastructure Initiative, focuses on identifying natural infrastructure and beneficial use opportunities. Through map based visualizations of environmental, geomorphic and sediment conditions, as well as upcoming USACE projects, and an interface for users to add their resource needs and resource availability, this portal will help discover natural infrastructure connections and inspire innovative opportunities.

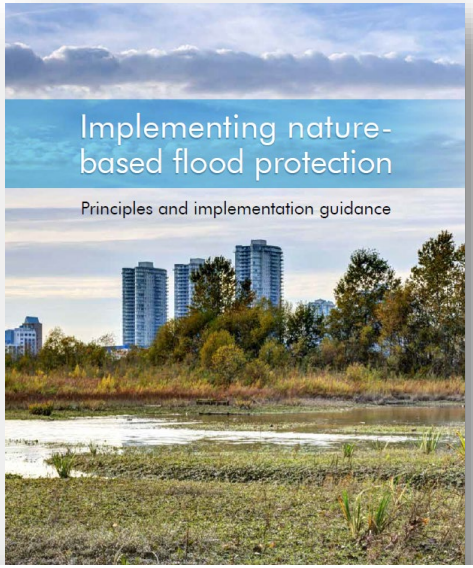


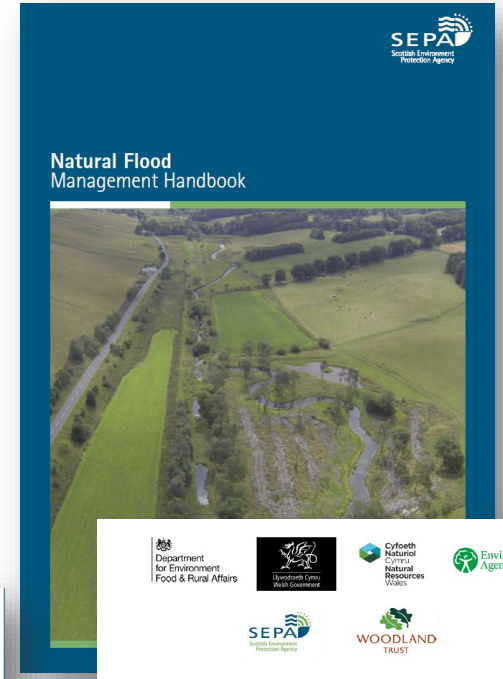

Partners: CAT The Nature Conservancy DIG DCTS AECOM

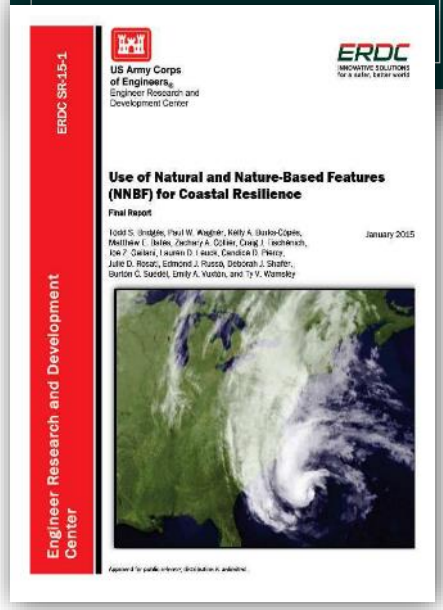
https://ewn.el.erdc.dren.mil/tools.html

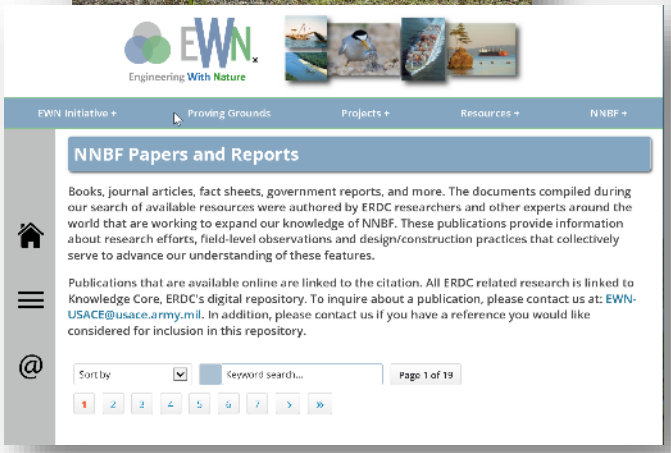
# NATURE-BASED GUIDANCE, STANDARDS, EVIDENCE

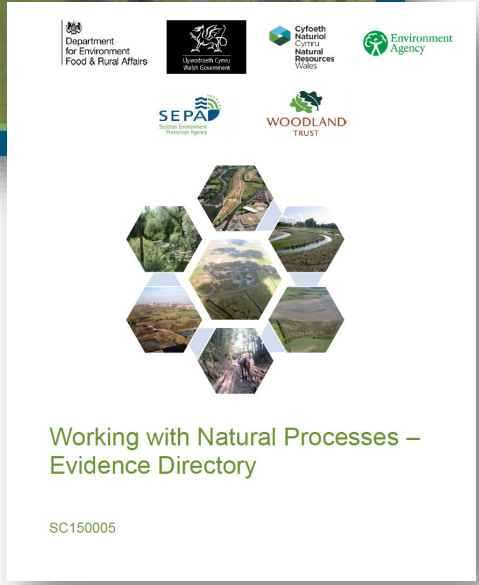
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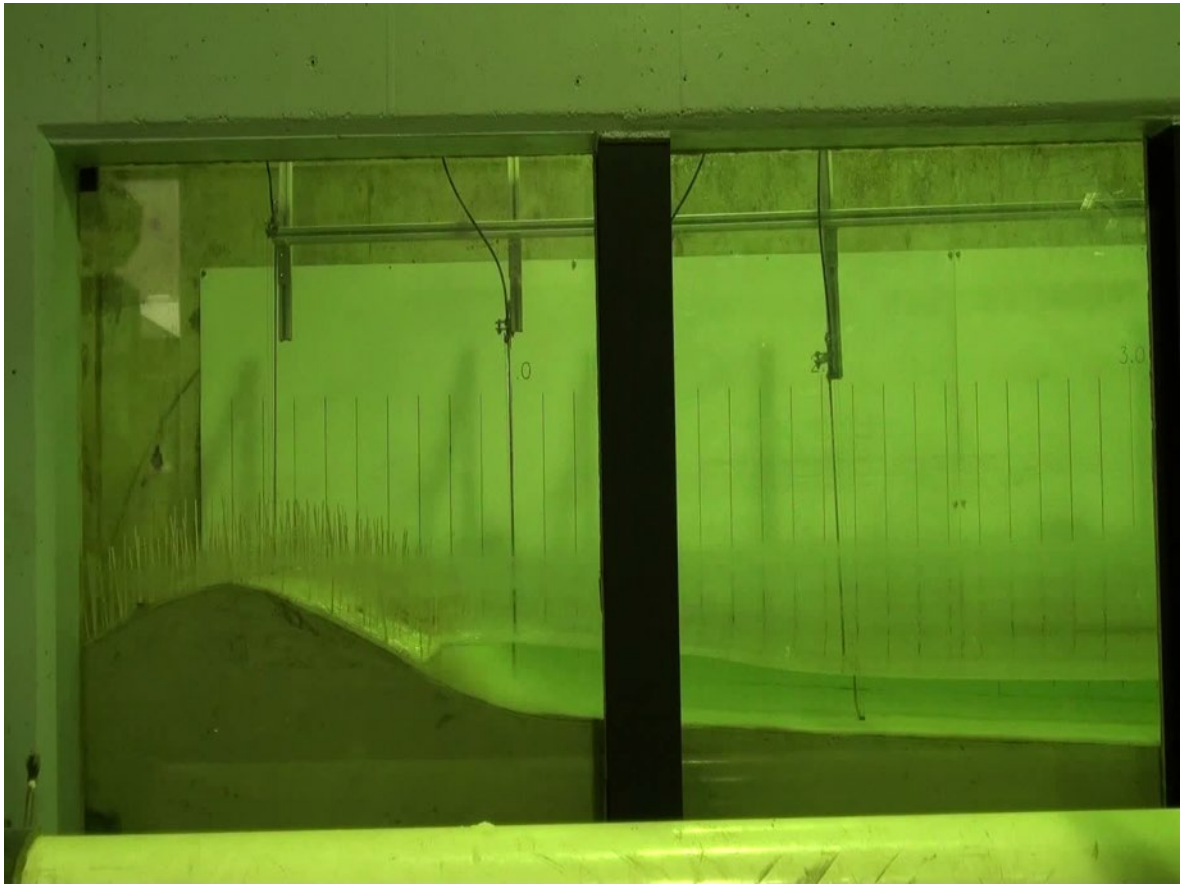
# EROSION OF COASTAL DUNES: THE VALUE OF DUNE VEGETATION



Dr. Duncan Bryant

# 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

# NATURE-BASED SOLUTIONS AS LEADING PRACTICE

TECHNIEK MAAKT JE WERELD

**DE INGENIEUR**

## "HYDRAULIC ENGINEERING COMPANIES MUST USE NATURAL PROCESSES"

OCTOBER 3, 2019

In the coming decades, the principle of '*building with nature*' must be leading in hydraulic engineering. That said Delta Commissioner Peter Glas on Wednesday on the Waterbouwdag, in the Jaarbeurs in Utrecht. '*Building with nature*' must become the guideline for future hydraulic engineering projects, says Glas. "Natural processes are more flexible and adaptive than concrete." Moreover, building where you use the power of nature is generally a lot more sustainable. "We have to think about the consequences of our actions," said Glas.

Delta Commissioner Peter Glas
Rijkswaterstaat

# NATURE-BASED SOLUTIONS AS LEADING PRACTICE

"There are many examples around the country where we have seen the positive role creating or restoring natural habitats such as salt marsh, floodplain meadows and woodland can play in reducing flooding or where natural flood management measures that create or restore habitats can slow the flow of floodwaters. Risk management authorities should work with those seeking to create or restore natural habitats as part of the nature recovery network to help ensure the network can contribute to reducing risk." Page 29-30

Environment Agency

Draft National Flood and Coastal Erosion Risk Management Strategy for England

Vision: a nation ready for, and resilient to, flooding and coastal change – today, tomorrow and to the year 2100.

**Measure 1.4.3: From 2021 risk management authorities will help to ensure that 75% of all water bodies are in natural or near-natural condition within 25 years.**

https://consult.environment-agency.gov.uk/fcrm/fcerm-national-strategy-info/

# ENGINEERING WITH NATURE ON CAPITOL HILL

NATURAL INFRASTRUCTURE:
A SMART INVESTMENT

Come hear representatives from Great Lakes Dredge and Dock, Caterpillar, AECOM, The Army Corps of Engineers and The Nature Conservancy discuss why and how their organizations are making investments in natural infrastructure.

**Thursday, March 21, 2019**
**10:30 am – 11:30 am**
**2253 Rayburn House Office Building**

Featured Speakers

**Bill Hanson, Great Lakes Dredge and Dock *(moderator)***
Vice President, Government Relations

**Don M. McNeill, Caterpillar**
Strategic Growth Manager
Director, Natural Infrastructure Initiative

**Michael J. Donahue, PhD, AECOM**
Vice President, Water Resources and Environmental Services and Director, National Coastal and Ecosystem Restoration Practice

**Todd Bridges, PhD, U.S. Army Corps of Engineers**
Senior Research Scientist (ST), Environmental Science, U.S. Army Engineer Research and Development Center

**Sarah Murdock, The Nature Conservancy**
Director, U.S. Climate Resilience and Water Policy

Click Here to Register

CATERPILLAR AECOM
US Army Corps of Engineers
EWN
The Nature Conservancy

Photo © Jennifer Emerling

Engineering With Nature

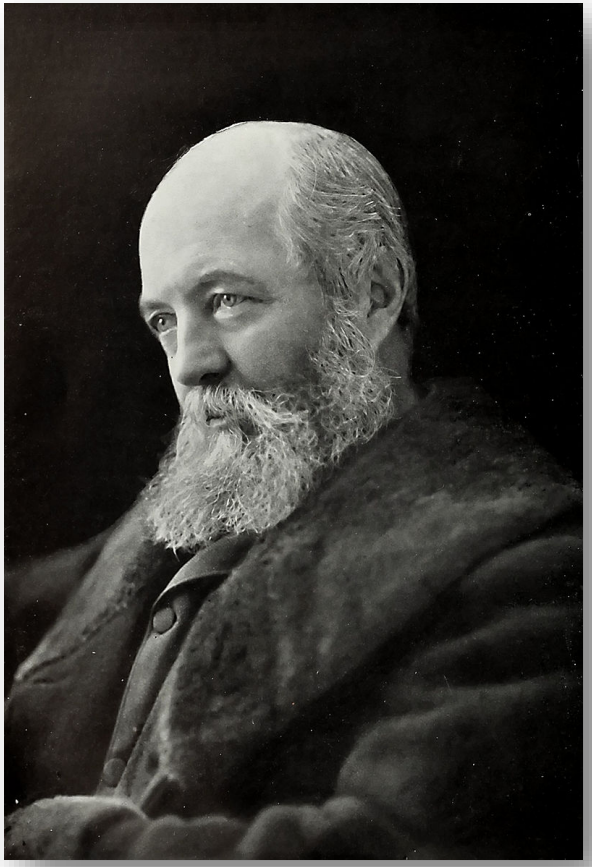
# COLLABORATION WITH ACADEMIA

- **University of Georgia**
  - Institute for Resilient Infrastructure Systems (IRIS)
  - Multiple levels of collaboration on EWN and NNBF
  - EWN curriculum development
- **University of Oklahoma**
  - Water Security
  - Focus on mid-western and western landscapes and water resources
  - Streams, rivers, reservoirs and related infrastructure and purposes
- **Texas A&M University**
  - Partnering through the Coastal Science and Engineering Collaborative (CSEC)
  - Joint research on NNBF
  - EWN Seminar spring 2018
  - Developing graduate curriculum to support EWN
- **Lamar University**
  - Civil and Environmental Engineering
  - Engineering With Nature course (fall 2019) taught by USACE staff

# Landscape Architecture: Bringing It All Together

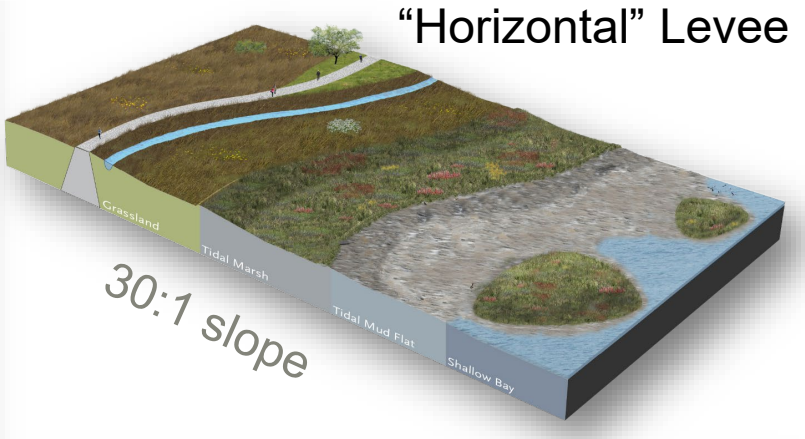
*"Perhaps more than any other person, Frederick Law Olmsted affected the way America looks."*

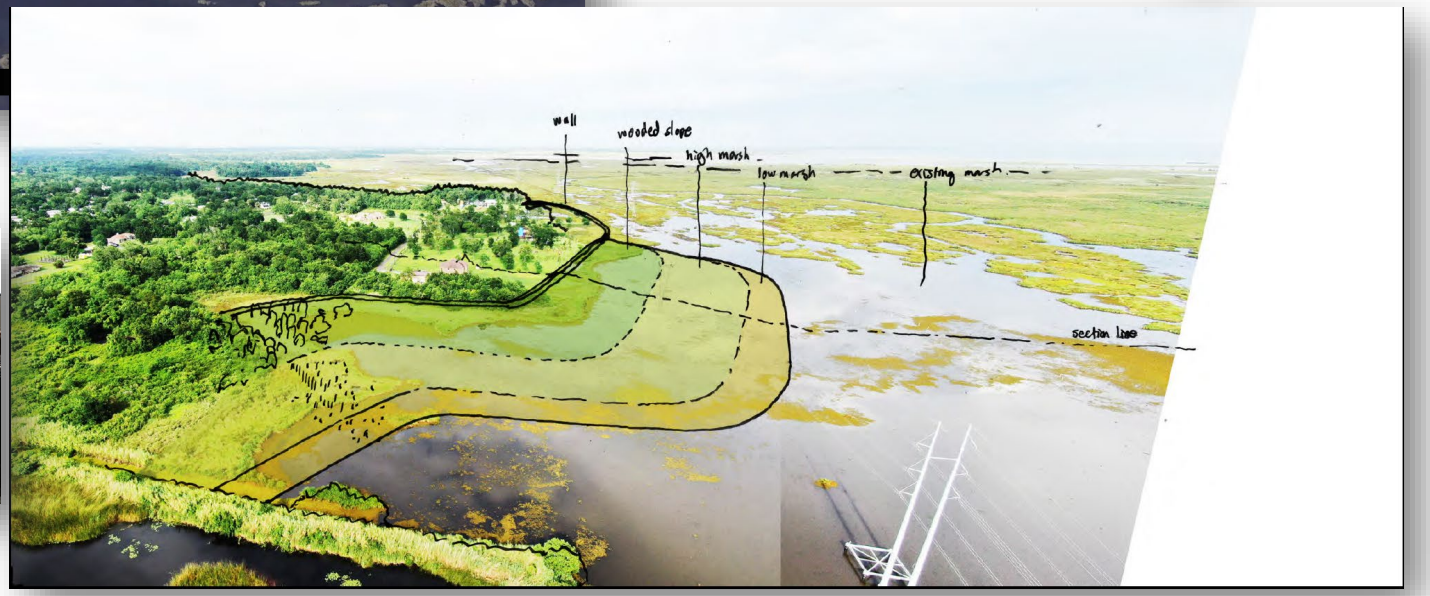
- Father of American Landscape Architecture
- Designs for >6,000 landscapes
  - NYC Central Park
  - US Capitol Grounds
  - Stanford University
  - USMA
  - Biltmore Estate
  - National Zoo
  - Louisville Park System



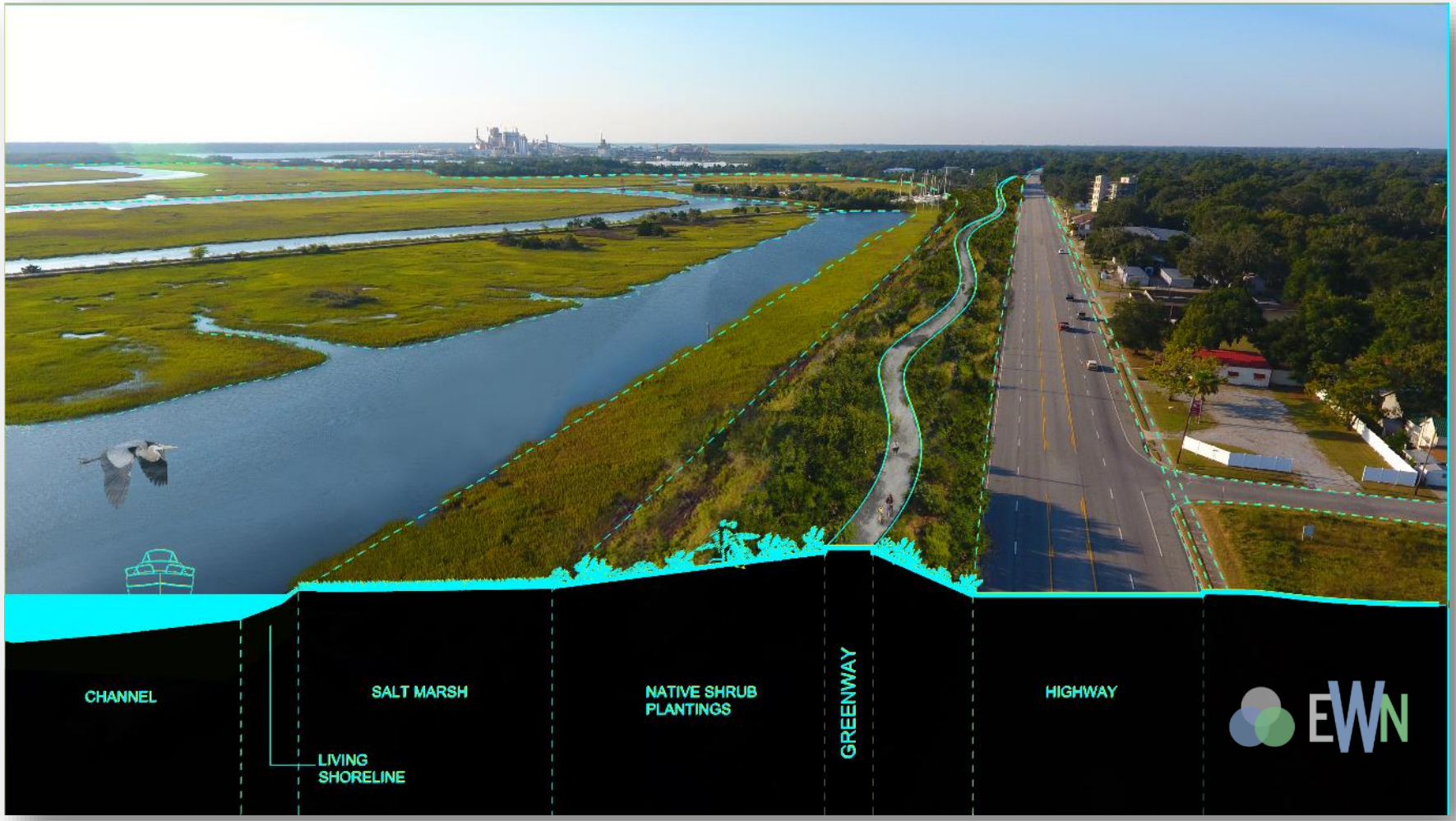
Frederick Law Olmsted
(1822-1903)

# SABINE TO GALVESTON, TEXAS





# SYSTEMS: INTEGRATION, COMPLEMENTARITY, REDUNDANCY, RESILIENCE, SUSTAINABILITY



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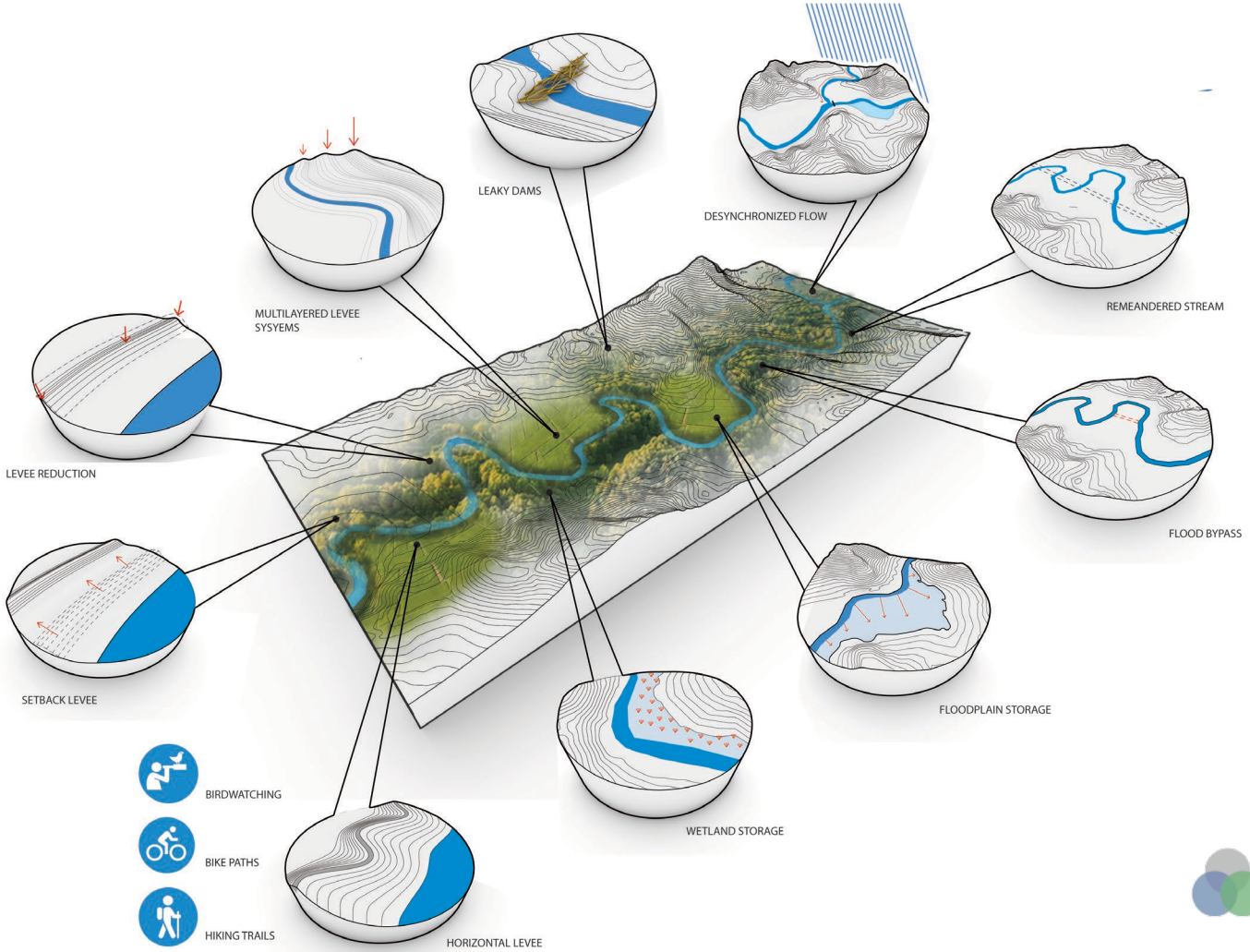
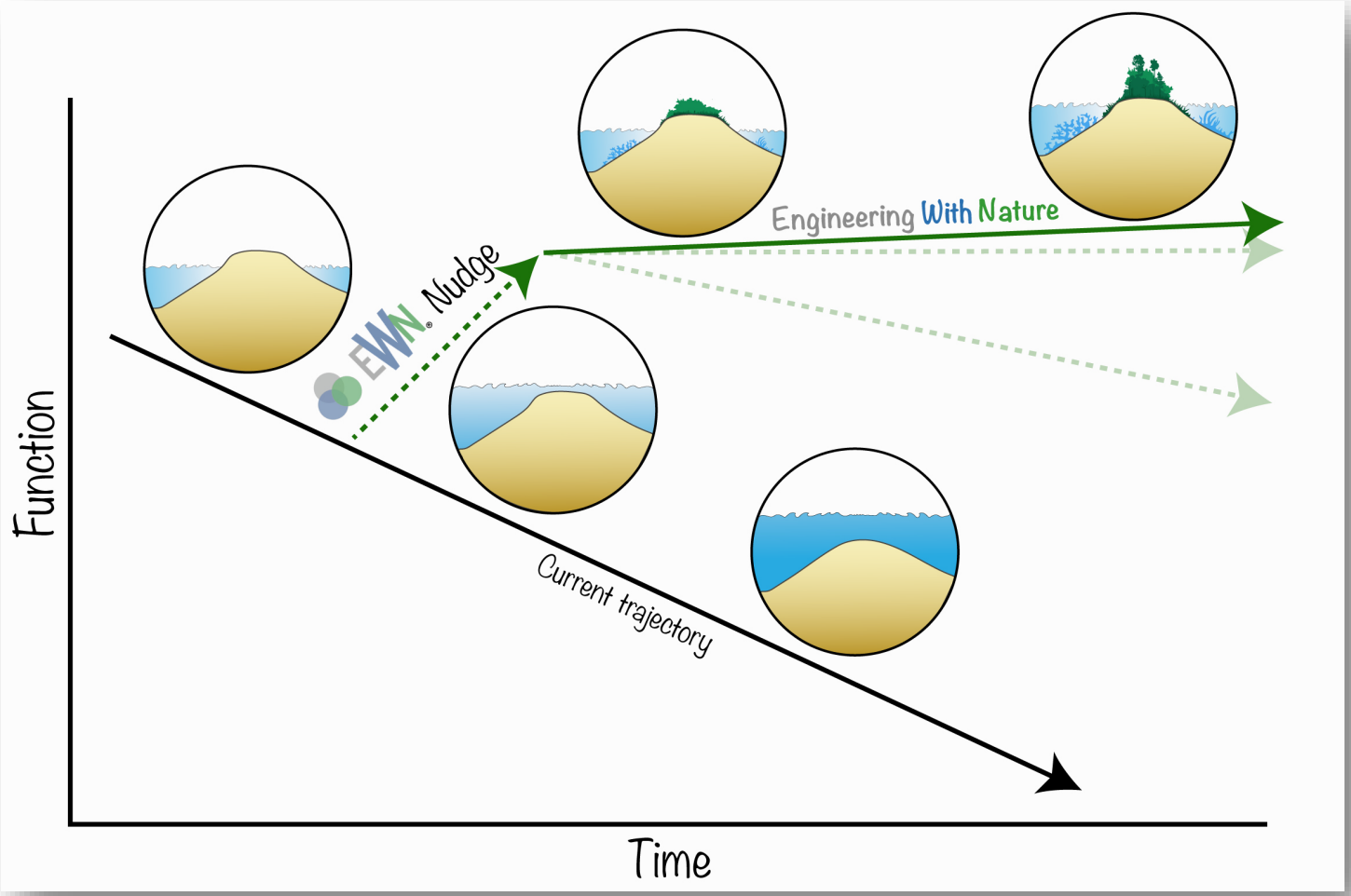


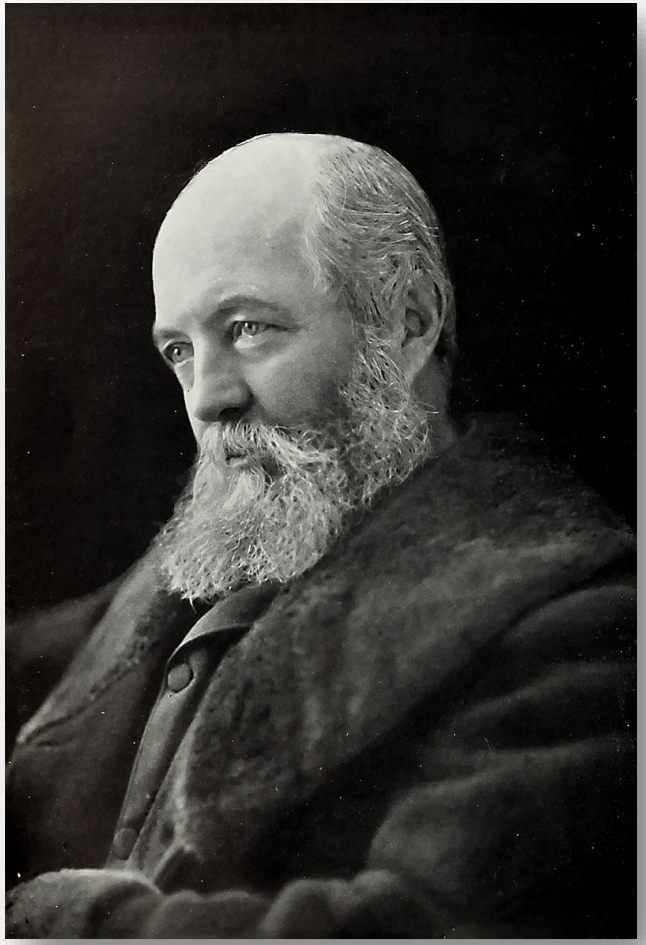
# *Engineering With Nature:* "Nudging" Trajectories



# FREDERICK LAW OLMSTED (1822-1903)

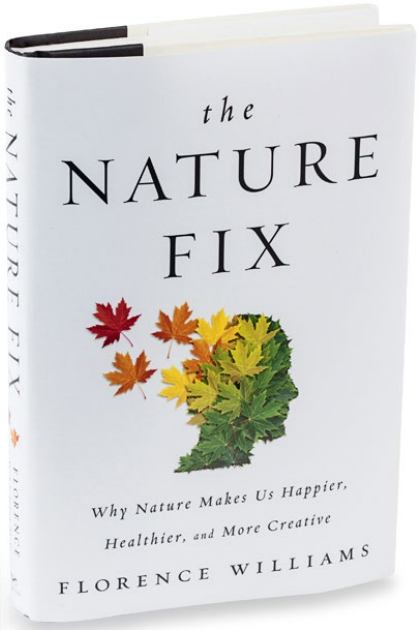
## The Nature-Human Connection

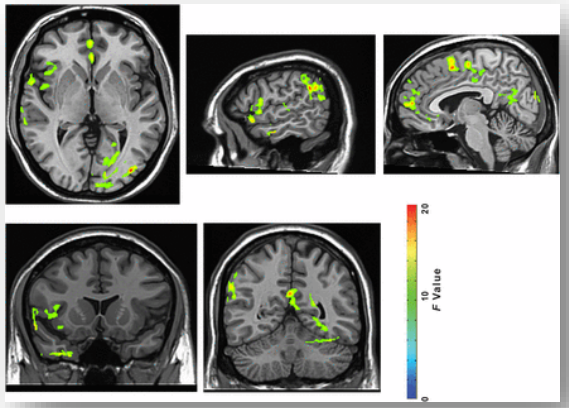
*"It is a scientific fact that the occasional contemplation of natural scenes of an impressive character, particularly if this contemplation occurs in connection with relief from ordinary cares, change of air and change of habits, is favorable to the health and vigor of men…"*



# NATURE AND HUMAN WELLBEING

- Science supports positive effects of contact with nature on:
  - Physical health
    - Blood pressure
    - Healing
    - Immunity
  - Mental health
    - Cognitive function
    - Anxiety
    - Depression
    - Socialization




**Nature experience reduces rumination and subgenual prefrontal cortex activation**

Gregory N. Bratman, J. Paul Hamilton, Kevin S. Hahn, Gretchen C. Daily, and James J. Gross

PNAS July 14, 2015 112 (28) 8567-8572; first published June 29, 2015 https://doi.org/10.1073/pnas.1510459112

# EWN SCIENCE, ENGINEERING, TECHNOLOGY: CAPABILITY TARGETS

**Fundamental processes**
- Sediment transport through and around NNBF
- Long-term engineering and environmental performance of features
- Benefits / Ecosystem 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

**Guidance development**
- For planning, design, construction, O&M

**Demonstration/pilot projects to innovate and learn**
- Facilitate necessary collaboration
- Evolve organizational culture and practice
- Produce credible evidence of success at field scale
- Fuel the “power of the story”

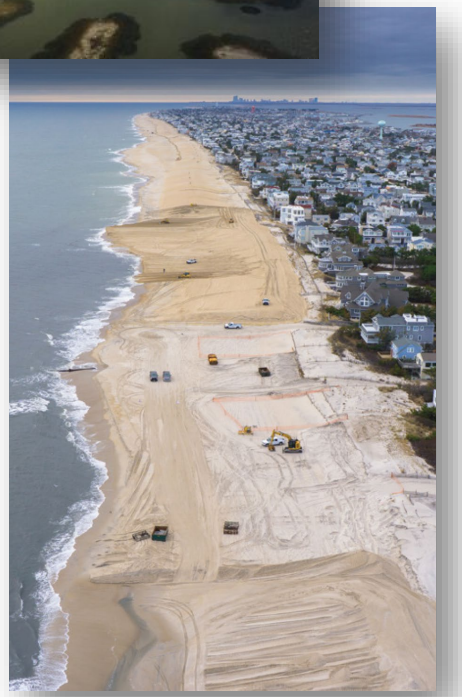
# INTEGRATED MODELING AND MONITORING

## Challenges

- Representing combinations of EWN features in system models
  - E.g., temporal and spatial scales
- Life cycle analysis or EWN features, to include O&M
- Development of planning level models and tools
  - E.g., development of models with a spectrum of resolution

## Opportunities

- Optimize placement and size of EWN features within a watershed
- Integrated hybrid modeling approaches to determine both local and system-wide impacts of EWN projects within watersheds
- Quantification of EWN benefits to enable planners to include these features in return on investment calculations
- Evaluation of improved ecosystem functions
  - E.g. reduced water levels, increased infiltration, pollutant filtration and improved surface water quality, reduced air temperatures due to urban heat islands, etc.
- Assessment of long-term cost savings of EWN strategies compared to conventional approaches
- Representation of “triple bottom line” benefits:
  - Economic
  - Environmental
  - Social
- Models to actively engage stakeholders and decision-makers



# “Satellite” Image of California, circa 1851
by Mark Clark

https://www.kcet.org/shows/lost-la/six-strange-maps-of-california