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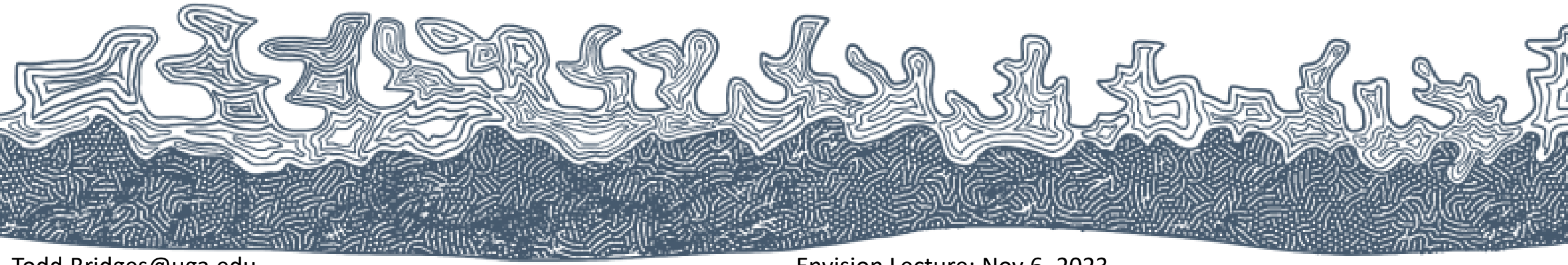
Institute for Resilient Infrastructure Systems

The Case for Nature + Engineering

Dr. Todd S. Bridges
College of Engineering
University of Georgia



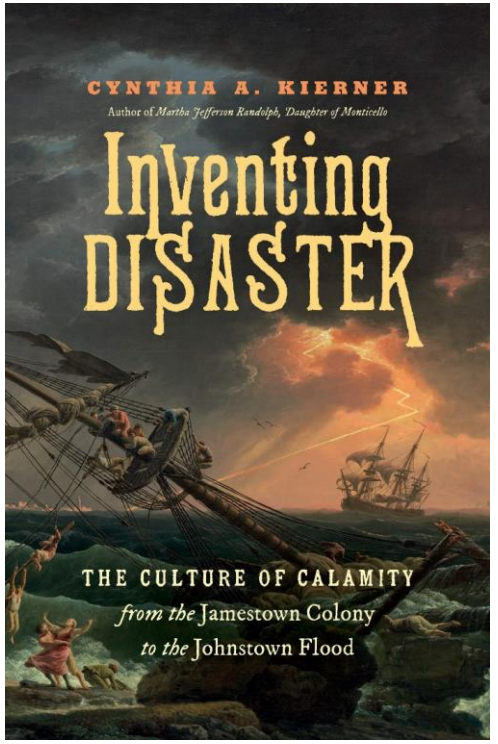
Todd.Bridges@uga.edu

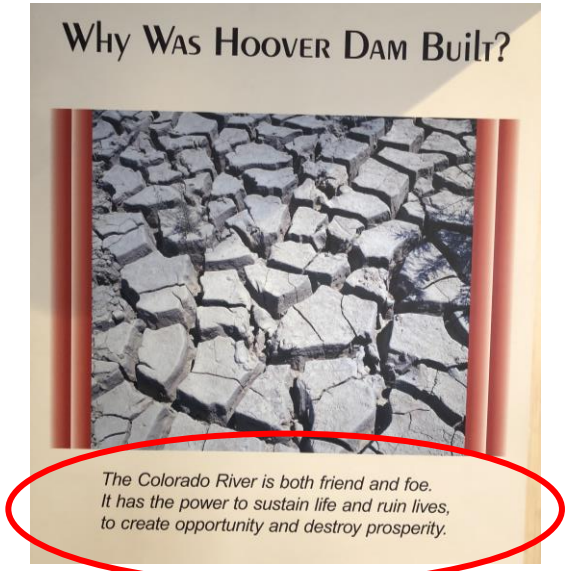
The Culture of Calamity

"…our modern approach to disaster is rooted fundamentally in an Enlightenment-inspired confidence in humanity's ability to conquer and control nature." Cynthia Kierner, 2019

Jamestown, Virginia (1607), 2020

Cynthia Kierner, Professor of History, George Mason University





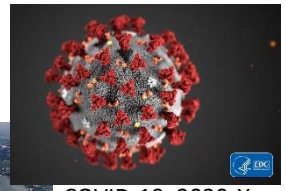
The Multi-Hazard World


Mt. Saint Helens, 1980

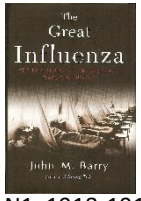

David Johnston, USGS

New Madrid Seismic Zone


San Francisco, 1906


COVID-19, 2020-X


HABs, Lake Erie; 2008-2017



H1N1, 1918-1919


Dust Bowl, 1930s

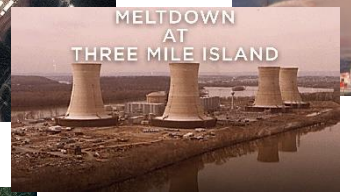

Offutt AFB, 2019



Camp Fire; CA 2018

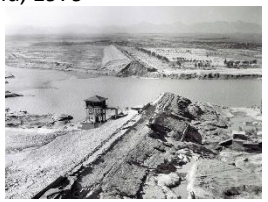

Beirut, Lebanon; 2020


Fukushima, 2011



Three Mile Island, 1979


Deepwater Horizon, 2010

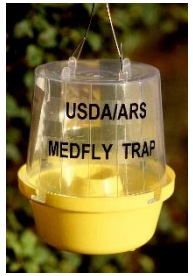

Banqiao dam failure; China, 1975


Hurricane Katrina, 2005

2020 record-setting storm season

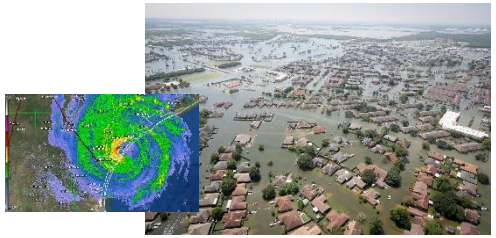

9/11


Civil unrest, 2020



Medfly “bio-attack”; CA, 1989


Flood of 1927; Tallulah, LA


Hurricane Harvey; landfall and Houston, 2017

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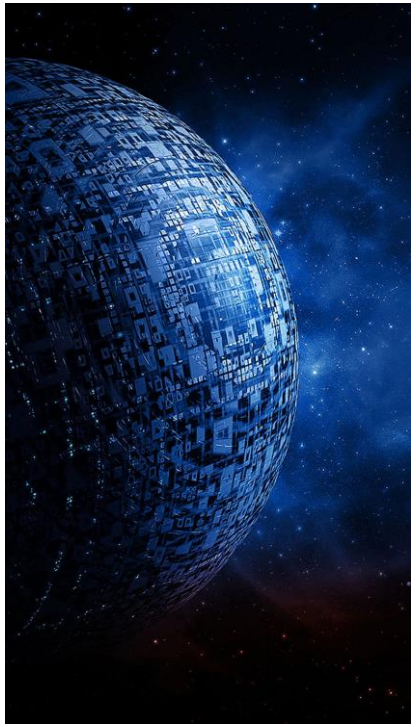
1900-2000: *The Century of Infrastructure* (US)

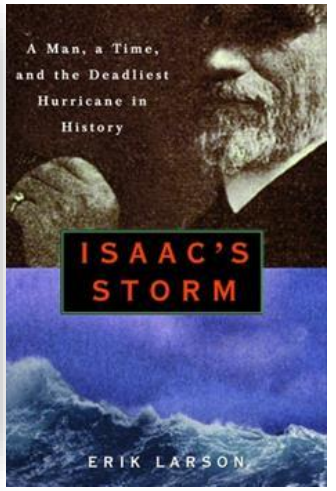
- 4,071,000 miles of roadway
  - 47,182 miles in the Interstate system
- 149,136 miles of mainline rail
- 640,000 miles of high-voltage transmission lines
- 614,387 bridges
- 90,580 dams
- >30,000 miles of flood levee
- 155,000 public drinking water systems
- ~5,000 military installations
- 926 ports, 25,000 miles of navigation channel



Galveston Hurricane (1900)

- Landfall 8 September 1900
- Estimated Category 4 Hurricane
  - ► 145 mph winds
- Estimated death toll: 6,000-12,000
- Response: Galveston seawall and island raising
  - ► >10-mile seawall,1902-1963
  - ► Land raised with 16M cubic yds sand

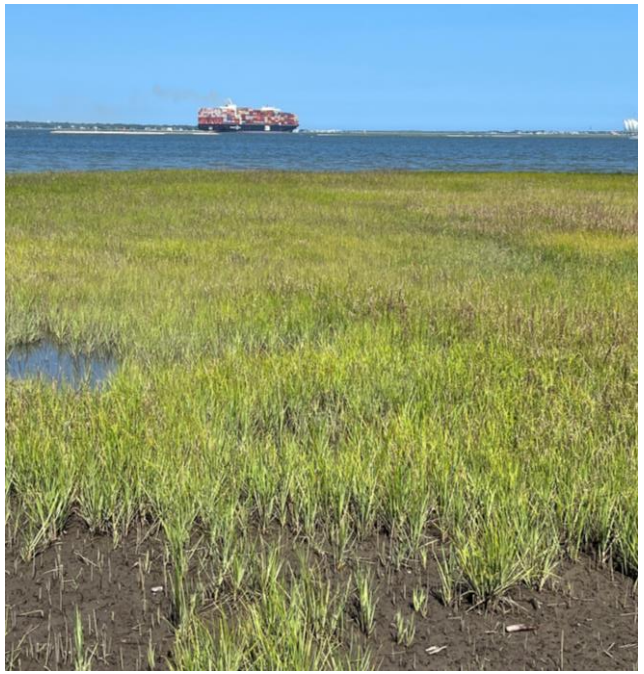
Dr. Isaac Cline, 1861-1955



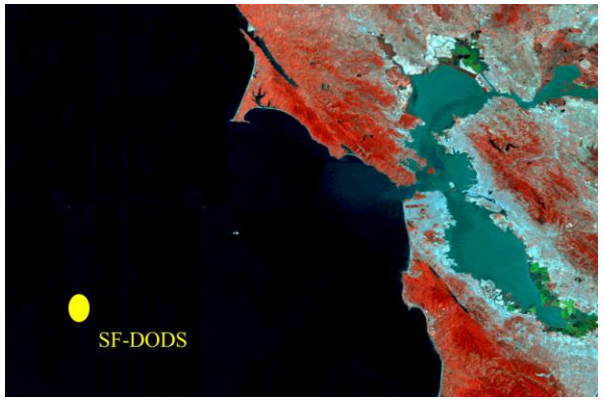
Charleston, SC

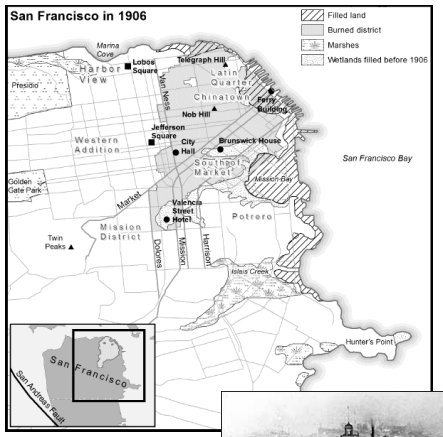
17th Century Charleston

20th Century Charleston



San Francisco Bay





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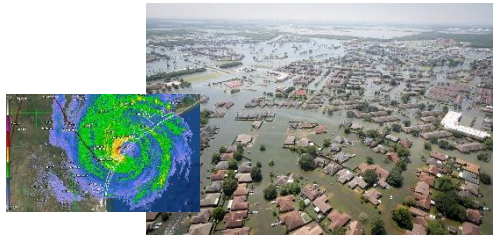
A Planetary Crisis of Our Own Engineering

Climate Change

Hurricane Katrina, 2005



Hurricane Harvey; landfall and Houston, 2017

2020 record-setting storm season

Offutt AFB, 2019

Lake Mead, 2022

Pollinator Declines

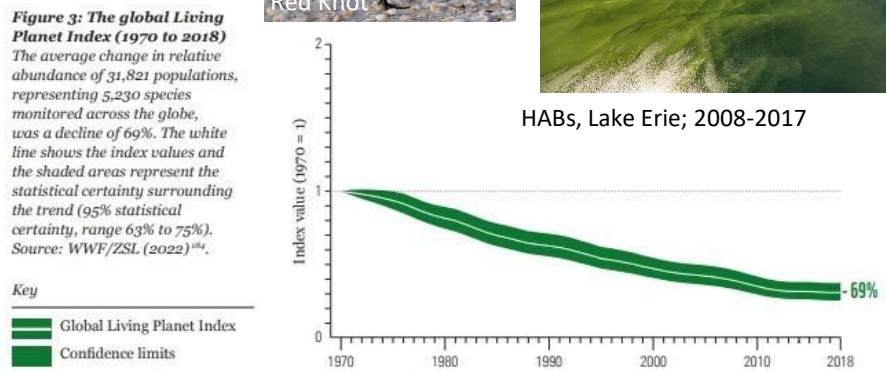
NYC Skyline, June 7, 2023; Photo B. Bajuelos Castillo

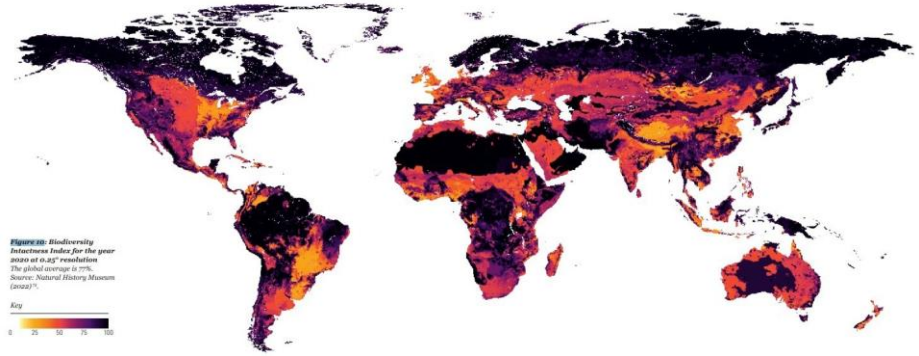
Fort Nelson, British Columbia, June 3, 2023

Biodiversity Loss

Red Knot

HABs, Lake Erie; 2008-2017





Biodiversity Intactness Index; WWF Living Planet Report 2022

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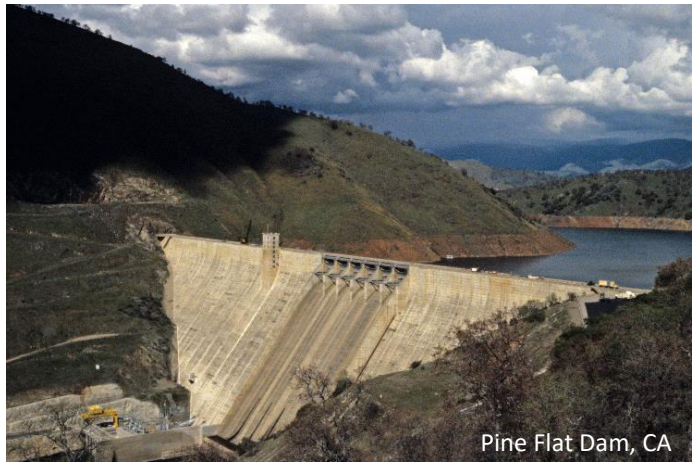
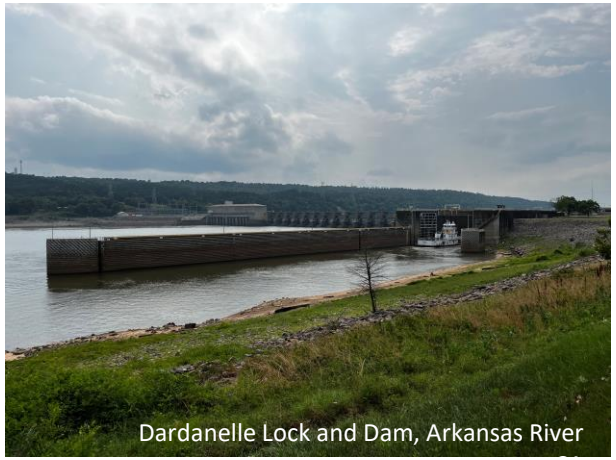
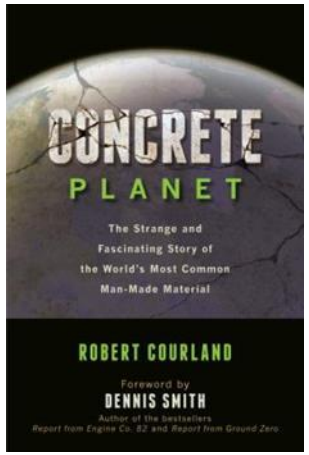
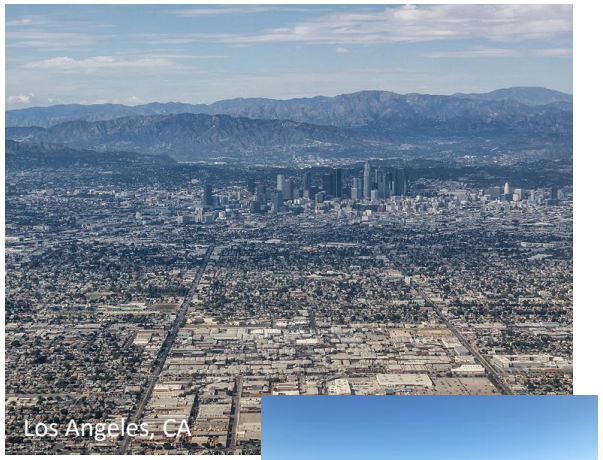
The 3 Parts of the Predicament:
Hazard + Climate Change + Landscape Transformation thru Engineering


Pine Flat Dam, CA


Dardanelle Lock and Dam, Arkansas River




Los Angeles, CA

>90,000 dams in the US, impounding
>600,000 miles of river


Los Angeles River

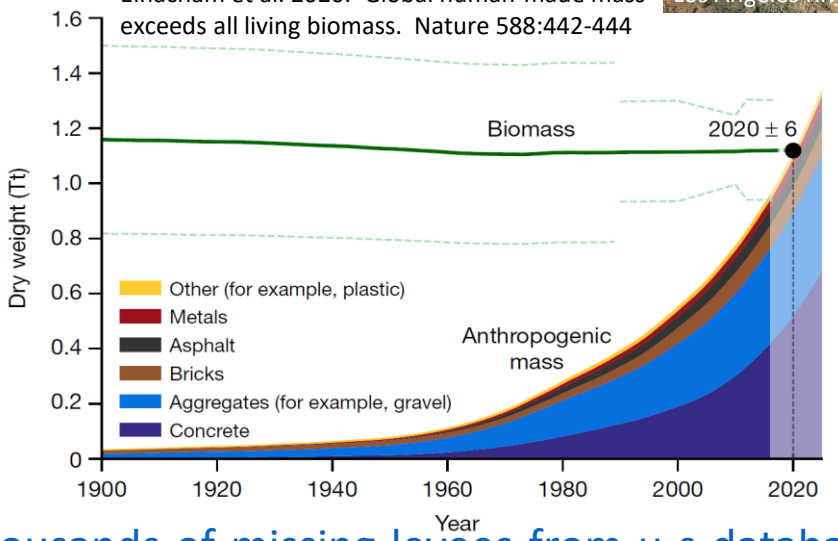
250,000 sq. miles of paved surface on the planet


MS River levee near Cairo, IL


Levee at Dogtooth Bend


River Bank, St. Louis, MO

Elhacham et al. 2020. Global human-made mass exceeds all living biomass. Nature 588:442-444



24,500 miles of levee in National Levee Database;
https://levees.sec.usace.army.mil/#/
>100,000 miles of levee total estimate for US;
https://eos.org/research-spotlights/algorithm-detects-thousands-of-missing-levees-from-u-s-database

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Ecological Engineering, 1962

***Ecological Engineering:* "the practice of joining the economy of society to the environment symbiotically by fitting technological design with ecological *self design*."**
HT Odum, 2003

Port Aransas Nature Preserve

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Ecological Engineering 20 (2003) 339–361

ECOLOGICAL ENGINEERING

www.elsevier.com/locate/ecoleng

Concepts and methods of ecological engineering

Howard T. Odum[a], B. Odum[b,*]

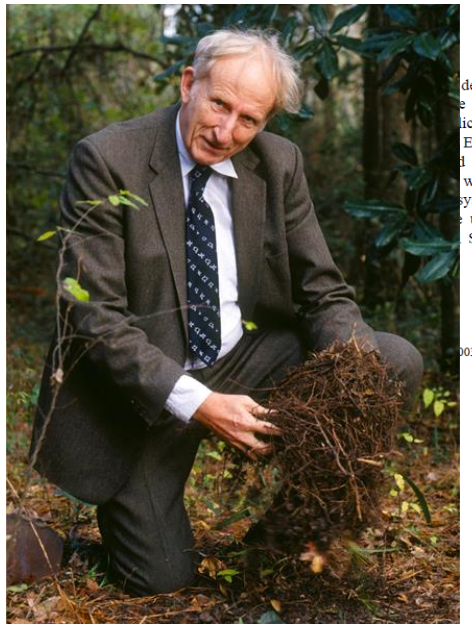
[a] *Environmental Engineering Sciences, P.O. Box 116450, University of Florida, Gainesville, FL 32611-6450, USA*
[b] *2160 N.W. 9th Ave., Gainesville, FL 32603, USA*

Received 14 June 2002; accepted 4 August 2003

Abstract

Ecological engineering was defined as the practice of joining the economy of society to the environment symbiotically by fitting technological design with ecological *self design*. The boundary of ecological engineering systems includes the ecosystems that self organize to fit with technology, whereas environmental engineering designs normally stop at the end of the pipe. For example, the coastal marsh wildlife sanctuary at Port Aransas, Texas, developed when municipal wastewaters were released on bare sands. The energy hierarchy concept provides principles for planning spatial and temporal organization that can be sustained. Techniques of ecological engineering are given with examples that include maintaining biodiversity with multiple seeding, experimental mesocosms, enclosed systems with people like Biosphere 2, wetland filtration of heavy metals, overgrowth and climax ecosystems, longitudinal succession, exotics, domestication of ecosystems, closing material cycles, and controlling water with vegetation reflectance.

Keywords: Ecological engineering; Waste recycle; Self organization; Energy hierarchy; Emergy; Transformity; Emdollars; Maximum power



Howard T. Odum, 1924-2002

1.1. Definitions

Engineering is sometimes described as the study and practice of solving problems with technological designs. The sketch in Fig. 1a shows the environment and the economy coupled symbiotically by exchange of materials and services. Environmental engineering develops the technology for connecting society to the environment. But the technology is only half of the interface with environment. The other half of the interface is provided by the ecosystems as they *self organize* to adapt to the special conditions. Ecological engineering takes advantage of the ecosystems as they combine natural resources and outputs from the economy to generate useful work.

defines what *ecological*
e of its principles, and
lication with examples
Ecological engineering
d cooperative environ-
we applied the name
system self design. By
used worldwide with
Society of Ecological

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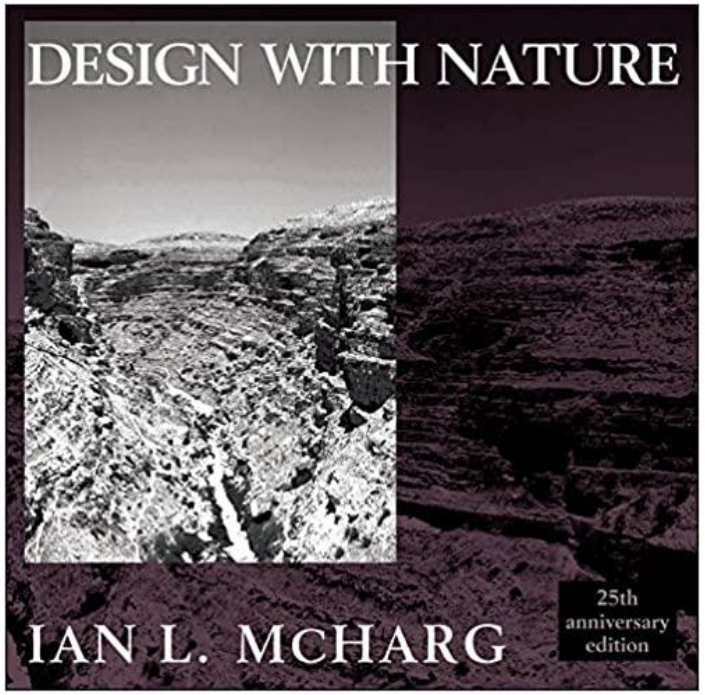
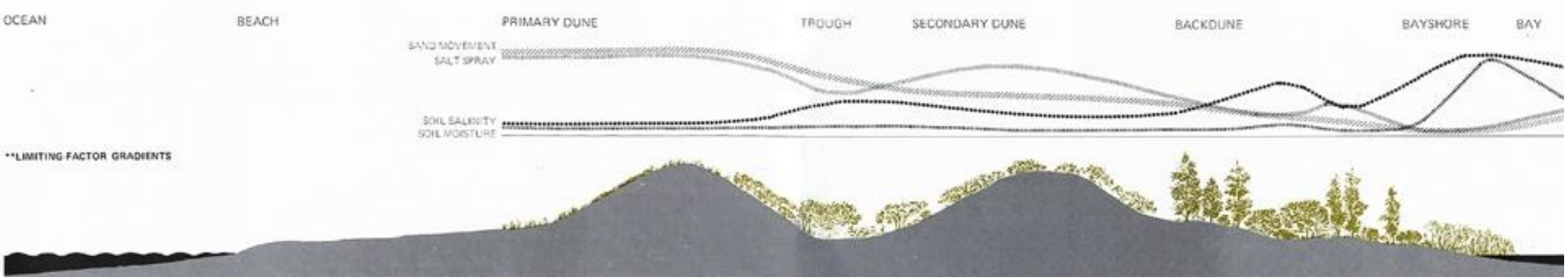
Design with Nature, 1969

"McHarg's emphasis is not on either design or nature by itself, but upon the preposition *with*, which implies human cooperation and biological partnership. He seeks, not arbitrarily to impose design, but to use to the fullest the potentialities—and with them, necessarily, the restrictive conditions—that nature offers."

Lewis Mumford, Introduction to *Design with Nature*

Ian McHarg, 1920-2001





"Between the sea and man stood two barriers, the one natural, the other its human surrogate: dune and dike" McHarg, *Design with Nature*

Nature-Based Solutions: A White House Priority

2022
Earth Day EO

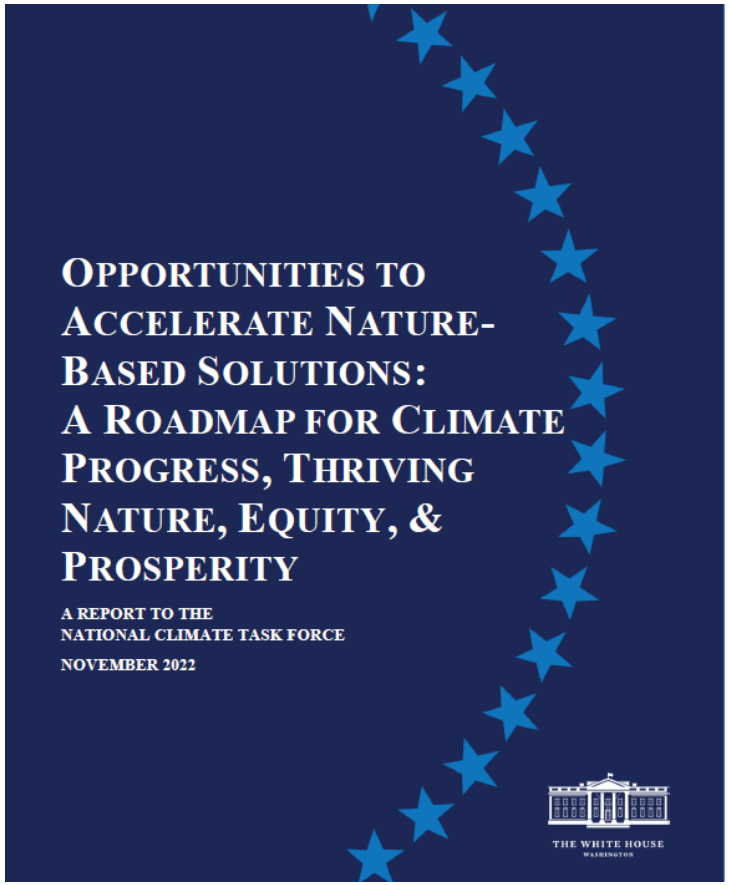
BRIEFING ROOM

Executive Order on Strengthening the Nation's Forests, Communities, and Local Economies

APRIL 22, 2022 • PRESIDENTIAL ACTIONS

EO 14072, Sec. 4. Deploying Nature-Based Solutions to Tackle Climate Change and Enhance Resilience: *"To further amplify the power of nature, including its ability to absorb climate pollution and increase resilience in all communities, today's Executive Order calls for the following:"*

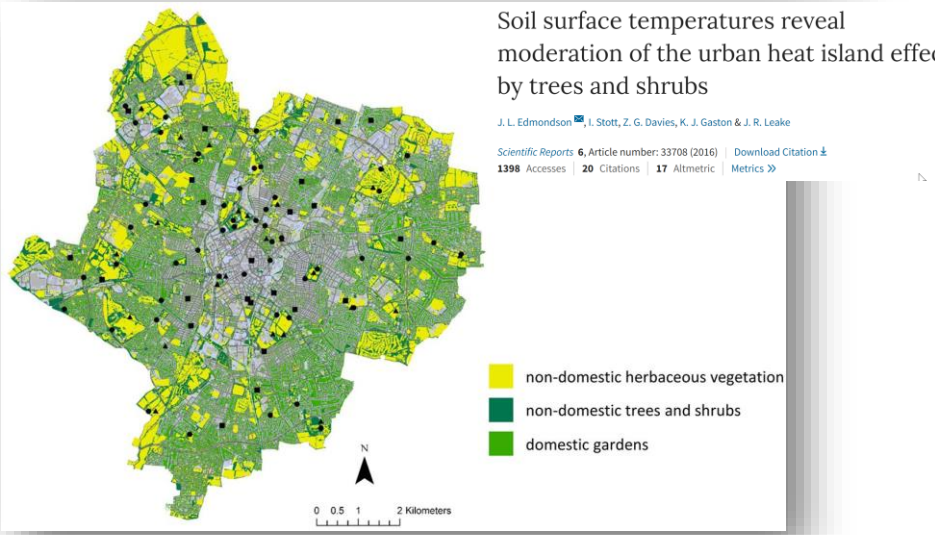
1) ***Report on Nature-Based Solutions***
2) ***Guidance on Valuing Nature***
3) ***First U.S. National Nature Assessment***



Nature-based Solutions: "Actions to protect, sustainably manage, or restore natural or modified ecosystems to address societal challenges, simultaneously providing benefits for people and the environment."

Trees are Multi-Functional Natural Infrastructure

- Shade surfaces (20-45°F cooler)
- Evapotranspiration plus shading can reduce peak summer temperatures by 2-9°F
- Reduce wind speed and winter heat loss from buildings by 10-50%
- Improve local air quality
- Increase water infiltration, reducing surface water run-off
- Support biodiversity
- Sequester carbon

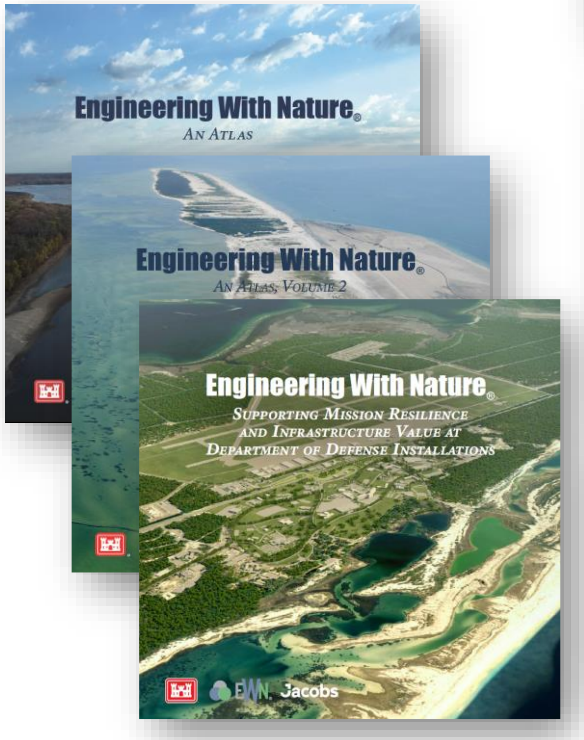


Engineering With Nature®

…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
- Increase and diversify infrastructure value
- Science-based collaboration to organize and focus interests, stakeholders, and partners

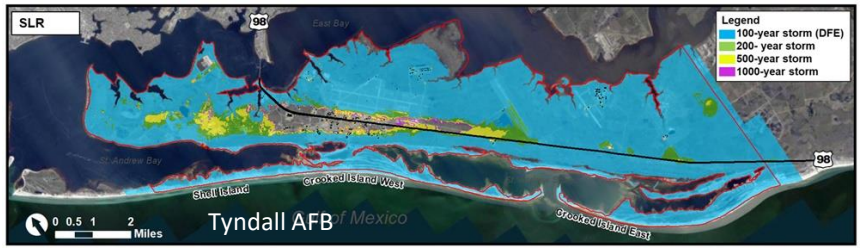


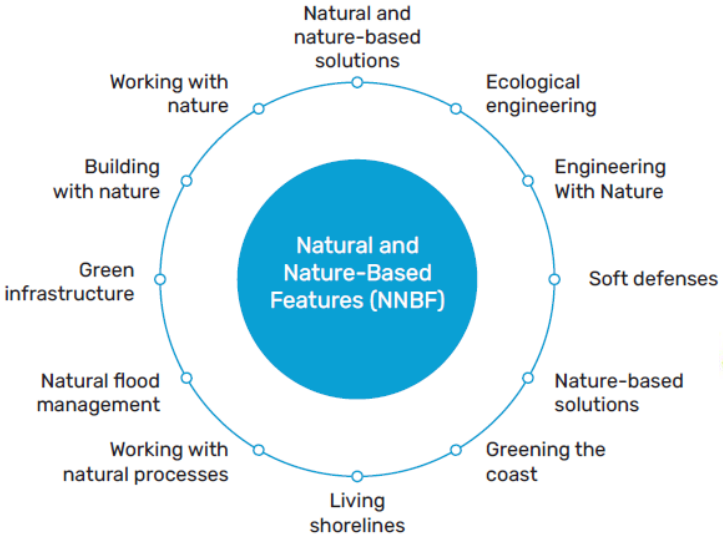
"We absolutely want to do more engineering with nature everywhere we work across the Corps, you have my commitment."

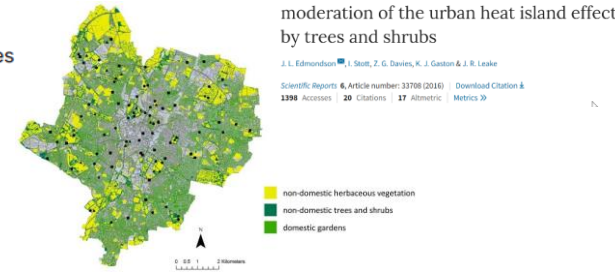
— LTG Scott A. Spellmon, 55th Chief of Engineers, to the House Committee on Transportation & Infrastructure, Water Resources & Environment Subcommittee (24 June 2021)

Nature-Based Solutions: *Conserving, restoring, and engineering nature for the benefit of people and nature*

- **Coastal Storm Risk Management**; e.g., an island-wetland complex that attenuates storm surge and waves.
- **Inland Flood Risk Management**; e.g., a restored inland floodplain that provides space for high flows.
- **Surface Heat Reduction**; e.g., creation of green space, forest restoration.
- **Drought and Wildfire Resilience**; e.g., restored native vegetation + grazing + 'slow-water' interventions + ecological forest management.
- **Water Resilience**; a constructed freshwater wetland that absorbs excess nutrients and recharges depleted groundwater aquifers.
- **Climate Change Mitigation**; e.g., restored native grasslands / plant communities that sequester carbon in soils.







Fort Pierce City Marina, Florida

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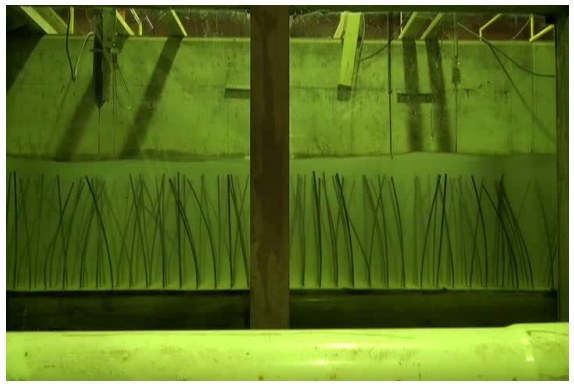
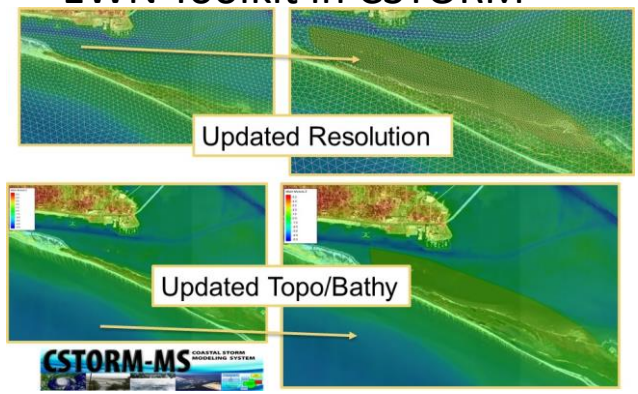
The Science of Nature-Based Solutions: *Using Multiple Lines-of-Evidence*

- **Physical Modeling**
- **Numerical Modeling**
- **Natural Analogs**
- **Scaled Demonstrations**
- **Experience**
  - **Project Monitoring**
  - **Traditional Ecological Knowledge**
  - **Engineering Judgment**



EWN Toolkit in CSTORM



https://ewn.erdc.dren.mil/story-maps/engineering-with-nature-ewn-toolkit-for-erdcs-cstorm/

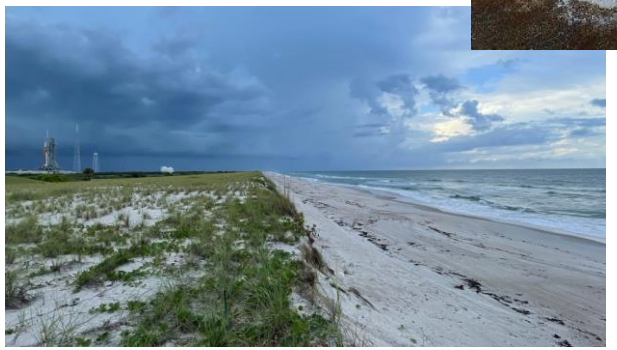
scientific reports

OPEN

Resistance, resilience, and recovery of salt marshes in the Florida Panhandle following Hurricane Michael

Katherine A. Castagno[1,2✉], Tori Tomiczek[3], Christine C. Shepard[4], Michael W. Beck[5], Alison A. Bowden[2], Kiera O'Donnell[1] & Steven B. Scyphers[1]

Characterizing the fragility, resistance, and resilience of marshes is critical for understanding their role in reducing storm damages and for helping to manage the recovery of these natural defenses. This study uses high-resolution aerial imagery to quantify the impacts of Hurricane Michael, a category 5 hurricane, on coastal salt marshes in the Florida Panhandle, USA. Marsh damage was classified into several categories, including deposition of sediment or wrack, fallen trees, vegetation loss, and conversion to open water. The marshes were highly resistant to storm damages even under extreme conditions; only 2% of the 173,259 km² of marshes in the study area were damaged—a failure rate much lower than that of artificial defenses. Marshes may be more resistant than resilient to storm impacts; damaged marshes were slow to recover, and only 16% of damaged marshes had recovered 6 months after landfall. Marsh management mattered for resistance and resilience; marshes on publicly-managed lands were less likely to be damaged and more likely to recover quickly from storm impacts than marshes on private land, emphasizing the need to incentivize marsh management on private lands. These results directly inform policy and practice for hazard mitigation, disaster recovery, adaptation, and conservation, particularly given the potential for more intense hurricane landfalls as the climate changes.



Huamantanga, Peru. People use and maintain 1,400-year-old amunas, canals. Credit: Diego Pérez/Forest Trends

400 publications in the NBS library @ https://ewn.erdc.dren.mil/?page_id=368

Evaluating Diverse, Multi-Purpose Benefits

Policy Research: *Current federal alternative evaluation process does not comprehensively value economic, environmental, and social benefits. These constraints screen out or exclude Nature-Based Solutions (NBS) and could lead to outcomes inconsistent with the Administration's priorities around community resilience and equity.*

Approach:

- **Summarize** historical and current alternative evaluation policies and practices
- **Identify** 6 historical planning studies that considered NBS alternatives suitable for case study analysis
    1. *Jacksonville Harbor (NAV, South East)*
    2. *Jamaica Bay Reformulation (CSRM, North East)*
    3. *Southwest Coastal (CSRM, Gulf Coast)*
    4. *South Platte River and Tributaries (FRM, North West)*
    5. *West Sacramento (FRM, Pacific)*
    6. *South San Francisco Bay Shoreline (FRM, Pacific)*
- **Review** updated valuation methods and planning frameworks that incorporate environmental and social benefits
- **Analyze** case studies using updated methods and exploratory analysis to look beyond current policy constraints

National Summit: *Measuring What Matters*
November 30, 2022; Washington D.C.

"It matters because it matters to the President."

"Our sponsors no longer want to see 'off the shelf' solutions."

"We can't value everything, but we need to value what we can."

Michael L. Connor, ASA(CW)

https://ewn.erdc.dren.mil/?p=7841

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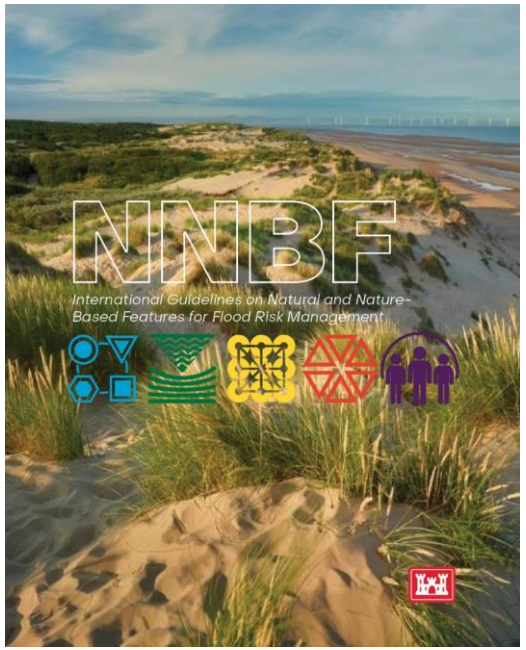
THE WATER INSTITUTE OF THE GULF

Develop Guidance: *International Guidelines on Natural and Nature-Based Features for Flood Risk Management*

NNBF Guidelines Table of Contents

- Chapter 1. Introduction
- Chapter 2. Principles, Frameworks, and Outcomes
- Chapter 3. Community Engagement
- Chapter 4. Systems Approach
- Chapter 5. Performance
- Chapter 6. Benefits and Costs of NNBF
- Chapter 7. Adaptive Management
- Chapter 8. Introduction to Coastal Systems
- Chapter 9. Beaches and Dunes
- Chapter 10. Coastal Wetlands and Intertidal Areas
- Chapter 11. Islands
- Chapter 12. Reefs
- Chapter 13. Plant Systems
- Chapter 14. Environmental Enhancements
- Chapter 15. Introduction to Fluvial Systems
- Chapter 16. Fluvial Systems and Flood Risk Management
- Chapter 17. Benefits and Challenges of NNBF in Fluvial Systems
- Chapter 18. Fluvial NNBF
- Chapter 19. Fluvial NNBF Case Studies
- Chapter 20. The Way Forward



https://ewn.erdc.dren.mil/?page_id=4351

www.engineeringwithnature.org

Winner, Environment Agency Flood & Coast International Excellence Award, 2022

NNBF Guidelines

- >1,000 pages, 5-year effort
- >70 multi-sector organizations
- >170 authors and contributors

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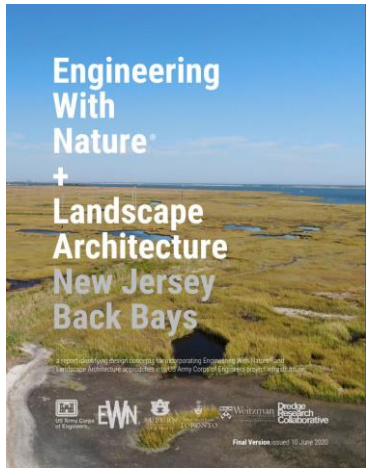
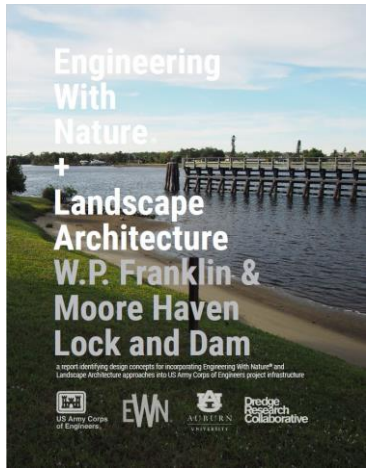
Design with 'Nature-First Thinking'





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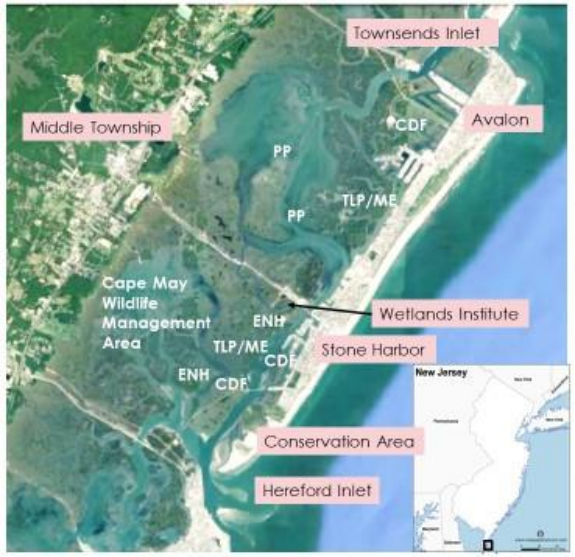
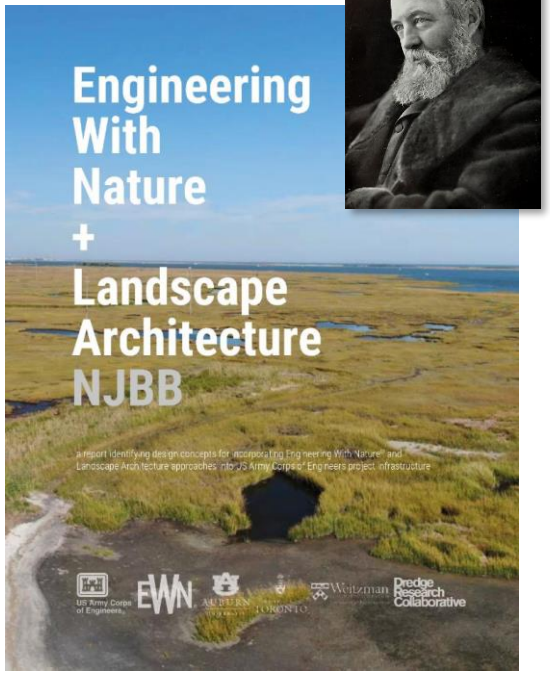
https://ewn.erdc.dren.mil/?page_id=81

Up-Scaled Partnering: *SMIIL*

Seven Mile Island Innovation Laboratory

- Collaboration and partnership that s building first-of-their-kind NBS projects in coastal New Jersey
  - Began in conversation
  - Accelerated by a storm (Sandy)
  - Progressed through piloting
  - Now in full-scale implementation





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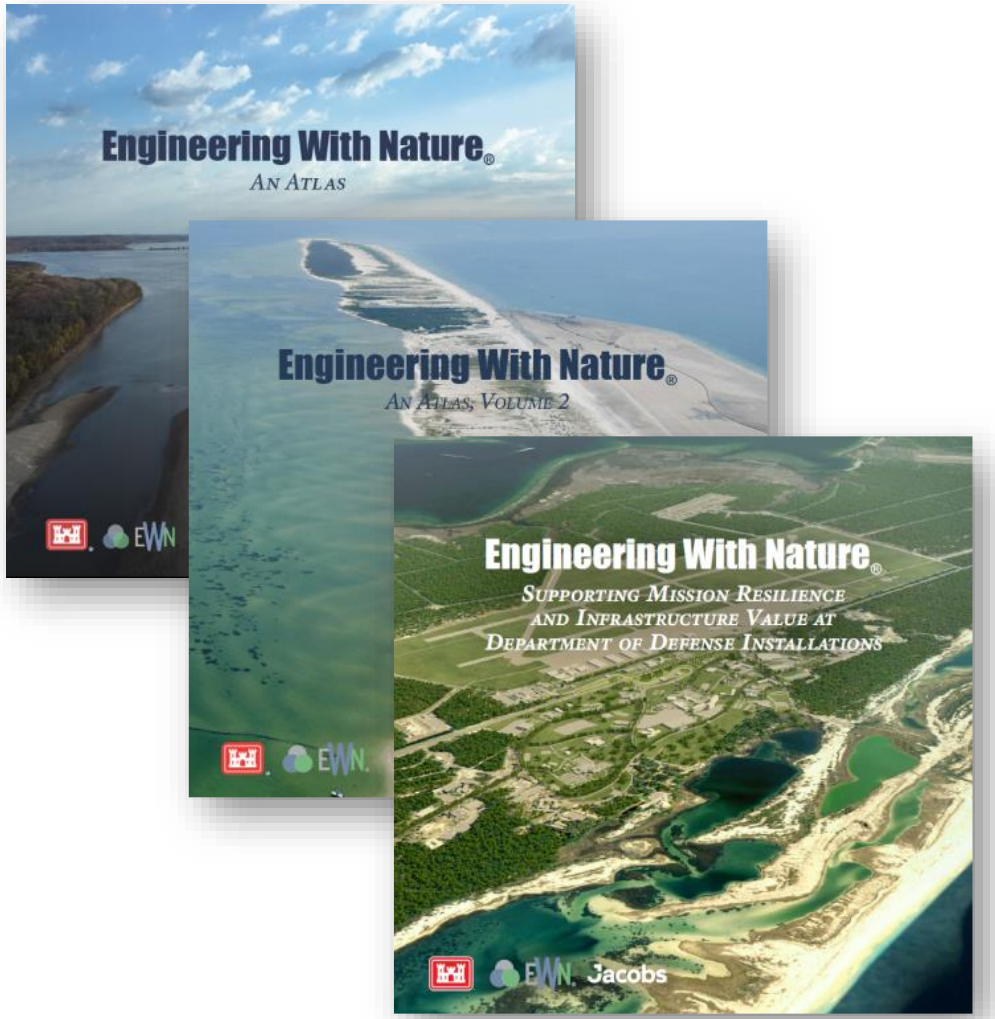
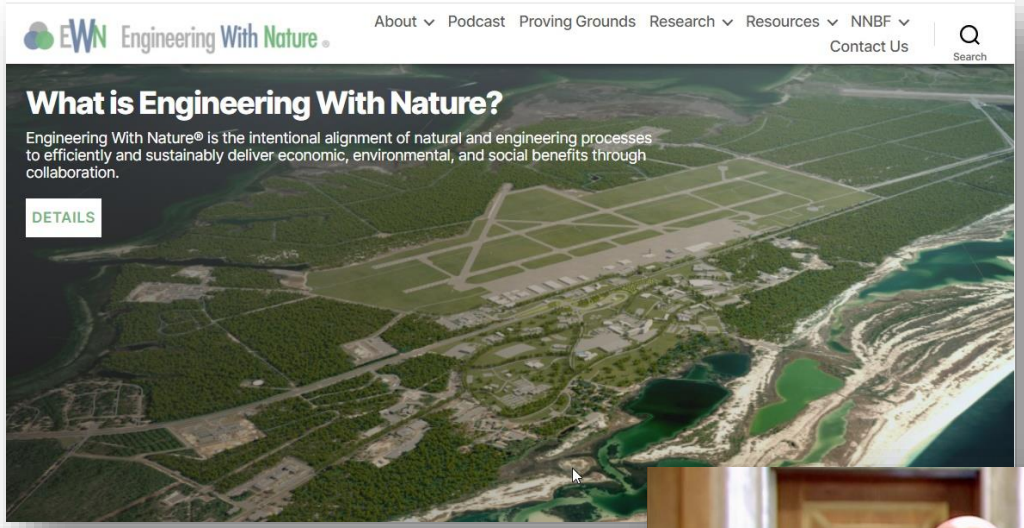
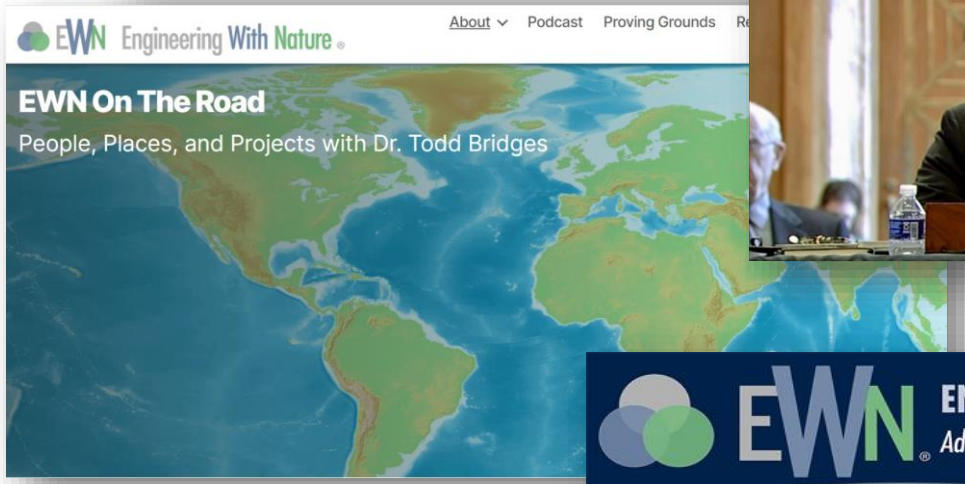
Spark Conversation, Thinking, and New Ideas







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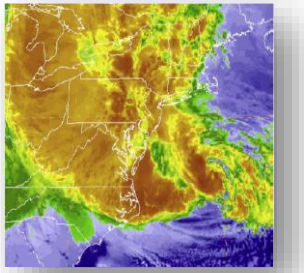
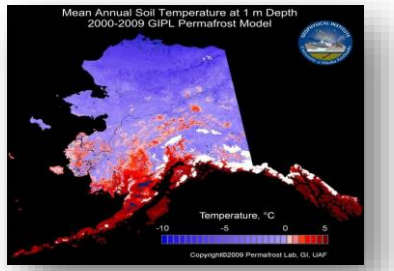
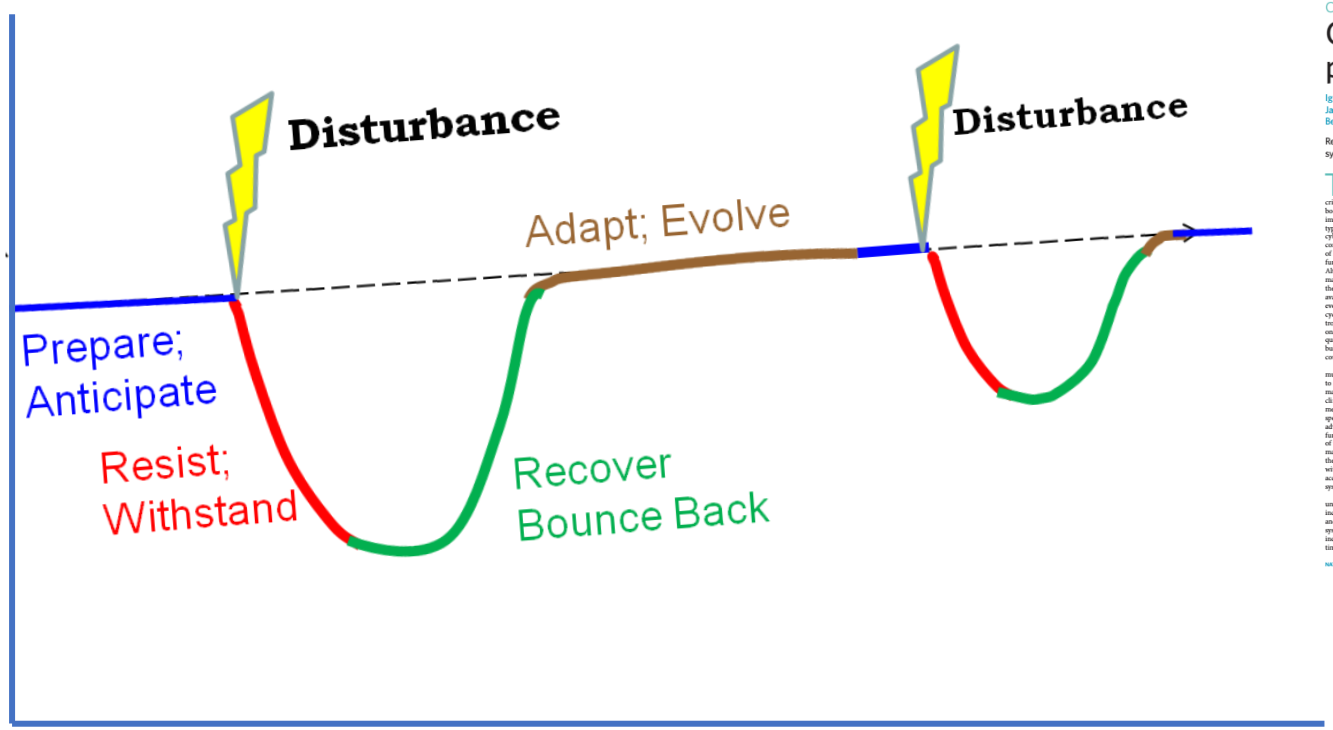
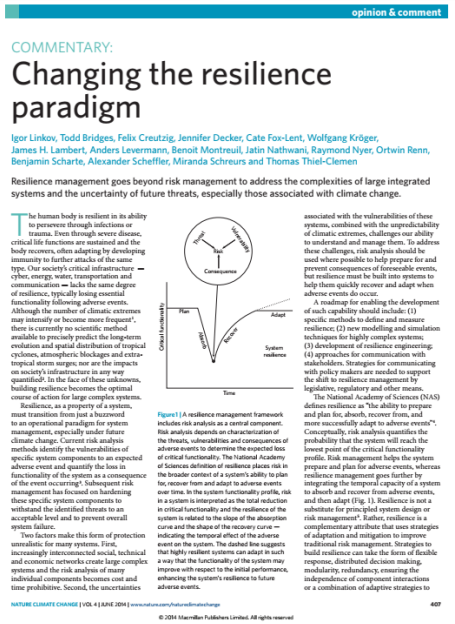
Resilience









opinion & comment

COMMENTARY:

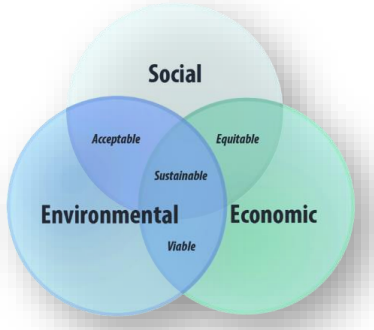
Changing the resilience paradigm

Igor Linkov, Todd Bridges, Felix Creutzig, Jennifer Decker, Cate Fox-Lent, Wolfgang Kröger, James H. Lambert, Anders Levermann, Benoit Montreuil, Jatin Nathwani, Raymond Nyer, Ortwin Renn, Benjamin Scharte, Alexander Scheffler, Miranda Schreurs and Thomas Thiel-Clemen

Resilience management goes beyond risk management to address the complexities of large integrated systems and the uncertainty of future threats, especially those associated with climate change.

Linkov, Bridges, Creutzig, et al. 2014. Changing the Resilience Paradigm. *Nature Climate Change* 4: 407-409.

Sustainability, NEPA (1969): "create and maintain conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations."



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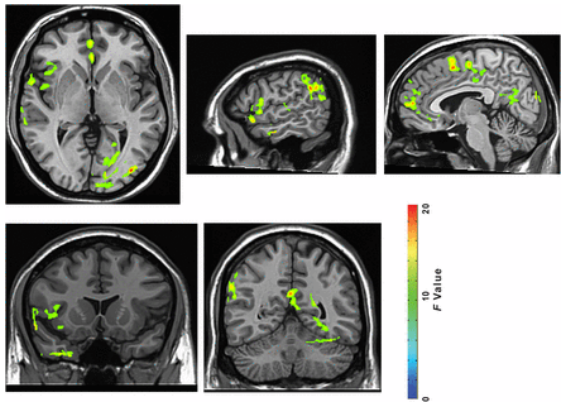
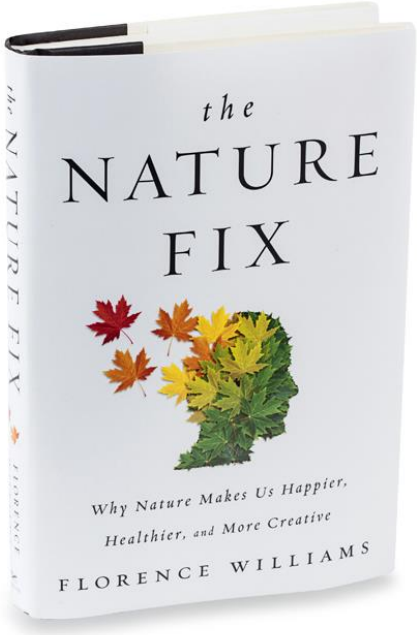
Resilience: the ability of a ***system*** to **Prepare for**, **Resist**, **Recover**, and **Adapt** to achieve functional performance under the stress of disturbances through time.

Elevate the Human Dimension

- Science says that nature directly supports human wellbeing!
  - Physical health
    - Blood pressure
    - Healing
    - Immunity
    - Etc.
  - Mental health
    - Cognitive function
    - Anxiety
    - Depression
    - Socialization
    - Etc.

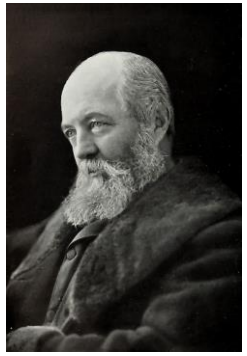




Nature experience reduces rumination and subgenual prefrontal cortex activation

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

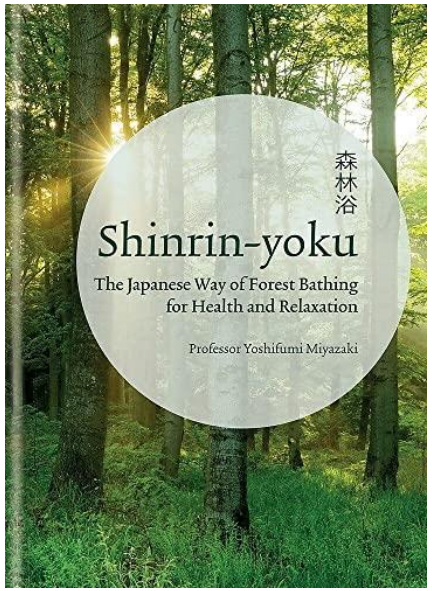
PNAS July 14, 2015 112 (28) 8567-8572; first published June 29, 2015 https://doi.org/10.1073/pnas.1510459112



scientific reports

Urban street tree biodiversity and antidepressant prescriptions

Melissa R. Marselle[1,2,3✉], Diana E. Bowler[1,2,4], Jan Watzema[1,2], David Eichenberg[1,2,5], Toralf Kirsten[6,7] & Aletta Bonn[1,2,4]



"It is a scientific fact that the occasional contemplation of natural scenes... is favorable to the health and vigor of men…" **Frederick Law Olmsted (1822-1903)**

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The Institute for Resilient Infrastructure Systems

UNIVERSITY OF GEORGIA
Institute for Resilient Infrastructure Systems

Vision: *Natural and conventional infrastructure working together for thriving communities, businesses and natural systems.*

- >50 faculty, researchers, staff spanning 15 colleges, public service organizations, and extension programs at UGA.
- >60 graduate students focused on resilient infrastructure.
- >12 collaborative research and implementation projects with communities and military installations.
- Partnering across sectors.
- Producing high-impact products, education, and training for a new wave of 21st century professionals.
- The Network for Engineering With Nature (N-EWN), https://n-ewn.org/ .

https://iris.uga.edu/

The Path to a More Resilient Sustainable and Future

- Prioritize solutions that value nature
- Pursue opportunities to partner rather than conquer nature
- Promote integration rather than segregation

EWN On the Road: The Dune Protecting Artemis