New Initiatives Improve Wetland Restoration Outcomes: Engineering with Nature and the Use of Natural and Nature-Based Features

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For some time, the U.S. Army Corps of Engineers has supported an initiative called *Engineering With Nature*® (EWN) and the application of *Natural and Nature-Based Features* (NNBF), both of which promote the incorporation of natural processes and structures into the design and operation of ecological restoration and flood risk reduction projects. Each approach is introduced below, with an emphasis on potential applications in a wetland restoration context. Additionally, examples of recent and ongoing case studies that align with these initiatives are discussed.

Historically, practitioners designed wetland restoration projects and assessed their outcomes based upon observations made in unaltered reference areas (Brinson and Reinhardt 1996). However, many restoration projects failed to: follow anticipated trajectories, achieve project milestones, and provide wetland functions at magnitudes observed in unaltered locations (Zedler and Callaway 1999). Differences in landform, hydrology, soils, vegetation community dynamics, and landscape-level ecological processes between restored and reference locations were identified as factors limiting the success of restoration efforts (Zedler 2000). Also, many areas lack appropriate reference areas to determine pre-disturbance conditions which poses a challenge to achieving restoration success (Otte et al. 2021).

Recently, researchers and practitioners have increasingly emphasized the integration of natural and nature-based structures and processes into interdisciplinary frameworks to improve restoration project outcomes (Kurth et al. 2020). These concepts build upon previous research recognizing that restoration projects mimicking natural processes and structures provide higher levels of ecological functions than those constructed using traditional techniques (Streever 2000; Foran et al. 2018).

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ENGINEERING WITH NATURE

During the past decade, the U.S. Army Corps of Engineers (USACE) has cultivated the EWN initiative (Figure 1), which promotes the intentional alignment of naturaland engineering processes to deliver economic, environmental, and social benefits efficiently and sustainably through collaboration (King et al. 2020; https://ewn.erdc.dren.mil/). Internationally, similar initiatives such as Working with Nature (WwN) have been introduced (Aiken et al. 2021). The integration of nature-based processes and features into project design is an essential component of the EWN and WwN approaches, which has shown utility in a variety of wetland restoration contexts. The following sections describe three recent EWN projects that used dredged materials in conjunction with natural processes to increase wetland functions in both riverine and coastal settings.

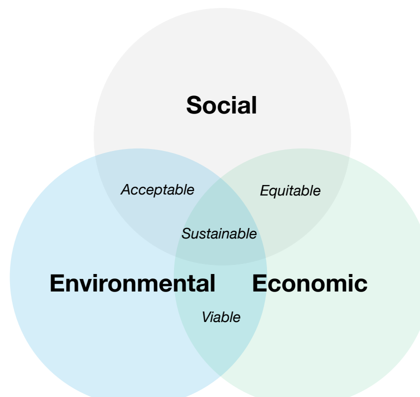

Figure 1: Key elements of EWN, which highlight the intersection of social, environmental, and economic interests. (Source: https://ewn.erdc.dren.mil/?page_id=7.)

KEY ELEMENTS OF *ENGINEERING WITH NATURE®:*

- Using science and engineering to support sustainable delivery of project benefits.
- Utilizing natural processes to maximum benefit, thereby reducing demands on limited resources, minimizing the environmental footprint of projects, and enhancing the quality of project benefits.
- Broadening and extending the base of benefits provided by projects to include substantiated economic, social, and environmental benefits.
- Applying science-based collaboration to organize and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays while producing more broadly acceptable projects.

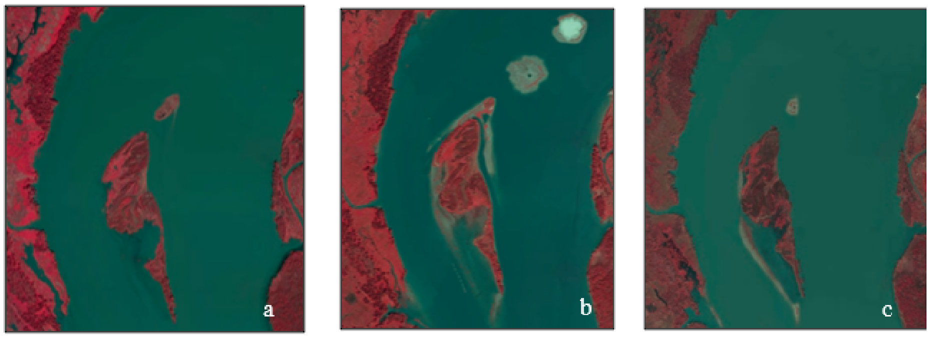

Figure 2: Horseshoe Bend Island in the Atchafalaya River, LA., with examples of island development in 2010 (a), 2011 (b) and 2012 (c). (Source: USACE New Orleans District.)

ATCHAFALAYA RIVER – HORSESHOE BEND ISLAND

In Louisiana's Atchafalaya River, a 35-ha wetland island was created using dredged sediments that were strategically released into the water column upstream from a submerged shoal, allowing the river to sort and transport the sediments using natural processes (Figure 2; Berkowitz et al. 2016). While the release of dredged sediments into the water column may seem counter-intuitive to USACE navigation protocols, the creation of the island adjacent to the navigation channel decreased the cross-sectional area of the river, which increased flow velocities, decreased shoaling, and reduced maintenance dredging requirements. Notably, the wetland island now provides a wide array of habitat, water quality, and hydrologic functions, highlighting how EWN projects can promote better environmental outcomes while achieving engineering objectives through nature-based processes (Foran et al. 2018).

NEW JERSEY SALT MARSH - AVALON

The application of thin sediment layers shows substantial promise to help coastal wetlands offset impacts from sea-level rise by supplementing marsh elevations while maintaining established vegetation communities (Raposa et al. 2020). In a coastal setting near Avalon, New Jersey fragmentation degraded a marsh system, stressing vegetation and reducing marsh resiliency to sea level rise (Berkowitz et al. 2017). Thin layers of dredged sediments were intentionally deposited onto the degraded marsh, mimicking storm driven sediment transport processes (Figure 3). Sediment placement reduced areas of pooling, increased marsh elevation, and improved conditions for salt marsh vegetation. This approach helped maintain the adjacent navigation channel while improving the physical stability in marsh platform and promoting rapid revegetation (VanZomeren et al. 2018).

CHESAPEAKE BAY – SWAN ISLAND

In the Chesapeake Bay, continued subsidence, shoreline erosion, and sea level rise have resulted in degraded and fragmented conditions in an offshore marsh, threatening total island submergence. The Swan Island Project (Figure 4) is currently utilizing EWN principles to restore ecosystem functions via dredged material deposition while protecting the Town of Ewell, MD from erosion and storm surge impacts (Davis et al. 2021; https://en.erdc.dren.mil/?p=2841). Dredged material placement restored the islands spatial footprint, increased surface elevation, improved conditions for plant growth, and increased the capacity of the site capacity to protect coastal communities. This project demonstrates how EWN principles can deliver both ecological and engineering benefit, including flood risk reduction (Aiken et al. 2021).

These projects collectively highlight the benefits of deliberately integrating natural features and processes into wetland restoration design to improve environmental outcomes while increasing resiliency and the protection of both natural and built infrastructure.

NATURAL AND NATURE-BASED FEATURES

Concurrent with the EWN initiative gaining momentum, a group of international collaborators from academia, agencies, non-governmental organizations, and the private sector worked to develop technical guidance promoting the use of Natural and Nature-Based Features (NNBF) to address flood risk management challenges and identify ecological restoration opportunities across a variety of landforms and landscapes (Figure 5; Bridges et al. 2021). The comprehensive guide, released in September 2021, includes >1000 pages that reflect the growing body of knowledge and experience from around the world to inform the process of conceptualizing, planning, designing, engineering, constructing, and operating NNBF (https://ewn.erdc.dren.mil/?page_id=4351). Within the NNBF framework, natural features (e.g., wetlands and reefs)

Figure 3: Avalon, NJ tidal marsh restoration. Dredged sediment thin layer placement application (a) and site conditions before (b) and one year (c) after restoration where the areas of sediment deposit are visible. (Source: Berkowitz et al. 2017; Google Earth, 2022.)

Figure 4: Swan Island in Chesapeake Bay, Maryland before dredged sediment placement (a), two months (b), and 1 year after placement. Note the observable increases in vegetation and reduced marsh fragmentation from (c). (Source: USFWS; NOAA.)

develop through the action of natural physical, biological, and chemical processes over time, whereas, nature-based features are created using design, engineering, and construction approaches to mimic natural features and provide similar, if not identical, ecological services. As a result, the EWN initiative and NNBF guidelines are complementary and can be applied in concert to improve project outcomes.

The incorporation of nature-based features and processes into wetland restoration science is not new, and practitioners have recognized the utility of incorporating these elements into project design for several decades, especially with regards to improving the delivery of habitat functions (e.g., Soots and Landin 1978). However, the current emphasis and commitment to applying EWN and NNBF principles at enterprise scales is notable and

NATURAL AND NATURE-BASED FEATURES PRINCIPLES:

- Uses a systems approach to leverage existing components and projects through interconnectivity.
- Engages communities, stakeholders, partners, and multidisciplinary team members to develop innovative solutions.
- Identifies sustainable and resilient solutions to produce multiple benefits.
- Anticipates, evaluates, and manages risks to project or system performance.
- Expects change and manages adaptively

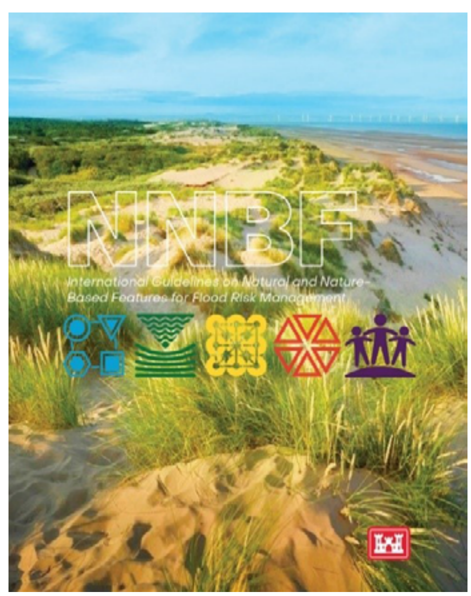

Figure 5: Key elements of NNBF, which uses natural processes to address flood risk and identify ecological restoration opportunities across a variety of landforms and landscapes. (Source: King et al. 2021.)

institutionalizing these approaches across public, private, and non-profit organizations will result in wider application of these concepts. Recent hearings at the U.S. Senate Committee on Environment and Public Works and endorsement from the Commander of USACE, the National Oceanic and Atmospheric Administration Administrator, and leaders from the Netherlands Rijkswaterstaat, the World Bank, the United Kingdom Environment Agency, and the World Wildlife Fund communicate the degree of support EWN and NNBF are currently experiencing (https://www.epw.senate.gov/public/index.cfm/2021/6/oversight-hearing-on-water-resources-projects).

WETLAND RESTORATION IN THE UPPER MISSISSIPPI RIVER BASIN

To further highlight these initiatives, the following describes examples of how EWN and NNBF is currently being integrated into a regional wetland restoration program. Wetlands and other aquatic resources in the Upper Mississippi River basin were altered by the historic construction of navigation dams and levees prior to 1940 and the intensification of agriculture in the catchment (Sparks et al. 2010). To address these challenges, the Upper Mississippi River Restoration (UMRR) program was authorized in 1986 to design and construct ecosystem restoration projects including the development of floodplain islands, backwater areas, and other wetland and aquatic ecosystem components to increase habitat functions, re-establish forested wetlands, and improve water quality while maintaining opportunities for commercial and recreational navigation (Theiling et al. 2014). Early restoration efforts, constructed using sandy dredged sediments, displayed poor vegetation establishment and growth. In response, recent floodplain and island restoration designs place nutrient-rich, fine-grained sediments dredged from backwater areas on top of the sandy dredged sediments removed from the navigation channel to improve soil health and promote vegetation establishment. This approach mimics natural patterns of floodplain evolution, in which coarse sediments are deposited in natural levee and point bar positions near the channel, and fine-textured sediments are transported into highly productive backswamps and abandoned oxbows.

Recent projects employing this approach include the Conway Lake Habitat Rehabilitation and Enhancement Project (HREP) near Lansing, IA, at which experimental plots have been established to evaluate vegetation responses to varying depths of fine-grained sediment placement (Figure 5). Similarly, the McGregor Lake HREP near Prairie du Chien, WI is utilizing experimental blends of coarse and fine soils to mimic natural patterns of floodplain sediment deposition to improve wetland establishment and function. These projects adhere to EWN and NNBF principles by creating ecosystem features that imitate natural soil characteristics, deliver habitat and biogeochemical functions, and provide opportunities for recreation while aligning with navigation, ecological restoration, and flood risk reduction objectives.

Ongoing research at the Conway and McGregor Lakes HREPs will assess the relationships between construction designs that incorporate EWN and NNBF features with conventional construction techniques by monitoring vegetation response, changes in soil biogeochemistry, and the delivery of wetland functions. Established forested wetlands will also be evaluated, allowing for comparisons between natural areas and those created using a variety of techniques. Assessing habitat, hydrology, and biogeochemical functions in restored and natural sites in the UMRR will inform future restoration site selection considerations and promote the use of EWN and NNBF into wetland restoration initiatives throughout the region.

CONCLUDING REMARKS

We believe the deliberate expansion of EWN and NNBF into wetland restoration projects has multiple benefits for natural resources and society. We, therefore, encourage

Figure 6: Post construction conditions (a,b) at the Conway Lake HREP, where fine grained soils (c) were incorporated into the wetland project design. (Source: USACE St. Paul District.)

practitioners across the wetland science community to adopt these frameworks to improve restoration outcomes, communications across stakeholder groups, and the transdisciplinary integration of engineering approaches with ecological and social sciences. These initiatives are applicable in all wetland landscape settings (e.g., riverine, coastal, and geographically isolated wetlands) and spatial scales ranging from small footprints in urban areas to regional efforts to improve the functions of large river systems or coastal zones. As a result, EWN and NNBF can positively influence how we work and increase the capacity of our restoration efforts to deliver the wetland functions required to address the challenges of sea level rise, increased storm frequency and intensity, loss of biodiversity, and associated impacts to cultural resources, natural infrastructure, and the built environment.

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