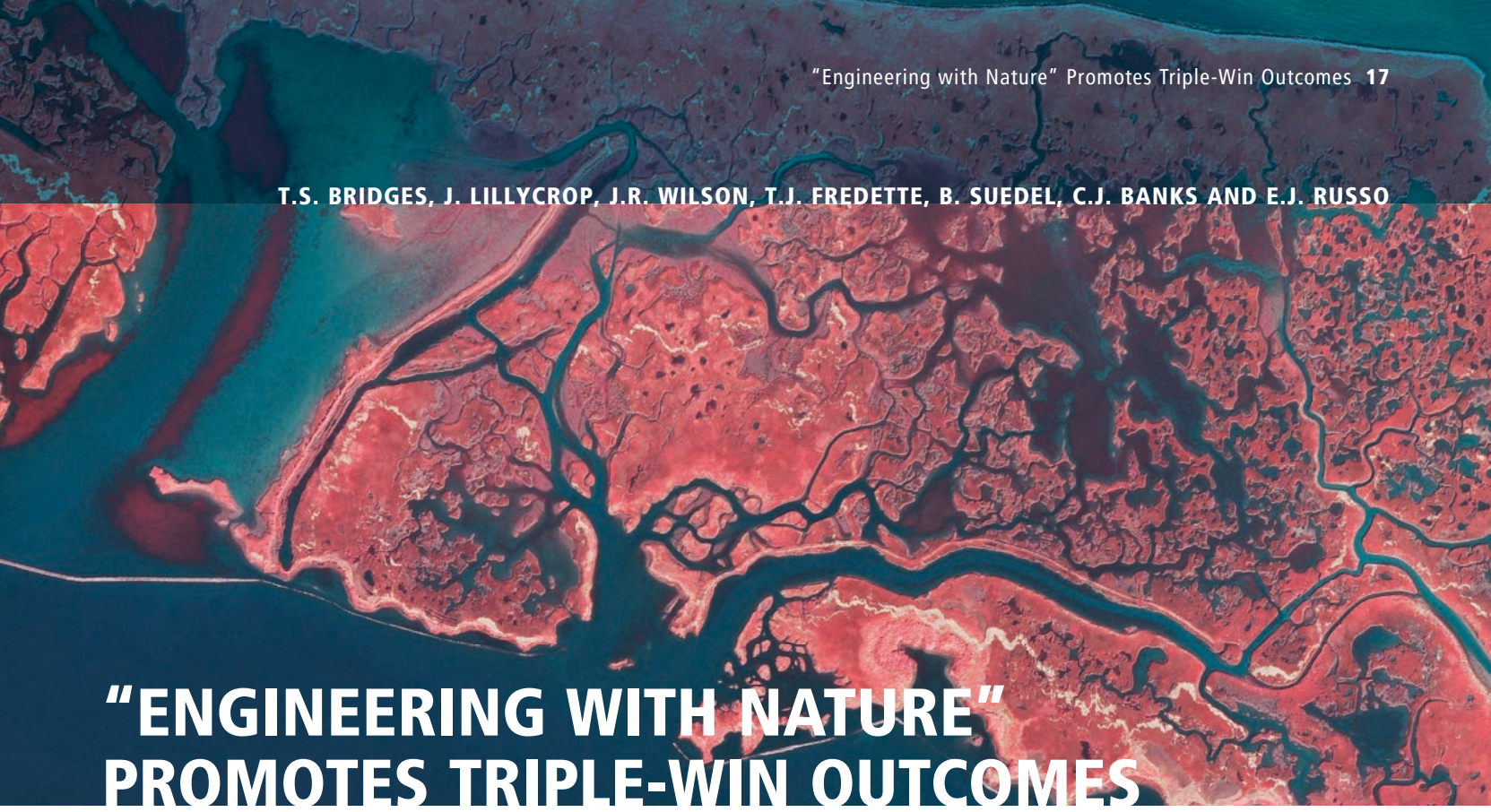
T.S. BRIDGES, J. LILLYCROP, J.R. WILSON, T.J. FREDETTE, B. SUEDEL, C.J. BANKS AND E.J. RUSSO



"ENGINEERING WITH NATURE" PROMOTES TRIPLE-WIN OUTCOMES

ABSTRACT

The US Army Corps of Engineers' "Engineering With Nature" (EWN) initiative supports sustainable development of infrastructure by advancing technical and communication practices in order to *intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes*. The tools and projects that have been developed through EWN support planning, engineering, and operational practices that beneficially integrate engineering and natural systems to produce more socially acceptable, economically viable, and environmentally sustainable projects.

The EWN initiative's focus on developing practical methods provides an achievable path toward an ecosystem approach to navigation infrastructure development. By combining sound science and engineering with advanced communication practices, the EWN initiative is providing a robust foundation for collaborative project development. Engineering With Nature is being pursued through innovative research, field demonstrations, communicating lessons learned, and active engagement with field practitioners across a wide range of organisations. The objectives of EWN are consistent with those communicated in the "Working with Nature" philosophy of the World Association for Waterborne Transport Infrastructure (PIANC) and the "Building with Nature" initiative of EcoShape Foundation, a public-private knowledge institute in the Netherlands.

INTRODUCTION

Pursuing the objective of sustainable development of navigation infrastructure poses both challenges and opportunities for the US Army Corps of Engineers (USACE). Advancing best practices will involve identifying the practical actions that can be taken to better align and integrate engineering and natural systems to produce more socially acceptable, economically viable and environmentally sustainable projects. Engineering With Nature (EWN) is a USACE initiative that supports more sustainable practices, projects, and outcomes by working to *intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental and social benefits through collaborative processes* (www.engineeringwithnature.org; Figure 1). The EWN initiative's focus on developing practical methods provides an achievable path toward an ecosystem approach to navigation infrastructure development and operations that is applicable across multiple USACE missions and business lines.

Above: Aerial photo of the wetlands at the Mississippi River Gulf Outlet taken in November 2013 as part of the Beneficial Use of Dredged Material Monitoring Programme.

Science, engineering and demonstration projects within the EWN initiative illustrate the use of:

1) science and engineering to produce operational efficiencies supporting sustainable delivery of project benefits;
2) natural processes to maximum benefit, thereby reducing demands on limited resources, minimising the environmental footprint of projects, and enhancing the quality of project benefits;
3) approaches that will broaden and extend the base of benefits provided by projects to include substantiated economic, social, and environmental benefits;
4) science-based collaborative processes to organise and focus interests, stakeholders, and partners to reduce social friction, resistance, and project delays while producing more broadly acceptable projects.

The objectives of EWN are consistent with those communicated in the Working with Nature (WwN) philosophy of the World

Association for Waterborne Transport Infrastructure (PIANC 2011; http://pianc.org/workingwithnature.php) and the goals of EcoShape's Building with Nature (BwN) programme in the Netherlands (http://www.ecoshape.nl/).

The WwN philosophy seeks win-win solutions for navigation development projects by promoting project development that proceeds in the following way:

1) establishing project need and objectives;
2) understanding the environment;
3) making meaningful use of stakeholder engagement that identifies win-win options; and
4) preparing project proposals/designs to benefit navigation and nature.

PIANC has undertaken a number of WwN activities to promote the philosophy, including development of a WwN project certification process and awards programme, engaging social media, and a photography competition in order to ensure a robust collection of WwN images for presentations, website content, and so on.

In parallel, the BwN approach advocates a different way of thinking, acting and interacting. Building with Nature strives to:

1) gather and develop ecosystem knowledge enabling water-related building with nature;
2) develop scientifically based and location-specific design rules and environmental norms;
3) develop expertise in applying the BwN concept;
4) demonstrate that BwN solutions work, with practical examples; and
5) determine ways to ensure that the BwN concept is adopted by society.

Project examples are collected in the web-based BwN Design Guideline (www.ecoshape.nl/en_GB/wiki-guideline.html).

Engineering With Nature within the USACE is being pursued through innovative research, field demonstrations, communicating lessons learnt, and active engagement with field practitioners and USACE partners and stakeholders. The capabilities and practices being developed through the EWN initiative provide direct support to the USACE Civil Works Strategic Plan (Sustainable Solutions to America's Water Resources Needs: Civil Works Strategic Plan 2011 – 2015), the USACE Campaign Plan (e.g., Objectives 1c, 2c, 2d, 4b) (USACE 2011), as well as the recently "reinvigorated" USACE Environmental Operating Principles (USACE 2012).

Figure 1. The EWN approach provides overlapping benefits resulting in more sustainable projects.

Developing sustainable and resilient infrastructure systems for military installations and Civil Works will require USACE to evolve its approaches to planning, engineering and operating infrastructure. Advancing these practices will involve identifying the practical actions that can be taken to better align and integrate engineering and natural systems to produce more socially acceptable, economically viable, and environmentally sustainable projects.

EWN IN PRACTICE

The EWN initiative is developing and demonstrating, through multiple projects, the capabilities that are needed to achieve sustainable, triple-win project outcomes. The following project summaries are provided to illustrate the range of supporting projects that are completed or underway.

Sustainable Sediment Management through Strategic Placement and Innovative Beneficial Use Practices

Sediment management is a costly and challenging endeavour. Designated placement sites are limited in space and environmental restrictions limit where sediment can be placed and how it can be used. The EWN initiative, in collaboration with the Regional Sediment

TODD S. BRIDGES
is the US Army's Senior Research Scientist for Environmental Science and serves as the Programme Manager for the Dredging Operations Environmental Research (DOER) programme, Director of the Center for Contaminated Sediments, and the USACE lead for 'Engineering With Nature'. He received his Bachelor's and Master's degrees in Biology/Zoology from California State University, Fresno and his PhD in Biological Oceanography at North Carolina State University.

JEFF LILLYCROP
is Technical Director for Civil Works at the US Army Engineer Research and Development (R&D) Center. He is responsible for integration of Environmental, Flood Risk Management and Navigation Research and Development and is Chair of the Committee on the Marine Transportation System Integrated Action Team for R&D. He received his BSc and MSc in Coastal Engineering in 1981 and 1983, respectively, from the University of Florida.

JOSEPH WILSON
is a technical specialist developing policy and guidance for environmental aspects of the Corps' National Dredging Programme. Prior to joining the USACE in 1977, he performed research in deep-sea oceanography at the University of North Carolina Marine Bio-Medical Research Center. He serves as headquarters programme monitor for the Aquatic Nuisance Research, DOER, Dredging Operations Technical Support (DOTS) and Water Operations Technical Support programmes.

THOMAS FREDETTE
earned his BSc in Marine Biology from Southeastern Massachusetts University (now UMass-North Dartmouth) in 1977, and a MSc and PhD in Marine Science from The College of William and Mary in 1980 and 1983, respectively. In 1986, he joined the USACE as Programme Manager for DAMOS (Disposal Area Monitoring System). Since 2009 he is a Research Biologist for the US Army Engineer R&D Center. He has represented the US at the London Convention Scientific Group since 2001.

BURTON SUEDEL
is a research biologist at the US Army Engineer R&D Center, Environmental Laboratory, Vicksburg, Mississippi. He obtained both his Bachelor's and Master's degrees in biology from the University of North Texas and his PhD in biological sciences from the University of Mississippi. He chairs PIANC's EnviCom Working Group 143, which recently completed a report on standard practices for conducting initial environmental assessments for navigation and infrastructure projects.

CYNTHIA BANKS
is a research biologist at the US Army Engineer R&D Center, Environmental Laboratory in Vicksburg, Mississippi. She received a BSc in Environmental Science (2000) and MSc in Hazardous Materials Management (2003) from Jackson State University. Since 1995, she has been involved with areas including wetlands, coastal ecology, risk assessment and environmental research related to dredging and currently serves as manager of the USACE DOTS Programme.

EDMOND RUSSO
serves as the Deputy District Engineer for Programmes and Project Management at the USACE, Galveston (Texas) District. He previously served as Division Chief at the US Army Engineer R&D Center, Vicksburg, Mississippi. Prior to joining the USACE he worked at Fugro-McClelland (Southeast), Inc., in New Orleans, Louisiana.
He received his Bachelor's from Louisiana State University, Master's from University of New Orleans and his PhD from Louisiana State University, all in Civil Engineering.

Management (RSM) Programme, is focusing technology development and field demonstrations to highlight opportunities for innovative sediment management practices that can reduce operational costs while also providing for an expanded range of environmental benefits as shown in Figures 2 and 3.

Members of the EWN team have been collaborating with the Philadelphia, Jacksonville, Mobile, New Orleans, San Francisco, and Buffalo Districts of USACE (in addition to others) on a range of navigation projects where EWN approaches can provide more sustainable solutions for sediment management.
EWN principles and practices are being used by Philadelphia District to plan and design post-Hurricane Sandy dredging projects that will create new environmental habitats along the coast of New Jersey.

In-bay, thin-layer placement of sediment is currently being pursued and demonstrated by Mobile District as an alternative to using the ocean dredged material disposal site. The in-bay alternatives would provide substantial cost savings, reduce fuel usage associated with as much as a 30 mile transit distance, while providing for several beneficial uses of sediment. The EWN team members partnered with the RSM Programme to provide technical and scientific support in identifying and monitoring placement sites in Mobile Bay. Sediment placement within Mobile Bay will help to retain sediments within the system, provide opportunities for wetlands and marsh creation, and provide hundreds of acres of critical habitat.

Science that Informs How Biology Makes Use of Engineering

Threatened and Endangered Species significantly affect many USACE mission areas (e.g., flood risk management, navigation, hydropower generation, water supply).
The interior population of Least Tern (ILT) (Figure 4) has been federally listed as endangered since 1985. ILT populations are generally associated with sandbar habitats on large rivers of the central United States and, as such, have caused considerable conflict in several USACE mission areas, leading to increased expenditures.

Figure 2. Beneficially using material dredged from the navigation channel for placement along shorelines to reduce erosion and enhance environmental habitat (Perdido Pass, Alabama).

The USACE Navigation Programme has formed an EWN collaboration with the American Bird Conservancy and the US Fish and Wildlife Service (USFWS) and recently the US Geological Survey-Mississippi State University to develop the science and modelling capability to support decision making.
A range-wide metapopulation model is being used to support a range-wide assessment

Figure 3. Long-distance pumping of dredged sediment for beneficial use and wetland restoration on the Gulf Coast.

Figure 4. Interior Least Tern has been federally listed as endangered since 1985.

(www.leasttern.org). In addition to providing the scientific, ecological basis for evaluating cost-efficient project designs and management scenarios, the model will be used to provide evidence for delisting ITL from the endangered species list. Delisting of the ILT, through collaborative data gathering, modelling, and conservation planning, supported by research and development investments, is expected to dramatically reduce USACE project costs.
In addition, a US Army Engineer Research and Development Center (ERDC) led project sponsored by Department of Defense (DoD) Strategic Environmental Research and Development Programme has developed an approach for evaluating alternative management scenarios to address environmental effects on Threatened and Endangered coastal birds that will be caused by sea-level rise at military installations.
The project integrated climate, land use and ecosystem information into a tool set that assesses vulnerabilities related to Threatened and Endangered bird species at Eglin Air Force Base.

The presence of these coastal birds currently poses restrictions on land used for training. The project team developed a series of modelling and assessment tools to evaluate alternative, long-term investment strategies that would minimise the compounding influence of sea-level rise and bird habitat effects on installation land use and training. The final project report can be found at www.serdp.org/content/download/18101/201737/file/RC-1699-FR.pdf.

Building Habitat into Navigation Infrastructure

The USACE has over 100 miles of navigation structures such as breakwaters in the Great Lakes region. An ERDC-led project sponsored by the Great Lakes Restoration Initiative is being used to demonstrate opportunities to expand the range of benefits that can be provided by infrastructure projects. As shown in Figure 5, during routine maintenance of breakwaters in Cleveland Harbor in 2012 and 2013, design modifications were made to the submerged toe blocks of the structure to provide features that will create habitat opportunities for Great Lakes fish and invertebrates.

Existing breakwaters constructed in the Great Lakes provide limited habitat for fish and invertebrates, mostly in the form of small refuge spaces between concrete or rock sections, while the rest of the structure is relatively inhospitable for most organisms owing to the featureless nature of the blocks. The Cleveland Harbor Green Breakwaters Project is examining the opportunities to create substantially more habitat surface on the breakwater by modifying the shape and surface texture of the constructed blocks using textured liners or modified walls in the concrete block forms.

Initial field observations indicated that grooved and dimpled block surfaces had more early colonisers than the unmodified blocks. In order to evaluate the approach more broadly, Ashtabula Harbor, which is along the southern shore of Lake Erie at the mouth of the Ashtabula River, has been identified as a second project site. The Ashtabula project will incorporate tern nesting blocks on top of the breakwater.
The long-term implication from these projects is that with consistent application of these simple modifications during structural repairs, there is tremendous potential to increase multiple benefits associated with built navigation infrastructure. Construction of an innovative environmental breakwater for Cleveland Harbor to support the Great Lakes Restoration Initiative was recently awarded a PIANC WwN Certificate of Recognition. The Cleveland Harbor project will be recognised at the 33rd PIANC World Congress in San Francisco in June 2014.

Figure 5. Habitat-enhanced toe block installation during breakwater repair operations.

Sustainable Management of Contaminated Sediment

In 2009, ERDC team members collaborated with the US Navy and the private sector in developing and publishing a US Department of Defense (DoD) technical guide on the use of Monitored Natural Recovery for contaminated sediment sites (www.serdp.org/Program-Areas/Environmental-Restoration/Contaminated-Sediments/ER-200622).

Development of the guidance was sponsored by DoD's Environmental Security Technology Certification Programme to support clean-up activities within the Department. The US Navy estimates that its sediment cleanup liabilities include $1 billion in future remediation costs. The guidance document provides a science and engineering framework for utilising naturally occurring physical, chemical and biological processes to accomplish risk reduction at contaminated sediment sites. The guidance illustrates opportunities for applying EWN for sediment cleanup at substantially lower costs – both in economic and environmental terms – compared to conventional methods that predominantly rely upon sediment removal.

GIS Database of Projects Demonstrating EWN Practices

The Engineering With Nature Project Mapping Tool (EWN ProMap) is a geography-based data viewer for communicating information about projects that illustrate EWN opportunities. The EWN ProMap can be accessed at http://155.82.160.6/applications/opj/V013/public/viewer.swf.

The EWN ProMap, shown in Figure 6, provides project information on water resources projects that illustrate key attributes of the EWN approach:

1) Science and engineering are used to produce operational efficiencies;

Figure 6. EWN ProMap Screen Capture. ProMap allows users to explore and share information relevant to developing projects that implement EWN principles and practices.

2) Making maximum use of natural processes;
3) Broadening the range of benefits provided by the project; and
4) Using science-based collaborative processes.

The overall aim of EWN ProMap is to provide a communication tool that allows users to explore and share information relevant to developing projects that implement EWN principles and practices. Projects can be viewed based upon infrastructure type (e.g., dredging project, breakwater, lock & dam) or by their environmental or social benefits. Many current and past USACE (and partner) projects have incorporated EWN principles and practices. Broadly communicating this portfolio of projects within and external to USACE will provide opportunities for expanding on these successes.

Examples of projects included in the EWN ProMap are Mobile District's Deer Island Restoration Project, St. Louis District's use of river chevrons, and Wilmington District's coastal reef constructed of rock dredged from the Cape Fear River, North Carolina. The Deer Island project aims to re-establish marshes along the Mississippi coast. The completed restoration is shown in Figure 7.

This project represents an EWN opportunity by demonstrating the use of strategic placement of sediment for beneficial use of dredged material. The project approach maintains sand in the littoral coastal system and contributes to sustainable fisheries by providing essential habitat for juvenile fish, crabs, and shrimp. Multiple benefits including recreation, shoreline and storm protection, marsh restoration and habitat creation are achieved as a result of this project.

The St. Louis District has led the way for river engineering with its use of chevrons that direct flows to maintain the location of the navigation channel while preserving the function of secondary channels for habitat along the Mississippi River as shown in Figure 8.

These structures are sustainable in that they create and/or improve habitat for fish, macro-invertebrates and other species in the river. In addition, the structures utilise the river's energy to maintain navigable depths in the main channel, improve current sets through the navigation spans of several bridges, and deposit sediment downstream of the chevrons for increased environmental diversity in the reach, which ultimately reduces dredging. The St. Louis District's projects embody the EWN concept by demonstrating how cost-effective engineering practices can enhance the habitat value of navigation infrastructure.

In the late 1990s, as a part of a capital dredging project on the Cape Fear River in Wilmington, North Carolina, an offshore hard-bottom reef was constructed using rock dredged from the river. Standard practice would have been to dispose of the rock in the designated disposal site. However, members of the project team in the Wilmington District recognised the opportunity to create a regionally rare form of coastal habitat in the South-East Coast of the United States.

The project team collaborated with engineers and biologists to design the offshore reef called the Wilmington Offshore Fisheries Enhancement Structure (WOFES). The reef's longest arm, known as Leg "A", is approximately one nautical mile in length and

Figure 7. Aerial view of Deer Island post-restoration with re-established marshes.

Leg "B" is 2,000 feet long (Figure 9). Fisheries surveys performed after construction of the structure have documented the environmental benefits associated with the project, which has served as the location for multiple fishing tournaments since its construction.

EWN for Coastal Resilience

Coastal systems are a critical component of the infrastructure of the United States. The USACE recognises the need to encourage and sustain the resilience of these coasts. Engineering With Nature research scientists created a research partnership in 2012 that seeks to accomplish three goals:

1) Advance the efficiency of engineering and operational practices involving dredging and dredged material management;
2) Expand and extend environmental benefits produced through sediment management; and
3) Improve the resilience and sustainability of coastal systems facing short- and long-term uncertainties related to climate change and other drivers.

The collaboration draws together scientists and engineers from ERDC, US Fish and Wildlife Service, US Geological Survey and other organisations to develop capabilities to characterise and manage coastal wetlands in response to sediment and nutrient flux, climate change and sea level rise, and beneficial use of dredged sediments. The project is applying advanced technologies for measuring, predicting and promoting mineralogical sediment processes in coastal wetland environments in order to sustain these features into the future. The tools and technologies developed through this collaboration support planning, engineering and operations in coastal systems. This joint effort represents a research partnership that spans the Navigation, Ecosystem Restoration, and Flood Risk Management business lines of the USACE.

EWN ACTION PROJECTS

The multiple benefits gained through EWN applications are ideal for field demonstrations. Investments are being made in EWN Action Projects in order to demonstrate EWN principles and practices across a range of applications. The current EWN Action Projects and descriptions are listed below. Six of the seven projects connect ERDC scientists and engineers with technical staff in USACE Districts to foster collaboration and implementation of new practices. Additional information related to these projects is available at www.EngineeringWithNature.org.

Sediment Retention Engineering to Facilitate Wetland Development (San Francisco Bay, California)

This EWN Action project is ongoing at two restoration sites in San Francisco Bay where evaluations of project performance, including reduction in wave energy, circulation, sedimentation, channel morphology, and vegetative cover will be measured as a function of berm morphology. The results will be used to develop guidelines and best practices in the design of berms intended to speed accretion and channel formation in bay restoration projects.

Realising a Triple Win in the Desert: Systems-level EWN on the Rio Grande (Albuquerque, New Mexico)

Three recently completed system-level studies on the Middle Rio Grande (MRG) used EWN to achieve sustainable development of water resources in the desert. These studies balanced social, environmental, and economic considerations using traditional benefit metrics (i.e., habitat units) to support transparent decision-making. The MRG projects will be used to document the benefits, in the form of ecosystem goods and services, which are being produced.

Atchafalaya River Island Creation through Strategic Placement (Morgan City, Louisiana)

This EWN Action project provides biological and hydrological monitoring data to quantify benefits and otherwise improve the understanding of the maturation of beneficial use of dredged material within the Atchafalaya Basin. The project documents how a river island was successfully created using dredged material, taking advantage of the natural hydrological processes inherent in the system.

Figure 8. Chevrons at Bolter's Bar on the Mississippi River help maintain the location of the navigation channel while preserving secondary channels for habitats.

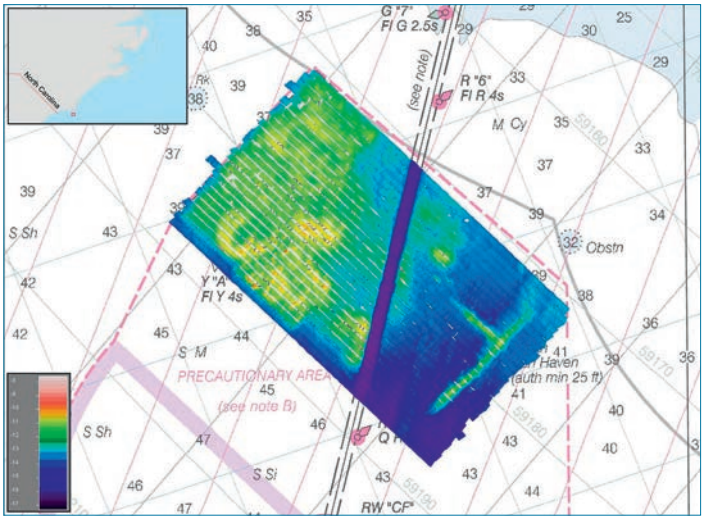


Figure 9. Survey of the Wilmington Offshore Fisheries Enhancement Structure, a constructed offshore reef.

Project findings will help direct future dredged material placement practices in the basin and other riverine systems.

Portfolio Framework to Quantify Beneficial Use of Dredged Material (New Orleans, Louisiana and New England)

This EWN Action Project is developing an analytical approach for evaluating beneficial use projects as a portfolio of opportunities that must balance both risks and benefits. Developing a balanced project portfolio requires information about the array of project risks (e.g., implementation, project performance, and so on) as well as the array of expected project benefits, including the amount of enhancement as a function of the material properties and the benefits achieved from the project.

Ashtabula Breakwater Tern Nesting Habitat Demonstration Project (Ashtabula, Ohio)

The Ashtabula breakwater tern nesting demonstration project is creating and evaluating simple, low cost modifications to the concrete blocks used to repair the breakwater that will provide habitat for birds. The design includes incorporation of suitable nesting substrate (gravel) and predator deterrence features. If the demonstration is successful, it will provide a means of returning the common tern *(Sterna hirundo)* to the local bird community. Historically, the common tern nested in the area, but has not been recorded locally for decades because of the lack of suitable habitat.

Living Shoreline Creation through Beneficial Use of Dredged Material (Duluth, Minnesota)

This EWN Action project will identify and develop low-cost, shallow-water dredged material placement methods, utilizing both engineered and natural processes. The methods will be used to maximise the habitat value achieved by using the dredged material to restore aquatic and wetland habitat. Finding cost-effective approaches for material handling that will produce the desired habitat is critical for development of future shoreline habitat restoration projects in the Great Lakes.

A Sustainable Design Manual for Engineering With Nature Using Native Plant Communities

The Sustainable Design Manual describes how to utilise plant communities within the built environment and to create sustainable landscapes that perform engineering functions. The design manual is important because it promotes native plant communities, which in turn support native fauna. Many plant communities exist on USACE lands and will provide stability in designed landscape elements that are part of USACE facilities and landscapes throughout the US.

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CONCLUSIONS

Solutions that beneficially integrate engineering and natural systems can greatly support sustainable development of navigation infrastructure. "Engineering With Nature" enables more sustainable delivery of economic, social and environmental benefits associated with infrastructure while directly supporting USACE's Civil Works strategic planning goals and other directives. Such directives encourage creating synergies between sustainability and the execution of projects and programmes.

Many past, current and planned projects in the U.S. exemplify aspects of the EWN approach by:

1) Making use of science and engineering to generate operational efficiencies;
2) Maximising the productive use of natural process;
3) Expanding the range of benefits provided by projects; and
4) Applying science-based collaborative approaches.

As indicated through the project descriptions above, a wide variety of projects illustrating the EWN approach in marine coastal, riverine, and lake environments are currently in place and there are major opportunities for the USACE to incorporate EWN principles into future projects. In 2013, the EWN project team received the USACE Chief of Engineers Environmental Award in Natural Resources Conservation. This achievement confirms support in advancing the use of EWN within current and future practice. It ensures that EWN will continue to be pursued through innovative demonstrations, communicating about lessons learnt, focused research and development, and active engagement and collaboration with our partners and stakeholders. Ultimately, EWN provides an emerging and innovative path to more sustainable projects.