THE WATER INSTITUTE

INTEGRATION OF NATURE-BASED SOLUTIONS AND ALTERNATIVES INTO USACE CIVIL WORKS PROJECTS

Opportunities to Accelerate Practical Implementation

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PREFACE

In collaboration the U.S. Army Corps of Engineers (USACE) Engineering With Nature® (EWN) program, the Water Institute (the Institute) completed a study in 2023 that evaluated policies and practices potentially hindering inclusion of Nature-Based Solutions (NBS) into Civil Works projects where they could potentially advance multiple USACE Mission Areas (Ehrenwerth et al., 2022; Fischbach et al., 2023a, 2023b; Windhoffer et al., 2023). That study included a comprehensive review of USACE project alternative evaluation methods, as well as identification and assessment of approaches for incorporating a wider range of social, environmental, and economic benefits and costs into NBS alternative evaluation.

In the study presented here, the Institute has extended that collaboration with EWN to identify pathways for accelerating NBS at a practical level. This work included elicitation of input from engineers and planners across USACE Districts, Technical Centers of Expertise, the Institute for Water Resources (IWR), and the Engineering Research and Development Center, as well as engagement of representatives from other public and private entities with relevant expertise. In addition, the Institute conducted two case studies evaluating the consideration and implementation of NBS at Deer Island, Mississippi and for the South Platte River and Tributaries in Denver, Colorado. The Institute synthesized feedback and case study findings to identify both challenges practitioners face in implementing NBS and the opportunities they have found to include these solutions in their projects despite those impediments. Based on this evaluation and input received from USACE personnel, the Institute developed a strategic framework for accelerating NBS incorporation into USACE Civil Works projects to extend their application and broaden the benefit they provide.

ACKNOWLEDGEMENTS

This report builds on a completed multi-year research effort that was led by the Institute to evaluate policies and practices limiting consideration of Nature-Based Solutions (NBS) and Natural and Nature-Based Features (NNBF) in U.S. Army Corps of Engineers (USACE) Feasibility Studies. The authors gratefully acknowledge the partners and collaborators from across USACE, the Institute, and other organizations who supported that foundational research as well as the current effort, which extends that research to focus on NBS implementation across a range of USACE authorities.

Guidance and feedback throughout this research effort were provided by Dr. Jeff King (USACE Engineering With Nature® program) and the USACE Engineering With Nature® practitioner leads: Mr. Edward Brauer (St. Louis District); Mr. David Crane (Omaha District); Ms. Elizabeth Godsey (Mobile District); and Ms. Danielle Szimanski (formerly of Baltimore District). Mr. Crane, Ms. Godsey, and colleagues at the Omaha and Mobile Districts, respectively, also provided information and materials to support case study evaluation of completed USACE studies at Deer Island, Mississippi and South Platte River and Tributaries, Colorado. Valuable information on the implementation of NBS was also provided by participants from across a spectrum of public and private organizations during two facilitated workshops.

Dr. Amanda Tritinger (USACE Engineering With Nature® program), Dr. Burton Suedel (USACE Engineer Research and Development Center), and Ms. Marriah Abellera (Institute for Water Resources) also provided valuable input and feedback on preliminary findings.

Content of this report was reviewed by Alyssa Dausman and the report was reviewed, edited, and formatted by Charley Cameron of the Institute. Dexter Ellis developed and improved figures throughout the document. Other key Institute personnel include Jordan Fischbach, who led the initial Institute effort focused on NBS evaluation that motivated this study, and members of that study team.

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This work is dedicated to the memory of Justin Ehrenwerth, whose vision and boundless energy helped blaze the trail we follow to a future where the benefits Nature-Based Solutions can provide to people, society, underserved communities, and ecosystems are wholly realized.

EXECUTIVE SUMMARY

Nature-Based Solutions (NBS) utilize environmental landforms and processes to address flooding, erosion, and other coastal and inland issues while often providing co-benefits such as habitat, recreational use opportunities, and sediment management cost-savings. For these reasons, Congress has directed the U.S. Army Corps of Engineers (USACE) to consider and include Natural and Nature-Based Features (NNBF)—NBS designed to reduce flood and coastal storm risk—in Civil Works projects. In addition, the Water Resources Development Act (WRDA) of 2007 (WRDA, 2007) and associated Principles, Requirements, and Guidelines (PR&G) direct USACE to more broadly consider NBS, as well as co-benefits to communities and ecosystems, when evaluating Civil Works project alternatives. Draft Agency Specific Procedures (ASPs) for implementation of the PR&G dictate that USACE practitioners develop a fully Nature-Based Alternative (NBA) in Feasibility Studies, include NBS in all alternatives where practical, and consider all economic, environmental, and social benefits in alternative evaluation (Federal Register, 2023a).

Gray infrastructure such as levees and seawalls have been preferentially used in USACE Civil Works flood risk management (FRM) and coastal storm risk management (CSRM) projects in cases where opportunities may have existed to utilize NBS or hybrid green-gray solutions. In addition to the loss of associated benefits to communities and ecosystems, this gap between NBS opportunity and execution presents significant impediments to successfully satisfying the directives set forth by Congress and the draft ASPs. Understanding the reasons behind this gap, and laying out a clear strategy for closing it, is therefore vital for USACE Civil Works and the Engineering With Nature® (EWN) program that supports it.

Prior research focused on USACE Feasibility Study policies and practices identified several opportunities to broaden consideration of NBS, including using an integrated, multi-objective approach to scoping planning studies; formulating integrated alternatives designed to provide a range of co-benefits; evaluating alternatives using metrics that span this range of co-benefits; developing USACE guidance, resources, and tools for monetizing NBS ecosystem services; and applying transparent, multi-criteria decision analysis as the primary approach for alternatives ranking and selection (Fischbach et al., 2023a, 2023b).

The research presented here builds on that effort by evaluating challenges and opportunities associated with NBS across a wider range of USACE authorities, including Feasibility Studies, Standing Authorities (Continuing Authorities Program; Flood Control and Coastal Emergencies Act), and Comprehensive and Watershed Studies, as well as across planning, design, construction, and post-construction project phases. This scope is consistent with draft ASPs, which are applicable to all USACE planning and construction projects with limited exceptions for activities such as research. The challenges identified represent impediments limiting NBS consideration in the past, while the opportunities are ways USACE personnel have implemented NBS under current and prior policies and guidance. Lastly, the report outlines a strategic framework designed to enable more widespread consideration and use of NBS, thereby supporting and accelerating USACE alignment with WRDA 2007, PR&G, and draft ASPs.

There were three primary activities associated with this work. First, Institute personnel led working sessions to elicit input from the EWN practitioner leads who coordinate engagement of USACE Districts and Divisions on the use of NBS, as well as with personnel from the USACE Institute for Water

Resources (IWR). Second, the Institute reviewed documentation from District personnel on two case studies used to identify impediments to, and enablers for, NBS implementation: Deer Island, Mississippi and South Platte River and Tributaries, Colorado. Lastly, the Institute led workshops with District personnel and external partners to identify additional pathways to accelerate NBS in practice.

These activities led to identification of challenges and opportunities across a range of USACE authorities, as well as within all phases of project implementation from planning to post-construction activities (Table ES 1).

Table ES 1. Summary of opportunities and challenges identified for NBS implementation, organized by project phase and authorization type.

Phase	Opportunities	Challenges
Planning, Authorization, and Funding: Overarching	Successful NBS implementation often leverages multiple USACE authorities, and supportive and engaged local sponsors can catalyze NBS implementation	Practitioners—particularly new planners—may be unfamiliar with all USACE authorities and/or with regulatory and consulting requirements associated of other agencies (Endangered Species Act; Essential Fish Habitat, etc.)
Planning, Authorization, and Funding: Feasibility Studies	NBS have been considered across multiple phases, including as part of Value Engineering studies	Timeline, scope, and review requirements (e.g., the 3x3x3 rule[1]) may inhibit consideration of NBS given that practitioners and reviewers may have insufficient budget or time to formulate these alternatives, which typically have fewer guidelines, templates, and exemplar projects when compared to gray infrastructure.
Planning, Authorization, and Funding: Standing Authorities	Small-scale NBS have often been constructed using standing authorities, particularly WRDA 1992 Section 204 Beneficial Use of Dredge Material	Funding and scope of standing authorities limits project scale, and beneficial use of dredge material may be cost-prohibitive or impractical due to timelines, sediment characteristics, etc.
Planning, Authorization, and Funding: Comprehensive and Watershed Studies	Broader regulatory authorities have enabled greater consideration of holistic and system-wide NBS benefits, including through use of incremental benefit analysis rather than benefit-cost analysis	Comprehensive and Watershed studies do not typically lead directly to project construction authorization and funding, but instead may result in recommendations for non-Federal action or follow-on Feasibility Studies. Recommended NBS therefore do not have a direct implementation pathway and may be subsequently removed from consideration prior to authorization or construction (e.g., during a follow-on Feasibility Study).
Project Implementation: Design and Implementation	NBS can support different paradigms of protection, such as "multiple lines of defense" (in combination with gray infrastructure) and/or as sacrificial features during storms	Many NBS lack standard construction methods or guidance, which can lead to delays or difficulties during implementation. In addition, many NBS would require large areas of real estate to be implemented as standalone solutions at the spatial scales needed to accrue substantial FRM or CSRM benefits; this real estate may be unavailable and/or prohibitively expensive.

Phase	Opportunities	Challenges
Project Implementation: Post-Construction	Beaches and dunes represent a template for NBS use in FRM and CSRM, while beneficial use has supported maintenance of small-scale, low cost NBS	Lack of time and funding for AM inhibits improved design and benefit quantification of NBS, while standard Operations and Maintenance approaches are not conducive to the greater and/or more uncertain risk associated with NBS. In addition, maintaining NBS features over planning time scales may be impractical or expensive, particularly if implemented over large spatial scales.

[1] The 3x3x3 rule requires that Feasibility Studies lead to a final report no later than 3 years after date of initiation; have a maximum cost of $3 million; and complete 3 levels of vertical review: District, Major Subordinate Command, and USACE Headquarters (USACE, 2014, 2015).

The Institute then coordinated with EWN to develop a strategic framework for broader consideration and application of NBS in the future—and thus support implementation of the PR&G and associated draft ASPs, once finalized—based on the synthesized challenges and opportunities, as well as recommendations from USACE and other NBS practitioners. This framework is comprised of four overarching objectives (Figure ES 1) to advance a goal of promoting widespread integration of NBS with nonstructural and structural measures to reduce flood risk, maintain navigable waterways, and deliver a broad array of ecosystem services to local communities. These objectives are consistent with the draft ASPs, which direct USACE to, for example, closely engage with partners early and often during planning and project development. Each of these objectives is associated with a set of enablers, which are activities that can be undertaken by USACE personnel alone or in coordination with partner organizations to advance that objective in practice.

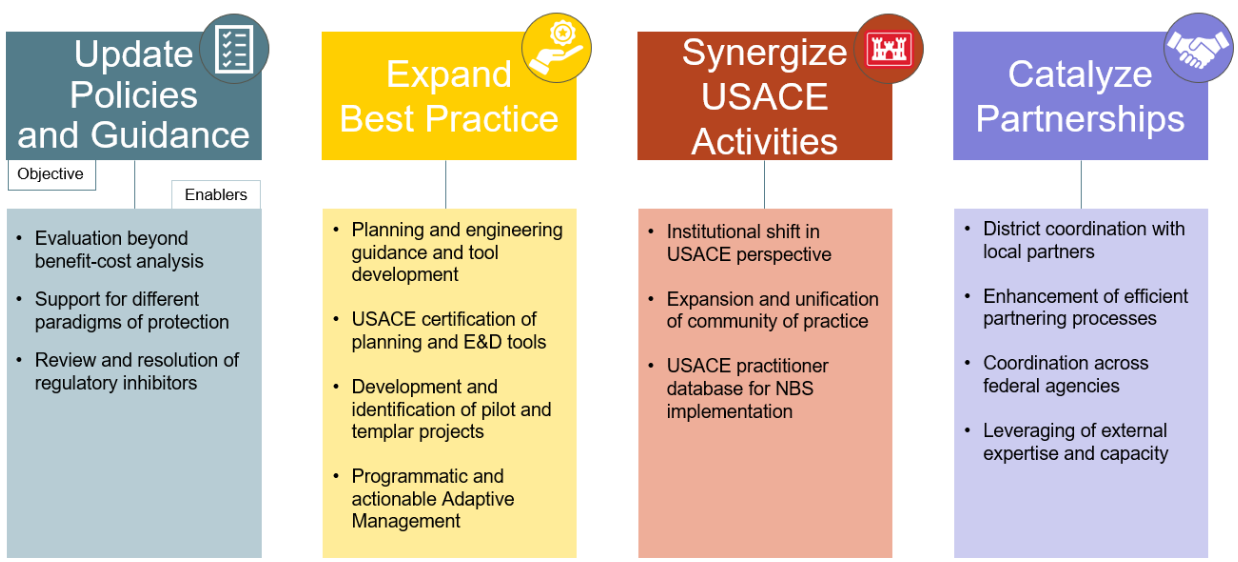

Figure ES 1. Objectives and enablers that comprise a strategic framework for accelerating implementation of NBS within USACE Civil Works projects.

USACE and EWN seek transparency and accountability as responsible stewards of public funds. The Institute has therefore also developed suggested metrics for tracking progress to ensure effective implementation of this strategic framework and, as needed, redirect effort if desired outcomes are not achieved. These metrics fall into two categories:

1. **Objective Metrics**. Metrics measuring progress in advancing the four strategic objectives (Figure ES 2). Evaluation of these metrics quantifies the progress USACE and EWN have made in implementing the framework outlined here.
2. **Outcome Metrics.** Metrics measuring progress in NBS implementation within the USACE Civil Works program.

Update Guidelines and Policies

- Policies and guidelines updated to support NNBF implementation

Expand Best Practice

- Planning and engineering guidance updated for different types of NNBF
- USACE certified tools including different types of NNBF
- USACE approved E&D models including different types NNBF

Synergize USACE Activities

- Trainings conducted & personnel participation in NNBF community of practice
- NNBF projects catalogued in the inventory and/or Districts participating

Catalyze Partnerships

- Partnering activities conducted by Districts, Divisions, and Headquarters with local sponsors, other Federal Agencies, and other stakeholders

Figure ES 2. Suggested metrics for characterizing progress in advancing each of four objectives identified for accelerating the implementation of NBS.

The suggested outcome metrics are based on the identified high-value opportunity to develop a new USACE Practitioner Database in support of accelerating NBS implementation. This database would be comprised of an inventory of Civil Works studies and flood risk management, coastal storm risk reduction, navigation, and ecosystem restoration projects that incorporate NBS, which are cross-referenced with tools, models, and guidance used in study and project implementation. The proposed database is itself an identified enabler to advance the objective of synergizing USACE Activities that would support USACE practitioners by improving dissemination and discoverability of information and exemplar projects relevant to NBS. In addition, outcome metrics of completed studies and projects that include NBS can be calculated annually to track progress incorporating NBS in USACE Civil Works practice. The outcome metrics can then be analyzed in combination with the objective metrics to determine the effectiveness of each objective in advancing NBS implementation, allowing successful strategies to be identified and resources focused accordingly.

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LIST OF ACRONYMS

Acronym	Term
AERP	Aquatic Ecosystem Restoration Project
AM	Adaptive Management
ASP	Agency Specific Procedure
BCA	Benefit-Cost Analysis
BCR	Benefit Cost Ratio
BU	Beneficial Use
BUDM	Beneficial Use of Dredged Material
CAP	Continuing Authorities Program
CCD	City and County of Denver
CE/ICA	Cost Effective and Incremental Cost Analysis
CG	Construction General
CSRM	Coastal Storm Risk Management
C-STORM	Coastal Storm Modeling System
DIMR	Deer Island Marsh Restoration
E&D	Engineering & Design
EcoFIP	Ecological Floodplain Inundation Potential
ENV	Environmental
EPA	Environmental Protection Agency
EQ	Environmental Quality
ER	Ecosystem Restoration
ERDC	Engineer Research and Development Center
EWN	Engineering With Nature®
E&C	Engineering and Construction
FACStream	Functional Assessment of Colorado Streams
FACWet	Functional Assessment of Colorado Wetlands
FRM	Flood Risk Management

Acronym	Term
FWOP	Future Without Project
FY	Fiscal Year
GI	General Investigation
GI	Green Infrastructure
HEC-FDA	Hydraulic Engineer Center Flood Damage Analysis Model
IWR	Institute for Water Resources
LERRD	Land, Easements, Rights of Ways, Relocations, and Disposal
MAM	Monitoring and Adaptive Management
MDMR	Mississippi Department of Marine Resources
MsCIP	Mississippi Coastal Improvements Program
MVN	New Orleans District
NAV	Navigation
NBA	Nature-Based Alternative
NBS	Nature-Based Solutions
NED	National Economic Development
NEPA	National Environmental Policy Act
NER	National Ecosystem Restoration
N-EWN	Network for Engineering With Nature
NGO	Non-Governmental Organization
NJDMM	New Jersey Dredged Material Management
NJDMU	New Jersey Dredged Material Utilization
NNBF	Natural and Nature-Based Features
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and Maintenance
OMB	Office of Management and Budget
OMRR&R	Operations, Maintenance, Repair, Rehabilitation, and Replacement
OSE	Other Social Effects
P&G	Principles and Guidelines

Acronym	Term
PCX	Planning Centers of Expertise
PDT	Project Delivery Team
PIANC	International Navigation Association
PL	Public Law
POC	Person of Contact
PR&G	Principles Requirements & Guidelines
RED	Regional Economic Development
RSM	Regional Sediment Management
SAJ	Jacksonville District
SME	Subject Matter Expert
SOPs	Standard Operating Procedures
TEK	Traditional Ecological Knowledge
UDFCD	Urban Drainage and Flood Control District
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WRDA	Water Resources Development Act

1.0 INTRODUCTION

Nature-Based Solutions (NBS) are actions inspired by or copied from nature that deploy various natural features and processes. NBS can be adapted to systems in diverse spatial areas and to those facing a range of social, environmental, and economic challenges. These anthropogenic solutions are designed to address flooding, erosion, and other coastal or inland issues by utilizing environmental processes, landforms, and ecosystems. Natural and nature-based features (NNBF) are specific applications of NBS to provide engineering functions relevant to flood risk management, while producing additional economic, environmental, and/or social benefits. The term *nature-based feature* was defined by Congress as "a feature that is created by human design, engineering, and construction to provide risk reduction by acting in concert with natural processes," and a *natural feature* is "created through the action of physical, biological, and chemical processes over time" (Carter & Lipiec, 2020). Examples of NBS include coastal beaches and sand dunes, wetlands, restoration of river hydrologic connectivity, and coral reefs. NBS can provide many benefits when used alone or in conjunction with structural alternatives (i.e., "green-gray infrastructure"), including habitat creation, opportunities for recreational use, and increases in adjacent property values (Fischbach et al., 2023b).

Despite their potential benefits, however, a variety of factors have contributed to structural and non-structural solutions being selected over NBS in many U.S. Army Corps of Engineers (USACE) Civil Works projects (Windhoffer et al., 2023). The importance and timeliness of developing strategies for closing the gap between opportunities for NBS inclusion in water resource management and their implementation in the USACE Civil Works program is significantly high given that that Congress has explicitly directed the agency to consider NBS as potential alternatives to or in combination with structural (or "gray") solutions such as jetties, seawalls, and other hard barriers and/or nonstructural alternatives such as elevating vulnerable buildings and acquiring land in floodplains (Carter & Lipiec, 2020). As a result of Section 2031 of the Water Resources Development Act (WRDA) of 2007 an interagency Council on Environmental Quality issued Principles, Requirements, and Guidelines (PR&G) in 2015 directing USACE to consider NBS and to broadly consider the full range of economic, environmental, and social benefits that project alternatives provide when making recommendations and executing projects. The Assistant Secretary for the Army subsequently developed draft Agency Specific Procedures (ASPs) for implementation of the PR&G as directed by Section 110 of WRDA 2020 (Federal Register, 2023a; WRDA, 2020). The draft ASPs provide directives and guidance to USACE practitioners for inclusion and evaluation of NBS as part of planning and project construction, with mandates requiring inclusion of a fully Nature-Based Alternative (NBA) and an environmentally preferred alternative in the final suite of project alternatives; incorporation of NBS in all alternatives where feasible; and consideration of a full range of economic, environmental, and ecosystem benefits when evaluating alternatives, including those that can be quantified in non-monetary terms or qualitatively described in addition to those that can be valuated monetarily.

The work presented here supports accelerating the use of NBS in USACE Civil Works planning and construction projects by:

- Synthesizing current challenges and opportunities in NBS implementation; and
- Developing a strategic framework for accelerating NBS in practice into the future.

A prior Water Institute (Institute) case study analysis of Feasibility Studies identified factors associated with lack of consideration and/or implementation of NBS within USACE Civil Works projects, including scoping of studies and/or project alternatives within a single USACE mission area; lack of available or widespread use of tools for capturing the monetary benefits of NBS in benefit-cost analysis (BCA); and the BCA process discounting or excluding NBS benefits that could not be effectively monetized (Fischbach et al., 2023b). This work identified opportunities for NBS advancement from a policy and practice perspective, which is built upon here through direct engagement of USACE personnel and partners with a practitioner's perspective. In addition, the current work expands the range of USACE authorities considered, as well as identifies challenges and opportunities across all phases of project implementation from planning through post-construction operation.

There were three primary activities associated with this work. First, Institute personnel conducted a series of working sessions with USACE Engineering With Nature® (EWN) practitioner leads who assist EWN and USACE in coordinating engagement across USACE Districts and Divisions on the use of NBS. These sessions elicited input on challenges and opportunities for NBS implementation, as well as provided feedback on the selection of two case studies for evaluating practical impediments to NBS implementation (Appendix A). The second activity conducted by the Institute was to review documentation and elicit input from District personnel on the consideration, evaluation, and implementation of those case studies, which were selected as Deer Island, Mississippi and the South Platte River and Tributaries, in Colorado (Appendix B). The case studies were used as tangible examples to prompt additional input on impediments to, and enablers for, NBS implementation. Lastly, the Institute coordinated three virtual workshops with District personnel and external partners as a third source of information on pathways to accelerate NBS in practice (Appendix C). The first two workshops focused on coastal and inland projects, respectively, to allow for a deeper dive into the challenges of NBS in different project types. The third workshop was used to review a draft synthesis of challenges and opportunities related to NBS with USACE personnel, as well as to refine a strategic framework for accelerating NBS implementation in the future. Institute personnel also coordinated with personnel from the USACE Institute for Water Resources (IWR) to leverage synergistic activities where possible and include relevant information previously collected through IWR activities.

The input from those tasks was synthesized into a set of challenges and opportunities associated with current and recent NBS implementation; these are organized into the phases of USACE project construction from planning studies through to construction, operations and maintenance (O&M), and adaptive management (AM; Section 2.0). The challenges represent impediments to NBS that, if resolved, would allow for more widespread implementation, while the opportunities capture existing USACE practices and policies that have enabled use of NBS in Civil Works projects. A strategic framework for accelerating NBS implementation in the future was then developed based on the analysis of challenges and opportunities and other input received from USACE practitioners and experts in the field (Section 3.0), along with metrics that can be used to evaluate success (Section 4.0). This strategic framework can support USACE and EWN by providing a roadmap in support of practical implementation of the PR&G and draft ASPs, once finalized.

2.0 NBS RETROSPECTIVE: CHALLENGES AND OPPORTUNITIES

USACE practitioners can plan or enable NBS implementation through multiple pathways including Feasibility Studies, Standing Authorities such as Beneficial Use of Dredged Material (BUDM), and Comprehensive Studies, each of which has its own challenges and opportunities. An overarching opportunity USACE personnel have capitalized on to accelerate NBS in practice has been through coordination with partners to leverage the multiple regulatory pathways available within USACE. The need for acceleration of NBS across all USACE authorities is also consistent with the draft ASPs, which are applicable to all USACE planning and construction projects with limited exceptions for, for example, research activities and support to partners that does not directly result in additional federal investment in water resource management projects.

2.1 PLANNING, AUTHORIZATION, AND FUNDING

The first point at which NBS can be considered by USACE is during the initial project planning phase, which is comprised of a study to evaluate alternatives for advancing water resource management objectives within the USACE mission (Section 2.1). In most cases, the planning phase leads to a Recommended Plan that must then be congressionally authorized through either a standing authority held by USACE or through new congressional action. Authorized projects must also be funded for construction, typically as a 50/50 split between federal funding and support from the local (i.e., non-federal) sponsor unless otherwise specified by Congress. Federal funding can come from discretionary use of USACE funds authorized for specific purposes or through appropriations of funds by Congress for the specific project.

Mechanisms for USACE to plan water resources projects can be divided into three overarching categories: (1) Feasibility Studies authorized by Congress at a selected location as part of advancing one or more USACE missions areas, including flood risk management (FRM), coastal storm risk management (CSRM), deep draft navigation (NAV), and ecosystem restoration (ER); (2) studies conducted under standing USACE authorizations including the Continuing Authorities Program (CAP), also to advance objectives for a selected location; and (3) comprehensive/basin-wide studies or watershed assessments that evaluate water management alternatives for larger regions and across multiple objectives, either specifically authorized by Congress (comprehensive studies) or conducted as part of a standing authority for watershed assessments under Section 729 of WRDA 1986 (WRDA, 1986).

2.1.1 Congressionally Authorized Site-Specific Feasibility Studies

Feasibility Studies are authorized by Congress and direct USACE to identify and evaluate alternatives for addressing water resource management issues at a specified location. A brief overview of this evaluation process and its relationship to NBS consideration by USACE can be found in this section, with more information available in Ehrenwerth et al. (2022) and Fischbach, Dalyander et al. (2023b). There are several challenges and opportunities associated with how NBS must be evaluated as part of Feasibility Studies that can limit the consideration and/or selection as part of alternatives. A prior Institute review identified several of these factors (Fischbach et al., 2023b), which were further evaluated and expanded upon during the activities of the current effort.

Since 1983 planning for USACE projects has been guided by the Principles and Guidelines (P&G), which dictates that the federal objective of water and land resource management is contributing to national economic development (NED) while also complying with other statutes related to, for example, environmental protection (Ehrenwerth et al., 2022; USACE, 2000). NAV, FRM, and CSRM projects are evaluated based on their contribution to this NED "account", with BCA used as the standard to identify the project alternative that provides the greatest monetized benefit to cost ratio (BCR). The benefits of project alternatives can also be assigned to three other accounts: environmental quality (EQ), which captures non-monetary effects on natural and cultural resources; regional economic development (RED), which captures more localized impacts to income, employment, and other economic metrics; and other social effects (OSE), which captures impacts not included in the other accounts (USACE, 2000). The federal objective for ecosystem restoration projects, however, is to contribute to national ecosystem restoration (NER) and the EQ account (USACE, 2000). In this case, the standard applied is the net increase in quantity or quality of ecosystem resources as a function of the incremental cost, with the alternative that has the greatest incremental benefit identified as the "best buy" plan. This distinction is highly relevant to NBS implementation given that, in many cases, NBS provide a broader range of economic, environmental, and social benefits than gray infrastructure solutions that advance more targeted objectives (e.g., a marsh to mitigate wave energy, reduce erosion, and protect coastal infrastructure may also provide habitat and eco-tourism opportunities, whereas a seawall may almost exclusively provide economic benefit through infrastructure protection).

USACE planning guidance established prior to the PR&G included recommendation of the NER plan (best buy) for ecosystem restoration studies; the NED plan (highest BCR) for FRM, CSRM, and NAV studies; development of both an NED and NER plan for multi-purpose studies; and allowed exceptions in some cases (Fennell, 2019). For example, a locally preferred plan may be recommended with the local sponsor responsible for additional costs incurred beyond the NED or NER plan. Feasibility Studies can also be authorized as multi-purpose with alternatives evaluated based on tradeoffs between NED and NER benefits (USACE, 2000). In practice, Feasibility Studies have implemented multi-purpose studies by focusing NER or NED by spatial region rather than as an integrated effort, or they may seek a waiver to exempt the study from NED analysis (Appendix A). Draft Recommended Plans are subject to review by the public and approval by the USACE "vertical team" (i.e., Division and Headquarters personnel). Once finalized, a chief's report is issued with the results of the Feasibility Study and the Final Recommended Plan. The Office of Management and Budget (OMB) reviews the Feasibility Study, determines consistency with executive branch policies, and informs USACE of the findings (Fennell, 2019). Personnel at each review stage must therefore be familiar with, and supportive of, the specific NBS included within a Recommended Plan for implementation to occur.

USACE Feasibility Studies are also subject to other constraints influencing inclusion of NBS in project alternatives. The Water Resources Reform and Development Act (WRRDA) of 2014, Section 1001, requires that Feasibility Studies initiated after June 2014 follow the "3x3x3" rule (WRRDA, 2014). Reports on Feasibility Studies must be typically be completed no later than 3 years after the date of initiation (the last year of which is usually focused on internal and external report reviews) and at a total cost of no more than $3 million; have a federal cost share limit of $1.5 million; and include USACE review at the 3 levels of District, Major Subordinate Command (i.e., Division), and Headquarters throughout the study (USACE, 2015), although exceptions are allowed in the case of complex studies.

The initial formulation and design of NBS alternatives may require more time and cost than gray infrastructure, particularly given that NBS that have fewer guidelines and established best practice, making it more challenging in many cases for project teams to consider these alternatives within a study's scope. Policy waivers exempting a study from the 3x3x3 rule can be sought to provide study teams with additional time and budget to evaluate more complex features like NBS, but uncertainty in the timeline, costs, and ultimate success in pursuing a waiver can result in hesitancy to do so.

The Recommended Plan that results from a Feasibility Study requires Congressional authorization for construction and funding. Each year, OMB reviews USACE projects that have been authorized for construction and assesses them against criteria such as a BCR exceeding 2.5:1 to determine if they will be included in the President's budget request for the year (Fennell, 2019); NBS benefits must be monetized for inclusion in this evaluation. Congress ultimately determines which projects to authorize funding for, including consideration of the President's budget request. The construction phase includes the detailed engineering and design (E&D) necessary for project implementation as well as construction itself.

Although Feasibility Studies can be authorized as multi-purpose, most are authorized within a single business line (e.g., navigation, flood risk management, ecosystem restoration), which can constrain how alternatives are developed and evaluated, and often inhibits full consideration of NBS co-benefits such as habitat provision, flood risk reduction, and recreational use (Fischbach et al., 2023b). Even if Congress authorizes Feasibility Studies as dual purpose, practitioners indicated that limited USACE guidance, support, and tools exist (and/or are readily discoverable) to reconcile the inherently different processes of using BCA to evaluate alternatives against the NED standard and best buy analysis to evaluate alternatives against the NER standard, particularly in a way that will receive "vertical team" approval (within USACE) and be favorably reviewed by OMB (Appendix A, Appendix C). These two approaches—NED BCA and NER best buy analysis—are so inherently different that they are difficult to effectively combine into a single holistic approach applied to the same spatial area, and any methodology to do so would need to be supported by the vertical chain of command in USACE as well as by OMB.

For studies where the NED standard and BCA is applied, alternatives that incorporate NBS are frequently not economically justified when compared to gray infrastructure solutions. For the South Platte River and Tributaries Feasibility Study, for example, the USACE team spatially divided the area of interest into the South Platte River, where the NER standard was used, and the Harvard and Weir Gulch tributary areas, where the NED standard was applied. USACE chose ecosystem restoration as the primary objective for the main stem of the river because prior evaluation of NBS and ecosystem restoration opportunities indicated that the benefits that would be provided in that area could not justify the cost (Appendix B). Institute re-analysis of the study was consistent with this finding, with a BCR below 1.0 for the South Platte NBS alternatives even with inclusion of additional recreational use and natural capital benefits. In addition, the Institute effort highlighted that there are gaps in methods and tools for monetizing the benefits of NBS, such as water quality improvements and increases to property values, and that NBS would have been more likely to have been included under the NED standard if (1) a broader range of monetizable benefits could have been included; and/or (2) multi-objective analysis not relying exclusively on benefit monetization could be used in conjunction with BCA in selecting a Recommended Plan (Fischbach et al., 2023b).

Input from District personnel highlighted additional challenges for NBS in Feasibility Studies (Appendix A, Appendix C). First, methods used to evaluate alternatives must be certified by USACE for the spatial area in which they are being applied. This constraint is more limiting for NBS than for gray infrastructure solutions because of the wide variety of NBS and the relatively limited number of certified tools and engineering guidance documents available for design or benefit quantification. The techniques used by the Institute to quantify natural capital enhancements from NBS in the South Platte River and Tributaries Feasibility Study have not been certified by USACE, for example, and thus could not have been used by District personnel without first seeking certification (Fischbach et al., 2023b). When certified or potentially certifiable methods for formulating or evaluating NBS exist, they may not be readily discoverable by USACE personnel, and/or there may be a tendency for practitioners to rely on more familiar measures (i.e., structural or non-structural measures) in the formulation and evaluation of alternatives (Appendix C). Similarly, Feasibility Study teams must develop their approach for formulating and evaluating multi-purpose Feasibility Studies on a case-by-case basis, rather than having standardized guidance for how to incorporate NED- and NER-based methods in a way that could more fully capture the co-benefits of NBS. Lastly, Feasibility Study teams wishing to apply an NER-based best buy analysis for studies not specifically authorized for ecosystem restoration must seek a waiver, creating an obstacle for use of this analysis in cases where alternatives including NBS may provide high incremental benefit for their cost even if they are not the alternatives with the lowest BCR (Appendix A, Appendix C). Each additional step required for alternative formulation and evaluation that could potentially increase consideration of NBS alternatives (e.g., acquiring a waiver for use of NER-based best buy analysis; seeking USACE certification of new tools for quantifying value) adds time that is often unavailable within studies constrained to last no more than 3 years per the 3x3x3 rule. Additionally, the cost of a new model certification is estimated to be between $15,000 and $65,000. This cost would be borne by the project, reducing contingency funds and compounding the difficulty in meeting the time constraint of 3 years or seeking a waiver. Furthermore, there may be varying support across Districts and Divisions for seeking and granting waivers for best buy analysis and/or for pursing USACE certification of new tools.

Another impediment identified is that the relatively large spatial footprint needed for NBS (wetlands, marshes, etc.) compared to gray infrastructure (seawalls, levees, etc.) can limit their inclusion in FRM and CSRM studies (Appendix A, Appendix B, Appendix C). The real estate cost of land acquisition—assuming suitable land area is available—reduces the BCR, often to below the value for alternatives that rely on gray infrastructure. The South Platte River and Tributaries case study provides an example of this issue: the alternatives considered for the Harvard and Weir Gulch regions relied primarily on gray infrastructure and non-structural measures despite interest in ecosystem restoration due in large part to the spatial area required for NBS and, specifically, the high cost of real estate in the Denver area (Appendix B.2).

A final technical challenge identified for Feasibility Studies is a lack of methods and approved tools for designing NBS alternatives and evaluating associated risks and risk contingencies (Appendix A, Appendix C). Established engineering guidance exists for most gray infrastructure solutions (levees, seawalls, groins, etc.) with standardized, analytical tools for designing the structure to achieve the desired goals and quantify the risk of failure. USACE practitioners can therefore readily scale and cost these alternatives for evaluation in Feasibility Studies, including for the estimation of costs for operations and maintenance. Engineering guidance for NBS are not available in most cases, however, with limited exceptions such as for the design of beaches and dunes for CSRM[1]. Developing appropriate design, scale, and cost alternatives such as marsh creation for flood risk mitigation requires more time-consuming methods such as site-specific deterministic modeling. In some cases, there are gaps in the underlying best available science (e.g., attenuation of wave energy by different types of marsh and wetland plants; Appendix A, Appendix C). This includes the lack of available USACE approved tools for designing NBS.

The above challenges to evaluating NBS relative to more traditional infrastructure alternatives also presents an additional potential issue in that the selected alternative may exclude NBS that stakeholders would like to be included and that the local sponsor and regulatory agencies may prefer. This puts the regulators in the position of needing to formally recommend changes to the Recommended Plan and the local sponsor in the financially infeasible position of needing to either fully fund these additional features themselves or accept a solution that does not fully meet their needs. In some cases, this has resulted in a project being delayed or even reevaluated to address concerns by the local sponsor and other regulatory agencies (Appendix C).

2.1.2 Standing Authorities

Congress has granted USACE several standing authorities that allow planning studies, construction projects, and funding to be initiated without the need for additional Congressional authorization. USACE efforts conducted under the USACE CAP begin with a request for assistance from a potential local sponsor (Department of the Army, 2019); therefore, opportunities for NBS implementation have often been realized through close coordination of USACE with local and regional partners. An additional standing authority relevant to NBS implementation outside of the CAP (Appendix A, Appendix C) is PL 84-99 (USACE, 2008), the Flood Control and Coastal Emergencies Act. These authorities and the associated challenges and opportunities for NBS implementation are described below.

2.1.2.1 Continuing Authorities Program

The CAP is comprised of nine standing authorities granted to USACE by Congress across a variety of focus areas (Table 1; Department of the Army, 2019; Normand, 2023; USACE Savannah District, n.d.). The local cost share requirement for these projects may be lower than for Feasibility Studies, and CAP authorities may be used to improve projects that were originally part of a specifically authorized Feasibility Study (Department of the Army, 2019). CAP projects are, however, more limited in scope than Feasibility Studies. These authorities have therefore presented opportunities for implementation of smaller-scale NBS and not toward, for example, projects to reduce flood risk over a large spatial area that require a large initial investment. Limited annual funding is available for CAP projects, which further restricts the number and scale of projects that can be implemented. Implementation of NBS under CAP studies requires alignment and support from Divisions and Headquarters, since they are subject to the same vertical team review associated with Feasibility Studies (USACE, 2015). In addition, they are also subject to evaluation against the NED and NER standard (Department of the Army, 2019).

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[1] Engineering guidance for other types of NNBF was under development as of the time of this report's publication.

Table 1. Legislature included in the USACE Continuing Authorities Program (CAP) (USACE, 2000; USACE Savannah District, n.d.).

Authorizing Legislature	Description	Cost Requirements
Section 14, Flood Control Act of 1946	Emergency streambank and shoreline protection for public facilities and services	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: 65/35 federal and local sponsor Federal Limit: $5,000,000
Section 103, River and Harbor Act of 1962	Protection of shores of publicly owned property from hurricane and storm damage	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: 65/35 federal and local sponsor for storm damage reduction Federal limit: $10,000,000
Section 107, River and Harbor Act of 1960	Small navigation projects	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: varies by design depth Federal limit: $10,000,000
Section 111, River and Harbor Act of 1968	Mitigation of shoreline damage caused by Federal navigation constructions	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: 50/50 federal and local sponsor Federal Limit: $12,500,000
Section 204, WRDA 1992 Amended by Section 125, WRDA 2020	Beneficial use of dredged material	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: local sponsor pays 35% of cost in excess of base plan Federal Limit: $10,000,000
Section 205, Flood Control Act of 1948	Flood risk management	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: varies Federal Limit: $10,000,000
Section 206, WRDA 1996	Aquatic ecosystem restoration	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: 65/35 federal and local sponsor Federal Limit: $10,000,000
Section 208, Flood Control Act of 1954	Snagging and clearing for flood damage reduction	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: local sponsor pays 35-50% Federal Limit: $500,000
Section 1135, WRDA 1986	Construction modifications for improvement of the environment	Study: 100% federal up to $100,000, then shared 50/50 with local sponsor Construction: 75/25 federal and local sponsor Federal Limit: $10,000,000

Although multiple CAP authorities present opportunities for NBS implementation, USACE practitioners highlighted beneficial use of dredge material (BUDM) from federal navigation channels (Section 204d of WRDA, 1992) as a mechanism they frequently leverage to implement those NBS that require sediment for construction (e.g., Appendix B.1). These NBS include wetlands, marshes, beaches, and dunes, all of which can provide flood risk reduction and recreational benefits as well as supporting ecosystem restoration. BUDM can support NBS implementation while also alleviating challenges USACE faces in finding efficient and cost-effective ways to dispose of sediment dredged as part of navigation channel maintenance (Appendix A, Appendix C). In addition, the Chief of Engineers has directed USACE Districts to beneficially use 70% of all dredged material by 2030 (https://budm.el.erdc.dren.mil/), with NBS implementation representing a key opportunity to advance progress toward that goal.

Dredge material management plans developed for navigation projects (i.e., Section 204d projects) can include placement locations identified through Section 204 studies and have thus provided an opportunity for long-term maintenance of associated NBS (Appendix A). BUDM projects are not evaluated through the same processes used for FRM and CSRM projects. Disposal options other than the least cost option can be selected for navigation channel construction or operations projects, provided that the incremental cost increase is reasonable compared to environmental or storm/flood risk reduction benefits (South Atlantic Division Regional Sediment Management Center of Expertise, 2023). The associated guidance directs the complete life cycle costs of projects to be used in conducting benefit and cost evaluation, allowing for more comprehensive assessment of the full costs and benefits of NBS compared to gray and green/gray solutions. In addition, the federal portion of increased incremental costs can be provided as an authorized aquatic ecosystem restoration or nourishment project (South Atlantic Division Regional Sediment Management Center of Expertise, 2023), providing flexibility in funding source. USACE practitioners have further used engagement of state and local partners, including non-governmental organizations, to catalyze opportunities for NBS implementation through BUD. For example, BUDM sites can be identified and permitted in anticipation of expected dredging activities through coordination of local partners with Districts, as is being done through coordination of the Texas General Land Office, Ducks Unlimited, and the Galveston District (https://www.glo.texas.gov/coastal-grants/projects/gomesa-26-budm-master-plan-21-155-005-c878.html).

Implementation of NBS through BUDM is not without its challenges, however (see Appendices A.2, B.1, and C.1). Locations where NBS are desired may be far from navigation channel dredging projects, and transporting sediment across long distances increases costs and degrades incremental benefit. The timeline, scale, and requirements of a potential USACE NBS project may also misalign with the timing, quantity, and type of material available for placement. For example, an NBS project may not complete review before the dredged material must be disposed of, or a different distribution of sediment grain sizes may be needed than is available. In addition, the volume of dredged sediment may not align with the quantity needed for planned NBS, creating challenges of how to dispose of the excess volume or source the sediment shortfall. Partnering opportunities have been used to overcome these challenges in some cases, but because BUDM projects using material from federal navigation projects must meet USACE risk assessment standards, not all projects designed by other entities are eligible. Furthermore, partnering projects may be slow to implement due to the time required to meet regulatory requirements and/or to set up the necessary partnering agreements. The timeline and requirements of engaging USACE on BUDM projects has, in some cases, led organizations with the funding and desire to execute NBS projects to move forward without USACE involvement.

2.1.2.2 Flood Control and Coastal Emergencies Act (PL 84-99)

Another authority highlighted by District personnel (Appendix A, Appendix C) as relevant to NBS implementation was PL 84-99, the Flood Control and Coastal Emergencies Act (*Flood Control and Coastal Emergency Act*, 1941). PL 84-99 gives USACE the authority to rehabilitate levees and other measures in response to floods, storms, and other disasters if those measures are classified for FRM and CSRM and meet other requirements in regards to, for example, maintenance (USACE Omaha District, 2020). This mechanism can enable NBS to be repaired and maintained after a flooding event if they are classified as FRM or CSRM projects. In addition, cost effectiveness (i.e., incremental benefit for cost) is used as the criteria for PL 84-99 alternative evaluation (USACE Omaha District, 2013b), which may be conducive to capturing the benefits of some NBS solutions.

There are several challenges associated with the application of PL 84-99 to NBS, however. Regulatory guidelines may discourage use of NBS, such as vegetated levees being considered deficient and potentially ineligible for repair under PL84-99 (Department of the Army, 2014). In addition, standard operating procedures (SOPs) and guidance for enhancing, repairing, or maintaining levees under PL84-99 may not otherwise allow or encourage the incorporation of NBS. Despite these challenges, however, practitioners have found opportunities to incorporate NBS and EWN principles into PL84-99 projects. For example, portions of levees along the Missouri River rehabilitated under PL 84-99 were set back from the original locations to provide ecosystem benefits as well as flood risk reduction and reduced damage to critical infrastructure, providing a cost-effective repair along with ancillary benefits (USACE Omaha District, 2013b). However, this was only possible because it was the “least cost” alternative and was technically feasible only because opportunities arose to work with conservation partners to purchase and leverage land needed for construction. An additional caveat is that the purpose of the setbacks was not to provide ecosystem benefits; this was an incidental outcome of the least cost, most technically feasible structural repair alternative.

2.1.3 Comprehensive Studies

USACE has two mechanisms for conducting studies that evaluate management alternatives on regional scales. The first are comprehensive studies specifically authorized by Congress, such as the Mississippi Coastal Improvements Program (MsCIP, Appendix B.1). The authorizing language specifies the spatial region of interest, time scale and scope of the study, and objectives for consideration (FRM, CSRM, ecosystem restoration, etc.), and may also specify the method to be used to evaluate alternatives (BCA or cost effectiveness). Comprehensive studies can result in recommended alternatives for construction using standing USACE authorities; identify sites for follow-up with targeted Feasibility Studies; and/or integrate existing studies or projects into a comprehensive plan. For example, an Aquatic Ecosystem Restoration project at Deer Island, Mississippi that was in the planning phase under a CAP authority (Section 528 of WRDA, 2000) was incorporated into the comprehensive plan that ultimate resulted from MsCIP (Appendix B.1).

Watershed studies are conducted under a standing authority granted to USACE by Section 729 of WRDA 1986 (WRDA, 1986). As in the case of other USACE standing authorities, watershed studies are initiated through a request from a potential local sponsor who must also sign a 25% cost-sharing agreement. Watershed studies are opportunities for USACE collaboration with partners and may lead to recommendations for action in the form of management plans, watershed or river base assessments, or comprehensive plans, including those that would be initiated or led by other entities (USACE CECW-P, 2019). The effort focused on congressionally authorized comprehensive studies based on feedback from USACE personnel that watershed studies often lead to non-federal action. However, some of the findings presented here for comprehensive studies may be applicable to watershed studies given their similar focus on multi-objective regional planning.

USACE practitioners identified several opportunities associated with comprehensive studies (Appendix A, Appendix C) that were also highlighted in case study evaluation of NBS planning and implementation at Deer Island within MsCIP (Appendix B.1). First, comprehensive studies generally provide more flexibility to consider the holistic, system-wide benefit of potential alternatives than can be considered in site-specific Feasibility Studies. In the case of MsCIP, for example, cost effectiveness and incremental benefit could be used to identify the Recommended Plan despite CSRM being a primary objective of the study. The planning process can therefore allow for wider consideration of NBS benefits and use of multi-objective analysis in conjunction with BCA to recommend alternatives, consistent with an opportunity identified for broader consideration of NBS in Feasibility Studies (Fischbach et al., 2023b). Comprehensive studies typically have longer timelines and less restricted budgets than the 3x3x3 constraints imposed on Feasibility Studies, reducing several impediments that can limit full consideration of NBS. Alternative formulation also allows broader consideration of more holistic, systemwide approaches to CSRM and FRM, which can be conducive to use of NBS and green/gray solutions. For example, the MsCIP plan incorporated a “multiple lines of defense” approach, with a combination of barrier islands, gray infrastructure, and marshes providing protection from large-scale coastal storms as well as to mitigate smaller scale, recurrent flooding associated with smaller events (Appendix B.1). This formulation process is more conducive to inclusion of NBS than studies exclusively focused on protecting infrastructure in a targeted area from large storms, in which case gray infrastructure solutions like seawalls or flood gates are like to have a higher BCR.

Despite these opportunities, however, there are challenges associated with comprehensive studies as a mechanism for NBS implementation. Comprehensive studies may identify and evaluate alternatives including those that incorporate NBS, but they often include recommendations for additional analysis of these alternatives through, for example, a site-specific Feasibility Study. This additional analysis can take an additional 3 years or more to complete, and ultimately the alternatives including NBS that were identified in the comprehensive study may not be recommended or authorized for construction due the challenges associated with NBS evaluation in Feasibilities Studies (see Section 2.1.1). It may also be difficult to find federal funding and/or a local sponsor support to construct the full extent of the comprehensive plan’s holistic, systemwide strategy, such as NBS as part of a multiple lines of defense approach.

2.2 PROJECT IMPLEMENTATION

Implementation phases of a USACE project begin after it has been planned, authorized, and funded, and include post-authorization E&D; permitting; Land, Easements, Rights of Ways, Relocations, and Disposal (LERRD); construction; operations, maintenance, repair, rehabilitation, and replacement (OMRR&R); and, in some cases, AM (USACE, 2000). A short description of each of these phases is included below, organized into project development and post-construction periods, and followed by the associated challenges and opportunities identified by practitioners (Appendix A, Appendix C) and through case study analysis (Appendix B).

2.2.1 Post-Authorization and Construction

Costs for implementation and the allocation of responsibility between USACE and the local sponsor varies by project type (e.g., NAV, ER, FRM, etc.) and authorization (e.g., Feasibility Study, authority under CAP; USACE, 2000). Project E&D occurs between completion of pre-authorization planning and construction and is comprised of the more detailed design work necessary to implement a project. USACE typically conducts project E&D, but a pilot program exists allowing a local sponsor to lead the work and be reimbursed by USACE (see additional information for the South Platte case study, Appendix B.2). Permitting includes acquiring the necessary approvals from regulatory entities responsible for management of land or resources potentially impacted by the project (e.g., U.S. Fish and Wildlife Service [USFWS]). Partner organizations building NBS in coordination with USACE under CAP such as BUDM require permits from the Regulatory Program of USACE that is responsible for approving construction activities occurring in the "waters of the United States"[2]. LERRD is a complex process that includes acquisition of land and/or rights to use the land necessary for a project and access to areas necessary for construction (access channels, pipelines for pumping dredged material, etc.; USACE, 2000). Lastly, construction consists of building the project on the landscape.

An objective to increase inclusion of NBS in projects, where appropriate, is made more challenging by the diversity of NBS that exist (e.g., construction practice and lessons learned from, for example, oyster reef construction is not readily transferable to restoring wetlands). The wide spectrum of NBS approaches that can be constructed across different landscapes (wetlands, dunes, increasing hydrologic connectivity, etc.) also results in a high degree of variability in the regulations, policies, and practice impacting all phases of implementation. This variability makes it challenging for practitioners to consider a wide range of NBS that could potentially be appropriate for their projects, given that they must familiarize themselves with multiple regulations and information applicable to each type of NBS potentially under consideration. A multiple lines of defense approach to CSRM, for example, could potentially include oyster reefs, wetlands, beaches and dunes, or mangroves. Each of these NBS types has its own design, implementation, and permitting constraints. The experience gained may not, however, be transferable to a future project that considers different types of NBS; the same types of NBS applied to a different landscape; or for a project planned or executed under a different type of authorization. A full description of the variability in factors impacting all types of NBS across each phase of project implementation was beyond the scope of this study, but additional information is provided below where applicable to identified opportunities and challenges.

Input received from practitioners (Appendix A, Appendix C) and case study analysis (Appendix B) demonstrate that USACE practitioners have found opportunities to construct a variety of types of NBS. Most identified examples of constructed NBS were associated with smaller-scale projects constructed through standing authorities such as beneficial use, as part of comprehensive studies, and/or for the

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[2] A recent court case (Sackett vs. Environmental Protection Agency, 2023) led to the U.S. Environmental Protection Agency and Department of the Army amending the Code of Federal Regulations in September, 2023 to narrow the definition of "waters of the United States" to exclude wetlands (Federal Register, 2023b). Practitioners indicated the potential for significant implications for implementation of this type of NBS, but the regulation change was too recent to evaluate these impacts.

primary purpose of ecosystem restoration. For example, wetland and marsh creation at Deer Island was implemented under aquatic ecosystem restoration and BUDM projects, with additional planned NBS incorporated into the MsCIP comprehensive study (Appendix B.1). There were fewer examples identified by the project team for constructed NBS resulting from Feasibility Studies that focused on FRM or CSRM. This gap is consistent with earlier Institute findings that NBS are often excluded from consideration early in the planning process of Feasibility Studies and/or from the Final Recommended Plan (Fischbach et al., 2023b), as well as with other challenges identified by practitioners (Section 2.0). Practitioners did note that beach and dune restoration are an exception to this trend. Design guidelines for beaches and barrier islands to mitigate coastal storm impacts have been developed over the course of decades (e.g., USACE, 1989). Dunes and beaches therefore represent a potential templar for developing guidance, standards, certification protocols, and pilot projects for other types of NBS within, for example, a multiple lines of defense approach to FRM or CSRM.

Practitioners have also found opportunities to implement NBS in a manner that shifts away from an established paradigm in which projects are designed and implemented exclusively to provide protection against “design” storms or floods (major events, i.e., those that drive catastrophic widespread flooding and damage). Instead, NBS can be implemented as part of a regional ecosystem management approach that protects communities against a variety of different scale flooding hazards while also providing broader ecosystem service and economic benefits. In the case of MsCIP, for example, Deer Island and the barrier islands within the Mississippi coastal system (Ship Island, Cat Island) are being restored as part of a multiple lines of defense approach (Appendix B.1). NBS can mitigate high-frequency, low-level flooding events, while also providing benefits such as habitat creation, recreational fishing and ecotourism opportunities, and potential cost-savings for dredged material disposal. It should be noted, however, that the USACE authority for CSRM requires designing to a hurricane or storm unless the local sponsor requests that non-storm flooding (king tides, wind events, etc.) be investigated under the authority granted to USACE through Section 8106(a) of WRDA 2022 (WRDA, 2022).

Practitioners did, however, identify multiple challenges associated with designing and building NBS (Appendix A, Appendix C). One such challenge is a lack of information and guidelines for project design, quantification of expected performance, and estimation of risk that the project will not meet targets set for objectives including FRM and CSRM. There are multiple and diverse types of NBS (marsh and wetlands, beaches and dunes, oyster reefs, restoring the hydrologic connectivity of rivers, bank stabilization, floodplain connectivity, etc.), each with its own unique considerations for E&D and construction. Except for beaches and dunes, engineering guidance for most NBS is limited and/or still in development. Tools to support E&D of NBS have been developed in some cases, such as the creation of an EWN C-STORM (Coastal Storm Modeling System) modeling toolkit (USACE ERDC, 2022), but are not widely available across all types of projects and NBS. Because fewer USACE projects incorporating NBS have been put on the landscape, there are also fewer templates that practitioners can follow in designing or applying construction techniques. The creation of a database of EWN projects[3] has facilitated access to information

[3] https://ewn.erdc.dren.mil/pro-map/

and prior projects. In addition, pilot projects at EWN Proving Grounds[4]—Districts and Divisions used to test and document NBS advancements—have made significant progress in helping address these challenges. However, practitioners indicated more example projects are needed across different use cases and field sites for many types of NBS. Practitioners also indicated that NBS require more field fitting (i.e., flexibility and adaptability in construction) than traditional gray infrastructure, because of both the lack of established construction approaches/templates and the inherently greater variability and uncertainty associated with constructing NBS that include dynamic elements (e.g., sand and sediment) and/or living components (e.g., vegetation). For example, engineers discovered that the underlying soil could not support the weight of geotubes intended to be used to close a breach during the Deer Island restoration but were able to mitigate the issue in the field through planting of dense vegetation (Appendix B.1).

2.2.2 Post-Construction

Post-construction activities for USACE projects vary depending on the USACE authority under which they are constructed. Projects authorized for NAV, FRM, CSRM, or as part of the CAP include plans and funding for OMRR&R, comprised of the annual costs and activities associated with keeping the project or its components operating as designed and built during initial construction (e.g., regular dredging required to keep a channel open; recurrent maintenance on a levee; etc.; USACE, 2000). In contrast, post-construction activities for ecosystem restoration projects may include monitoring and AM, in which data on project performance is regularly collected to evaluate whether desired objectives are being achieved and to inform future projects (USACE, 2000).

As previously noted in Section 2.1.2, USACE teams can implement NBS as part of the post-construction OMRR&R of NAV projects via BUDM. Maintenance of beaches and dunes authorized for coastal storm risk management can be repaired under the Flood Control and Coastal Emergency Act (PL84-99), but most types of NBS are authorized as part of ecosystem restoration projects and USACE post-construction management is restricted to monitoring in these cases. Practitioners indicated this is one challenge of NBS (Appendix A, Appendix C): if the project fails to meet its objectives or perform as expected, any additional cost is the responsibility of the local sponsor. This responsibility may discourage some entities from partnering with USACE for NBS implementation, particularly given that the management and maintenance of NBS may be more complex, with higher risk of failure, than for more established gray infrastructure or non-structural alternatives.

Practitioners identified several additional challenges associated with post-construction AM for NBS (Appendix A, Appendix C). Monitoring costs for ecosystem restoration projects are not typically cost shared with the local sponsor, but if included may not exceed 1% of the cost of initial construction. Plans for very complex ecosystem restoration projects may include AM (i.e., contingency plans allowing adjustments to the project to be made if targeted outcomes are not achieved), but must not exceed 3% of the total project cost excluding monitoring expenses (USACE, 2000). Project AM is also typically

[4] https://ewn.erdc.dren.mil/proving-grounds/

constrained to the first 5 years after initial construction. These constraints can make it challenging to collect sufficient data for use in improving E&D of NBS, which in most cases is less established and field-tested than gray infrastructure solutions that have been used by USACE for decades. Similarly, there are few established mechanisms for disseminating modeling and data collection undertaken as part of monitoring and AM to other practitioners in USACE, and relatively few funded efforts focused on reevaluated project performance or comprehensively comparing results across projects. This gap makes it difficult for practitioners to fully utilize data that has been collected to advance best practices in NBS construction, including revision of planning tools and E&D models to improve utility for NBS.

3.0 STRATEGIC FRAMEWORK FOR ACCELERATING NBS AND NBA FORMULATION AND IMPLEMENTATION

The need for effective, USACE-wide coordination to resolve impediments to NBS implementation and achieve the directives laid out by the PR&G and draft ASPs underscores the need for a comprehensive strategic framework for accelerating NBS and NBA formulation and implementation in the USACE Civil Works program. This strategic framework (Figure 1) includes an overarching goal set as a guidepost for EWN and its partners, along with a set of four objectives representing high-level, conceptual pathways to advance that goal. Also included are "enablers," which are activities that can be led or supported by EWN, other entities in USACE, and/or in collaboration with partners to further those objectives. This strategic framework provides a foundation for EWN and USACE at large to identify and prioritize future actions advancing each enabler, with examples provided to support implementation. Finally, the strategic framework supports quantifiable evaluation of success as actions are taken, which support a continued effort toward strategies that prove successful (Section 4.0).

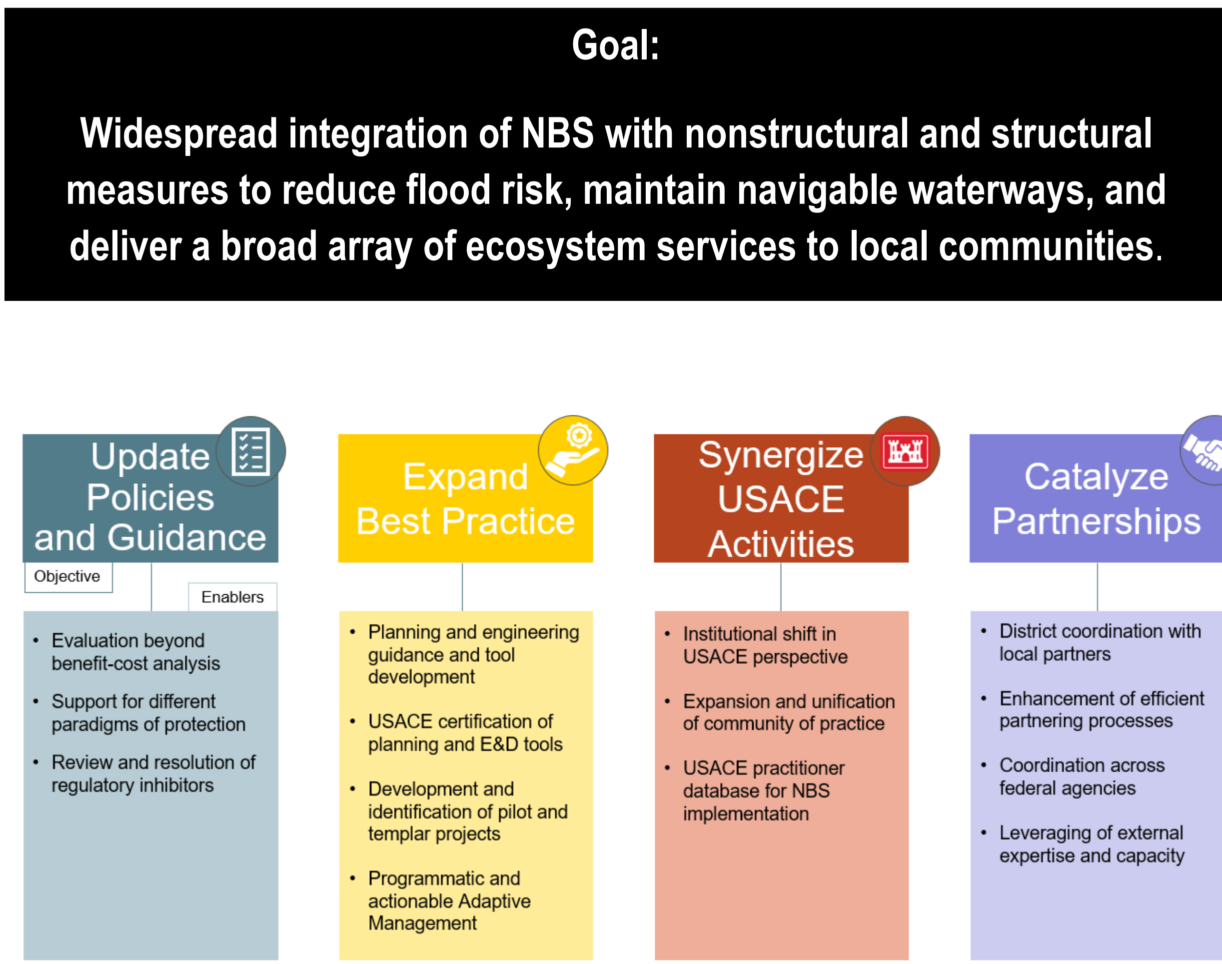

Figure 1. Strategic framework to accelerate NBS and NBA formulation and evaluation. The framework is comprised of a goal, four high-level objectives, and enablers (i.e., activities that can be taken by EWN and its partners).

3.1 UPDATE POLICIES AND GUIDANCE

Practitioners identified inconsistency or incompatibility of existing policies with NBS implementation and a need for more specific and relevant guidance as a challenge impeding inclusion of these features across all project phases. Updating and revising guidance and policy documents is therefore a high-value objective supporting the acceleration of NBS in practice. Enablers to support the achievement of this objective include:

- Evaluation beyond the BCA;
- Support for different paradigms of protection; and
- Review and resolution of regulatory inhibitors.

USACE policies and guidance are established by Headquarters in response to legislation passed by Congress, with materials for supporting implementation developed by the USACE IWR. Projects and studies are ultimately implemented by District personnel under the oversight of Divisions and Headquarters, including through review of draft plans and recommended alternatives. Actions taken to advance this objective and the enablers described below would therefore require coordination across USACE.

3.1.1 Evaluation Beyond Benefit-Cost Analysis

NBS often provide a wide range of economic, environmental, and social benefits, many of which are difficult to effectively monetize within BCA. This is recognized by the PR&G and draft ASPs, which prescribe that plans should be recommended based on their capacity to maximize the public benefit inclusive of economic, environmental, and social outcomes. One pathway to accelerating NBS in practice—and a need in order to meet the requirements of the draft ASPs—is to update policies and guidance documents to support more widespread use of alternative evaluation beyond BCA. As noted in a prior Institute study (Fischbach et al., 2023b), one example action that can be taken to advance this enabler is a policy shift toward multi-objective analysis in which BCA provides a minimum threshold for alternative consideration rather than being used as the primary benchmark for alternative evaluation.

The development of practical methods for multi-objective that can be applied by USACE practitioners is also necessary to implement the PR&G and draft ASPs. Other BCA policies and guidance documents also could be updated to accelerate NBS implementation, such as recommending the use of incremental benefit analysis for projects authorized as ecosystem restoration in combination with FRM or CSRM. Alternatively, or in conjunction with those actions, guidance documents could be updated to provide more specific information on the types of benefits to consider for inclusion in analyses, as well as on the spatial and temporal scales over which these benefits are evaluated. For example, expanding guidance for how to include regional sediment management (RSM) and a wider range navigation channel maintenance costs in calculating costs and benefits of BUDM alternatives (e.g., additional cost savings that would be realized by future USACE NAV projects if capacity is preserved in low-cost disposal areas identified in Dredged Material Management Plans). This action is also consistent with the draft ASPs, which prescribe inclusion of upstream and downstream effects (i.e., watershed-based approach) and consideration of other existing or planned federal and non-federal projects when evaluating costs and benefits.

3.1.2 Support for Different Paradigms of Protection

Gray infrastructure solutions often provide cost-effective strategies for mitigating the risk associated with large (i.e., "design") storms typically considered within CSRM projects. However, NBS can be used in conjunction with hard infrastructure as part of a more holistic and system-based approach to risk mitigation and advancing the USACE Civil Works mission. These features can mitigate high-frequency flooding events and provide other environmental and social benefits, thereby having potential to maximize overall public benefit consistent with the guidance provided in the draft ASPs. In major storms, NBS may become sacrificial features that reduce flooding in combination with other elements of the system, with the expectation that they might need to be rebuilt in those cases. USACE staff and partners called for the need to review and update guidance and policies to support these types of multiple lines of defense approaches and expand consideration of green/gray solutions, including more comprehensive evaluation of their overall costs and benefits. For example, annual maintenance costs and failure risk of gray infrastructure may be lower in some cases when protected by NBS as part of an integrated solution when compared to the same infrastructure implemented as part of a standalone approach. Similarly, updating guidance to support practitioners considering a broader range of watershed impacts in riverine systems would be more conducive to use of NBS. More specifically, this could be accomplished by enabling a more comprehensive evaluation of associated costs and co-benefits, such as the downstream flood risk mitigation benefits that may be provided through an NBS-based approach to enhance hydrologic connectivity and reconnect historical floodplains.

3.1.3 Review and Resolution of Regulatory Inhibitors

USACE practitioners identified that challenges can arise for NBS implementation by project partners during the permitting process for project construction. Specifically highlighted were challenges in receiving USACE regulatory approval to, for example, construct wetlands using BUDM. Similarly, USACE practitioners identified that vegetated levees, a potential NBS opportunity in riverine systems, do not meet standards for certification. These issues can delay implementation, reduce the scale of planned features, or potentially exclude NBS that were originally planned for a project. One enabler through which USACE can support broader NBS implementation is therefore a review of USACE regulatory policies to identify inhibitors and potential obstacles to implementing specific types of NBS. These inhibitors can then be evaluated to determine potential mitigation strategies, such as development of guidance documentation for specific NBS identifying potential permitting issues and suggesting early engagement of the regulatory program (i.e., during project planning phases) to identify solutions. This recommendation aligns with the draft ASPs, which direct USACE practitioners to engage partners early in the process and to integrate alternative evaluation with regulatory processes associated with, for example, the National Environmental Policy Act (NEPA).

3.2 EXPAND BEST PRACTICE

Input from USACE practitioners reflected that personnel across Districts have leveraged opportunities for NBS under authorities including BUDM, Aquatic Ecosystem Restoration, and Comprehensive Studies. However, practitioners also identified that inclusion of NBS requires familiarity and engineering expertise specific to the type of NBS being considered, which varies across USACE personnel and Districts. In addition, planning tools and models for alternative evaluation and E&D must be certified and approved by USACE for the location they applied; include the specific NBS of interest; and be discoverable by practitioners. A key objective to accelerating NBS implementation is therefore to expand best practice through the development and distribution of relevant guidance, tools, data, and information. Associated enablers include:

- Planning and Engineering Guidance
- USACE Certification and Approval of Planning and E&D Tools
- Development of Pilot Projects
- Programmatic and Actionable AM

The IWR develops planning guidance for USACE personnel, while the development of new engineering guidance often engages personnel with relevant experience from across ERDC (Engineer Research and Development Center) the USACE Centers of Expertise, and Districts. These personnel can also support coordination with the EWN program to identify high-value pilot projects to test or demonstrate NBS techniques. Advancing this objective will require coordination across these entities, as well as with Headquarters in the case of issuing of new guidance.

3.2.1 Planning and Engineering Guidance and Tool Development

One of the challenges identified by USACE practitioners is that relatively limited planning and engineering guidance exists for most types of NBS when compared to resources available for gray infrastructure solutions[5]. Significant variability exists in the benefits provided by different types of NBS, as well as in the factors that must be considered during E&D. The potential issues; benefits and costs to include in alternative evaluation; engineering parameters; and risk considerations for restoring hydrologic connectivity in riverine systems, for example, are significantly different than for the construction of marshes along the coast. For this reason, actionable guidance would need to be developed for each individual category of NBS across the planning and E&D phases of the project, which could be prioritized based on surveys of USACE practitioners on the types of NBS that they have included (or are most likely to include) in Civil Works projects in the future. Documentation that has been developed for beach and dune systems—an NBS type that has been implemented within CSRM projects—could provide a template of the types of information to include. In addition, the draft ASPs recommend collaboration with other federal agencies and external partners in identifying and developing tools for, for example, alternative formulation and evaluation.

One particularly high-value area of guidance and tool development for accelerating NBS implementation is in supporting BUDM. Tools and inventories that enable matching BUDM sites with planned navigation dredging locations could expand these opportunities and overcome challenges such as mismatch of available material and/or dredging timing with opportunities at permitted NBS creation sites. Similarly, completing and maintaining inventories characterizing the demand and supply of sand and other types of sediment can support holistic and regional sediment management approaches that enable more

[5] Engineering guidance for other types of NNBF was under development as of the time of this report's publication.

widespread use in NBS such as marshes, beaches, and dunes (Appendix C). Other challenges that could potentially be addressed through engineering solutions including innovations that reduce the cost of transport and guidance for E&D to retain dredged sediments within the natural system for long-term benefit. In addition to supporting implementation of NBS, these activities would also assist USACE practitioners in achieving a Chief of Engineers goal to reach 70% use of dredged sediments by 2030 (ERDC, n.d.).

3.2.2 USACE Certification of Planning, E&D Tools

USACE practitioners must use planning tools that have been certified, and similarly models used in the E&D phase are evaluated and designated as preferred for use for specific applications. This requirement can impede NBS implementation given that fewer tools and models exist that include these features compared to gray infrastructure (Appendix A). Tools must be certified for their specific region of interest, therefore existing tools that have been applied at one location may not be portable to other, similar locations, unless the certification designates use on a regional or nationwide scale. Practitioners wishing to use non-certified tools must complete a certification process, which may not be feasible within the timelines dictated by the authorization for the project. An important enabler of NBS in practice is therefore the expansion of regionally and nationally certified planning tools and designated preferred-for-use E&D models, building on existing efforts such as the EWN® Toolkit Expansion.[6]

Example actions that could be taken under this enabler include surveying practitioners to determine the most high-value tools for their planning process, then evaluating if tools developed by the academic community or other partners could be adapted and certified for national use. Another example action would be comparing high-value tools with an inventory of currently certified tools and preferred-for-use models that are only approved at a local or regional scale and initiating the reviews necessary to expand approval for use across all Districts. In some cases, planning tools and models that are identified as high value may need to be targeted for new development through coordination with USACE researchers (e.g., ERDC), and/or in collaboration with partners.

3.2.3 Development and Identification of Pilot and Templar Projects

USACE practitioners identified that pilot projects that have been previously developed at EWN Proving Grounds[7] provide a valuable resource that supports NBS planning, design, and construction. These small NBS pilot projects, if planned, executed, and monitored strategically, can support the establishment of replicable construction, adaptation, and monitoring techniques for eventual larger projects. An action that would support accelerating use of NBS in practice is therefore expanding the existing portfolio of EWN pilot projects to encompass a wider range of NBS across a broader range of locations. In addition, targeted retrospective efforts could be supported to assess and document the outcomes of NBS constructed across a range of USACE authorities (Feasibility Studies, CAP, and Comprehensive Studies),

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[6] https://ewn.erdc.dren.mil/tools/the-ewn-tool-kit/).

[7] https://ewn.erdc.dren.mil/proving-grounds/

using these retrospective ‘pilot projects of opportunity’ as templar projects to identify lessons learned and best practice.

3.2.4 Programmatic and Actionable Adaptive Management (AM)

Adaptive management presents significant opportunities for advancing NBS implementation given the existing uncertainties and unknowns in how different types of green infrastructure (GI) solutions perform on the landscape; the associated best practice of design and construction; and methods of risk evaluation. In addition, it is highlighted in the draft ASPs as a critical tool for minimizing risk and maximizing the benefits provided by water resource management projects.

Enablers identified to expand best practice and accelerate NBS implementation include the development and dissemination of guidance, models, and tools for planning, designing, and constructing different types of NBS. However, these tools must be underpinned by data and analysis of NBS performance. In some cases, data on NBS performance have been collected as part of monitoring of prior projects, but the District practitioners who collected the data may not have the time or resources to analyze that information or to compare the results across multiple projects to develop guidance on best practice. An action that could be taken to advance this enabler would therefore be inventorying and analyzing monitoring data that have been collected by Districts around the country for different types of NBS, then using the results in support development of guidance, tools, and models as part of a programmatic approach to AM.

USACE staff may have insufficient time or expertise to analyze NBS performance and develop best practice guidance across the range of potential applications. Partnerships with universities and other research institutions may be a cost-effective way to gather data, analyze NBS performance, and inform NBS design and implementation. Another action that could be taken is surveying opportunities for NBS to be incorporated into existing Civil Works projects as part of a site-specific AM approach. USACE practitioners identified that damaged gray infrastructure in FRM and CSRM projects is often repaired or replaced under PL 84-99. At some sites, however, there may be valuable opportunities for NBS to be included as part of a multiple lines of defense approach that can reduce the risk of gray infrastructure failure while providing benefits such as provision of habitat and recreational use opportunities.

3.3 SYNERGIZE USACE ACTIVITIES

The breadth of opportunities that USACE practitioners have found to incorporate different types of NBS within their projects reflects a significant amount of existing institutional knowledge that can be leveraged to expand their use. However, identified challenges to implementation included more widespread willingness to consider NBS and green/gray infrastructure solutions; familiarity with different types of NBS and their benefits; and relevant expertise in planning, engineering, and construction varied across USACE across Districts and the vertical chain of review required for most projects. Input received also reflected that there are significant actions being taken across USACE in advancing NBS planning and construction practice that could have an expanded impact with greater visibility and coordination. Associated enablers include:

- Institutional Shift in USACE Perspective
- Expansion and Unification of Community of Practice

- USACE Practitioner Database for NBS Implementation
- Training on NBS Implementation and Evaluation

Entities with institutional knowledge relevant to NBS implementation include EWN, IWR, ERDC, the Centers of Expertise (for example, the Regional Sediment Management Center of Expertise, which develops guidance and best practices for BUDM, among other activities), and District, Division, and Headquarters personnel. Advancing this objective and associated enablers would therefore rely on coordination across these groups, as well as Headquarters and Division personnel engaged in the review and approval of NBS as part of projects and studies.

3.3.1 Institutional Shift in USACE Perspective

USACE practitioners who have successfully implemented NBS shared that a key component to catalyzing these opportunities was a willingness to consider alternatives other than status quo, gray infrastructure solutions. The draft ASPs recognize this need, and mandates that a fully NBA and an environmentally preferred alternative be included in the final suite of alternatives evaluated, while also encouraging inclusion of NBS within all alternatives where feasible. Practitioners indicated that fostering this shift toward broader consideration of NBS and the development of associated best practice requires opportunities for testing and improving approaches, as well as institutionalization of a growth mindset. Though it will take time, an institutional shift in USACE perspective that incentivizes experimentation and growth mindsets at all levels therefore has the potential to facilitate more creative approaches to planning, implementation, and post-construction O&M, including greater consideration and inclusion of NBS and the development of practical and viable NBA.

There are several specific actions that could be taken to foster this shift in perspective. Engagement and cross-training of project delivery teams and personnel that conduct vertical team reviews at the District, Division, and Headquarters level could engender more consistent recognition and review of the benefits, costs, and appropriate applications of different types of NBS. Similarly, USACE personnel that conduct regulatory and environmental assessment could be engaged to work with project delivery teams in developing pilot and template projects for different NBS types that meet regulatory requirements, and to create streamlined and integrated processes for alternative evaluation and permitting consistent with the draft ASPs.

3.3.2 Expansion and Unification of Community of Practice

The USACE Civil Works program—and thus opportunities for NBS implementation—spans 9 Divisions and 45 Districts, in addition to relevant expertise found within IWR, ERDC, the Centers of Expertise, and beyond. An important enabler to accelerating NBS implementation is continued strengthening, expansion, and unification of an NBS community of practice across these groups. Significant progress toward enabling coordination across these entities has occurred through the efforts of the EWN and other entities, such as the development of a EWN Implementation Cadre as a location for information sharing and exchange between USACE personnel. Actions that can be taken in the future include targeted outreach to expand participation within the EWN Implementation Cadre; continued provision and expansion of webinars and working sessions that bring together personnel from across the organization; and designation of District-level NBS coordinators to support project teams as a single point of contact to disseminate relevant information across their team.

3.3.3 USACE Practitioner Database for NBS Implementation – NBS Toolbox

Data, models, tools, and guidance documents must be discoverable and accessible in order to have value. USACE and the EWN network have begun to categorize certified and non-certified tools and resources across several webpages, currently referred to as the NNBF Toolbox. However, one of the challenges identified by practitioners during this effort is that the resources that are available to practitioners to support the planning and construction of NBS projects are still difficult to identify or find, particularly for new USACE personnel. A high-value enabler for accelerating NBS implementation is therefore the development of a sortable and searchable database of available resources (e.g., expanding on the example shown in Appendix D). Such a database could include guidance documents, planning tools, and E&D models, cross-linked to the types of NBS they include or are appliable to; projects that have utilized them as examples; the specific environments and types of projects to which they can be applied; and the relevant project phase for application. An action that could support this enabler is the development of an automated tool (e.g., based on artificial intelligence) that can scan reports and other documentation as an initial mechanism for database population. In addition, incentives and/or requirements for practitioners to add new projects or tools to the database could be developed. Directives within the PR&G and associated draft ASPs magnify the relevance and value of this enabler, given that USACE planning and construction projects will be required to formulate a fully NBA, as well as considering NBS within all alternatives.

3.4 CATALYZE PARTNERSHIPS

USACE Civil Works projects are founded in partnership and coordination. Feasibility Studies and CAP activities are initiated by a local sponsor that shares the associated costs, while project implementation requires permitting and consultation with regulatory agencies such as the USFWS, National Oceanic and Atmospheric Administration (NOAA), and the Environmental Protection Agency (EPA). Accelerating NBS implementation therefore relies on partner engagement early and throughout the process to collaboratively identify opportunities for green infrastructure and to resolve impediments that limit their consideration and construction. These partners and collaborators include EWN experts, local sponsor(s), Tribal leaders, other local experts, and regulators, consistent with directives within the draft ASPs for USACE to engage closely with partners including those with traditional or local knowledge that can support quantification or description of project benefits. In addition, expanding NBS best practice will rely on targeted research and development to improve planning and E&D tools, which may be most efficient and effective through leveraging of external expertise. Enablers for this objective are therefore:

- District Coordination with Local Partners
- Enhancement of Efficient Partnering Processes
- Coordination Across Federal Agencies
- Leveraging of External Expertise and Capacity

USACE Districts are the vanguard of NBS implementation, as well as in working with local partners and regulatory agencies on project implementation. As such, they have a key role in engaging existing and potential partners as part of expanding the use of NBS. USACE Divisions, Headquarters, and IWR can support Districts in these activities by issuing guidance and directives that encourage expanded outreach focused on NBS. In addition, EWN and ERDC can support the development of models and tools that support NBS implementation through engagement of the academic and research communities.

3.4.1 District Coordination with Local Partners

Local partners play a significant role in the initiation and goal setting of USACE projects. Increasing awareness of NBS and available authorization and funding mechanisms among local partners can help ensure that communities are aware of potential green infrastructure solutions and the benefits they provide. These communities and local partners can then use that information to initiate requests for NBS projects that effectively serve their community's needs. Examples of actions that can be taken include working with interested landowners such as non-governmental organizations, Tribal Nations, governmental agencies, and community members to identify site-specific opportunities for NBS where easements could be used to reduce the real estate cost of implementation. Additionally, Districts could designate coordinators that are knowledgeable about funding authorities, requirements, BUDM opportunities, and other aspects of NBS implementation to serve as a point of contact and outreach coordinator for their District's area of responsibility.

3.4.2 Enhancement of Efficient Partnering Processes

Local sponsor interest in NBS implementation presents strong opportunities for accelerating NBS implementation. However, practitioners indicated that these supporters may become discouraged and pursue mechanisms for advancing their projects outside of the USACE Civil Works process if, for example, the timeline of implementation becomes too long. That implementation pathway may itself become blocked if the local partner is not fully aware of regulatory requirements, such as if they are seeking to use BUDM from federal navigation channels and do not meet required project standards. Local sponsors also have different internal capacities for advancing NBS that they may wish to leverage. For example, some partners have already conducted preliminary E&D for potential NBS and prefer to lead project implementation rather than serving as primarily a funding entity for USACE implementation. Section 204 of WRDA 1986 (WRDA, 1986) enables partners to lead implementation for BUDM and be cost-reimbursed for those activities, while a pilot program for this funding model has also been implemented for projects resulting from Feasibility Studies (e.g., Appendix B.2). Activities that can be undertaken to advance this enabler include identifying additional opportunities for efficient partnering processes such as wider implementation of flexible cost-sharing (e.g., opportunities for USACE cost reimbursement to the local sponsor as well as vice versa) that can be tested through pilot programs prior to institutionalization more broadly. Another example action is conducting a targeted retrospective at locations where potential local sponsors opted to pursue NBS construction outside of the USACE Civil Works process to identify and resolve specific impediments leading to this outcome. Lastly, select pilot Civil Works projects with strong potential for NBS implementation could be exempt from the typical project time requirements to identify opportunities for streamlining and improving partnering processes.

3.4.3 Coordination Across Federal Agencies

Multiple federal agencies and organizations play pivotal roles in the planning and construction of USACE Civil Works projects and thus the potential for accelerated implementation of NBS. Regulatory agencies including USFWS, NOAA, and EPA are part of permitting and consulting, which practitioners identified as an impediment to NBS implementation in some cases. Many times, these consultations occur after planning and preliminary identification of alternatives, so issues that are identified at this project phase can lead to delays and the need for iteration and alternative refinement that may not fit within the project timeline. NBS implementation can therefore be increased through early engagement across regulatory agencies and streamlining of the permitting process, consistent with recommendations within the draft ASPs to integrate USACE alternative evaluation processes with, for example, NEPA where possible. In addition to permitting, congressionally authorized Feasibility Studies are reviewed and recommended for funding by the Office of Management and Budget (OMB), which conducts their own review and evaluation of benefits and costs as the foundation for recommendation. OMB recently released guidance prescribing method for evaluating ecosystem services benefits, which are consistent with the draft ASPs by prescribing wider consideration of environmental and social benefits in alternative evaluation (OMB, 2023).

In addition to USACE Civil works project implementation, other federal agencies have tools and methods relevant to NBS planning and E&D that could be leveraged by USACE, such as for valuating ecosystem services. Communication and coordination with other federal agencies are therefore key enablers for advancing use of NBS with USACE projects. Actions that could be taken to advance this enabler include reevaluating workflows to engage representatives from regulatory agencies earlier in the alternative identification and design process; working with federal agencies and local sponsors to determine if there are opportunities for programmatic environmental assessments inclusive of NBS alternatives that can streamline permitting processes; determining if existing ecosystem service valuation methods developed by other federal agencies can be certified for USACE use; developing simplified playbooks for integration of alternative evaluation and NEPA; and identifying if and how cost and benefit evaluation processes between USACE and OMB can be aligned and include a more comprehensive range of NBS benefits.

3.4.4 Leveraging of External Expertise and Capacity

Practitioners indicated that the breadth and diversity of NBS that can be constructed on the landscape, combined with fewer available tools for planning, evaluation, and E&D, present challenges to their implementation. Each type of NBS, from beaches to oyster reefs to reconnection of hydrologic connectivity, has different design considerations, provides different benefits at varying cost, and responds differently on the landscape. In addition, there are varying levels of scientific understanding and available data across different types of green infrastructure. For example, beaches and dunes have been used extensively as part of CSRM projects, and tools and methods for planning and executing these NBS are well established. In contrast, there are limited tools available for planning, designing, and evaluating the failure risk of saltwater marshes, forested freshwater wetlands, or mangroves when used as part of flood or coastal storm risk mitigation. USACE researchers and engineers can contribute substantially to filling gaps such as these. However, increasing engagement of external entities with specific expertise and capacity to fill targeted gaps and needs for each type of NBS would accelerate the rate at which the necessary tools and methods can be brought into USACE workflows. One specific source of information recognized within the draft ASPs is local knowledge, including traditional knowledge held by Tribal communities. USACE Districts have Environmental Justice Strategic Plans providing procedures for coordinating with underserved communities, including Tribal Nations, which provide a foundation for this engagement. Opportunities for incorporating indigenous knowledge into USACE planning and project implementation could be further catalyzed with additional guidance specific to tapping this source of information for supporting NBS alternative formulation and evaluation. Example actions that could be taken include District personnel engaging external experts earlier and more frequently in the alternative design and evaluation process; coordinating with researchers on pilot projects for developing NBS-relevant tools; expanding engagement of the Network for Engineering With Nature (N-EWN); and developing procedures for working with Tribal communities and local stakeholders to elicit input throughout the alternative formulation and evaluation process.

4.0 CHARACTERIZING SUCCESS

USACE and EWN seek effective, cost-efficient mechanisms for accelerating consideration and implementation of NBS when they can advance project objectives and provide broad benefits. Metrics for evaluating progress and success provide a mechanism for tracking progress and, as needed, redirecting effort and resources to those activities that are most effective in achieving the goal of widespread integration of NBS with nonstructural and structural measures to reduce flood risk, maintain navigable waterways, and deliver a broad array of ecosystem services to local communities.

The ultimate measure of success in achieving this goal will be the incorporation of NBS into constructed USACE Civil Works projects. However, solely measuring this outcome does not provide a mechanism for evaluating progress across the objectives and enablers identified for advancing NBS, or a means to determine what activities are the most effective in advancing those outcomes. Two categories of metrics are therefore suggested for characterizing progress: objective metrics, capturing progress made to advance objectives and track success in enabler implementation; and outcome metrics, capturing outcomes achieved in advancing acceleration of NBS (Figure 2). Together, objective and outcome metrics can be used to focus future efforts by identifying strategies, objectives, and enablers that are most successful.

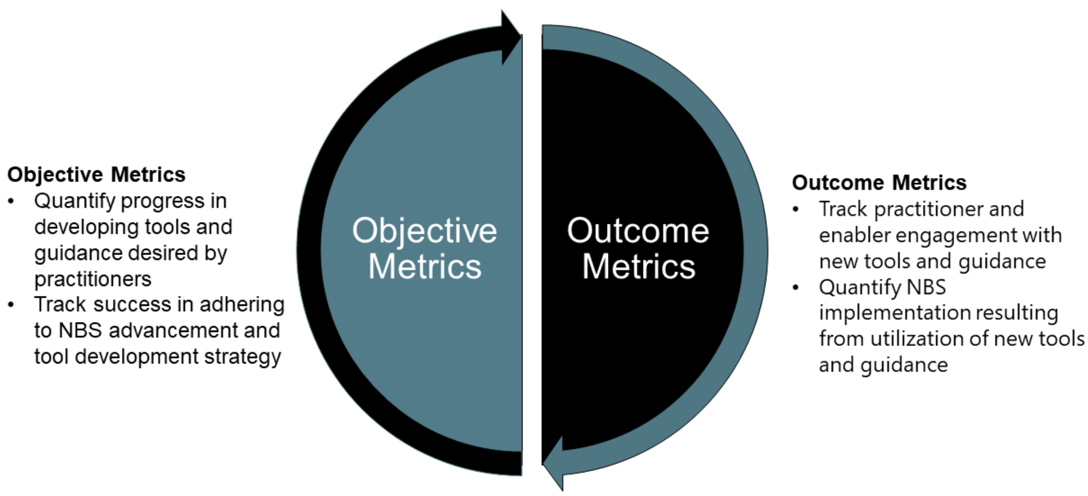

Figure 2. Framework for evaluating success. Included are objective metrics, used to evaluate progress in advancing the objectives and enablers of the strategic framework; and outcome metrics, used to characterize success in advancing incorporation of NBS in USACE Civil Works projects.

The first component of evaluating success is a set of objective metrics (Figure 3). These metrics quantify the progress that has been made in advancing the enablers identified within the strategic framework and are used to characterize progress made in implementing actions to advance NBS implementation. For example, the number and type of policies and guidelines that have been updated to be more conducive to NBS alternative identification and evaluation; the number of tools that have been developed or certified to include more categories or types of NBS; and the number of trainings that have been conducted by EWN or its partners to increase awareness of, and capacity for, NBS planning, evaluation, and E&D within USACE.

Update Guidelines and Policies

- Policies and guidelines updated to support NNBF implementation

Expand Best Practice

- Planning and engineering guidance updated for different types of NNBF
- USACE certified tools including different types of NNBF
- USACE approved E&D models including different types NNBF

Synergize USACE Activities

- Trainings conducted & personnel participation in NNBF community of practice
- NNBF projects catalogued in the inventory and/or Districts participating

Catalyze Partnerships

- Partnering activities conducted by Districts, Divisions, and Headquarters with local sponsors, other Federal Agencies, and other stakeholders

Figure 3. Suggested objective metrics for quantifying progress in advancing NBS enablers.

The second component of categorizing success relies on evaluating progress in NBS implementation, which can be shown in the desired outcome of the objectives. The suggested foundation of the outcome metrics is the development of a USACE Practitioner Database, which was also identified by practitioners as a high-value opportunity for accelerating NBS implementation in practice. This database would include categories of NBS (beaches, dunes, restoration of hydrologic connectivity in riverine systems, marshes, etc.) cross-linked to available planning tools, E&D models, guidance documents, pilot and example projects, and other resources supporting their planning and construction. Example data fields could also include use of multi-objective or incremental cost/benefit analysis; use of watershed planning and multiple lines of defense; inclusion of NBS and green/gray solutions; and other enablers included within the strategic framework. The database could also include additional information such as NBS that were considered and excluded, where possible, along with the reasons these options were not carried forward.

This database would also serve as a natural framework for quantifying success in accelerating NBS implementation by enabling the calculation of outcome metrics: annual statistics of the number of projects that include NBS of various types across different USACE business lines and authorization types. These outcome metrics can then be used in conjunction with the objective metrics to evaluate the activities that are most successful and/or to refine those actions that are not leading to more widespread consideration and construction of NBS. For example, the outcome of efforts targeted toward development of tools supporting E&D of wetlands and marshes as part of CSRM projects can be evaluated by analyzing the number of NBS projects and/or the percentage of planned or constructed NBS projects that used these tools over time that used. Such analysis would require care in interpretation given the variety of factors that may influence the implementation of NBS (e.g., local sponsor support, cost, site suitability, etc.). However, the objective and outcome metrics provide the framework for a transparent and data-driven approach to accelerating the implementation of NBS across the USACE Civil Works program.

Finally, a mechanism that would effectively capture the outcome metric "quantify NBS implementation resulting from utilization of new tools and guidance" involves implementing periodic, perpetual feedback opportunities to understand how practitioners are putting these new tools and guidance to use. This would guide the development of the next round of tools and guidance, and would allow for a data-driven evolution of these resources to maximize utility.

5.0 CONCLUSION

The activities conducted under this study (described in Section 1.0 and in Appendices A–D) have identified challenges which have impeded more widespread implementation of NBS within USACE Civil Works projects in recent years, as well as opportunities that USACE practitioners have found and utilized to successfully construct NBS despite these impediments (Table 2). These challenges and opportunities span USACE authorities (Feasibility Studies, Standing Authorities, and Comprehensive and Watershed Studies), as well as all phases of project implementation from planning to post-construction activities.

Table 2. Summary of opportunities and challenges identified for NBS implementation, organized by project phase and authorization type.

Phase	Opportunities	Challenges
Planning, Authorization, and Funding: Overarching	Successful NBS implementation often leverages multiple USACE authorities, and supportive and engaged local sponsors can catalyze NBS implementation	Practitioners—particularly new planners—may be unfamiliar with all USACE authorities and/or with regulatory and consulting requirements associated of other agencies (Endangered Species Act; Essential Fish Habitat, etc.)
Planning, Authorization, and Funding: Feasibility Studies	NBS have been considered across multiple phases, including as part of Value Engineering studies	Timeline, scope, and review requirements (e.g., the 3x3x3 rule[1]) may inhibit consideration of NBS given that practitioners and reviewers may have insufficient budget or time to formulate these alternatives, which typically have fewer guidelines, templates, and exemplar projects when compared to gray infrastructure.
Planning, Authorization, and Funding: Standing Authorities	Small-scale NBS have often been constructed using standing authorities, particularly WRDA 1992 Section 204 Beneficial Use of Dredge Material	Funding and scope of standing authorities limits project scale, and beneficial use of dredge material may be cost-prohibitive or impractical due to timelines, sediment characteristics, etc.
Planning, Authorization, and Funding: Comprehensive and Watershed Studies	Broader regulatory authorities have enabled greater consideration of holistic and system-wide NBS benefits, including through use of incremental benefit analysis rather than benefit-cost analysis	Comprehensive and Watershed studies do not typically lead directly to project construction authorization and funding, but instead may result in recommendations for non-Federal action or follow-on Feasibility Studies. Recommended NBS therefore do not have a direct implementation pathway and may be subsequently removed from consideration prior to authorization or construction (e.g., during a follow-on Feasibility Study).
Project Implementation: Design and Implementation	NBS can support different paradigms of protection, such as "multiple lines of defense" (in combination with gray infrastructure) and/or as sacrificial features during storms	Many NBS lack standard construction methods or guidance, which can lead to delays or difficulties during implementation. In addition, many NBS would require large areas of real estate to be implanted as standalone solutions at the spatial scales needed to accrue substantial FRM or CSRM benefits; this real estate may be unavailable and/or prohibitively expensive.

Phase	Opportunities	Challenges
Project Implementation: Post-Construction	Beaches and dunes represent a template for NBS use in FRM and CSRM, while beneficial use has supported maintenance of small-scale, low cost NBS	Lack of time and funding for AM inhibits improved design and benefit quantification of NBS, while standard Operations and Maintenance approaches are not conducive to the greater and/or more uncertain risk associated with NBS. In addition, maintaining NBS features over planning time scales may be impractical or expensive, particularly if implemented over large spatial scales.

[1] The 3x3x3 rule requires that Feasibility Studies lead to a final report no later than 3 years after date of initiation; have a maximum cost of $3 million; and complete 3 levels of vertical review: District, Major Subordinate Command, and USACE Headquarters (USACE, 2014, 2015).

The Institute has coordinated with EWN to develop a strategic framework that overcomes the challenges and expands these opportunities. This framework is designed to advance a goal of promoting widespread integration of NBS with nonstructural and structural measures to reduce flood risk, maintain navigable waterways, and deliver a broad array of ecosystem services to local communities. The framework is comprised of four overarching objectives along with associated enablers which are activities that can be undertaken by USACE personnel alone or in coordination with partner organizations to advance that objective in practice (Figure 4).

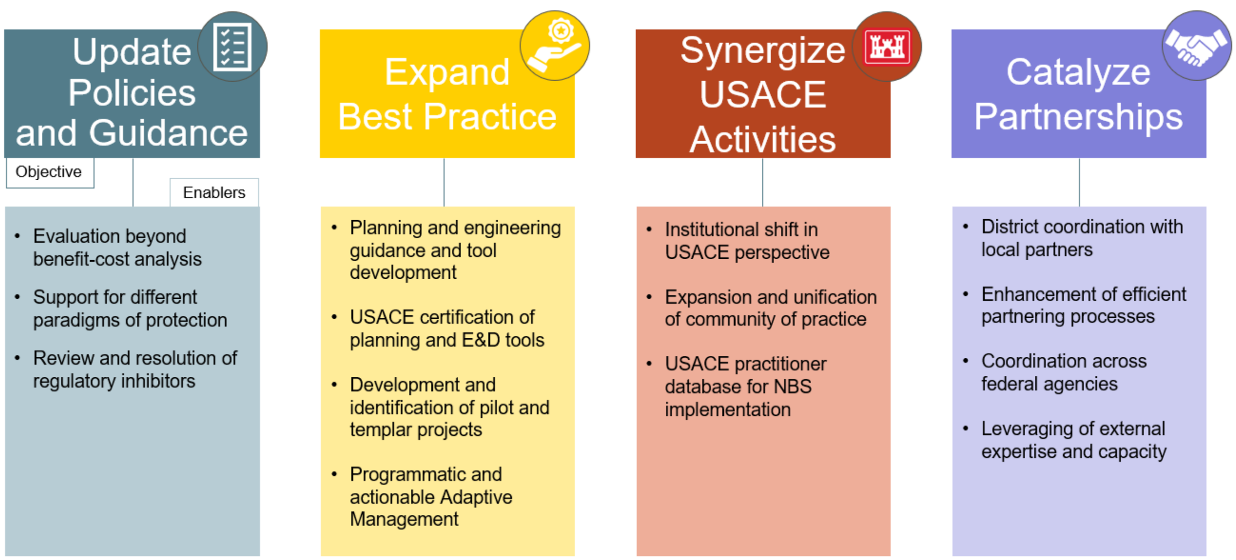

Figure 4. Objectives and enablers that comprise a strategic framework for accelerating implementation of NBS within USACE Civil Works projects.

Lastly, the Institute has also developed suggested metrics for tracking progress in advancing this strategic framework and to redirect effort as needed to achieve the desired goal. These metrics include: (1) objective metrics for measuring progress in advancing the four strategic objectives (Figure 5); and (2) outcome metrics for measuring progress in NBS implementation within the USACE Civil Works program, which are comprised of annual statistics of NBS features and projects that have been included in completed USACE Civil Works studies and constructed projects. Together, the strategic framework and associated objective and outcome metrics provide an actionable, transparent, and adaptable path for broader consideration and implementation of NBS, as well supporting USACE in successfully transitioning to compliance with the PR&G and associated draft ASPs.

Update Guidelines and Policies

- Policies and guidelines updated to support NNBF implementation

Expand Best Practice

- Planning and engineering guidance updated for different types of NNBF
- USACE certified tools including different types of NNBF
- USACE approved E&D models including different types NNBF

Synergize USACE Activities

- Trainings conducted & personnel participation in NNBF community of practice
- NNBF projects catalogued in the inventory and/or Districts participating

Catalyze Partnerships

- Partnering activities conducted by Districts, Divisions, and Headquarters with local sponsors, other Federal Agencies, and other stakeholders

Figure 5. Suggested metrics for characterizing progress in advancing each of four objectives identified for accelerating the implementation of NBS.

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APPENDICES

APPENDIX A. WORKING SESSIONS WITH EWN PRACTITIONER LEADS

The Institute elicited input from the USACE EWN practitioner leads on obstacles to NBS implementation and pathways for accelerating NBS implementation. The EWN practitioner leads at the time of this project who provided input included:

- Edward Brauer, St. Louis District
- David Crane, Omaha District
- Elizabeth Godsey, Mobile District
- Danielle Szimanski, Baltimore District [April–August 2023]

A.1 ELICITATION OF INFORMATION

Input from the EWN practitioner leads was primarily elicited via a series of virtual working sessions that ranged from 1–3 hours in length (Table A-1), utilized the Mural© online whiteboarding tool (Figure A-1), and were facilitated by the Institute.

Table A-1. Working sessions held with the USACE EWN practitioner leads.

Date	Objectives	Topics of Discussion
April 6, 2023	Introduce project background and objectives Provide context and background on the work Discuss and outline next steps in EWN Practitioner Lead Engagement	Project Overview Prior Study: Findings and Discussion Next Steps
May 5, 2023	Begin characterizing challenges and opportunities in NBS implementation Begin characterizing NBS success: goals, objectives, and success metrics Identify parameters of good pilot studies	Challenges and Opportunities in NBS Implementation Desired Parameters of Pilot Studies Characterizing Success Next Steps
June 22, 2023	Clarify or refine May 5 workshop synthesis with EWN lead input Finalize workshop themes and identify participants or categories of participants Identify two pilot studies based on the identified parameters	Clarification or refinement of: Challenges and Opportunities in NBS Implementation, Synergistic Programs Workshops Pilot Studies Next Steps

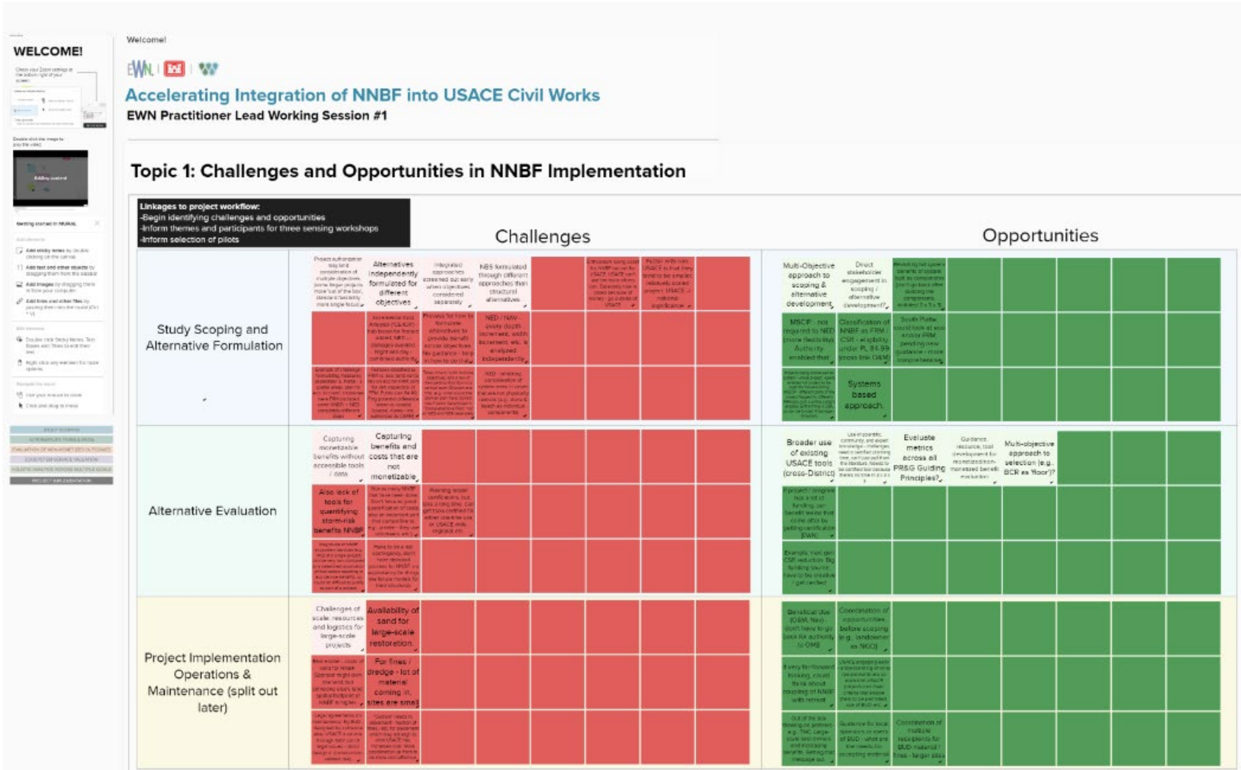


Figure A-1. Portion of a Mural© board used in eliciting input from the EWN Practitioner Leads

The EWN practitioner leads also reviewed draft synthesis documents prepared by the Institute and provided additional input via email, including materials and survey results previously developed through working with the USACE EWN Implementation Cadre (https://ewn.erdc.dren.mil/ewn-implementation-cadre/). The synthesis of input received from the EWN practitioners on challenges and opportunities of NBS in practice is provided below, organized by the type of enabler that would allow for accelerating use of NBS in USACE Civil Works.

A.2 INPUT RECEIVED FROM EWN PRACTITIONER LEADS: CHALLENGES, OPPORTUNITIES, AND ENABLERS

The first set of challenges for implementation of NBS in practice are those associated with practice or guidance given to Districts for execution of the USACE mission. In most cases, USACE Headquarters would need to implement enablers for overcoming these challenges or for otherwise expanding opportunities in implementation of NBS. However, in some cases these challenges are associated with the underlying Congressional authorization of Feasibility Studies (Table A-2).

Table A-2. Input from USACE EWN practitioner leads on challenges and opportunities relayed to policy and guidance. NNBF: Natural and Nature-Based Features; FRM: Flood Risk Management; CSRM: Coastal Storm Risk Management; NED: National Economic Development; BCR: Benefit/Cost Ratio; NER: National Ecosystem Restoration; PL: Public Law; O&M: Operations and Maintenance: EWN: Engineering With Nature.

<table>
<tr><th>Challenge</th><th>Opportunity or Enabler</th></tr>
<tr><td>Single business line project authorization limits considerations of multiple objectives. Some larger projects may have multiple focus areas that enable more out-of-the-box thinking, but standard Feasibility Studies are typically single focus.</td><td>Multi-objective, multi-business line project authorizations.</td></tr>
<tr><td>FRM/CSRM projects are evaluated against NED standard (BCR, consideration of damages avoided), whereas ecosystem restoration projects are evaluated against NER standard (incremental cost analysis). They are fundamentally different processes and non-standard approaches are needed to formulate/evaluate of NNBF and integrated NNBF / structural projects.</td><td rowspan="4">1. Systems-based project evaluation that allows all benefits to be assessed comprehensively and across all business lines.
2. Classification of NNBF features and measures as FRM / CSRM, which provides eligibility under PL 84-99
3. Maintenance of NNBF projects approached/funded through the same mechanisms as gray infrastructure projects</td></tr>
<tr><td>Features / measures are classified as FRM/CSRM or ecosystem restoration even when occurring together, vs. approach as a system and formulating/evaluating accordingly. NNBF usually classified as ecosystem restoration (exception for coastal dunes).</td></tr>
<tr><td>Incremental nature of analysis such as for navigation studies (every depth/width increment is analyzed independently), can make it more difficult to formulate and evaluate integrated and holistic approaches with NNBF.</td></tr>
<tr><td>When NNBF are used for FRM/CSRM, maintenance is generally on the local sponsor.</td></tr>
<tr><td>No USACE agency guidance exists for implementation of NNBF and there are questions in the Districts about the implementation of NNBF under existing policies.</td><td>Develop specific USACE agency guidance from planning through implementation and O&M on the use of NNBF.</td></tr>
<tr><td>Need for explicit commitment to NNBF from the top down (note, taken from EWN survey synthesis)</td><td>1. Authorization of pilot projects with higher risk thresholds, which can then be incorporated into a database of examples (see below).
2. Requirement that NBS features be included / considered in projects and/or that extra NBS costs be allowed (statues, policies, regulations)</td></tr>
</table>

The second set of challenges and associated opportunities identified during engagement of the EWN practitioner leads do not require changes in USACE policies or guidance to be addressed. USACE Districts, ERDC, IWR, or Centers of Expertise—either alone or in combination with research or practitioner partners—could address these issues through, for example, the development of tools, guidelines, or workflows for implementation. These challenges and opportunities are further categorized by project stage (planning, implementation, and operations/management).

The tools and guidance identified could be disseminated in multiple forms. Based on the survey results of USACE practitioners provided by the EWN leads, a combination of planning bulletins/circulars, engineering regulations/manuals, webinars, and web-based formats could be the most impactful.

Table A-3. Input from USACE EWN practitioner leads on challenges and opportunities relayed to study scoping, alternative formulation, and alternative evaluation that could be addressed through actions taken by Districts, ERDC, IWR, or the Centers of Expertise. NNBF: Natural and Nature-Based Features; EWN: Engineering With Nature; ERDC: Engineer Research and Development Center; IWR: Integrated Water Resources; USACE: U.S. Army Corps of Engineers.

Challenge	Opportunity or Enabler
Lack of awareness / guidance / support (and/or time, under 3x3x3) for how to formulate alternatives with a systems-based approach. This includes multi-objective project formulation for comprehensive benefits across accounts as well as integrated green/gray solution. Not as many NNBF projects have been put on the landscape so there are fewer templates to follow, and it is harder to quantify costs. There may be private examples, but because they rely on volunteers, etc., the costs cannot be compared.	1. Develop walkthroughs (planning bulletins/circulars) and web-based searchable database of real-world examples for Districts, including points of contact, frequently asked questions, etc. 2. Revisit the full system benefits of projects that were built component-wise, which could then be incorporated as examples in (1). 3. Develop approaches for quantifying the benefit enhancement / cost reduction of gray infrastructure in combined approaches (e.g., sediment in front of sea walls / levees reducing O&M costs or likelihood of failure) 4. Develop mechanisms (e.g., mailing list, leveraging of the EWN cadre, etc.) for project delivery team members to be made aware when relevant new documents are released, including Feasibility Study "success stories," ERDC reports, etc. (from EWN surveys)
Lack of USACE certified tools that can be readily used on USACE computers (i.e., without installation) for how to evaluate benefits and costs of NNBF and integrated green/gray projects. Need processes that can pass vertical team review. Tools must be certified under the business line and spatial area that they are applied. Even if a tool exists, a practitioner may not be able to find it (no centralized database or way to search, especially across business lines), and certification takes a long time.	1. Searchable database of certified tools to add more functionality to the list of tools available 2. Focused effort to certify tools that exist in the scientific/technical community and to broaden the certification of tools that were approved on a project/local/regional basis 3. Incentivization/funding provided to Districts/ERDC/IWR to add certified tools to a database and/or to get tools certified for national use. 4. Regular bulletins indicating when planning tools have been added to the database.
Lack of tools/methods for estimating NNBF risk and formulating risk contingencies (i.e., equivalent of failure models used in structural analysis).	Develop USACE-approved methods for quantifying evaluating / quantifying NNBF risk and failure models.

Challenge	Opportunity or Enabler
Difficulty in getting vertical team alignment with NNBF formulation and evaluation (note, from the EWN survey) Review-by-review variability in how NNBF projects are reviewed going up the chain for approval (note, from the EWN survey)	Coordination workshops and training that includes representation from various levels within USACE.

Table A-4. Input from USACE EWN practitioner leads on challenges and opportunities related to engineering, design, and construction that could be addressed through actions taken by Districts, ERDC, IWR, or the Centers of Expertise. ERDC: Engineer Research and Development Center; IWR: Integrated Water Resources; NNBF: Natural and Nature-Based Features; USACE: U.S. Army Corps of Engineers; OMB: Office of Management and Budget; O&M: Operations and Maintenance; BUDM: beneficial use of dredge material.

Challenge	Opportunity or Enabler
Lack of information quantifying the performance of NNBFs and/or design guidelines corresponding to quantified expected performance levels. NNBF typically have more variability and need for field fitting (i.e., flexibility and adaptability in construction) (note, from the EWN surveys) Need for clarity on procedures for getting funding/authority for projects on the Proving Grounds (note, from the survey results)	1. Conduct analysis of prior NNBF implementation projects and/or testbed cases 2. Develop a USACE-specific version of the EWN Atlas, with POCs (persons of contact) for information 3. Develop/update engineering manuals (e.g., Coastal Engineering Manual) on NNBF implementation (note, the EWN surveys have some specific examples of the type/detail of information needed) 4. Process for identifying projects for the Proving Grounds that align to District-identified needs for NNBF pilots
The spatial footprint of purely NNBF projects (e.g., marsh creation tends to be larger over the same length of protected area than for structural alternatives for the same benefit, and real estate is expensive.	1. Coordination with other entities and rethinking / reframing USACE's potential role, for example, partnering with organizations like The Nature Conservancy that may have land available (linkage to partnering opportunities given below) 2. If there is a particularly forward-looking local partner, could conceptually be part of managed retreat / long term resilience planning. 3. Tools and processes supporting increased consideration of comprehensive, integrated green/gray solutions, where NNBF may be used to protect and enhance portions of a hard structural measure.
For finer grain material, there is often a lot of material available from dredging, but the need/requests are typically for smaller projects or for a subset of the sediment (i.e., specific fraction of fines). This creates costing issues because only part of material on dredge can be used, might only want specific sed characteristics, etc.	1. Districts do not need to go back to OMB for navigation dredging for O&M. Development of long-term regional placement plans by identifying needs across future potential projects, and/or identify recurrent BUDM placement areas. 2. Cross-entity, regional coordination on projects and partnering with organizations to develop more comprehensive, multi-agency plans (see below).

Challenge	Opportunity or Enabler
Conversely, there may be insufficient sand available (or the cost may be prohibitive) for large-scale restoration specifically. In both cases, it is also difficult to align dredging schedules and/or locations with windows of opportunity for NNBF creation (e.g., timing with a permitted project; material placement considerations for threatened and endangered species; and time required to update engineering and design plans for projects as needed).	

Table A-5. Input from USACE EWN practitioner leads on challenges and opportunities related to operations and maintenance and AM that could be addressed through actions taken by Districts, ERDC, IWR, or the Centers of Expertise. USACE: U.S. Army Corps of Engineers; EWN: Engineering With Nature; FRM: Flood Risk Management; CSRM: Coastal Storm Risk Management; NNBF: Natural and Nature-Based Features; AM: Adaptive Management; E&D: Engineering and Design; MsCIP: Mississippi Coastal Improvements Program; O&M: Operations and Maintenance.

Challenge	Opportunity or Enabler
Features / measures classified as FRM or ecosystem restoration even when occurring together, and NNBF tends to be classified as ecosystem restoration (exception coastal dunes). USACE can repair / address failures of FRM / CSRM projects/features under Public Law 84-99 (including dunes on the coast), but for most NNBF that is not possible since they are classified as ecosystem restoration.	1. Classification of NNBF as FRM / CSRM, which would allow eligibility under PL 84-99. 2. Projects put on the ground as a 'whole system' approach under FRM / CSRM where the entire project, including NNBF, can be funded for repair if damaged (e.g., MsCIP)
Lack of time/funding (or authorization for navigation or FRM/CSRM, since monitoring and AM is only authorized for ecosystem restoration) to revisit projects that have been put on the ground to identify the holistic, system-wide benefits to improve future planning, implementation. Modeling and data collection done as part of monitoring and AM is not explicitly tied to the conceptual ecological model and other tools that might be used in planning/E&D.	1. Retrospectives to revisit/reevaluate full system benefits of projects that were built component-wise and as part of an AM approach where possible. 2. Retrospectives to compare the results of planning-level evaluations with the data/results collected as part of monitoring and AM 3. Incorporation of the results of (1) and (2) into best practice and guidance.
O&M is typically very different and more complex than the O&M needs of gray infrastructure (note, from EWN survey). In addition, O&M is typically transferred over to the local sponsor for ecosystem restoration projects, where it may then become a maintenance cost issue.	Development of specific guidance documents for O&M of NNBF, including cost considerations over project lifecycles. Development of O&M templates could also be helpful for the field and our sponsors.

The last set of challenges for accelerating NNBF within USACE Civil Works could be addressed through coordination with partners, including reevaluating the mechanisms and degree of coordination that Districts have with potential local sponsors and stakeholders. These opportunities require buy-in from other entities, so the pathway for the action necessarily starts with outreach and engagement beyond USACE.

Table A-6. Input from USACE EWN practitioner leads on challenges and opportunities that could be addressed through USACE coordination with stakeholders and partners. USACE: U.S. Army Corps of Engineers; EWN: Engineering With Nature; NNBF: Natural and Nature-Based Features; NGOs: Non-Governmental Organizations; BUDM: Beneficial Use of Dredge Material; FRM: Flood Risk Management; CSRM: Coastal Storm Risk Management; O&M: Operations and Maintenance;

Challenge	Opportunity or Enabler
Coastal: organizations with funding and desire to execute NNBF projects (e.g., NGOs) may move forward without USACE because they are not then constrained by USACE process/timeline. However, there are challenges of scale: magnitude of NNBF ecosystem services (e.g., water quality) of a single project/measure can be very low. A coordinated, watershed-level approach (i.e., USACE level of National Significance) can result in more substantive eco service benefits.	Out-of-the-box thinking on partnerships with NGOs (e.g., The Nature Conservancy and Ducks Unlimited) that have land where BUDM could be used.
Conversely, lack of confidence in the FRM/CSRM reduction benefits of NNBF by the sponsor / states / partners in some cases and/or concern about the long-term O&M cost	Increased quantification of NNBF benefits, risks, and costs coupled with development of information / awareness materials for partners.
Legal constraints on use of material in BUDM. If someone else designs the project but it does not meet USACE standards (e.g., for risk), cannot be used.	1. Increased up-front coordination with partners and potential users of BUDM; increase awareness of the value of early USACE engagement so non-USACE projects can meet criteria for BUDM and permitting. 2. Development of guidance documents / websites for partners on the requirements for BUDM that can be used up front in their project planning.
Coordination for beneficial use of sediment. BUDM placement opportunities may not be timed well, have specific constraints (e.g., fraction of fines), or be very small scale when volume dredged in nav projects is large.	Regional sediment management planning –coordination of multiple recipients for BUDM coupled with understanding of the volume/rate at which BUDM becomes available that would allow efficient use of all material.
Partnership agreements and other coordination mechanisms are absent or take a lot of time/effort to develop	Streamlining of the process of partner coordination and being more forward looking on NNBF opportunities.

A.3 INPUT RECEIVED FROM EWN PRACTITIONER LEADS: SYNERGISTIC PROGRAMS AND POLICIES

The EWN practitioner leads were asked to identify programs or activities that are synergistic with advancement of NNBF in practice and could thereby support acceleration of NNBF implementation throughout coordination and/or through focused efforts to consider how NNBF could advance these policies and programs.

- **Goal for 70% of dredged sediment to be repurposed by 2030**. Many NNBF projects (beach/dune nourishment, wetland/marsh creation, etc.) require sediment, therefore they could be a key component of achieving this goal. Providing guidance and tools to Districts that enable more NNBF projects will advance this goal.
- **Regional Sediment Management Program**. Given the integral role of sediment and RSM in NNBF implementation, particularly large-scale projects, coordination with the RSM program could provide opportunities for leveraging activities and funding.
- **Planning Centers of Expertise (PCX).** PCX could potentially lead implementation of some of the opportunities identified above, such as certification of tools for project evaluation and increased awareness of certified tools across business lines.
- **Public Law (PL) 84-99**. PL 84-99 Emergency Response to Natural Disasters gives USACE the authority to act quickly where needed. As noted above, if NNBF are classified as FRM/CSR (and/or if a complete project with NNBF as a component is classified as FRM/CSR), then they can be repaired under PL84-99 authority. In addition, Standard Operating Procedures (SOPs) could be developed for incorporation of NNBF in PL 84-99 projects, such as the USACE Northwestern Division SOP for converting borrow areas to wetlands.
- **Engineering Research and Development Center (ERDC)**. Establishing and maintaining more direct connections between ERDC/EWN research tasks with applicable Civil Works Planning Study Project Delivery Teams (PDTs) could help accelerate NNBF in practice by identifying critical research needs (e.g., risk / failure /benefit quantification as identified above), helping connect researchers with subject matter experts (SMEs), etc.

APPENDIX B. CASE STUDIES

Case study selection began with the Institute working with the EWN practitioner leads to identify factors comprising a "wish list" for an ideal pair of studies for analysis. The case studies focused specifically on NBS used as part of USACE FRM and CSRM projects, therefore the term "NNBF" is used throughout. The preferred characteristics of the studies identified included:

- **Studies that would be illustrative of specific challenges and opportunities associated with NNBF implementation that were preliminarily identified by the EWN practitioner leads (Appendix A)**
  - Obstacles transitioning NNBF from planning through implementation (construction and, AM, and operations and maintenance (O&M))
    - How projects/measures evolve as they are put on the ground
    - If designs that were conceived of during planning could be implemented in practice
    - How constructed project size compared to what was planned
    - Evaluation of if/how much of the expected benefits identified during planning were accrued, and specifically if they were within a range of tolerance of what was expected
    - If there were accrued benefits that were not identified or accounted for during planning
  - Success stories in combined green and gray infrastructure, and including illustrating how green infrastructure may enhance the benefits or longevity of gray infrastructure
- **Two studies that varied from each other across several factors**
  - Location (coastal vs. inland as well as region of the United States)
  - Spatial scale
  - Funding authority
  - Phase of the project (planning vs. implementation vs. O&M, although the team noted that a project that has completed implementation could also be assessed in terms of planning)
  - Degree of incorporation of integrated green/gray or systems approach to planning vs. more traditional, measure-wise formulation
  - Implementation (or not) on an EWN Proving Ground (i.e., locations identified for innovation and testing; https://ewn.erdc.dren.mil/proving-grounds/)
- **Studies that met addition criteria of suitability**
  - Recent enough that records were available, and which had been conducted under similar guidance as to today and/or were currently in O&M
  - Studies for which knowledgeable District personnel that are actively engaged in the EWN cadre are available to provide information

Studies considered included the South Platte River and Tributaries; Mississippi Coastal Improvements Program (Ship Island and Deer Island Projects); South San Francisco Bay; Coastal Texas; Tampa Bay Harbor; Tangier Island Restoration; Missouri River Levee Setbacks; Mobile Harbor; Guadalupe River; Pooles Island; Southwest Coastal Louisiana; and Wicomico River Wetland Restoration.

The two sites selected as case studies were the South Platte River and Tributaries, Colorado, and Deer Island, Mississippi. South Platte is an inland (riverine) flood risk management and ecosystem restoration project for which a Congressionally authorized Feasibility Study was conducted focusing on an urban waterway section of the river where it passes through the city of Denver. It was among the case studies included by the Institute in a previously completed analysis wherein the original benefit cost analysis (BCA) was updated to incorporate additional monetized and non-monetized benefits of NNBF (Fischbach et al., 2023b). A partnering agreement has been signed between USACE and the local sponsor, the consolidated City and County of Denver, and components of the project have moved into implementation since the Feasibility Study was completed. South Platte therefore represents a recently completed inland flood risk management site that has progressed to the implementation phase, meeting the criteria identified for case study selection. The site has two additional benefits as a case study, as well. First, factors such as timeline, funding, and technical requirements were not included in the original Institute analysis, therefore the current effort allows these and other challenges, opportunities, and enablers from a practitioner perspective to be incorporated and contrasted to the original findings. Second, the evolution of challenges and enablers for NNBF as a project passes from the planning phase through to implementation could be explored.

Deer Island is a coastal site along the Gulf of Mexico in the southeastern United States. A variety of USACE-related authorization and funding mechanisms have been used to evaluate and implement NNBF alternatives at this site, including Congressionally authorized feasibility and comprehensive studies, beneficial use of dredge material, and emergency response. These efforts have led to the construction of marsh, beach, dune, and shallow water habitat at the site, with additional engineering and design of marsh creation using beneficial use of dredge currently underway as of October 2023. Deer Island therefore meets the site-specific criteria of case study site selection and also presents an opportunity to contrast the challenges, opportunities, and enablers of NNBF implementation for a site that differs from South Platte in multiple ways, including authorization, funding, geographic location, and types of NNBF considered.

B.1 CASE STUDY 1: DEER ISLAND, MISSISSIPPI

Deer Island (Figure B-1) is a 4.5 mile long island located in Harrison County, Mississippi, just offshore of the mainland near the mouth of Biloxi Bay (Roth et al., 2012; Smith et al., 2015; USACE Mobile District, 2010). In addition to providing habitat for a variety of native species, Deer Island attenuates energy from waves, providing protection to the City of Biloxi during storm events and reducing shoreline erosion of the mainland (Smith et al., 2015). Deer Island is owned by the State of Mississippi and is managed by the Mississippi Department of Marine Resources (MDMR) under the Coastal Preserves program (Roth et al., 2012; Smith et al., 2015).

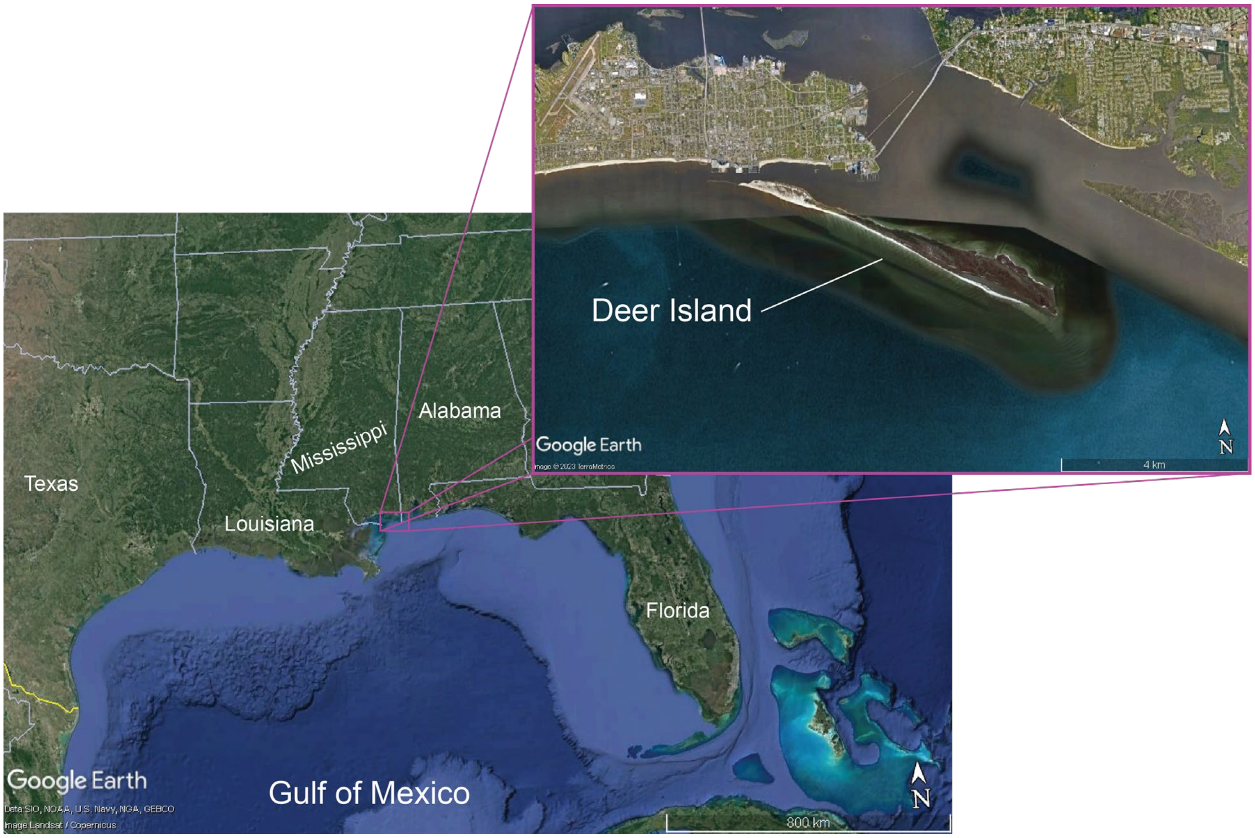


Figure B-1. Location of Deer Island, Mississippi in the northern Gulf of Mexico.

Tropical storms, sea level rise, and other drivers have led to near-continuous erosion of Deer Island for decades, with a cumulative land loss of approximately 300 acres, or 34% of the islands area, between 1850 and 2010 (USACE Mobile District, 2010). This loss of land area and associated ecosystem services has led the state of Mississippi and USACE to pursue restoration of the island going back beyond 2000, when Public Law (PL) 106-541 (Section 528 of WRDA, 2020) authorized Federal participation in restoration projects to preserve coastal wetlands and barrier island in the state of Mississippi (WRDA, 2000).

The state of Mississippi and USACE have pursued a variety of mechanisms to support Deer Island restoration and construction of NNBF (Figure B-2), with an overarching goal of MDMR to restore the entire island to its 1850s footprint (Ramseur, 2020). Early efforts can be broadly categorized under two approaches: projects authorized for ecosystem restoration (i.e., NNBF authorized under the "demand side" of environmental restoration, including a USACE-led WRDA, 2020 Section 528 project), and beneficial use (BU) of dredge material (i.e., NNBF authorized under the "supply side" of sediment disposal, including USACE projects conducted under Section 204 of WRDA 1992 (WRDA, 2020) or led by outside entities and permitted by USACE under Section 404 of the Clean Water Act (*Clean Water Act*, 1972)). In addition, more holistic and comprehensive evaluation of Mississippi coastal restoration, including at Deer Island, was authorized by Congress as part of the Mississippi Coastal Improvements Program (MsCIP) (*Department of Defense, Emergency Supplemental Appropriations to Address Hurricanes in the Gulf of Mexico, and Pandemic Influence Act*, 2005).

Figure B-2. Natural and Nature-Based Features at Deer Island, Mississippi. Shown are projects authorized under WRDA 2000 Section528 as Aquatic Ecosystem Restoration Projects (AERP) and later incorporated into the Mississippi Coastal Improvements Program (MsCIP) comprehensive plan; beneficial use (BU) projects authorized under WRDA 1992 Section 204 and WRDA 2016 Section 1122; BUDM sites DIMR1 and DIMR2 filled with dredge material from the Port of Gulfport navigation deepening project; and project led by the Mississippi Department of Marine Resources (MDMR) to place bags of oysters as part of a living shoreline approach.

B.1.1 Natural and Nature-Based Features: Aquatic Ecosystem Restoration

Section 528 of WRDA 2000 authorized coastal wetland and barrier island restoration in the State of Mississippi as an Aquatic Ecosystem Restoration Project (AERP). As such, the primary objectives were protection of the aquatic ecosystem and shoreline protection to support reestablishment of marsh and maritime forest, although additional desired benefits such as mainland storm protection were also identified in coordination with stakeholders (Smith et al., 2015; WRDA, 2000). The original project authorization included restoration of a 95-acre breach at the west end of the island and restoration of the southern shoreline (Smith et al., 2015; USACE Mobile District, 2010) and received initial funding in 2006 under the Energy and Water Development Appropriations Act PL 109-103 (*Energy and Water Resources Appropriations*, 2005; USACE Mobile District, 2010). Following Hurricane Katrina, Congress authorized $2,277,965,000 in emergency response and recovery funds under PL 109-148 in December of 2005, including $75,000,000 for the state of Mississippi to accelerate completion of authorized projects such as the Deer Island AERP (*Department of Defense, Emergency Supplemental Appropriations to Address Hurricanes in the Gulf of Mexico, and Pandemic Influence Act*, 2005). USACE coordinated with Mississippi to identify the projects to be funded under that source, allocating $7,500,000 for Deer Island (USACE Mobile District, 2010).

Planned actions at Deer Island to restore the damage from Hurricane Katrina included closure of the west end breach and restoration of the southern shoreline, as well as restoration of Grand Bayou (Figure B-2) (USACE Mobile District, 2010). The original design for the west end required 1.95 million cubic yards of sediment and would have included a rip-rap dike to close the west end breach, while the original design of the southern shoreline project included placement to recreate the 1850s footprint of the island (Smith et al., 2015). The Grand Bayou Restoration was intended to place 367,000 cubic yards of material to restore beach, dunes, maritime forest, and marsh. Restoration alternatives were evaluated to identify the National Ecosystem Restoration (NER) plan, and a project that included three components—west end breach restoration, Grand Bayou restoration, and southern shoreline restoration—was identified as the "best buy plan" providing the greatest incremental benefit for increased cost. All sediment for the project was planned to be sourced from a permitted offshore borrow site (USACE Mobile District, 2010). Although originally slated to begin in 2008, the contract for restoration of the Deer Island AERP had to be terminated due to hurricanes Ike and Gustav (Smith et al., 2015). These storms caused further erosion of Deer Island, and in response Congress allocated an additional $7,250,000 under PL110-329 (*Consolidated Security, Disaster Assistance, and Continuing Appropriations Act*, 2009) and $7,750,000 under PL111-32 (*Supplemental Appropriations*, 2009) for Deer Island.

Restoration at Deer Island under the AERP and the Flood Control and Coastal Emergencies Program occurred between 2010 and 2013 and included several NNBF measures (Smith et al., 2015; Figure B-2). The design for the west end breach closed the breach with geotubes overtopped with sediment and plantings, restoring a living shoreline and reducing the need for, and cost of, rock resources (Smith et al., 2015). Several challenges were encountered during construction, however: the weight of sand used to close the west end breach was too heavy for the underlying soil, leading to displacement. Rather than reverting to use of a hard structure, this challenge was overcome through dense native grass plantings (CH2M Hill, 2011a; Smith et al., 2015). The southern shoreline component of the project included restoration of approximately 2 miles of sandy beach material and planting of 325,000 native plants. The project team identified an opportunity to further NNBF implementation and BUDM at Deer Island. Sediment was placed offshore of the island to create a long gap (i.e., a lagoon) between the placed material and the shoreline of Deer Island. This area was designed to provide 100 acres of open water that could be used as a BUDM site for fine-grained material dredged as part of maintaining the nearby Biloxi Lateral and East Access Navigation Channels (Smith et al., 2015). In addition, the lagoon was designed with connectivity to the Gulf of Mexico to provide habitat for larval and juvenile shellfish and finfish in the short term, while supporting establishment of marsh and maritime forest in the long term (Lang, 2012). Although authorized under Section 528 as part of the AERP project, the installation of these NNBF were also identified within the recommended alternative for Deer Island under MsCIP as part of a multiple lines of defense approach to CSRM and ecosystem restoration (described below in B.1.2)

Figure B-3. Restored southern shoreline of Deer Island including lagoon created as a future beneficial use site. From Smith et al. (2015).

B.1.2 Natural and Nature-Based Features: Beneficial Use of Dredge Material

In addition to authorized restoration projects, construction of NNBF has occurred at Deer Island through use of dredged material, with USACE BUDM authorized under Section 204 of WRDA 1992 (Figure B-2) (WRDA, 1992). Under this authority, USACE coordinated with MDMR and other stakeholders to prepare the Long-Term Comprehensive Master Plan for Beneficial Uses of Dredged Material along Coastal Mississippi (USACE Mobile District, 2002) and the companion Implementation of Long-Term Comprehensive Master Plan for Beneficial Uses of Dredged Material along Coastal Mississippi (USACE Mobile District, 2003). These documents identified and evaluated BUDM projects, including providing preliminary designs and identification of criteria for sites. These plans included identification of a 45-acre marsh restoration area on the northeastern side of Deer Island, which could be used as a pilot site for other BUDM restoration projects in the state (Byrnes & Berlinghoff, 2012).

Funding for BUDM at Deer Island under the USACE Continuing Authorities Program (WRDA 1992 Section 204) was provided in Fiscal Year (FY) 2003 and by PL 109-103 in FY2005 (WRDA, 1992). A site that could contain 279,000 m^3 of material dredged under the Biloxi Harbor Federal Navigation Project was constructed between 2002 and 2003 (Roth et al., 2012), and between 2003 and 2005 approximately 40 acres of wetlands was restored along the northeastern shoreline of Deer Island at this location (USACE Mobile District, 2006). In addition, MDMR used $20,000 from the NOAA Community-based Restoration Partnership program in 2010 to deploy oyster bags along the shoreline adjacent to this BUDM site to mitigate shoreline erosion, provide oyster habitat, and increase community awareness of wetland protection activities (Roth et al., 2012). The wetlands that were constructed on the northeastern shoreline, as well as the rest of Deer Island, suffered erosion and land loss during Hurricane Katrina in August 2005, with approximately 25% of the placed material and 50% of the plants at the BUDM site lost in the storm (Byrnes & Berlinghoff, 2012). Despite these impacts and the development of a small breach in the BUDM containment dyke, however, USACE assessed the site after the storm and noted that much of the vegetation was thriving in the restoration area (USACE, 2009).

Multiple efforts to develop NNBF using BUDM have also been led by other entities that have coordinated with USACE in attaining BUDM material and regulatory permits. MDMR worked with partners to replant marsh and dune vegetation in the BUDM site in 2008 using funds from the Coastal Improvement Assistance Program (Byrnes & Berlinghoff, 2012), while overall management of the USACE Section 204 BUDM site was turned over to MDMR in 2009 (USACE Mobile District, 2015). MDMR subsequently received a permit from USACE to add material the existing BUDM area, redesignated DIMR1 (Deer Island Marsh Restoration 1), as well as to create an adjacent BUDM site to the west, designated DIMR2 (Deer Island Marsh Restoration 2) (USACE Mobile District, 2015; Figure B-2). The Gulf Coast Ecosystem Restoration Council (RESTORE Council), created by the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act of 2012 (33 U.S.C. § 1321(t)), has also supported BUDM at Deer Island, identifying the site in its Initial Funded Priorities List and approving $3,000,000 for restoration at the site in 2015 (Gulf Coast Ecosystem Restoration Council, 2015).

Material dredged as part of expanding the Port of Gulfport (approximately 29 km to the west of Deer Island) was identified in 2012 for BUDM at these Deer Island locations (Anchor QEA, LLC, 2015; Roth et al., 2012). Under this effort, the USACE containment dyke destroyed by Hurricane Katrina was rebuilt and an estimated 200,000 cubic yards of material was placed within DIMR1, while DIMR2 was created using approximately 130,000 cubic yards of sediment to create 40 acres of wetland (Ramseur, 2020; Ramsuer, 2014; Figure B-2). The new expansion cell was designed in coordination MDMR, the Port, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Mississippi Department of Environmental Quality, and other stakeholders. Material dredged from Graveline Bayou in Jackson County was also placed at the site (Byrnes & Berlinghoff, 2012). Post-construction monitoring of the site indicates successful creation of marsh with similar species composition and diversity as natural marsh in the area (Lang, 2012).

Under Section 1122 of WRDA 2016, USACE was instructed by Congress to develop a pilot program for implementation of BUDM projects for multiple purposes including storm damage reduction, recreation, risk management, and reduction of disposal costs (WRDA, 2016). In late 2018, Deer Island was identified as one of the ten projects selected under this pilot program, with MDMR as the local sponsor for the effort (USACE, 2018). Planning for this project is currently underway as of September 2023, and will include placement in the lagoon created in the modified AERP design (Figure B-2).

B.1.3 Natural and Nature-Based Features: Comprehensive Evaluation

Congress authorized the Mississippi Coastal Improvements Program (MsCIP) Comprehensive Plan in December 2005 under the Department of Defense Emergency Supplemental Appropriations to Address

Hurricanes in the Gulf of Mexico (PL109-148). This authorization passed in response to Hurricane Katrina, and as a comprehensive study had greater flexibility for holistic consideration of NNBF and restoration alternatives including at Deer Island. MsCIP was authorized for the purposes of "hurricane and storm damage reduction, prevention of saltwater intrusion, preservation of fish and wildlife, prevention of erosion, and other related water resource purposes," at full Federal expense. In addition, the authorization prescribed that cost-effective analysis be conducted in lieu of benefit-cost analysis in selecting the Recommended Plan (*Department of Defense, Emergency Supplemental Appropriations to Address Hurricanes in the Gulf of Mexico, and Pandemic Influence Act*, 2005).

USACE Mobile District led development of a Recommended Plan for MsCIP between 2006 and 2009 through a process that included extensive public engagement; identification of structural, non-structural, and environmental measures; and evaluation of potential measures at different target sites along the Mississippi coast (USACE, 2009). Development of the comprehensive plan included a priority to promote the long-term future sustainability of the coast of Mississippi in addition to mitigating damage done to the coast by Hurricane Katrina and other storms in 2005. Other objectives identified for MsCIP through stakeholder collaboration included minimizing risk to loss of life, cost-effective restoration of environmental resources, cost-effective measures to reduce hurricane damage while not encouraging growth in high-risk areas, and development of a resilient coastline (USACE, 2009). As part of comprehensive and holistic management of the coast, the MsCIP team did not limit initial input on management alternatives to only those actions that could be taken by USACE or under the authority of MsCIP. For example, the Deer Island AERP project above—which was in the planning and authorization phase at the time of the MsCIP study— was identified as a related project. A concept underlying the MsCIP plan is "Lines of Defense," in which multiple approaches are used along the coast to reduce the risk of storm damage. These lines of defense include: barrier islands; dunes along mainland coasts; raised roadways, seawalls, and ring levees; inland gray infrastructure flood barriers; and non-structural alternatives such as relocation of emergency services (USACE, 2009).

The preliminarily identified concept for Deer Island under MsCIP included complete and multi-faceted restoration to its pre-Camille footprint (i.e., prior to 1969) as a barrier within the multiple lines of defense concept (USACE, 2009). It was not yet confirmed that the Deer Island AERP (in progress at the time of the MsCIP study) would include restoration of the southern shoreline and the project team determined there were additional opportunities for restoration at the site beyond the extent of that study, therefore the alternatives considered for the island included portions of the restoration plan for that project as well as new elements. Alternatives identified for consideration included: restoration of the southern shoreline; repairing the BUDM containment area at the northeast end of the island that was breached in Hurricane Katrina; extension of existing breakwaters to reduce wave energy along the northern and southern shoreline of the island; restoring tidal marsh at the northeastern end; and combined restoration plan that spanned measures drawn from the other alternatives. Deer island was one of five ecosystem restoration sites that were carried through to the final array for evaluation under MsCIP (USACE, 2009).

Alternative evaluation for Deer Island and the other ecosystem restoration sites followed methodologies developed by the USACE Institute for Water Resources for identifying the "best buy" alternative, i.e., those providing the highest value for the dollar (Orth, 1994; Robinson et al., 1995), with data and analyses for Deer Island supported with input from the prior AERP and BUDM studies. The

Congressional Authorization for MsCIP precluded benefit-cost analysis as the final means of selected alternatives; however, a mechanism was needed to compare benefits and outcomes across alternatives. Tables were therefore developed to compare alternative costs; benefits including monetary/economic, environmental, and societal; implementation and design considerations; environmental outputs; damages prevented; site and technical considerations; source materials; and other issues.

Project benefits and costs were organized under the "System of Accounts" under which USACE is authorized to implement projects: National Economic Development (NED); Regional Economic Development (RED); Environmental Quality (EQ); and Other Social Effects (OSE; (USACE, 2009). As an ecosystem restoration project, the USACE team did not explicitly calculate damages prevented or emergency costs avoided under the NED account for the Deer Island alternatives but did qualitatively consider recreational and ecosystem tourism benefits. Under EQ, the team considered the quantity (acreage) of restored habitat, impacts to cultural and historical sites, impacts to biological and natural resources, and other factors. Dollar values were assigned for each alternative to RED benefits including impacts to home sales, income, employment, and taxes. Anticipated outcomes qualitatively considered for the Deer Island alternatives under OSE included security of life, health, and safety; community cohesion; tax values; community growth; public facilities; and reduction in loss of life (USACE, 2009).

Alternatives for Deer Island were also qualitatively compared to objectives of coastal protection (flood, hurricane, and/or storm damage reduction) and recovery of lost environmental resources; benchmarked against constraints identified in coordination with stakeholders, such as minimizing negative environmental impacts; and compared to USACE criteria of effectiveness, completeness, acceptability, and efficiency (USACE, 2009). In addition, alternatives were assessed based on whether or not they would be integrated components of the overall system consistent with the multiple lines of defense concept; the degree of difficulty in reversing their implementation as needed under an AM approach; risks of failure, environmental damage, impacts to life and safety, and impacts to mental and physical health, as well as residual economic risk, overall reliability, and sensitivity to relative sea level rise (USACE, 2009). Lastly, the alternatives were assessed against stakeholder preferences as well as the Federal recommendation based on the NER standard (i.e., the "best buy" alternative). This combination of qualitative and quantitative evaluation of overall costs and benefits was enabled by the authorization and comprehensive nature of MsCIP and allowed much more complete and holistic evaluation of the Deer Island alternatives than can often be conducted as part of targeted USACE Feasibility Studies (Fischbach et al., 2023b). The combined restoration plan was identified as the most beneficial in this analysis, and included restoration of 128 acres of emergency tidal marsh, 78 acres of coastal maritime forest, 86 acres of beach habitat, and 30 acres of dune habitat, as well as the extension of existing breakwaters to reduce wave energy (USACE, 2009).

Because most components of the MsCIP combined Deer Island ecosystem restoration alternative had been previously designed, evaluated, and permitted under the prior authorized USACE projects, it was recommended for construction in Phase I of MsCIP implementation. The recommended construction included restoration of the northern and southern shorelines and creation of 400 acres of wetlands, in addition to restoration of beach, dune, and coastal maritime forest. The Chief's Report recommending the project noted the hurricane and storm risk reduction benefits the project will provide to the mainland Biloxi area, while assigning the Federal (USACE) cost of the Deer Island presentation to the ecosystem restoration account. Monitoring and AM costs for the projects were included in the combined (Federal and local) cost of $21,520,000 and were anticipated as less than 3% of the total cost, with MDMR (the local sponsor) responsible for operations and maintenance of the project beyond the five years covered as part of AM (Van Antwerp, 2009). Other components of the recommended alternative that were not previously permitted, including construction of the breakwater and westward expansion of the Section 204 BUDM site, were identified as future decisions that would require additional evaluation for compliance with regulations such as NEPA (USACE, 2009).

The MsCIP Comprehensive Plan, including the remaining recommended restoration and repair of hurricane damage to Deer Island, was authorized by Section 7002(4) of PL113-121, the Water Resources Reform and Development Act (WRRDA) of 2014 (WRRDA, 2014), for hurricane and storm damage risk reduction and environmental restoration. Funding had previously been identified in 2009 under PL111-32, the Supplemental Appropriations Act, in which Congress allocated $439,000,000 in Flood Control and Coastal Emergencies funding for island and ecosystem restoration projects to restore historic levels of storm damage risk reduction along the Mississippi Gulf Coast at full Federal expense. The initial focus of MsCIP was on restoration of the barrier islands; once completed, USACE Mobile District coordinated with the state of Mississippi to identify other restoration priorities. The expanded restoration of Deer Island was approved by the Assistance Secretary of the Army of Civil Works in 2021 as authorized by the Flood Control and Coastal Emergencies Act (USACE, 2008) with a total of $35,000,000 for the project. This project began that year with a Comprehensive Plan Design Kickoff, with construction slated to begin in 2024 (Godsey, 2023).

B.1.4 Challenges and Opportunities

The restoration at Deer Island, Mississippi, highlights several challenges and opportunities in accelerating the implementation of NNBF in the USACE Civil Works Program. First, there are multiple authorities and pathways through which USACE can lead or support NNBF implementation. NNBF constructed at Deer Island have included construction of beach, dune, marsh, maritime forest, and shallow water lagoon habitat, led and/or funded by USACE under: aquatic ecosystem restoration (WRDA, 2000 Section 528); beneficial use of dredge material (WRDA, 1992 Section 204 and WRDA, 2016 Section 1122); coastal storm disaster or emergency response (PL109-148, PL110-329, PL111-32; PL84-99); and Civil Works appropriations (PL 109-103). In addition, USACE has supported NNBF implementation through coordination with MDMR and other entities through establishing BUDM sites and the regulatory permitting process. Each of these mechanisms represents an opportunity for USACE to support or implement NNBF, and in the case of Deer Island the Mobile District proactively considered holistic management of the island across authorities by, for example, designing the AERP project to support BUDM placement in the long term. However, the need to navigate multiple authorities and funding sources is also a potential challenge for NNBF implementation, particularly for USACE project teams that may not have the flexibility, support, or time necessary to consider how different authorities and funding streams could be leveraged at a given site. Earlier authorization and funding for more comprehensive evaluation of NNBF at Deer Island to advance coastal storm risk protect, recreation, ecosystem restoration, and other benefits—such as was ultimately considered under the MsCIP Comprehensive Study—could have potentially accelerated more widespread implementation of NNBF at Deer Island.

Deer Island also illustrates several technical challenges and opportunities associated with NNBF alternative evaluation, engineering and design, and implementation. The Recommended Plan for the AERP project was developed using tools for evaluating the incremental benefit of restoration developed by USACE IWR, which enabled the Feasibility Study to be completed within the timeline and budget of the project. During project implementation, however, USACE discovered that the underlying soil could not withstand the weight of the geotubes used to close the breach at the west end of the island, a challenge that was ultimately overcome through dense vegetation planting. These outcomes highlight the critical need for NNBF-specific tools to support alternative evaluation and engineering and design that are robust, can identify and support mitigation of implementation risks, and fit within the timeline and budget of USACE projects.

The MsCIP Comprehensive Plan also highlights an additional opportunity for alternative formulation and evaluation in NNBF and green/gray infrastructure. In MsCIP, a “multiple lines of defense” approach was considered as part of a holistic approach to CSRM and ecosystem restoration. This perspective can support NNBF by allowing these features to provide benefits for which they are well adapted, such as protection from smaller storms, recreational use, and provision of habitat. At the same time, gray infrastructure solutions or nonstructural alternatives can be used in combination to provide benefits such as risk reduction and protection from larger storms.

Lastly, the restoration of Deer Island reflects the opportunity and need to consider the benefits provided, and the approach to operations and maintenance or AM, differently for NNBF and green/gray infrastructure than for traditional hard engineering approaches. Ecosystem restoration and BUDM projects at Deer Island contribute to protection of the mainland from storms, recreational use, ecotourism, protection of cultural resources, and positive impacts on the local economy (USACE, 2009). Outside of storm protection, these benefits are typically greater than what would be accrued from an infrastructure solution such as a sea wall or surge gate, which regardless may not be feasible at this location. Storms have led to significant erosion of these features, however. NNBF such as barrier islands, beaches, dunes, and marshes may serve as sacrificial features that absorb storm wave energy and incur erosion in protecting the mainland, such as occurred at Deer Island during Hurricane Katrina (Byrnes & Berlinghoff, 2012), rather than as permanent and immutable features. This outcome also reflects the importance of AM in managing NNBF, which may need to be repaired or replaced following storm events.

B.1.5 Enablers

The history of NNBF at Deer Island also highlights several enablers for accelerating NNBF implementation in the USACE Civil Works program. First, the project highlights that Districts can leverage a variety of funding mechanisms and authorities for NNBF implementation, including direct authorization Feasibility Studies, continuing authority programs such as BU, emergency supplemental legislature, and comprehensive planning. As was noted in a prior Institute study (Fischbach et al., 2023b), the associated constraints and requirements of the authorization can limit consideration of NNBF. In the case of MsCIP, the authorization explicitly required cost effective analysis rather than BCA in evaluating alternatives, avoiding challenges that are often associated with monetizing NNBF benefits. In addition, MsCIP allowed the Mobile District flexibility to consider the environmental system holistically and comprehensively, allowing for inclusion of NNBF as part of a “multiple lines of defense” approach. Greater flexibility in authorization and funding could accelerate NNBF implementation by allowing for broader adoption of approaches such as “multiple lines of defense” and alternative evaluation based on cost effectiveness rather than the BCA.

Deer Island furthermore demonstrates the considerable value of state and local partner coordination in enabling implementation of NNBF. USACE has coordinated extensively with MDMR and other stakeholders for decades, including participating in the Mississippi Beneficial Use Group (BUG) comprised of state, federal, and local partners that was formed after the 2005 hurricane season. The BUDM sites on the northern shoreline of Deer Island have been developed and maintained through efforts led by both USACE and MDMR, further reflecting the importance and value of coordination.

Restoration at Deer Island also illustrates the value of BUDM as an enabler for NNBF implementation, particularly in combination with partner coordination and advanced planning (i.e., developing dredge disposal plans, project designs, and pursuing permitting in advance of when material is available from navigation channel dredging). Opportunities for BU, site considerations, potential locations, and in some cases specific designs were included in multiple planning documents for Deer Island, including the Long-Term Comprehensive Master Plan for Beneficial Uses of Dredged Material along Coastal Mississippi (USACE Mobile District, 2002); Implementation of the Long-Term Comprehensive Master Plan for Beneficial Uses of Dredged Material along Coastal Mississippi (USACE Mobile District, 2003); the updated Master Plan for the Beneficial Use of Dredged Material for Coastal Mississippi (CH2M Hill, 2011a); the Project Management Plan for Selected Beneficial Use Projects along Coastal Mississippi (CH2M Hill, 2011b); and the Gulf Regional Sediment Management Master Plan: Case Study Compilation (Byrnes & Berlinghoff, 2012). Deer Island illustrates that proactive planning and identification of BUDM opportunities can enable more widespread use of NNBF.

The case study at Deer Island illustrates that there are several approaches District personnel can take to accelerate NNBF in practice, which could be facilitated USACE-wide through greater access to guidance and tools, as well descriptions of templar projects or studies and the associated lessons learned. This information dissemination could occur in several ways. First, the development of short guidance docs that District personnel can use to identify potential funding mechanisms and authorities for NNBF, along with the associated processes, constraints, limitations, and opportunities for each mechanism. These guidance documents can also provide information on the leveraging of BUDM in NNBF implementation, including the benefit of partner coordination and regional planning as part of that process. Searchable databases of case studies would also enable relatively inexperienced District personnel to identify templar projects to use as examples and/or from which to glean lessons learned across all phases of alternative identification and evaluation, engineering and design, implementation, AM, and operations and maintenance. The development of searchable databases of case studies could also be used as a dissemination mechanism for information and tools related to specific NNBF, given that in some cases USACE personnel have developed and utilized appropriate certified tools and techniques that other Districts may not be familiar with.

B.2 CASE STUDY 2: SOUTH PLATTE RIVER AND TRIBUTARIES IN THE DENVER, COLORADO AREA

The South Platte River flows from the mountains of central Colorado north into Nebraska, traversing approximately 439 miles before its confluence with the North Platte River and draining approximately

$24{,}300\ mi^2$ of area across Colorado, Nebraska, and Wyoming (Dennehy et al., 1993). The river and two major tributaries, Weir Gulch and Harvard Gulch, pass through the city of Denver, where they provide critical habitat linkages been the Rocky Mountains and Great Plains river systems as well as recreational opportunities to local residents (USACE, 2019). Urbanization of the watershed and river alteration have led to several issues, however. Riparian floodplain areas along the river have been developed, leading to flood risk for residents and reducing habitat area for associated species. In addition, riverine flow is regulated through operation of multiple reservoirs upstream at Chatfield, Cherry Creek, and Bear Creek constructed as part of addressing the growing need for potable water in the region as well as for flood control purposes (USACE, 2019).

Concerns to preserve and improve habitat, enhance recreational opportunities and other ecosystem services provided by the river, and reduce flood risk exposure have spurned interest to restore areas of the South Platte River and its tributaries in the Denver area. One such effort, coordinated by the City & County of Denver (CCD), the Mile High Flood District, and the Greenway Foundation, led to the development of the River North Greenway Master Plan (2007), River South Greenway Master Plan (2008) and combined River Vision Implementation Plan outlining projects that could advance multiple objectives including maximizing health and safety, improving ecological function, enhancing visibility and accessibility of the river, continuing transformation of the environment and economy, and expanding resource opportunities and partnerships (CCD et al., 2022; “The Denver Story,” 2022). Local entities have invested extensively in implementation of these plans and other restoration efforts along the South Platte, including $40 million in habitat restoration and enhancement projects along a 20-mile stretch of the river between 2011–2018 (USACE Omaha District, 2018) and over $90 million in total local investment through 2021 (“The Denver Story,” 2022). Local restoration has followed a “string of pearls” approach, conducting multiple individual projects with a long-term goal of a larger, connected habitat corridor. These partners—and others—have coordinated closely with USACE on efforts focused on ecosystem restoration and flood risk management for the South Platte River, with CCD serving as the local sponsor for USACE-led Feasibility Study and implementation projects in the area.

In 2008, Congress extended authorization for a feasibility (“General Investigation”, GI) study to identify opportunities for advancing objectives of flood risk reduction and floodplain management, water supply and quality, recreation, environmental restoration, and watershed management for the South Platte River and Tributaries in Adams and Denver Counties (USACE, 2019). A Feasibility Cost Share Agreement was established between CCD and USACE in 2014, thereby initiating a study to evaluate opportunities to restore wetland, riparian, and instream habitat, and to understand and reduce flood risk (USACE, 2019). The USACE Omaha District held a series of public meetings to elicit input on the types of measures and alternatives to consider in the analysis, and an early decision was made by USACE in coordination with CCD to develop and evaluate alternatives separately for three regions: the main stem of the South Platte River, Harvard Gulch Watershed, and Weir Gulch Watershed (Figure B-4; (USACE, 2019).

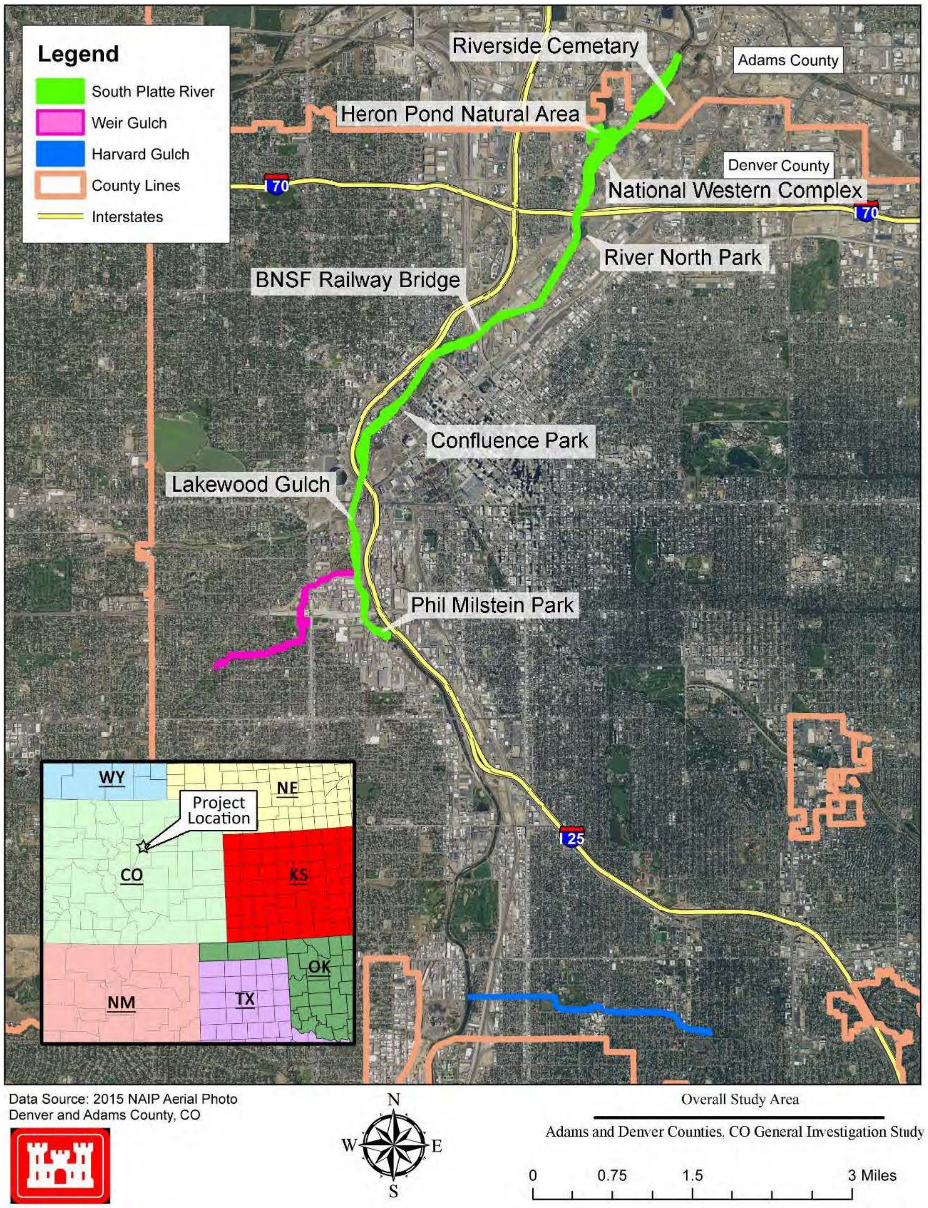


Figure B-4. Components of the South Platte River and Tributaries study (USACE, 2019).

Concurrent with the South Platte River and Tributaries GI study, CCD requested assistance from USACE in 2010 under Section 1135 of WRDA 1986, which gives USACE the authority to evaluate and implement modifications to previously implemented USACE projects and the areas they directly impact (WRDA, 1986). The impetus behind the study in this case was the construction of the three multi-purpose flood control dams upstream of Denver to create the Chatfield, Cherry Creek, and Bear Creek reservoirs, collectively the Tri-Lakes Projects. The impacted area focused on for the Southern Platte Valley Section 1135 study was 2.4 miles of the South Platte River and floodplain including the Harvard Gulch outfall (Figure B-5; USACE Omaha District, 2018). It is approximately 3 miles to the south (upstream) of the South Platte reach of the GI study (USACE, 2019).

Figure B-5. Components of the Section 1135 Southern Platte Valley study (USACE Omaha District, 2018).

B.2.1 Natural and Nature-Based Features: South Platte River and Tributaries Feasibility Study

The South Platte River and Tributaries Feasibility Study was authorized as a multi-objective project to advance both flood risk management and ecosystem restoration; the region of interest was divided based on which of those two goals was the primary objective, with subsequent implications for how alternatives and measures—including NNBF—were evaluated. The South Platte River region was conducted as an ecosystem restoration project; therefore a “best buy” plan was developed based on incremental benefit for cost analysis used for evaluating the federal interest associated with the NER account. This decision was made based on the results of a previous assessment by CCD and the Urban Drainage and Flood Control District (UDFCD) that the flood risk management benefits associated with ecosystem restoration (i.e., with implementation of NNBF) would not lead to a positive benefit cost ratio (BCR) if evaluated against the NED account (USACE, 2019). Conversely, alternatives for Harvard and Weir Gulches were formulated for flood risk management and evaluated based on BCA to determine the federal interest under the NED account. A combined NED/NER plan was not developed for either gulch because of the high real estate cost associated with land acquisition coupled with the estimated low value of ecosystem restoration; however, opportunities for ecosystem enhanced were considered where possible (USACE, 2019). Recreational benefits and opportunities were also considered where possible.

South Platte River: Ecosystem Restoration

The South Platte project area was subdivided into six spatial reaches for analysis and alternative development (note, reach 6 of the study includes the Sun Valley and Zuni Reach that were included in an earlier GI study described above). Future without project (FWOP) outcomes were first established as a benchmark for formulating and evaluating potential alternatives (USACE, 2019). The Functional Assessment of Colorado Streams (FACStream) Model – Version 1.0 (Johnson et al., 2015) was used to assess the stream function (biological, chemical, and physical) relative to its natural state for FWOP. Variables assessed included flow and sediment regime; water quality; stream morphology, stability, and physical and biotic structure; and flood plain connectivity, vegetation, and debris for riparian habitats (USACE, 2019). The habitat functionality of the study area was also assessed using the Functional Assessment of Colorado Wetlands (FACWet), a similar tool for evaluating the ecosystem function of wetland habitat (Johnson et al., 2013). This analysis determined that the environmental conditions in the South Platte River were currently degraded, and that any small-scale, local restoration efforts conducted outside of a USACE-led, large-scale restoration effort would likely accrue relatively small benefits that would be offset by future ecological stress and associated degradation (USACE, 2019).

Formulation of alternatives to FWOP for South Platte began with identification of over 25 ecosystem restoration management measures believed to advance the primary objectives of riparian, wetland, and in-channel habitat restoration and ancillary objectives of flood risk damage reduction and creation of recreational opportunities (USACE, 2019). A variety of NNBF and green/gray infrastructure solutions were included in the measures: adding or regrading wetland benches; restoring submerged wetlands or creating wetland features at storm outfalls; adding cobble bars or jetties to improve aquatic habitat; replacing river drops with pool-riffle-run complexes; bank stabilization or slope reduction; infrastructure (sewer, trolley tracks) relocation to allow for river widening; and removal of invasive species combined with native vegetation planting (USACE, 2019). The initial set of measures was screened against USACE criteria for completeness, effectiveness, efficiency, and acceptability. Most of the NNBF and green/gray measures passed this screening, with the exception of several that were determined to have limited ecosystem restoration value (for example, an existing canal in one reach of the river would undermine the effectiveness of sewer removal in widening the river and reconnecting it to riparian habitat) (USACE, 2019). After initial screening, USACE then combined the remaining measures into 26 reach-based sub-alternatives. These sub-alternatives were further screened against the project objectives before being combined to develop complete alternatives (i.e., alternate plans) for evaluation based on incremental cost-benefit evaluation (USACE, 2019).

A total of 12 plans were generated from the sub-alternatives using the USACE IWR Cost-Effectiveness and Incremental Cost Analysis (CE/ICA) tool, a USACE certified software program that is a component of the IWR Planning Suite (https://www.iwr.usace.army.mil/missions/economics/iwr-planning-suite/). A series of public meetings were then held to elicit input on the alternatives, before plans were compared and refined based on price, scale, and uniqueness. A final set of alternate plans was selected for integrated USACE planning under the National Environmental Policy Act (NEPA), then evaluated for incremental cost and benefit. The plan with the highest benefits for South Platte ("Plan #9") included restoration of 160 acres of riparian and wetland habitat; 100 acres of aquatic habitat; and reconnection of 190 additional acres of existing habitat and green space, while also providing recreational benefits and removing approximately 100 structures from the South Platte River floodplain (USACE, 2019).

Prior to finalization of this alternative as the Recommended Plan, USACE coordinated with CCD and other stakeholders to evaluate cost, schedule, and policy risks. Cost risks were identified first through qualitative assessment. Those factors considered to present medium or high risk were then quantitatively assessed with the CrystalBall Software Package, a spreadsheet-based model for conducting Monte Carlo simulation of potential future scenarios (Gonzalez et al., 2005). Cost risks evaluated included real estate acquisition cost and local economic growth (USACE, 2019). Schedule risks considered included availability and timing of project funding, as well as the amount of time required for coordination with local stakeholders given the amount of existing infrastructure within the project footprint. Policy risks considered included site contamination and land acquisition (USACE, 2019). No risks specific to NNBF implementation success or effectiveness were considered, which is notable given the comprehensive risk analysis considered for other aspects of the project and that tools for evaluating NNBF risk was previously identified by the EWN leads as a gap and potential enabler of accelerating NNBF implementation.

The South Platte portion of the GI study was evaluated in a previous Institute study focused on identifying benefits that could be included in alternative evaluation, along with mechanisms of monetized and non-monetized benefit quantification and evaluation (Fischbach et al., 2023b). Ecosystem service benefits considered in that study included recreational use, flood risk reduction, habitat creation, and property value increases. The Institute estimated monetized value of recreational use and natural capital, which was used to recalculate the BCR for the Recommended Plan #9 (estimated BCR of 0.42) as well as for an additional alternative (plan #12, estimated BCR of 0.42). Benefits identified that could not be effectively monetized in the Institute study due to lack of study-specific data (and thus were excluded in the updated BCR) included property value increases associated with ecosystem restoration. Specifically, overall improvements to the South Platte River in downtown Denver (i.e., not limited exclusively to the USACE project) could generate $18 billion in increased property values (Doedderlein & Binnings, 2017). The Institute also noted that relocation of infrastructure along the river as part of ecosystem restoration would lower the associated flood risk, and benefit that was not possible to monetize in the BCR reevaluation (Fischbach et al., 2023b).

Weir and Harvard Gulches: Flood Risk Management

The primary objective identified for the Harvard and Weir Gulch reaches was reduction of flood risk to life, safety, property, and infrastructure, with ancillary objectives to restore habitat if possible and provide incidental recreational benefits. Initial formulation of alternatives for Harvard and Weir Gulches consisted of the identification of 20 flood risk reduction measures (USACE, 2019). This initial array for Harvard Gulch included structural (i.e., modification of flood extent through channel modifications, barriers, or stormwater storage) and non-structural (i.e., modification of structures or behaviors to reduce flood risk) measures, as well as those explicitly identified as ecosystem restoration and recreational enhancement. NNBF considered included wetland benching, wetland and riparian plantings, and noxious plant replacement as ecosystem restoration measures. Opportunities to couple ecosystem restoration with structural measures to restore tributary flow (such as increasing the size of culverts or enlarging flood channels) were also considered. A similar array of measures, also comprised of structural and non-structural measures as well as ecosystem restoration and recreation measures, was developed for Weir Gulch. NNBF included in the Weir Gulch measures included wetland benching, wetland and riparian plantings, and noxious plant replacement, as well as FRM measures with NNBF or green/gray factors such as restoring flow and creating backwater/oxbow wetlands. The measures for each site were combined into a set of alternatives that were evaluated against the NED standard using benefit-cost analysis. For each tributary, four alternatives were developed: Alternative 1, no-action case; Alternative 2, improvements to the flood channel coupled with opportunities for ecosystem restoration, where possible; Alternative 3, nonstructural measures; and Alternative 4, which combined elements of Alternatives 2 and 3. The economic benefits of the alternatives were calculated using the Hydrologic Engineering Center Flood Damage Analysis model HEC-FDA for monetizing the benefits associated with flood risk damage reduction (Davis & Burnham, 2000).

Only the non-structural alternative—comprised of building floodproofing and elevation, as well as acquisition of highly at risk properties—was found to be economically justified at Harvard Gulch, therefore NNBF were not included in the Recommended Plan (USACE, 2019). NNBF and ecosystem restoration opportunities could potentially become feasible in the future at sites included in the non-structural alternative if property owners opt to take advantage of voluntary buyouts. For Weir Gulch, multiple plans were found to be economically justified (BCR greater than one), with the structural plan found to have the highest BCR. USACE conducted additional optimization to refine elements of the plan such as the channel size and degree of culvert modifications, and identified recreational opportunities that could be incorporated such as site amenities and trail enhancement. The Recommended Plan included expansion of culverts, widening the river channel, and regrading the river slopes, with potential for NNBF including designing upper portion of the regraded slopes to accommodate native trees, shrubs, and grasses in some areas and incorporating wetland plantings along the bank where possible, such as in City-owned parks (USACE, 2019). However, the project as designed was not "expected to result in cumulative improvements or impairments to aquatic habitat in or beyond the study area" (USACE, 2019).

B.2.2 Natural and Nature-Based Features: Southern Platte Valley Section 1135 Study

Studies conducted under the WRDA 1986 Section 1135 authority have differing cost-share requirements and funding limitations than specifically authorized Feasibility Studies like the GI effort described above. The cost of a study completed under the Section 1135 authority is typically 100% federal for the first $100,000, then a 50/50 split between USACE and the local sponsor (WRDA, 1986). A waiver was approved for South Platte to allow for a 50/50 split of study costs between USACE and CCD, however, and a Feasibility Study Cost Share agreement including that stipulation was signed in 2016. As a Section 1135 study, the primary purpose of the Southern Platte Valley study was ecosystem restoration, but recreational features could be considered if designed to enhance visitor experience of natural features without diminishing the ecosystem restoration value of the project (USACE Omaha District, 2018). Alternatives formulated under the study also could not increase flood risk to the local community.

The Southern Platte Valley Section 1135 study was completed by the USACE Omaha District in 2018 (USACE Omaha District, 2018). The Section 1135 study and the South Platte ecosystem restoration area of the GI study following similar alternative formulation and evaluation approaches. Because the studies were authorized separately, explicit consideration of potential project synergies or interactions in alternative development such as the cumulative benefit that could be accrued from the projects was limited. However, the GI study did highlight that together the projects identified under the Recommended Plans of the two studies would result in restoration of an 11 mile long segment of the South Platte river, leading to overall ecosystem benefit (USACE, 2019), and the Section 1135 study was formulated with explicit recognition of the importance of connectivity and compatibility between projects recommended therein and those in the GI effort (USACE Omaha District, 2018).

The identified objectives for the Section 1135 study were to restore in-channel habitat complexity and connectivity, as well as restore riparian and wetland habitat adjacent to the river. There were several constraints, however, several of which could potentially impact the scope of NNBF considered. The area along the river in the region of study is completely urbanized, and the project could not increase flood risk or lead to other negative socio-economic impacts. Extensive infrastructure is in the area, as well, including large sanitary sewer lines running along the river channel; utility and natural gas lines the cross the river under existing drop structures; and bridges across the river. The cost and feasibility of relocating this infrastructure was identified as beyond the scope of the study. Other considerations identified included that high real estate values would make land acquisition challenging; hazardous, toxic, and radioactive contaminants could be found in the area; and downstream impacts must be considered given the limited spatial reach of the target area (USACE Omaha District, 2018).

The Section 1135 study began with identification of measures in coordination with CCD and with input from other partners including USFWS, Colorado Parks and Wildlife, and the UDFCD. These measures included 22 site-specific measures comprised of NNBF such as modification of in-river drops and other aspects of channel flow to improve fish passage and otherwise improve aquatic habitat; relocation of roads or structures and/or other bank modification to increase or improve riparian and wetland habitat; rerouting of the channel; revegetation; and acquisition of water rights for increased control of river flow (USACE Omaha District, 2018). This initial array was screened for completeness, effectiveness, efficiency, and acceptability, leading to several measures being removed due to funding or other feasibility constraints, such as the known presence of contaminants. A final array of measures was then combined into site-specific alternatives, including FWOP. Three alternatives were subsequently eliminated based on technical feasibility or concerns of conflict with City safety regulations, leading to a final array of 17 site-specific alternatives spread across three spatial reaches in the study area (USACE Omaha District, 2018).

These alternatives were evaluated for incremental cost and benefit in terms of habitat units using the USACE IWR CE/ICA tool, as well as FACWet and FACStream models for evaluating the ecosystem restoration benefits of the measures and alternatives where appropriate (FACWet for those alternatives impacting wetlands; FACStream for those alternatives impacting aquatic habitat; and both for alternatives impacting both). Cost estimates were also developed by USACE for each of the alternatives, which determined that all 17 alternatives could not be implemented given the cost constraints of a Section 1135 project; however, several alternatives for specific reaches were also mutually exclusive (USACE Omaha District, 2018). The CE/ICA tool evaluated 8,424 different combinations of alternatives, with 65 alternative combinations found to be cost effective (not superseded by incremental cost of other alternatives). These alternatives were formulated into 11 “best buy” plans plus the FWOP alternative. The first “best buy” plan was identified as the alternative with the lowest incremental cost per habitat, with larger cost-effective alternatives then benchmarked in terms of increases in cost and habitat unit output;

under USACE policy, any best buy plan is potentially eligible for selection as the Recommended Plan (USACE Omaha District, 2018).

Based on this analysis, a Recommended Plan ("Plan 10") was selected. Plan 10 includes restoration of 8,196 ft of aquatic habitat (22.01 acres), along with 10.82 acres of riparian and 1.49 acres of wetland habitat and was estimated to completely satisfy connectivity objectives for in-stream habitat. NNBF are also included as part of enhancements of existing habitats, namely the construction of weirs and riffle ramps to facilitate fish passage over existing river drop barriers as well as the development of low-flow side channels providing oxbow habitat adjacent to the main stem of the river (USACE Omaha District, 2018). There were two other best buy plans that were projected to result in slightly greater benefit in terms of habitat unit creation (12.91 and 12.92 habitat units, vs. 12.88 habitat units for Plan 10), but the incremental cost to incremental output of these plans was significantly higher ($211,670 and $3,757,000 compared to $92,480 for Plan 10). Recreational features included to enhance visitor experience of the natural environment include the installation of an elevated boardwalk to reduce damage to the restored area, educational signage, and construction of an overlook over the Harvard Gulch outfall to the South Platte River, which will also be set back and modified for aesthetic improvement (USACE Omaha District, 2018).

B.2.3 South Platte River and Tributaries: Funding, Engineering and Design, and Implementation

The South Platte River and Tributaries project was authorized under WRDA 2020, with dual authorization under ecosystem restoration and flood risk management (WRDA, 2020). Consistent with the Feasibility Study, the primary objective of the 6.5 miles of the project along the South Platte river is ecosystem restoration with a secondary benefit of flood risk management. Conversely, flood risk management protection is the primary objective for both Weir and Harvard Gulches, with an ancillary recreational benefit for both sites and ecosystem restoration as a secondary benefit for Weir Gulch. The CCD submitted a Memorandum of Understanding agreeing to a federal cost share of $344,076,000 and a local sponsor cost of $206,197,000, for a total projected project cost of $550,273,000 (CCD, 2022).

A partnering agreement was signed between USACE and CCD in May 2023, including an implementation plan that allows for construction to occur in stages by river reach (Department of the Army & CCD, 2023). The project was identified for inclusion in a Public-Private Partnership (P3) Pilot Program, wherein CCD would incur construction costs and be subsequently reimbursed by USACE. This program is intended to reduce costs and accelerate implementation of Civil Works projects (USACE, 2023). CCD will design and construct the project while satisfying all applicable legal, permitting, and implementation requirements, with USACE providing approval of project plans, periodic inspections, and approval of the as-built projects (Department of the Army & CCD, 2023). Project construction at South Platte and the Weir Gulch reaches are targeted for completion in 2053, while Harvard Gulch is targeted for completion in 2043. The project will be constructed in segments, allowing for CCD to be reimbursed for the federal cost-share portion as segments are completed. Consistent with USACE policy for monitoring and AM of ecosystem restoration projects, USACE will be a cost-sharing partner on those activities for ten years following completion of construction of the South Platte project (USACE, 2019).

Monitoring of completed projects will be cost-shared for the first ten years by USACE and CCD, with expenses estimated as $705,000 for the first 5 years and then $38,000/year thereafter. All costs for operation and maintenance of the ecosystem restoration measures for the South Platte river must be covered by CCD, with an estimated total cost of $7,126,000 and $6,341,000 for the first and second 5-year periods post-construction (Department of the Army & CCD, 2023; USACE, 2019). Potential AM approaches that might be required were identified by USACE at an estimated cost of $23,536,00 in the first 10 years, which could be cost-shared between CCD and USACE (USACE, 2019).

B.2.4 Natural and Nature-Based Features: Other Related USACE Studies and Projects

The focus of this case study is on USACE-led efforts that have incorporated consideration and implementation of NNBF in the Denver region of the South Platte River over the last 10 years. However, several older and related regional studies and projects are illustrative of additional challenges and opportunities in NNBF implementation.

USACE was authorized to conduct a GI assessment of ecosystem restoration opportunities for the Denver County Reach of the South Platte River in 2000 under House Document 669. Restoration alternatives for this study focused on a reach of the river including the Zuni Power Plan and led to Chief's Report in 2003 recommending an alternative that included removal of a low head dam that was impeding flow; modification of channel banks and trail relocation; revegetation; and construction of pools and riffles to improve aquatic habitat (Flowers, 2003). Per USACE the "Denver Zuni GI…was locally implemented", although details of the specific restoration done were unavailable (USACE Omaha District, 2018).

USACE also conducted a WRDA 1986, Section 1135 study referred to as the "Colfax 1135 project", which was constructed in 2002. This effort focused on a 3,000 ft segment of the South Platte River approximately 4 miles downstream of the Southern Platte Valley Section 1135 study (WRDA, 1986). NNBF and ecosystem restoration implemented under this project included widening the channel, building wetland benches, plantings, and improvement of aquatic habitat four hydraulic structures and low-flow channels (USACE Omaha District, 2018).

The Chatfield Storage Reallocation Project is being developed upstream of the study area but will impact flow conditions to the site. The Chatfield Dam and Lake Project was originally authorized under the Flood Control Act of 1950 and was constructed in 1967 (*Flood Control Act*, 1950). Over time, additional legislation was passed authorizing dam operations under multiple objectives, including recreation, fish and wildlife habit, and water supply (USACE Omaha District, 2013a). The Chatfield Storage Reallocation Project was the result of a Feasibility Study authorized under the Omnibus Appropriations Act of 2009 and completed in 2013. The study was designed to address objectives related to water supply, flood control, and recreation, along with avoidance of negative environmental impacts. The recommended alternative and project being constructed includes an additional 20,600 acre-feet of new water storage, with 2,100 acre-feet for storage designated as an environmental pool to be released during low flow conditions to support downstream South Platte River aquatic and riparian habitat needs (USACE, 2019). This effort was authorized by USACE and implemented by the Chatfield Reservoir Mitigate Company (https://chatfieldreallocation.org/about/crmc/), with the Colorado Department of Natural Resources as the local sponsor and multiple town and municipal water providers serving as partners. The impacts of this project were considered in developing the FWOP projections for the South Platte River and Tributaries

Feasibility Study, and the potential impact on the area was also noted for the Southern Platte Valley Section 1135 study (USACE Omaha District, 2018).

B.2.5 Challenges and Opportunities

Prior Institute evaluation of the South Platte River portion of the USACE Feasibility Study identified several challenges and opportunities for NNBF implementation (Fischbach et al., 2023b). First, it is difficult to fully quantify and valuate some of the benefits associated with NNBF and green/gray infrastructure. USACE studies must be conducted within the authorized funding and timeframe for the project using certified planning tools and models. Even without those constraints, however, data were unavailable to robustly monetize some benefits identified by the Institute study, such as property value increases associated with river habitat restoration. It was similarly challenging to quantify the benefits of a targeted ecosystem restoration effort that, along with other efforts in the area, could lead to widespread regional benefit in the context of extension other restoration projects and plans led by USACE, CCD, and other stakeholders. This issue is particularly challenging in the case of an area like the South Platte River in Denver, where partners outside of USACE have been approaching ecosystem restoration through an approach grounded in smaller projects leading to greater cumulative and widespread benefit.

The prior Institute analysis focused on calculation of a BCR, whereas the USACE Feasibility Study used cost-effectiveness to identify the Recommended Plan for the South Platte River. Together, these analyses highlight an additional challenge inherent to consideration of NNBF in USACE Feasibility Studies, namely that different evaluation methods are used for alternatives evaluated against the NED vs. NER accounts. Authorization as single-purpose projects can limit consideration of NNBF that often provide multiple types of benefits, and even in cases of dual authorization it can be challenging to fully integrate the two methodologies (BCA and cost effectiveness). The Institute study proposed multi-objective decision analysis as an opportunity to overcome this challenge (Fischbach et al., 2023b), which the MsCIP study (described above for Deer Island) illustrates can be effective in developing projects if, as was the case for that study, the authorizing language allows for it. The original USACE study at South Platte did consider multiple objectives in alternative formulation, although in that case either NED or NER was identified as the primary objective each spatial area.

Several additional challenges and opportunities were identified during the current case study assessment of the South Platte River and Tributaries study. One specific cost that was identified by USACE as a key limiting factor precluding consideration of NNBF for floor risk management in Harvard and Weir Gulches was real estate. To be effective in providing floodwater storage and supporting flood risk reduction, NNBF such as marsh and riparian restoration require more spatial area for implementation than gray infrastructure measures. The corresponding benefits provided as recreational use, property value enhancements, increases in water quality, and other ecosystem services may be insufficient to justify the associated real estate costs. This challenge may be particularly acute for benefits that are difficult to monetize due to lack of data or methods that fit within the constraints of USACE study timelines, and/or that are inherently difficult to monetize (e.g., community cohesion and sense of place benefits associated with the aesthetic value of NNBF, or an increase in property value that may be more significant for low-income property owner compared to the same dollar-for-dollar increase in property value for a higher-income property owner).

As was the case for Deer Island, the local sponsor and stakeholders for South Platte strongly support ecosystem restoration. These entities have spent decades coordinating with USACE and each other to develop plans and projects for ecosystem restoration and, by extension, incorporation of NNBF in river management. This finding reinforces that there is an opportunity to accelerate NNBF in practice through regional coordination and partnering, including with USACE playing various roles in supporting project partners. However, funding limitations or other constraints can present challenges within these partnerships, such as the need for funding to be allocated to support construction of USACE projects authorized under Section 1135 and other continuing authority programs ("The Denver Story," 2022). Project construction costs may be reduced and timelines shortened if a partnering agreement can be reached for the local sponsor to pay for implementation up front and be reimbursed by USACE (USACE, 2023), as is being done for implementation of the South Platte River and Tributaries GI study. However, not all local sponsors would have the funds or in-house capacity to lead implementation of NNBF.

As was also the case for Deer Island, multiple USACE authorization and funding mechanisms have supported evaluation of NNBF within the geographic area of the South Platte River, namely Congressionally authorized Feasibility Studies and a Section 1135 environmental restoration project under the Continuing Authorities Program. This reality reflects that there are multiple opportunities for consideration of NNBF, each with its own limitations and constraints that may limit holistic evaluation of alternatives that include NNBF. For example, some measures considered under the Southern Platte Valley Section 1135 project were excluded based on the funding constraints of that authority, while the spatial focus of the GI study did not include the same spatial extent. Similarly, the upstream Chatfield Storage Reallocation Project could potentially benefit and interact with ecosystem restoration and flood risk management measures taken for reaches of the river in Denver. Separate authorizations, combined with the already complex requirements of that project to balance multiple objectives and consider downstream impacts across a large spatial area, would have made evaluation of integrated alternatives considering flow regime and local restoration exceedingly challenging under the existing authorities. In contrast, the MsCIP study was authorized as a comprehensive study with fewer constraints, allowing Deer Island restoration and other NNBF approaches in that study to be considered holistically as multiple components in an interconnected system.

B.2.6 Enablers

Several enablers identified through the case study of Deer Island are relevant to South Platte. First, Districts and their partners can leverage multiple authorizations and funding mechanisms to enable the design and implementation of NNBF, including Congressionally authorized Feasibility Studies as well as continuing authorities like Section 1135. However, comprehensive studies that enable regional and holistic evaluation of benefits across multiple objectives can provide substantial benefit in supporting innovative NNBF approaches. For example, a comprehensive study authorized to consider flood risk management, ecosystem restoration, recreational use, and water supply for the South Platte River watershed could potentially consider a wider range of alternatives for the watershed than has previously been evaluated, with measures spanning from reservoir management through local ecosystem restoration and the implementation of green/gray infrastructure. This type of approach would be analogous to an inland version of a coastal comprehensive study like MsCIP, which incorporated Deer Island into a "multiple lines of defense approach." In this case, multiple measures and approaches in a large spatial footprint could be considered as part of holistic watershed management.

Next, the studies conducted for South Platte illustrate the importance of planning tools that can evaluate the benefits of NNBF as an enabler for their implementation. The South Platte River and Tributaries GI study and Southern Platte Valley Section 1135 study both used the FACWet and FACStream tools that were developed by the Colorado Department of Transportation for Colorado to evaluate wetlands and aquatic ecosystem habitat under FWOP and alternatives. The development of similar tools for other watersheds, as well as the certification and use of similar tools developed for other regions by partners, would enable methods used by the USACE Omaha District for evaluation NNBF benefits to be used in other locations. Similarly, adding NNBF measures to existing planning tools could also support more widespread consideration and implementation. For example, the studies conducted for the South Platte River relied on USACE-certified tools for evaluating the benefits and risks of structural and non-structural alternatives, including HEC-FDA for projecting and calculating flood damage reduction and CrystalBall Software Package for estimating risk, but these tools do not allow for similar evaluation of all types of NNBF.

As was the case for Deer Island, the South Platte study also highlights partnering and collaboration as a significant enabler of NNBF. USACE has partnered with CCD and other stakeholders to evaluate and implement ecosystem restoration for the South Platte River for decades, underscoring the importance of District personnel participation and engagement in regional planning initiatives. Coordination with partners is also a potential mechanism for addressing one significant challenge to NNBF implementation in urban settings, namely the cost of real estate required for the projects themselves. Land that is already owned by municipalities or that could be acquired as park land or green space by the city or non-governmental organizations, for example, provides opportunities for implementation of NNBF for more modest costs. This opportunity could be further catalyzed by project authorization and evaluation that allows for greater consideration of the ancillary benefits of NNBF such as recreational use, which would be consistent in many cases with desired outcomes of local partners for land use. Lastly, an additional enabler for NNBF in USACE working with partners is the development of reliable, streamlined funding mechanisms to support construction. As noted above, the South Platte River and Tributaries GI study is part of a pilot program allowing local sponsors to incur the initial cost of project implementation and be subsequently reimbursed by USACE. In comparison, a cost-sharing agreement has not yet been reached to implement the alternative identified in the Section 1135 study completed a year earlier, which must be funded through the continuing authorities program on the federal side. Reliable federal funding streams for projects that incorporate NNBF would streamline their implementation, particularly in cases of underserved communities where local sponsors and stakeholders may not have sufficient capital to fund the entire cost of the study and be reimbursed for the federal share.

APPENDIX C. WORKSHOPS

The Water Institute (Institute), in partnership with the Engineering With Nature® (EWN) Program and other USACE entities, organized and hosted three virtual workshops. The first two were designed to elicit input from a broad array of experts that was then synthesized by Institute personnel. The third workshop was held to receive input from USACE EWN practitioner leads on these draft outputs, along with findings from the case studies. Input from this final workshop informed the synthesis of challenges, opportunities, and enablers for accelerating NNBF in practice found in this report.

In the course of this work, the Institute became aware of complementary work being undertaken by IWR, including a workshop entitled “USACE Vision for Nature-based Solutions” held in July 2023. Findings from that workshop were shared and discussed with Institute staff and the key actions identified in the IWR workshop were considered and are consistent with the specific opportunities and enablers identified in this report. The Institute continued to coordinate with IWR staff in the drafting of the findings of this report, including but not limited to IWRs involvement in all three sensing workshops, to leverage synergistic activities and include relevant information previously collected through their own activities.

C.1 WORKSHOPS 1 AND 2

The first two 4-hour virtual workshops were designed to elicit input on challenges, needs, and opportunities for accelerating NNBF implementation in practice as outlined in this report. The first workshop, held on September 11, 2023, focused on challenges and opportunities in implementing nature-based solutions for coastal systems. The second workshop, held on September 18, 2023, focused on inland waterways.

A total of 84 experts and thought leaders spanning a diversity across key disciplines, sectors, and perspectives, both within the federal government and externally (e.g., academia, state and local governments, non-profit agencies) were invited. USACE EWN practitioner leads, other District personnel, and individuals with relevant expertise on the EWN challenges in practice provided information on needs and practical opportunities for accelerating EWN implementation in practice.

Participants were first invited to provide input utilizing the Mural© online whiteboarding tool by planning stages (study authorization and scoping, alternative formulation and evaluation, Recommended Plan selection and Assistant Secretary of the Army/Office of Management and Budget review and approval; Table C-1, Table C-2, Table C-3) and implementation stages (project engineering and design and construction, and operation and maintenance or AM; Table C-4, Table C-5) of projects. Participants were also invited to provide input that may be specific to projects in inland waterways, coastal habitats, or beneficial use/regional sediment management. More than 170 comments were received regarding challenges and more than 110 comments were received regarding opportunities, with most comments falling into the “general category of each stage of a project. During the workshops, groups then were invited to discuss the written input provided to elaborate on identified challenges and opportunities. Themes emerged from the input received as highlighted below.

Input received during the two workshops. During the workshops, participants were given the opportunity to provide written input on a Mural Board. This was followed up with group discussions of that written input. The information in the tables below has been further organized and, in some cases, paraphrased from what was written by participants on the Mural Board based upon those group discussions.

Table C-1. Study Authorization and Scoping

Category	Challenges	Opportunities

General	• Study authorizations limit scope
	  o GI vs. CAP – GI generally allows for more flexibility (scope, schedule & budget) to consider NNBF than CAP.
	  o GI authorities can be designated as multipurpose, CAP projects are inherently simpler, so options are more confined.
	  o Sometimes authorizations are general, but point to geographic areas and objectives (e.g., CSRM) that drive teams to formulate features more robust than NNBF.
	  o Funding pots can silo study teams into storm risk management only if funded under FRM.
	  o Legislators may limit scopes of authorizations as a way of limiting discretion within agencies and increasing ability to maintain oversight. (SAJ (Jacksonville District) has examples of limitations induced by study authority).
	• Narrowly defining project at scoping stage
	  o Teams sometimes feel that language in authorities sometimes limits their options.
	  o Modifications to existing CSRM/FRM projects are perceived to be limited, precluding consideration of NNBF.
	  o Geographic scope
	    ▪ Study focus on project footprint rather than larger system (e.g., embayment, riverine reach) limits evaluation of impacts
	    ▪ Individual CSRM project authorizations vs. Watershed authorities
	    ▪ Sometimes there are permitting challenges because of lack of support from Federal agencies to allow NNBF on existing habitats regardless of current value and health.
		• Change project authorization approaches.
		  o Include language that may not explicitly identify FRM as the only purpose. Language like "other allied purposes" is often included in study authorizations to steer project to NNBF considerations.
		  o New Jersey Dredged Material Management study and NJ DMU study are good examples of studies with one authority that were able to be discussed under different funding programs including CSRM and AER.
		  o GI authorities can be specifically designated as multipurpose, or at least allow the study team to pick which features of the project will follow NED/ BCA process and which will follow CE/ICA and NER process. (e.g., Adams and Denver Counties, GI, the sponsor really pushed for this, but how can we get more studies set up like this even without sponsor asking specifically for it?).
		  o Identify a USACE-wide authority to accelerate NBS adoption in civil works projects (e.g., BUDM 70/30 rule).
		  o Modify PL84-99 to overcome the "like for like" rebuilding directive.
		• Widening scope
		  o Identify study scopes that may need greater than three years to complete and make early requests for additional time and/or budget.
		  o Better understand and communicate about NNBF benefits.
		    ▪ Recognize the engineering benefits of NNBF as more than environmental add-ons.

Category	Challenges	Opportunities
	○ Focus on low frequency events vs. higher frequency events that NNBF may be particularly effective at mitigating. NNBF deemed 'juice not worth the squeeze' when the focus is on lower frequency events. ○ Inclusion of recreational features varies by authority. • Perceived 3x3x3 rule constraints ○ Scoping often focuses heavily on funding and time constraints. ○ Funding constraints ▪ Limit ability to develop new tools (e.g., new approaches/technology or strong conceptual models) or other evaluation methods within a given study. ▪ Multi-faceted projects increase cost, sometimes beyond limits of budget. ▪ NNBFs may be screened out early in the process due to perceived or actual costs. ▪ Sometimes there is a cost limitation within existing partnerships. ○ Timing constraints limit ability to research benefits that are not already understood. Default is conventional approaches and structural measures. • Knowledge inconsistencies and inertia ○ Differing understanding between Districts/Study Teams regarding options available to teams to consider NBS. ▪ Not infusing study teams with new staff or other input from outside of USACE may limit innovations in thinking. ▪ Some Districts have examples of successfully incorporating NNBF (e.g., NJ DMM study; MVN (New Orleans District); Mobile District), while	▪ Provide a clear definition of how NNBF qualify as either structural and/or nonstructural measures. ▪ Consider multiple benefits that EWN can provide. ○ Foster a culture of innovation. ▪ Reward experimentation ▪ Bring in growth-minded thinkers into project teams and give them equal voice. ▪ Engage NNBF concepts from the beginning of the project. ▪ Empower project teams to trust their judgement to make good decisions. ▪ Develop objective statements that may advance through time (e.g., pursue higher levels of protection through time). ○ Provide a "systems" view. ▪ Incorporate reviewers on each team tasked with the "systems" view and connect comments of multiple reviewers. ▪ Seek examples of systems thinking (e.g., Rockefeller Foundation's city resilience officers) • Expand knowledge and tools ○ Provide more explicit guidance and training ○ Consider pilot projects and mechanism(s) for incorporating that knowledge into future studies. ○ Cultivate interest in alternative methods from Corps and partners.

Category	Challenges	Opportunities
	others feel there are constraints that cannot be overcome at the present time. ○ Challenges for existing projects to shift objectives through time or do something different. ○ Challenges of making decisions with many metrics vs. a few may drive teams toward simplifying the scope.	○ Look to guidance currently being developed by EWN for E&C (engineering and construction). • Engage and consult with experts outside of USACE ○ Utilize local sponsors for their technical and political expertise. ○ Engage tribal partners for traditional ecological knowledge (TEK) ○ Update tribal consultation practices to better incorporate or honor local knowledge and practices. ○ Stakeholders' engagement: ▪ Meaningfully include stakeholders in study scoping/alternative development. ▪ Engage early and often throughout the process to clearly identify problems, opportunities, and objectives. ○ Create multiple groups with people internal and external to USACE to work together to overcome obstacles. ○ Include NNBF/EWN subject matter experts in the scoping teams.
Inland	• Regulatory disincentives to having NNBFs in flood control channels because of operations & maintenance issues. • Inland waterways are Federal responsibilities.	• Look beyond USACE for guidance that could be helpful (e.g., PIANC report focused on bank stabilization).
RSM/BU	• Authority issues ○ Federal Standard ○ State requirements • Scoping issues ○ The concepts of RSM and BUDM are navigation centric. There is a need to proactively identify sand	• Sand solutions have traditional NED benefits; infuse this knowledge into study teams • Information Improvements ○ Improve understanding of available sediment volumes, sediment characteristics, and timing/frequency

Category	Challenges	Opportunities
	resources to support NNBFs in a way that supports future BUDM considerations that are innovative and out of the box. ○ BUDM is often focused at the project level rather than the system level. • Timing and cost issues ○ Difficulty lining up dredging, funding, timing, and locations for beneficial use. ○ BUDM project scoping needs to be far in advance of maintenance dredging. ○ Transport costs from suitable locations can be prohibitive. ○ Costs can be viewed in a narrow perspective, leading to least cost alternative as offshore disposal. • Information issues ○ Limited investment in sand resource identification. ○ Studies may not account for additional material under BUDM 70/30 initiative when identifying potential sediment sources. ○ Lack of awareness that dredged sediments are available and can be used as a natural resource to aid flood risk reduction. ○ Challenges of quantifying benefits over 20- and 50-year horizon. ○ Incomplete reports or incomplete transfer of information (e.g., Fate of fine-grained sediment study that was intended to expand the use of BUDM as well as higher fine-grained sediment from borrow areas in FL).	○ Improve or develop tools to help planners line up dredging cycles, BUDM placement locations. ○ Identify and inventory sediment types and quantities anticipated from dredging cycles for greater ease in incorporating into CSRM/FRM/ENV/NAV (navigation) studies. ○ Important to identify locations and characteristics of sediment that could support NNBF construction. • Partnering ○ Proactively identify and work with project partners that may support BU. ○ Find mechanisms for regional/national working groups to collaborate with to address obstacles. ○ Integrate planning teams with dredging operations teams. ○ Review success stories for additional opportunities (e.g., there are several project and programmatic examples of interagency partnerships on Texas projects). • Broaden Scope ○ Think in a system-wide context for the 70/30 goal. ○ Phase CSRM measures to enable increased BU
Coastal	No unique comments	No unique comments

Table C-2. Alternatives Formulation & Evaluation

	Challenges	Opportunities

General	• Information/tools constraints
	  ○ Lack of tools to calculate costs and full range of benefits of NNBF.
	  ○ Insufficient models for specific priority species and habitats to quantify outputs associated with NNBF.
	  ○ Existing tools are often not integrated, leading to increased time and cost of evaluations.
	  ○ Still a new topic so there is not a surplus of information available to study teams to understand how they could incorporate NBS into their scope.
	  ○ NNBF may be screened out early in the process due to actual or perceived costs relative to benefits.
	  ○ Insufficient certified models to account for ecosystem service benefits/co-benefits in BCA for CSRM/FRM projects.
	  ○ Lack of comprehensiveness of NBI economics.
	  ○ Uncertainty over future climate risks (e.g., drought, accelerated sea level rise, increased storm intensity) adds significant cost and uncertainty with respect to performance and permanence of alternatives.
	• Study set up
	  ○ Limiting geographic scale of the study leads to specific project impacts not being understood at the system scale.
	  ○ Engagement structures may not accommodate sufficient input, limiting the range of alternatives considered.
	  ○ NED focus in CSRM/FRM projects drive alternatives formulation.
		• Improve tools, methodologies, information availability.
		  ○ Develop and inventory methods to quantify habitat value.
		  ○ Improve, develop, inventory models to quantify NER for CSRM/FRM projects (e.g., EcoFIP (ecological floodplain inundation potential).
		  ○ Review existing certified specialized models for applicability to cross-disciplinary solutions.
		  ○ Increase information exchange between Districts regarding successes and challenges of incorporating NNBF into projects.
		  ○ Learn from successes (e.g., research on mangroves, living shorelines, salt marshes NNBF benefits) and share information across study teams.
		  ○ Integrate artificial intelligence to consider solutions (e.g., incorporate models into alternatives development).
		  ○ Develop a USACE-wide way to monetize ecosystem service benefits.
		  ○ Develop clearer comparison of NNBF benefits, performance thresholds, etc. vs gray infrastructure (e.g., rip rap) to remove a barrier in getting to implementation (e.g., EM 1110-2-1601 updates for biotechnical bank stabilization would facilitate alt development).
		• Alternatives development and evaluation considerations.
		  ○ When developing alternatives, identify a suite of projects with aligned co-benefits.

	Challenges	Opportunities
	○ Considering NNBF as alternatives to structure features rather than complementary/redundant features sets up situation where they must be evaluated uniquely for their benefits and weighed against gray infrastructure. ○ Restoring projects to pre-disaster status should be revisited. Cannot expect different results doing the same thing over and over. • Time/cost constraints ○ Teams often feel constrained by the 3x3x3 rule. ○ Insufficient time and funding leads teams to remove some alternatives from consideration that may be more complex/uncertain. ○ Multi-purpose projects need modeling/evaluation beyond just qualitative assessments. If those tools do not exist/are not available (e.g., due to lack of certified models), the 3x3x3 rule often does not allow for development of necessary tools. ○ Study leads may be reluctant to risk schedule impacts for evaluating NNBFs. ○ Resources are limited to reliably calculate benefits of NNBF at the project site scale. ○ Cost increases must be balanced with increased benefits. ○ Real estate costs may limit study footprint, which often precludes inclusion of NNBF. ○ For spatially large projects that could also hold a large cost, address impacts on provisions of other goods and services (e.g., ecotourism) during the planning stage. • Risk assessments ○ Uncertainty re: performance of NNBF for CSRM/FRM goals increases risk.	○ For projects with larger footprints and multiple benefits, consider the true cost of gray infrastructure in comparison to the true cost of NNBF. Factor in real estate, feature construction costs of all the ecosystem services nature provides for free that we would otherwise have to pay for. Include the cost of gray failure and repetitive loss through inability to adapt. ○ Consider the environmental impacts of different actions (e.g., embedded carbon in concrete). ○ Consider NNBF as integral features in plan formulation rather than being restricted to environmental activities. ○ Address impacts of on provisions of other goods and services (e.g., ecotourism). • Encourage innovation ○ Rely on WRD 2016 Sec. 1184 which requires evaluation of NNBFs. ○ Consider the benefits of NNBFs as mechanism to address climate change. ○ Consider watershed level hazard mitigation planning with an eye to multi-benefits of NNBF. ○ Measure project benefits at multiple scales (i.e., project and system scales). ○ Consider ways to consider resiliency other than simply gray infrastructure. ○ Encourage study teams to recommend holistic solutions regardless of net benefits and or overall costs. Trust knowledge and experience of planners to find the best holistic alternative. ○ Consider alternatives that evaluate co-benefits of NNBF and gray infrastructure within a single alternative rather than evaluating them separately.

	Challenges	Opportunities
	o Increased risk of incorporating NNBF because of insufficient knowledge of performance against objectives. o Risk is easier to anticipate for gray solutions. Similarly, risk acceptance and tolerance may be lower for NNBF than for traditional measures. o Insufficient understanding of potential unintended consequences. o Lack of inclusion of “future without action” in the risk assessment sometimes leads to incomplete understanding of risk of incorporating NNBF. o Permanence or lack thereof of NNBF (especially coastal features such as wetlands and barrier islands) within the context of a 50-year project life may make these features appear to be too risky. o Reversibility of actions for both conventional infrastructure and NNBF is not well understood or quantified in studies. • Team composition o NNBF subject matter experts are often missing during plan formulation and evaluation phase. o Lack of team member (either USACE, Local Sponsor, other) to spearhead NNBF or at least to think outside of the box for developing and evaluating alternatives. o Moving beyond ‘status quo’ for methods and features is challenging for many teams. o Insufficient expertise to bring into study teams; need for training of engineers for these analyses. • Beyond study teams o Receiving permits can be difficult. o Lack of buy-in by vertical teams regarding the models for alternative assessments.	o For projects with multiple partners, divide tasks in a way that aligns with each group’s mission. More fully and meaningfully incorporate participation from other federal agencies to evaluate the full range of project benefits. o Use structured decision making and trade off analysis with a multidisciplinary and agency team to evaluate alternatives more fully. • Address other perceived limitations. o Consider potential time/cost constraints early in the study to determine whether requests should be made to go beyond this rule via Vertical Team Alignment Memos. Vertical Team Alignment Memos allow for a study team to appropriately scope their study to account for additional analyses needed for NNBF evaluation. o Work with educators (e.g., universities) to bring more awareness of NNBF and evaluation needs. o Ensure vertical alignment within the project review chain. o Cross-train staff (e.g., project delivery and review teams, ecosystem restoration staff, CSRM staff) to better understand benefits of NNBF. o Incorporate uncertainty into NNBF concepts by developing and evaluating a range of costs and benefits. • Broaden stakeholder engagement o Work with regulators, other agencies, and NGOs that may not have the same goals early and throughout process to address concerns. o Look for additional opportunities to engagement stakeholders (e.g., land grants).

	Challenges	Opportunities
	◦ Value engineering process may screen out more innovative alternatives. ◦ Technical and/or policy reviewers may ask for more details for NNBF than non-NNBF measures/alternatives.	
Inland	• USACE guidance for levees and channel projects (e.g., PL 84-99) does not allow for flexibility or creativity in incorporating NNBF. ◦ Specific example: vegetated riprap and allowing for natural vegetation of riprap is contrary to guidance to keep area “clean” for inspections. • Increasing sediment transport may increase turbidity and increase 404 compliance concerns. • O&M manuals (i.e., 205 projects) lack flexibility and framework for NNBF solutions.	• Seek partnerships outside of USACE (e.g., synergies with private landowners such as farmers who need NNBF benefits as well.
RSM/BU	• Regulatory issues ◦ Regulatory hurdles to beneficial reuse of sediment. ◦ Challenges of permitting timing and project clearance to stay in front of dredging opportunities. • 3x3x3 planning limits new sand resource evaluation during study phase and pushes it to PED. NNBFs that require sand therefore cannot be properly evaluated absent knowledge of sand sources. • BUDM alternatives for navigation Feasibility Studies generally must be least cost in order to be considered during the formulation phase. Very little design and quantification of benefits is done at this stage. • The size of BUDM projects is often too small for the large dredges needed for the channel.	• Proactively work with regulatory agencies to obtain permits in advance of dredging cycles. • Develop and inventory methods to quantify and evaluate the tradeoffs of sediment extraction. The true NER calculation would consider both benefits and impacts. • Find options other than simply cost to drive alternatives evaluation and selection. • Work with industry to find logistical solutions.
Coastal	No unique comments	No unique comments

Table C-3. Recommended Plan & OMB Process

	Challenges	Opportunities

General	• Ideas emerging from value engineering process do not get translated into solutions.
	• Few, if any, are successful in getting waivers to the 3x3x3 rule to complete the work needed to justify the preferred alternative if it is not the NED plan.
	• Certain policies may create a lesser benefit. When advocating for a new process or policy beware of unintended consequences.
	• Presentation and consideration of ecosystem benefits
	  ○ Project delivery teams often feel an aversion to recommending atypical plans because of concerns of lack of receptivity from the Vertical Team.
	  ○ Need better approach to assess ecosystem services. May be difficult to demonstrate that benefits of NNBF are worth the additional costs.
	  ○ Uncertainty how to balance CSRM/FRM benefits with ecosystem benefits when decisions are made based upon BCA.
	  ○ Perception that OMB does not give equal consideration to habitat value.
	  ○ The non-NED plan can be selected but seems to be discouraged.
	  ○ There are challenges in working with OMB regarding which agency executes a multi-purpose NNBF.
	  ○ OMB often is focused on uncertainty in lifecycle costs, leading teams to be overly conservative.
	  ○ Teams are required to identify plans that maximize benefits across all categories (NED, RED, EQ, OSE) but this is very new, and few projects have done this.
		• Review recent OMB guidance on natural benefits related to NNBF.
		• Pursue comprehensive benefits plan waiver.
		• Encourage teams to development plans across NED, RED, EQ, and OSE
		• Consider EJ benefits which may point toward greener solutions.
		• Ensure that local sponsors are able to provide examples of successful projects to increase USACE leadership support.
		• Develop a national database of costs and benefits of NNBF.
		• New PR&G agency-specific procedures should provide more flexibility to account for multiple benefits.
		• Utilize "future without action" to assess long-term benefits.
		• Provide for increased vertical alignment within the project review chain.
		• Provide cross-training for PDT and review team members to better understand benefits of NNBF.

Inland	No unique comments	No unique comments
RSM/BU	No unique comments	No unique comments
Coastal	No unique comments	No unique comments

Table C-4. Project Engineering & Design, Construction

	Challenges	Opportunities
General	• Design considerations ○ Insufficient in-house expertise to design or evaluate NNBF. ○ Insufficient means to share knowledge and successes across USACE. ○ Insufficient design standards or engineering manual for NNBF. ○ Few plans and specs to refer to for building/maintaining NNBF. ○ Uncertainty regarding environmental parameters such as future streamflow or water table height which will affect performance. ○ Minimal performance data of specific environmental properties (e.g., survival rates of vegetation). ○ Insufficient consideration of engineering benefits of natural solutions and consideration as part of mitigation. ○ Lack of availability of cost engineering data and tools for non-traditional materials. ○ ○ Permit delays due to insufficient detail for regulatory arms to confidently assess impacts. • Construction considerations ○ Insufficient number of trained construction contractors to work with ecological materials. ○ Lowest cost construction contracts may lead to contractors unfamiliar with methods. ○ Traditional accuracy in construction specifications may not be germane to natural systems. ○ Insufficient construction management guidance for NNBF.	• Guidance ○ Create centralized location for existing NNBF engineering guidance and mechanism for it to be certified for use in USACE projects. ○ Create new design manuals to assist E&D of NNBF. • Overcome real estate hurdles ○ Reduce construction footprint to allow for natural processes (e.g., allowing a river to propagate a headcut for river realignment) ○ Develop trust between USACE and local sponsor/community to avoid condemning land. ○ Expand use of non-traditional real estate mechanisms (e.g., new forms of easement or payment for ecosystem services frameworks). ○ Clearly understand and communicate the scale of the project early on. • Draw upon a variety of expertise. ○ Use “Industry Days” during the E&D to inform the plan and ensure constructability. ○ Incorporate landscape architects into the team. ○ Work with other entities with similar goals such as conservation groups and industry partners. ○ Engage Tribal Nations for incorporation of traditional knowledge. ○ Include construction experts on E&D team. ○ Partner with other federal agencies to fund/implement ecosystem restoration elements. Do a gap analysis of authorities and where there are gaps that none of the

	Challenges	Opportunities
	◦ Sourcing and vendors for NNBF materials is limiting. ◦ Higher uncertainty in construction costs for NNBF compared to gray infrastructure leads to imbalanced bids. • Real estate/landowner considerations ◦ NNBF often requires more real estate than traditional CSRM/FRM approaches, which can be a significant burden on the sponsor and/or local community. ◦ Landowner is required to have perpetual management of infrastructure. This has caused many NGO's/states/local sponsors to be averse to being long-term landowner of any floodplain projects.	partner agencies can fill, then brainstorm who can and invite them to the table. ◦ Work with IWR and Environmental Advisory Board to highlight where USACE policy conflicts with SME/state of the practice for NNBF and strategically seek policy updates.
Inland	No unique comments	No unique comments
RSM/BU	• Logistical issues. ◦ The size (footprint) of NNBF is often too small for the type of construction equipment to bring sediment sources to the site. ◦ Timing of dredging and sediment placement is not always coordinated. ◦ Consider smart borrow area use strategies and long-term use strategies that could facilitate meeting the 70/30 BUDM goal as part of CSRM. • Information considerations. ◦ Insufficient regional sediment management plans to strategically use borrow areas in a way the minimizes waste and reduces long-term costs. ◦ Geotechnical information needed to dredge often does not align with information needed for use in NNBF. This leads to missed opportunities due to increased cost and time. ◦ Insufficient ability to articulate and quantify benefits of BUDM	• Seek creative solutions. ◦ Consider ways to move material to reduce the cost of transport (perhaps via a value engineering workshop). ◦ Retain dredged sediment within the system to allow natural processes to engineer with nature. Some BUDM opportunities involve placing sediment within the river's footprint to help restore side channel habitat. ◦ Seek creative opportunities to place fill in a way that allows natural processes to refine the placement of material for ecological benefit. • Address information gaps. ◦ Characterize different sediment types for different uses (e.g., fine sediment for marshes, rock for reef restoration, sand for beaches, etc.). ◦ Develop tool(s) that can support matching BUDM sites with navigation dredging timing and locations.

	Challenges	Opportunities

	• Timing and cost considerations.
	  o Costs are usually a contributing factor in BUDM considerations. If it is cheaper to go to a disposal facility, that is the option chosen over BU.
	  o Mismatch between navigation requirements with RSM opportunities.
	  o Misalignments between dredging cycles and clearance/availability of BUDM sites (identification of sites, project development, obtaining permits).
		o Use the Regional Sediment Management program to monitor performance of projects and inform future design.
		o Complete development of regional sediment inventories.
		• Other timing and logistical considerations.
		  o Match BUDM locations with the right type of dredge for direct placement vs. offshore placement.
		  o Prepare sites early to allow alignment with dredging schedules.

Coastal	• There is sometimes a reluctance by resource agencies to allow for restoration even if the habitats are degraded.	• Work closely with all stakeholders, including other federal agencies, to address concerns and get buy in. • Seek examples of successes and share the information with others (e.g., existing hardbottom habitat offers unique opportunities to engineer with nature, especially of those habitats are degraded.) • Transitions from riverine to coastal offer ample opportunities to engineer with nature, especially employing hybrid designs when they are highly developed. • .

Table C-5. Operations & Maintenance; AM

	Challenges	Opportunities

General	• AM of NNBF
	  ○ Performance of NNBF in meeting CSRM/FRM objectives is not well understood, increasing risk of project.
	  ○ Incorporating AM into NNBF can be costly and more labor-intensive than for gray infrastructure.
	  ○ Need an AM framework and funding that allows NNBF implementation into the future.
	  ○ Including AM costs into overall project implementation costs is challenging. These costs are often the first to be cut when budgets are tight.
	  ○ Recovery period (or system performance) may not be realized within the time period allotted for AM.
	  ○ MAM (Monitoring and Adaptive Management) guidance is geared toward ecosystem restoration. Need MAM guidance on CSRM/FRM projects with green features.
	  ○ Guidance is unclear on where MAM ends and O&M starts with certain NNBF (e.g., living shorelines using rip rap).
	  ○ Views differ on what AM is; need clearer guidance.
	  ○ There are no MAM requirements for non-aquatic ecosystem restoration mission areas.
	• Operations & maintenance
	  ○ Guidance and authorities' considerations.
	    ▪ Lack of flexibility to adjust O&M where NNBF may be best (e.g., vegetated rip rap, allowing for some aggradation/deposition of sediment on systems with grade controls or protected toe).
	    ▪ Need better O&M manuals that have adaptability or flexibility for temporal and spatial considerations.
		• Generally, increase knowledge base and exchange of information.
		  ○ Build a database of existing monitoring and performance data to inform future efforts.
		  ○ Partner with non-traditional partners such as the Department of Commerce and Economics or Education. Build coalitions with community colleges, high schools, and trade schools for O&M training. Train the next generation to understand and accept the multi-benefit and need for NNBF.
		  ○ Improve ability to use lessons learned from aquatic ecosystem restoration MAM and M&M for other applications/mission areas.
		  ○ Consider funding ecosystem restoration as a cost share long-term investment.
		  ○ Whether gray or green, O&M and AM apply to features. But these aspects are generally better understood/predicted for gray infrastructure making it feel like an easier lift. Increasing understanding of performance of green features may help project teams feel more comfortable incorporating them into projects. (e.g., NNBF may seize on self-organizing capacity of ecosystems, which could reduce O&M through time).
		• AM:
		  ○ Consider mechanisms to fund future AM in the same way as periodic nourishment is funded in coastal projects.
		  ○ Conduct post-project monitoring to build an understanding of the benefits of NNBF.
		  ○ Use research & development funds to monitor performance of NNBF, both for engineering

	Challenges	Opportunities
	▪ Outside of beaches, USACE does not have maintenance authorization; therefore, maintenance responsibilities fall to the local sponsor. ▪ O&M funding for aquatic ecosystem restoration is different than other authorities in that it is limited in duration and mainly the responsibility of the nonfederal sponsor. ▪ Specifications in O&M manuals are unclear for nonfederal sponsors. ▪ O&M and continuing construction are different in CSRM vs. FRM. For CSRM, periodic nourishment is funded as continuing construction with different cost share and is almost a form of AM. FRM projects do not have these benefits. o Information constraints. ▪ Tools are inadequate to confidently understand maintenance needs, increasing long-term risk of the project. ▪ Lack of clarity whether funded repairs of CSRM projects allows for incorporation of NNBF into engineered dunes/beaches. ▪ Discrepancies in the authorized project nourishment frequency and volume needed for berm/dune projects and what is actually needed after storm impacts. ▪ Uncertainty over future climate risks adds significant O&M cost uncertainty for projects or features over a 50-year project life. ▪ Asset management plans are unclear for some NNBF. o Time and budget constraints	performance and any assumed ecosystem goods & services they provide. o Ecosystem restoration projects require MAM, but other mission areas do not. Require MAM for non-restoration features as well. o Adopt a culture of learning and innovation to facilitate incorporation of lessons learned. o Use a multidisciplinary and multiagency team in the development and implementation of MAM. o Link to ERDC staff for monitoring. o Use researchers in the development and implementation of MAM. • Operations & maintenance o Approach and guidance updates. ▪ Need a paradigm shift in thinking with respect to NNBF to cater O&M to the solution (e.g., vegetated rip rap vs. clean). ▪ Consider modifying O&M guidance that bridges construction, monitoring, and maintenance transition to nonfederal sponsor. ▪ Fund NNBF through CG (Construction General) accounts for cost sharing with nonfederal sponsor and continued maintenance. ▪ For aquatic ecosystem restoration projects that incorporate NNBF that also result in CSRM/FRM benefits, incorporating that aspect of the project into cost-shared monitoring could be used to help inform future CSRM/FRM NNBF. o Reduce O&M needs.

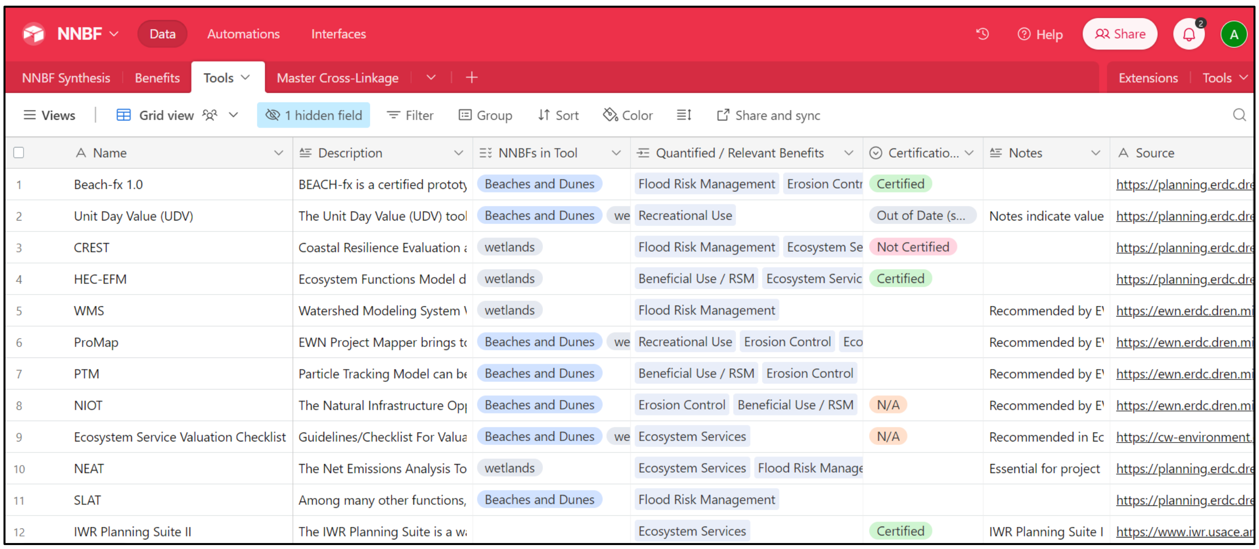
	Challenges	Opportunities
	▪ Long-term funding for modifying operations plans (e.g., water control manuals) are notoriously underfunded or delayed. ▪ O&M for aquatic ecosystem restoration is limited to 10 years for non-structural elements only. Other elements must be maintained by the nonfederal sponsor who may not have funds or staff needed to fully maintain features.	▪ Assess alternatives at the planning stage with respect to climate risks to help mitigate the risk of unanticipated long-term O&M costs. ▪ Address root of the problem (e.g., channel incision). ▪ Accept or expect site dynamicism as a project outcome. ▪ Better understand how and which NNBF may result in lower O&M needs and costs.
Inland	No unique comments	No unique comments
RSM/BU	[*Author's note: Comment on O&M in the context of beneficial use is referring to navigation channel O&M rather than that of the BUDM site.*] • Beneficial use alternatives for navigation Feasibility Studies generally must be least cost in order to be considered during the plan formulation stage. Very little design and quantification of benefits is done at this (O&M) stage. • Identifying sufficient and feasible BUDM placement sites can be problematic. • BUDM may be more costly than other forms of disposal and without another federal project to offset the cost, could impact the amount of material than can be dredged.	• For channels that require regular dredging, opportunities to manage BUDM placement adaptively exist. • Monitoring will greatly enhance our ability to manage dredge material placement adaptively. • Seek collaboration opportunities for dredged material placement. • Section 1122 Pilot Program allows a great opportunity to help demonstrate beneficial use placement.
Coastal	No unique comments	No unique comments

C.2 WORKSHOP 3

The third and final workshop was held with USACE EWN leads as well as staff from the USACE IWR to review all findings of challenges impeding the practical implementation of NBS; objectives and opportunities to accelerate NBS in practice; enablers for catalyzing those opportunities, and metrics for characterizing success. Information shared by the Institute in this final workshop is incorporated directly in this report and feedback from the USACE staff provided insight needed to refine the final content of this report.

APPENDIX D. USACE CERTIFIED BENEFIT QUANTIFICATION TOOLS FOR NBS

The database below (Figure D-1) is a very simple, early iteration of a more sophisticated tool that could support the acceleration of NBS and increase efficiency for USACE staff responsible for locating and using specific guidance documents, planning tools, and E&D models. A tool like this could cross-link to different types of NBS with information about specific environments and types of projects (including relevant phase for application). An automated tool could further support this enabler (e.g., Artificial Intelligence) by collecting and scanning materials and other documentation to streamline database population.



	Name	Description	NNBFs in Tool	Quantified / Relevant Benefits	Certificatio...	Notes	Source
1	Beach-fx 1.0	BEACH-fx is a certified prototy	Beaches and Dunes	Flood Risk Management, Erosion Contr	Certified		https://planning.erdc.dre
2	Unit Day Value (UDV)	The Unit Day Value (UDV) tool	Beaches and Dunes, we	Recreational Use	Out of Date (s...	Notes indicate value	https://planning.erdc.dre
3	CREST	Coastal Resilience Evaluation a	wetlands	Flood Risk Management, Ecosystem Se	Not Certified		https://planning.erdc.dre
4	HEC-EFM	Ecosystem Functions Model d	wetlands	Beneficial Use / RSM, Ecosystem Servic	Certified		https://planning.erdc.dre
5	WMS	Watershed Modeling System \	wetlands	Flood Risk Management		Recommended by E\	https://ewn.erdc.dren.mi
6	ProMap	EWN Project Mapper brings tc	Beaches and Dunes, we	Recreational Use, Erosion Control, Eco		Recommended by E\	https://ewn.erdc.dren.mi
7	PTM	Particle Tracking Model can be	Beaches and Dunes	Beneficial Use / RSM, Erosion Control		Recommended by E\	https://ewn.erdc.dren.mi
8	NIOT	The Natural Infrastructure Op	Beaches and Dunes	Erosion Control, Beneficial Use / RSM	N/A	Recommended by E\	https://ewn.erdc.dren.mi
9	Ecosystem Service Valuation Checklist	Guidelines/Checklist For Valua	Beaches and Dunes, we	Ecosystem Services	N/A	Recommended in Ec	https://cw-environment.
10	NEAT	The Net Emissions Analysis To	wetlands	Ecosystem Services, Flood Risk Manage		Essential for project	https://planning.erdc.dre
11	SLAT	Among many other functions,	Beaches and Dunes	Flood Risk Management			https://planning.erdc.dre
12	IWR Planning Suite II	The IWR Planning Suite is a wi		Ecosystem Services	Certified	IWR Planning Suite I	https://www.iwr.usace.ar

Figure D-1. Example of database to support and accelerate the use of NBS.

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