VALUING SEDIMENT MANAGEMENT: OPPORTUNITIES AND BEST PRACTICE FOR MORE HOLISTIC CONSIDERATION OF IMPACTS

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PREFACE

The Water Institute (the Institute) received support from the Gulf of America Alliance to conduct a study on the methods for valuing sediment as part of regional sediment management (RSM) and beneficial use of dredge materials (BUDM). This effort builds on prior Institute work focused on valuing nature-based solutions, many of which (marsh, beach, dune, etc.) require sediment placement (Dalyander et al., 2024a; Ehrenwerth et al., 2022; Fischbach et al., 2023; Windhoffer et al., 2023).

In the work presented here, the Institute conducted three case studies and synthesized the results to identify kinds of sediment placement benefits that may be underutilized in project evaluations; factors leading to increased benefits or reduced costs of sediment placement projects; and best practices in sediment evaluation. In addition, the Institute engaged subject matter experts from around the Gulf to provide input on the preliminary results and to identify other factors for consideration.

This process resulted in the development of an actionable, best practice workflow—presented in this report—that can be used by practitioners in determining locations for sediment placement that maximize the overall benefit, and to more holistically consider the impacts of placement in evaluating projects.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

This document provides an overview of a framework developed by the Water Institute for approaching valuation of beneficial use of dredged material (BUDM) to streamline the process of finding useful locations to place dredge material created in other projects (e.g., navigation related dredging). This workflow assumes that a user has a source of sediment and is looking for ways to use it, but many features of the workflow can be applied to other use cases such as regional sediment management.

The workflow consists of five steps: preliminary scoping, description, quantification, monetization, and final synthesis.

- Preliminary scoping involves defining one or more regions of interest surrounding potential project sites and beginning a broad list of the potential impacts of sediment placement at those sites across the region. This includes both direct impacts like the creation of habitat, but also indirect impacts like the effect of the created habitat on other adjacent parts of the region of interest. The goal at this stage is to think expansively while also looking for issues that might rule out a project as a potential placement option.
- Description involves creating detailed qualitative descriptions of the impacts and how they are connected to the placement of sediment and each other. At this stage impacts may be removed from the broad list if literature review or expert judgment suggests they are not significant or unlikely to occur.
- Quantification involves taking the list of qualified impacts and developing quantitative estimates of the magnitude of benefit, like acres of habitat created or number of structures protected from flooding. Importantly, quantification may not be appropriate or possible for all impacts; the workflow assumes that impacts that are not quantified will still be revisited in the synthesis step.
- Monetization goes further in taking quantified impacts and converting the quantification into a monetized value for ease of comparison. As in the quantification step there may be some benefits that cannot be monetized.
- Lastly, impacts are considered holistically in a synthesis step using principles such as cost effectiveness as a screening tool rather than a final determination and decision support tools like stop light charts.

Importantly the workflow is intended to be iterative, with the possibility of returning to and revising previous stages based on the discovery of new information (or in some cases a lack of information) in a follow-up stage.

In this report, the workflow is applied retrospectively to three sediment placement case studies: Egmont Key in Florida, Caminada Headland in Louisiana, and Laguna Madre in Texas. Of these three, Egmont Key and Laguna Madre are both cases of strict BUDM, while Caminada Headland is not. Nevertheless, the lessons from Caminada Headland can be applied to BUDM. For each case study the preliminary scoping and qualification stages are completed in their entirety, with the later stages being somewhat limited by the retrospective nature of the case study. Instances where more data could have aided analysis are noted for each case study. Additionally, key findings for each case study are summarized.

The report closes with an overall synthesis of the results. Notable findings include:

1) the importance of holistic assessment of costs and benefits to ensure that non-monetized benefits do not fall out of consideration between BUDM and other sediment disposal options;
2) the importance of additional data collection in monetizing benefits from protections to built infrastructure, habitat creation, and recreational use;
3) development of appropriate benchmark cases (particularly the future without action) to measure preservation of existing benefits against;
4) the importance of understanding the impact of sediment quality on potential uses; and
5) BUDM's utility as a cost-saving measure by allowing for greater quantities of sediment placement, or a shorter distance of sediment transport when compared to other sediment disposal options.

In addition to these key results, the report summarizes several additional elements of best practice such as: 1) the utility of the workflow beyond a purely BUDM context for considerations such as ecosystem restoration; 2) the importance of a higher-level holistic approach in terms of both the interconnectedness of local regional effects of sediment placement and understanding dredging and placement as a combined, rather than a separate, activity; 3) the need for pilot studies to aid decision making about sediment placement in advance of sediment generation activities.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Term
AG	Advisory group
BAMM	Borrow Area Management and Monitoring
BCR	Benefit-cost ratio
BICM	Barrier Island Comprehensive Monitoring
BUDM	Beneficial use of dredge material
CPRA	Coastal Protection and Restoration Authority
DMDU	Decision making under deep uncertainty
FWOA	Future without action
FWOP	Future without project
GIWW	Gulf Intracoastal Water Way
GOAA	Gulf of America Alliance
LASMP	Louisiana Sediment Management Plan
LOOP	Louisiana Offshore Oil Port
NBS	Nature-based solutions
NSI	National Structure Inventory
ODMDS	Ocean dredge material disposal site
RSM	Regional sediment management
SAV	Submerged aquatic vegetation
SDM	Structured decision making
SLR	Sea level rise
T&E	Threatened and Endangered Species
TAG	Trustee advisory group
UDV	Unit day value
USFWS	U.S. Fish and Wildlife Service
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VOI	Value of Information
WTP	Willingness to pay

INTRODUCTION

Storms, sea level rise, subsidence, disruptions to sediment supply, and other natural and anthropogenic disturbances are driving coastal erosion, habitat loss, and risk to communities throughout the northern Gulf Coast (Dietz et al., 2018; Houser et al., 2008; Pendleton et al., 2010). Gray infrastructure, including seawalls, jetties, and riprap, have historically been used to stabilize vulnerable shorelines, yet hard structures can have undesired side effects such as exacerbating downstream erosion and destruction of habitat (Ehrenwerth et al., 2022). Nature-based Solutions (NBS) or hybrid infrastructure solutions have been increasingly recognized as an important tool for reducing or mitigating these losses. Most of these approaches—including marsh, dune, and beach restoration—rely on placement of sediment. Conversely, billions of dollars are spent every year dredging sediment in rivers, ports, and other navigable waterways; as of 2022, the U.S. Army Corps of Engineers (USACE) alone was spending approximately $1.5 billion every year on navigation project dredging (Coleman, 2022). The significant investments made in removing sediment from locations where it is undesirable, and the opportunities for enhanced benefit through sediment placement as part of coastal restoration, suggest that considerable cost savings and overall benefit could be achieved through more holistic management approach. One example of such an approach would be Regional Sediment Management (RSM), a systems-based approach to address sediment management for more sustainable solutions across multiple projects and programs.

Widespread implementation of green infrastructure and RSM faces several challenges, however. Project alternative evaluation processes often rely on benefit-cost ratio (BCR) calculations based on monetized valuation, though the BCRs calculated in such an analysis are not standardized and often are only progressed to the point of cost neutrality with some categories of benefits excluded completely (Ehrenwerth et al., 2022). Recent guidance on project evaluation processes have thus deemphasized use of BCRs in favor of multi-objective approaches to evaluation that can account for both monetized and non-monetized benefit (Council on Environmental Quality, 2014; Water Resources Development Act, 2020). Social, environmental, and economic benefits of sediment placement, such as the storm risk reduction provided by marsh or beach restoration, may be undervalued or excluded in BCR calculations due to a lack of readily available tools for robust valuation (Dalyander et al., 2024a). This undervaluing can be significant, particularly given that competing uses for sediment and the offshore areas from which it is often dredged, combined with depletion of borrow areas, have reduced the availability of quality material for placement (Khalil & Finkl, 2011).

The primary goal of the work presented here was to develop best practice guidance for more comprehensively and accurately capturing the impacts associated with RSM and beneficial use of dredged material (BUDM). The work consisted of two components. First, an advisory group (AG) with subject matter expertise in sediment management and valuation was assembled to provide input and guidance (Appendix A). Second, three case studies were identified (Case Study Selection) and evaluated to identify impacts of beneficial use and RSM that are undervalued in BCR calculations, as well as to determine factors leading to improved BCRs in RSM and sediment placement through increased benefits and/or reduced costs. The results of the case study and input from the AG were then synthesized into the findings presented here, which include a best practice workflow for a use case of identifying placement locations for available dredged sediment and maximizing benefit (see: Workflow For Capturing the Impacts of Regional Sediment Management and Beneficial Use of Dredged Materials).

WORKFLOW FOR CAPTURING THE IMPACTS OF REGIONAL SEDIMENT MANAGEMENT AND BENEFICIAL USE OF DREDGED MATERIALS

This section outlines a proposed workflow for valuing the impacts (benefits and negative effects) of dredged sediment and how to use those valuations in decision making. This workflow was developed in conjunction with the report's retrospective case study analysis. However, the workflow can also be used prospectively to understand the varying tradeoffs between alternative sites for sediment placement, and how those sites could change the categories of benefits or negative effects resulting from that sediment.

The workflow is intended to be used as best practice for what to do with a known quantity or source of dredged material. While modifications could be made to address the specific needs of RSM activities, such as trying to understand where sediment could be sourced for a specific restoration project, the workflow described here is based on a known source of sediment that needs to be placed. As such, that source of sediment will guide the evaluation and identification process. Within the context of project evaluation, the sediment is assumed to derive value primarily from how it is used rather than being valuable as a resource.

The conceptual diagram shown in Figure 1 lists the five linked steps of the workflow, beginning with a Step 1prescreening process ("initial evaluation") that can be returned to at any point as new impacts (indicated in the first with blue arrows), alternatives, or valuations are discovered that require additional screening. The workflow activities, outputs, and resources to be developed are further described in Table 1.

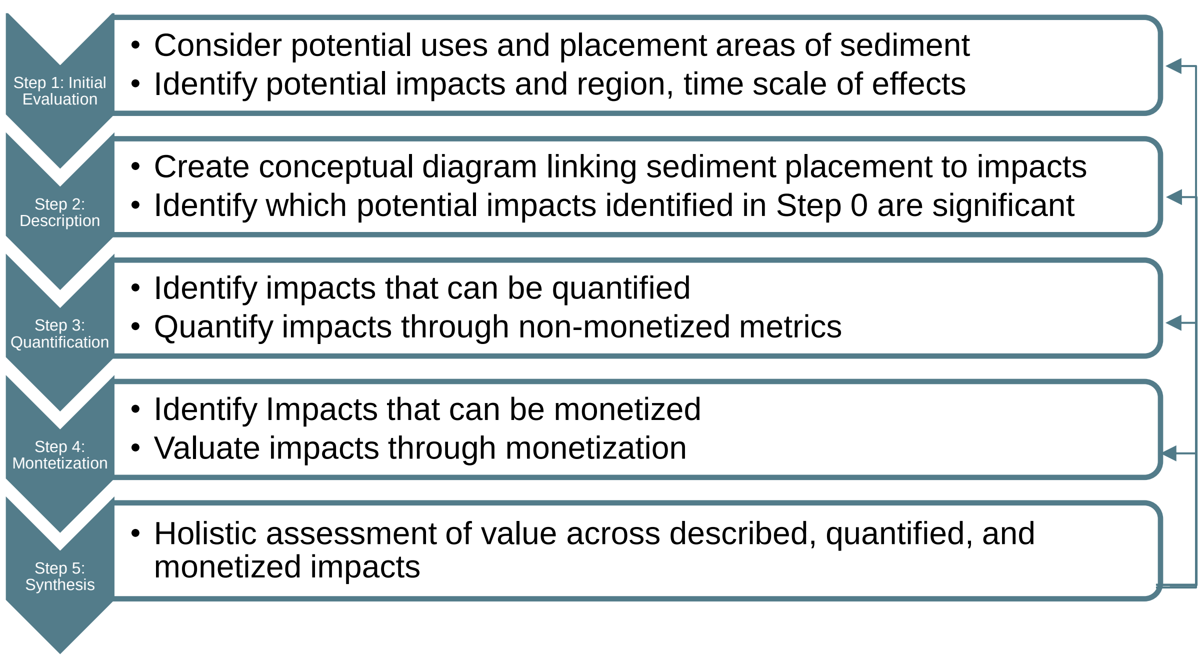

Figure 1. Draft workflow for sediment placement valuation. Blue arrows on the right denote that prior steps can be revisited as part of an iterative process.

Table 1. Draft resources and output for the sediment placement valuation (Figure 1). The resources described will be developed through ongoing case study analysis during future reporting periods of the project.

Workflow Step	Activities & Outputs	Resources
Step 1: Initial Evaluation	• Consider potential uses and placement areas of sediment. • Define region of interest • Consider potential impacts (benefits and negative effects) in the region identified. • Consider time scale of impact (e.g., pre-, during, or post-construction) • Conduct literature review of information sources	• Best practice guidance • Reference sheet of sediment types linked to habitats that can be created, with caveats and considerations on use • Reference sheet of potential benefits of different habitat types
Step 2: Description	• Create conceptual diagram linking sediment placement to impacts • Identify which potential impacts identified in Step 1 are significant	• Best practice guidance, including flags for revisiting Step 1 • Reference sheet of habitat interconnectivity • Reference sheet of conceptual diagram creation
Step 3: Quantification	• Develop table of quantified impacts	• Best practice guidance, including flags for revisiting Steps 1–2 • Examples of quantification metrics for ecosystem services
Step 4: Monetization	• Develop table of monetized impacts	• Best practice guidance, including flags for revisiting Steps 1–3 • Examples of tools for valuation
Step 5: Synthesis	• Synthesize described, quantified, and monetized impacts. • Consider and evaluate tradeoffs	• Best practice guidance, including flags for revisiting Steps 1–4 • Examples of tradeoff evaluation

1. INITIAL EVALUATION & IDENTIFICATION OF POTENTIAL IMPACTS

Step 1 in the process can be viewed as a brainstorming and problem definition phase of work. Although this step marks the beginning of the evaluation process, it may need to be revisited as new impacts are identified as the result of later steps of the process. At the end of this step, the evaluator will have an idea of both the *region of interest* (a geographic area that the evaluator is looking at, which is more expansive than the *project area* where the sediment is placed) as well as a list of potential impacts to investigate in the region of interest. These initial components will provide the inputs for Steps 1–4 in the evaluation process. The actions in Step 1 are also intended to identify any factors that might make a project area infeasible, such as permitting issues or being located too great a distance from the sediment source.

The workflow assumes that the evaluator is starting with a potential source of sediment for which they wish to evaluate potential beneficial use opportunities. This assumption provides two important guidelines relevant to Step 1. First, the type of sediment available constrains the types of projects that can be implemented. For example, certain sediment types will be suitable for beach nourishment, while others will not. Second, the location of the sediment source determines where sediment projects can be placed. Because of the expense of moving sediment long distances, distant projects may prove cost prohibitive.

At the start of the evaluation, if no projects have been identified, a literature review can be performed to determine the types of habitats that can be created with the available sediment. Once a list of these habitats has been generated, project sites that could benefit from the sediment can be identified by searching for regions located near the sediment source that currently or historically contained those habitats. These are the specific regions that will be referred to as *project areas*. A literature review at this stage may be helpful to identify locations facing issues such as erosion, sea level rise, and/or habitat loss near the sediment source. Additional considerations include state and local permitting requirements.

Each project area forms the *center* of a region of interest that is constructed by considering the direct effects of the project itself, and its indirect effects on the surrounding area. For example, a barrier island restoration project might have many direct benefits in the project area, such as the creation of habitat for nesting birds. However, it also has many other effects on the surrounding region, potentially providing flood risk mitigation for inland structures and/or creating lagoon habitat in the waters being sheltered by it. Table 2 provides a list of potential other habitat types created and impacts outside the project for each habitat type. Not all of these will be relevant to every project area. However, to ensure that all potential effects on the region of interest are evaluated, it is important that all items listed in Table 2 are carefully considered. A literature review can also be conducted to search for information on surrounding habitat types and whether they are relevant to the sediment placement.

Table 2. Table of habitat type references and direct and indirect benefits and impacts.

Reference Sheet of Habitat Type Impacts and Connections	Direct Impacts	Indirect Connections
Wetland habitat restoration (marsh, swamp)	Reduction of wave and storm surge, Protection of threatened and endangered (T&E) species	Protects upland habitat, created by barrier islands
Upland habitat restoration (maritime forest, etc.)	Recreation, protection of T&E species	Protected by wetlands and beach and dune
Aquatic habitat restoration, nearshore placement (shallow shelf placement, infilling of borrow areas, SAV habitat, oyster reefs, etc.)	Recreation, Prevention of erosion, Protection of T&E species, Reduction of waves	Protects beach and dune, protected by barrier islands
Beach and dune nourishment	Recreation, Reduction of wave and storm surge, Protection of T&E species, Reduced shoaling into nav channel	Protected by updrift placement

Once the region of interest has been composed and habitats have been linked to the project area, it is then possible to begin constructing a preliminary list of impacts. The purpose of this step is not to fully evaluate any of the impacts, but rather to identify which impacts warrant further investigation, as well as to rule out some impacts that do not apply given the project type. Table 2 provides a list of common potential impacts for each habitat type. Impacts can be quickly screened for inapplicability in this step. For example, no analysis is needed to conclude that a marsh restoration more than 200 miles from the nearest significant population center is likely to have minimal flood risk reduction benefits, even though flood risk reduction benefits are one of the listed benefits for the marsh habitat. A literature review can be conducted for each of the habitat types identified with a specific focus on the geographic region of interest to determine if there are any other impacts not captured in this table that may be relevant. A list of commonly used resources for each step of the process is provided in Appendix C.

2. QUALIFICATION OF IMPACTS

In Step 2 of the workflow, the evaluator can begin to use the defined regions of interest and potential impacts to qualitatively describe how those impacts derive from project actions. This information takes the form of a conceptual diagram, where the direct and indirect impacts are described for each region of impact and habitat type. For example, for the creation of a sandy beach habitat, direct benefits such as recreation opportunities are listed. The diagram connects the placement of sediment to specific habitats, and then connects the impacts of creating, protecting, or otherwise modifying those habitats. The diagram can then be used to build a table listing the types of benefits or negative effects under consideration, their associated locations, and potential considerations for their effects. Example conceptual diagrams and impact tables are provided in the individual case studies (see the Case Studies chapter). A similar use of linking conceptual diagrams has also been proposed for general ecosystems good and services valuation for USACE (Wainger et al., 2020).

The goal of this step is to develop a narrative description of the significance of potential impacts and determine which are most relevant. It is therefore important for the evaluator to consider which mechanism of the sediment placement creates the impact, and what the magnitude may be. Relevant information includes the specific location of the impacts, as well as specifics on who or what might be affected. For example, nearshore placement may offer benefits to a particular plant species that has indirect impacts on migratory birds. At this stage, concerns about how an impact might be quantified may arise. However, keeping these impacts in the conceptual diagram and advancing them to the next stage allows for further investigation; not all impacts can be quantified or monetized, but the workflow allows for inclusion of impacts that may be qualitatively described or even inconclusively quantified.

During the process of creating this diagram, the evaluator may find that an entire category of habitat or benefit was overlooked in the previous step. In this instance, the evaluator can return to Step 1 to add this category, review relevant literature, and better describe the impacts. This iterative component is similar to existing USACE guidance on ecosystems service valuations, which encourages revisiting previous steps in the process when new information comes to light to suggest additional categories of benefit (Wainger et al., 2020).

Additionally, any negative effects or other disqualifying factors are important to note at this early stage. The evaluator may want to consider if negative effects might prevent the permitting of a project, for example, and work through those questions with the regulatory agency before continuing with the workflow. The impact of placement on cultural resources may be especially important to consider as potentially disqualifying, as different kinds of cultural resources will require different treatments to ensure their preservation. At this stage, best practice would be to consult on these resources both with archaeological experts to determine the best methods of protection and with stakeholders to determine whether placement is permissible.

3. QUANTIFICATION OF IMPACTS

To build on the impacts described in Step 2, the evaluator can begin to consider how each impact listed in the table might be quantified. Table 3**Error! Reference source not found.** provides an abbreviated list of options for quantifying various categories of impacts.

Table 3. Sample table for quantification of benefits

Reference Sheet of Potential Impacts	Potential Quantification Metrics	Data Sources
Local or regional protection of the **built environment** through impacts to: 1. Hydrodynamics (reduction of waves, storm surge, high tide flooding) 2. Sediment dynamics (reduction of nearfield or downdrift erosion)	Structures at risk Populations at risk	National Structure Inventory (NSI) Census
Provision, enhancement, or protection of **habitat** (wetland, including marsh, mangrove, etc.; sandy beach or dune; maritime forest; etc.) Note that conversion of habitat from one type to another may result in negative impacts as well when habitat is converted from one type to another	Change in habitat area Population of species	Numerical habitat-change models Literature
Provision, enhancement, or protection of **recreational opportunities or other anthropogenic uses** (kayaking, birdwatching, hiking, beachgoing, etc.)	Area of recreation Annual Visitors	National Park Service
Protection of **cultural resources** (historically significant landmarks or structures; Native American cultural sites; sites of significant to the local community; etc.)	Number of cultural resource sites at risk	State historic preservation offices Tribal resource offices
Miscellaneous impacts including avoidance or increase in costs to maintain navigable waterways (shoaling rate, dredge disposal, etc.), restore or manage ecosystems, etc.	N/A, depends on specific impact	N/A, depends on specific impact

Generally, quantification of impacts can be grouped into categories, such as 1) protection of the built environment; 2) provision, enhancement, protection, or conversion of habitat; 3) provision, enhancement, or protection of recreational opportunities or other people-oriented uses; 4) protection of cultural resources; and 5) other miscellaneous impacts, such as avoided or increased costs of navigation. Each of these categories has potential quantification methods that are grounded in literature and guidance. It is important to keep in mind that same mechanism may produce both benefits and negative effects, as when a gain in area of one habitat type comes at the cost of converting another habitat type (see Fischbach et al., 2023 for an example applied to Sacramento, CA). In this case the relative change in each type of habitat should be quantified. Similarly, the timing of impacts should be considered, including impact durability and the potential for impacts changing over time (for an example of measuring short term negative effects of project construction see DeJong et al., 2024).

Some impacts may not be quantifiable, such as the protection of cultural resources; this does not mean that these benefits are not important. The protection of a particular cultural or historic resource may be a primary or fundamental benefit of the sediment placement; for example, if sediment placement is protecting a significant landmark or an irreplaceable Native American cultural site. Impacts that are more abstract can still be significant.

Other challenges to impact quantification include data availability or analytical capacity and/or lack of modeling to project the degree of impact. Even when an absence of data precludes quantification, it is important that impacts are considered if they are deemed to be significant.

Examples of impact quantification can be found in the Case Studies chapter.

As the evaluator quantifies potential impacts, they may conclude that a considered impact is not significant. For example, flood risk reduction may have been identified in earlier steps as a potential benefit, but if no structures have reduced flooding due to the place (or the reduction in flooding is insignificant), the evaluator may choose to remove that category at this stage.

Resources for impact valuation are numerous; literature reviews from DeJong et al. (2024) and Fischbach et al. (2023), for example, may support specific quantification methods and techniques.

4. MONETIZATION OF BENEFITS AND IMPACTS

The third step in the workflow considers the quantified impacts from Step 3 and performs monetary valuations where feasible. The evaluator can take each impact previously identified and match it with a monetization method, such as the Unit Day Value (UDV) method for monetizing recreation benefits. While monetization methods vary in complexity, they provide a basis for understanding the potential economic value of benefits provided by the placement of sediment and/or the economic cost of negative effects of placement.

A reference table of monetization methods is below in Table 4. As noted in the previous step in the workflow, some impacts may not be able to be quantified or monetized because of data availability but may still be relevant or qualitatively significant while others, particularly cultural resources like cemeteries and sacred lands, are simply not appropriate to monetize due to their irreplaceable nature. Some methods, such as hydrodynamic modeling, require significantly more effort to use. If modeling information is available and can be integrated, it can be used; other substitute monetization methods may provide sufficient information in some cases for example using increases in beach width as a proxy for usage (Moeller, 1965). Some impacts may only be partially monetizable; for example, the full monetary benefit of an increase in a habitat area may not be monetizable but if good quantitative information on carbon sequestration potential for that habitat is available (see for example, Foran et al., 2018), it could be partially monetized using a global cost of carbon.

Table 4. Reference table of selected monetization methods

Reference Sheet of Potential Impacts to Consider	Monetization Methods
Local or regional protection of the **built environment** through impacts to: 1. Hydrodynamics (reduction of waves, storm surge, high tide flooding) 2. Sediment dynamics (reduction of nearfield or downstream erosion)	Consequence analysis (e.g., Hydrologic Engineering Center Flood Impact Analysis Hazus etc.)
Provision, enhancement, or protection of **habitat** (wetland, including marsh, mangrove, etc.; sandy beach or dune; maritime forest; etc.)	Habitat valuation databases
Provision, enhancement, or protection of **recreational opportunities or other anthropogenic uses** (kayaking, birdwatching, hiking, beachgoing, etc.)	UDV methodology
Protection of **cultural resources** (historically significant landmarks or structures; Native American cultural sites; sites of significant to the local community; etc.)	Not generally appropriate, site-specific considerations are required
Miscellaneous impacts including avoidance or increase in costs to maintain navigable waterways, restore or manage ecosystems, etc.	Variable

The evaluator can build a table of monetized impact values, organized by categories (built environment, habitat, recreation, etc.). The monetized values can be added together but do not necessarily reflect the sum of all impacts or a complete benefit-cost analysis. Further exploration of the total impacts is described in Step 4.

5. SYNTHESIS OF IMPACTS

In Step 5, the evaluator can take stock of all impacts—qualitatively described, quantified, and monetized—and use analytical approaches to assess the tradeoffs between alternatives. This framework assumes use in a prospective analysis where an evaluator would be able to collect, create and request data on all considered alternatives. Step 5 is more challenging for an evaluator in the context of a retrospective analysis, like this report. First, information about alternatives that were not selected is more difficult to obtain, especially those that were abandoned early in the analysis. Second, not every analysis suggested by the framework was performed, and thus data may not be available to support full monetization. Throughout this report there were many cases where the Institute team found benefits that could have potentially been quantified or monetized but given the data availability (or lack thereof) only qualitative assessments could be performed. These cases are noted in the respective case study chapters.

If the cost of the sediment placement is known, a preliminary BCR can be constructed with the monetized benefits. However, this may leave out important nuances, such as discounting benefits across time, and/or failing to include the full value of natural resources. Additionally, the BCR often leaves out important quantified or qualitative impacts that can be considered holistically using other methods. Thus the BCR should be used as a screening tool to eliminate projects as infeasible with additional methods that can better account for non-monetizable benefits used to make the final selection. For example, a stoplight chart, as used in Fischbach et al. (2023), offers a way to evaluate different alternatives against a range of impact. The stoplight chart can highlight alternatives with singularly negative consequences as well as ones where tradeoffs between specific benefit categories can be considered.

Other methods can be used to synthesize benefits across a range of alternatives, including structured decision making (SDM; Gregory et al., 2012). The SDM process uses a formal consequence analysis and tradeoffs process that measures alternatives against a set of fundamental objectives developed with the decisionmaker. In complex natural resource management scenarios, a formalized SDM process may be advantageous in determining where sediment placement can satisfy competing objectives. Tradeoffs can be evaluated quantitatively, examining how different alternatives perform against, for example, habitat preservation and navigation objectives. Other comparable methods like Multiple Criteria Decision Analysis can also be used (Belton & Stewart, 2012).

Methods used for decision making under deep uncertainty, often referred to as DMDU can also be used to evaluate the performance of a certain alternative under future conditions. This can be particularly relevant in the case of uncertain impacts around SLR or storm surge. DMDU methods like adaptation pathways (Haasnoot et al., 2013) can be useful for structuring alternatives to account for uncertain futures based on assessment with a method like Robust Decision Making (Lempert, 2019).

The final output of this workflow step is a synthesis of benefits and negative effects. As noted, it can take many forms, owing to the number of alternatives under consideration or the number of impacts identified. A synthesis of impacts may raise new questions, as well. For example, a synthesis might show that a project formulation of a single deposition of sediment leads to lower benefits than expected. An evaluator may want to consider an alternative that consists of several smaller depositions of sediment and alternative sequenced placements over time. This could also be true in the inverse, where small depositions with small benefits are screened out early but could add up to a larger benefit that would have made it through the entire workflow. The flexibility of this approach allows for reconsideration at multiple steps.

CASE STUDIES

EGMONT KEY, FLORIDA

Background

Egmont Key is an island located at the mouth of Tampa Bay along the west coast of Florida (Figure 2). The island includes Egmont Key National Wildlife Refuge (https://www.fws.gov/refuge/egmont-key), which was established in 1974 to protect the island's natural and cultural refuges, and is co-managed by U.S. Fish and Wildlife Service (USFWS) and Florida State Park Service (https://www.floridastateparks.org/parks-and-trails/egmont-key-state-park). Highlights of the park (Florida State Parks, 2014) include a historic lighthouse; remnants of Fort Dade; recreational opportunities such as fishing and picnicking; the Tampa Bay Pilots Association station; and wildlife including gopher tortoise, box turtle, and nesting shorebirds (Figure 3).

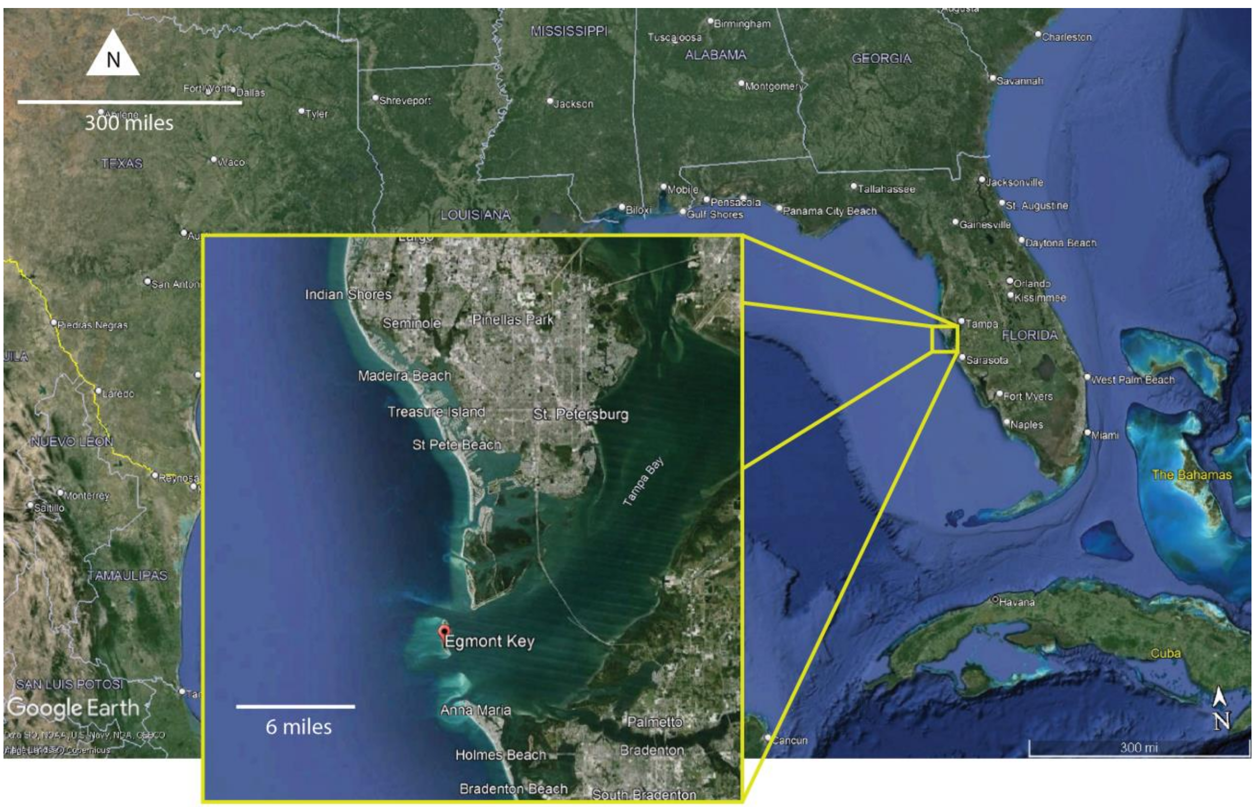

Figure 2. Location of Egmont Key along the west coast of Florida.

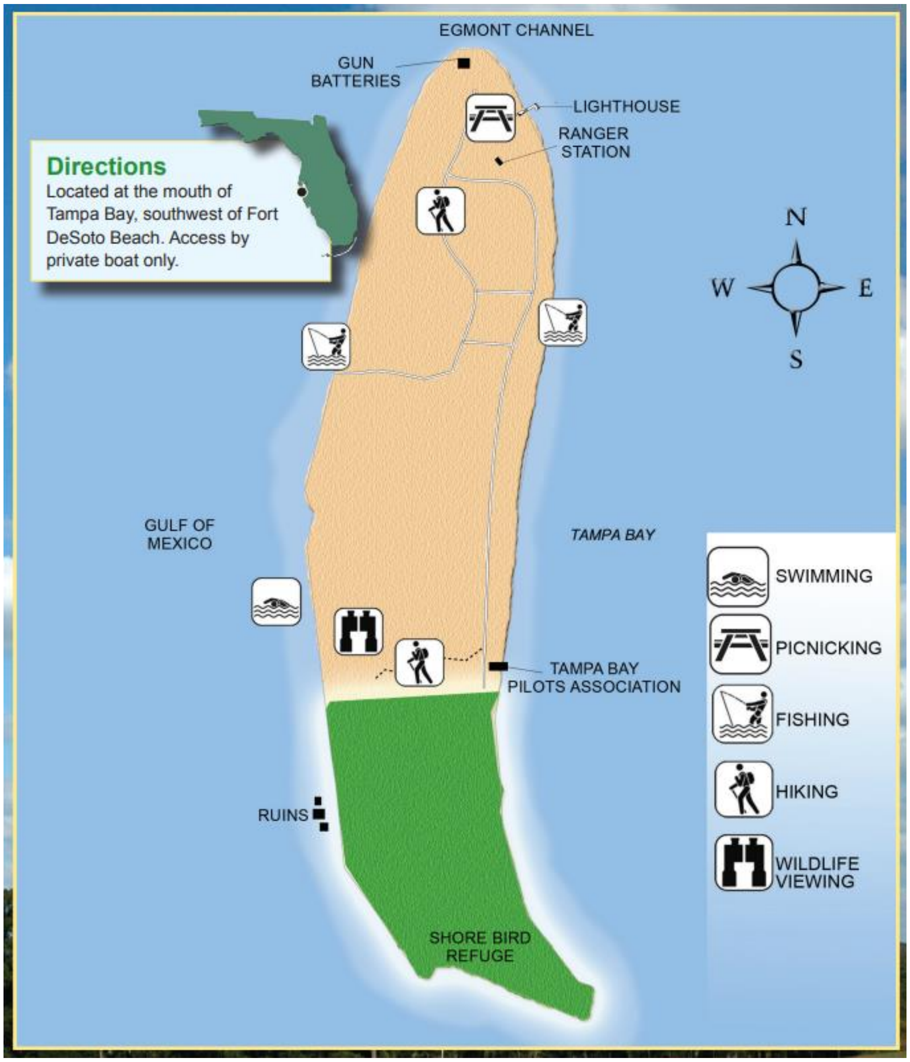

Figure 3. Map of Egmont Key State Park. The remnants of Fort Dade are comprised of the gun batteries to the north and battery ruins to the south (shown), as well as brick-lined walkways and foundations throughout the central portion of the island. The Light House cemetery is located to the north near the Egmont Key Lighthouse. Image from the Florida State Park Egmont Key Informational Brochure (Florida State Parks, 2014).

Egmont Key has been the site of multiple placements of dredged sediments, totaling over 3 million cubic yards (cy) of sediment sourced from the Tampa Harbor navigation channel (Table 5). Egmont Key is also identified as a BUDM site for a planned future deepening of the channel (USACE, 2024e). The primary focus of the case study analysis is the planned 2028 Tampa Bay Deepening Project, for which more data and analysis are available than for prior placements (USACE, 2024e).

Table 5. Beneficial use of dredged material (BUDM) for beach placement at Egmont Key, Florida (K. Legault, USACE Jacksonville District, personal communication, 2024). "Federal Cuts and Channels" indicates the location from which material was dredged; more information is available in the Tampa Harbor Navigation Improvement Study Integrated General Reevaluation Report and Environmental Impact Statement (USACE, 2024e).

Federal Cuts & Channels	Year Dredged	Volume (Cubic Yards)	Volume (m^3)	Cost	Cost/Cubic Yard	Cost/m^3
Egmont 1	2006	1,048,961	801,988	$11,858,302	$11	$15
Egmont & Mullet Key	2014–2015	623,496	476,696	$11,590,366	$19	$24
Egmont Cuts 1 & 2 & Mullet Key Cut	2018–2019	435,100	332,657	$12,970,158	$30	$39
Egmont Cuts 1 & 2 & Mullet Key Cut	2022	1,080,000	825,719	$27,442,360	$25	$33
*Tampa Bay Deepening (Planned)	2028	3,700,000	2,829,000	$66,349,000	$18	$23
	* Focus of the case study presented here					

Application of Workflow

Because of the retrospective nature of the case study analysis, the application of the best practice workflow began with identifying potential impacts, along with the spatial area and time scale over which those impacts occur. In addition, hurricanes Helene and Milton severely impacted Egmont Key in October 2024 while the case study analysis was nearing completion. Impacts included the destruction of a U.S. Coast Guard pilot station on the island, significant coastal erosion, and a storm surge of 8.5 feet (2.6 meters), which led to significant loss of island vegetation (Wilson, 2024). The retrospective analysis was conducted based on data and information available prior to these storms. **Any specific outcomes for Egmont Key would need to be reassessed using post-storm information from hurricanes Helene and Milton**.

Step 1: Initial Evaluation

Review of available literature identified potential post-construction and long-term impacts of sediment placement at Egmont Key including (Table 6):

- Reducing storm surge and wave energy propagation into Tampa Bay;
- Providing or protecting barrier island and nearshore habitat, including beach and dune, upland scrub habitat, submerged aquatic vegetation (SAV), mangroves (Figure 4);
- Providing habitat for threatened and endangered or keystone species, including piping plover, sea turtles, and gopher tortoise;
- Providing recreational opportunities such as kayaking, beachgoing, and hiking;
- Protecting cultural resources including a lighthouse and cemetery, noting that the placement is not expected to negatively impact any cultural resources; and
- Impacts to navigation, including a potential negative impact of increased shoaling into a downstream shipping channel.

Table 6. Initial assessment of potential impacts of sediment placement at Egmont Key, FL. The specific magnitudes of any benefits dependent on footprint retention, will vary based on the extent of degradation in without project conditions. Additional modeling would be required to determine the specific extent of degradation in this case.

Impact Category	Impact	Location of Impact	Time Period
Built Environment	Storm surge reduction and protection of residential & commercial areas	Northern end of Tampa Bay	Post-construction, while footprint is retained
Built Environment	Wave attenuation and protection of residential & commercial areas	Tampa Bay, northeast of Egmont Key	Post-construction, while footprint is retained
Habitat	Creation of sandy beach and dune habitat (colonial beach-nesting shorebirds, sea turtles, etc.)	Area of placement at Egmont Key; preservation of beach/dune habitat downstream in littoral system	Post-construction, while footprint is retained; longer-term benefit from sediment retention in the system
Habitat	Protection of upland habitat/scrubland (gopher tortoise, box turtle, etc.)	Area inland of placement area at Egmont Key	Post-construction, while footprint is retained; longer-term benefit from sediment retention in the system
Habitat	Seagrass & mangrove habitat (manatee, dolphin, sea turtles, wading/diving birds, etc.)	Shallow areas in the lee of Egmont Key	Longer-term benefit from extension of island footprint lifespan
Recreational Opportunities	Kayaking, birdwatching, hiking, beachgoing, fishing, etc.	Beach, dune, and upland areas of Egmont Key	Post-construction while footprint is retained; longer-term benefit from extension of island footprint lifespan
Cultural Resources	Ft. Dade Batteries; ruins of the Fort Dade village; Ft. Dade cemetery; Light House Cemetery; place of historic significance to the Seminole Tribe of Florida	Varies (see Figure 3)	Longer-term benefit from extension of island footprint lifespan
Miscellaneous	Navigation benefits including protection of Tampa Bay Pilots Association pilot station; protection of in-service lighthouse	Pilot station on the west end of the island; lighthouse on the north end of the island (see Figure 3)	Longer-term benefit from extension of island footprint lifespan
Miscellaneous	Negative impact of increased shoaling of sediment	Shipping channel north of Egmont Key	During and post-construction
Miscellaneous	Reduction in long-term sediment disposal costs through preservation of capacity in disposal sites	Multiple around Tampa Bay	Longer-term benefit

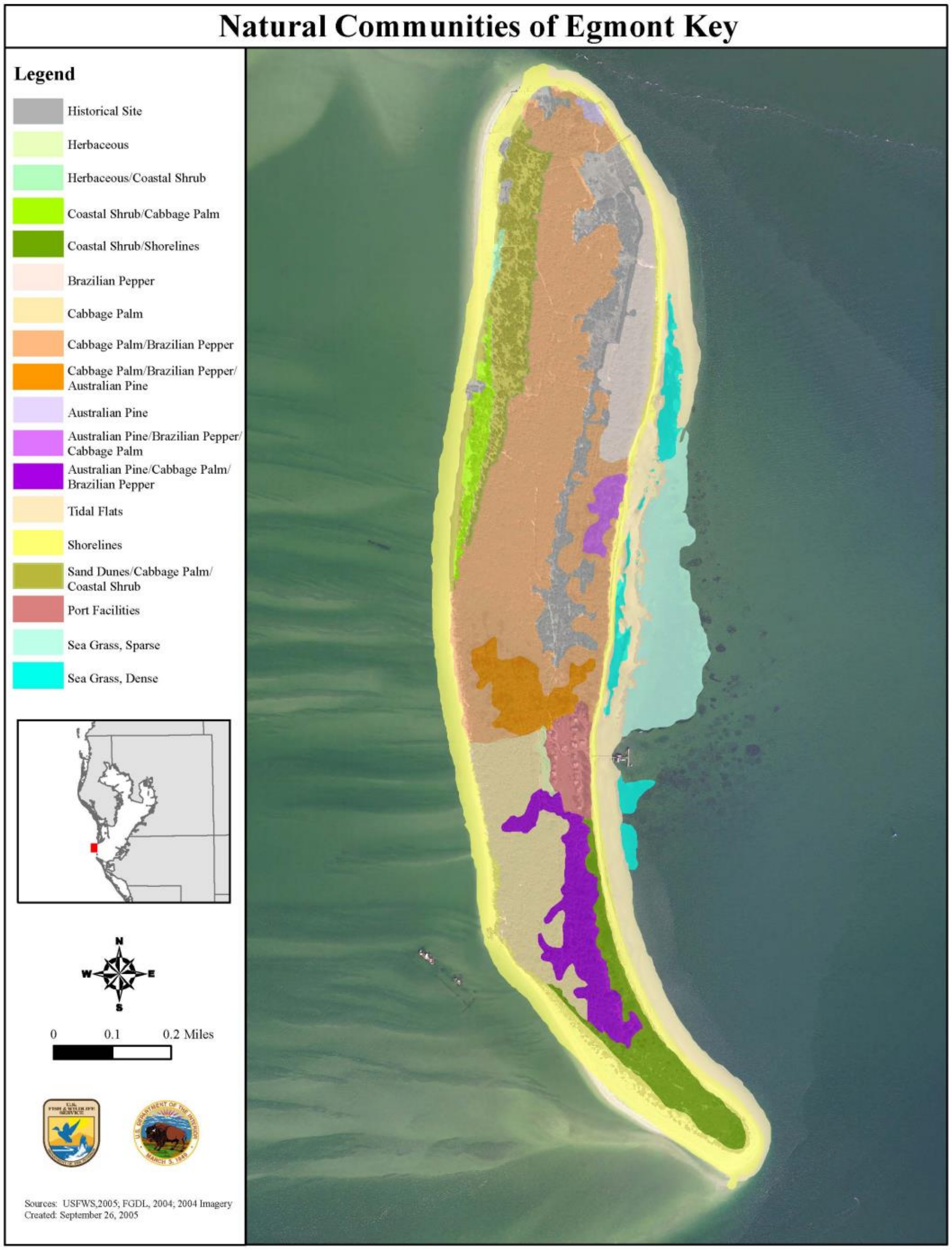

Figure 4. Distribution of habitat on Egmont Key as of September 2005. Note that significant changes have occurred at the island in the time since this map was created, particularly as a result of hurricanes Helene and Milton in fall 2024. (S. Garner, USFWS, personal communication, 2024).

Potential construction impacts of sediment placement at Egmont Key include (USACE, 2024e):

- Minor and temporary impacts to existing upland plant communities in areas of placement, with long-term gain through planting for habitat creation and erosion control;
- Minor and temporary impacts to nearshore habitats during placement due to increased turbidity;

- Temporary displacement of fish and wildlife from placement areas;
- Risk of introduction of rats from dredging vessels, mitigated through established control measures;
- Minor and temporary impacts to manatees, sea turtles, birds, and fish species that utilize island or adjacent shallow water and SAV habitat;
- Temporary degradation of water and air quality;
- Impacts to now-submerged cultural resources, including Ft. Dade batteries; and
- Temporary restriction of visitor access to portions of Egmont Key.

Step 2: Description

The project team created a conceptual diagram to link the placement of sediment at Egmont Key to the potential benefits and impacts identified in Step 1 (Figure 5). Placement of sediment at Egmont Key directly creates beach, dune, and upland habitat, while creation of beach and dune habitat indirectly benefits upland habitat. In addition, sediment placement at Egmont Key preserves a larger island footprint, which is expected to decrease as a result of long-term erosion without sediment placement (USACE, 2024e).

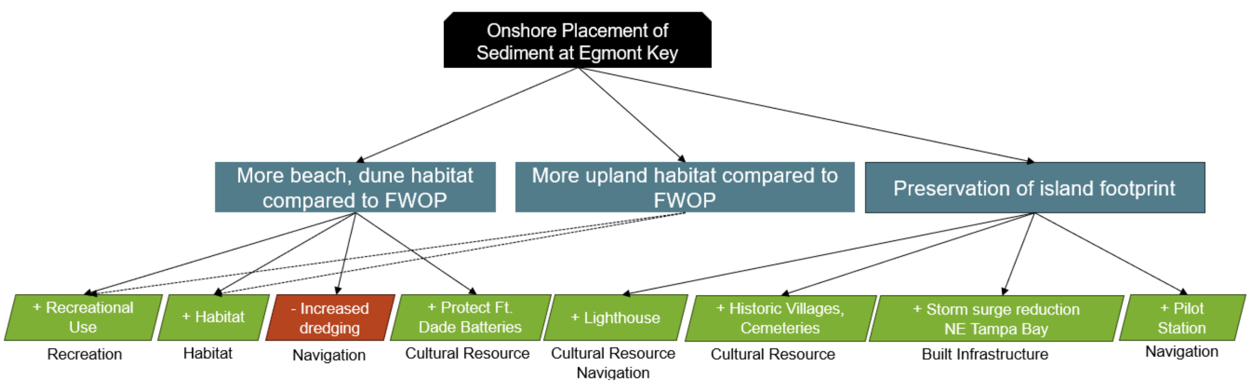

Figure 5. Conceptual diagrams of the benefits and impacts of sediment placement at Egmont Key, FL. FWOP denotes Future without Project.

Literature review and evaluation of impact scale and significance led to the removal of several potential benefits and impacts identified in Step 1. First, the impacts of sediment placement during construction were removed from consideration given that all effects are minor and temporary. The estimated wave attenuation benefit provided by Egmont Key is also small outside of the immediate vicinity of the island, with wave reductions of less than 1.6 feet (0.5 meters) during storm conditions even for a complete loss of the subaerial island footprint (Ulm et al., 2016). Given the high demand for the sediment used in Egmont, the next best use for the sediment would not be storage but rather placement at another site. Thus, potential benefits through preservation of existing dredge disposal site capacity were removed (Dalyander et al., 2024b; USACE, 2024d).

The team also assessed the potential significance of preservation of upland habitat and the island footprint as indirect effects of beach and dune placement. USACE assessed that shoreline erosion at Egmont Key could result in degradation of upland habitats if sediment was not placed on the beach and dune (USACE, 2024e). The risk of complete island inundation (i.e., total loss of the island footprint) is small, and only likely to occur on 50–100 year time scales under high rates of SLR with no additional placement (Ulm et al., 2016; USACE, 2024e). Erosion rates and loss of the island footprint have been significant over time, however, with a loss of 40% of the island area during the century leading up to 2003 (Stott & Davis, 2003). In addition, storms can drive much higher rates of episodic erosion (e.g., annual loss of 34,600 cy or 26,500 m^3 of sediment volume in 1996–1997 compared to a long-term average rate of 4395 cy or 3,360 m^3 between 1877–1996; Stott & Davis, 2003). Therefore, preservation of upland habitat and the overall island footprint were retained in the conceptual model.

Recreational benefits including beachgoing, fishing, hiking, and sightseeing (e.g., viewing of the lighthouse and historic village ruins) were combined to a single benefit. Visitors to the island are likely to enjoy multiple activities during a single visit, thus differentiating could potentially lead to double counting. Several qualifiers were identifying in considering the value of these benefits:

- **Habitat:** The isolated nature of Egmont Key benefits some species given there is less anthropogenic disturbance and, in some cases, predator activity. T&E or keystone species that utilize the island or adjacent nearshore areas include piping plover (designated critical habitat), red knot (under consideration for critical habitat designation), sea turtles (green and loggerhead specifically, with between 100–150 document nests per year between 2017–2023), manatee, and gopher tortoise (USACE, 2024c). The island is also a documented nesting area for American oystercatcher and black skimmers (USACE, 2024e).
- **Recreation use**: Egmont Key provides similar recreational opportunities (beachgoing, hiking, kayaking, opportunities to tour a historic fort) to Ft. DeSoto (https://pinellas.gov/parks/fort-de-soto-park/), a 1,135 acre (4.5 million m^2) Pinellas County park located approximately 2.5 miles (4 km) to the northeast of Egmont Key and accessible from the mainland via car. The public ferries to Egmont Key operate out of downtown St. Petersburg, FL (just north of Ft. DeSoto) and from Ft. DeSoto itself, therefore the visitor base for this park and Egmont Key are similar. Differentiating factors for Egmont Key from Ft. DeSoto that recreational users may consider include the lighthouse, cemeteries, and the relative isolation (i.e., accessible only via boat).
- **Cultural resources:** Similar to Ft. Dade on Egmont Key, Ft. Desoto was constructed in the late 1800s in the lead up to the Spanish-America War. Ft. Desoto has a similar design to Ft. Dade, and the batteries are in better overall condition. However, Ft. Dade has unique significance ("dark history") to the Seminole Tribe of Florida due to its use as in internment site for Native Americans during the mid-1800s. In addition, a cemetery can still be found on the island (USACE, 2024e).

Step 3: Quantification

The Institute team identified several impacts that could be quantified with readily available data (**Error! Reference source not found.**) including storm surge mitigation, acreages for some habitat types, number of recreational visitors, and volume of sediment shoaling into the Tampa Bay Navigation Channel. However, data availability generally limited this analysis to quantifying the overall value of Egmont Key (i.e., assuming the sediment placement preserved the island footprint that would otherwise disappear on some time scale). These impacts could be more robustly quantified when applying the workflow as part of project design, when there may be opportunity for incorporating targeted data collection or analysis as part of screening and/or engineering and design. The metrics that could be calculated with targeted new data collection are included for reference in **Error! Reference source not found.**.

Table 7. Quantification of potential impacts of sediment placement at Egmont Key, FL. Quantification Metric and Metric Value include impact estimates based on readily available data and modeling that could be used in this retrospective case study. Potential Metric indicates metrics that could be quantified with additional targeted data collection or analysis (in bold), which could be scoped in applying the workflow in practice.

Impact Category	Impact	Quantification Metric	Metric Value	Potential Metric with Targeted Data Collection or Analysis
Built Environment	Storm surge reduction and protection of residential & commercial areas	Difference in maximum water levels with and without Egmont Key	-4 in to 6 in (-10 cm to 15 cm) for a 100-year storm, spatially varying across Tampa Bay (Ulm et al., 2016). Note: full value of Egmont Key	Number of structures protected could be quantified with predicted surge under SLR scenarios with and without project, when combined with infrastructure/structure inventories and maps.
Habitat	Sandy beach and dune habitat Upland habitat/scrubland Seagrass & mangrove	Habitat acres created with project	~150 (600,000 m^2) total acres of sandy beach and dune (USACE, 2024b), including ~5 acres (20,000 m^2) of sea turtle and ~10 acres (40,000 m^2) of nesting bird habitat (USACE, 2024e). Note: habitat acreages are expected to be refined during engineering & design	Habitat acres could be quantified with base habitat distribution and project design. Future benefit in year-acres could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates.
Recreational Opportunities	Kayaking, birdwatching, hiking, beachgoing, fishing, etc.	Beach, dune, and upland areas of Egmont Key	220,000 visitors, based on 218,668 visitors in 2019-2020. (Cutshaw, 2020) Note: full value of Egmont Key	Recreational value of the sediment placement over time could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates.
Cultural Resources	Ft. Dade Batteries; ruins of the Ft. Dade village; Ft. Dade cemetery; Light House Cemetery; place of historic significance to the Seminole Tribe of Florida	Varies (see Figure 3)	N/A (qualitative only). The resources themselves can be counted, but this does not accurately reflect their value	The estimated time scale for which the sediment placement would provide benefit could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates.
Miscellaneous	Navigation benefits including protection of Tampa Bay Pilots Association pilot station;	Pilot station on the east end of the island; lighthouse on the north end of	N/A (qualitative only)	The estimated time scale over which the sediment placement would provide benefit could be quantified from baseline and

Impact Category	Impact	Quantification Metric	Metric Value	Potential Metric with Targeted Data Collection or Analysis
	protection of in-service lighthouse	the island (see Figure 3)		with project conditions, SLR, and erosion/island loss rates.
	Negative impact of increased shoaling of sediment	Increase in shoaling into the shipping channel	Total of 43,500-159,900 cy (33,200–122,200 m^3) of material over historical infilling rates during the first 3 years after placement (USACE, 2024a)	N/A (data were available for impact quantification)

The project team's literature review identified a study in which the storm surge value of Egmont Key was quantified through numerical modeling of different storms with return intervals varying from 5- to 200-years (Ulm et al., 2016). This study assumes complete loss of Egmont Key. Based on USACE SLR projections, complete inundation of the island is unlikely to occur until 50–100 years into the future under intermediate and high SLR projection (USACE, 2024a), therefore modeling complete loss of the island is likely to overestimate the value of sediment placement at the island. Results of this study must be interpreted in light of this, but can still potential help benchmark the effect of erosion at Egmont. Spatial variability in impacts varied depending on the storm return interval, with smaller storms (25-year return interval or less) resulting in increases in water level along the entire coastline of Tampa Bay while larger storms (100-year return interval) led to decreases along portions of the coastline (central region of Tampa Bay) and similarly scaled increases at the northern end of the bay (2–6 in or 5–15 cm). One additional metric that could be used to quantify this impact is the number of structures within the floodplain for different events with and without Egmont Key restoration. This metric could be calculated by overlaying with and without project flood conditions for a design storm with a structure inventory or infrastructure map, which could then be used to quantify the number of structures protected by the project. This metric could not be calculated for the retrospective analysis because the study from which the differential increase in surge values were taken did not include absolute values of water level with and without Egmont Key (Ulm et al., 2016).

Another metric for quantifying value is to use the acreage created or protected for varying habitat types. The environmental impact study for the deepening study indicated that an estimated 150 total acres (0.6 km^2) of beach, dune, and nearshore habitat will be directly created by the sediment placement at Egmont Key (USACE, 2024b), including 5 acres (0.02 km^2) of sea turtle and 10 acres (0.04 km^2) of shorebird habitat (USACE, 2024e). More detailed estimates of habitat creation, which will be conducted during the engineering and design phase of the project, would enable benefits to be more fully quantified. Similarly, the acreage of SAV and mangrove habitat protected by the project could be quantified with estimates of the baseline habitat acreage and erosion rates of Egmont Key to benchmark the timeline over which the island footprint would be preserved by sediment placement.

Recreational use was quantified based on the number of annual visitors to Egmont Key, estimated as 220,000 (Cutshaw, 2020). This value captures the total number of visitors to the island under the assumption that the sediment placed will preserve the overall island footprint. Targeted analysis to estimate the lifespan of the island footprint with and without project could be used to refine the time scale of this impact, including determination of what types of recreational uses might be impacted and the relative value of the sediment placement compared to the entire island. This analysis would not necessarily require complex, process-based models: for example, analytical or empirical models of erosion rates could be used as a first-order approximation of the time scale over which the island would remain subaerial with and without sediment placement.

The Institute team considered methods for quantifying the impact of sediment placement to cultural resources at Egmont Key, such as counting the number of resources protected and/or estimating visitor access and use of each. However, the team determined that qualitative evaluation of impacts was more appropriate for these specific resources. Quantification metrics may not accurately capture ecosystem service benefits (Hirons et al., 2016), which are described as the “nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences” (Reid et al., 2005). The benefits are particularly difficult to quantify for Egmont Key, given that (1) the condition of the batteries and historic villages are poor compared to the proximally located Ft. DeSoto, built in the same era; and (2) the value of the cemeteries and the historical significance of the site to the Seminole Tribe of Florida are arguably incalculable (i.e., quantifying to compare to other benefits and costs constitutes a “taboo tradeoff” [Tetlock et al., 2000]). The benefit of the sediment placement to these resources in the context of time scales, however, could be quantified through improved estimates of the increased lifespan of the island footprint with and without project to determine the number of years these cultural resources would be protected. Similarly, the benefit that sediment placement provides to the pilot station is closely tied to time scale over which the footprint of Egmont Key is preserved due to sediment placement.

The final metric that could be quantified for the Egmont Key sediment placement is the negative impact that sediment infilling could have on the need for dredging of the adjacent ship channel. USACE has used empirical analysis of historical infilling after prior BUDM placements at Egmont Key to estimate the increase in sediment infilling in the adjacent shipping channel because of nearshore and onshore placement. An estimated 43,500–159,900 additional cubic yards (33,200–122,200 m^3) of material is expected to shoal into the channel during the first 3 years post-placement, after which shoaling rates are expected to equilibrate to historical values (USACE, 2024a).

Step 4: Monetization

The benefits that could be monetized for BUDM at Egmont Key using readily available data include overall economic impact of the island and the negative impact of shoaling into the navigation channel (**Error! Reference source not found.**).

Table 8. Monetization of sediment placement impacts at Egmont Key, FL. Valuation Method and Monetized Value includes impact estimates based on readily available data and modeling that could be used in the retrospective case study. Potential Valuation describes monetized value that could be captured with additional targeted data collection or analysis (in bold), which could be scoped in applying the workflow for potential projects.

Impact Category	Impact	Valuation Method	Monetized Value	Potential Valuation with Targeted Analysis
Built Environment	Storm surge reduction and protection of residential & commercial areas	Dollar value of structures protected by Egmont Key	N/A	Dollar value of structures protected could be calculated with data **identified in** Error! Reference source not found. **in conjunction with structure value from the National Structure Inventory.**
Habitat	Sandy beach and dune habitat Upland habitat/scrubland Seagrass & mangrove	Monetized value of carbon sequestration of seagrass & mangroves	N/A	Future benefit in year-acres calculated using **data identified in** Error! Reference source not found. **could be combined with carbon capture value per acre.**
Recreational Opportunities	Kayaking, birdwatching, hiking, beachgoing, fishing, etc.	Economic contribution of Egmont Key (shown) Recreational Use-Day Value	$18,963,464/year (Cutshaw, 2020) Note: full value of Egmont Key and includes all economic impact	Value of the sediment placement could also be quantified through recreational use-day value approaches using **data identified in** Error! Reference source not found.**.**
Cultural Resources	Ft. Date Batteries; ruins of the Ft. Dade village; Ft. Dade cemetery; Light House Cemetery; place of historic significance to the Seminole Tribe of Florida	N/A	N/A (qualified only)	N/A
Miscellaneous	Navigation benefits including protection of Tampa Bay Pilots Association pilot station; protection of in-service lighthouse	Cost of relocating the pilot station and/or lighthouse could be considered, depending on time scale of impact	N/A	If the protection of the island footprint, calculated using **data identified in** Error! Reference source not found**.,** is significant, the economic value could be calculated by **estimating the relocation cost of the pilot house.**
	Negative impact of increased shoaling of sediment	Increased cost of dredging associated with more shoaling of sediment into the shipping channel	$435,000 - $4,317,300. Calculated from estimated increase in shoaling (USACE, 2024a) and historic dredging costs in (Hershorin et al., 2019)	N/A (data were available)
Dredging Cost	Egmont Key's proximal location to dredging can result in a cost savings or a cost increase compared to disposal at upland sites that are farther from nearby channel cuts.	Cost of BUDM at Egmont Key compared to alternate disposal at an upland site	Range from savings of $22,500,000 to an added cost of $54,000,000, calculated from historical cost rates for upland disposal ($15/cy for dredging and $2-3/cy for disposal) compared to beach nourishment ($10-27/cy for dredging and $2-3/cy for disposal) (Hershorin et al., 2019)	N/A (data were available)

The Florida State Park System conducted an economic analysis of its park units and estimated the total direct economic impact (number of new dollars spent in a local economy by non-local park visitors and park operations) of Egmont Key at $18,963,464/year (Cutshaw, 2020). This value was calculated as:

$$TDE = N_{att} * \overline{NL_{perc}} * \overline{E_{day}} + E$$

Where:

TDE = Total direct economic impact

$\overline{NL_{perc}}$ = Average non-local visitor percentage

$\overline{E_{day}}$ = Average per person / day expenditure

E = FY expenditures by the Florida State Park system

Florida State Parks used 0.74 as the non-local ratio (Cutshaw, 2020), an average per person/day expenditure of $116.89 using data from Visit Florida and included $48,988 as the approximate expenditure of the Florida State Park system based on financial year 2019–2020 data. This formulation does not explicitly or exclusively relate to the recreational use value of the park (i.e., some visitors to the park may be drawn by cultural resource value). Since these benefits are not monetized in the current framework, however, there is no risk of double counting. This approach also does not consider the recreational value provided to local residents who visit the island. The recreational benefit of the sediment placement specifically could be valuated using a recreational use-day approach from engineering and design of the placement, once designed.

The cost per cubic yard of increased shoaling into the navigation channel could also be monetized using estimated dredging cost per cubic yard. Maintenance dredging of this area of the channel has historically been placed back at Egmont Key, which has an average cost of $10–27/cy ($13–35/m^3 Hershorin et al., 2019). This leads to an increased cost of $435,000–$4,317,300 for the projected increase in sediment shoaling into the shipping channel from the placement at Egmont Key. An important benchmark for this value is the baseline cost of maintaining the Tampa Harbor shipping channel, from which the annual average maintenance dredging removes 550,570 cy/year (420,940 m^3/yr USACE, 2024a). The increase due to placement at Egmont Key is therefore on the order of 3–10% per year for the first 3 years. The variation in cost is due to factors including volume placed, distance of transport, type of material, equipment used, and dredging location (Hershorin et al., 2019). The State of Florida 'Sand Rule' requires that sediment with fines in excess of 20.7% on average should not be placed. A study determined that placing sediment with fines in excess of the rule at Egmont Key would ultimately produce cost savings by expanding the amount of material sourced from proximal locations (Brutsché et al., 2019).

The data limitations for impact quantification (**Error! Reference source not found.**) did, however, limit monetized valuation for several benefits. The protection Egmont Key provides to the built environmental could be monetized using the National Structure Inventory (USACE, 2022). However, projections of flooding for the Tampa Bay region with and without project would be required. Similarly, carbon capture by seagrass, mangroves, and other vegetated areas created or protected by the project could be estimated, if the increased longevity of these regions due to sediment placement could be calculated. Lastly, the monetized value of protection of the pilot station and lighthouse as navigation aids could be valuated with information on (1) the future with and without project conditions to inform the time scale over which the resources would be protected; and (2) estimates of costs to relocate and/or replace the pilot station and/or lighthouse.

Another factor in BCR calculations is sediment placement cost. The BCR for the Tampa Harbor Deepening project did not differentiate costs for Egmont Key, but differential costs between BUDM and alternate disposal options were available (Hershorin et al., 2019). The estimated disposal costs for the Tampa Bay area (as of 2019) are similar for upland disposal ($15/cy or $20/m^3 for dredging and $2–3/cy or $3–4/m^3 for disposal) as for beach nourishment ($10–27/cy or $13–35/m^3 for dredging and $2–3/cy or $3–4/m^3 for disposal). Based on these values, the differential cost between placement at Egmont Key and in the upland site is -$5/cy or -$6/m^3 (lower cost of BUDM at Egmont Key) to $12/cy or $17/m^3 (increased cost of BUDM at Egmont Key). For the estimated 4.5 million cy (3.4 million m^3) that will be placed at Egmont Key (USACE, 2024e), the incremental cost of placement would be between a savings of $22,500,000 and an added cost of $54,000,000. This range illustrates one challenge in relying on BCR and valuation when considering sediment value: at the screening level (ahead of engineering and design), the unknowns and uncertainties associated with placement can cause significant variation in the cost estimates. This uncertainty highlights the value in using an assessment such as the workflow provided here, which does not rely exclusively on monetization and can be applied iteratively on targeted data collection and analysis to reduce the uncertainties most critical to making and/or justifying a decision on where to place sediment.

Step 5: Synthesis

A summary of benefits, negative impacts, and costs of BUDM at Egmont Key is presented in Table 9. Several impacts could not be quantified or monetized due to the retrospective nature of this analysis, which could potentially be addressed through targeted data collection or analysis. These categories are also presented and illustrate that applying the workflow to screen sediment placement opportunities can also identify high-value data collection or analysis opportunities.

The most significant qualitative benefits identified for placement of sediment at Egmont Key include habitat creation and protection, including for key species such as piping plovers, red knots, sea turtles, manatees, and gopher tortoises; preservation of a unique recreational opportunity in the form of a relatively isolated island that is readily accessible by boat or public ferry; and protection of cultural resources, including a lighthouse, cemetery, and site of significance to the Seminole Tribe of Florida. The only negative impact identified was a relatively small, short-term increase in shoaling to the adjacent shipping channel. Also of note is the relatively low cost of BUDM when benchmarked against alternate disposal at an upland site.

The most significant unknown identified for Egmont Key is the value of sediment placement in prolonging the longevity of the island footprint. Egmont Key had a subaerial area of 518 acres (2.1 km^2) in 1942, which had decreased to 247 acres (1 km^2) by 2002 (Tyler, 2016). Erosion rates over yearly to decadal scales are highly variable due to the impacts of storms (for example, 0.3 km^2 of the area was lost in the 4 years between 1979 and 1985). Robust analysis of project island loss rate with and without project would require empirical, deterministic, or probabilistic models that can account for SLR and sediment dynamics; however, a simple linear projection using historical rates is provided here as a benchmark. Assuming historical long-term erosion rates continued from 2002 into the future, Egmont Key would be reduced to 23% of its 1942 area by 2030 and could potentially be submerged by roughly 2055. This analysis suggests that the one-time nourishment from the Tampa Harbor deepening coupled with potential future placement of operations & maintenance (O&M) to maintain the deepened channel could have a significant benefit on the preservation of recreational, cultural, environmental, and economic benefits on time scales of 20–30 years and beyond.

An additional benefit that could not be fully quantified was the potential overall long-term value of Egmont Key as part of a RSM approach to managing the Tampa Harbor Navigation Channel. Egmont Key will continue to erode in the future, thus requiring additional sediment placement to maintain its size. However, its proximal location to portions of the navigation channel also provide capacity for continued disposal at nominal or reduced cost. One high value opportunity to both quantify and enhance the value of sediment placement for the Tampa Bay region would be to conduct a holistic economic and impact analysis of dredging and placement, i.e., expand the analysis conducted by , incorporating estimated dredging volumes and costs from the Tampa Harbor Deepening study (USACE, 2024e) and applying the workflow developed here). This approach would allow sediment placement benefits to be maximized and costs reduced on a larger scale.

Table 9. Synthesis of benefits and impacts of sediment placement at Egmont Key. The benefits and impacts are qualified and quantified relative to an alternative of upland disposal of sediment (i.e., no BUDM at Egmont Key). Colors in the Qualified Impact and Value of Targeted Data Collection & Analysis indicate the magnitude of impact (light blue = low positive impact or value of information (VOI); dark blue = high positive impact or VOI; gray = neutral impact; light orange = low negative impact. No large negative impacts were identified).

Impact Category	Qualitative Impact	Quantification and/or Monetization	Value of Targeted Data Collection & Analysis
Built Environment	Egmont Key protects Tampa Bay from storm surge, which protects structures along the bay shoreline from flooding. The magnitude of this benefit is estimated as low given available estimates of change in storm surge attributable to Egmont Key.	Difference in maximum water levels of -4 in to 6 in (-10 cm to 15 cm) for a 100-year storm, spatially varying across Tampa Bay (note: full value of Egmont Key)	Estimates of island longevity with and without project along with associated flood modeling could be used to quantify structures protected and economic value. The VOI is low, however, given the estimated magnitude of impact.
Habitat	Sediment placement would create sandy beach and dune habitat while protecting upland, scrubland, seagrass, and mangroves. Similar habitat is regionally available, but Egmont Key's isolation increases habitat value. Key species include piping plover (designated critical habitat), red knot (under consideration for critical habitat designation), sea turtles, manatee, and gopher tortoise. The magnitude of this benefit is therefore estimated as high.	Creation of ~150 total acres (0.6 km^2) of sandy beach and dune, including ~5 acres (0.02 km^2) of sea turtle and ~10 acres (0.04 km^2) of nesting bird habitat	Habitat creation could be better quantified with estimates of island longevity and habitat distribution with and without project, which could also be used to monetize carbon sequestration impacts. The VOI is high given the acreages of habitat under consideration and the potential for island-scale and regional benefits.
Recreational Opportunities	Recreation at Egmont Key is similar to proximally located Ft. DeSoto, but the Key provides a unique opportunity for ready access by boat or public ferry to a relatively isolated location. There are a significant number of visitors each year, many of which utilize the eroding beach areas, and it provides substantial economic benefit to the region. The magnitude of this benefit is therefore estimated as high.	220,000 visitors a year with an economic impact of $18,963,464/year (note: full value of Egmont Key and includes all economic impact)	This impact could be better quantified by estimating island longevity with and without project. The VOI is high given that Egmont Key is a unique recreational resource (isolated island yet readily accessible by boat).
Cultural Resources	The cultural resources on the landscape that are most unique to Ft. Dade when compared to nearby Ft. DeSoto (i.e., the cemeteries and lighthouse) are not at immediate risk of loss to erosion but may become so in the future. Egmont Key is also a place of historic significance to the Seminole Tribe of Florida, with an unknown relative value of different sites on the island. The magnitude of this benefit is therefore estimated as high, with a qualification that analysis of long-term project benefit to island preservation would be needed to accurately quantify project value.	N/A	This impact could be better quantified by estimating the lifespan of the island with and without project. The VOI is high given it could be used to determine the added lifespan afforded to the cultural resources by the project. In addition, robust evaluation would require more direct engagement of tribal representatives to qualitatively assess the significance of this benefit.

Impact Category	Qualitative Impact	Quantification and/or Monetization	Value of Targeted Data Collection & Analysis
Miscellaneous	Navigation benefits include protection of the Tampa Bay Pilots Association pilot station and an in-service lighthouse. These resources are not at immediate risk of loss to erosion but may become so in the future. The magnitude of benefit is therefore estimated as low, with a qualification that analysis of long-term project benefit to island preservation would be required to accurately quantify project value.	N/A (qualitative only)	This impact could be better quantified by estimating the lifespan of the island with and without project. The VOI is high given it could be used to determine the added lifespan of the lighthouse and pilot house. In addition, robust evaluation would require more direct engagement of with the U.S. Coast Guard to determine the cost of relocation.
	Sediment placement at Egmont Key will temporarily increase shoaling into the adjacent shipping channel. For reference, the average annual maintenance dredging of the Tampa Bay shipping channel is 550,570 cy/year, therefore the increase represents 3–10% increase for the first three years and is estimated as a low magnitude impact.	Total of 43,500–159,900 cy (33,200–122,200 m^3) material over historical infilling rates during the first 3 years after placement with an estimated cost of $435,000–$4,317,300	N/A (data were not available for valuation)
Dredging Cost	The proximal location of Egmont Key to the Tampa Harbor shipping channel can result in cost savings or a cost increase for disposal of sediment from channel cuts compared to upland disposal, depending on factors such as equipment used and distance transported. This impact is therefore neutral.	Range from savings of $22,500,000 to an added cost of $54,000,000, based on historical cost rates for upland disposal ($15/cy or $20/$m^3$ for dredging and $2-3/cy or $3–4/$m^3$ for disposal) compared to beach nourishment ($10-27/cy or $13–35/$m^3$ for dredging and $2-3/cy or $3–4/$m^3$ for disposal)	Existing RSM plans (Hershorin et al., 2019) could be updated to monetize overall cost of channel maintenance, including the relative cost of disposal at Egmont Key. This analysis could be used to maximize the overall benefits and reduce the overall costs of maintaining the Tampa Harbor shipping channel. The VOI is high, given that it would capture the value of sediment placed at Egmont Key as well as evaluate overall RSM benefits and costs.

Key Findings

Key factors identified that enhanced the benefits of sediment placement at Egmont Key and/or that reduced the associated cost:

- Egmont Key is proximally located to an area of recurrent maintenance dredging, reducing transport costs. The cost per cubic yard of BUDM at Egmont Key can be comparable to alternate upland dredge disposal options, depending on channel cut location, material dredged, and equipment used.
- Factors that influenced the historical cost of disposal at Egmont Key included volume of sediment placed, type of material dredged, location of placement, and location of dredging (Hershorin et al., 2019).
- A variety of equipment types can be used to place sediment on the beach or in the nearshore off of Egmont Key, including hopper, mechanical, and cutter-suction dredges (Hershorin et al., 2019). An evaluation of sediment placement with fines in excess of the State of Florida "Sand Rule" (on average 20.7%) found that post-construction beach sand was within this limit, suggested potential opportunities or cost savings associated with expanding the type and volume of material from proximal locations that can be used at Egmont Key (Brutsché et al., 2019).
- Egmont Key has been the site of historical BUDM. This factor streamlines the permitting and approval process for site placement during the planned 2028 Tampa Harbor Deepening (e.g., there is an existing Memorandum of Agreement between USACE, USFWS, the Florida State Historic Preservation Office).
- Egmont Key provides a diverse range of benefits, including social (recreational use, cultural value, etc.), economic (protection of infrastructure along the shoreline of Tampa Bay, visitor contribution to local economic), and environmental benefits (provision of barrier island habitat and use by multiple species, including threatened, endangered, and keystone species). This diversity of benefits both enhances the overall net benefit of sediment placement and underscores the importance of consideration of non-monetized (or non-monetizable) benefits.
- Erosion at Egmont Key threatens the subaerial footprint of the island, which provides added local and regional benefit (e.g., protection of the bay from storm surge; protection of proximal seagrass habitat; provision of a prime location for a pilot station). The relative benefit of sediment in preserving key, strategic areas of the landscape are important considerations in impact evaluation.

The application of the best practice workflow is from the perspective of having sediment to place (i.e., BUDM). A potentially useful benchmark in valuing sediment is the cost that would be associated with restoring Egmont Key for the express purpose of environmental restoration (i.e., the primary goal is the restoration of the island in the absence of BUDM). In 2014, the NOAA Restore Council considered an ecosystem restoration and storm damage reduction project comprised of placing 670,000 cy (512,000 m^3) of material on the western shoreline of Egmont Key to create approximately 39 acres (0.15 km^2) of coastal habitat; in addition, a support structure, such as a pile wall, would have been constructed to inhibit coastal erosion (Department of the Army, 2014). The Egmont Shoal Borrow Area was identified as the sand source for the initial placement, which would then be maintained through periodic renourishment with BUDM. The overall cost of the project was estimated as $25,000,000, including $4,000,000 in mobilization/demobilization and $15,000,000 in beach nourishment costs. Sourcing the material using BUDM from the Tampa Harbor deepening avoids these costs—an estimated total of $19,000,000—while providing a greater volume of materials (3,700,000 cy or 2,829,000 m^3). Because the costs of BUDM at Egmont Key and alternate, non-BUDM sites is comparable, there would be minimal additional costs for the Tampa Harbor deepening to offset the significant savings from sourcing sediment for the restoration.

Challenges and Opportunities

- Many of the identified benefits are closely tied to the island's footprint over time (i.e., compared to a future without action) and/or the increase in lifespan before the island potentially submerges, but data is not readily available on this information. A simple estimate using historical erosion rates suggests this benefit may be significant on time scales of 20–30 years. Robust quantification of this value—even through simple empirical models of erosion and island loss—would enable quantification and, in some cases, valuation of benefits.
- Assessment of the benefits of sediment placement under a dynamic future (e.g., incorporating SLR and storm effects in evaluating future with and without project) was hampered by lack of modeling data focused on these features. With targeted data, empirical modeling, and analysis, the acreages with and without action could be more robustly assessed.
- Baseline maps of habitat acreages and projections for future without action were unavailable, impeding opportunities to quantify and or monetize the impacts of placement. Developing habitat maps was beyond the scope of this effort. However, emerging methods in mapping habitat classes for barrier islands that rely on satellite imagery and/or a combination of satellite and *in situ* data could potentially be used to support a more robust habitat assessment (Enwright et al., 2019).

CAMINADA HEADLAND, LOUISIANA

Background

Caminada Headland is located in southeast Louisiana, extending from Belle Pass on its western side to Caminada Pass to its east (Figure 6 and Figure 7). The eastern portion of the Headland includes Elmer's Island Wildlife Refuge, managed by the Louisiana Department of Wildlife and Fisheries This land feature is considered one of the most important least tern nesting areas in the state, serves as nesting habitat for Wilson's plovers and diamondback terrapin, and provides important habitat for other coastal fish and wildlife. This includes birds listed as threatened through the Endangered Species Act, such as piping plovers and red knots (Arnold III & Weddle, 1978; USACE, 2012). The Headland also provides important storm surge and wave reduction for Port Fourchon, which is located just north of the western portion of the Headland. Port Fourchon is a nationally important port which furnishes approximately 18% of the country's oil supply and is the land base for the Louisiana Offshore Oil Port (LOOP). The LOOP handles approximately 15% of the nation's foreign oil imports and is connected by pipelines to 50% of the U.S. refinery capacity. The port also services the commercial fishing, seafood, shipping, tourism, and recreation industries. Highway 1 connects the Headland to communities located further inland. It is the only hurricane evacuation route for the residents of Grand Isle and Cheniere Caminada, and for the workers that support Port Fourchon and the LOOP (USACE, 2012).

Figure 6. Location of Caminada Headland along the Louisiana coast.

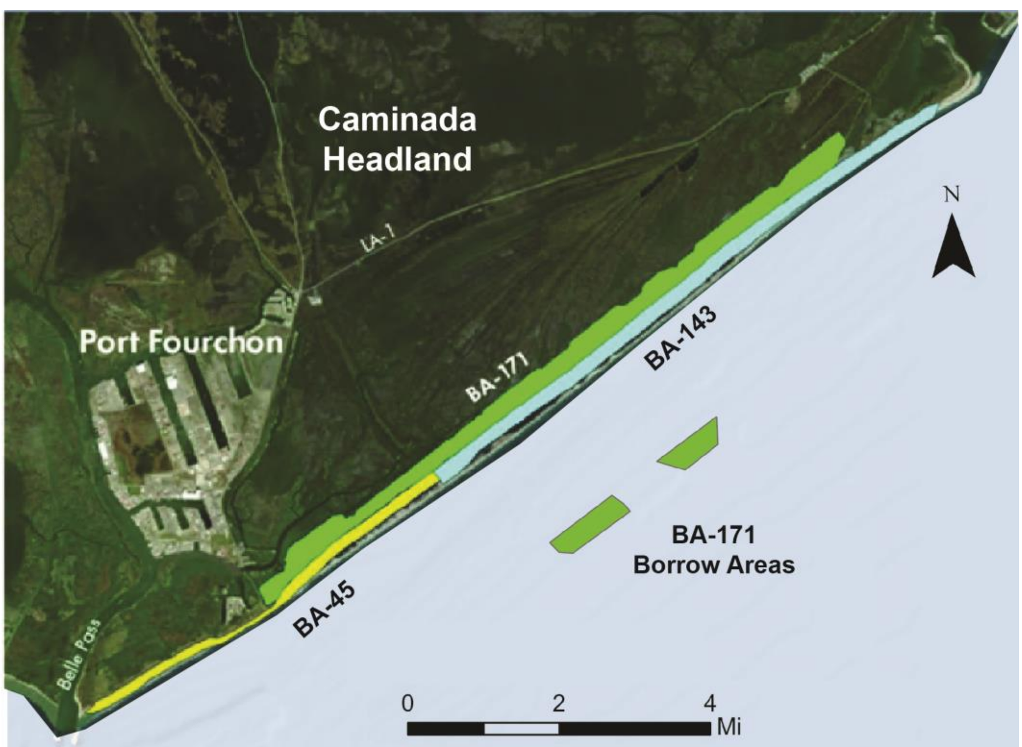

Figure 7. Caminada Headland restoration projects area. Construction occurred in three increments as indicated by the project codes.

The Caminada Headland is the erosional remnant of the formerly active Bayou Lafourche delta lobe of the Mississippi River that was abandoned approximately 800 years ago for a more hydraulically efficient route that evolved into the modern Birdsfoot delta (Yocum et al., 2022). As a result of deltaic abandonment, the Lafourche delta lobe no longer receives sediment from the Mississippi River, resulting in reworking of the deltaic landscape by waves, tides, and storms to form an erosional headland with flanking barrier islands. Over the historical period (1855–2005 post-Hurricane Katrina), Caminada Headland eroded at a rate of 37 ft/yr (11 m/yr), with rates of up to 190 ft/yr (58 m/yr) in the years following Hurricane Katrina (Martinez et al., 2009).

Restoration of Caminada Headland was included in the Louisiana Coastal Area Barataria Basin Barrier Shoreline Restoration study and Environmental Impact Statement (USACE, 2012) but was not authorized for construction. The project was later funded and implemented in three increments by the Louisiana Coastal Protection and Restoration Authority (CPRA)with the overarching goal to protect and preserve the integrity of the headland by restoring the beach, dune, and backbarrier marsh with sediment resources introduced from outside of the active system, to offset a significant deficit in the coastal sand budget that is the root cause of headland erosion and habitat loss (Miner et al., 2009). The project was planned as a comprehensive set of actions to achieve regional restoration goals with increments based on funding availability. The three increments, herein referred to by their project codes and collectively as the Caminada Headland Restoration Project, include BA-045 and BA-143, which together restored more than 13 miles (21 km) of beach and dune habitat, and BA-171 which restored approximately 900 acres (3.6 km^2) of back barrier marsh habitat directly landward of the restored beach and dune projects (Figure 7).

The other projects discussed in this report (Egmont and Laguna Madre) beneficially used material from navigation channel dredging. The Caminada Headland Restoration Project used dedicated offshore borrow areas to source the sediment needed for construction. It has been included in this report as an example of how broader RSM needs to be considered, consistent with recommendations from the TAG (Appendix B: Case Study Selection), as part of demonstrating how both beneficial use and dedicated dredging can be used alone or in concert to achieve regional goals. The decision to use dedicated dredging for the project was based upon an alternatives analysis for the Caminada project which determined that the highest-quality compatible sediment available for this restoration work would be obtained by dredging identified offshore areas that contained sufficient volumes of appropriate grain sizes required to complete the restoration (USACE, 2012). In addition to the dedicated dredging and fill projects, USACE has, since 1990, placed material dredged from the Belle Pass Federally authorized navigation channel both east and west of the pass to increase littoral sediment supply in the region and allow the dredged sediment to be naturally dispersed by currents and wave action. While the value of this beneficial use cannot be measured in acres restored, qualitative assessment indicates that this additional sediment supply to the surf zone extends the life of the reconstructed headlands through longshore drift (Corbino, 2024).

Cost comparisons between the Caminada Headland Restoration Projects (Table 10) and the beneficial use projects analyzed in this report should be made with care. Included in the cost calculations for BA-45 and BA-143 were beach/dune fill, mobilization and demobilization, sand fencing, sea turtle relocation and tissue sampling, and endangered species observation. Included in the cost calculations for BA-171 were hydraulic dredge mobilization and demobilization; dredge pipeline mobilization, installation and demobilization, general mobilization and demobilization, earthen containment dikes, hydraulic dredging and marsh creation, and daily bird abatement. Additional costs to complete the projects that were not included in this calculation for BA-045 include surveying, settlement plates, and restricted vehicle access signs. Costs not included in the calculation for BA-143 include surveying, sand fencing, settlement plates, restricted vehicle access signs, Elmer's Island road restoration gravel and road repairs, and walking path signs. Not included in the calculation for BA-171 are surveying and settlement plates. The costs not included are those that occur beyond the costs for dredging and placement. These were removed for the Caminada Headland Restoration Project costs so that it was comparable to the beneficial use projects evaluated in this study (that did not include those components).

Table 10. Construction information for Caminada Headland restoration.

Construction Unit and Sediment Source	Year Constructed	Volume Placed (Million Cubic Yards)	Volume Placed (Million m^3)	Cost ($)	Cost per Volume Placed ($/CY)	Cost per Volume Placed ($/$m^3$)
BA-045	2014–2015	3.62	2.77	$62,653,450	$17	$22
BA-143	2016	5.22	3.99	$135,898,672	$26	$34
BA-171	2023	2.45	1.87	$29,167,992	$12	$15

Construction of BA-045 was completed in 2015. It restored approximately 5.9 miles of beach and dune habitat through the placement of approximately 3.62 million cy (2.76 million m^3) of sediment. The project created 373 acres (1.51 km^2) of Gulf subtidal, Gulf intertidal, supratidal, and dune habitats for an increase of approximately 214 acres (0.86 km^2) over pre-construction conditions (CEC, 2015). Construction of BA-143 was completed in 2016. It restored approximately 7.4 miles (11.9 km) of beach and dune habitat, continuing the BA-045 footprint east to Caminada Pass through the placement of 5.22 million cy (3.99 million m^3) of sediment. A total of 686 acres gulf subtidal, gulf intertidal, supratidal, and dune habitats were created or restored for an increase of 226 acres (2.77 km^2; CEC, 2017). Both BA-045 and BA-143 projects included sand fencing and vegetation plantings. The sediment source for the projects that constructed beach and dune habitat was Ship Shoal, an offshore sand shoal located approximately 30 miles (48 km) from the headland (Figure 8). Ship Shoal has been extensively studied and identified as the most optimal sand resource for restoring barrier islands along this sector of coast that includes Isles Dernieres, Timbalier Islands, and Caminada Headland due to the coarser sand grain size (with high compatibility with the native dune and beach sands) and minimal fines content relative to other potential borrow sources in the region (Khalil et al., 2007; Kulp et al., 2001; Penland et al., 1990). It has been shown that, within the suitability range of sand grain sizes (relative to the native grain-size at the fill location), for barrier island restoration projects, coarser sand results in greater benefits to project lifespan and resilience to storm impacts (Caffey et al., 2022; Georgiou et al., 2019; Penland et al., 2003). However, due to the distance from borrow source to sediment placement location, utilization of this preferred high-quality sand resource required somewhat novel dredging and sand conveyance operations that involved combinations of hopper dredges and cutterhead dredges with sand transported via towed scow barges in lieu of a continuous pipeline that impacted project costs (CEC, 2015).

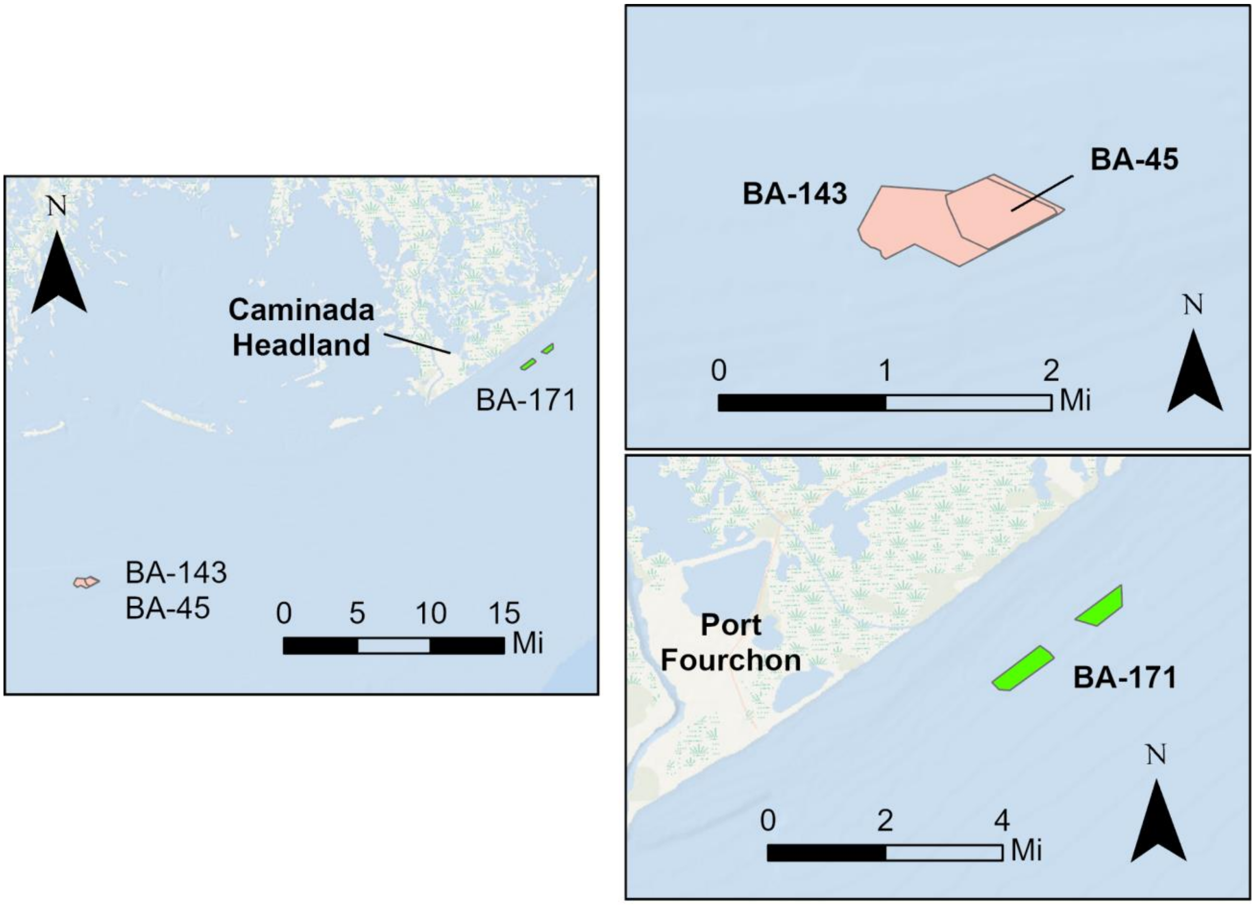

Figure 8. Maps displaying the borrow areas utilized for the reviewed restoration projects (left panel; BA-045, 143, and 171). BA-171 was sourced from a nearshore borrow site shown in green (right, top panel). BA-045 and BA-143 come from borrow areas within Ship Shoal (right, bottom panel; Ship shoal [left] for BA-45 and South Pelto Blocks 13 & 14 [right] for BA-143).

Construction of BA-171 was completed in 2023 and created back barrier intertidal marsh and nourished ~900 acres (3.6 km^2) of emergent marsh behind ~8 miles (13 km) of the Caminada beach using mixed sediment resources from the Gulf (Figure 8). It is anticipated that this project will result in nearly 330 acres (1.3 km^2) of net benefit over a 20-year project life. Sediment was dredged from just offshore of the project area, from two separate borrow areas, for a total of ~2.45 million cy (1.87 m^3; Sigma Consulting Group, Inc., 2023).

Application of Workflow

Because of the retrospective nature of the case study analysis, the application of the best practice workflow began with identifying potential impacts, along with the spatial area and time scale over which those impacts occur. The retrospective analysis was conducted based on the data and information available to evaluate and improve best practice available in project completion reports and post-construction monitoring reports (CEC, 2015, 2017).

Step 1: Initial Evaluation

Review of available literature identified potential post-construction and long-term impacts of the Caminada Headland Restoration Project as shown in Table 11.

Table 11. Initial assessment of potential impacts of restoration of Caminada Headland, Louisiana.

Impact Category	Impact	Location of Impact	Time Period
Built Environment	Wave attenuation and storm surge reduction and protection of residential and commercial areas	Port Fourchon, Highway 1, and communities along the Highway 1 corridor including Grande Isle and Leeville	Post-construction
Habitat	Increase in sediment transport to sediment-starved region through introduction of new sediment to the littoral zone	Caminada Headland and areas downdrift	Post-construction
Habitat	Long-term alteration of tidal prism, reducing further formation of tidal passes and allowing closing or narrowing of existing breaches, resulting in reduction of land loss rates in the region	Caminada Headland and areas downdrift	Post-construction
Habitat	Net increase of habitat acres over future without project; provision of platform for beach and dune migration	Caminada Headland	Post-construction
Habitat	Creation and restoration of sandy beach and dune habitats (colonial beach-nesting shorebirds, sea turtles, etc.)	Caminada Headland; increased sediment supply for islands downdrift in littoral system	Post-construction; longer-term benefit from sediment retention in the system
Habitat	Creation and restoration of back barrier marsh/mangrove habitat (wading birds, fish, etc.)	Area inland of beach/dune habitat restoration	Post-construction; longer-term benefit platform for beach and dune migration
Recreational Opportunities	Boating, beachgoing, birdwatching, fishing, etc.	Beach, dune, and back barrier portions of Caminada Headland	Post-construction; longer-term benefit from extension of island footprint lifespan
Cultural Resources	No significant cultural resources found	Not applicable	Not applicable
Miscellaneous	Navigation benefits including preservation of integrity of Belle Pass	Belle Pass is to the west of the project area (see Figure 7)	Longer-term benefit from extension of island footprint lifespan

Potential construction impacts of Caminada Headland restoration were expected to include (USACE, 2012):

- Temporary, short-term, and minor water quality negative impacts, with increased turbidity and potential reduction in dissolved oxygen associated with placement of dredged material.
- Temporary and short-term increase in commercial vessel traffic during construction.
- Temporary and short-term decrease in access to recreational resources benefits, offset by long-term increases.

- Temporary and short-term increase in noise during construction impacting fish and wildlife species.
- Temporary and short-term reduction in air quality during construction impacting fish and wildlife species.

Step 2: Description

A conceptual diagram was created linking the Caminada Headland Restoration Project to the potential impacts identified in Step 1 (Figure 9). The Caminada Headland Restoration Project directly creates beach, dune, and back barrier wetland (herbaceous marsh/mangrove) habitat. In addition, this project preserves a larger island footprint and extends the life of the island beyond what is expected in future without action (FWOA) projections.

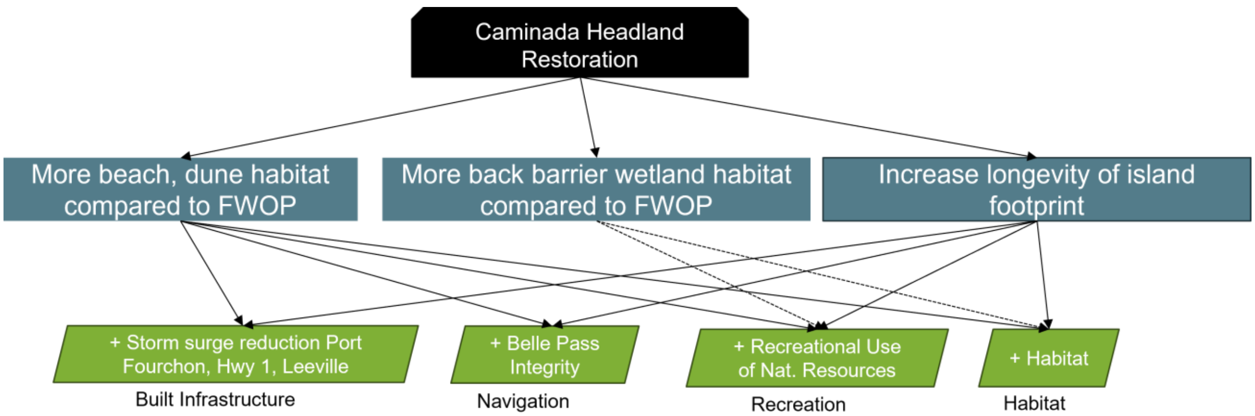

Figure 9. Conceptual diagrams of the impacts of restoration of Caminada Headland, LA. FWOP denotes future without project.

Literature review and evaluation of impact scale and significance led the Institute team to remove several potential impacts identified in Step 1. The temporary impacts of sediment placement, water quality, noise, air quality, vessel traffic, and recreational use during construction were removed from consideration given that all effects are minor and short-term.

The team then assessed long-term impacts by comparing future-with to FWOA. Without action, it was projected that Caminada Headland would lose 3,750 acres (15.2 km^2) by 2050 (USACE, 2012), resulting in reduction or complete loss of associated habitat benefits including those to built infrastructure, coastal processes, wildlife and fisheries, navigation, and recreational use. With the project (inclusive of all three increments), it was estimated that there will be a net increase of more than 2,000 acres (8.1 km^2) at the end of the 50-year project life (USACE, 2012). Anticipated benefits to the built infrastructure, navigation, habitat, fish and wildlife species, and recreational use are highlighted below.

- **Built Infrastructure:** Caminada Headland serves as a “line of defense” for Port Fourchon and Highway 1, providing storm surge and wave energy reduction. Restoration of the headland provided long-term, undetermined levels of increased protection for this infrastructure.
- **Navigation:** Caminada Headland restoration improves the integrity of Belle Pass by retaining the eastern-bounding geomorphic feature that defines the channel.

- **Recreational Use:** Restoration and preservation of the headland ensures continued recreational opportunities such as boating, beachgoing, birding, and fishing. Interpretive signs informing the public of the historic nature of the area were installed at Elmer's Island Wildlife Refuge at the easternmost end of the project area. The refuge, managed by the Louisiana Department of Wildlife and Fisheries, provides access for recreation and education opportunities. Restoration of the headland extends and improves those opportunities.
- **Habitat:** Caminada Headland restoration provides long-term and beneficial impacts to the barrier shoreline system.
    - **Headland integrity:** The headland size and function is improved over FWOA projections by restoring and creating protecting barrier island and nearshore habitat, including beach and dune, back-barrier marsh, and mangrove habitat which also serve to reduce further degradation and loss of important estuarine/marine habitat. The back-barrier marsh also serves as a platform for landward beach/dune system migration and the vegetation provides friction to help retain sand that might otherwise be lost to deeper water in the back barrier (Johnson et al., 2020).
    - **Coastal processes:** Sediment dynamics are improved by introducing new sediment into the littoral zone, thereby increasing transport in a sediment-starved area. Long-term alteration of the tidal prism reduces further formation of tidal passes and allows closing or narrowing of existing breaches, resulting in reduction of land loss rates in the region.
    - **Vegetation:** There is a net increase in vegetation from planting native species, offsetting temporary negative impacts to existing vegetation caused by sediment placement.
    - **Fish and wildlife:** Habitat for threatened and endangered or keystone species is created, improved, and preserved, thereby improving the quality of important stopover habitat for migrating neotropical birds, and providing critical habitat for threatened piping plovers, common nighthawks, least terns, and sea turtles. Essential fisheries habitat is improved.

Step 3: Quantification

The Institute team identified several impacts that could be quantified with readily-available data (Table 12) including acreages for some habitat types, Port Fourchon revenue from tenants, and hydrocarbon production and distribution activities that are supported out of Port Fourchon. However, data were unavailable for quantification of other identified impacts. A monitoring report of BA-045 and BA-143 from 2021 provided quantifiable data values for habitat acreage produced in Caminada Headland after those projects were completed (Georgiou et al., 2022).The post-construction project area of BA-045 had 232.3 acres (0.9 km^2) of dune and 72.8 acres (0.3 km^2) of supratidal habitat, for a combined total of 305.1 acres (Georgiou et al., 2022). The total land by 2019 was 241.8 acres (1 km^2). BA-143 post-construction had 420.8 acres (1.7 km^2) of dune habitat, and 180.0 acres (0.72 km^2) of supratidal habitat. These projects created 803 (3.2 km^2) acres of created beach and dune environments as of the 2021 monitoring report (Georgiou et al., 2022).

Table 12. Quantification of impacts of sediment placement at Caminada Headland, LA. Quantification Metric and Metric Value include impact estimates based on readily available data and modeling that could be used in this retrospective case study. Potential Metric indicates metrics that could be quantified with additional targeted data collection or analysis (in bold), which could be scoped in applying the workflow in practice.

Impact Category	Impact	Quantification Metric	Metric Value	Potential Metric with Targeted Data Collection or Analysis
Built Environment	Wave attenuation and storm surge reduction and protection of residential & commercial areas	Amount of protection provided by the increase in beach and dune elevation after project completion	N/A (qualitative only)	Storm surge and hydrodynamic (wave) models could be utilized to assess the amount of protection provided by the Caminada Headland's beach and dune system before and after project completion.
Habitat	Increase in sediment transport to sediment starved region through introduction of new sediment to the littoral zone	Change in sediment dynamics	The initial shoreline change rate between 2016 and 2018 (post-construction), was found to be -6.6 ft/yr (2.0 m/yr), a 75% reduction of pre-construction rates (2008-2012). Note that the movement of the shoreline seaward was due to project construction and not a gradual progradational process, so the yearly rates are not reflective of coastal processes (Georgiou et al., 2022).	Time series topobathymetry data collected over time to quantify erosion and depositional trends. These data can be used to calibrate (and ultimately validate) sediment transport models to assess benefits of sand introduction over time with and without project.
	Net increase of habitat acres over FWOP; provision of platform for beach and dune migration	Habitat acres created with project compared to future projections	2001 acres (8.1 km2) were the projected net increase of habitat acres with the implementation of these restoration projects (CEC, 2015, 2017; Sigma Consulting Group, Inc., 2023)	Habitat acres could be quantified with base habitat distribution and project design. Future benefit in year-acres could be quantified from baseline and with project conditions, SLR, and erosion rates.
	Creation and restoration of sandy beach and dune habitats (colonial beach-nesting shorebirds, sea turtles, etc.)	Habitat acres created with project	1059 acres (4.3 km2)of beach and dune habitat created after project completion (CEC, 2015, 2017)	Monitor to develop metrics for different species use and preferences (e.g., elevation, vegetation type and distribution, sediment grain size, shell content, etc.) within the beach and dune habitats to quantify optimal acreage for each.

Impact Category	Impact	Quantification Metric	Metric Value	Potential Metric with Targeted Data Collection or Analysis
	Creation and restoration of back barrier marsh/mangrove habitat (wading birds, fish, etc.)	Habitat acres created with project	Monitor marsh/mangrove habitat created after the completion of BA-171 (Sigma Consulting Group, Inc., 2023). ~ 942 acres of marsh	Habitat acres could be quantified with base habitat distribution and project design. Marsh should reduce the volume of sand lost from the beach to overwash (Johnson et al., 2020). This could be monitored in the years following project completion. Future benefit in year-acres could be quantified from baseline and with project conditions, SLR, and erosion rates. Alternatively scores from the Wetland Value Assessment performed for BA-171 could be used in lieu of areas (USGS Wetland and Aquatic Research Center, 2025)
Recreational Opportunities	Boating, beachgoing, birdwatching, fishing, etc.	Visitation of Elmer's Island wildlife refuge, beach, marsh, back barrier areas of Caminada Headland	Visitors to habitats created/maintained and used for recreational uses. 8,357 people took the ferry to Elmer's Island in 2023 compared to 5,220 people in 2022. This amount further increased in 2024 to 8,534 riders by June. Note: this does not include recreational use of the full area of sediment placement.	The recreational value of the sediment placed over time could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates. In addition, data on overall visitor statistics to the entire project area would enable more comprehensive assessment.
Cultural Resources	No significant cultural resources found	N/A	N/A	N/A

BA-045 was completed to protect the barrier shoreline between Belle Pass and 5.9 miles eastward, while BA-143 extended this restoration another 7.4 miles (11.9 km) to Caminada Pass (13.3 mi). This produced subsequent shoreline change that was analyzed in Georgiou et al. (2022), comparing pre- and post-construction erosion/apparent growth rates. These results indicated the pre-construction period had negative, albeit highly variable rates of shoreline change. Available data shows values ranging from -53.8 ft/yr (-16.4 m/yr)over the period between 1932–1956 to -23.6 ft/yr (-7.2 m/yr) between 2008 and 2012 (Georgiou et al., 2022). After construction, there was an apparent growth rate of 27.2 ft/yr (8.3 m/yr) due to the new shoreline being established 300 ft (91.4 m) seaward of the pre-construction shoreline. This is an average rate of 24.3 ft/yr (7.4 m/yr) between 2012 and 2018 (pre- and post-completion), although this movement is due to project construction and not a gradual process (Georgiou et al., 2022). Between 2016 and 2018 (post-construction), the shoreline change rate was found to be -6.6 ft/yr (-2.0 m/yr), which is a quarter of pre-construction rates (2008–2012; Georgiou et al., 2022). Although this displayed continual erosion and landward movement of the shoreline, it also indicated that the restoration projects effectively slowed down the rate of shoreline erosion along the Caminada Headland (Georgiou et al., 2022).

Another beneficial impact of these projects was the restoration of the degraded (and in some places absent) beach and dune system. The average elevation of the dune template reached 6.1 ft (1.9 m) in 2017 compared to 1.7–3.4 ft (0.5–1 m) prior to construction of BA-045, while the beach template reached 3.5 ft from an initial elevation of 0.3 ft (0.1 m) in 2010. Within the BA-143 project footprint, the average elevation within the dune template reached 7.2 ft (2.2 m) post-construction, compared to 2.0 ft (0.6 m) in 2010, and the beach template was elevated to -0.4 ft (-0.1 m) from -2.7 ft (-0.8 m) in 2010 (Georgiou et al., 2022). The amount of combined dune and supratidal area were 606.5 acres (2.5 km^2) in 2021 compared to 321.4 acres (1.3 km^2) in 2010, showing the success of BA-045 and BA-143 in creating a stable dune and beach platform despite continued erosional processes (Georgiou et al., 2022). This increase in dune height after project completion would theoretically help attenuate wave action and storm surge to the back barrier of Caminada Headland (Sallenger Jr., 2000). While the specific amount of protection may require the use of storm surge models of the area with and without project implementation, an increase in dune and beach elevation is expected to mitigate overwash and attenuate wave action on the coast.

Creation of back barrier marsh and mangrove habitat was the main objective for BA-171 in Caminada Headland. This project built upon the work of BA-045 and BA-143, focusing on the back barrier area of the previously restored regions of the headland. The goal of the project was to create and/or nourish ~900 (3.6 km^2) acres of back barrier marsh using sediments pumped from offshore borrow sites in the Gulf, and to create a platform upon which the beach and dune can migrate (Sigma Consulting Group, Inc., 2023). This was planned to reduce the likelihood of breaching, improve the longevity of the barrier shoreline, and protect wetlands and infrastructure to the north and west (Sigma Consulting Group, Inc., 2023). Vegetated back barrier wetlands also reduce the amount of sand that is lost from the beach and dune system during storm overwash events by providing friction that reduces flow velocities and attendant sand transport (Johnson et al., 2020). This project was completed in 2023, so further monitoring of the benefited land is necessary to determine the extent of this impact.

Recreational uses of Caminada Headland can potentially be quantified by assessing the maintained and created environments that can be used for those purposes in the region. Beaches, marsh, and back barrier areas have been created by multiple restoration efforts. This includes the BA-045 and BA-143 projects, as well as other initiatives that have been implemented in the region such as the Coastal Wetlands Park in Port Fourchon, a built wetlands park that has an area of over 100 acres (0.4 km^2), utilizing dredged material from newly developed slips in Port Fourchon (Greater Lafourche Port Commission, 2025). While in the past, mitigation meant marsh creation in inaccessible areas, this initiative brings mitigation with a recreational component (Greater Lafourche Port Commission, 2025). The Coastal Wetlands Park is designed as a recreational and educational area open to the public, providing outdoor activities for both Port Fourchon workers and visitors. Visitor statistics for Caminada Headland were not readily available to quantify recreational use of this area. This metric, along with habitat stability over time, could be used to refine this quantification. Elmer's Island Wildlife Refuge is another important recreational area on the eastern end of Caminada Headland. This is a location that serves both recreational and educational purposes and is a common location for birdwatchers and nature lovers. Statistics for shuttle operations to Elmer's Island are available for 2021 through June 2024. In 2022, there were 5,220 shuttle riders, which increased to 8,357 shuttle riders in 2023. This value has further increased through June 2024, with up to 8,534 shuttle riders up to that date.

Step 4: Monetization

The impact categories that could be monetized for Caminada Headland using readily available data were mostly those that were related to land/habitats created and maintained. Monitoring reports after the implementation of projects in this region determined the changes over time in habitats, vegetation, and created land. Other reports detailed the cost of implementation of these projects, and the estimated future costs of maintenance and nourishment of the headland. Utilizing these data sources, the cost value of some of these monitored project objectives can be evaluated.

For the monetization of habitat impact categories in Caminada Headland like marsh/mangrove environment, the acreage of created/benefited habitat can be used alongside monetary values provided from Harte Research Institute (2025) for Louisiana environments. BA-171 was designed and implemented to create ~900 acres (3.6 km^2) of marsh environment in the back-barrier area of Caminada Headland landward of the previously completed BA-045 and BA-143 projects (Georgiou et al., 2022). Based on (Barbier et al., 1997) values, coastal wetlands of LA were calculated to be worth approximately \$161 per acre (\$40,162 per km^2 adjusted to \$US 2019). Approximately 900 acres (3.6 km^2) of marsh habitat at this rate would be valued at \$144,585. Beach and dune environments are not well represented in the Blue Value database for Louisiana, so monetization of these habitats could not be readily calculated in the same fashion from available data.

The data limitations for impact quantification (Table 13) did, however, limit monetized valuation for several benefits. Impact categories like the creation and restoration of habitats for local species could be qualified but not quantified, preventing monetization.

Table 13. Monetization of sediment placement impacts at Caminada Headland, LA. Valuation Method and Monetized Value includes impact estimates based on readily available data and modeling that could be used in the retrospective case study. Potential Valuation describes monetized value that could be captured with additional targeted data collection or analysis (in bold), which could be scoped in applying the workflow for potential projects.

Impact Category	Impact	Valuation Method	Monetized Value	Potential Valuation with Targeted Analysis
Built Environment	Wave attenuation and storm surge reduction and protection of residential & commercial areas	Dollar value of structures protected by Caminada Headland	N/A	Dollar value of structures could be obtained from the National Structure Inventory. Along with storm surge models, this could be used to place a cumulative value of the structures that are being protected in response to different environmental conditions.
Habitat	Increase in sediment transport to sediment starved region through introduction of new sediment to the littoral zone.	N/A	N/A	Could be evaluated using morphology modeling (Caffey et al., 2022). Analysis of how the restored Caminada Headland interacts with its downdrift neighbors (change in acreage) over 50 yrs, with and without project.
Habitat	Net increase of habitat acres over future without project; provision of platform for beach and dune migration	N/A	N/A (value of beach/dune habitats in LA not available)	The monetized difference in habitat acres created/benefited by the projects compared to the projected future without project.
	Creation and restoration of sandy beach and dune habitats (colonial beach-nesting shorebirds, sea turtles, etc.)	N/A	N/A (value of beach/dune habitats in LA not available)	Value of beach and dune habitat acreage created and maintained in Caminada Headland using "blue value" (or other habitat valuations).

Impact Category	Impact	Valuation Method	Monetized Value	Potential Valuation with Targeted Analysis
	Creation and restoration of back barrier marsh/mangrove habitat (wading birds, fish, etc.)	Monetized value of marsh & mangroves as a habitat	Based on(Barbier et al., 1997), coastal wetlands of LA are worth $160.65 adjusted to $US 2019. BA-0171 was designed to create 900 acres of marsh and back barrier habitat, which would be valued at $144,585 using this metric.	Future benefit in year-acres calculated using data identified in Table 12 combined with ‘blue value’ (Harte Research Institute, 2025) of land created or carbon capture value per acre.
Recreational Opportunities	Boating, beachgoing, birdwatching, fishing, etc. as well as Elmer’s Island Wildlife Refuge	Economic contribution of Caminada Headland’s Recreational Use-Day Value	N/A	8,357 people took the ferry to Elmer’s Island in 2023. Using this value would allow for the valuation per visitor based on recreational day-use values if created.
Cultural Resources	No significant cultural resources found	N/A	N/A	N/A

Step 5: Synthesis

A summary of benefits and negative effects in Caminada Headland is presented in Table 14. Several impacts could not be quantified or monetized due to the retrospective nature of this analysis, which could potentially be addressed through targeted data collection or analysis. These categories are also presented and illustrate that applying the workflow to screen sediment placement opportunities can also identify high-value data collection or analysis opportunities.

The most significant qualitative benefits identified from the placement of sediment in Caminada Headland include creation of habitats for key species (i.e. piping plovers, sea turtles, etc.); creation of marsh and mangrove habitats; maintenance of the back barrier tidal prism to mitigate land loss; recreational use (i.e. fishing, boating, bird watching) at Elmer's Island wildlife refuge; and the 100% beneficial use of sediments dredged from Belle Pass.

Since BA-045, BA-143, and BA-171 have been completed, monitoring reports provide a review on the current status of these project areas compared to historic rates, pre-implementation. Georgiou et al. (2022) reported the changes in different land acreage across numerous habitats in Caminada Headland and highlights the net gain in land, and relative stability of open water area after project implementation. This monitoring report was completed before the implementation of BA-171 (2023), so the marsh creation designed for that project needs future monitoring to evaluate its stability.

Table 14. Synthesis of benefits and impacts of sediment placement at Caminada Headland. Colors in the Qualified Impact and Value of Targeted Data Collection & Analysis indicate the magnitude of impact (light blue = low positive impact or value of information (VOI); darker blue = high positive impact or VOI; gray = neutral impact.. No negative impacts were identified).

Impact Category	Qualitative Impact	Quantification and/or Monetization	Value of Targeted Data Collection & Analysis
Built Environment	Wave attenuation and storm surge reduction and protection of residential & commercial areas	Difference in water level pre- and post- project completion	Estimates of headland longevity before and after project implementation along with associated flood modeling could be used to quantify structures protected and economic value.
Habitat	Increase in sediment transport to sediment starved region through introduction of new sediment to the littoral zone	Between 2016 and 2018 (post-construction), the shoreline change rate was found to be -6.6 ft/yr (2 m/yr), which is a quarter of pre-construction rates (2008-2012)	Shows that the rate of shoreline change has reduced notably from pre-completion rates. This reduction in shoreline change, however, was not monetized.
	Net increase of habitat acres over future without project; provision of platform for beach and dune migration	2001 (8.1 km^2) acres were the projected net increase of habitat acres with the implementation of these restoration projects (CEC, 2015, 2017; Sigma Consulting Group, Inc., 2023)	Habitat acres could be quantified with base habitat distribution and project design. Future benefit in year-acres could be quantified from baseline and with project conditions, SLR, and erosion rates.

Impact Category	Qualitative Impact	Quantification and/or Monetization	Value of Targeted Data Collection & Analysis
	Creation and restoration of sandy beach and dune habitats (colonial beach-nesting shorebirds, sea turtles, etc.)	1059 acres (4.3 km^2) of beach and dune habitat created after project completion	Displays the amount of beach and dune habitat acres that were created as of project completion. 803 acres of beach and dune habitat were reported as of 2021 within the project areas (Georgiou et al., 2022). This acreage could be further analyzed with the relative value of beach and dune acres as habitat; however, this information was not readily available for Louisiana beaches.
	Creation and restoration of back barrier marsh/mangrove habitat (wading birds, fish, etc.)	Based on (Barbier et al., 1997), coastal wetlands of LA are worth $160.65 per acre or $40,162 per km^2 adjusted to $US 2019. BA-0171 was designed to create 900 acres (3.6 km^2) of marsh and back barrier habitat, which would be valued at $144,585 using this metric	Future benefit in year-acres calculated using **data identified in Table 12 combined with 'blue value' of land created or carbon capture value per acre.**
Recreational Opportunities	Boating, beachgoing, birdwatching, fishing, etc. as well as Elmer's Island Wildlife Refuge	Visitors to habitats created/maintained and used for recreational uses. 8,357 people took the ferry to Elmer's Island in 2023 compared to 5,220 people in 2022. This amount further increased in 2024 to 8,534 riders by June	This analysis shows an increase in visitation to a key recreational area on Caminada Headland in the years after project completion. While this increase is a noted positive impact, without the metrics of shuttle riders before project implementation, these values cannot be thoroughly assessed.
Cultural Resources	No significant cultural resources found	N/A	N/A

Key Findings

This case study led to several key findings regarding factors that increase the benefit and/or reduce the cost of sediment placement, and which are applicable to RSM more broadly.

Borrow Source:

- Caminada Headland's beach and dune restoration projects (BA-045 and BA-143) utilized sediments from Ship Shoal, an offshore LA sediment resource. This resource, and many others in the Gulf, are partially (and in some instances completely) obstructed due to the presence of oil and gas infrastructure. This reduces the total volume that can be extracted from these sources; increases project costs due to more complicated engineering and design and longer sediment transport distances to the fill site; and complicates dredging operations when having to work in limited space and within segmented borrow areas. Ultimately, reduced availability of the limited sediment resource increases the cost of projects using those resources.

- Project performance and lifespan is highly dependent on sand grain size. Coarser sediment has lower mobility, provides for more resilient dunes (more windblown sand is retained locally), and provides for more suitable substrate for dune and back barrier marsh vegetative plantings (Caffey et al., 2022; Feher et al., 2018).
- The BA-045 borrow design at Ship Shoal included multiple avoidance areas for potential cultural resources based on a clearance survey conducted at 30 m line-spacing. Prior to BA-143 construction, CPRA worked in cooperation with the Bureau of Ocean Energy Management (the federal agency responsible for managing Federal offshore sediment resources) to conduct archeological dive investigations at the sites that had been avoided. The sites were cleared, freeing up an additional 2.7 million cy (2.1 million m^3) of sand for BA-143 construction.
- The BA-045 and BA-143 projects combined to be the largest coastal restoration project to use offshore sand at the time they were constructed. The transport distance from the Ship Shoal borrow source to the fill was also the longest at over 30 miles. To accomplish this, novel dredging operations were employed where cutterhead dredges were used in combination with hopper dredges. Typically, a cutterhead dredge operation will require a continuous pipeline deployed on the seabed to transport dredge material to the fill site. In this case, for the first time offshore in the US, scow barges were used instead of a pipeline. This involved the cutterhead pumping into the barge and the barge being towed to a pump-out site near the fill area. This cut down on time to deploy and maintain the pipeline during construction and allowed for more rapid resumption of work after disruptions from storms.

Placement:

- BA-045 and BA-143 created an increase in dune and beach habitat acres as well as elevation. (Georgiou et al., 2022).
- While CPRA has a project monitoring program, the duration and rigor of monitoring of specific projects often varies based on the project funding source. The BA-045 and BA-143 projects benefited from a detailed analysis of post-project performance monitoring (habitat acres, shoreline change, elevation change, etc.) and reporting (Georgiou et al., 2022) that provided valuable information used in this report to demonstrate and quantify project benefits.
- Besides project-specific monitoring, Louisiana also has a robust long-term, regional monitoring program to inform adaptive management and future project planning. Components of this program relevant to the barrier island restoration program include:
    - Barrier Island Comprehensive Monitoring (BICM) Program. Data such as topography/bathymetry, shoreline position, sediment grain size, and habitat acres are collected for the entire Louisiana barrier shoreline every 5–10 years. These data are analyzed to document and quantify habitat change, sediment dynamics, elevation change, shoreline change, and island area (among other metrics) change over decadal timescales with some baseline data extending back to the mid-1800s. This regional, long-term dataset has been valuable to demonstrate the benefits of individual projects beyond their project footprint and the cumulative benefits of multiple projects on the overall system.
    - Borrow Area Management and Monitoring (BAMM) Program. Select borrow areas are monitored post-construction to track the character and timing of recovery (CB&I, 2015; Khalil et al., 2018). This has been valuable to demonstrate that the physical and biological impacts associated with excavating sediment resources are temporary and

localized. In some cases the borrow areas refill with sediment suitable for subsequent restoration projects.

- Louisiana Sediment Management Plan (LASMP). Provides for an inventory of potential sediment resources, defines sediment needs programmatically, and informs strategic planning for best use of limited sediment resources. This informs the Louisiana Coastal Master Plan and the implementation of projects contained therein to ensure that sediment resources are available for the projects and that the most suitable sediment is allocated to best meet project goals.

- Additional monitoring reports for Caminada Headland since the completion of BA-171 will help to further quantify the total benefit of the placed material.
  - Future reviews could assess the stability of the beach and dune habitats in response to restoration of the back barrier marsh environments.
  - The change in open water within the headland would also be of interest, since the material from this project was placed in the back barrier area.

Challenges and Opportunities

- While Louisiana has a robust monitoring and data collection program, it is important that the data collection efforts consider the modeling needs (e.g. shoreline change rates) associated with forecasting sediment transport with and without project, and other types of alternative analysis that can inform optimal allocation and valuation of limited sediment resources.
- Numerical modeling should be employed more frequently to inform alternatives analysis, demonstrate the value of a project, and determine the sediment resources required to construct it. This can also inform holistic sediment management to determine optimal placement methods and locations to maximize benefits. These benefits extend beyond the project footprint and barrier system and modeling approaches can be used to evaluate benefits to protecting infrastructure and interior wetlands from barrier island restoration projects.
- Recreational valuation here is difficult, since most recreation on Caminada Headland appears to be sport (i.e., boating, fishing, hunting, etc.). These have fewer visitation statistics than a more active recreational environment (i.e., an amenity beach).
- Industry outweighs recreation here, so impacts that affect this commercial infrastructure are of great importance.
  - The maintenance of Belle Pass for navigation purposes produces dredged material. This material is 100% beneficially used within the surrounding area of the headland.
  - Since Port Fourchon is a commercial industry hub, its stability is of great economic importance.

LAGUNA MADRE, TEXAS

Background

The lower Texas coast is defined by Padre Island, a 115-mile-long (185 km) barrier island chain that is one of the longest in the world. The island separates the western Gulf from the Laguna Madre, a back barrier lagoon and estuary that stretches from Baffin Bay near Corpus Christi, Texas to Port Isabel, Texas (Figure 10). Port Mansfield, Texas is a small town and port located on Laguna Madre. In 1957 the

Willacy County Navigation District constructed a 13 km channel from the Gulf Intracoastal Waterway (GIWW) through Laguna Madre and Padre Island to form a new Gulf entrance (Figure 11). The immediate Port Mansfield region contains numerous protected natural and cultural refuges including portions of the Padre Island National Seashore, the Lower Rio Grande National Wildlife Refuge, and the Laguna Atascosa National Wildlife Refuge. These parks and refuges contain unique coastal habitats that are home to myriad species and provide broad ecosystem services. Laguna Madre is notably one of only five hypersaline coastal ecosystems worldwide and hosts over 75% of the seagrass habitat of the entire Texas coast (Onuf, 2006)**.** The shore of Padre Island is also one of the main nesting sites of Kemp's ridley sea turtles, one of the most endangered sea turtle species globally (Culver et al., 2020).

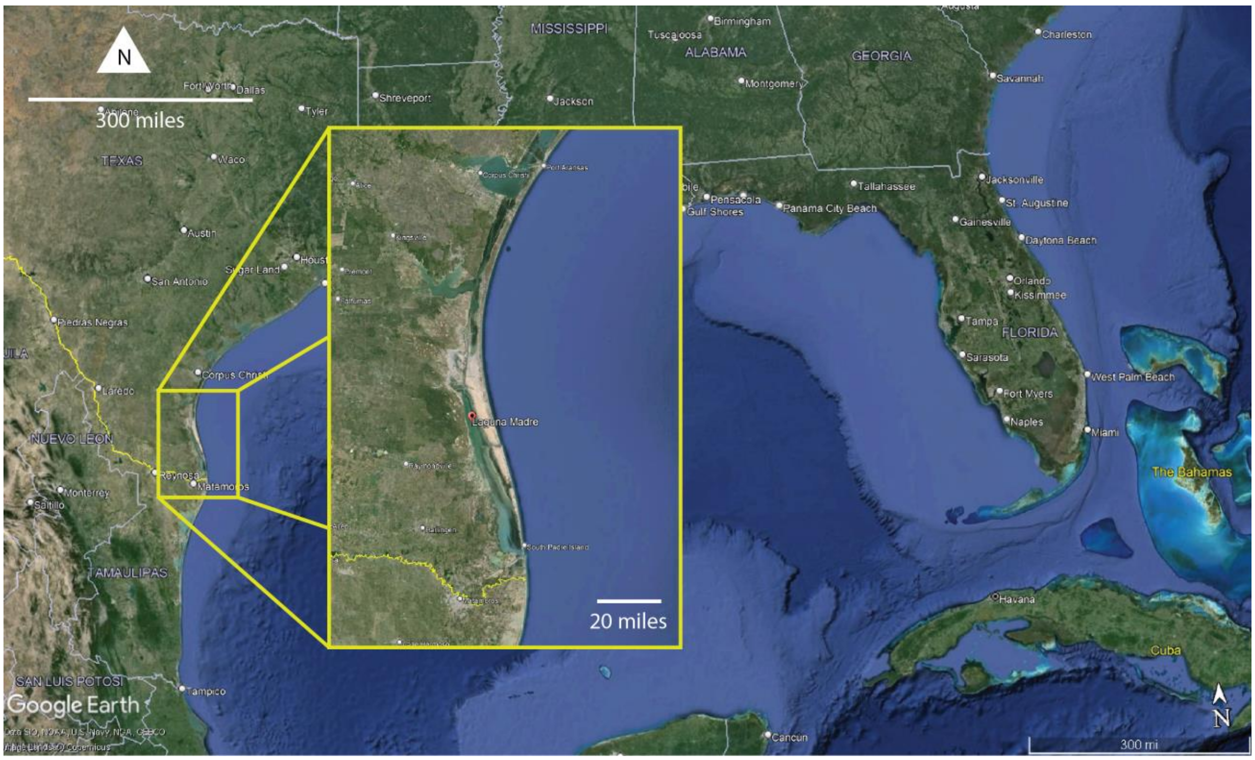

Figure 10. Location of Port Mansfield along the South Texas Coast.

The Port Mansfield Channel is a shallow draft channel originally dredged to enable commercial and recreational navigation between Lower Laguna Madre and the Gulf (Kieslich, 1977). The channel was dredged to an initial depth of 10 ft with a subsequent deepening to 17 ft (5.2 m) in 1962. Initial construction in 1957 led to the notable discovery of a series of 1544 Spanish galleon shipwrecks when the dredge cutterhead inadvertently cut through the hull of a buried galleon, showering the beach with gold and silver coins. The wrecks and associated artifacts led to the formation of the Mansfield Cut Underwater Archaeological District, adjacent to the Padre Island National Seashore (Arnold III & Weddle, 1978).

Construction of the Port Mansfield Channel and associated jetties led to disruption of the net northward littoral sediment transport cell of Padre Island, with the sediment accumulating along the south jetty and the shoreline rapidly eroding north of the channel (Figure 11). Shoreline erosion of southern Padre Island National Seashore has been identified as a risk to habitats of several threatened and endangered species, including the Kemp's ridley sea turtle and the piping plover shorebird.

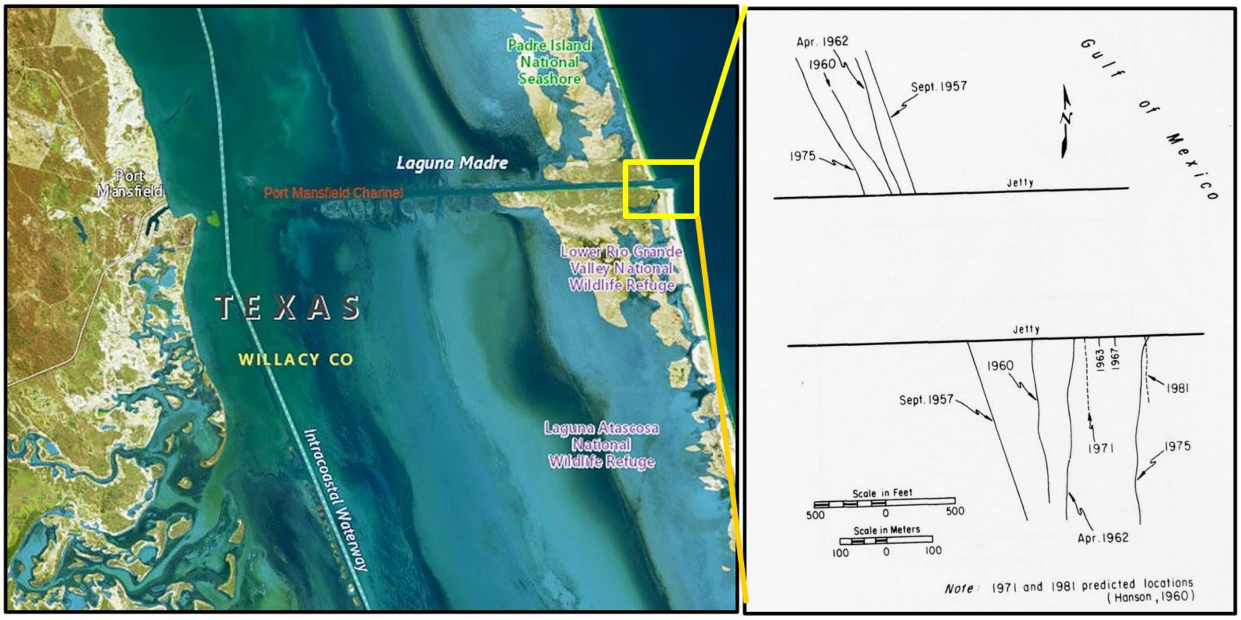

Figure 11. Location of Port Mansfield Channel and Laguna Madre. Inset panel shows measured shoreline positions following channel construction, with shoreline erosion north of the channel and shoreline progradation to the south. Modified from "A Case Study of Port Mansfield Channel, USACE, 1977".

Dredge material from initial channel construction and subsequent maintenance was historically placed on storm protection levees adjacent to the Port Mansfield Channel, then from 1963–1990 moved by hopper dredge to an initial ocean dredge material disposal site (ODMDS), and from 1990 to 2011 a newly designated ODMDS located ~2 miles offshore of the channel entrance (EPA, 2008). Designation and use of the ODMDS for maintenance dredging was in large part driven by the lack of any suitable estuary or upland placement site (*Federal Register*, 1990). Laguna Madre, the home to the largest seagrass meadows in Texas, has for decades been the focus of work quantifying the effect of dredge-induced turbidity on these ecosystems (Onuf, 1994). Potential adverse effects on the lagoon limited the use of more economical thin layer placement or traditional upland disposal sites, necessitating the more costly transport to the ODMDS (TXDOT, 2015). From 1963 to 2002 maintenance dredging occurred roughly every 2 years, with ~4.5 million cy (3.1 million m^3) of material transported and discharged to the ODMDS (Figure 12). Data was not available from 2002 through 2011. From 2011 to 2020 no maintenance dredging occurred, in part due to high dredging and disposal costs compared with commercial and navigational benefits (TXDOT, 2015), leading to near complete siltation of the channel with associated reduction in navigability and hydrologic exchange between Laguna Madre and the Gulf.

Maintenance Dredging History

STARTED	COMPLETED	QUANTITY DREDGED (CUBIC YARDS)
February 4, 1963	February 17, 1963	43,899
August 11, 1964	August 20, 1964	80,613
November 19, 1965	November 28, 1965	90,749
October 3, 1966	December 17, 1966	96,287
June 1, 1967	September 4, 1967	97,333
June 5, 1969	June 15, 1969	161,110
June 16, 1970	July 26, 1970	99,097
May 15, 1972	July 23, 1972	416,569
May 28, 1973	July 23, 1973	314,900
August 5, 1974	September 12, 1974	81,216
May 1, 1976	August 1, 1976	292,433
September 6, 1977	September 30, 1977	534,000
August 4, 1978	September 27, 1978	226,296
July 16, 1979	August 4, 1979	364,534
November 6, 1980	December 3, 1980	302,181
May 10, 1983	July 5, 1983	372,765
April 4, 1986	May 14, 1986	104,196
March 23, 1988	June 14, 1988	132,937
November 14, 1988	December 7, 1988	169,585
March 9, 1990	September 30, 1990	131,692
June 28, 1991	November 25, 1991	98,748
February 3, 1994	April 6, 1994	242,813
March 4, 2002	March 20, 2002	117,271
Total		4,571,224
Average		198,749

Figure 12. History of Port Mansfield Channel maintenance dredging from 1963 to 2002. All materials were transported by hopper dredge to an ODMDS nearby.

In 2020 Port Mansfield Channel was the subject of a new BUDM project coordinated between USACE, the National Park Service (NPS), and key local partners to restore navigation to Port Mansfield, enhance shoreline stability of Padre Island, maintain hydrologic exchange and salinity maintenance of Laguna Madre, and continue the growth of a Laguna Madre rookery known as Port Mansfield Bird Island. Prior to 2020 beneficial placement was not considered an option by USACE and partners, but new opportunities for placement in Padre Island National Seashore and estuarine bird island rookeries appeared to enable cost-effective dredging compared with transportation to the ODMDS (TXDOT, 2015; USACE, 2021b). Between 2020 and 2021 USACE dredging removed ~2.5 million cy (1.9 million m^3) of material from the channel, using 970,000 cy (726,000 m^3) for beach nourishment on Padre Island National Seashore and ~ 1,500,000 cy (1,146,000 m^3) for Laguna Madre Bird Island (USACE, 2021; Figure 12). Following the reopening of the channel and successful material placement, USACE and other stakeholders have begun planning for continued semi-annual maintenance dredging, BUDM placement, and planning for a more significant channel deepening and large scale BUDM placement on Padre Island

National Seashore and the Port Mansfield Bird Island Rookery under the Coastal Texas Protection and Restoration Plan, as seen in Figure 13 (USACE, 2021b). Table 15 contains information on the timing, amount and cost of these BUDM placements.

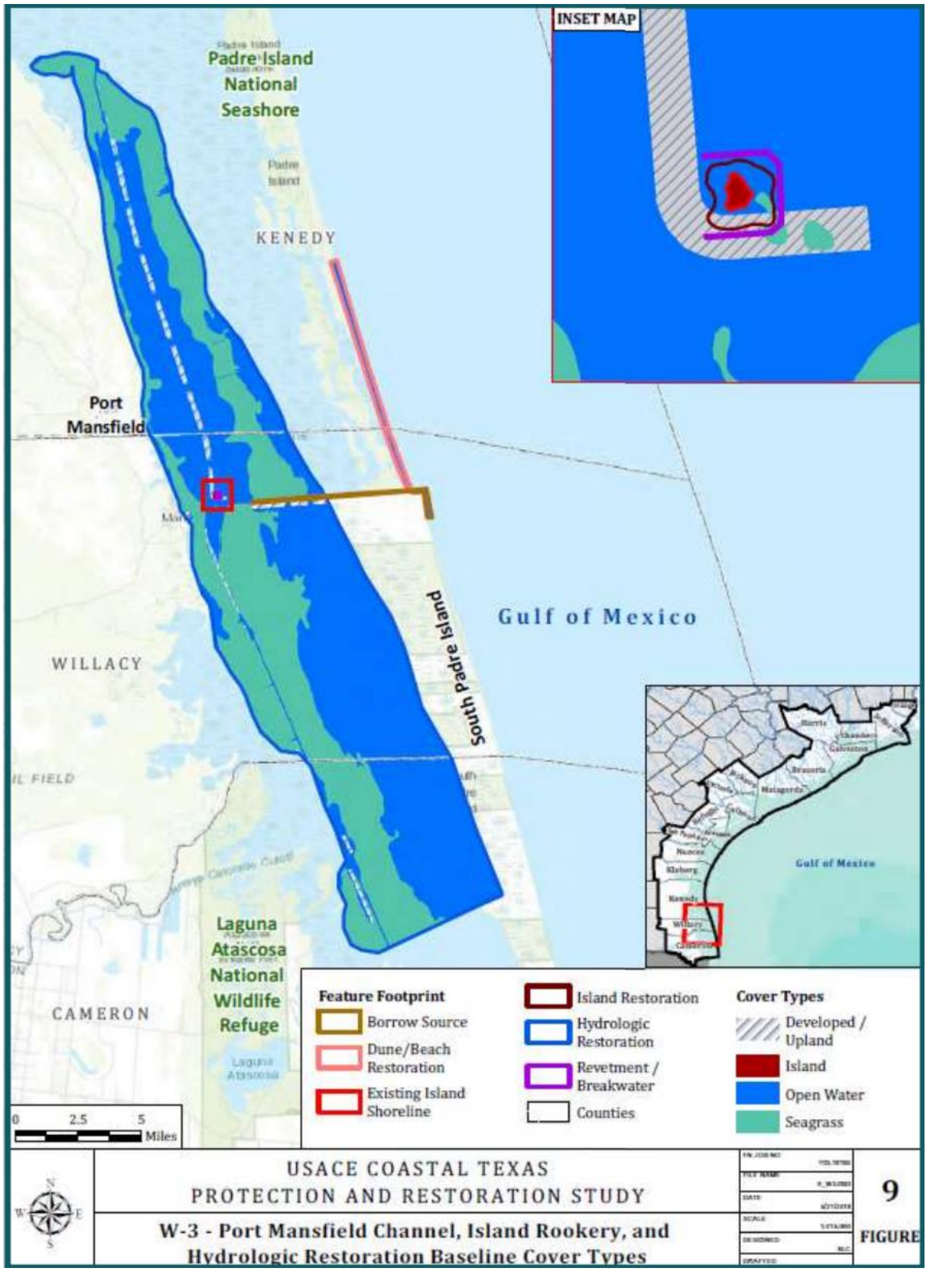

Figure 13. USACE Coastal Texas Protection and Restoration Study Plan for Port Mansfield Channel Area. Borrow source is the existing Port Mansfield Channel, with placement sites located on Padre Island National Seashore and the Port Mansfield Bird Island Rookery as constructed in the 2020–2021 BUDM activity.

Table 15. Construction Information for Port Mansfield (Laguna Madre) navigation and restoration project

Construction Unit and sediment source	Year Dredged	Volume Placed (Cubic Yards)	Cost	Cost/Cubic Yard
Channel to Port Mansfield	2020–2021	2,524,720	$25,177,696	$9.97
Channel to Port Mansfield	2024	2,000,000	N/A	N/A
Port Mansfield Channel, Island Rookery, and Hydrologic Restoration	TBD	TBD	$65,914,000	TBD

Application of Workflow

Step 1: Initial Evaluation

Literature review of Laguna Madre and Port Mansfield identified several potential impacts of channel dredging and associated placement (Table 16) including:

1. Providing commercial and recreational access between Laguna Madre and the Gulf;
2. Protecting cultural resources of Padre Island National Seashore and the Mansfield Cut Underwater Archaeological District, which contain artifacts related to Spanish settlement and trade;
3. Creating and protecting barrier island and back barrier habitat such as beach and dune systems, shallow lagoons, and seagrasses;

Table 16. Initial assessment of potential impacts of Port Mansfield (Laguna Madre), Texas. The specific magnitudes of any benefits dependent on footprint retention, will vary based on the extent of degradation in without project conditions. Additional modeling would be required to determine the specific extent of degradation in this case.

Impact Category	Impact	Location of Impact	Time Period
Navigation	Opening of Mansfield Channel to authorized depth (17 feet)	Channel to Port Mansfield between GIWW and the Gulf	Post-construction, subject to continued semi-annual maintenance dredging
Habitat	Creation of beach and dune habitat	Southern Padre Island National Seashore	Post-construction, while footprint is retained
	Maintenance of shoreline and nearshore through new sediment in rapidly eroding area caused by jetty construction	Southern Padre Island National Seashore	Post-construction
	Net increase of habitat acres over FWOP, particularly beach habitat suitable for critically endangered Kemp's Ridley Sea Turtles	Southern Padre Island National Seashore	Post-construction, while footprint is retained

Impact Category	Impact	Location of Impact	Time Period
	Creation and restoration of colonial nesting bird rookery habitat	Laguna Madre, Laguna Atascosa National Wildlife Refuge	Post-construction, long-term sediment retention
	Creation and restoration of back barrier marsh, seagrass habitat (wading birds, fish, etc.)	Padre Island National Seashore	Post-construction, while footprint is retained; longer-term benefit platform for beach and dune migration
	Reduction of hypersalinity	Laguna Madre lagoon	Post-construction, subject to continued semi-annual maintenance dredging
Recreational Opportunities	Boating, beachgoing, birdwatching, fishing, etc.	Padre Island National Seashore, National Wildlife Refuges, the Gulf	Post-construction while footprint is retained; longer-term benefit from extension of island footprint lifespan.
	Deep-water sportfishing access from Port Mansfield to the Gulf	The Gulf	Post-construction, subject to continued semi-annual maintenance dredging
	Beach and dune access by boat; vehicular access and public use of beach	Padre Island National Seashore, Laguna Atascosa National Wildlife Refuge	Post-construction, subject to continued semi-annual maintenance dredging
Cultural Resources	Preservation of Mansfield Cut Underwater Archaeological District	Padre Island National Seashore	Post-construction while footprint is retained
Miscellaneous	Enabling Port Mansfield commercial activity	Port Mansfield	Post-construction, subject to continued semi-annual maintenance dredging

Step 2: Description

The linkages of sediment placement and potential impacts identified in the Port Mansfield Channel area are presented in Figure 14. Benefits associated with Port Mansfield Channel are centered on the placement of sediment directly creating and maintaining habitats and the island footprint, and the continued open channel between Laguna Madre and the Gulf enabled by project construction and long-term maintenance. The opening and continued maintenance of the Port Mansfield Channel allows direct access between central Laguna Madre, Port Mansfield, the GIWW, and the open Gulf. Otherwise, the nearest outlets of Laguna Madre are located ~115 miles (185 km) apart, severely limiting recreational and commercial traffic. Additionally, Laguna Madre is a hypersaline restricted basin due to very limited freshwater inflows. Port Mansfield Channel allows lower salinity Gulf waters to exchange with Laguna Madre providing for the existence and growth of estuarine and lagoonal habitats, particularly seagrass meadows. The value of preserving and growing these habitats is somewhat debatable, as it does come at the cost of reducing the amount hypersaline environment which has some value as a unique habitat.

The benefits and impacts of dredging the Channel to Port Mansfield and associated placement of the dredged sediments are closely linked in this area. The opportunity to cost-effectively place materials in Padre Island National Seashore and estuarine bird island rookeries sites adjacent to the channel appears to be a major factor in cost-effectively maintaining channel navigation and hydrologic exchange between Laguna Madre and the Gulf (TXDOT, 2015). The workflow developed in this project is intended to primarily consider the benefits of sediment placement directly, distinct from the benefits of the sediment sourcing or removal itself. For the Port Mansfield/Laguna Madre case study the Institute team identified and catalogued the impacts of both the sediment placement and the sediment sourcing, but constrain the quantification, monetization, and synthesis steps (workflow steps 2–4) to direct sediment placement impacts. However, recognizing the benefits of dual consideration (placement and sourcing) in a holistic RSM framework is an important finding of Port Mansfield, and so this case study summarizes the combined benefits and impacts within the key findings.

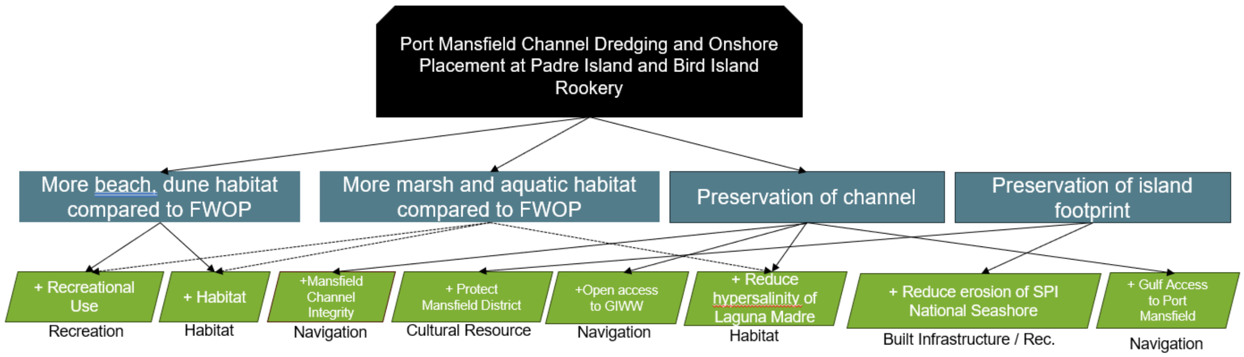

Figure 14. Conceptual diagram of the benefits and impacts of restoration at Laguna Madre, Texas.

This study assessed the potential significance of the impacts identified in Step 1 (Table 16) to determine which specific elements should be included in the final evaluation. Impacts were grouped into a set of categories: navigation, habitat, recreational use, cultural resources, and miscellaneous. As noted above, the quantification, monetization, and synthesis steps of this case study were constrained to benefits/impacts of the sediment placement, rather than the sediment sourcing and dredging itself. The following provides context for specific factors and benefits identified in the Port Mansfield Channel study, and whether these impacts are due to **sediment placement** or **sediment sourcing**:

4. **Navigation:** Dredging of Port Mansfield Channel is required to maintain commercial and recreational navigability of the channel, enabling access from Port Mansfield to the Gulf, and access to and from the GIWW from central Laguna Madre. (**Sediment Sourcing)**
5. **Habitat:** BUDM of Port Mansfield Channel sediments supports habitat restoration and sustainability objectives across several systems, in addition to the positive impacts maintaining hydrologic connectivity between Laguna Madre and the Gulf.
    - **Coastal Processes:** The northern portion of Padre Island is in a net erosional state, particularly the area of Padre Island National Seashore north of Port Mansfield Channel, in part driven by the interruption of northward longshore sediment transport by the channel jetties. The long-term erosion rates of the island are ~2.6 ft/yr (0.8 m/yr Paine et al., 2021). Port Mansfield Channel appears to capture large quantities of these sediments, leading to rapid siltation in the absence of maintenance dredging (USACE, 2021b). Dredging of sediments from the channel and placement north of the jetties helps to restore northward sediment connectivity and alleviate erosion of Padre Island. (**Sediment Placement)**

Beach Habitat: Padre Island beaches host the most nests for the critically endangered Kemp's ridley sea turtle within the U.S. Recent efforts identified potential beach geomorphic and sedimentologic parameters associated with this critical habitat (Culver et al., 2020). Restoring and long-term preservation of Padre Island beach, dune, and nearshore systems is likely to help support this species. Padre Island is also a key component of the Central Flyway, with over 380 distinct documented bird species, including 16 classified as threatened or endangered such as the piping plover. (**Sediment Placement)**

Marsh/Estuary Habitat: Mansfield Bird Island Rookery is one of several rookery islands located within Texas bays and estuaries and serves as a main habitat for several colonial nesting birds at the boundaries of the Padre Island National Seashore, Laguna Atascosa National Wildlife Refuge, and Lower Rio Grande Valley National Wildlife Refuge. Originally constructed by dredge material from the GIWW, BUDM placement is now designed to help build new wetlands within Laguna Madre. (**Sediment Placement)**

Submerged Aquatic Vegetation: Laguna Madre contains more than 75% of all seagrass cover of the entire Texas Coast, and is one of only five hypersaline ecosystems globally (Onuf, 2006). Lower Laguna Madre contains turtle grass, manatee grass, and shoal grass meadows over 65% of its total area. Laguna Madre is naturally hypersaline due to limited freshwater inflows, and the mediation of salinity began in the 1950s with the construction of the GIWW and several inlets to the Gulf (Onuf, 2006). Increasing cross-lagoon circulation and exchange with the Gulf has led to salinities decreasing from historic highs of >50 ppt. Shifts in species composition and overall coverage have previously been attributed to changing lagoon salinity and turbidity, in part due to anthropogenic factors such as GIWW maintenance dredging (Figure 15; Merkord, 1978; Onuf, 1994). Trends in seagrass composition and ecosystem health have historically been analyzed relative to a baseline set in the 1960s when comprehensive decadal monitoring began, and do not reflect fully "natural" conditions prior to waterway construction (Onuf, 2006). **(Sediment Sourcing)**

The opening of the GIWW and the dredging of Port Mansfield Channel led to a relative freshening that enabled the rapid expansion of manatee and turtle grasses throughout the lower Laguna Madre post-1960s (Figure 15). These seagrass beds represent critical habitat for numerous species, and are still responding to salinity gradients and other environment factors, with the specific effects being under-studied (Texas Department of Water Resources, 1983). The lagoon has seen a shift from 64% shoal grass coverage in the mid-1960s to less than 30% in 1998, with the balance taken up by manatee and turtle grasses (Onuf, 2006). **(Sediment Sourcing)**

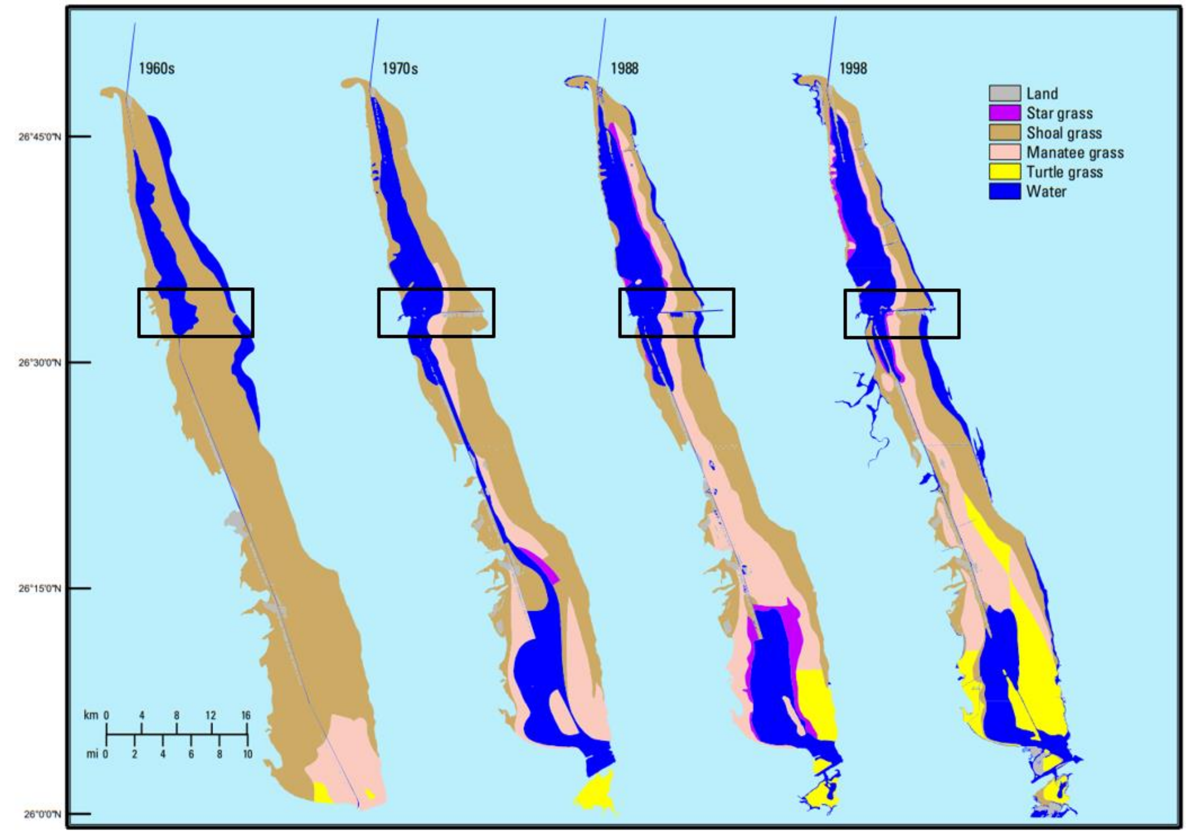

Figure 15. Distribution of seagrass meadows in Lower Laguna Madre from 1960s to 1998. The black box indicates the region surrounding the Port Mansfield Channel. Modified from Onuf, 2006.

6. **Recreational Use:** Padre Island National Seashore and the adjacent NWRs provide recreational activities in the form of beachgoing, camping, kayaking and recreational boating, fishing, and birdwatching. Laguna Madre and the lower Rio Grande Valley in general host over 2 billion migratory birds passing through the central flyway every year, and an estimated 700,000 tourists per year (USFWS, 2010). **(Sediment Placement and Sediment Sourcing)**
7. **Cultural Resources:** The area immediately surrounding the Port Mansfield Channel is designated the Mansfield Cut Underwater Archaeological District and is home to three 1554 Spanish shipwrecks. The ships were part of a treasure fleet that sailed from Mexico in 1554 and were blown onto Padre Island by a storm. The wrecks were discovered during dredging of the Port Mansfield Channel, when the cutterhead encountered a wreck and began lifting gold and silver coinage onto the beach (Arnold III & Weddle, 1978). Maintaining the footprint of the Padre Island beach and nearshore helps to maintain the integrity of the buried shipwrecks, the exact location of which is restricted. **(Sediment Placement)**
8. **Miscellaneous:** Commercial activity of Port Mansfield has historically been minimal, in part due to the irregular navigability of Port Mansfield Channel. The channel has rarely been maintained to its full authorized depth of 17 feet (5.2 m). The 2020–2021 dredging activity was in part sponsored by the Willacy County Navigation District and the Port of Port Mansfield, with the

intent to expand the commercial activity of the port and enable international barge traffic from Mexico. Continued dredging of the channel and associated sediment placement is intended to allow for significant growth of commercial and recreational operations of the port, with $24 million of private and state investment ongoing in expanded port capabilities. **(Sediment Sourcing)**

Step 3: Quantification

The Institute identified impacts within each category that could be quantified with available data (Table 17), including acreage created for some habitats, rates of shoreline erosion, morphology of Padre Island, and number of recreational visitors. The Institute study team was limited to what had been previously quantified in existing studies conducted by USACE, NPS, USFWS, and academic researchers which provide significant value but may mask the specific impacts created solely by the 2020–2021 project. Several other metrics were identified as being quantifiable, particularly those related to navigation and commercial activity, but those benefits are not specifically related to the sediment placement impact.

Table 17. Quantification of potential impacts of sediment placement at Port Mansfield Channel, Texas.

Impact Category	Impact	Quantification Metric	Metric Value	Potential Metric with Targeted Data Collection or Analysis
Habitat	Sandy beach and dune habitat	Habitat acres created with project; dune crest height; shoreline width; shoreline erosion rate	~30 total acres (0.1 km^2) of sandy beach and dune estimated from aerial imagery; increase of dune crest height from 14.7 to 18.0 ft (4.5 to 5.5 m); shoreline advancement of ~554 ft (169 m)	Habitat acres could be quantified with base habitat distribution and project design. Future benefit in year-acres could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates.
	Colonial nesting bird habitat; Seagrass	Habitat acres created with project; wetland elevations pre and post project	N/A	Habitat acres could be quantified for designated rookery island; tracking of sub-tidal to inter-tidal habitat elevations to quantify effect of BUDM placement within rookery island footprint.
Recreational Opportunities	Kayaking, birdwatching, hiking, beachgoing, fishing, etc.	Visitors to Port Mansfield, Padre Island National Seashore, National Wildlife Refuges	700,000 (Full value of Lower Laguna Madre, USFWS)	Recreational value of the sediment placement over time could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates.
Cultural Resources	Preservation of Mansfield Cut Underwater Archaeological District	Preservation of Island Footprint; rate of shoreline change	Shoreline advanced ~554 ft (169 m) compared to ~2.6 ft/y (0.8 m/yr) erosion prior to 2020	Ongoing Padre Island National Seashore monitoring program could be leveraged to track effect of dredging and placement activity on Padre Island shoreline position, volume of sediment retained.

Lower Laguna Madre and Padre Island have been the site of robust, long-term monitoring programs related to shoreface geomorphology, estuary habitat, species distributions, and other datasets due to the presence of the National Seashore and NWRs and long-term investments by the State of Texas and USACE. In particular, the Gulf Coast Network conducts bi-annual geomorphic monitoring of the Padre Island National Seashore (Figure 16).

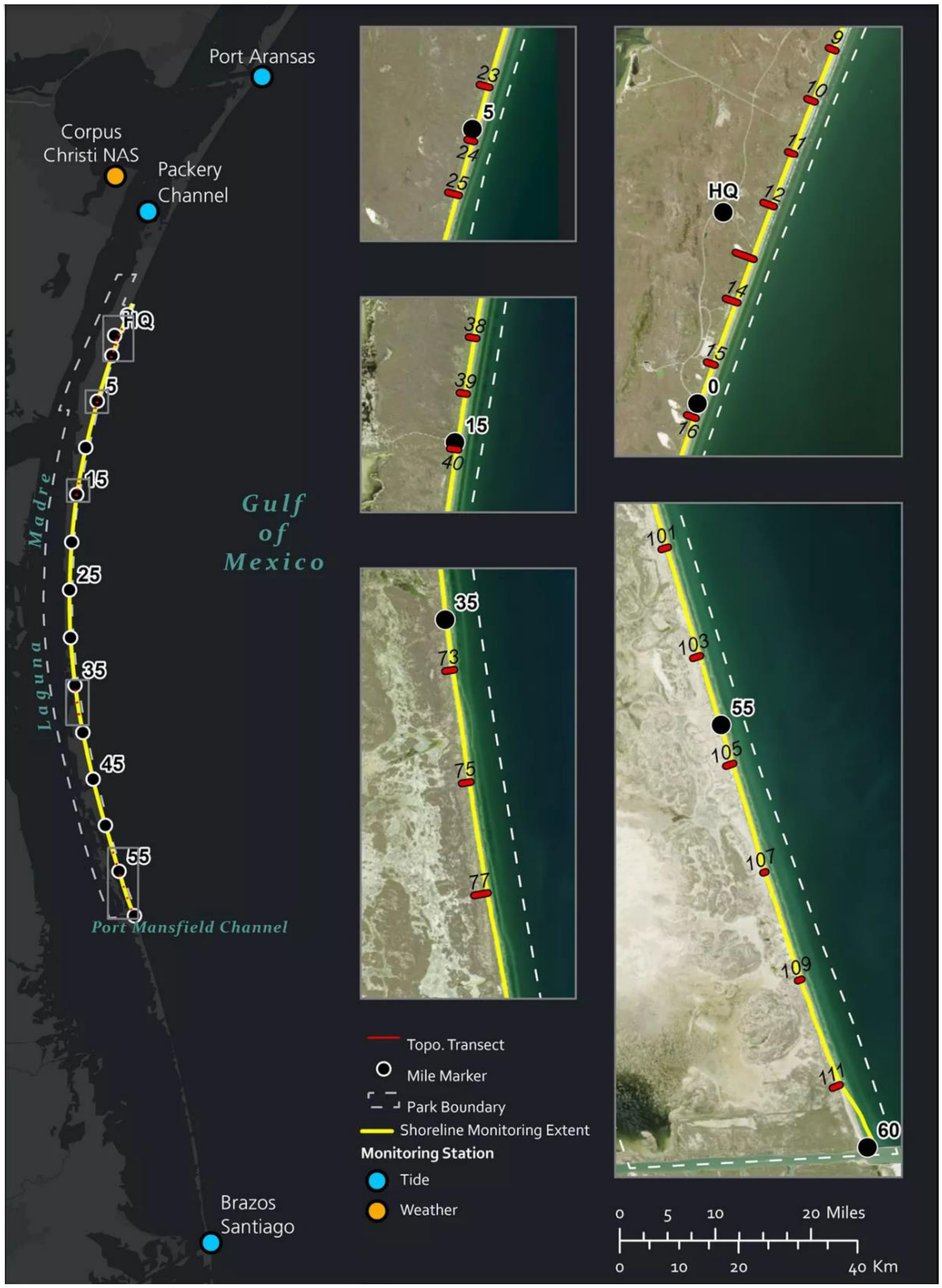

Figure 16. Location of transects and shoreline monitoring zones conducted by the Gulf Coast Network and the National Parks Service. Stations 55 to 60 encompass the beach placement area of the Port Mansfield Channel. Modified from Bracewell (2024).

Literature review identified several studies conducted by NPS measuring shoreline erosion rates in the area adjacent to Port Mansfield Channel (e.g., Bracewell & Carlson, 2022) which captured the placement of the 2020–2021 dredged sediments onto the beach. This study found that the placement increased the dune crest height from 14.7 to 18.0 ft (4.5 m to 5.5 m), widened the beach by ~ 544 ft (169 m), and led to over 30 new acres (0.1 km^2) of sandy beach immediately adjacent to the north jetty. An experimental learning study conducted with NASA oversight found similar positive metrics of sandy beach habitat following the 2020–2021 placement, with significant gain in beach acres (Tanh et al., 2022; Figure 17).

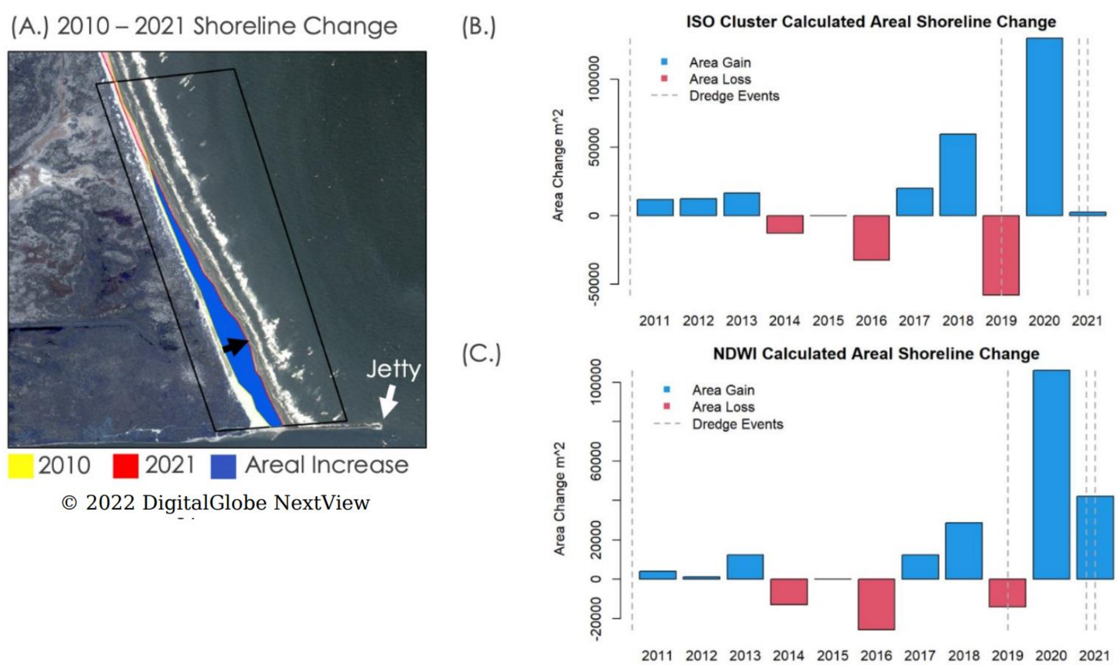

Figure 17. Area change of Padre Island National Seashore from 2011–2021. Initial dredging and placement in 2020 led to increase of sandy beach area by >30 acres. Modified from NASA DEVELOP report Tanh et al. (2022).

The impact of sediment placement to the Mansfield Cut Historical District was assessed from the nature of the district and the uncertainty of the exact location of the cultural resources within. The exact locations of the archaeological finds are restricted, with the surrounding region designated as a cultural resource area (Figure 18; Arnold III & Weddle, 1978). The continued undisturbed burial of the 1554 shipwrecks is likely to require relative stability of the current island footprint, as shoreface and nearshore erosion may expose and mobilize artifacts located within the underwater district. The exact quantification of these benefits may be possible by using existing monitoring data to estimate the depth of shoreface and nearshore erosion, and the timescale on which these artifacts may be disturbed. Comparison of these rates of change with the measured offset of erosion gained by sediment placement may help to quantify the specific sediment benefits relative to cultural resources.

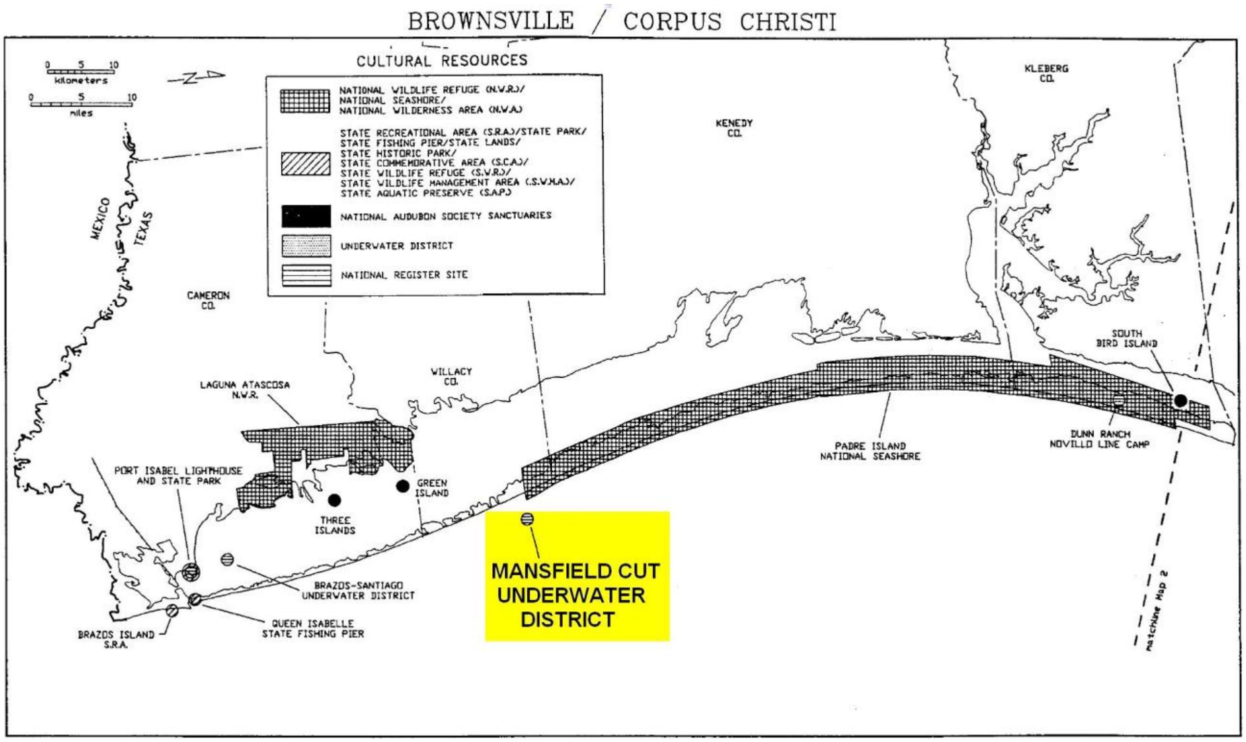

Figure 18. Location of the Mansfield Cut Underwater District (Arnold III & Weddle, 1978).

Step 4: Monetization

Several of the benefits and impacts with monetization potential are due to the combination of both sediment placement and sediment sourcing (the dredging activity itself). Many, if not all, of these benefits are derived from the decision to dredge the Mansfield Cut; this decision unlocks several additional benefit categories, including navigation (direct access to the Gulf), habitat benefits from the reduction of hypersalinity and preservation of the rare habitat types found in Laguna Madre, and recreational opportunities like birding and sportfishing that are made possible either by the navigational access of the cut or the habitat benefits themselves. The Institute team examined how the benefits and impacts of dredging could best be attributed to the sediment placement rather than the sediment sourcing. Consideration of the joint benefits within a RSM framework are further detailed in the case study key findings.

Using this more holistic view of the Laguna Madre ecosystem and its effects, impact categories can be more closely examined. For example, in navigation, the economic value of port activity, such as the value of cargo transiting through Port Mansfield or the economic impact of local investments and construction at the port, could be considered monetized benefits. An investment of ~$24M in port commercial facilities is currently in progress (Taylor, 2024). Charters and recreational fishing are particularly valuable, and studies or reports of their revenue could be examined in future constructions of benefits.

Habitat benefits are numerous, and some can be monetized. While beach and dune habitat has not been the subject of many valuation studies, it has been studied for cultural value, or "existence value" (Richardson & Nicholls, 2021). Sediment placement in Laguna Madre supports the creation and maintenance of a wide variety of colonial nesting bird habitat and seagrass ecosystems. Bluevalue.org has habitat value of seagrass estimates including a 2002 study from New York that estimates a value of $4,474 per hectare per year (Johnston et al., 2002). Migratory birds, including threatened and endangered species such as the piping plover, rely on habitat at Laguna Madre. Valuation of endangered species habitat can vary using willingness to pay (WTP) methods (Loomis & White, 1996). Literature reviews have placed these values at anywhere from $5 to $100 per species per household per year, but a study of an urban wetland in Mexico indicates that migratory habitat in particular can hold much higher valuations, between $2800 and $4000 per hectare (Revollo-Fernández, 2015). When considering household interest or WTP for the preservation of a species, it is important to consider that households who value the habitat highly may not live in the area. A study could use a per-household value and apply it to the local population adjacent to Laguna Madre, such as Willacy and Cameron counties, but this would leave out the many thousands of people who care about migratory birds that use this habitat. In the case of the piping plover, there is a notable affected group outside the study region is a conservation team spanning the Great Lakes region (part of their historic nesting range) comprised of two countries, multiple federal agencies, six state and provincial departments, Tribal governments, five universities, many NGO partners, and hundreds of volunteers ("Great Lakes Piping Plovers," n.d.). The Chicago monitoring team alone engages dozens of volunteers each summer to care for the birds that nest at Montrose Beach (Montanaro, 2023). Valuations of piping plover habitat should consider the investments in time, money, and care that go into saving a species like this across its migratory range.

These habitat investments also unlock additional benefits in the recreation impact category. A valuation method such as the USACE Recreational Use Day Value could be used in the future for the impacts of a specific BUDM project. Studies have been done on the economic impact value of sportfishing and diving, such as this private consultant study from 2018 that looked at the impacts of the sportfishing industry in the region (Aaron Economic Consulting, LLC, 2018). This study estimated the economic impact in the Rio Grande Valley at $45.6 million in 2017 dollars. Additionally, the area is a growing birding destination, owing to its migratory bird habitat and the number of species that can be found in the Rio Grande Valley area and at Laguna Madre. Over 400 species use Laguna Atascosa National Wildlife Refuge, drawing many guided trips. Valuations of "destination birding" include the economic impact that birders provide to the area, including hotel stays, rental cars, food and sundry purchases, guided tours, other activities, and more.

Cultural resources like the Mansfield Underwater Archaeological District are difficult to provide with a monetary value, as they do not have a replacement cost and represent a heritage and history. The value is qualitative, from the shoreline advancement and sediment placement that buries the artifacts, preserving them further, which is considered archaeological best practice. However, it may be that in the future, a project could be proposed that would disturb these artifacts, and thus a required cost would be to place sediment there purposefully to protect them; avoiding this cost through BUDM could be considered a monetary benefit.

Table 18 below represents only the monetized values attributed to sediment placement in Laguna Madre; however, as shown in this section, a holistic view of sediment sourcing and placement allows for more expansive valuations.

Table 18. Monetization of sediment placement impacts at Laguna Madre, Texas. Valuation Method and Monetized Value includes impact estimates based on readily available data and modeling that could be used in the retrospective case study. Potential Valuation describes monetized value that could be captured with additional targeted data collection or analysis (in bold), which could be scoped in applying the workflow for potential projects.

Impact Category	Impact	Valuation Method	Monetized Value	Potential Valuation with Targeted Analysis
Habitat	Creation and restoration of sandy beach and dune habitat	N/A – bluevalue.org would have been used, however a specific habitat values for ecosystem services for beach and dune habitat could not be located	N/A	Qualitative 'existence' value or endangered species habitat valuations with WTP estimates could be used for future placement projects.
	Colonial nesting bird habitat, seagrass	Valuation from bluevalue.org – ~$4500/hectare/year	N/A (Would require monitoring the acreage change in bird habitat and seagrass in Laguna Madre pre- and post-sediment placement)	Dollar value per unit area could be multiplied by change in habitat area if the latter were available.
Recreational Opportunities	Boating, beachgoing, birdwatching, fishing, etc.	Economic contribution of southern Padre Island National Seashore, Laguna Atascosa Wildlife Refuge Recreational Use-Day Value; Port Mansfield charters	N/A	The Recreational Use Day Value method can be used in future project evaluations of sediment placement for a more precise valuation.
Cultural Resources	Preservation of Mansfield Cut Underwater District	N/A	N/A	Qualitative assessments are more appropriate for the cultural resources of this archaeological district.

Step 5: Synthesis

The combined benefits and costs of sediment placement associated with dredging of Port Mansfield is provided in Table 19. The dredging and placement of ~2.5 million cy (1.9 million m^3) of sediment on Padre Island National Seashore and the Port Mansfield Bird Island rookery was linked to a number of quantitative and qualitative benefits. Where able, specific quantified and monetized values were provided, while in other cases potential targeted data collection and analysis are suggested that could aid in full implementation of the valuation workflow. As noted in Step 2, this synthesis is constrained to benefits that could be primarily attributed to the sediment placement itself, rather than the linked dredging and placement activity which is further detailed in key findings.

Table 19. Synthesis of impacts, monetization, and targeted data collection & analysis in Port Mansfield, Laguna Madre

Impact Category	Qualitative Impact	Quantification and/or Monetization	Value of Targeted Data Collection & Analysis
Habitat	Sandy Dune and Beach Habitat Creation in Padre Island National Seashore	Placement of ~970,000 cy (726,000 m^3) of sediment into the beach and nearshore area, reversing historical coastal erosion trends, creating ~30 acres (0.1 km^2) of new beach area, increasing dune crest heights from 14.7 to 18.0 ft (4.5 to 5.5 m), and advancing shoreline by ~554 ft (169 m)	Impact to overall Padre Island National Seashore coastal sediment budget could be constrained by reanalysis of biannual monitoring program to track sediment input across whole zone.
	Creation of estuary colonial nesting bird habitat in bird island rookeries	Placement of ~1,500,000 cy (1,100,000 m^3) of sediment into the bird island footprint defined by existing levees. No measurements exist of elevations or acreage created	Pre and post elevation measurements could capture effect of sediment on maintaining colonial bird habitat elevations above intertidal range, increasing overall acreage. Longitudinal bird counts could constrain impact of habitat on species diversity and numbers.
Recreational Opportunities	Increase in beach and dune habitat allow continue access to beaches at southern end of Padre Island National Seashore	Increase of beach area by 30 acres (0.1 km^2), reversal of long-term erosional trends	Tracking of shore visitors to Padre Island National Seashore could constrain use-day value of recreational access, and benefit to maintaining sandy beaches across Padre Island.
	Growth of beach, dune, and back barrier bird habitat supports destination birding in Laguna Madre	Linked habitat of Laguna Madre and Padre Island support over 400+ species, numerous guided trips, festivals, and other bird-centric recreational activities sustained by these habitats	Difficult to collect data for due to wide geographic range. Could provide information on overall conservation dollars spent.
Cultural Resources	Placement of sediment in the beach and nearshore of the Mansfield Cut Archaeological District	Increase of beach area and restoration of sediment to the nearshore helps to maintain burial of potential artifacts and cultural resources located within the Mansfield Cut District, which overlaps with the southern portion of Padre Island National Seashore	Preservation of Island footprint helps continued burial of resources. In other projects intentional protective burial of cultural resources has been required.

The most significant quantifiable benefits were related to the placement of ~970,000 cy (726,000 m^3) of sediment on the southern end of Padre Island National Seashore north of the Mansfield Cut. The lower reach has been in an erosional state since the creation of Mansfield Cut in 1957, with loss of beach, dune, and nearshore habitat. 2020–2021 sediment placement led to initial creation of ~30 acres of sandy beach and dune habitat, the seaward movement of the shoreface, and a stabilization of shoreline retreat rates for some distance from the placement site. This increase in habitat and beach area relative to the base-line scenario additionally provided qualitative benefits such as increased habitat for species including the Kemp's ridley sea turtle, piping plovers, and other key species. Additionally, the stabilization of the island footprint enables the continued burial of the adjacent Mansfield Cut Archaeological District, which contains numerous potential buried artifacts and cultural resources.

The placement of material in the estuary bird island rookery also appeared to support the continued existence of key colonial nesting bird habitat, although data or analysis was not available to quantify the effect relative to base-line. An additional qualitative benefit noted for the project area is the continued existence of the unique linked Laguna Madre and Padre Island habitats and ecosystems. The region is one of the most diverse birding environments in North America, in addition to providing unique lagoonal and barrier island habitats. Many of the qualitative benefits identified in this study have been the focus of regional economic impact studies, such as tourism dollars spent, visitors for recreational birding, and sports fishing. These impacts were not able to be fully quantified here due to the difficulty in constraining the specific effect of this single area and project, but are included for their importance in consideration of the holistic system.

Key Findings

Sediment placement at Padre Island and Laguna Madre from dredging of Port Mansfield Channel was found to have numerous benefits as detailed in steps 1–4. Importantly, the Institute team found that many of these benefits were closely linked with benefits and impacts of the dredging itself: the opening of the channel to navigation and hydrologic exchange. The combined impacts can be considered in a holistic RSM framework, as the economic and ecosystem benefits of renewed navigation and subaqueous ecosystems are made manifest by the ability to dredge the cut and economically place the associated sediment. For the past several decades of maintenance dredging these sediments were required to be placed in offshore ODMDS to limit potential ecosystem and habitat impacts, with associated increased transport and disposal costs (TXDOT, 2015). The ability of the sediments to be beneficially placed in the Padre Island National Seashore and the estuarine bird island rookery appears to have been a factor in allowing the dredging to occur. Sediment placement options are not solely a function of valuation and transport costs, but also regulations governing potential placement sites. The opportunity for more cost-effective BUDM beach placement in South Padre Island was enabled by NPS working with stakeholders on placement opportunities that were also consistent with requirements of governing legislation (Haas, 2025). Approaching the channel maintenance and associated BUDM in Laguna Madre with a holistic RSM perspective appears to have enabled the cost-effective dredging of the channel, leading to:

- Commercial and recreational navigation of Port Mansfield Channel: Growth of commercial activity of Port Mansfield, increase in sports fishing and recreational charters.
- Hydrologic exchange and connectivity between Laguna Madre and the Gulf: Alleviation of hypersalinity, continued support of diverse seagrass ecosystems and habitat in the lagoon relative to later 20th century baselines as established by long-term monitoring.
- Ecosystem and habitat support: Continued maintenance of the combined Laguna Madre and Padre Island ecosystems, including local and migratory bird habitat.

These benefits are not directly associated with the enumerated impacts of the sediment placement directly as detailed in the case study workflow but are important factors when considering the success of the project in supporting multiple stakeholder lines, habitat types, and cross-jurisdictional interests. The full combined quantification of benefits from both sediment placement and sediment sourcing is provided in Table 20.

Table 20. Quantification of potential impacts of sediment placement and sediment sourcing at Port Mansfield Channel, Texas.

Impact Category	Impact	Quantification Metric	Metric Value	Potential Metric with Targeted Data Collection or Analysis
Navigation	Access between the Gulf and Laguna Madre (commercial)	Number of vessels transiting Port Mansfield Channel	N/A	Continued tracking of number of vessel transits and utilization of Port Mansfield
Habitat	Sandy beach and dune habitat	Habitat acres created with project; dune crest height; shoreline width; shoreline erosion rate	~30 total acres (0.1 km^2) of sandy beach and dune estimated from aerial imagery; increase of dune crest height from 14.7 to 18.0 ft (4.5 to 5.5 m); shoreline advancement of ~554 ft (169 m).	Habitat acres could be quantified with base habitat distribution and project design. Future benefit in year-acres could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates.
	Colonial nesting bird habitat; Seagrass	Habitat acres created with project; wetland elevations pre and post project	N/A	Habitat acres could be quantified for designated rookery island; tracking of sub-tidal to inter-tidal habitat elevations to quantify effect of BUDM placement within rookery island footprint
	Lagoonal and back barrier habitat	Trends in submerged aquatic vegetation; turbidity; lagoonal salinity	N/A	Monitoring of ongoing salinity trends pre and post channel dredging with control for freshwater input; local mapping of seagrass and marsh habitat at annual scales
Recreational Opportunities	Kayaking, birdwatching, hiking, beachgoing, fishing, etc.	Visitors to Port Mansfield, Padre Island National Seashore, National Wildlife Refuges	700,000 (Full value of Lower Laguna Madre, USFWS)	Recreational value of the sediment placement over time could be quantified from baseline and with project conditions, SLR, and erosion/island loss rates.
	Deep-sea sportfishing	Recreational traffic from Port Mansfield to the Gulf	N/A	
Cultural Resources	Preservation of Mansfield Cut Underwater Archaeological District	Preservation of Island Footprint; rate of shoreline change	Shoreline advanced ~554 ft (169 m) compared to ~2.6 ft/yr (0.8 m/yr) erosion prior to 2020	Leverage ongoing Padre Island National Seashore monitoring program to track effect of dredging and placement activity on Padre Island shoreline position, and the volume of sediment retained.
Miscellaneous	Enabling commercial growth of Port Mansfield	Implementation of public and private funding commitments to sustain Port	New long-term investments million for Port Mansfield Channel	Inclusion of expanded footprint BUDM projects mirroring 2021 effort in Texas Coastal Study; Investment of

Impact Category	Impact	Quantification Metric	Metric Value	Potential Metric with Targeted Data Collection or Analysis
		Mansfield Channel and grow commercial facilities		~24 million by private stakeholders, TXDOT, and others in Port Mansfield commercial facilities including container handling, aggregate queuing yards, and airport expansion.

Challenges of Retrospective and Perspective Opportunities

- Reducing periods of hypersalinity in the Lower Laguna Madre Estuary has been indicated as a major potential benefit of past and future maintenance of the Port Mansfield Channel, but salinity trends are relative to conditions already reflective of anthropogenic modification. Prior to GIWW and Mansfield Cut construction, Laguna Madre experienced salinities above 50 ppt, levels which have rarely been observed since the 1960s. Proposed benefits and project goals of cut maintenance are relative to these post 1960s salinities.
- Initial construction of the Bird Island rookery was accomplished using materials from dredging the GIWW, with subsequent maintenance dredging of both the GIWW and the Port Mansfield Channel (2021 event) using the rookery as a placement site. Quantifying the benefit of this placement is challenging as the initial footprint was set by factors other than the BUDM opportunity, and so habitat metrics such as acres are relatively static, while others such as relative elevation are not measured or tracked.
- Immediate impact of beach and nearshore sediment placement was measured in Padre Island National Seashore. Subsequent analysis of synoptic beach monitoring programs could help constrain the total footprint of the placement impact on shoreline erosion rates and explicitly analyze the timescale of benefit compared to pre-project erosion rates.

SYNTHESIS OF CASE STUDIES

Workflow as Best Practice: Holistic Consideration of Impacts

Across all three case studies, the workflow as outlined in Chapter 1 shows the consistent need to consider impacts of all kinds—described, quantified, and monetized—when determining where to place sediment. This holistic lens allows for consideration of impacts beyond those that can be quantified or monetized, such as resources or protections afforded to cultural heritage sites, endangered species habitats, or nationally significant port infrastructure. Holistic consideration of impacts in a stepwise workflow also allows a decision maker to revisit alternatives if new impacts or costs are discovered through the process and acknowledges that sediment placement can satisfy multiple kinds of objectives, from economic to ecological to cultural.

The workflow also supports consideration of interconnected benefits. Throughout the case study analysis process, many outcomes of sediment placement had interconnected benefits across multiple benefit categories, such as more beach and dune habitat leading to benefits in built infrastructure, navigation, recreation, and habitat. Several examples are available from each case study:

- In Egmont Key, the cultural and ecosystem benefits provided by the sediment placement are the basis for recreational uses of the site. Visitors to Egmont come because of the cultural resources that are protected by the sediment placement, as well as to recreate on the beach or hike in the upland areas. These recreational benefits are made possible because of the protection/provision of other benefits.
- For both Caminada Headland and Egmont Key, the sediment placement creates regional benefits by attenuating waves. The emplaced sediment and restored barrier serves as part of a “multiple lines of defense” strategy providing diffuse regional benefit to the broader area as well as specific quantified benefits in the form of wave reduction for nearby communities.
- Caminada Headland and Laguna Madre are both key stopover locations for migratory birds on the Central and Mississippi flyways. These benefits to bird life extend far beyond the project sites to support declining and endangered species whose migratory range can extend from the northern Arctic to far reaches of South America. Additionally, these birds are often supported by conservation efforts beyond an individual sediment placement site, such as the piping plover example in the Laguna Madre case study.
- In Laguna Madre, many benefits were interconnected because of the transformative impacts of the Mansfield Cut and its continued dredging. Without this channel, there would be no port infrastructure, no access to the Gulf and its sportfishing, no rookery islands to place sediment, and a hypersaline environment hostile to many species (note, however, that habitat value is somewhat subjective: Laguna Madre is one of the few hypersaline lagoons in the United States, making it a unique habitat). Additionally, the sediment placement was determined to be cheaper than the prior use of an ODMDS. The interconnected nature of these benefits shows that the whole can be greater than the sum of its parts, even if monetization of benefits within that whole is not possible.

Common Factors Leading to Greater Benefits

Across all three case studies, there were common factors associated with increasing benefits of sediment placement across the shared benefit categories of recreation, habitat, navigation, cultural resources, and built infrastructure.

Recreation benefits are often the easiest to quantify and monetize. The USACE planning method of Unit Day Value for recreation offers a standardized way to value recreation benefits, which includes enabling the consideration of specialized recreation (USACE, 2021c). However, the use of this method is dependent on having robust or estimable data on visitation. In addition to, or in absence of, the Unit Day Value methodology, economic impact studies can occasionally be applied to capture recreation benefits, as in the case of Laguna Madre. Regional economic development organizations, state agencies, advocacy nonprofits, and other groups will often have information on the economic impacts of key recreational areas (for example, the Florida State Park analysis of the economic impact value of Egmont Key), and these studies can supplement or complement other estimations of recreational benefit.

Habitat benefits often have a high quantity or value but can be difficult to monetize without (1) monitoring data capturing acreage created and projected change over time and (2) regional and habitat-specific dollar values per unit acre. Unit values, such as a dollar value per acre of a specific kind of habitat, can be found in scientific literature or by using a resource that collates such information (e.g., bluevalue.org). However, databases such as these do not contain values for all habitat types or locations. As sediment placement can create different kinds of habitat and impact a wide variety of species, there are many opportunities in this benefit category to enumerate and monetize many kinds of benefits, from both the acreage and species perspective. Acreage in particular can also be assessed using morphology modeling to look at future acreage under different project conditions and alternatives, if resources allow.

Navigation benefits, like recreation benefits, are often monetized using economic impact methodologies. However, these economic impacts are often the result of dredging and placement together, rather than placement specifically and thus fall outside the context of the workflow. The dollar value of a port investment, such as in Port Mansfield, Texas, is likely attributable to the dredging maintenance of the Mansfield Cut, rather than the placement of the existing source of sediment. In that case study, however, the overall cost of dredging and placement was reduced to a feasible level because of the opportunities for beneficial use. Assessing the benefits of dredging and placement together allows for consideration and attribution of these important economic impacts.

Cultural resources benefits were the most difficult to quantify or monetize across the three case studies. The protection of cultural resources is an important qualitative benefit of sediment placement, as seen in Laguna Madre and Egmont Key, because the sediment protects archeological and historic resources that cannot be replaced. This binary nature of cultural resource protection—there are no substitutes available for these resources—makes it difficult to value. Noting where cultural resources are protected through sediment placement is an important qualitative benefit to capture in the workflow.

Finally, built infrastructure benefits can be both quantified and monetized with sufficient modeling and analytical tools, especially in a forward-looking analysis of different alternatives where the benefits can be robustly benchmarked against a no-action case. Benefits to infrastructure like wave attenuation, storm surge reduction, or other risk modeling can be quantified for placement alternatives. Consequence modeling, such as with tools from USACE's Hydrologic Engineering Center or their equivalent, can provide estimates of avoided flood damages in monetary terms. However, these tools require time, resources, and specialized expertise to use, which may be beyond the scope of projects (particularly beneficial use, where the primary focus is on the dredging rather than placement).

Several other considerations for benefits estimation can be delineated across benefit categories. First, it is key to use an appropriate benchmark for evaluation of benefits. The clearest benchmark for estimating the benefits of sediment placement for coastal projects is a future without action (FWOA) alternative. This allows for benefit estimation against the cost of no action in erosional systems, as the sediment placement can "hold the line" against a FWOA where thousands of acres would be lost (as in Caminada Headland) or the entire island could be lost (as in Egmont Key). Caminada Headland was projected to lose 3,750 acres by 2050 without restoration; Egmont Key's continued existence and recovery is predicated on sediment placement to maintain land area. Rather than framing these benefits as additive only—as in, they are creating new area that adds to land that already exists—benchmarking against a FWOA allows the cumulative short- and long-term benefits of sediment placement over the lifetime of the project to be accounted for.

Second, considering opportunities for recurrent sediment placement paired with recurrent or dedicated dredging can offer additional increases in benefits. In the Caminada Headland case study, the recurrent dredging offers appropriate material for continued placement to benefit the headland. The recurrent nature of the dredging and placement allows the longer-term overall benefits beyond the immediate benefits from a one-time placement.

Lastly, consideration of the quality and compatibility of sediment with its placement area is important. First and foremost, the sediment must be compatible with the site and acceptable from a permitting perspective—which varies by state—across factors including grain size, lack of contaminants, and color. Within the range of suitable sediment, however, factors can enhance the quality and benefit of the sediment placement. For example, the sediment from Ship Shoal used for restoring Caminada Headland is comparatively coarser (though still under fine grain category of sediment texture) , grain size sediment than the comparatively finer sediment available from other sources, which makes it both compatible as well as preferable in reducing the sediment loss rate. In turn, the project's lifespan and performance are increased because of this reduced loss rate. In Laguna Madre, the same material is placed in two places with differing qualitative impacts. Sediment placed on the beach increases the acreage, which is the typical metric used for quantifying habitat benefits. The placement in the back barrier, however, increases the elevation of the placement area, allowing for its use as bird nesting habitat, but does not increase the acreage of that site. These different placements offer different qualitative benefits. Pilot studies can be useful for investigating placement opportunities and qualitative differences that can lead to new practices, further increasing opportunities for sediment placement and increased benefits. At Egmont Key, for example, regulations prohibited the placement of fine sediment, which previously limited the source of dredged material that could be placed. However, a pilot study indicated that winnowing of fines leads to acceptable material being placed and retained on the beach, allowing more dredged material to be placed at the site while retaining the same quality of habitat created.

Common Factors Leading to Reduced Costs

Sediment management costs can be associated with both dredging and placement; the workflow and focus of this study was predominantly focused on sediment placement (i.e., sediment has been dredged and must be placed somewhere), including factors that contribute to transport costs. Placement costs in the workflow are therefore assessed against alternatives that may include other beneficial use sites or disposal in nearshore, offshore, or upland sites. Through this lens, the change in relative placement cost is benchmarked against costs associated with alternate use or storage of material. Several common factors across case studies were identified that were associated with reducing or increasing placement cost, including location and distance, economies of scale, and recurrence.

Location of dredging and distance from the potential placement site was a key factor in all three cases. Egmont Key had comparable costs for beneficial use as for alternate upland storage sites because of the proximal location of the island to the Tampa Harbor navigation channel where dredging occurs. In the case of Caminada Headland, the placement costs were directly related to the distance from the dedicated dredging site, and Ship Shoal was chosen as the source site due to the sediment quality, despite being farther from the placement area than other potential sources. At Laguna Madre, however, beneficial use of sediment was cheaper than using the ODMDS.

Economies of scale also lead to reduced costs per cubic yard for larger placement volumes, given that mobilization and demobilization costs are relatively fixed regardless of the amount of sediment and, in some cases, sediment dredging and transport equipment required may have less cost per cubic yard for increased volume. Egmont Key is an example of this, with costs of beneficial use per cubic yard decreasing for larger sediment placements. Locating placement areas that can accommodate a large volume of available material can help scale down the relative costs of placement.

Finally, costs can be reduced over time through recurrent sediment placement and dredging at the same sites and/or through proactive regional planning of placement and dredging, such as by considering a portfolio of placement projects alongside planned dredging. In Laguna Madre, maintaining the Mansfield Cut for navigation coupled with placement unlocks habitat benefits, the economic impacts of reduced hypersalinity in the back lagoon, direct Gulf access for sport fishing, and more. Similarly, at Egmont Key, recurrent dredging and placement reduced costs, streamlined permitting, and reduced the timeline of the placement projects.

Challenges of Retrospective Analyses and Lessons Learned

The retrospective analysis of case studies conducted here had certain limitations, including data availability (i.e., data sources are confined to existing monitoring data rather than having the opportunity for targeted data collection); resources for detailed analysis of alternate placement locations, including establishing benchmark costs for scenarios of traditional disposal or a full assessment of a FWOA; and opportunities for iterative analysis after initial data collection. These gaps limit the benefits that can be quantified and monetized, since the attribution of benefits to sediment placement is most appropriately assessed in the short- and long-term through comparison against a baseline without placement.

Insufficient monitoring data for quantifying, developing, and testing approaches for benefit assessment were a particular challenge for the retrospective analyses. For example, in the Laguna Madre case, impacts to hypersalinity are a key source of benefits deriving from the Mansfield Cut dredging, but are most appropriately benchmarked against the lagoon conditions before dredging took place. Although post-dredging monitoring data exist, data from prior to the dredging work would be needed to establish a baseline and identify the changes to salinity over time that arise from the water exchange. In addition to serving as a benchmark for individual projects, more widescale monitoring of sediment projects could provide more opportunities to develop and test simple, empirical approaches for estimating benefits and costs over time, augmenting or replacing more deterministic models for, for example, estimating habitat change over time.

Recent advances in satellite and aerial imagery and associated analyses do present potential opportunities for cheaper monitoring and/or to provide baseline information in some cases. For example, aerial imagery could be used to monitor the number of colonial bird nests in an area, reducing the cost and increasing the monitoring area over traditional surveys. Similarly, satellite imagery presents opportunities for monitoring acres of habitat created or maintained over time, benchmarked against pre-project baseline conditions using historical imagery; however, this approach is limited to larger placement options for free, readily available satellite data that have relatively coarse (tens of meters) resolution. Supplemented with other monitoring data, these emerging data sources and analyses could be used to assess benefits for future projects.

Another cross-cutting lesson apparent in the case studies is that pilot projects and/or testing new approaches as part of projects enables expanded testing and investigation of sediment management opportunities that could increase benefits or reduce costs such as innovative equipment options or novel dredging or placement practice. For Caminada Headland, for example, novel dredging operations enabled sediment to be dredged and transported from Ship Shoal despite the distance from that sediment source to the placement area. The benefits of developing and testing innovative approaches for the project can be accrued much more broadly by serving as an example for future operations. Similarly, in Laguna Madre, disposal of sediment at the ODMDS was expensive, and the potential positive and negative impacts of beneficial use to the lagoonal habitat were not as well understood. A pilot study examining placement options for this sediment may have shown the benefits of recurrent dredging and placement together and enabled coupled sediment and system management sooner.

DISCUSSION AND IDENTIFIED BEST PRACTICES

Across all three case studies, the workflow laid out in Chapter 1 serves as a best practice guide for evaluating opportunities for a case of having sediment to use and determining the most beneficial potential location for placement. Particularly for areas with recurrent dredging, early consideration of placement opportunities is key to increasing beneficial use, as this early consideration opens opportunities by allowing time for permitting, environmental consultations, and engineering and design ahead of when sediment becomes available; reduces costs; streamlines overall timelines; allows for consideration of sediment's quality and compatibility with multiple potential placement areas; and allows for economies of scale and/or proactive pairing of appropriately scaled placement areas with expected sediment volumes from dredging. In Laguna Madre, for example, opening the placement area enabled recurrent dredging at a lower cost than using the ODMDS, while at Egmont Key, recurring beneficial use of dredged material resulted in cost savings while meeting the objective of restoring the island.

While the workflow was based on a use case of having a defined source of sediment and needing to evaluate opportunities for placement, in the case of environmental restoration the key questions are how and where to source potential sediment. Although beyond the scope of this study, a similar approach to the workflow could be taken, in which the qualitative, quantitative, and monetized benefits and negative impacts of dredging and restoration for alternate source and placement areas are assessed. For example, dedicated dredging of an offshore shoal complex could, in some cases, have negative impacts to benthic habitats. When considered as part of a holistic assessment approach, these negative impacts may offset costs of, for example, transport of sediment from a navigation dredging project that is slightly farther away.

Holistic and complete analysis of sediment value requires consideration of interconnected local and regional benefits. Benefit categories such as habitat creation or protection of cultural resources may be difficult to monetize, but they can unlock benefits that are relatively easy to value such as recreational use. In those cases, the value of recreation can be monetized while the added benefit of habitat creation or cultural resource protection can be considered as a magnifier (i.e., described or quantified benefit suggested that an analysis such as a benefit-cost ratio is likely to undervalue true sediment value).

In addition, considering placement and dredging costs and benefits independently rather than considering both as part of a RSM approach can lead to missed opportunities. For example, environmental restoration at Egmont Key using dedicated dredging from a more distance source would be more expensive than beneficial use of material from the proximal navigation channel; conversely, from a navigation channel maintenance perspective, the costs of beneficial placement are comparable to alternate disposal options. Taken alone, environmental restoration could be cost prohibitive using dedicated dredging, while beneficial use is an even tradeoff in cost to alternate disposal. Evaluated holistically on a systemwide scale, however, beneficial use clearly becomes the highest benefit, lowest cost option. The best practice workflow presented here focuses on a use case of having sediment and assessing the benefits of alternate sediment placement locations, but other methods can be used for evaluating opportunities in cases such as Egmont Key where environmental restoration may be a primary objective. For example, environmental restoration benefits could be identified and quantified, and the incremental benefit per cost of cubic yard of sediment from dedicated dredging benchmarked against the same value for sediment derived from beneficial use. The sourcing impacts would need to be considered in this use case as well—for example, costs of dredging or transport might increase, or there may be negative impacts of dredging to benthic habitat or submerged cultural resources—and would thereby allow for a comprehensive assessment of sourcing and placement impacts together. Another opportunity for more holistic evaluation is calculating the total costs and benefits of a portfolio of smaller potential projects, including both sourcing and placement, and benchmarking the total cost of a RSM approach to executing the portfolio (including, for example, leveraging of programmatic approaches to permitting, coupling multiple project placements with dredging to minimize mobilization and demobilization costs, etc.) against the costs of executing each individual project one by one.

Finally, piloting evaluation of equipment options and testing of placement opportunities provides an important opportunity to enhance benefits and reduced costs, particularly where there is recurrent dredging. Pilot projects work in concert with early consideration of placement, as pilots can be conducted if there are specific concerns about cost, operations, sediment quality, transport, and the like. The novel dredging operations at Ship Shoal, for example, allowed for placement of sediment at Caminada Headland despite the longer transport distance from this offshore borrow site.

This larger vision is of RSM that is holistic, identifies needs early in the process, considers sourcing and placement together, and uses pilot projects to test and refine approaches allows for increased benefits and reduced cost.

CONCLUSION

This report developed and refined a best practice workflow for evaluating potential placement areas for a given source of sediment and applied the workflow to three case studies of sediment placement at Laguna Madre, Texas; Caminada Headland, Louisiana; and Egmont Key, Florida. Application of the workflow identified several opportunities for more complete valuation of sediment through an approach that describes, quantifies, and monetizes impacts across a comprehensive set of categories including habitat, recreation, infrastructure protection, and cultural resources. Case study analysis also identified factors that can increase benefits and reduce costs for projects that incorporate beneficial use of dredged material and/or RSM approaches. Because of the limitation of a retrospective analysis, the effort also considered best practices beyond the workflow, such as consideration of the complete sourcing and placement costs and benefits for project or project portfolio alternatives on a holistic and regional basis. In addition, early consideration of placement and sourcing locations can increase opportunities for beneficial use, benefit communities and ecosystems, and achieve local and regional dredging and restoration objectives at lower costs and shorter timelines.

Regional sediment management and beneficial uses of dredged material therefore have potential to improve project value by reducing costs while increasing many types of benefits, including those analyzed in this report: recreation, habitat, navigation, cultural resources, and built infrastructure. While three Gulf Coast case studies were reviewed, the workflow—and the overall lessons learned and identified best practices—are broadly applicable to other coastal contexts.

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APPENDICES

APPENDIX A. ADVISORY GROUP

The Institute began the project by establishing an AG of decision-makers, practitioners, and stakeholders with expertise and experience in prioritizing and valuating sediment placement projects. The team used a "snowball" approach to identify AG participants, starting with the Regional Sediment Management (RSM) working group of the Gulf of America Alliance (GOAA) Habitat Resources Team (HRT) and expanding based on recommendations from that group to the targeted size of 15–20 participants. This target number was selected as large enough to include a diversity of perspectives across agencies while being small enough to facilitate direct engagement and discussion during working sessions (Table A-1).

Table A-1. Participants in the advisory group (AG).

First	Last	Organization
Amanda	Tritinger	U.S. Army Corps of Engineers (USACE) Engineering With Nature program
Ashley	Long	Bureau of Ocean Energy Management
Christina	Mohrman	Gulf of America Alliance
Doug	Piatkowski	Bureau of Ocean Energy Management
Elizabeth	Godsey	USACE Mobile District and Engineering With Nature Practice Lead
Jared	Harris	Mississippi Department of Marine Resources
Jeff	King	USACE Engineering With Nature program
Jeff	Corbino	USACE New Orleans District
Jim	Pahl	Louisiana Coastal Protection and Restoration Authority
Jim	Haas	National Park Service
Katie	Brutsché	USACE Regional Sediment Management program
Kelly	Legault	USACE Jacksonville District
Laurel	Reichold	USACE Regional Sediment Management Center of Expertise
Lauren	Pourciau	Louisiana Coastal Protection and Restoration Authority
Matthew	Vincent	Louisiana Coastal Protection and Restoration Authority
Ray	Newby	Texas Department of Transportation
Roxane	Dow	Florida Department of Environmental Protection
Syed	Khalil	Louisiana Coastal Protection and Restoration Authority
Valerie	Morrow	USACE Mobile District

The AG was engaged through a series of six working sessions. Topics included elicitation of input on criteria for case study selection and on potential case study locations; presentation of draft results from case studies and elicitation of feedback; and presentation of draft results on best practice and overall findings, with discussion and elicitation of input (Table A-2).

Table A-2. Working session topics with the Advisory Group (AG).

Working Session	Date	Topic Area
1	2-Feb-2024	Kickoff and Project Overview
2	6-March-2024	Elicitation of Criteria for Case Study Selection
3	9-July-2024	• Discussion of Case Study Selection • Overview of Concept for Evaluation Framework
4	18-Sept-2024	• Presentation of Workflow and Application to Egmont Key • Elicitation of Input to Improve Workflow and Egmont Key Case Study
5	14-Jan-2025	• Refinement of Workflow and Egmont Key Case Study • Presentation of Preliminary Results for Caminada Headland and Laguna Madre • Elicitation of Input to Improve Caminada Headland and Laguna Madre Case Studies
6	18-Feb-2025	• Refinement of Caminada Headland and Laguna Madre Case Studies • Presentation of Case Study Synthesis • Presentation of Best Practice and Overall Findings • Elicitation of Input on Synthesis, Best Practice, and Overall Findings

APPENDIX B. CASE STUDY SELECTION

The Institute worked with the AG (Advisory Group) to identify criteria for case study selection, including:

- Data availability for reanalysis;
- Diversity in spatial scale and location, including across the northern Gulf;
- Inclusion of projects of varying habitat type and different types of environmental benefits (e.g., inclusion of barrier islands, marsh creation, etc.);
- Potential inclusion of dedicated dredging as well as beneficial use of dredge material;
- Potential inclusion of an ongoing study vs. completed studies;
- Project completion recent enough to be under current evaluation procedures for U.S. Army Corps of Engineers (USACE) benefit-cost analysis or incremental benefit analysis.

In addition, AG members identified the following potential case study sites:

- Matanzas Pass / Ft. Meyers (Florida)
- Egmont Key (Florida)
- East Pass (Florida)
- Pensacola Pass (Florida)
- Mobile Bay RSM (Alabama)
- Caminada Headland (Louisiana)
- Pierce Marsh – West Galveston (Texas)
- Causeway Bird Island in Corpus Christi Bay (Texas)

The Institute team evaluated these potential case studies and others identified through literature review and AG input against site selection criteria and selected six sites from which a portfolio of case studies could most likely be created to meet the case study criteria: MacDill Air Force Base Beneficial Use of Dredged Material from Tampa Harbor Navigation Channel Deepening (Florida); Egmont Key (Florida); Deer Island (Mississippi); Caminada Headland (Louisiana); Gulf Intracoastal Waterway – Laguna Madre Avian Habitat (Texas); and Pierce Marsh Restoration (Texas). These sites span the northern Gulf Coast, are of varying size and scope, and include multiple types of habitat restoration projects. Together, the sites also include both beneficial use of dredge material and dedicated dredging.

The Institute team determined that further evaluation was needed to select 3–4 case studies from this list of 6, and conducted a preliminary analysis based on a review of available literature and data. This evaluation included identifying the study title; location; status and timeline; USACE district, if applicable; local sponsor, if applicable; USACE Mission Area, if applicable; authority for study/project; if beneficial use of dredged material was incorporated, and if no, what made the project RSM; if the site has an adaptive management or dredge management plan; and project characteristics such as the type of analysis done by the original data team, approximate scale of sediment placement volume, approximate scale of the constructed project, and type(s) of habitat created.

Based on this initial assessment, the Institute team selected three case study sites:

- **Eastern Gulf Coast:** Egmont Key (Florida)
- **Central Gulf Coast:** Caminada Headland (Louisiana)
- **Western Gulf Coast:** Gulf Intracoastal Waterway – Laguna Madre Avian Habitat (Texas)

A key factor in selecting these sites was the availability of data and prior analysis (e.g., benefit-cost evaluation, modeling, etc.) that could be leveraged by the project. In addition, these case study locations span the northern Gulf, include a variety of created habitat types, and have sourced material from both beneficial use of dredge material and dedicated dredging. Each location has been the site of multiple restoration projects, providing multiple sources of data and information for site-specific benefit and cost evaluation as well as enabling the Institute team to consider regional benefits by combining evaluation of multiple projects.

APPENDIX C. DESCRIPTIONS OF COMMONLY USED RESOURCES

The following is a list of resources with brief explanations for their use that can be commonly applied throughout the process to assist on common categories of benefits.

C.1 BUILT ENVIRONMENT PROTECTION

The most common way of assessing benefit to the built environment is to rely on standard methods of flood risk consequences. The state of practice, in short, is to develop flood maps (typically maximum depth for a given annual return period) and extract depths at the locations of structures. These depths are then run through depth damage functions which translate these depths relative to the first-floor elevation of the structure into a percentage of the structure's value damaged which can be multiplied by the value of the structure to produce monetized damage. Exposure (i.e., the presence of floodwaters at a structure) can be calculated similarly using the same flood data and structure information.

This analysis is dependent on the ability to produce flood maps, which is typically done with software such as the Hydrologic Engineering Center's River Analysis System (HEC-RAS) or ADCIRC (Luettich & Westerink, 2004; USACE, 2021a).

Additionally, an inventory of structures in the area being analyzed is also required for this and other kinds of analysis (e.g., consideration of erosion). The most straightforward source for this information is the National Structure Inventory (NSI), which is a nationwide inventory of structure created by USACE (USACE, 2022). The NSI contains all the information required to perform flood consequence modeling described above, however structure inventory information may not always be up to date.

Lastly the consequence analysis itself can be performed using several dedicated pieces of software including the Hydrologic Engineering Center's Flood Impact Analysis and HAZUS (FEMA, 2009; USACE, 2015).

C.2 HABITAT RESTORATION AND CREATION

The most important component of an estimate of habitat restoration and creation will be the overall area of different habitats created. This analysis is performed using a variety of different geological and ecosystems models.

Once such an estimate is developed, the monetized value of created habitat will typically be assessed by multiplying the estimated area by a per area unit dollar value of the habitat. These unit dollar values are typically estimated using econometric methods ranging from direct elicitation of preferences (typically referred to as contingent valuation, e.g., Loomis et al., 2000) to more complex methods such as hedonic price methods that rely on existing data like home values to assess the benefit of ecosystems services using models (e.g., Moore et al., 2020). Regardless, the specific method, these econometric models may be beyond the scope of any particular BUDM assessment and often literature review must substitute for running additional econometric studies.

Archives of existing habitat valuation studies can be relied on to locate existing assessments either within the region of interest or for comparable habitats otherwhere (this later approach is typically referred to in the ecosystems services valuation literature as benefit transfer). Bluevalue.org is one such archive that contains lists of studies on a wide variety of habitats, methods and specific sources of habitat value that can serve as a useful starting point for literature review and source of relevant data.

One example alternative approach specifically for wetland habitats is the Wetland Value Assessment (Roy, 2006). While not fully monetizable, the approach does provide a framework for quantification using standardized Average Annual Habitat Units which allows comparison across alternatives and even across different evaluations.

C.3 RECREATION BENEFITS

Recreation benefits are most straightforwardly assessed using the existing USACE methodology for Unit Day Valuation (UDV; USACE, 2021b). Briefly this method relies on expert judgment and use of a simple rubric to calculate the value of one unit day of recreation activities in an area like a park or nature preserve. This value is then multiplied by the average annual visit days to determine the overall annual value of the recreation benefit. Alternative methods such as those used in habitat valuation could also be applied in this category as appropriate.

C.4 CULTURAL RESOURCES

As described above, anything beyond the qualification of cultural resources is often difficult due to the unique and irreplaceable nature of the value they provide. Nevertheless, rough guidelines for thinking about how to treat and interact with these resources do exist and may be of use. Briefly the types of cultural resources that may be encountered when dealing with BUDM include: (1) archaeological sites; (2) built environment (a distinct subcategory of the built environment described above); (3) sacred lands or landscapes; (4) underwater cultural heritage; and (5) cemeteries. The best practice for approaching these different categories varies.

Archaeological sites, based upon existing state site files and cultural resources surveys, classified as National Register of Historic Places (National Register) listed or eligible should be considered during the scoping phase of a project. Known sites that are not National Register-eligible can be disregarded as irrelevant to proceeding with a project. If National Register-eligible archaeological sites cannot reasonably be avoided in projects, their capping with deposited sediment is not necessarily a negative outcome. As a general rule, because archaeology is one of, if not the only, science or social science that destroys much of its data during the recovery phase (i.e., via the destruction of context in the excavation process), a general notion of site avoidance has permeated modern archaeological practice (Wildesen, 1982). In support of this goal, the deposition of sediment atop a fully subsurface archaeological site serves two beneficial purposes: (1) capping or sealing the underlying site for posterity; and (2) protecting the site from would-be looters. Such capping is not advisable when the sediment to be deposited contains harmful contaminants that can negatively impact the integrity of the site below (Davis et al., 2004).

The built environment refers to all manner of anthropogenically-made or modified structures. As with above-ground archaeological sites (many of which will overlap with the “built environment” category of sites), any inquiry in a scoping exercise for projects should only consider those structures that are or may be classified as National Register listed or eligible. Other structures can largely be disregarded as a limiting factor for the use of an area for a project (though they may still be relevant to other categories of benefit if they are in current use). For those sites classified as National Register listed or eligible, avoidance is the best practice. Although the National Historic Preservation Act (1966a; 1966b) does not mandate avoidance of adverse impacts to any sites covered by that law, to the extent possible, impacts should be minimized where unavoidable. It is unlikely that intact structures will be suitable for capping in situ as with some of the archaeological sites noted above, as such a practice undermines the general preference for making these sites visible on the landscape.

Sacred lands and landscapes are an increasingly important resource to consider during an impacts analysis to cultural resources in general. However, aside from specifically designated sites or landscapes under the Antiquities Act or other nationwide law that applies to federal or tribal property (e.g., *American Indians Religious Freedom Act*, 1978; *Archaeological Resources Protection Act*, 1979; *Native American Graves Protection and Repatriation Act*, 1990), there is little, if any, legal protection or mandate that applies to these lands. Simply, sacred lands were not part of Congress' calculus when considering lands to protect under laws such as the National Historic Preservation Act (1966a; 1966b) or National Environmental Policy Act (1970). Nonetheless, best practices in recent decades have included both attempting to avoid such sites when alternative uses are proposed or, when not avoidable, consulting with affected groups to mitigate or minimize harm to the maximum extent practicable.

Underwater cultural heritage includes both sunken vessels and former terrestrial archaeological or built environment sites that have become inundated. In most cases, the impacts to archaeological and built environment sites should be treated in the same manner as reviewed above. Sunken vessels present several complexities that are not present with other cultural resources. In most cases, the vessels encountered during scoping will be historic vessels associated with Western cultures, meaning that Indigenous consultation is not required by law. Within state waters, these sites are protected by the Abandoned Shipwrecks Act (1988), a law by which Congress ceded regulation of such sites to each individual state in whose waters the vessel is located. Although each state's law is different, for most known vessels, avoidance is the best practice. Unlike subsurface (terrestrial) archaeological sites, capping vessels can often do more damage to the remaining components than simple avoidance. Whether to avoid such sites will be dependent upon the records available in each state's archaeological site files. In cases where vessels have been determined to have no research value, capping or other impacts may be an available solution. Additional complexity is added if the vessels are known flagships of sovereign nations (whether military or not) or if the vessels are known military vessels (including aircraft and spacecraft). Under recent jurisprudence relating to claims to sovereign nation's vessels and the Sunken Military Craft Act (2004), avoidance of these cultural resources is always the best practice (if not mandated by law). None of the international conventions for the protection of underwater cultural heritage are applicable in U.S. waters.

Cemeteries, like underwater cultural heritage, present a complex web of cultural heritage considerations, often coupled with continuous mourning practices in landscapes of grief. Despite these complexities, cemeteries can often be easily managed in BUDM contexts. Unlike any other type of property, cemeteries are uniquely classified in the United States (Seidemann, 2018a, 2018b). Cemeteries can only be used for "cemetery purposes" under the law in every state in the nation (Seidemann, forthcoming). While, what constitutes “cemetery purposes” is unclear, a use of land for continued interment of human dead or the cessation of any noncemetery uses is consistent with existing law. Historically, cemeteries have also been used as places of respite, relaxation, and community gathering (Sloane, 1991). Thus, “greenspace” is also acknowledged as a viable use of cemeteries, especially those that no longer present a presence on the ground surface. Such a “greenspace” use is also consistent with a BUDM use of unmarked cemeteries. In the case of unmarked cemeteries, as with subsurface archaeological sites, professional standards are met by capping the site with additional matrix, thus protecting it from adverse impacts. Moreover, because most BUDM sites are used for coastal land building that is not intended or expected to be redeveloped into anything other than greenspace, it is doubtful that any cemetery so covered will be put to a noncemetery use. Recent literature has examined the question of whether capping cemeteries constitutes a structurally violent reuse of the landscape (Seidemann & Halling, 2019). In that analysis, many of the cemeteries that were capped in one way or another—usually by developing a noncemetery use atop the sites—were the burial places of disadvantaged communities. For situations in which the land was put to a nonconforming use (e.g., a roadbed, a school, condominiums) when the descendant community was not consulted prior to the reuse and the human remains therein were not removed, such a reuse was determined to be structurally violent. However, the reconversion of one of the sites from a school to greenspace (a park) was determined to be consistently bringing the land back to a cemetery use. With this background, a best practice for any reuse of unmarked cemetery property begins with consultations with the descendant community. In cases in which the community is amenable to capping the site with BUDM as a protective measure, such a use violates no laws and may be accomplished in a manner consistent with capping subsurface archaeological sites. Unmarked cemeteries are typically referred to as those sites with no surface commemoration associated with the burials. Many such sites are the burial places of the disenfranchised (Bates, 2019). Indeed, coastal areas in the United States are littered with Indigenous and Enslaved peoples’ burial sites (see e.g., Stojanowski, 1997 discussing Bird Island off Florida’s Gulf Coast). Even at a scoping level, consultation when known cemeteries will be impacted is essential because, though often protective of the site, capping may be regarded as disrespectful or desecration by descendant communities, resulting in legal challenges at worst and resentment and distrust at best if not accomplished pursuant to consultation. Conversely, marked cemeteries—those burial sites with some surface commemoration—should be avoided at all costs. From a best practices perspective, depositing BUDM on a marked cemetery, as with built structures or shipwrecks, risks destruction of the cultural resources represented by that surface commemoration. Although not an inconsistent use of the property, capping such a site likely would not pass muster as a viable landscape alteration under state and federal law. Marked cemeteries should be avoided or, if avoidance is impossible and mitigation is impractical, such sites should be protected from seepage of BUDM into their boundaries.

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